Misch's AVOIDING COMPLICATIONS IN Oral Implantology

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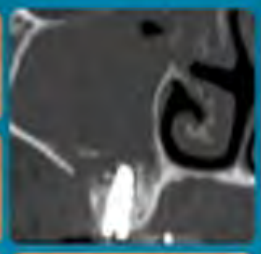

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Misch's Avoiding Complications in Oral Implantology

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Foreword

Oral Implantology has developed and progressed into a central core of the art and science of dentistry. This field, over the course of its existence, has transformed from a modality on the fringes of the profession to being embraced by virtually every component and aspect of our discipline. However, as with any clinical dental or medical discipline, patient outcomes continue to drive improvement of diagnoses, techniques and therapies. Improved management of patient clinical variations to treatment and unexpected results fortunately are a product of adverse experiences. Simply put, the tough cases and negative clinical situations are the best teachers, and we are wise to grow as clinicians from them.

This textbook specifically addresses implant complications for doctors on any point of their clinical learning curve, from novices to veteran clinicians with decades of experience. As our profession continues to grow and share data on clinical experiences, new complications continue to arise, giving us all a chance to benefit in knowledge from said complication. Presently, our profession is producing many excellent meetings and publishing textbooks related to new concepts in the field of Oral Implantology. However, very little has been dedicated to complications in the literature and from the podium. This is understandable, as it is not particularly enjoyable to discuss the negative consequences that occur during treatment, sometimes even despite our best efforts. This book will provide the profession with a well-needed, comprehensive textbook on a subject that is most likely to increase in frequency in the future because of the ever-growing popularity of dental implants.

The editors of this text, Professors Randolph R. Resnik and Carl E. Misch, collectively bring over a half-century of clinical education and experience to these chapters. Not only have they spent decades as top educators in this field, they have also spent countless hours mentoring implant clinicians across the world, reviewing cases and helping to provide counsel for the management of complications that occur along the way. Those experiences are what shape the content of this text. The information is presented in a logical sequence of clinical decision making, yet clearly is literature based on science and peer-reviewed research. The subject matter is very diverse and

comprehensively encompasses all facets of implant dentistry; diagnosis and treatment planning, surgical intervention, prosthetic rehabilitation, and the post-operative and maintenance phases of this discipline. The implant complications case reports contained in these chapters are well-documented and well-illustrated to serve as an outstanding guide for patient care.

Professors Resnik and Misch have assembled a wealth of talent in the field of Oral Implantology which provides a unique blend of clinical, academic, research, and medico-legal experience. These contributors have spent their careers on the front lines of this field, encountering many of the situations that are discussed, either directly or indirectly. Their goal is to reduce the clinical evidence of avoidable and unavoidable complication episodes that an implant clinician may encounter in their practice.

The authors took a great deal of care to make this text extremely comprehensive in scope, and it shows in the delivery of the content. Through a unique technique of discussing the etiology, prevention, and management of each complication, the reader is guided by the authors to a better understanding of the fundamentals of treatment, making them able to obtain a strong foundation for the understanding and treatment of these adverse events.

On a personal note, I have had a long relationship with Professors Resnik and Misch, both professionally and personally. I value the clinical and research mentorship provided to me by them over the past quarter of a century, and feel fortunate to call these men professional colleagues and friends. We who call ourselves practitioners of Oral Implantology have all been in some way touched by their contributions to the field at large.

Jon B. Suzuki DDS, PhD, MBA

Preface

Dental implants have become an accepted therapeutic approach to rehabilitate patients with edentulous sites. Vast amounts of time and resources have been dedicated to research and development within the discipline, and as a consequence, very high survival rates are reported throughout the literature with a wide range of implant types and systems. Despite all of these advances in oral implantology, treatment associated with dental implants is not free of complications. There is a learning curve necessary to build clinical competency from both surgical and prosthetic aspects of treatment, and situations occur that lead to less than ideal outcomes. Even with a high degree of experience, complications can and will arise. These complications can occur intra-operatively, post-operatively, or many years after success. Therefore, it is inevitable that the implant clinician today will be confronted with some sort of complication during the implant treatment process.

The genesis of this complications book comes from over 25 years of teaching at the Misch International Implant Institute. Private practice in oral implantology and teaching hands-on surgery to doctors taught me that if you do enough procedures, whether surgical or prosthetic, complications will arise. What sparked my interest was the understanding that even if a clinician is as careful as possible, problems associated with the treatment do occur. Additionally, because more dental implants are being placed and restored today, this obviously will lead to more complications. Unfortunately, very little exposure is given to the diagnosis, etiology, prevention, and management of these complications. Even the most benign procedures may lead to significant long-lasting devastating complications to the patient.

The lecture podium is an area where more often than not, successes are discussed. New procedures and protocols are introduced, and examples are given that outline the utility of the presenter's findings. As an educator that deals with the reality of complications with students and practicing clinicians that I mentor, I found that a large opportunity existed to aid in the deeper understanding of clinical practice by discussing how and why things go wrong during implant treatment. The popularity of the Complications seminar over the years and the feedback we received helped solidify the

conviction that I held – facing the sometimes harsh reality of what errors may occur and focusing on how to prevent them. This ultimately helps instill a greater sense of confidence going forward in the pursuit of excellent clinical care.

Because of the popularity of dental implants and the ever-changing technological atmosphere, the profession is in need of a literature based, comprehensive summary of possible complications. Technology is a vital component of the dental implant industry. Because technological advances in implant dentistry are changing at an alarming rate, procedures are often recommended without guidelines for evaluation. In the past, our philosophy would entail no recommendation on a product or technique without at least five years of data and experience. However, today, dental advertising and manufacturers often give the industry misleading and inaccurate information that may be detrimental and lead to complications.

Misch's Avoiding Complications in Oral Implantology is designed to be a comprehensive guide to the diagnosis, etiology, and management of a wide range of treatment planning, surgical, prosthetic, and maintenance complications. The underlying theme of this book is the idea that the best way to treat complications is to "prevent" them from occurring. Therefore, this book includes factual information that is literature based which allows the implant clinician to have a thorough understanding of basic principles and a strong foundation for the recognition of complications.

The five parts of this book discuss diagnosis and treatment planning, surgical, prosthetic, periodontal and maintenance, and mediolegal aspects of dental implants;

- **Part 1:** The diagnosis and treatment planning chapters include an understanding of various types of complications, radiographic imaging complications associated with the implant patient, factors associated with proper treatment planning, and the medical evaluation of the dental implant patient.
- **Part 2:** Surgical complications are discussed, which include the ideal positioning of implants in all planes along with the treatment of malpositioned implants. Additional chapters include bone grafting complications, the treatment and prevention of bleeding issues, the prevention of nerve injuries along with ideal management, incision line opening, intra-operative complications, and post-operative problems.

- **Part 3:** The Prosthodontic complications chapters include a detailed summary of fixed and removable complications. This encompasses all aspects of treatment planning, procedural, and post-prosthetic complications. An entire chapter is dedicated to dental implant occlusion, specific for various types of prostheses along with biomechanical factors.
- **Part 4:** The periodontal and maintenance chapter includes a detailed evaluation to the scientific basis of periodontal related complications. The etiology, management, and prevention of these complications is discussed.
- **Part 5:** The last chapter is dedicated to the possible medical-legal aspects of implant dentistry. The entire legal process from pre-suit to a trial is reviewed with unprecedented recommendations on the most common asked questions concerning the legal process.

In summary, ***Misch's Avoiding Complications in Oral Implantology*** is comprised of the most comprehensive, in-depth summaries of possible complications the implant clinician may encounter. This book is not meant to scare the implant clinician, but to educate them on what may possibly occur. My experience over the years has led me to understand that clinicians actually feel more confident about procedures when they are aware of the most significant pitfalls that may arise. The reader will build a strong foundation of knowledge to manage the complication with a fact-based protocol to decrease morbidity of the situation. Ideally, the implant clinician will obtain an understanding that the information in this textbook is meant to elevate the science and discipline of implant dentistry, as its focus is not specifically on how to perform a procedure, but how to overcome negative outcomes. As an added benefit, the text reviews a great deal of the fundamentals of implant surgery and prosthetic care, which only adds to a clinician's understanding.

My hope is that this book encourages clinicians to be conscious of potential complications, whether benign or life threatening, so they lead to better overall treatment outcomes for patients.

Randolph R. Resnik DMD, MDS

Acknowledgments

I would like to express my sincere gratitude to the many people that have supported me in the writing of this book. First, I would never have had the insight, ambition, and aspiration to write this book if not for the two mentors in my life, my late father, Dr. Rudolph Resnik and Dr. Carl Misch.

My father was the perfect father, role model, educator, clinician, and a true pioneer in the field of fixed prosthetics. He was my hero and my best friend, and the number one reason I am where I am today. His endless support and encouragement gave me the strength and motivation to succeed both personally and professionally. It is through his life-long example that I emulate his work ethic, tenacity, and drive by giving 110% in all that I do.

Dr. Carl Misch was not only my mentor, but also a very close personal friend and fellow colleague for 30 years. His endless energy and enthusiasm inspired me to take on and complete such a laborious task as writing this book. Carl, the true "pioneer of modern implantology", allowed me to be at the forefront of this challenging profession and carry on his unprecedented principles and teachings in the field of oral implantology.

This journey would not have been possible without the support of my wonderful family. First, I want to thank my wife Diane, she is my high school sweetheart, my best friend and number one fan. She has been my rock to lean on and with her unwavering support I have been able to become the best at what I do. I also want to thank my two wonderful children, Christopher and Allison, who have made me so proud of their accomplishments and have driven me to complete this book. Christopher, who is following in my footsteps, soon to enter a prosthodontic residency and Allison who is pursuing her dream in medical school. And last of all, my two furry companions, Charlie and Nellie, who sat by my side patiently for endless hours in the writing of this book.

I am sincerely appreciative to all the additional chapter authors for sharing their expertise with the writing of this book. Their dedication to implant dentistry, and especially their friendship and personal support to me, is greatly appreciated: Dean Jon Suzuki, Steven Caldwell, Robert Resnik, Glenn Jividen, Joseph Cillo, Jarrett Faust, John Preece and Frank DeLuca.

A special note of thanks to the staff at Elsevier for their energy, enthusiasm and creativity with the content of this book. In particular, Courtney L. Sprehe, Jolynn Gower, Kathy Falk, Jennifer Flynn-Briggs, and Abigail Bradberry for their dedication and long hours of work in the development of this book.

At last but not least, I would like to extend my gratitude to the thousands of doctors that have trained with Dr. Misch and myself at the Misch International Institute over the last 25 years. They have given us the desire to and ambition to write this book and take the academic level of implant dentistry to the next level.

Randolph R. Resnik DMD, MDS

In Memoriam

The world constantly teaches us lessons along the path of life, and one of its most bittersweet truths becomes apparent when we are put in the presence of a genius. Certain individuals enter this world and make such an impact that we are left in awe of their accomplishments. They truly make a mark on what we know of life. The last lesson they bring us regards the frailty of life's gift. These geniuses, like all beings, leave this life, and we are left to wonder what we will do without their guiding light.

Recently, the medical community at large has lost one of its true geniuses, Dr. Carl E. Misch. His passion and life-long dream was to elevate the standard of care in implant dentistry, and he worked tirelessly in the pursuit of that end. Through the development of various principles and classifications that have led to the origins of modern implant dentistry, he truly changed the lives of his students, colleagues, and patients. Along with his gifts as a highly skilled clinician was an uncanny ability to engage and teach fellow dentists what he had learned along the way. He unselfishly gave others the gift of his knowledge, as his true belief was to always “share what you have learned”. Carl Misch was, in the truest sense of the words, a pioneer, teacher, clinician, friend, and colleague.

During his dental school years, the inquisitive dental student became fascinated with the little known field of oral implantology, which was still considered a discipline on the fringes of contemporary dental practice. Regardless, Carl aggressively pursued is passion and placed his first implant as a 4th year dental student. Additionally, he was elected class president by his classmates and was awarded a main podium position as a dental student at an International Congress of Oral Implantology in Germany. His fascination for knowledge in oral implantology led him to travel the world, seeking knowledge and experience from any of the earlier founders of oral implantology. This led to his tenacious pursuit of acquiring experience from some of the true pioneers in implant dentistry include the likes of Leonard Linkow, Ken Judy, Hilt Tatum, Robert James, P.I. Branemark and Dr. Hans Grafelman.

In 1984, Dr. Misch founded the “Misch International Implant Institute”, which was one of the first hands-on, one-year continuums for dental implant

education. The Institutes scientific based curriculum became world-renowned and remains at the forefront today of implant dentistry through research, education, and its unique clinical applications. The Misch philosophy and teachings have evolved and expanded over the years, and has been taught in many cities in the United States, along with locations in Brazil, Canada, France, Italy, Japan, Korea, Monaco, Spain, and the United Kingdom. Through the years, six major universities have used the Misch Institute exclusively for the implant dentistry curriculum of their oral surgery, periodontal, or prosthodontic residencies. To date, over 5000 dentists have been trained by the Misch Institute and is known worldwide as the premier center for dental implant training.

Dr. Misch, in his life, was awarded numerous post-doctoral degrees and recognitions. He was bestowed two Ph.D. degrees (honoris causa) from the University of Yeditepe in Istanbul, Turkey, and Carol Davila University of Medicine and Pharmacy in Bucharest, Romania. He was awarded an honorary degree and member of Omicron Kappa Upsilon, the national dental honor society. Additionally, he has been presented with twelve fellowships in dentistry, including the American College of Dentists, International College of Dentists, Royal Society of Medicine, American Association of Hospital Dentistry and the Academy of Dentistry International. In 2014, the American Dental Association's Board of Trustees awarded the Distinguished Service Award to Dr. Misch. This is the highest honor conferred by the ADA.

In the 1990's, Dr. Misch authored the text, *Contemporary Implant Dentistry*, which is currently in its third edition and has become one of the most popular textbooks in dentistry. This book has been translated into 9 languages, including Japanese, Spanish, Portuguese, Turkish, Italian and Korean. Additionally, his prosthetic text, *Dental Implant Prosthetics (Elsevier)* is in its second edition. His books are used in dental schools throughout the world for graduate and postgraduate programs. In March 2017, the long-awaited textbook *Avoiding Complications in Oral Implantology* will be published by Elsevier, which is co-authored by myself and Dr. Misch. Dr. Misch authored over 250 articles and repeatedly lectured in every state in the United States as well 50 different countries throughout the world. Dr. Misch also held 16 patents in dentistry and was the co-inventor of the BioHorizons Maestro Implant System.

Dr. Misch held Diplomate status at the American Board of Oral Implantology / Implant Dentistry and served as Board President and

member of the examining committee. He also served as President of several implant organizations including the International Congress of Oral Implantologists, American Academy of Implant Dentistry, Academy of Implants and Transplants and the American College of Oral Implantologists. He was a past president and Co-Chairman of the Board of Directors of the International Congress of Oral Implantologists, the largest global implant organization. Other accomplishments include being deemed a “Knight” by the King of Sweden and a chevalier of La Confrérie des Chevaliers du Tastevin, an esteemed French wine society.

Dr. Misch had an unprecedented impact on the field of implant dentistry, as most techniques and procedures today are based on his original principles and classifications. In my opinion, one of the truest signs of a genius is the ability to foresee the need of technology well before the mainstream of society even recognizes the concept. He had more to do with the inception, evolution, and current principles used today in implant dentistry than any other practitioner in the field. Few people in the field have contributed more than Dr. Misch. He gave his life to implant dentistry; he had a singular focus towards the understanding that if properly utilized, dental implants could have significant positive impacts on the health of civilization at large. His passion was centered on perfecting that craft to ensure that his vision of implantology as a common treatment method became reality. He was a true pioneer, in a time that he went against the odds and encountered much resistance. He has stimulated a renaissance in implantology that will continue to touch everyone he met.

Dr. Misch will be remembered as the consummate clinician, researcher, professor, and father. He lived and taught what he believed, teaching right up to the end of his life. His fire for sharing his love of our profession pushed him on and gave him the energy continue, even under the most complicated of circumstances. That is the beauty of life. Certain geniuses come along with great gifts. The best of these decide to dedicate their lives to sharing those gifts with others. That is a great description of Dr. Carl Misch, and I, as well as the rest of our community, will never forget him. His legacy will live on in the clinicians he has educated, the teachers he has influenced, and the patients that will benefit from his tireless and profound work. Carl, rest in peace.

Randolph R. Resnik

Dedication

This Book is Dedicated in Loving Memory of my father

Rudolph Resnik DDS

1927–1990

Classification of Dental Implant Complications

Randolph R. Resnik

One of the main tenets of dentistry is the restoration of a patient to optimal form, function, and esthetics. In the history of the profession, few advancements have facilitated dentists in this pursuit more than the advent of the dental implant. Though historical evidence reveals humans were attempting to replace missing teeth with foreign materials since ancient times, the science of fully replacing teeth with biologically compatible materials has been a very recent phenomenon. Oral implantology, which encompasses the replacement of missing teeth and their supporting structures with biologically compatible materials, has drastically improved the quality of life for millions of individuals. Patients who were once hopelessly edentulous now have the opportunity to achieve a full restoration to full chewing capability. People who were once destined to undergo radical and continuous loss of the bone that supports esthetically vital facial muscles now have a chance to maintain a youthful appearance. Young patients who were born with congenitally missing teeth now can go through life with a normal esthetic presentation without having to cope with a removable appliance. Though the study of dental implants is a rather recent phenomenon compared to other medical subjects, the impact that the field has had on the quality of life for patients around the world is staggering.

Due to the work of the many pioneers in the field, oral implantology has become a highly successful and viable option for the treatment of edentulous areas. High success rates for implant treatment have been shown through numerous clinical studies. However, as more implants are being placed, the number of complications are increasing. Even with technologic advances in oral implantology, this type of treatment is not void of complications, even many years after completion. These complications appear both surgically and prosthetically, with varying degrees of severity in consequence. Prosthetic complications leave patients without the restorations they ultimately desire, due to functional and esthetic issues stemming from inadequate implant placement, improper diagnosis, or a lack of understanding about the forces

acting upon the prosthetic components. Surgical complications can lead to implant failure, neurosensory impairments, infections, significant bleeding episodes, and possibly death. As oral implantology grows as a discipline, the field of dentistry will be confronted with these complications, and knowledge of how to treat them is pivotal to the long-term success of the treatment.

Complication Studies

In review of the literature, many studies have evaluated the prevalence of complications, both surgically and prosthetically. McDermott et al., in a retrospective study, evaluated approximately 2400 implant cases and determined an overall complication frequency of 13.9%.[1] Jung et al. reported a 39% complication rate associated with fixed implant-retained restorations over a 5-year period.[2] Serrano et al. in a multi-center retrospective study found a 50% complications rate with removable implant prostheses.[3] Many other studies have evaluated the specific complications (Table 1.1).

TABLE 1.1

Summary of Complication Journal Articles

	Category	Study Findings
CBCT COMPLICATIONS		
Schneider (2009)[1]	Computer Generated Guide Accuracy	• Meta-regression analysis reported a mean deviation of 1.07 mm at entry point and 1.63 mm at the apex
D'haese (2012)[2]	Immediate Loading Guided Surgery	• Reviewed six papers with an average complication rate to 42% when stereolithographic guided surgery was combined with immediate loading
Arisan (2010)[3]	Guide Accuracy	• Bone-supported guides had the highest mean deviations (5.0° ± 1.66° angular, and 1.70 ± 0.52 mm and 1.99 ± 0.64 mm for implant shoulder and tip, respectively
Valente (2009)[4]	Template Guided Flapless Surgery	• Mean lateral deviations coronal (1.4 mm) and apical (1.6 mm). Mean depth deviation was 1.1 mm and mean angular deviation was 7.9 degrees
BLEEDING COMPLICATIONS		
Hong (2012)[5]	Coumadin	• Frequency of persistent bleeding (2%) with patients on Coumadin • Extractions + implant placement = bleeding increases to 4.8%
Balaguer Martí (2015)[6]	Mandibular Bleeding	• Most common area for heavy bleeding after implant surgery is in the mandible (canine > incisor > first premolar) • Most common artery is Sublingual artery, usually from lingual perforation
Zijderveld (2008)[7]	Lateral Window Bleeding	• 2% significant bleeding complications after lateral window preparation
Goodacre (2003)[8]	Postoperative Ecchymosis	• 24% of all dental implant sites manifest noticeable ecchymosis. The location of the ecchymosis is influenced by gravity
NERVE COMPLICATONS		
Burstein (2008)[9]	Mandibular Nerve Impairment	• Meta-analysis of implant placement nerve injury studies show a range of incidence from 0% to 13%
Bartling (1999)[10]	Mandibular Nerve Impairment	• An incidence of 8.5% nerve impairment was found at the first postoperative appointment
Libersa (2007)[11]	Temporary vs. Permanent Nerve Injury	• Evaluated transient vs. permanent implant-related nerve injuries with 75% of injuries being permanent
Pogrel (2000)[12]	Inferior Alveolar Block Nerve Impairment	• 1 : 26,762 inferior alveolar nerve blocks result in nerve impairment with 36% causing a dysesthesia
INFECTION COMPLICATIONS		
Powell (2005)[13]	Dental Implant Infection	• 1.14% infection rate after stage I and stage II surgery
Gynther (1998)[14]	Dental Implant Infection	• 0.7% infection rate after surgery
Greenstein (2008)[15]	Wound Dehiscence	• Incision line opening prevalence ranging from 4.6%–13.7%
Lekovic (1997)[16]	Wound Dehiscence with Membrane	• 30% prevalence of soft tissue dehiscence's was noted when barriers were placed as part of guided bone regeneration procedures
Urban	Sinus Graft Infections	• 2.3% developed a sinus graft infection post-surgery

(2012)[17]		
Sicilia (2008)[18]	Titanium Alloy Sensitivity	• Type IV hypersensitivity reaction (titanium alloy sensitivity) Ti allergy was reported with a 0.6% prevalence
Davies (1990)[19]	Air Embolism	• Report of three fatal cases of air emboli after implant placement
SURGICAL COMPLICATIONS		
Hämmerle (2002)[20]	Guided Bone Regeneration	• Retrospective studies reporting success or survival rates for implants in regenerated bone ranging from 79.4%–100% after 5 years
Levin (2007)[21]	Autogenous Onlay Grafts Complications	• Survival rate was 96.9%, marginal bone loss around implants ranged from 0 to 3.3 mm only 5% of the implants presented marginal bone loss 1.5 mm over the follow-up time
Chiapasco (2009)[22]	Allograft and Membrane	• In the postoperative period, 20% of the nonresorbable membranes and 5% of the resorbable ones underwent exposure/infection
Chaushu (2010)[23]	Cancellous Block Grafts	• Partial and total bone-block graft failure occurred in 10 (7%) and 11 (8%) of 137 augmented sites
Nkenke (2009)[24]	Sinus Graft Complications	• Sinus graft complications 0%–32%
Di Girolamo (2005)[25]	Benign Paroxysmal Positional Vertigo	• Osteotome sinus technique leading to benign paroxysmal positional vertigo (BPPV) with a prevalence of 3%
Schwartz-Arad (2004)[26]	Sinus Membrane Perforation	• Most common complication during sinus graft procedures is perforation of the Schneiderian membrane during its elevation is 40%
Chrcanovic (2009)[27]	Mandibular Fracture	• Mandibular fracture is most likely to occur in the very atrophic mandible with a prevalence of 0.2% of the patients with inserted implants in an edentulous mandible
Galindo-Moreno (2012)[28]	Implant Migration	• In 80% of the cases in the reported study was either performed as sinus augmentation via osteotome approach (33.3%) or no augmentation (46.7%) at all
PROSTHETIC COMPLICATIONS		
Kourtis (2004)[29]	Prosthetic Complications	• Prosthetic Complication frequency: Screw Loosening – 34%, Broken Screw – 13%, Uncemented Restoration – 20%, Fractured Prosthesis – 20%
McDermott (2003)[30]	General Complications	• 13.9% frequency of complications including inflammatory (10.2%), prosthetic (2.7%), and operative (1.0%)
Sadid-Zadeh (2015)[31]	Single Implant Restoration & Fixed Implant Prosthesis in Partially Edentulous	• Meta-analysis showing an overall incidence of technical or mechanical complications of 10.8% for single implant crowns and 16.1% for partially edentulous implants = over a 5 year period
DeBoever (2006)[32]	Screw Loosening	• 12% incidence of screw loosening within 3 years
Chaar (2011)[33]	Screw Loosening	• Screw Loosening – 4.3% less than 5 years, 10% between 5–10 years
K-T Yao (2011)[34]	Implant Screw Settling Effect	• 2%–10% of the initial preload is lost as a result of settling within the first few seconds or minutes after tightening
Goodacre (2003)[35]	Overdenture Complications	• 30% clip/attachment loosening, relines required 19%, overdenture fracture 12%
Pjetursson (2012)[36]	Fixed Implant Prosthesis	• 5-year – 34% of fixed prosthesis had complications • 10-year survival rate of 77.4% for the gold–acrylic fixed implant prosthesis • The survival rate of implant-supported fixed prosthesis (all types) was 95.4% after 5 years and 80.1% after 10 years of function
Sailer (2007)[37]	Fixed Implant Prosthesis	• Meta-analysis reported 5-year (94.3%) and 10-year (88.9%) survival rate
Schley (2010)[38]	Zirconia Restorations	• Zirconia Restorations – 5-year complication-free rate of 76.41% for technical complications
Albrektsson (2012)[39]	Technical and Esthetic Complications	• Despite high survival of single implant crowns, technical, biological and aesthetic complications were reported with a rate of 8.8%, 7.1%, and 7.1%, respectively
Albrektsson (2012)[40]	Single Crown Success Rate	• Single implant crowns reported a 5-year (96.3%) and 10-year (89.8%) survival rate of implants and prosthesis
Goodacre (1999)[41]	Phonetic Complication	• Phonetic complication after implant prosthesis in 4%–8% of patients
IMPLANT FAILURE COMPLICATIONS		
Pjetursson (2012)[42]	Implant Failure	• Meta-analysis revealed an estimated survival of implants supporting fixed prosthesis of FDPs 95.6% after 5 years and 93.1% after 10 years
Albrektsson (2012)[43]	Implant Survival	• 5-year implant survival rate was estimated to be 97.7% and based on four prospective studies and 10-year implant survival rate was estimated to be 94.9%
Goodacre (2003)[35]	Implant Loss in Poor Quality Bone	• 16% implant loss in poor quality bone (~D4 Bone)

Lang (2012)[44]	Immediate Implants	• The annual failure rate of immediate implants was 0.82% (95% CI: 0.48%–1.39%) translating into the 2-year survival rate of 98.4%
Bulard (2005)[45]	Small Diameter Implant Failure	• Failure rate average for mini implants used for long-term prosthesis stabilization was 8.83% from 8 months – 5 years
Proussaefs (2004)[46]	Implant Failure After Membrane Perforation	• Implant survival at stage II surgery was 100% for nonperforated sites (100%) and perforated sites (69.6%)
Baig (2007)[47]	Smoking – Implant Failure	• Failure rate of implants in smokers = more than twice that in nonsmokers • Failure rate of implants placed in grafted maxillary sinuses of smokers is more than twice that seen in nonsmokers
Peled (2003)[48]	Diabetes – Implant Failure	• The success rate was 1 year (97.3%) and 94.4% (5 years) following implantation
PERIODONTAL COMPLICATIONS		
Pjetursson (2012)[49]	Soft Tissue Complications	• After 5 years, peri-implantitis and soft tissue complications approximately 8.5%
Jung (2012)[50]	Soft Tissue Complications	• Biological complications, 5-year cumulative soft tissue complication rate of 7.1% on single implant crowns
Schley (2010)[51]	Soft Tissue Complications	• Zirconia – biological complications, 5-year complication-free rate was 91.72%
Quirynen (2003)[52]	Periapical Pathosis	• 1% of implants placed during a 5-year period developed periapical pathosis
Marrone (2013)[53]	Peri-Mucositis vs. Peri-implantitis	• Prevalence of peri-implant mucositis and peri-implantitis was 31% and 37%, respectively
Fransson (2008)[54]	Peri-Implant Disease	• Prevalence of peri-implant diseases was reported to be 92%
Souza (2016)[55]	Keritinized Tissue	• Cross-sectional analysis reporting lack of adequate keratinized tissue leading to poor gingival health in 40.3% in posterior regions and 30.4% of implants in the anterior region

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Etiology of Complications

Increased Demand for Dental Implants

There is an ever-increasing demand for dental implants in the world's population today. This increased need and use of implant-related treatments result from the combined effect of several factors, including (1) an aging population that is living longer and more socially active, (2) tooth loss related to age, (3) consequences of fixed prosthesis failure, (4) anatomic consequences of edentulism, (5) poor performance of removable prostheses, (6) consequences of removable partial dentures, (7) psychologic aspects of tooth loss and needs and desires of aging baby boomers, (8) predictable long-term results of implant-supported prostheses, (9) advantages of implant-supported restorations, and (10) increased public awareness.[4]

A study by the American Association of Oral and Maxillofacial Surgeons noted a 69% incidence of at least one missing tooth in the 35- to 44-year demographic group.[5] By the age of 75, at least one quarter of adults will be completely edentulous. These statistics, when blended in with overall population studies, begin to paint the picture for implant demand. The percentage of the population over 65 years is increasing, as is the overall human population. The population in 2000 was 282 million and is projected to increase 49% to 420 million by 2050. Considering the effect of both a population increase and a greater percentage of that population being older than age 65, a dramatic overall increase in patient numbers can be expected. In 2003, 35 million people were older than age 65. This number is expected to increase 87% by 2025, resulting in almost 70 million people being older than age 65 (Fig. 1.1).[4] Therefore, because the older population are more likely to be missing teeth, the need for implant dentistry will dramatically increase over the next several decades.

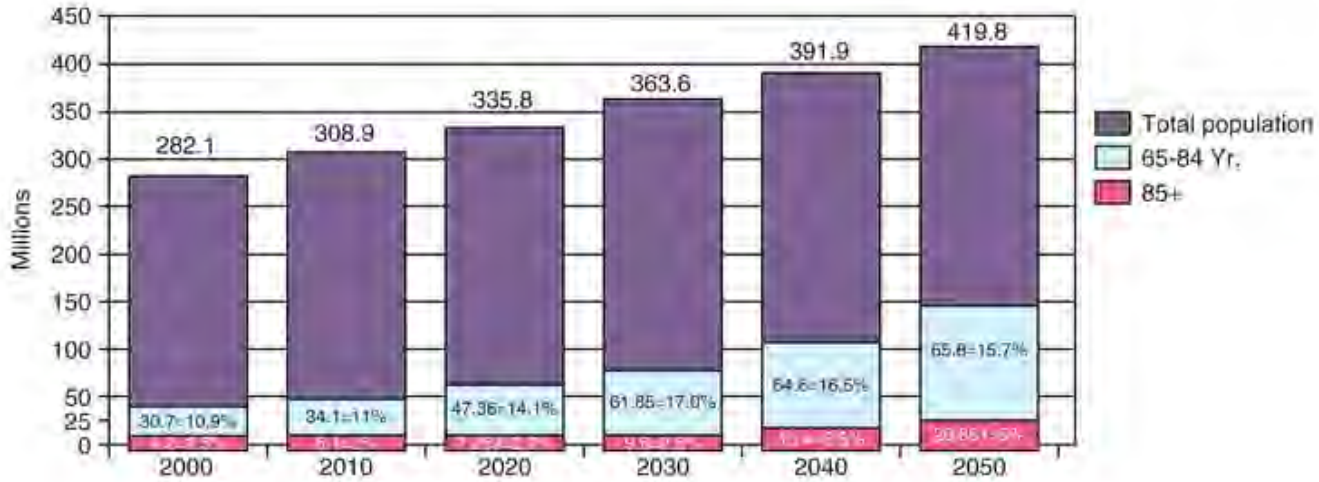

FIG 1.1 By 2050, 20.7% of the population will be older than age 65. In addition to the increasing percentage of 65-year-olds, the population is also increasing. As a result, 34.9 million people were older than 65 in 2000, and 86.6 million people will reach this milestone by 2050. (From Misch CE: *Contemporary implant dentistry,* ed 3, Mosby, St. Louis, 2008.)

An Accepted Treatment by the Population

The replacement of edentulous sites with dental implants is one of the most rapidly progressing disciplines in all of medicine. Advancements in the modification of soft and hard tissues, implant design, and prosthetic fabrication are leading to long-term success rates well over 90%. In addition, a surge of patient education materials for both dentists and their patients has led to a large increase in the public awareness of implants as a viable treatment modality. These factors are leading to explosive growth in the dental implant market.

Straumann corporation performed a penetration study that discussed the growth of the dental implant market by 2020. As of 2011, 15% to 20% of the population of patients seeking the replacement of a missing tooth or teeth received implant therapy as a restorative modality. This number is projected to increase to around 25% to 30% in just 9 years.[6] The implant market is slated to grow 6% to 8% in this short time frame. TechNavio's analysts forecast the global dental implant market to grow at a compound annual growth rate (CAGR) of 8.72% over the period 2014 to 2019. The overall dental implant market, which grew from $3.2 billion to $4.2 billion in 5 years, is expected to rise to over 6.5 billion by 2018.[7]

More Dentists Placing Implants

Due to the aforementioned boom of demand for oral implantology in the patient population as well as the lucrative nature of the procedure from an economic standpoint, more dentists are placing implants. Straumann reported that approximately 18% to 20% of US dentists are placing dental implants, with an average of 55–60 implants being placed by each clinician in a year. This is compared to a 2004 study by the American Dental Association (ADA) that had this number at 11%.[8,9] As recently as 10 years ago, oral implantology was not emphasized in the dental school curriculum, but it is now being taught as a core component of a student's education. The number of general practitioners placing implants is growing and will continue to grow in the future. Additionally, technological advances are making it easier and more profitable for clinicians to treat advanced cases.

Manufacturers Course Training

In the 2007 ADA survey, general practitioners were asked where they received their training in dental implant placement. Approximately 66% of these dentists had received specialty training after completing dental school. The bulk of the remaining practitioners had received their training in a course sponsored by a manufacturer. Due to the lack of exposure in the past to oral implantology in dental school, dentists are seeking quick access into the discipline for a low cost. Dental implant manufacturers are attempting to fill this void by hosting continuums in oral implantology for the dental population that is seeking an introduction to this discipline. Though these short courses are better than the alternative of having dentists receive no training at all prior to placing implants, there are definitely inherent drawbacks.

First, there is a lack of foundational didactic training on dental implant treatment planning, which is a cornerstone of successful treatment outcomes. A firm understanding on prosthetic design, force distribution, and site development is paramount to achieving consistent successful dental implant treatment outcomes. Secondly, the manufacturers tend to oversimplify the treatment protocols in an effort to embolden clinicians to offer implant placement in their respective practices. This places the dentist in a position of not being fully aware of the potential complications they can encounter during treatment and how to handle them should they arise.

Implants Being Placed in Compromised Sites

Due to the lack of formal training in comprehensive oral implantology, dentists may lack a firm appreciation for site development as it pertains to the hard and soft tissues. Many edentulous sites and prosthetic designs require modifications to the proposed implant site. There is a tendency for dentists (early on their learning curve) to develop treatment plans that allow them to avoid procedures they lack knowledge or comfort in, so implants may be placed in suboptimal areas, which leads to various negative esthetic, prosthetic, and surgical complications. Because of bone loss after tooth extraction, many sites are not ideal for implant placement (surgically and prosthetically). If the dentist lacks knowledge in bone grafting and site development, this may lead to alternative treatment options such as severely angled implant placement, excessively short implant bodies, or the placement of too few implants for the force requirements of the patient's proposed prosthetic design. All of these “shortcut” or “non-ideal” procedures may lead to an increase in complications, lower success rates, and subsequent legal ramifications.

Financial motivation may also affect decision making as it pertains to site development. A dentist may feel the pressure to “keep procedures in house,” which may lead to a deviation of proper treatment planning, especially if the clinician does not possess the skill or knowledge required to augment hard and soft tissue. In areas of the mouth that show a lack of bone height, width, density, or a lack of adequate soft tissue, a practitioner will be required to have greater education, experience, and skill to navigate a proper treatment plan from the surgical phases to final prosthetic completion. Cases with compromised tissue volumes typically require augmentation prior to implant placement, which requires a separate skill set. If a clinician does not possess these skills but proceeds with a modified treatment plan to work around the inherent difficulties that the patient's anatomy presents, numerous complications and morbidities can occur in all phases of treatment. This will ultimately lead to embarrassment, increased procedural cost, and possible legal repercussions.

Medically Compromised Patients

With the continued advent of new technologies, medications, and treatment options, patients are leading longer lives with higher degrees of social activity. This phenomenon will continue to increase as the population grows along with the understanding of disease prevention and treatment. The

impact of this for the modern dentist is the presence of a population of elderly patients who actively seek comprehensive dental care, in a search for a return to optimal form, function, and esthetics.

As was previously discussed, oral implantology is becoming a larger part of this patient population's knowledge base, and they are actively seeking this therapy to help enjoy a better diet, more active social lifestyle, and younger appearance. However, this also places a higher demand on the dentist to understand the medical complexities that are inherent in treating these patients. Patients present with numerous comorbidities, take many medications that may affect implant healing, and also pose a significant challenge for the clinician during the surgical phases of treatment.[10] Additionally, significant advances in medicine have led to the advent of new medications for many diseases. However, the interaction of these medications on the healing of dental implants can cause many complications and adverse effects (i.e., bisphosphonates).

A survey study was performed showing that with patients in the 57- to 85-year range, 81% took at least one prescription drug daily, with 29% taking at least five medications.[11] A practitioner performing implant surgery must know the patient's medical history, have a firm understanding of each medication, and be aware of how each of these medications affects not only the patient's ability to cope with the stresses of surgery but also the healing and integration of bone grafts and dental implants. Medications that are prescribed pre- and postoperatively may interact with the patient's existing drug regimen. These factors must all be taken into consideration before beginning a treatment protocol. A lack of awareness of the effects of medication on dental implant treatment may lead to numerous unforeseen complications.

When planning to begin treatment on an medically compromised patient, the clinician must also understand how various medical conditions may affect the final outcome. Cardiovascular and respiratory disease may complicate surgery. Uncontrolled diabetes has significant effects on surgical healing and implant integration. Anticoagulant therapies may pose a significant risk for bleeding episodes during treatment. Long-term steroid use can affect healing and infection risk. Each affirmative check on a medical questionnaire should be investigated and evaluated for a risk of possible complications to surgery.

Lack of Medical Clearance Prior to Surgery

A key to success in treatment for the medically compromised patient is an area that is sometimes overlooked by the dental professional, and that is a strong working relationship with the patient's physician. While performing the medical evaluation on a patient presenting with a positive health history, the implant dentist should take the time and effort to consult with the treating physician to establish a pre- and postoperative plan, including drug protocols, ensuring that the patient experiences an outcome free from drug interactions and medical complications. Surgical clearances should also be obtained in an effort to minimize the risk that a patient experiences medical complications or life-threatening emergencies during implant surgery. A failure to obtain such clearances puts the implant dentist in a serious medicolegal risk, should complications occur. (See the Medical Consultation Form in Chapter 2.)

Immediate Implant Procedures

Throughout the history of the discipline of oral implantology, research studies have been performed to help practicing clinicians understand all aspects of implant dentistry, in an effort to provide patients with the best chances of experiencing a successful outcome. These studies have shaped our understanding of how the body responds to the different implant and graft materials, how the forces of mastication act on these materials, and how the microbial environment affects the long-term success of implant restorations. As this understanding increased, designs for implants were established, treatment protocols and healing times were authored, and drug regimens were established to maximize the chance that treatments were successful.

However, as the demand for implant services has increased, so has competition in that marketplace. Dental professionals compete for patients, and dental implant manufacturers compete for market share. This has led to the advent of more and more dental implant procedures that deviate from the established clinical guidelines set forth and confirmed by previous research. Though many of these procedures and treatment protocols can work and have been shown to be effective in the right hands, the skill requirements of these procedures may prove to be too high for some practitioners, especially those early on a learning curve. This leads to numerous surgical and prosthetic complications.

In an effort to reduce the time in which a patient had to wait for a final restorative outcome, a movement began to not only immediately place an

implant at the time of extraction but also to load the implants at the same time. In the right circumstances (proper bone volume, density for rigid fixation, and lack of infection), this treatment has been shown to be clinically effective. However, with the confirmation that these procedures can indeed work, we have seen an exploitation of the treatment protocol to encourage this type of procedure as a matter of routine. The pressures on implant dentists to produce "teeth in a day" may predispose them to taking shortcuts and making surgical compromises that put the patient at great risk for implant/prosthetic failure. The implant dentist must understand that certain clinical criteria must be present for these procedures to work, and that factors such as medical status, the presence of infection, or inadequate bone volumes contraindicate such shortcuts.

Catering to a larger population of dentists who may not possess the skills to create adequate bone volumes by grafting, manufacturers have also pushed the boundaries in implant design in an effort to remove barriers to entry into the implant field. For example, to avoid the problem of having to build posterior maxillary bone volumes to ensure proper vertical axis loading of implants, clinicians have invented techniques involving angled placements of implants with severely angled abutment interfaces. Although these techniques have been shown to be successful, surgical experience and case selection are crucial factors for long-term success.

Overuse of "Mini" Implants

Recently, the use of "mini" dental implants to support removable and fixed prosthesis has dramatically increased in implant dentistry. Initially, the intended application of mini implants was for provisional restorations during the healing phase of conventional endosseous implants (> 3.3 mm diameter). In time, the use of mini implants was expanded to retain removable and fixed prostheses, which have become extremely controversial. Manufacturers have since modified the procedure to include minimally invasive techniques, which include inserting the implant into the bone via flapless surgery. These techniques have been marketed toward faster, easier, and less traumatic procedures. However, this marketing has led to more mini implants being placed in sites that would be more ideally suited (surgically and prosthetically) for conventional endosseous implants. This has led to nonideal implant positioning, neurosensory impairment, atypical implant prosthesis, poor emergence profiles, biomechanical issues, and implant

fractures.

At this time, there are very few studies evaluating the success of mini implant under functional biting forces and long-term success. Finite element stress analyses of mini implants have been shown to exhibit high levels of risk because stress transmission to bone and fatigue fracture. Bulard and Vance evaluated over 1000 implants and reported a 13.6% failure rate.[12] Shatkin reported more failures in the maxilla with a 17% failure under a complete denture.[13] Other studies have shown fatigue fracture to be responsible for 5% and 20% of all implants lost during function.[14] Therefore, mini-implants definitely have a place in implant dentistry treatment planning, however in most cases should not be substituted for conventional size implants.

Poor Treatment Planning

One of the easiest ways to minimize complications, yet one of the most overlooked by implant dentists, is the ability to accurately and effectively treatment plan according to sound scientific principles. Each patient presents a different challenge for the clinician, which makes detailed knowledge of dental anatomy as well as the engineering of prosthetic cases so vital to successful outcomes.

Without significant knowledge of a patient's maxillofacial anatomy, an implant clinician is placed in a potentially dangerous situation. The implant dentist must know the volume of bone in a proposed implant site and be aware of any undercuts that may be present. The presence of vital structures such as sinuses and nerves must be accurately identified and evaluated. Without this information, the clinician may perforate bony structures, causing neurosensory impairment that provides sensation to the face and oral structures or possibly severing blood vessels that may cause life-threatening bleeding complications.

Excuses for this lack of detailed knowledge are quickly evaporating, as radiographic modalities such as cone beam computed tomography (CBCT) imaging are quickly becoming the standard of care. Having an accurate 3-D representation of the patient's anatomy along with a firm understanding of how to read and interpret the image puts the clinician in a much better position to avoid significant complications.

Using a working knowledge and accurate representation of the patient's anatomy, the clinician must be aware of overall site selection and implant

positioning as it pertains to the demands of the restoration. If a clinician does not take into consideration the design and demands of the final prosthesis, there exists a significant potential to place the implant in a position that places destructive forces upon it during loading, which will cause either prosthetic or implant integrative failure.

Protocols have been established featuring key implant positions to assist the implant dentist in properly selecting sites that optimize safe loading during function as well as establishing safe distances between the multiple implants and/or adjacent teeth. Following these guidelines can assist the clinician in knowing where the optimal site for an implant lies, which then allows for an evaluation of that exact site as it pertains to the need for additional bone volume via grafting. Neglecting these rules can place the patient at significant risk of implant loss, adjacent tooth loss, or prosthetic failure (see Chapter 6).

Poor Communication With Patients

The implant dentist must understand the demands of the patient's existing oral condition and their expectations for prosthetic options. Patients who exhibit parafunction require greater implant numbers or implants of greater size dimensions. A patient who shows more teeth during smiling may require a different esthetic presentation than one with a low lip line. Patients with thin tissue biotypes in an esthetic area may require tissue augmentation prior to implant placement. All of these factors must be known to the practitioner prior to beginning treatment to avoid problems.

Armed with all of the knowledge regarding implant treatment planning, the clinician can and must effectively communicate with the patient regarding expectations and demands. Many health care providers, including implant dentists, encounter complications when they acquiesce to the demands of a patient to perform questionable procedures. This can be avoided by knowing all of the ramifications of each treatment option and having the ability to communicate them. The patient must be made aware of all possible options and the strengths/limitations of each. They must understand the financial implications of treatment and know how that affects their treatment outcome. An example of this would be the edentulous mandible, where the number of implants placed dictates the type and stability of the final prosthesis. If a patient is made aware initially of their choice of two implants supporting a denture is much less stable than the

alternative of four, the chances of disappointment are reduced. Communicating the treatment options clearly and setting clear expectations can help prevent numerous complications, including medicolegal issues.

Poor Understanding of Complications and Failure to Refer

No clinician expects to be faced with complications during treatment. Despite all of the education, experience, and skill they may possess, at some point the implant dentist will be confronted with a complication. As important as the prevention of complications is to the discipline of oral implantology, the quick identification and treatment of these events is equally important. The implant dentist must understand the myriad of risks associated with each procedure and how to react to these issues should they arise. During surgery, the severing of a blood vessel requires a rapid response to ensure the prompt resolution of the incident. Failing to recognize or respond to a bleeding incident in a quick manner could lead to life-threatening complications. If a complication during surgery was noted, such as the potential severing of a nerve, the clinician does the patient a terrible disservice by avoiding the situation altogether and "hoping things heal on their own." Prompt referrals for imaging and specialty treatment are necessary and are the responsibility of the practitioner to allow the patient the best chance of a full recovery.

Even after a seemingly successful surgery, the patient must be monitored for postoperative complications. Incision line opening, one of the most common surgical complications, poses a risk to a successful outcome, especially with grafting. Serious postoperative infections may occur that require prompt antibiotic therapy and even possible hospitalization. All of these conditions must be anticipated by the implant dentist prior to the beginning of treatment, and a plan must be in place ahead of time to safely navigate the "slippery slope" that these complications present. The clinician must know how to recognize each complication and what avenues to pursue to get the situation under control, even if it means referral to another doctor.

Complication Classification

Although quality assessment is gaining increased attention in implant dentistry, there exists no accepted consensus on how to define and quantify complications. Because of the absence of a consensus, there is little continuity in the literature with regards to complications. In medicine, Clavien et al proposed a classification of complications, which has subsequently been used in the medical literature for outcome assessment. However, this classification may not be the most practical for the assessment of oral implantology complications.[15]

- Grade 1: Any deviation from the normal postoperative course that does not require pharmacologic intervention (i.e., pain, swelling)
- Grade 2: Any deviation from the normal postoperative course that does require pharmacologic intervention (i.e., infection)
- Grade 3: A deviation that requires surgical intervention (i.e., incision and draining)
- Grade 4: Life-threatening complication requiring hosptitalization (i.e., sublingual hematoma)

Because of the wide variation in the field of oral implantology, the authors have developed various classifications, which is dependent on type and phase of treatment.

Minor vs. Major

A *minor complication* is self-limiting and usually of short duration, with no permanent or lasting deficits. (e.g., swelling and bruising).

A *major complication* is a more serious complication that is longer lasting, potentially permanent, with associated possible morbidities (e.g., infection, nerve impairment).

Unavoidable vs. Avoidable

An *avoidable complication* is a complication such as a nerve impairment caused by placing an implant in the mandibular canal, without the use of a CBCT scan to give the clinician an accurate representation of the proper nerve location.

An *unavoidable complication* is a complication that cannot be avoided or

preventable in most instances and is not directly a result of negligence of the implant clinician. An unavoidable complication does not negate legal ramifications. However, it does favor the implant clinician, as it is considered a complication that most likely could not have been avoided (e.g., nerve impairment secondary to administration of inferior alveolar nerve block).

Reversible vs. Irreversible

Reversible complications are complications that usually resolve on their own and have no associated long-term morbidity (e.g., improper angulation upon implant placement after the first drill osteotomy, which may be corrected easily).

Irreversible complications are complications that are permanent and cannot be reversed, thus having increased severity and consequences (e.g., mandible fracture after implant placement).

Legal Ramifications

In the past, legal issues concerning implant dentistry were minimal. In today's practice, this is becoming an ever-increasing and serious problem. Many years ago, the majority of complications were basically thought of as risks of the procedure. Today, such complications are deemed a deviation from the standard of care by many. It is true that fewer dental lawsuits are brought before the court system today as compared to in the past, but the cases that appear before the court today carry enormous awards if successfully tried for the plaintiff. Additionally, many more cases are being settled out of court because of the expense of litigation. Today, cases involving complications such as nerve impairments due to negligence can settle in the six- to seven-figure range.

Furthermore, with the advent of CBCT technology, the field of oral implantology is moving more toward “perfection.” For example, if an implant fails, many possible reasons may be given to explain why this has happened. Most doctors believe an informed consent will minimize these issues; however, this is usually not true. If negligence is proven against the clinician, the informed consent is deemed inadmissible, as a patient cannot consent to negligence. Most likely, in the future, insurance premiums may become so high for these procedures that it will limit the use of implants by many practitioners. For the clinicians who continue to provide implant services, it will be mandatory that they be vigilant in the prevention and proper handling of complications.

Complications Prevention

In all aspects of health care, practitioners discuss the virtues of disease prevention with their patients. In the practice of implant dentistry, it is vital that clinicians practice that same philosophy as it pertains to complications. The best way for the implant dentist to treat complications is to “prevent” them.

Increase Education

The first method of complication avoidance is the pursuit of education. Implant dentists must have a firm and deep understanding about a wide spectrum of subjects ranging from CBCT interpretation and diagnosis, treatment planning, hard and soft tissue management, prosthetic design, esthetic presentation, pharmacology, surgical principles, and numerous other subjects. It is vital that the aspiring or practicing implant clinician achieve a level of expertise in all aspects of the discipline. Though the level of time and effort devoted to implant education is increasing in dental schools, the implant dentist must continue to add to his or her knowledge regarding both the prosthetic and surgical facets of oral implantology.

Comprehensive postgraduate continuing education courses are available to dentists seeking a deep understanding of implantology. These typically consist of a combination of intense didactic and laboratory training sessions. The courses offer the implant clinician an opportunity to obtain a strong foundation of the diagnostic, surgical, pharmacologic, and prosthetic sciences as they pertain to implant treatment. Some courses also offer a hands-on component to assist dentists early on their respective learning curves with respect to various procedures they have never been exposed to.

Seek Accreditation

It is also highly recommended for clinicians to test themselves by seeking accreditation with the various implant boards and groups. Groups such as the American Board of Oral Implantology/Implant Dentistry (ABOI/ID), the International Congress of Oral Implantologists (ICOI), and the American Academy of Implant Dentistry (AAID) offer fellowship and diplomate status to clinicians who pass various didactic tests, while also presenting their own cases and research for peer review. This higher level of accreditation is vital for the implant dentist to perform because it helps to build a deeper

understanding and greater mastery of the various aspects of oral implantology. The level of competency and credibility, after the many hours of study and preparation it takes to complete the accreditation process, cannot help but to make a clinician more knowledgeable about the field, which is a crucial step toward avoiding complications.

Literature Review Updates

Another way for the prevention of implant complications is to become familiar with the process of literature review. As the advances in the field of oral implantology increase, more competition will arise, which will inspire new advances in the field. While some of these advances will stand the test of peer review and clinical success, many new procedures and equipment ideas will push boundaries and make unsubstantiated claims. A good piece of advice for the avoidance of complications is to “not be the first, nor the last” to the latest trends or ideas in the field. Before implementing a new procedure or piece of technology, it is wise to extensively research the subject to evaluate the validity of the advancement. Be skeptical of manufacturer-driven studies because they may show a significant bias toward the positives in the methods or materials they intend to take to market. Be hesitant to accept any claim made by a company or spokesperson until unbiased research has tested and proven its validity and the test of time.

Patient Information

In order to prevent complications with the patient relationship, the practitioner should give all possible treatment plans and options to the patient. This is absolutely paramount because it builds a set of expectations and a knowledge base for the patient and provider. An example of this would be the restoration of a missing single, edentulous site. The patient should be given an option of no treatment (which must always be offered), removable prosthetics, fixed prosthetics, or implant retained prosthetics. The patient should be informed of the advantages, disadvantages, risks, and potential complications regarding each treatment option. Doing so not only gives the patient greater peace of mind because they are actively participating in the choice of treatment but it also gives the clinician the comfort of knowing that they accurately prepared the patient for the upcoming therapy. Expectations of compliance for each treatment option should also be discussed and

documented. All medical therapy is a two-way street between patient and provider, and the patient must be responsible for compliance.

Do Not Rush Treatment

During treatment, the clinician can avoid substantial complications by avoiding the urge to rush through the proper sequence and timelines for implant dentistry. Oral implantology is unlike other disciplines in dentistry because patients often have to cope with the difficulties of transitional removable prosthetics, perimucosal extensions, sutures, and other items they may find uncomfortable. The implant dentist may feel some pressure to lessen graft healing, implant integration, or progressive loading timelines in an effort to make the patient happy. The clinician must explain to the patient that these timelines are necessary for proper therapy to be completed, and there isn't much that can be done to lessen the window and still ensure a favorable outcome.

Treat for the Long Term, Not the Short Term

The implant clinician may also be faced with the dilemma of a nonideal outcome (e.g., bone loss upon uncover, open contact, ill-fitting margin). Though this can be a significant source of embarrassment for the clinician and stress for the patient, it must be explained that for long-term success, the situation may require modification. Though the pressure to do so may seem severe, the clinician must NOT alter their best judgment by putting their patients at risk. Most of the time-related problems and pressures from patients in regards to comprehensive implant treatment can be handled on the front end of treatment with the aforementioned treatment presentation. The patient who is prepared for what is to come is much less likely to have problems and try to force the clinician into rushed procedures.

Follow-Up Care

The last aspect of complication prevention is a policy of strong follow-up care. Keeping communication open with the patient through the phases of treatment is vital to staying on top of any potential complication issues. The patient should be instructed to inform the clinician of any difficulties immediately as they pertain to incision line opening, neurosensory issues, or possible infection. Postoperative evaluations also provide the implant dentist

with opportunities to evaluate healing, transitional prosthesis fit, incision line closure, the presence of infection, and the post-prosthetic phase. A good follow-up care protocol builds strong bonds with patients and also allows the implant dentist the chance to identify and quickly respond to numerous complications.

Summary

Oral implantology is a discipline filled with complexity. The field demands its practitioners to have a high level of expertise in a vast array of areas, many of which evolve at a fast rate. The oral environment is dynamic, and perfect healing conditions are not always possible. Complications will inevitably happen, but steps can be taken to prevent them. These include a thorough and comprehensive medical/dental history; radiographic survey including CBCT; a strong working knowledge of head and neck anatomy as well as surgical, prosthetic, pharmacologic, and follow-up care principles; and the ability to identify and treat a wide array of complications should they occur.

Every dentist who places or restores implants should be aware of these complications and know how to manage them. Some of the issues will require little intervention, while others may require the services of professionals in other areas of expertise. It is the duty of the implant dentist to recognize all of these situations and know the proper protocols to follow to ensure that the patient's chances of success are maximized.

According to numerous market research studies, the future of dental implants seems to be extremely bright. With no other full-tooth replacement therapy on the immediate horizon, the implant dentist enjoys the ability to provide the ideal solution for the restoration of missing teeth. The clinicians who provide this service can enjoy a good lifestyle while providing patients with a second chance at regaining ideal form, function, and esthetics.

With the many opportunities that implant dentistry provides comes a distinct responsibility and a sobering reality. Oral implantology is a difficult field to master, and the consequences of failure can be catastrophic. Patients may be at risk for life-threatening complications. The stresses of surgery during anesthesia pose a life risk for some patients. The various types of neurosensory impairments that patients have suffered as a complication of implant treatment are tragic, life changing, and have proven to be costly to the implant clinician. The professional and financial ramifications of some of these complications for the implant dentist are staggering.

In the face of these scary realities, groups of well-trained and passionate professionals continue to provide this wonderful service to thousands of grateful patients every single day. Oral implantology is a life-changing discipline, not only for the patients, but for the providers with the skill, knowledge, and passion to provide the treatment with excellence. It is the mission of this textbook to provide all of those practitioners with a

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Medical/Medication Complications in Oral Implantology

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A comprehensive preoperative medical assessment of patients considering implant treatment is vital to successful outcomes as well as the avoidance of significant complications. Studies have shown that the medical status of patients (i.e., medical history, American Society of Anesthesiologists [ASA] category) has a direct correlation with endosseous implant failure.[1] The need for implant-related treatment increases with the age of the patient. As a result, the implant dentist treats more elderly patients with associated comorbidities than any other specialist in dentistry. An estimated 12% of the US population is 65 years of age or older; this number is expected to reach 21% (64.6 million) in the year 2030.[2] The increased life span of the population directly correlates with implant dentistry being one of the fastest growing areas in medicine. Additionally, studies have shown that 15% to 25% of patients presenting to dental practices are medically complex, which encompasses a history of systemic diseases, multiple medications, and age-related issues.[3] Because the number of medically compromised patients seeking dental implant therapy is increasing, it is paramount the implant clinician understand the effect of systemic diseases and associated medications on the intraoperative surgical procedures, which have a direct relationship with the successful osseointegration of dental implants.

Contraindications to Treatment

Initially, when determining if a patient is a potential candidate for implant treatment, a thorough medical and physical evaluation must be performed. From this information, the existence of a possible medical contraindication is ascertained. In medicine, a contraindication is defined as a condition or situation that potentially makes the procedure in question inadvisable. There exist two types of contraindications, absolute and relative, with respect to dental implant procedures. An *absolute contraindication* is a condition that makes the procedure completely inadvisable. A *relative contraindication* is a condition that necessitates caution and is acceptable as long as the benefits outweigh the risks. To further clarify the contraindications in the field of implant dentistry, they may be classified into three categories.

- ***Surgical contraindication:*** A condition that places the patient at risk during the surgical procedure (e.g., advanced heart disease) and that potentially could result in a medical emergency. However, the condition does not impact morbidity or success of the implant procedure.
- ***Implant contraindication:*** A condition that places the endosseous implant healing at risk (e.g., IV bisphosphonates), resulting in a decreased success rate and increased morbidity. However, the condition does not impact the intraoperative medical condition of the patient or place the patient as a medical risk.
- ***Surgical/implant contraindication:*** The combination of a surgical procedure risk along with a risk for the success of implant healing or longevity.

Medical History

A comprehensive method of obtaining and documenting a patient's medical history is essential to ascertain an accurate diagnosis in order to determine an effective treatment plan algorithm. A thorough patient evaluation provides the foundation for determining the patient's surgical, anesthetic, and prosthetic risk, which directly affects morbidity and associated complications. The review of the patient's medical history is the first opportunity for the implant clinician to speak directly with the patient. The practitioner should not underestimate the value of the medical history interview. Asking questions that show an understanding of the listed medical conditions, current medications, and related common problems is paramount for the safety and well-being of the patient.

The two basic categories of information addressed during the review of the medical history include the current review of the patient's systemic health condition and an evaluation of recent and current medications. This detailed medical history should also address possible allergies, family and social histories, all of which may impact the future dental implant treatment, both surgically and prosthetically. Each positive answer on the medical history may have a direct impact on the care of the patient and proposed treatment. The implant clinician must have a strong understanding of positive responses associated with the medical history.

Cardiovascular System

Are you currently being treated for high blood pressure, or have you been told by a health care professional that you have high blood pressure, or hypertension? Yes/No?

Hypertension is a highly prevalent cardiovascular disease, affecting over 50 million Americans and 1 billion people worldwide. An estimated 7.1 million deaths per year are attributable to hypertension, along with 62% of cerebrovascular disease and 49% of ischemic heart disease. Approximately 30% of adults with hypertension are unaware they have hypertension, and two thirds of patients treated are not controlled to blood pressure less than 140/90 mm Hg.[4] The overall prevalence of hypertension is approximately 30% to 45% of the general population; however, a steep increase with aging is present.[5] Untreated, undiagnosed, and uncontrolled hypertension is a serious problem in society today. Because implant dentists treat a high percentage of

elderly patients, coupled with the high prevalence in the general population, incidence of treating patients with uncontrolled or undiagnosed hypertension is very high. This places the implant clinician at risk because intraoperative hypertensive episodes may result in cardiac arrhythmias with possible myocardial ischemia issues, which may lead to possible cardiovascular events such as myocardial infarction or cerebrovascular events.

Classification of Hypertension

In February 2014 the members of the eighth Joint National Committee (JNC8) on high blood pressure issued new guidelines for the treatment and management of high blood pressure in adults (Table 2.1). This report redefined treatment goals and thresholds for initiating treatment as well as a reevaluation of many common medications used to treat high blood pressure.[6] For years, medical providers treated blood pressure to a goal of 120/80 mm HG based on the recommendations of JNC7. JNC8 examined five new critical blood pressure trials. The most compelling and reproducible outcome in all the trials was lowering the diastolic blood pressure to less than 90, which resulted in fewer cardiac events and a reduction in overall mortality.

TABLE 2.1
Blood Pressure Treatment Guidelines

Category	Systolic (mm Hg)	Diastolic (mm Hg)	TREATMENT	
			Preoperative	Intraoperative
Ideal	<120	<80	None	None
Prehypertension	120–139	80–89	Recheck, possible MD consultation	Recheck, stress reduction protocol
Grade 1 hypertension	140–159	90–99	Recheck, possible MD consultation, (relative)	Monitor, stress reduction protocol
Grade 2 hypertension	160–179	100–109	Recheck, MD consultation, (absolute)	Monitor, discontinue procedure, possible ER referral
Hypertensive crisis	>180	>110	Recheck, emergency care, (absolute)	Monitor, abort immediately, emergency care

Additionally, JNC8 examined the medications used to treat blood pressure and concluded first-line treatments should be limited to four classes of medications; angiotension-converting enzyme inhibitor (ACEs), angiotension receptor blockers (ARBs), thiazide-type diuretics, and calcium channel blockers (CCBs). The implant clinician must have a thorough understanding concerning how hypertensive states may impact both surgical success and

implant longevity.

Surgical/Implant Implications

Intraoperative elevated blood pressure.

The implant dentist and staff must be knowledgeable about the measurement, detection, and treatment of hypertension. The accurate measurement of blood pressure, along with a review of all medications including herbal and over-the-counter medications, should be an integral part of the implant consultation and examination. This information must be reviewed in detail with the patient prior to surgery. If an automatic blood pressure–monitoring system is being utilized, a manual sphygmomanometer should be available to manually verify abnormal readings. Elevated readings (>160/100) should be verified by manual techniques and the procedure discontinued until the blood pressure returns closer to the patient's baseline or within a more acceptable range.

Orthostatic hypotension.

Hypertensive patients are more susceptible to orthostatic hypotension when brought from a supine to an upright position. This is caused by an excessive fall in blood pressure, which results in faintness, light-headedness, dizziness, confusion, or blurred vision. Resolution of this complication will occur rapidly upon placing the patient back in a supine position. Allowing patients to sit upright slowly will minimize these complications, especially after longer procedures and in susceptible patients. Unless a patient has a serious medical contraindication (e.g., congestive heart failure, renovascular disease, chronic edema), they should be instructed to hydrate prior to the surgical procedure. This may help reduce the occurrence of orthostatic hypotension.

Antihypertensive medications + NSAIDs.

The use of nonsteroidal antiinflammatory drugs (NSAIDs) has been shown to lessen the effectiveness of various antihypertensive medications by inhibiting prostaglandin production, leading to intraoperative hypertensive episodes. Blood pressure regulation is highly prostaglandin dependent, especially as it relates to kidney function through the vasodilatory effects. NSAIDs possess a higher degree of interaction with diuretics, ACE inhibitors, ARB inhibitors, and beta blockers, which may modify prostaglandin-dependent pathways more than drugs that alter non–

prostaglandin-sensitive pathways such as calcium channel blockers and central acting drugs. Therefore, the interaction with hypertensive medications and NSAIDs result in a higher propensity to increase blood pressure.[7] Studies have related approximately 50 million patients are being treated with antihypertensive therapy, and 12 million use NSAIDs concomitantly. However, the short-term use of NSAIDs has not been shown to have a clinically significant effect.[8]

Beta blockers.

The implant clinician must take into consideration that beta blockers may potentiate the cardiovascular effects of epinephrine used in local anesthetics. The nonselective beta-adrenergic drugs, such as propranolol (Inderal) and nadolol, pose the greatest risk of adverse interactions.[9] The cardioselective beta blockers (Lopressor, Tenormin) carry less risk of adverse reactions. However, there is competitive clearance through the liver between both classes of beta blockers and the local anesthetic. This may lead to an increase in serum levels of the local anesthetic.[10] To avoid intraoperative hypertensive episodes, decreasing the dose and increasing the time interval between epinephrine-containing injections is recommended.[11]

Calcium channel blockers.

These medications used to treat hypertension or congestive heart failure may lead to gingival hyperplasia around natural teeth or implants (similar to Dilantin). Additionally, this drug classification has been associated with erythema multiforme (a benign rash characterized by patches of red raised skin) and other types of oral ulceration. Gingival overgrowth can result in pain, gingival bleeding, and difficulty in mastication, especially around implant prostheses. The incidence of gingival hyperplasia is approximately 1.7% to 3.8% of patients taking calcium channel blockers.[12]

Multiple antihypertensive drugs.

Patients with difficult-to-control blood pressure may be prescribed multiple classes of antihypertensive medications. Even though these patients are being treated with various antihypertensive medications, they are prone to possible elevation and spikes in blood pressure. With these patients, the clinician should seek medical evaluation and consultation, which may include a postoperative blood pressure–monitoring plan.

Susceptibility to other cardiovascular events.

Severe hypertension or elevation in blood pressure may lead to angina pectoris, congestive heart failure, myocardial infarction, retinal hemorrhage, or even a cerebrovascular episode. These conditions may be precipitated by a rapid increase in blood pressure during a local anesthetic injection or the inherent stress associated with the surgical procedure. A stress reduction protocol is paramount with hypertensive patients.

Implant healing.

Cardiac disease (hypertension) may theoretically affect blood supply to the implant site and hence reduce survival or success. However, multiple studies have shown no evidence of early or late failure in hypertensive patients receiving dental implants.[13,14]

Complication Prevention

Stress reduction protocol.

With hypertensive patients the blood pressure should be controlled before and during elective dental implant treatment. Because blood pressure often rises prior to dental and surgical procedures, a preoperative stress control protocol is mandatory (Box 2.1).

Box 2.1

Stress Reduction Protocol

- Premedication the night before a procedure (longer-acting benzodiazepine [diazepam 5–10 mg])
- Early morning appointment
- Explain entire procedure in detail
- Sedation (Oral/IV)
- Minimize waiting-room time
- Duration of treatment not to exceed patient's tolerance

- Profound local anesthesia
- Slow/aspiration LA administration
- Sufficient postoperative pain management

IV, intravenous; *LA*, local anesthetic.

Monitoring.

Accurate assessment of intraoperative vital sign monitoring is extremely crucial to prevent complications. If elevated blood pressure (Stage 2) is present, postponement or medical consultation is indicated. When measuring blood pressure in the office, adhere to the following:

- Allow the patient to sit for 3 to 5 minutes prior to obtaining blood pressure measurements.
- If blood pressure is elevated, recheck after 5 minutes, changing arms.
- Automatic blood pressure machines may report inaccurate readings in patients with a history of cardiac arrhythmia such as atrial fibrillation, which may also cause an erratic heart rate. Multiple measurements of the blood pressure should be taken, and if a significant variation exists, the blood pressure should be checked manually with a stethoscope and sphygmomanometer.
- Position cuff at the patient's heart level and make sure the cuff is snug, approximately 3 cm above the elbow.

Maintain antihypertensive therapy.

Patients under a physician's care with antihypertensive medications should be instructed to comply with their medication protocol, especially the morning of surgery. If patients do not maintain their medication protocol, inherent intraoperative vital sign fluctuations may result. A patient should never alter any physician prescribed medication unless otherwise instructed by their physician.

Slow administration of local anesthetics.

Control of pain and anxiety is paramount in patients with hypertension because endogenous catecholamines (adrenaline and norepinephrine) are released in response to pain and stress. Catecholamines increase blood

pressure and cardiac output, thus placing the patient at risk of a stroke or cardiac arrest. Slow administration and aspiration of local anesthetics containing epinephrine also will minimize potential complications. High blood pressure levels may have direct effects on cardiac output, total peripheral resistance, and mean arterial pressure. This may result in lowering of the heart rate (bradycardia), a decrease in blood pressure, and in extreme conditions cardiovascular failure resulting in cardiac arrest.

Reduction in the use of vasoconstrictors.

Especially in elderly patients, the indiscriminate use of local anesthesia with vasoconstrictor should be cautioned. Attention should be exercised with patients having a cardiac history, and the dose of vasoconstrictors like epinephrine should be reduced (<0.4 mg). This may lead to elevation in vital signs in hypertensive patients, which may possibly lead to cardiovascular events. A rule of thumb is 50% of the recommended maximum dose of local anesthetics can be given after 1 half-life of the local anesthetic.

Angina

- **Do you have chest pain with exertion or have you been treated for angina? Yes/No?**

Angina is defined as significant, painful chest pain as a consequence of exertion or stress. Angina pectoris is a form of coronary heart disease that is usually caused by arteriosclerotic heart disease. However, it may be caused by coronary artery spasm, severe aortic stenosis, aortic insufficiency, anemia, emboli, and hereditary connective tissue disease. The cause of angina is a discrepancy between the myocardial oxygen demand and the amount of oxygen being delivered through the coronary arteries. The classical symptom of retrosternal pain that often radiates to the shoulders, left arm, or mandible or to the right arm, neck, palate, and tongue is usually relieved by rest. Patients with a history of angina may be taking long-acting nitrates to prevent the occurrence of acute episodes. Sublingual or spray nitroglycerin is recommended for the treatment of acute episodes. When retrosternal pain occurs, myocardial infarction is part of the differential diagnosis. The pain is similar in region but is more intense and usually will not cease within 3 to 5 minutes. Risk factors for angina pectoris are smoking, hypertension, high cholesterol, obesity, and diabetes.

Surgical/Implant Implications

Acute angina attack.

In the event of an acute angina attack, immediate discontinuation of the surgical procedure should be completed with the administration of nitroglycerin tablets (0.3 to 0.4 mg) or sublingual nitroglycerine spray. Additionally, 100% oxygen should be given to the patient along with repositioning in a semisupine (45-degree) position. Vital signs should be monitored with evaluation for irregular heartbeats, which could indicate premature ventricular contractions as a result of myocardial ischemia. If the pulse remains irregular, medical assistance should be sought.

Stable vs. unstable angina.

The difference between stable and unstable angina must be understood. Stable angina relates to chest pain that is similar to past episodes of angina and is usually brought on by similar amounts of exertion or activity. It usually resolves within several minutes of rest or discontinuation of exerted activity. Nitroglycerin will most often relieve the chest pain.

Unstable angina is classified as chest pain or pressure with or without shortness of breath that is a change from the typical anginal pain symptoms the patient has been experiencing with exertion. Chest pain at rest or with minimal exertional activity can also be classified as unstable angina. Unstable angina or a myocardial infarction in the last 6 months would be an absolute contraindication to the use of local anesthetics with vasoconstrictors.

Complication Implication

Postnitroglycerin issues.

Nitroglycerin is a vasodilator that increases the blood supply to the heart and may lower systemic blood pressure. The net effect reduces the workload and oxygen demand of the heart, relieving chest pain. The side effects of nitroglycerin are important to recognize because the overall decrease in blood pressure may cause a decreased blood flow to the brain. Flushing of the face and shoulders along with severe headache is common. After administration, fainting is possible; therefore the patient should be sitting or lying in a supine position. As the heart attempts to compensate for decreased blood pressure, the pulse rate may increase to as much as 160 beats/min.

Complication Prevention

Decrease dental procedural stress.

It is important to minimize factors that can increase the heart rate, increase blood pressure, and subsequently increase myocardial oxygen demand. Stress reduction is critical to reduce catecholamine release, which may adversely impact the cardiac contributors to angina. It is important to initiate a stress reduction protocol to help alleviate any cardiac stress factors.

Use of nitrous oxide sedation.

Use of sedation, especially nitrous oxide (N_2O), will reduce the possibility of angina attacks. N_2O potentially can decrease coronary blood flow; however, studies have shown no cardiac morbidity.[15] Use of N_2O in patients with both a cardiac and pulmonary history such as chronic obstructive pulmonary disease (COPD) or emphysema should be avoided.

Hypertension treatment summary

- **Mild (relative):** May undergo most nonsurgical dental procedures performed with normal protocol. General cardiac precautions are advised, such as vital signs monitoring, and patients are instructed to bring their own nitroglycerin to their appointment. Advanced restorative procedures and minor implant surgery are performed with stress reduction protocol and sedation.
- **Moderate (absolute):** Medical consultation recommended for any elective implant treatment.
- **Severe (absolute):** Medical consultation recommended for any elective implant treatment.

Myocardial Infarction (MI)

- **Do you have a history of myocardial infarction or heart attack? Yes/No?**

Myocardial infarction (MI) is a prolonged ischemia or lack of oxygen resulting from a deficiency in coronary arterial blood supply that causes injury to the myocardium. The end result is cellular death and necrosis of the heart muscle. An acute MI may be precipitated when the patient undergoes unusual stress, either physical (painful stimuli) or emotional (anxiety). During an MI episode the patient usually will be symptomatic with severe chest pain in the substernal or left precordial area that may radiate to the left arm or mandible. Cyanosis, cold sweat, weakness, nausea or vomiting, and irregular and increased pulse rate are all signs and symptoms of MI.

Surgical/Implant Implications

Cardiovascular issues.

The intraoperative complications of past MI patients include arrhythmias and congestive heart failure (CHF). The larger the ischemic area, the greater the risk of heart failure or life-threatening arrhythmias. Any history of MI indicates damage to the coronary blood vessels. Therefore, recent infarctions correspond to higher morbidity and death rates, even with simple elective surgery. Approximately 18% to 20% of patients with a recent history of MI will have an increase in complications, which have a high mortality rate of 40% to 70%.[16]

Complication Prevention

Medical consultation.

A medical consultation should precede any extensive restorative or surgical procedure. Even though there are recommendations based solely on the length of time after an MI, the deciding factor on elective dental implant treatment is not only time but also the amount of myocardial damage. The implant clinician should follow the recommendation of the physician concerning treatment options, modifications, or contraindications.

Stress reduction protocol.

Dental implant surgery after MI may induce arrhythmias or aggravate cardiac ischemia. An increased blood pressure is not uncommon in the dental office setting because stress associated with treatment (i.e., white coat syndrome) leads to increased levels of catecholamine, which causes an increase in blood pressure and heart rate. The most important step in decreasing stress in the dental office is to integrate a comprehensive stress reduction protocol.

Reduction in the use of vasoconstrictors.

Epinephrine and other vasoconstrictors have several properties that can potentially result in adverse outcomes in patients that have not fully recovered from a recent myocardial infarction. Epinephrine is chronotropic, which results in an increased heart rate and force of contraction. Both of these result in an increased oxygen demand and could potentiate ischemia. Epinephrine does have some arrhythmogenic properties that could provoke ventricular fibrillation or tachycardia in recovering myocardial muscle. It is

best to minimize complications by consulting the patient's treating physician and closely monitoring vital signs when vasoconstrictors are used.

MI treatment summary.

The patient's physician should be consulted prior to elective dental implant treatment to verify the patient's current cardiac status.

- **Absolute (surgical):** Recent MI (depending on MD recommendation)
- **Relative (surgical):** History of MI (depending on MD recommendation)

Cerebrovascular Accident (CVA)

- **Do you have a history of cerebrovascular accident (stroke)? Yes/No?**

A stroke is a cerebrovascular accident (CVA) characterized by a sudden interruption of blood flow to the brain, causing oxygen deprivation. It is most frequently seen in patients with current cardiovascular diseases and is the fourth leading cause of death in the United States and a major cause of adult disability. The majority of strokes are ischemic resulting from narrowing or blocking of the blood supply to the brain. The etiology of ischemic strokes is embolic and thrombotic. Thrombotic strokes are the result of clots that form inside one of the brain's arteries. The clot blocks blood flow to the brain causing cell death. Usually, these result from plaque or other fatty deposits from atherosclerosis, which break off and become lodged in the blood vessel. Embolic strokes are the results of clots that form in other parts of the body and travel to the brain via the bloodstream. The clot eventually will lodge in a blood vessel and block flow of blood to the brain. It is important to ask patients if they have ever been diagnosed or treated for ministrokes or TIAs (transient ischemic attacks). These attacks are the result of brief (usually less than 24 hours) interruptions in blood flow causing strokelike symptoms.

Surgical/Implant Implications

Bleeding.

Although it is important to control blood pressure and treat elevated cholesterol in the management of individuals with a history of strokes, caution should be taken because most are on blood-thinning medication. Antiplatelet agents such as aspirin or clopidogrel may be used as single agents or in combination as part of stroke prevention treatment. Both of these medications irreversibly impact platelets' clotting ability and have been

shown to cause increased bleeding. In some cases warfarin (Coumadin) may also be used, which directly interferes with the body's clotting mechanisms. Evaluation and bleeding control are essential in these types of patients.

Limited dexterity.

Patients who have suffered a compromise in dexterity as the result of a stroke require alternative treatment planning for their final prostheses. A fixed prosthesis is usually the best solution for these patients because an implant retained prosthesis may lead to the inability to remove for routine hygiene. Additionally, poor oral hygiene when combined with xerostomia causes additional oral problems such as candidiasis, dental caries, periodontal issues, and mucositis lesions, which increase implant prostheses morbidity.

Complication Prevention

Current anticoagulant medications.

The goal of anticoagulation medication is to keep the blood thinned so clotting is more difficult. However, it is important to understand these medications work by various pathways and can impact clotting at different points in the clotting cascade or by directly inhibiting platelet function. The antiplatelet agents such as aspirin or clopidogrel have been shown to have a minimal impact on bleeding both intraoperative and postoperative.[17] Several studies have found no increased risk of bleeding during dental procedures when patients on Coumadin are within the therapeutic treatment range of an international normalized ratio (INR) below 3.0. In patients with mechanical heart valves, the upper limit of the therapeutic range can reach 3.5 to 4.0. In patients with artificial valves, the INR may be checked 24 hours prior to the implant surgery. Under no circumstances should a patient with a mechanical valve on Coumadin be instructed to stop or hold a dose without input from the patient's treating physician.

Hemostatic agents/surgical technique.

Ideal surgical technique should be followed which consists of nontraumatic incision and reflection of tissue. The surgical procedures should be minimized with a decreased surgical duration. The implant clinician must have experience with the use of active and passive hemostatic agents (see Chapter 7).

Treatment summary

- **Absolute (surgical):** Recent CVA incident (MD Consult)
- **Relative (surgical):** History of CVA + anticoagulants (MD Consult)

Congestive Heart Failure (CHF)

- **Do you have a history of congestive heart failure? Yes/No?**

Congestive heart failure (CHF) is a pathophysiologic state in which an abnormality in cardiac function is responsible for failure of the heart to pump blood in adequate volume to meet the needs of the metabolizing tissues. More than 3 million people in the United States suffer from CHF, with approximately 400,000 new patients being diagnosed each year. Every year 30% to 40% of patients with CHF are hospitalized, which accounts for the leading diagnosis-related group of hospitalized patients older than age 65.[18]

The heart pumps approximately 2000 gallons of blood per day to other organs and body tissues. It coordinates the function of two pumps simultaneously: the left side, the larger of the two sides, pushes the blood out into the body; the right side sends the blood to the lungs for oxygenation. When the heart has been damaged, the blood begins to back up in the lungs or body. The heart will attempt to compensate by increasing the rate of contraction and stretching the muscle to accommodate a larger volume of blood to contract with a greater force and eject more blood (Frank-Starling law). Both of these compensation attempts of the heart maintain circulatory needs in the short term; however, long term they may be problematic. Less blood is circulated because, in beating faster, the heart is left with less time to refill, while the extra effort increases the heart muscle's demand for oxygen. When this need is not met, the heart rhythms can become dangerously abnormal (arrhythmic) and may lead to death.

Surgical/Implant Implications.

CHF patients are very susceptible to intraoperative cardiovascular morbidity issues. Stress reduction protocol and strict monitoring should be followed. It is advisable to discuss the current condition of the patient with their treating physician (Box 2.2). Patients with CHF can be classified as compensated or uncompensated. In uncompensated heart failure, the pulmonary circulation is expanded and congested because the heart is unable to fully compensate. The classic symptoms are seen including shortness of breath especially with

exertion, fatigue, or lying supine. When the CHF patient is treated for heart failure through medical management and the symptoms are controlled, the patient is referred to as compensated.

Box 2.2

New York Heart Association Cardiac Disease Classification

NYHA I: (Relative) Patients that have no limitation of physical activity.

NYHA II: (Relative) Patients with cardiac disease that results in slight limitation to physical activity with symptoms such as fatigue, palpations, dyspnea, or angina pain.

NYHA III: (Absolute) Patients with cardiac disease who are comfortable at rest; however, less-than-ordinary activity causes fatigue, palpation, dyspnea, or angina pain.

NYHA IV: (Absolute) Patients with cardiac disease that results in the inability to carry on any physical activity.

Complication Prevention

Recognize CHF symptoms.

Although the treatment of CHF should be left up to the patient's physician, it is important to realize that CHF can worsen without warning or slowly over time. It is important to evaluate the patient's breathing at rest and with minimal exertion upon walking, as well as to determine if breathing has worsened when the patient is lying down. Changes in any of these patterns of breathing could indicate a decompensation of their congestive heart failure. Additionally, it is important to evaluate for neck swelling in the jugular area, which may indicate right-sided heart congestion.

Patient positioning.

CHF patients should be positioned in the most recumbent position in which they can breathe comfortably and efficiently. This is usually a semireclined or sitting upright position. Usually, the more upright the patient, the easier it is

for the patient to breathe.

Oxygen supplementation.

Oxygen supplementation (≈2 L/min) during implant procedures is highly recommended to minimize the possibility of hypoxia. The use of nitrous oxide in these patients is not advised.

Stress reduction protocol.

Previously described to prevent increased myocardial workload with a damaged heart.

- **Are you predisposed to infectious endocarditis? Yes/No?**

The pathogenesis of infectious endocarditis is complex and associated with many factors. Vessel turbulence in the endothelium of cardiac vessel or pulmonary shunts combined with bacteremia (streptococci, staphylococci, enterococci) from oral surgical procedures may cause bacteria proliferation at the site resulting in infection. These bacteria may enter the bloodstream and can infect the heart valves. In time the bacteria can destroy heart valves resulting in life-threatening cardiac conditions. For this reason, antibiotic coverage is recommended in high-risk individuals undergoing procedures that may cause these types of bacteremia. The guidelines issued in 1997 for endocarditis antibiotic prophylaxis were very broad. In 2007 the guidelines were updated using recommendations from the American Heart Association Endocarditis Committee (Box 2.3 and Table 2.2).

Box 2.3

Endocarditis Prophylaxis Recommendation

The American Dental Association, American Medical Association, and the American Heart Association have recommended antibiotic coverage in patients with the following conditions receiving elective surgery.

- Artificial heart valves
- Past history of infectious endocarditis
- Cardiac transplant that develops a heart valve problem
- Congenital heart disease with shunts or conduits[a] repaired

- Congenital heart defect with residual defect

Able to take oral medication: amoxicillin 2 g (50 mg/kg)

Unable to take oral medication: ampicillin 2 g IM or IV (50 mg/kg IM or IV); cefazolin or ceftriaxone 1 g IM or IV (50 mg/kg IM or IV)

Allergic to penicillin or ampicillin: cephalexin 2 g (50 mg/kg); clindamycin 600 mg (20 mg/kg); azithromycin or clarithromycin 500 mg (15 mg/kg)

Allergic to penicillin or ampicillin and unable to take oral medication: cefazolin or ceftriaxone 1 g IM or IV (50 mg/kg IM or IV); clindamycin 600 mg IM or IV (20 mg/kg IM or IV)

IM, intramuscular; *IV,* intravenous.

[a]Functional murmurs and organic heart murmurs do not require prophylactic antibiotic.

TABLE 2.2

Additional Cardiovascular Issues and Treatment Implications

Positive Response	Treatment Implications
Abdominal aneurysm	Rupture leading to high mortality, MD consultation (absolute)
Atrial fibrillation	Thrombin inhibitors, hemostatic measures
Prosthetic heart valve	Maintained at high INR, hemostatic measures
Pacemaker	Cardiovascular issue, stress reduction protocol, no electrosurgery
Fainting/lightheadedness	Orthostatic hypotension
Congenital heart defect	Cardiovascular issue, medical consult to determine extent
Ankle edema	Congestive heart failure, possible varicose veins

INR, international normalized ratio.

Cardiovascular disease treatment summary

- **Surgery:** The above mentioned cardiovascular diseases can have a direct impact on the intraoperative consequences of dental implant surgery. It is imperative a thorough evaluation of the cardiovascular history be completed. Medical consultation is highly recommended to determine a current cardiac status of the patient. Strict stress reduction protocols are an essential part of the dental treatment plan for all patients with a cardiac history.

- **Implant:** Cardiovascular diseases theoretically will have an impact on the healing of dental implants. These diseases have a direct effect on blood tissue supply, which may impair the healing process. For normal healing, the presence of oxygen will increase fibroblast activity, collagen synthesis, capillary growth, and macrophage activity. Because cardiovascular diseases compromise blood flow and reduce oxygen tension and nutrient elements, osseointegration would most likely be affected. However, many studies have shown no direct correlation between cardiovascular disease and dental implant failure.[19,20]

Endocrine System

Diabetes Mellitus

- **Do you have diabetes? (Yes)/No?**

Diabetes mellitus is a major endocrine disorder that affects approximately 7% of the population with another 2% to 3% undiagnosed. In patients age 60 years or older, 20.9% of all people in this age group suffer from diabetes (approximately 1 in 5). Approximately 20.8 million children and adults suffer from diabetes, which contributes to 225,000 deaths per year. Diabetes ranks as the sixth leading cause of death in the United States.[21]

The most current classification of diabetes includes three general clinical categories: type 1 diabetes, type 2 diabetes, and gestational diabetes (pregnancy). In type 1 diabetes, insulin is not produced from the pancreas. This type of diabetes develops most frequently in children. However, the incidence in the older population is increasing. Type 2 diabetes is much more common and accounts for approximately 95% of the diabetic cases. This type of diabetes almost always occurs in adults and results from the body's inability to respond properly to the action of insulin, which is produced from the pancreas. The incidence of type 2 diabetes is estimated to double by the year 2025 because of aging, unhealthy diets, and obesity.[22,23] A recent study revealed a much higher percentage of patients with undiagnosed diabetes visiting dental clinics than was previously reported.[24] An increased body mass index (BMI) and advanced age can be predictors of undiagnosed diabetes. In patients for whom the clinician has a higher suspicion of diabetes, questions concerning frequent urination (polyuria) or excessively thirst (polydipsia) should be determined. These symptoms have a higher correlation with diabetes and may require additional workup. Additionally, diabetics tend to have a higher prevalence of periodontal disease, caries, and

other dental problems such as oral candidiasis, recurrent stomatitis, and parotid gland dysfunction.[25]

Surgical/Implant Treatment Implications

Hypoglycemia.

The most serious intraoperative complication for diabetic patients is hypoglycemia, which usually occurs as a result of excessive insulin level, hypoglycemic drugs, or inadequate food intake. Weakness, nervousness, tremor, palpitations, or sweating are all signs of acute hypoglycemia. Mild symptoms can be treated with sugar in the form of orange juice or candy. If the symptoms are not addressed, they may evolve from minor symptoms to seizure, coma, and in rare cases death. In these severe cases, patients may become unconscious or barely arousable. For these symptoms the emergency administration of 50% IV dextrose should be completed. Additionally, glucagon should be available because this hormone may raise blood sugar through a direct effect on the liver. Glucagon may also be administered intramuscularly in a dose of 1 mg for adults over 20 kg. Patients taking sulfonylurea medications for diabetes (including glyburide, glipizide, and glimepiride) who do not have adequate carbohydrate intake prior to their procedure are at an increased risk of hypoglycemia. It is important that patients on these medications follow their regularly prescribed diet prior to the dental procedure.

Hyperglycemia.

The stress of surgery may provoke the release of counterregulatory hormones that will impair insulin regulation and may result in hyperglycemia and a catabolic state. The cause of hyperglycemia is multifactorial and may include any of several medications such as corticosteroids, beta blockers, epinephrine, diuretics, and some antipsychotic drugs. Hyperglycemia is usually slower to develop and may not necessarily demonstrate any physical symptoms. Patients should be instructed to monitor their blood sugars in the postsurgical period and contact their physician if their readings remain elevated from their normal baseline. In the acute setting, hyperglycemia can be treated with insulin or by increasing fluids in noncardiac patients. Emergency services should be called for patients who experience erratic breathing and/or fluctuating levels of consciousness associated with high blood sugar levels.

Bone formation.

Studies have shown hyperglycemia has a negative effect on bone metabolism, reducing bone mineral density, affecting bone mechanical properties, and impairing bone formation leading to poor bone microarchitecture.[26] There is a direct correlation between implant osseointegration and glycemic control.[27] It has been shown that osseointegration is more predictable in anatomic areas with abundant cortical bone, which is why the mandible has shown a greater bone formation than the maxilla.[28]

Infection.

Diabetic patients are prone to develop infections and vascular complications. The healing process is affected by the impairment of vascular function, chemotaxis, and neutrophil function, as well as an anaerobic milieu. Protein metabolism is decreased, and healing of soft and hard tissue is delayed, which may lead to the susceptibility of infection. Neuropathy and impaired nerve regeneration may be altered as well as angiogenesis.[29]

Implant failure.

Human clinical studies have indicated that no contraindications exist for patients who are well controlled by diet and oral hypoglycemic. However, for insulin-controlled patients, a contraindication for implants may exist depending on the state of control. Researchers have concluded that implants have a high success rate provided the diabetes is controlled (monitor to ensure that glycosylated hemoglobin [HbA_{1c}] <7.0). An increased failure rate of dental implants has been associated with poor metabolic control.[30] It is imperative that uncontrolled or patients exhibiting an elevated HbA_{1c} be treated prior to and during the implant surgery healing period.

Complications Prevention

Understand symptoms of diabetes.

Because of the high incidence of undiagnosed diabetes, the implant dentist must be aware of the major symptoms such as polyuria, polydipsia, polyphagia, and weight loss. Therefore, undiagnosed diabetic patients may predispose the implant procedure with an increased morbidity. In the future, type 2 diabetes will continue to grow at rates that may reach epidemic

proportions.

Determine glycemic control.

The glycemic control should be evaluated via HbA_{1c} test, *(hemoglobin A1c, glycated hemoglobin, A1c, or HbA_{1c},)* in conjunction with a consultation with the patient's physician. Ideally, the A1c should be maintained at less than 7% when appropriate. The HbA_{1c} test is ideal for evaluation of glycemic control because it will show the glycemic control over the past 3 months. The HbA1c measures the glucose bound to hemoglobin within the red blood cells. The test is a weighted average of blood glucose levels during the life of the red blood cells (120 days). This test is more accurate in the assessment of diabetic control in comparison to a fasting blood glucose, which can give a false positive or negative results (Table 2.3).

TABLE 2.3

Hemoglobin–Blood Glucose Treatment Regimen

Risk	Hemoglobin	Blood Sugar Level	Treatment Plan
	A1c	mg/dL	
Low	<6.0	<140	Stress reduction protocol, maintain glycemic control (relative contraindication)
Low/Medium	6.0–7.0	140–180	Stress reduction protocol, maintain glycemic control Patients with neuropathy, nephropathy, peripheral vascular disease, history of coronary disease, or ophthalmologic manifestation of diabetes (retinopathy) may be at higher risk despite controlled HbA_{1c}. Consultation with MD may be appropriate (relative contraindication)
Medium High	7.0–8.0	180–215	Patients without and secondary manifestations of diabetes such as neuropathy, nephropathy, peripheral vascular disease, or ophthalmologic (retinopathy) MD consult may be obtained (relative). Patients with coronary disease or other diabetic related conditions require MD consult (relative/absolute)
High Risk	>8.0	>215	MD referral and better glycemic control (absolute contraindication)

HbA_{1c}, glycosylated hemoglobin.

Medication prophylaxis.

Because of the reciprocal relationship between infection and glycemic control, the use of antibiotic prophylaxis is highly recommended. Ideally, a beta-lactam antibiotic should be used pre- and postoperatively. When antibiotic prophylaxis is administered to diabetic patients, studies have shown a 10.5% reduction in failure rate. Further reduction is achieved by maintaining a strict aseptic technique in combination with good surgical technique. Additionally, it has been reported that the use of a chlorohexidine gluconate (0.12%) rinse at the time of implant placement reduced the failure rate from 13.5% to a remarkable 4.4% in type 2 diabetic patients.[31] A pre- and

postoperative chlorohexidine regimen will decrease morbidity with implants in diabetics. These patients must practice meticulous oral hygiene and be recalled at regular intervals to minimize the possibility of peri-implantitis.

Corticosteroids use.

Even though corticosteroids (e.g., dexamethasone) have been shown to minimize edema and pain after implant surgery, this medication should not be used in oral- or insulin-controlled diabetics. Corticosteroids have been shown to cause hyperglycemic episodes and changes in blood glucose levels that are difficult to correct.

Treatment summary

- **Diet-controlled diabetic:** Determine/maintain diabetic control
- **Hypoglycemic-controlled diabetic:** Determine/maintain diabetic, stress reduction protocol, A1c-<7%
- **Insulin-controlled diabetic:** Determine diabetic control, stress reduction protocol, A1c-<7%

Thyroid Disorders

- **Do you have a thyroid problem? Yes/No?**

Thyroid disorders are the second most common endocrine problem, affecting approximately 1% of the general population, principally women. The thyroid gland is one of the larger endocrine glands in the body and is situated at the level of C5 and T1 vertebral bodies, just below the laryngeal prominence. The main function of the thyroid gland is to produce hormones, the most common being thyroxine (T4) and triiodothyronine (T3). Thyroxine is responsible for the regulation of carbohydrate, protein, and lipid metabolism. In addition, the hormone potentiates the action of other hormones such as catecholamines and growth hormones. Abnormalities in the thyroid gland can result in disorders of thyroxine production. Excessive production of thyroxine results in hyperthyroidism. Symptoms of this disorder include increased pulse rate, nervousness, intolerance to heat, excessive sweating, weakness of muscles, diarrhea, increased appetite, increased metabolism, and weight loss. Excessive thyroxine may also cause atrial fibrillation, angina, and CHF. Palpation of the patient's neck often reveals an enlarged thyroid gland (goiter) between the cricoid cartilage and the suprasternal notch.

Surgical/Implant Implications

Hyperthyroidism.

High levels of circulating free levels of T4 or T3 result in a very low TSH level indicating hyperthyroidism. These patients may also complain of fatigue, and usually have excess sweating or feeling of being hot despite the temperature, restlessness, loose stools, palpitations or elevated heart rate, weight loss, increased blood pressure, tremor, and feeling of nervousness or irritability.

Hyperthyroid: catecholamine sensitivity.

Patients with hyperthyroidism are especially sensitive to catecholamines such as epinephrine in local anesthetics. When exposure to catecholamines is coupled with stress (often related to dental procedures) and tissue damage (dental implant surgery), an exacerbation of the symptoms of hyperthyroidism may occur. This can result in a condition termed *thyrotoxicosis* or *thyroid storm*, which is an acute, life-threatening hypermetabolic state clinically presenting with symptoms of fever, tachycardia, hypertension, and neurologic and gastrointestinal abnormalities. Treatment of thyroid storm in the dental setting includes immediate medical attention. If left untreated, these symptoms may result in CHF and life-threatening cardiac arrhythmias.

Bleeding.

The increased blood pressure and heart rate that accompany hyperthyroidism may increase bleeding at the surgical site and require additional hemostatic techniques. It is also important to note that PTU or propylthiouracil is used to treat hyperthyroidism. This drug is an antagonist of vitamin K that has an adverse impact on the clotting cascade and may result in significant bleeding or postoperative hemorrhage.

Aspirin/NSAID use.

Use of aspirin or NSAIDs requires extreme caution in the hyperthyroid patient. Aspirin can increase free levels of the T4 hormone because of an interaction with protein binding. Additionally, many hyperthyroid patients are on beta blockers for heart rate and blood pressure control, and the use of NSAIDs can decrease the efficacy of beta blockers. Alternative pain medications should be considered in patients with hyperthyroidism (e.g., Ultram).

Hypothyroidism.

Underactive or low thyroid production results in hypothyroidism. This disorder can be caused by the thyroid gland not producing sufficient thyroid hormone. The related symptoms are a result of a decrease in metabolic rate, which cause symptoms such as tiredness, cold intolerance, and weight gain. The diagnosis of hypothyroidism or hyperthyroidism can be confirmed with blood tests measuring thyroid-stimulating hormone (TSH) and free levels of T4 or T3. Low levels of circulating T4 and/or T3 will result in the TSH being elevated, indicating hypothyroidism. These patients usually have symptoms of fatigue, dry skin, hair loss, constipation, feeling cold, irregular menstrual cycles, weight gain, and they can have an enlarged thyroid gland (goiter).

Hypothyroid: CNS depressants use.

The hypothyroid patient is particularly sensitive to central nervous system (CNS)–depressant drugs, especially narcotics and sedative drugs such as diazepam or barbiturates. The risk of respiratory depression, cardiovascular depression, or collapse must be considered. Patients with longstanding hypothyroidism may have prolonged bleeding requiring hemostatic control for excessive bleeding. Additionally, hypothyroid patients may exhibit delayed wound healing and predisposition to postoperative infection.

Hypothyroid: bone healing.

T4 affects bone metabolism by decreasing recruitment and maturation of bone cells and reducing the bone growth factor of insulin-like growth factor. Studies have shown that medically treated hypothyroid patients exhibit greater bone loss and a less favorable soft tissue response after stage I surgery but with no significant increased risk of failure.[32]

Complications Prevention

Ideal thyroid control (hypothyroid and hyperthyroid).

To minimize any possible detrimental effects related to implant treatment, the implant clinician should monitor the patient for ideal thyroid control. Reducing stress in thyroid patients along with patient education on the importance of medication control is paramount to decrease procedural morbidity. Additionally, hypothyroid patients should be well informed of a possible decreased complication and success rate.

Corticosteroid Treatment

- **Do you have a history of taking corticosteroids? Yes/No?**

Corticosteroids are used in medicine today to treat a host of diseases. They are responsible for many actions including carbohydrate, protein, and lipid metabolism, the immune response, and the body's response to stress. Corticosteroids are highly effective in suppressing or minimizing inflammation while their pharmacologic and physiologic mechanisms are potentially detrimental to several metabolic, hormonal, and immunologic functions in the body. Although corticosteroids are routinely used prophylactically in the field of dental implantology, long-term use for treatment of various diseases does pose many possible complications for the patient undergoing dental implant surgery. Cortisol is the main steroid in the body and is involved in metabolic processes, inflammatory responses, and the control of responses to stresses. Secretion of cortisol is regulated via the hypothalamus-pituitary adrenal axis (HPA) feedback axis; however, for patients who are taking exogenous steroids, the feedback response may not occur. In these situations, the patient may be predisposed to acute adrenal insufficiency (adrenal crisis).

Surgical/Implant Implications

Adrenal insufficiency.

Long-term corticosteroid use may decrease a patient's ability to cope with the stresses of extensive surgical procedures. This may precipitate an acute adrenal crisis. Patients who are susceptible to adrenal crisis include those who:

- are currently on daily systemic corticosteroids of 10-mg equivalent;
- are currently on daily systemic corticosteroids of 5-mg prednisone equivalent;
- have been taking corticosteroids regularly during the previous 30 days;
- have been taking corticosteroids for more than 1 month during the past year.[33]

Signs of acute adrenal insufficiency include hypotension, altered mental status, pallor, and a rapid but steady weak pulse. Emergency treatment includes terminating the procedure, summoning medical assistance, administering supplemental oxygen, and monitoring vital signs. Place the patient in a supine position and raise the patient's legs, if possible, to

counteract the low blood pressure. If available, administer 100 mg of hydrocortisone sodium succinate (Solu-Cortef) when it is clear that the patient's current symptoms are due to adrenal crisis rather than to cardiac, pulmonary, or other medical etiology.

Implant failure.

Long-term corticosteroid therapy has shown adverse effects such as reduced bone density, increased epithelial fragility, delayed healing (decreased protein synthesis), and immunosuppression. Animal studies have shown osseointegration to be compromised; however, no studies to date have shown increased morbidity or implant failure in patients under systemic corticosteroids.[34]

Complication Prevention

Supplemental steroid coverage.

For patients who have received supraphysiologic doses of corticosteroids, their HPA may be suppressed, placing them at risk (adrenal crisis) during dental implant surgery and requiring supplemental doses of corticosteroids. Various regimens have been proposed; however, the most accepted protocol involves doubling the normal daily oral dose on the day of the procedure.[35] Modification of systemic steroid use should only be completed after physician consultation.

Susceptibility to infection.

Systemic corticosteroids (long term) may compromise the patient's ability to fight infection. By decreasing leukocytosis, the patient is more susceptible to infection after dental implant procedures. Patients should always receive a prophylactic administration of systemic antibiotics (pre- and postoperatively) and an antimicrobial mouth rinse (chlorhexidine gluconate) to reduce the possibility of infection.

Hyperparathyroidism

- **Do you have hyperparathyroidsim? Yes/No?**

Hyperparathyroidism is an excess of parathyroid hormone (PTH) in the bloodstream due to overactivity of one or more of the parathyroid glands that maintain calcium balance. The clinical manifestations of this disease vary

widely depending on the severity. Mild forms may be asymptomatic, whereas severe hyperparathyroidism can cause bone, renal, and gastric disturbance. It has been noted that skeletal depletion occurs as a result of stimulation by the parathyroid gland, which results in alveolar bone being affected prior to bones such as the ribs, vertebrae, or long bones. In the oral and maxillofacial regions, altered trabecular bone patterns may be present that result in mobility of the teeth and compromised bone density.

Hyperparathyroidism falls into three categories: primary, secondary, and tertiary. Primary hyperparathyroidism involves one of the parathyroid glands becoming overactive and releasing excess parathyroid hormone. This results in high levels of calcium being released into the bloodstream from the bone, which leads to osteoporotic bones.

Secondary hyperparathyroidism is a chronic condition where the parathyroid glands release excess amount of parathyroid hormone because of chronically low blood calcium levels. Secondary hyperparathyroidism is usually due to conditions such as chronic kidney disease, vitamin D deficiency, and some gastrointestinal issues that impact calcium absorption.

Tertiary hyperparathyroidism can occur when the condition causing secondary hyperparathyroidism is treated. This is similar to vitamin D deficiency; however, the parathyroid glands continue to produce excess parathyroid hormone.

Surgical/Implant Implications

Bone involvement.

Dental implants are contraindicated (absolute) in areas of active bony lesions. However, implant placement may be initiated after treatment and healing of the affected areas. Altered trabecular bone pattern with the appearance of ground glass may also occur. In animal studies, secondary hyperparathyroidism affects alveolar bone more than any other bone of the skeleton, and central or peripheral giant cell tumors may be present in active lesion areas.[36]

Complication Prevention

Parathyroid control.

When the PTH is elevated, a serum calcium level is obtained to determine if the hyperparathyroidism is primary or secondary, and the condition is

usually treated with surgery or medication. In advanced disease, there are certain oral changes that can be present to suggest hyperparathyroidism. These patients have an increased risk for tori, and reduction in the radicular lamina dura is evident on dental radiographs. Many patients with higher levels of parathyroid hormone develop loose teeth and widening of the periodontal ligament space surrounding the teeth. Additionally, cortical bone loss at the angle of the mandible has been noted in this disorder.

Xerostomia

- **Do you have xerostomia? Yes/No?**

Xerostomia (dry mouth) may directly or indirectly have effects on dental implants. A decrease in salivary flow is also accompanied by a change in its composition. An increase in mucin and a decrease in ptyalin result in a more viscous and ropy saliva. Plaque formation is increased, and the reduced antibacterial action of the saliva results in a favorable environment for bacteria growth.

Surgical/Implant Implications

Oral complications.

Dental implants are not contraindicated in patients suffering from xerostomia. Case reports have been documented with successful implant placement with no increase in failure rate.[37] However, with the lack of saliva, implant patients may be susceptible to more oral lesions and the possibility of irritation from tissue-borne implant prostheses. Additionally, patients are at higher risk for incision line opening.

Complication Prevention

Oral bacterial infections.

Patients with xerostomia are at a higher risk for oral infections such as periodontitis, caries, and fungal infections. A comprehensive oral and periodontal examination must be completed with emphasis on a low periodontal pathogen bacterial count to reduce possible postoperative complications.

Increase saliva flow.

Stimulation of salivary flow may be achieved either by physiologic or pharmacologic means. Mouth rinses, chewing gum, or salivary substitutes may be used (Box 2.4).

Box 2.4

Xerostomia Treatment Regimens

- Drink water frequently: helps moisten mucosa and loosen mucus.
- Gum/candy: the use of sugarless gum or candy helps stimulate saliva flow.
- Avoid commercial mouth rinses containing alcohol or peroxide: further desiccate the mucosa.
- Avoid salty foods, dry foods (for example, crackers, toast, cookies, dry breads, dry meats/poultry/fish, dried fruit, bananas) and foods and beverages with high sugar content.
- Avoid drinks containing alcohol or caffeine. Alcohol and caffeine increase urination and desiccate the mucosa.
- Over-the-counter saliva substitutes: products containing xylitol (e.g., Mouth Kote, Oasis Moisturizing Mouth Spray, or ones containing carboxymethylcellulose)
- Prescription medications, after physician consultation (Evoxas, Salagen, Pilocarpine, Cevimeline)

Final prosthesis.

When treatment planning patients with xerostomia, a final prosthesis that is not tissue borne is recommended. A fixed-detachable (FP-3) prosthesis is highly recommended because of the lack of soft tissue coverage. If a removable prosthesis is warranted, an RP-4 is recommended because of the lack of soft tissue coverage. Additionally, removable prostheses worn in patients with xerostomia are associated with a high prevalence of fungal infections. If fungal infection is diagnosed, the use of a Nystatin medication is warranted (for additional endocrine implications see Table 2.4).

TABLE 2.4

Additional Endocrine Issues and Treatment Implications

Positive Response	Treatment Implications
Frequent urination	Diabetes (undiagnosed)
Increased thirst	Diabetes (undiagnosed)
Recent weight loss	Anxiety, depression, GI disease, diabetes, hyperthyroidism
Recent weight gain	Heart failure (water retention), corticosteroids, Cushing syndrome, hypothyroidism
Increased appetite	Diabetes, hyperthyroidism
Fatigue	Anxiety, depression, anemia, vitamin B deficiency, hyper/hypothyroidism, chronic pulmonary/cardiovascular disease
Frequent kidney stones	Hypercalciuria from hyperparathyroidism
Increased head/hand shoe size	Paget disease
Nontraumatic bone fractures	Osteoporosis, hyperparathyroidism, myeloma
Slow healing infections/sores	Undiagnosed diabetes, Cushing syndrome, coagulation factor deficiency, vitamin C deficiency, adrenal insufficiency
Pigment changes in skin (dark spots)	Undiagnosed diabetes, Addison disease, melanoma, hemochromatosis

GI, gastrointestinal.

Pulmonary System

Chronic Obstructive Pulmonary Disease (COPD)

- **Do you have chronic obstructive pulmonary disease? Yes/No?**

Chronic obstructive pulmonary disease (COPD) refers to a group of pulmonary diseases that block airflow, resulting in breathing difficulties. The two most common conditions that make up COPD are chronic bronchitis and emphysema. Chronic bronchitis is an inflammation of the bronchial tubes that produces an increase in mucous production and coughing. Emphysema occurs when the alveoli in the bronchioles of the lungs become damaged or destroyed creating symptoms of dyspnea (shortness of breath) that may worsen with mild activity.

Patients with COPD may have a combination of both conditions. These patients usually present with fatigue, history of recurrent respiratory infections, wheezing, and shortness of breath. In advanced disease states, patients may become oxygen dependent with tachypnea being present with some audible wheezing and shortness of breath even at rest. The various levels of COPD are classified via GOLD (Global Initiative for Chronic Obstructive Lung Disease), which classifies patients on their degree of airflow limitation. The airflow limitation is measured during pulmonary function tests (PFTs) measured as forced expiratory volume (FEV_1) (Table 2.5).

TABLE 2.5

COPD Stages and Related FEV_1 Values

Stage I	Mild COPD	FEV_1/FVC <0.70	FEV_1 ≥80% normal
Stage II	Moderate COPD	FEV_1/FVC <0.70	FEV_1 50%–80% normal
Stage III	Severe COPD	FEV_1/FVC <0.70	FEV_1 30%–50% normal
Stage IV	Very severe COPD	FEV_1/FVC <0.70	FEV_1 <30% normal, or <50% normal accompanied by chronic respiratory failure

COPD, chronic obstructive pulmonary disease; *FEV_1*, forced expiratory volume; *FVC*, forced vital capacity.

Surgical/Implant Implications

Anesthetic selection.

In rare instances, patients with COPD receiving local anesthetics have had adverse reactions. Increased doses of anesthetic solutions that contain sulfites may increase the risk of bronchospasm or allergic reactions. Most local anesthetics that are vasopressor anesthetics (e.g., epinephrine, levonordefrin), will contain the antioxidant sodium (meta) bisulfite. For COPD patients with a known allergy to bisulfites a local anesthetic without a vasopressor (e.g., mepivacaine HCL 3%, prilocaine HCL 4%) should be used.

Adrenal suppression.

Adrenal suppression may occur with long-term corticosteroid treatment, which is common with more advanced COPD patients.

Cardiovascular event.

For patients who have had a cardiovascular event, the patient's functional capacity should be ascertained (physician consultation) and a stress reduction protocol implemented. The implant clinician should avoid long or extensive surgical procedures.

Oxygen supplementation.

High flow rates of oxygen can result in respiratory depression and should not be used, especially with patients who require at-home oxygen use. Nitrous oxide is also contraindicated because of the negative impact on the respiratory drive. Low–flow rate oxygen supplementation (<2 L/min) during implant procedures is highly recommended, so as to minimize the possibility of hypoxia.

Bronchodilators/inhaled corticosteroids.

Bronchodilators and inhaled corticosteroids are the hallmark of treatment for COPD; however, they have been associated with an adverse impact on oral tissues.

Beta 2 agonists like albuterol have been associated with a decrease in saliva production and subsequent secretion resulting in xerostomia. Patients should always be instructed to bring their rescue inhaler (usually albuterol) to the procedure or, for more advanced COPD patients, their nebulizer and albuterol solution in case of an emergency.

Complication Prevention

Minimize elective procedures.

Dental implant management of patients with COPD is staged according to the severity of the disease. It is important to understand the severity of the lung disease before initiating any dental procedure. More advanced COPD patients have a higher propensity to retain carbon dioxide, which may directly lead to adverse intraoperative outcomes.

Use of sedation.

Sedation should be carefully evaluated in patients with COPD, and discussion with their treating physician is recommended. Potent sedatives such as narcotics and barbiturates should be avoided unless approved by the treating physician. These drugs can further depress the respiratory drive in more advanced COPD patients. Antihistamines may desiccate respiratory secretions, which may lead to compromised air flow. Additionally, nitrous oxide should not be used in COPD patients as it may lead to further respiratory depression (Table 2.6).

TABLE 2.6

Additional Pulmonary Issues and Treatment Implications

Positive Response	Treatment Implications
Asthma	Inflammatory process in lung is IgE/allergen mediated Determination of trigger: asthma or bronchospasm, including anxiety Albuterol on hand for surgery Approximation of severity determined by number of medications and frequency of use of albuterol rescue inhaler
Shortness of breath (dyspnea)	Asthma, COPD, heart disease, cardiomyopathy, CHF, arrhythmias, anemia, obesity, heart valve disease
Wheezing	Allergies, asthma, bronchitis, GERD, vocal cord dysfunction
Hemoptysis (blood in sputum)	Bronchitis, pulmonary embolism, CHF, lung cancer, blood thinners, TB
Cough	Postnasal drainage, asthma, GERD, ACE/ARB blood pressure meds, chronic bronchitis in COPD, other respiratory like bronchiectasis
Change in exercise tolerance	Any changes walking up stairs or walking more than 50 yards Cardiovascular, pulmonary, poor conditioning
Weight loss	Poorly controlled COPD, malignancy, TB, hyperthyroid, ethyl alcohol abuse
Dysphagia from stroke or other neuromuscular diseases	Risk of aspiration during dental procedure

ACE, angiotensin-converting enzyme; *ARB*, angiotensin-receptor blocker; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *GERD*, gastroesophageal reflux disease; *IgE*, immunoglobulin E.

Hematologic System

Erythrocytic Disorders: Polycythemia

- **Do you have a bleeding/blood disorder? Yes/No?**

Polycythemia is a myeloproliferative bone cancer condition that results in increased red blood cells and is characterized by an increased hematocrit (>48% in women, >52% in men) and hemoglobin level (>16.5 g/dL in women and >18.5 g/dL in men). The health concerns associated with polycythemia are a direct result of thicker blood due to an increased red blood cell count, placing the patient at a surgical risk. Primary polycythemia is relatively rare and caused by overproduction of red blood cells by the bone marrow. Secondary polycythemia is caused by chronic hypoxemia or an erythropoietin-secreting tumor. Conditions like COPD, CHF, pulmonary hypertension, testosterone replacement therapy, and sleep apnea may cause secondary polycythemia.

Surgical/Implant Implications

Thrombus formation.

Because of the higher viscosity of the blood in polycythemia patients, an increased possibility of stroke, myocardial infarction, pulmonary embolism

may occur.

Bleeding.

Excessive bleeding and clotting issues are common with polycythemia patients; good surgical technique and strict hemostatic control measures must be adhered to in order to minimize intraoperative and postoperative bleeding episodes.

Treatment summary.

Unless cleared by a physician, polycythemia is an absolute contraindication for dental implant treatment.

Erythrocytic Disorders: Anemia

Anemia, the most common hematologic disorder, is defined as a deficiency in red blood cells, resulting in low hemoglobin. The etiology of anemia is either underproduction of red blood cells or an increased destruction or loss (usually gastrointestinal or menstrual) of red blood cells. Iron deficiency anemia results from a lack of iron in the body or excessive loss of red blood cells. Various other anemias exist that are associated with vitamin deficiencies such as B_{12} or folate. Some anemias are the result of destruction of red blood cells. These are known as hemolytic anemias with sickle cell anemia as an example. Bone marrow dysfunction may also lead to anemia.

The general symptoms and signs are all a consequence of either a reduction of amount of oxygen reaching the tissues or alterations of the red blood cell count. The symptoms of mild anemia include fatigue, anxiety, and sleeplessness. Chronic anemia is characterized by shortness of breath, abdominal pain, bone pain, tingling of extremities, muscular weakness, headaches, fainting, change in heart rhythm, and nausea. The general signs of anemia may include jaundice, pallor, spooning or cracking of the nails, hepatomegaly and splenomegaly, and lymphadenopathy.

Surgical/Implant Implications

Bleeding.

Some anemias are associated with abnormal bleeding. During extensive surgery, the increased bleeding may cause a decreased field of view for the clinician and possible postoperative issues. Most often iron deficiency

anemia and other vitamin-dependent anemias are associated with increased bleeding.

Edema.

Increased edema and subsequent increased discomfort postsurgically are common consequences. In addition, the excess edema increases the risk of postoperative infection and morbidity. Not only are anemic patients prone to more immediate infection from surgery, they are also more sensitive to chronic infection throughout their lives. This may affect the long-term maintenance of the proposed implant or abutment teeth.

Oral soft tissue issues.

The oral signs of anemia affect the tongue. Symptoms include a sore, painful, smooth tongue, loss of papillae, redness, loss of taste sensation, and paresthesia of the oral tissues.

Bone healing.

Bone maturation and development are often impaired in the long-term anemic patient. A faint, large trabecular pattern of bone may even appear radiographically, which indicates a 25% to 40% loss in trabecular pattern. Therefore, the initial quality of the bone required to support the implant can be affected significantly. The decreased bone density affects the initial placement and may influence the initial amount of mature lamellar bone forming at the interface of an osseointegrated implant. The time needed for a proper interface formation is longer in poor-density bone.[38] However, after the implant is loaded successfully, the local strain environment will improve the bone density at the interface.

Complication Prevention

MD consultation/lab tests.

Lab tests for anemia include the hematocrit and hemoglobin. The hematocrit indicates the percentage of a given volume of whole blood composed of erythrocytes. An abnormal hemoglobin may result from its combination with substances other than oxygen (e.g., carbon monoxide) or genetic diseases (e.g., sickle cell diseases). Normal values for men are 13.5 to 18 g/dL; those for women are 12 to 16 g/dL. The minimum baseline recommended for surgery is 10 mg/dL, especially for elective implant surgery. For the majority of anemic

patients, implant procedures are not contraindicated.

Medications.

Preoperative and postoperative antibiotics should be administered and the risk of bleeding in anemic patients should not be potentiated by the prescription/use of aspirin. Hygiene appointments should be scheduled more frequently for these patients to decrease possible periodontal issues.

Leukocytic (WBC) Disorders

Leukocyte disorders are an important consideration in hematologic diseases. The WBC count normally ranges from 4500 to 13,500/mm^3 in the adult. Leukocytosis is an increase in circulating WBCs with various etiologies. There are multiple components of the white blood cell that can be increased: (1) neutrophils—main defense against bacterial infections; (2) lymphocytes—main defense against viral infections; (3) monocytes—largest type of leucocyte (white blood cell), which differentiates into phagocytes; (4) eosinophils—combat parasites and associated with allergies; (5) basophils—type of white blood cell; (6) blast cells—immature cells. Leukocytosis is defined as an increase in circulating WBCs in excess of 13,500/mm^3. The most common cause of leukocytosis is infection. Leukemia, neoplasms, acute hemorrhage, and diseases associated with acute inflammation or necrosis (e.g., infarction, collagen diseases) are more serious causes of leukocytosis. Physiologic conditions such as exercise, pregnancy, and emotional stress can also lead to leukocytosis in addition to chronic steroid use.

Leukopenia is a reduction in the number of circulating WBCs to less than 4500/mm^3. A decreased leukocyte count may accompany certain infections (e.g., infectious hepatitis), bone marrow damage (from radiation therapy), nutritional deficiency (e.g., vitamin B_{12}, folic acid), and blood diseases (e.g., anemia).[9]

Surgical/Implant Implications

Infection.

With patients suffering from leukocytosis or leukopenia, many complications can compromise the success of the implants and prosthesis. The most common is infection, not only during the initial healing phase but also long term, which may compromise the longevity of the implants and the final

prosthesis.

Bleeding.

Thrombocytopenia is caused by decreased production, increased destruction, or sequestration of platelets in the spleen, which results in potential bleeding complications during surgery. A platelet count should always be obtained via MD consultation, and a value lower than 50,000 U/L contraindicates elective dental surgery because of a significant risk of postoperative bleeding.[39]

Delayed healing.

Delayed healing is also a consequence of WBC disorders. For most dental implant procedures, the initial few months are critical for the long-term success of the implants and/or bone graft. Delayed healing may increase the risk of secondary infection and possibility of incision line opening.

Complication Prevention

MD consultation.

Because of the wide spectrum of hematologic disease states, the severity of the disorder and its associated medications should be evaluated with a strong recommendation of physician consultation (Table 2.7).

TABLE 2.7

Additional Hematologic Issues and Treatment Implications

Positive Response	Treatment Implications
Sickle cell anemia	Secondary infections are a common consequence with frequent history of osteomyelitis and bone infection. (absolute contraindication)
Leukemia	Experience anemia and thrombocytopenia. Although the infection is less severe than in acute leukemia, radiolucent lesions of the jaws, oral ulcerations, hyperplastic gingiva, and bleeding complications develop in these patients. (absolute contraindication)
Thalassemia	Multiple types (alpha, beta) and degrees of severity (major, minor) More severe forms can present some issues erythroid mass expansion directly into facial bones causing malocclusions. Medical consultation is recommended to determine severity of disease. Major (severe forms)—absolute contraindication Minor (less severe)—relative contraindication
Frequent nosebleeds (epistaxis)	Hypertension, sinus disease, bleeding disorders such as von Willebrand Spontaneous or frequent nose bleeds should have bleeding time and INR
Easy bleeding gums	Gingival disease, bleeding disorder, thrombocytopenia, leukemia, liver disease Further investigation may be warranted with platelet, CBC, bleeding time, PT, PTT
Heavy menstrual periods	Thyroid disease, dysfunctional uterine bleeding (fibroid, polyps, hormone imbalance), bleeding disorders, platelet dysfunction. If no obvious medical reason, check CBC, INR, bleeding time
Family history of bleeding disorder	If family history of bleeding issues, check CBC, INR, PTT, bleeding time to rule out hereditary bleeding disorders such as von Willebrand, hemophilia, coagulation factor deficiencies
Prolonged bleeding after cuts	Rule out coagulation defect, hereditary bleeding disorder, or platelet dysfunction; check CBC, INR, PTT, bleeding times
Easy bruising or spontaneous bruising	Platelet deficiency, coagulation factor issue, leukemias, vitamin K deficiency, chemotherapy, anticoagulation medication
History of excessive bleeding after dental surgery	If no definitive diagnosis that correlates with prolonged bleeding, check CBC, INR, PTT, bleeding time

CBC, complete blood count; *INR*, international normalized ratio; *PT*, prothrombin time; *PTT*, partial thromboplastin time.

Digestive System

Inflammatory Bowel Disease (IBD)

Do you have or have you been treated for inflammatory bowel disease? Yes/No?

Inflammatory bowel disease (IBD) is a chronic inflammation of all or part of the digestive tract. The number of people afflicted with this condition continues to increase. The two major forms of IBD are *ulcerative colitis* and *Crohn disease*. Patients will usually have symptoms of chronic or severe diarrhea, fatigue, rectal bleeding, and anemia. Ulcerative colitis is characterized as an inflammatory disease of the rectum and large intestine mainly affecting the mucosal lining. Crohn disease is an inflammatory disease of the entire digestive tract from mouth to anus, resulting in lesions of healthy tissue in between areas of inflammation. Most cases of Crohn disease originate within the terminal ileum.

Surgical/Implant Considerations

Infections.

Patients are susceptible to infections and healing issues usually associated with the immunosuppressive drugs. As well, their dietary restrictions may impact both of these issues, and postoperative antibiotics are usually indicated.

Adrenal issues.

During dental procedures, stress reduction protocol is essential. Excess stress can impact adrenal function and require additional corticosteroid augmentation. Postoperative pain episodes may increase stress on the adrenal gland, resulting in possible adrenal suppression complications.

Bleeding.

Many digestive disorder patients are anemic and, because of malabsorption, may not absorb all the necessary components of clotting factors as well as certain vitamins. Care should be taken to minimize bleeding.

Oral lesions.

There are many differences in the oral lesions and that manifest in patients with Crohn disease and those with ulcerative colitis. Many of these patients present with a glossitis, aphthous ulcerations, or a more classic marker of ulcerative colitis, pyostomatitis vegetans. This condition is characterized by pustules with thickened oral mucosa and surrounding erythema with some erosions.[40] Ulcerative colitis has extragastrointestinal manifestations that have been associated with erosive temporomandibular joint disease.[41] Crohn disease has been shown to have oral symptoms such as cobblestoning of the oral mucosa accompanied by ulcerations usually in a linear pattern along with hyperplastic folds of the buccal vestibules (mucosal tags).[42]

Complication Prevention

MD consultation.

A physician consultation is recommended to determine the extent of the patient's digestive disorder along with the current immune status. Most notably, an evaluation of delayed wound healing and postoperative infection susceptibility should be ascertained.

Antibiotics usage.

Antibiotics that have a high incidence of antibiotic-associated diarrhea or pseudomembranous colitis should be avoided (e.g., amoxicillin/clavulanic acid, erythromycin, clindamycin).

Use of probiotics.

Patients with IBD, especially those with ulcerative colitis, may benefit from the use of probiotics, especially when antibiotics are prescribed. Probiotics are live microorganisms that are added to food to change the intestinal microbial balance. The mechanism of action is controversial; however, theories include strengthening of the gut barrier, pathogen growth inhibition, and enhancement of mucosal and systemic immune responses.

Pain management.

Most NSAIDs may precipitate these disease states and should be avoided unless authorized by a physician.

Stomach Ulcers

- **Do you have stomach ulcers? Yes/No?**

Approximately 1 in 10 Americans will suffer from a version of gastritis or ulcer disease during their lifetime. Ulcers form when there is a break or breach of the lining of the stomach or intestine. Peptic ulcers form in the duodenum of the small intestine from being in contact with stomach acids. Duodenal ulcers are the most common type of ulcer. Ulcers that occur in the stomach are referred to as gastric ulcers. In rare cases, esophageal reflux can cause esophageal ulcers. There are several main causes for ulcer disease including excessive alcohol intake, stress, medications (NSAIDs, aspirin), and a bacterium *(H. Pylori)*.

Complication Prevention

Medications.

While there are no direct contraindications to the use of prophylactic antibiotics in patients with ulcer disease (except allergies), some patients may be more sensitive to certain types of antibiotics that may irritate their stomach. Pain management may be hampered by the inability to use NSAIDs or certain narcotics. To prevent bleeding from stomach ulcers,

analgesics and antibiotics should be cautiously used (MD clearance) in the treatment of implant surgical patients.

Liver Cirrhosis

- **Do you have liver problems? Yes/No?**

Cirrhosis of the liver is characterized by irreversible scarring and is usually caused by excessive alcohol intake, viral hepatitis B and C, and certain medications. Although patients with advanced disease can present with jaundice and itching, the diagnosis is usually confirmed by liver biopsy and blood tests. Cirrhosis may cause excessive bleeding, mental confusion, kidney failure, and accumulation of fluid in the abdomen (ascites). Cirrhosis is irreversible, and transplantation is becoming the most successful treatment for advanced disease states.

These patients may be predisposed to issues including the synthesis of clotting factors and the inability to detoxify drugs. Hemostatic defects of liver disease are not only the reduced synthesis of clotting factors, but also an abnormal synthesis of fibrinogen and clotting proteins, vitamin K deficiency, enhanced fibrinolytic activity, and quantitative and qualitative platelet defects. Of patients with liver disease, 50% have a prolonged prothrombin time (PT) and possible significant clinical bleeding. The inability to detoxify drugs may result in oversedation or respiratory depression. The laboratory evaluation of the implant candidate gives much insight into hepatic function. A basic panel of liver function tests (LFTs) or a comprehensive metabolic panel (CMP) can provide the needed information. In most patients with liver disease, it is recommended that a complete blood count (CBC), LFT, basic metabolic panel (BMP), bleeding time, and an international normalized ratio (INR)/PT test should be performed.

Surgery/Implant Implications

Bleeding.

Patients with no abnormal laboratory values for CMP, CBC, partial thromboplastin time (PTT), and PT are at low risk. A normal protocol is indicated for all surgical implant procedures. Ideally, INR values should be below 3.0. Patients with an elevated PT of less than 1.5 times the control value or bilirubin slightly affected are at moderate risk. Chronic severe liver disease may increase INR.

Medications.

Many drugs such as local anesthetics (lidocaine, prilocaine, mepivacaine, bupivacaine), sedatives (lorazepam, valium, alprazolam), and antibiotics (erythromycin, clindamycin) are metabolized primarily in the liver. Therefore, in some patients a dosage reduction may be warranted based on the current liver functioning.

NSAIDs.

NSAIDs should be avoided because they can be associated with renal failure. Acetaminophen at reduced dose is a possible alternative consideration. An accepted school of thought is that codeine and opioids should not be used or, if so, at very infrequent and lower dosages to avoid hepatic encephalopathy.[43] Additionally, tetracycline, erythromycin, and metronidazole should never be used in patients with advanced liver disease.

Complication Prevention

High risk (absolute).

Patients with a PT greater than 1.5 times the control value, mild to severe thrombocytopenia (platelets lower than 50,000/mL), or several liver-related enzymes or chemicals affected (bilirubin, albumin, alkaline phosphatase, serum glutamic oxaloacetic transaminase, and serum glutamic pyruvic transaminase) are at high risk. If there are any concerns, consultation with the patient's physician should be completed.

Strict attention to hemostasis.

Hemostatic agents should be used, such as bovine collagen or topical thrombin, in addition to good surgical technique and placement of additional sutures.

Bone Diseases

Osteoporosis

- **Do you have osteoporosis? Yes/No?**

The most common disease of bone metabolism the implant clinician will encounter is osteoporosis, an age-related disorder characterized by a decrease in bone mass, increased microarchitectural deterioration, and

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susceptibility to fractures. The World Health Organization defines osteoporosis as bone mineral density levels more than 2.5 standard deviations below the mean of normal young women.[44] Forty percent of postmenopausal women in the United States have bone mineral density levels denoting osteopenia, and 7% have scores correlated with osteoporosis.[45] As the population ages, the incidence of osteoporosis will continue to increase in both women and men.

TABLE 2.8

Additional Digestive Issues and Treatment Implications

Positive Response	Treatment Implications
Jaundice	Hepatitis, bile duct disorders, sickle cell anemia, autoimmune hemolytic disease pancreatic cancer
Hepatitis	Medical consultation, aseptic technique, preventive measures
Esophageal reflux	Infection, increased tooth decay/erosion
Hiatal hernia	Appointment duration not to exceed patient's tolerance
Nocturnal cough	Gastric reflux disease, chronic sinusitis, allergies
Dark tar-colored stools	GI bleeding (avoid anticoagulants, NSAIDs; need GI evaluation)
Frequent foul-smelling stools	Crohn disease, pancreatic cancer (gum disease), lactose intolerance (tooth decay, bone demineralization), celiac (gluten intolerance) disease (enamel erosion, aphthous ulcers)
Dysphagia (solid/liquid)	Reflux, esophageal spasm, stricture, esophageal mass, multiple sclerosis, Parkinson disease, stroke, poor oral clearance, high-volume suction, aspiration during treatment, protect airway rubber dam
Persistent pruritus (itching)	Celiac disease, liver disease, biliary disease (sclerosing cholangitis) All can lead to coagulopathy and excessive bleeding

GI, gastrointestinal; *NSAIDs*, nonsteroidal antiinflammatory drugs.

The osteoporotic changes in the jaws are similar to those in other bones in the body. The structure of the bone is normal; however, because of the uncoupling of the bone resorption and formation processes with emphasis on resorption, the cortical plates become thinner, the trabecular bone pattern becomes more discrete, and advanced demineralization occurs.[46] The loss of trabecular bone is accelerated in the edentulous patient because the factors involved in resorption are already established. Osteoporosis affects the trabecular bone mass loss to a greater extent than it does cortical bone.[47]

Surgical/Implant Implications

Surgical technique.

Underpreparation of the osteotomy site (or use of osteotomes) will result in the implant having more bone at the implant interface. Although not contraindicated, immediate stabilization of dental implants is a common concern because of decreased trabecular bone mass. Healing periods and

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implant surface characteristics should be selected for poorer-quality bone.

Bisphosphonates use.

Oral/IV bisphosphonates are common medications for osteoporosis. Studies have suggested there are different guidelines that should be observed in patients receiving intravenous bisphosphonate treatments in comparison to those patients on oral formulations of these medications. With oral bisphosphonates, a low probability of adverse effects on the success of dental implants. However, it is advised that a detailed medication history for patients treated for osteoporosis be completed. It is important to know which bisphosphonate they are taking along with the time duration. For those patients receiving treatment for more than 3 years, additional testing may be considered (C-telopeptide [CTx] test).[48] IV forms of bisphosphonate medications have been shown to have the most devastating effects within the oral cavity (osteonecrosis), despite similar mechanisms of action for both the oral and IV formulations. It is advised that all patients currently treated with bisphosphonates be advised of the possibility of bony necrosis of the jaw and be part of their informed consent. Intravenous administration of bisphosphonates has been considered an absolute contraindication for placement of dental implants with the concern for the increase risk of developing osteonecrosis of the jaw. This association has been based on patients who were receiving the IV form in treatment of metastatic cancer or Paget disease. However, medications like zoledronic acid (Reclast) are now being used routinely to prevent osteoporosis. The risk of developing medication-related osteonecrosis of the jaw in these patients is being investigated, however the patient should be informed of the potential complications.

Length of healing.

In osteoporotic patients, there is a decrease in cortical and trabecular bone; the repair process (implant healing) may be compromised. Sufficient time for healing should be adhered to with progressive prosthetic bone loading is highly recommended.

Peri-implantitis.

A strong correlation has been shown between periodontal disease and skeletal osteoporotic changes. Strict postoperative recall and periodontal evaluation should be adhered to.

Progressive bone loading.

Because of poorer bone quality, healing is compromised, necessitating progressive bone loading throughout the prosthetic rehabilitation. The poorer-quality bone is progressively increased to better-quality bone, which results in better bone quality at the implant interface.

Implant design.

Implant design should include greater width implants. Surface conditions of implant bodies should be designed to increase bone contact and density. Bone stimulation to the healed interface will increase bone density, even in advanced osteoporotic changes.

Complication Prevention

Understand risk factors.

Most clinical studies show no increased failure rate amongst osteoporotic patients.[49,50] However, patients should be well informed about the possible complications resulting from the poorer-quality bone. Osteoporosis is a relative complication and the patient should be instructed of possible complications.

Osteomyelitis

- **Do you have a history of osteomyelitis? Yes/No?**

Osteomyelitis is an acute or chronic inflammatory bone disease that is bacterial in nature. The radiographic appearance is a poorly defined, radiolucent area with isolated fragments of bone (sequestra) that can exfoliate or become surrounded by bone (involucrum). This disorder can be caused by odontogenic and periodontal infections, trauma, dental implants, immunocompromised states, and hypovascularized bone. The treatment includes aggressive surgical drainage, with possible intravenous antibiotic intervention. Osteomyelitis usually occurs in the mandible and is rarely seen in the maxilla, most likely due to the increased vascularization of this area.

Surgery/Implants Implications

Implant placement.

Implant placement in surgical sites that have been previously affected with

osteomyelitis leads to an increased morbidity. Because of the lack of vascularity, endosseous implants have a greater chance of bone loss, infection, and failure.

Treatment summary.

Osteomyelitis is usually an absolute contraindication unless the etiologic factors are corrected and adequate blood supply to the affected area is restored. A physician clearance should be obtained along with a comprehensive informed consent on the possible complications that may arise from implant placement into these sites.

Fibrous Dysplasia (FD)

- **Do you have fibrous dysplasia? Yes/No?**

Fibrous dysplasia (FD) is a rare, nonheritable, genetic disorder characterized by normal bone being replaced by immature, haphazardly distributed bone and fibrous tissues. The etiology of this bone disease is a gene mutation that prevents the differentiation of cells within the osteoblastic formation. FD can be further classified to involve one site (monostotic fibrous dysplasia [MFD]), multiple sites (polyostotic fibrous dysplasia [PFD]), or multiple locations (craniofacial fibrous dysplasia [CFD]). CFD lesions are usually unilateral and occurs twice as often in the maxilla vs. mandible. The diagnosis of CFD should be determined from the clinical evidence, histopathologic analysis of the biopsy specimen, and radiologic findings.[51] Most individuals with this disorder are diagnosed early in childhood.

Surgical/Implant Implications

Postoperative healing.

Healing after trauma in patients with FD is much different than for those with normal bone. The tissue is hypocellular, which leads to slow healing and an increased infection rate. These local infections may spread through the bone and result in more advanced complications.

Complication Prevention

Proper diagnosis.

The radiographic appearance is highly variable because of the disproportionately mineralized tissue and fibrous tissue in the lesion. This variability results with radiographic images depicting the typical "ground glass" appearance to early-stage radiolucencies and late-stage radiopacities.[52] Additionally, severe malocclusion, dental abnormalities, and facial asymmetry have been shown to be highly prevalent in CFD patients, which further complicates the prosthetic rehabilitation of these patients.[53]

Informed consent.

Because of the lack of research and studies, the patient needs to be well informed of possible morbidity and complications.

Treatment summary

- **Active lesion areas:** Absolute contraindication
- **Nonlesion areas:** Relative contraindication

Paget Disease

- **Do you have a history of Paget disease? Yes/No?**

Osteitis deformans, or Paget disease, is a common metabolic disease characterized by slow, progressive, uncontrolled resorption and deposition of bone. This disease is usually seen in Caucasian men older than 40 years. The etiology is unknown and usually affects the maxillary alveolar ridge twice as frequently as the mandibular ridge. Because of the enlargement of the middle one third of the face, the appearance of a "lionlike" deformity is often noted. Diastemas, tooth mobility, and bone pain are additional characteristics. Radiographically, a decreased radiodensity, large circumscribed radiolucencies, patchy areas of coalesced sclerotic bone (cotton-wool appearance), and marrow spaces that are replaced by fibrous tissue are observed. This disease has a wide spectrum of treatment ranging from no treatment or the use of bisphosphonates. For patients who are symptomatic, IV bisphosphonates are usually the preferred treatments. These drugs help decrease further bone breakdown, formation, and remodeling.

Surgical/Implant Implications

Bleeding.

During the active phases of this disease, bone is highly vascular with the possibility of arteriovenous shunts, which may cause hemorrhagic complications.

Infection.

Bone areas that are affected by this disorder are predisposed to develop osteosarcoma and possible osteomyelitis.

Treatment summary.

Oral implants are contraindicated in the regions affected by this disorder or in patients on IV bisphosphonates for the treatment of their Paget symptoms. For additional bone disease responses and treatment implication see Table 2.9.

TABLE 2.9

Additional Bone Disease Responses and Treatment Implications

Positive Response	Treatment Implications
Orthopedic prosthetic device	Antibiotic prophylaxis
Ectodermal dysplasia	Many studies completed showing successful treatment in ectodermal dysplasia patients
Cemento-osseous dysplasia (periapical cemental dysplasia)	Bone quality is questionable because of avascular cementum–like lesions (relative contraindication)
Osteomalacia	Hypomineralized bone, questionable bone quality (relative contraindication)

Autoimmune Disease

Do you have an autoimmune disorder? Yes/No?

Autoimmune disease refers to a group of more than 80 serious, chronic illnesses that can affect almost any organ in the body. Approximately 75% of autoimmune diseases occur in women; these diseases are thought to have a genetic predisposition. However, autoimmune diseases are among the most poorly understood diseases, with symptoms extremely variable among individuals.

Sjögren Syndrome

Sjögren syndrome is an autoimmune disease in which immune cells attack and destroy exocrine glands that produce saliva and tears. This disorder affects an estimated 4 million people in the United States, with a gender distribution of 90% female. The average age of onset for the disease is in the

late 40s. The classic symptoms of Sjögren syndrome are xerostomia and xerophthalmia (dry eyes). Sjögren syndrome often accompanies other immune diseases including rheumatoid arthritis and lupus.

Systemic Lupus Erythematosus

Systemic lupus erythematous is a chronic, potentially fatal autoimmune disease in which the immune system attacks cells and tissue in almost any part of the body. This disease usually affects women, and approximately 5 million people are afflicted with this disorder. Lupus presents and progresses with such variability that every case is different. Lupus can affect almost any part of the body including the kidneys, brain, blood vessels, heart, lungs, and skin.

The hallmark sign of lupus is a butterfly-shaped rash that often appears around the nose and extends to the cheeks. Some patients only develop the rash and this is termed *discoid lupus*. Oral ulcerations may be found in patients with lupus as well as silvery white (honeycomb) and raised keratotic plaques referred to as verrucous lupus erythematous. There is no cure for lupus, and most patients are treated with corticosteroids and immunosuppressive drugs.

Scleroderma

Scleroderma is a rare, chronic disease characterized by excessive deposits of collagen that cause musculoskeletal, pulmonary, and gastrointestinal involvement. The most common symptom is the hardening of the skin in which scarring can take place. Scleroderma can be localized or systemic. The localized version only impacts the skin, whereas the systemic version affects the skin, blood vessels, and major organs. Many patients also have concurrent symptoms of Raynaud phenomenon, which involves fingers and toes and results in vasoconstriction of blood vessels in response to cold. Esophageal motility issues are also common in the more systemic version. There is no cure for scleroderma, and various stages of the disease are treated with NSAIDs and immunosuppressant drugs.[54]

Rheumatoid Arthritis

Rheumatoid arthritis (RA) is a chronic, inflammatory autoimmune disease that causes the patient's immune system to attack the muscles and joints of the body. This disorder is known for its painful and disabling inflammation,

which leads to substantial loss of mobility and dexterity. Rheumatoid arthritis is treated with a wide range of medications including disease-modifying antirheumatic drugs, antiinflammatory drugs, and analgesic medications.[55] Rheumatoid arthritis patients in general are immunocompromised by associated medication treatments.

Surgical/Implant Implications

Implant surgery.

Certain medications may contraindicate implant surgery (steroids, immunosuppressive medications). Special care should be taken to inquire about the amount of NSAIDs the patient utilizes for daily pain control prior to surgical treatment because bleeding complications could occur. In patients with RA is important to get a comprehensive history of medications they are taking. Most current treatment regimens for rheumatoid arthritis involve the use of immunosuppressive medications.

Bone resorption and bleeding.

There appears to be a difference in patients who have isolated RA and those with RA associated with other connective tissue diseases. In patients with RA and other connective tissue diseases there is some evidence leading to increased bone resorption and higher bleeding rates.

Xerostomia.

RA patients are more susceptible to decay and having the mucous membranes become atrophic and friable. Because of the lack of salivary secretions, complications may arise with the use of a tissue-borne prosthesis. A fixed prosthesis is highly recommended.

Treatment summary.

In contrast to isolated RA, in RA patients with concomitant connective tissue disease (CTD), differences in the periimplant parameters such as pronounced marginal bone resorption and bleeding may be anticipated and appear to be significantly influenced by the patients' underlying disease.[56] Medical consult and evaluation should be conducted prior to any treatment.

Complication Prevention

Final prosthesis.

Because of the high incidence of xerostomia with autoimmune diseases, the final prosthesis should be non–tissue-borne (FP-1, FP-2, FP-3) to minimize any soft tissue coverage. In patients with limited dexterity, an overdenture (RP-4, RP-5) is contraindicated because of inability to remove attachment-secured overdenture.

MD clearance/informed consent.

Patients need to be well informed of the full extent of treatment with possible complications and alternatives.

Treatment summary (depends on severity of disease)

- **No medication:** Relative contraindication
- **Corticosteroids/immunosupressive drugs:** Absolute contraindication

Lifestyle

Smoking

- **Do you smoke? Yes/No?**

In the United States, an estimated 42.1 million people, or 18.1% of all adults (age 18 years or older) in the United States smoke cigarettes. Overall, smoking prevalence has declined from 2005 (20.9%) to 2012 (18.1%); however, tobacco is still the most preventable cause of death and disease in the United States.[57]

Smoking has been directly related to many oral diseases including periodontal disease, malignancies, and dental implant–related complications.[58] Studies have shown that over 7000 different gases and chemicals are found in cigarette smoke (e.g., nitrogen, carbon monoxide, carbon dioxide, ammonia, hydrogen cyanide, benzene, nicotine). In tissues, carbon monoxide displaces oxygen from hemoglobin molecules because of its stronger affinity.[59] Hydrogen cyanide has been shown to cause hypoxia in tissues. The adverse effects that smoking has on successful outcomes in implant surgery are well documented. Multiple retrospective studies have shown that smokers experienced almost twice as many implant failures compared with nonsmokers.[60]

Surgical/Implant Implications

Increased incision opening.

Studies have shown that smoking is directly related to increased incision line opening. Possible mechanisms for poor wound healing include the vasoconstrictive nature of nicotine; increased levels of fibrinogen, hemoglobin, and blood viscosity; increased platelet aggregation; and impaired polymorphonuclear neutrophil leukocyte function.[61] Therefore, added sutures along with tension-free closure is recommended.

Infection.

Tobacco smoke decreases polymorphonuclear leukocyte activity, resulting in lower motility, a lower rate of chemotactic migration, and reduced phagocytic activity. These conditions contribute to a decreased resistance to inflammation and infection.[62]

Implant/bone grafting failure.

Metaanalysis studies have shown a definite correlation between smoking and failure rates of implants and bone grafts.

Peri-implantitis.

Studies have shown in smokers a strong correlation between peri-implantitis and dental implants.

Complication Prevention

Informed consent.

With the possible detrimental effects of smoking on implants, it is recommended that patients be informed in detail about the risks of smoking. These possible consequences include increased marginal bone loss after implant placement and the presence of peri-implantitis. Additionally, there is a direct impact on the success rates of bone grafts, with almost double the failure rate in implants placed in grafted maxillary sinuses.

Smoking cessation.

A strong recommendation on smoking cessation before implant surgery is recommended because smoking cessation after implant surgery has been shown to improve implant survival.[63] Ideally, the patient is instructed to cease smoking for 2 weeks before surgery to allow for reversal of increased blood viscosity and platelet adhesion. Smoking cessation is continued for 8 weeks

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after implant surgery, which coincides with the osteoblastic phase of bone healing.[64] This has been shown to increase wound healing capabilities and reverse subgingival microflora.[65]

Ideally, smoking cessation should be a gradual process because withdrawal symptoms are less severe in patients who quit slowly. There exists the concept of the "five As" in smoking cessation:

(1) Ask—all patients should be asked about possible tobacco use;

(2) Assess—determine if the patient has ever quit smoking or is interested in smoking cessation;

(3) Advise—every smoking patient should be advised of complications that may arise from continued smoking;

(4) Assist—the smoking patient must be instructed on ways to quit smoking or be given a relevant physician referral; and

(5) Arrange—make arrangements to evaluate the success of the smoking cessation (Table 2.10).[66]

TABLE 2.10
Smoking Cessation Techniques

Technique	Instructions	Possible Side Effects
Nicotine gum (Nicorette)	Chewing gum that releases nicotine	TMJ, gastric irritation, difficulty for patients wearing removable prostheses
Nicotine inhaler (Nicotrol inhaler)	Puffing for approximately 20 minutes/hour	Dizziness, nausea/vomiting, confusion, blurred vision, palpitations
Nicotine lozenge (Nicorette)	Dissolving	Dizziness, nausea/vomiting, confusion, blurred vision, palpitations
Nicotine nasal spray (Nicotrol)	1–2 doses per hour for 2 months	Nasal mucosa irritation, dizziness, nausea/vomiting, confusion, blurred vision, palpitations
Nicorette microtab sublingual tablets	1–2 tabs hourly	Dizziness, nausea/vomiting, confusion, blurred vision, palpitations
Nicotine patch (Nicoderm CQ)	Worn during day	Skin irritation, dizziness, nausea/vomiting, confusion, blurred vision, palpitations
Rx Medication: bupropion SR (Zyban), varenicline tartrate (Chantix)	As directed	Bupropion SR: dry mouth, nausea, headache, dizziness, changes in appetite, weight loss or gain, worsening of anxiety, insomnia Varenicline tartrate: chest pain, dizziness, severe headache, easy bruising, vivid nightmares, sleep disturbance
Hypnosis	Mixed results supporting effectiveness	N/A
Acupuncture	Mixed results supporting effectiveness	N/A

Treatment summary

- **Any amount of smoking:** Relative contraindication
- **Excessive smoking (~ >1.5 packs/day):** Absolute contraindication

Alcohol

Do you drink alcohol? Yes/No?

Ethyl alcohol is one of the most widely used mood-altering drugs in the world. Approximately 17 million adults aged 18 and older have an alcohol use disorder. This is more common in men than women. Many with alcohol dependence disorders go undiagnosed. Because of the adverse impact of alcohol on dental implants, screening for undiagnosed alcohol-related disorders is beneficial. Excessive alcohol intake has been associated with surgical and dental implant-related issues such as liver and metabolic dysfunction, bone marrow suppression resulting in bleeding complications, predisposition to infection, and delayed soft tissue healing.[67]

Surgical/Implant Implications

Bleeding problems.

Alcohol interferes with coagulation on multiple levels leading to decreased platelet production (thrombocytopenia), impaired platelet function (thrombocytopathy), and diminished fibrinolysis. Patients who abuse alcohol are more susceptible to intra- and postoperative bleeding complications associated with dental implant surgery.

Infection.

Alcohol use leads to significant alterations of cell-mediated immune systems. Alcohol-induced immunosuppression results in a decrease in delayed-type hypersensitivity (DTH), which is a preoperative indicator for postoperative infectious complications.[68] Therefore, patients consuming alcohol (especially those who consume it immediately after surgery) are more susceptible to incision line opening and infection.

Increased bone loss.

Alcohol use also leads to decreased bone formation, increased resorption, and decreased osteoblast function, resulting in decreased bone density and integration issues. The use of alcohol has a direct effect on dental implant healing as studies have shown greater marginal bone loss and implant failure

associated with alcohol consumption.

Complication Prevention

Informed consent/decrease comorbidities.

The patient must be well informed of potential consequences of alcohol use, especially immediately after implant surgery.

Cessation program.

Abstinence can reverse many of alcohol's effects on hematopoiesis and blood cell functioning; the patient should be instructed on possible cessation treatments and programs. Ideally, patients should refrain from using alcohol for a minimum of two weeks or after incision line closure occurs.

Radiation Therapy

- **Have you ever received radiation therapy? Yes/No?**

Although the survival rate of patients with head and neck cancer has increased over the last 20 years, it still remains one of the deadliest forms of cancer. Aggressive treatment includes surgery, radiation, chemotherapy, or a combination therapy that inevitably leaves the patient with compromised anatomy and physiologic functioning. Patients are left with many deficits including oral mucositis, xerostomia, compromised healing, and reduced angiogenesis. This is a direct result of changes in the vascularity and cellularity of hard and soft tissue, damage to the salivary glands, and increased collagen synthesis that results in fibrosis. Because of these detrimental effects on the bone, wound repair and healing are significantly reduced after surgical procedures. When exposed to high levels of radiation, bone undergoes irreversible physiologic changes that include narrowing of the vascular channels (endarteritis), diminished blood flow, and loss of osteocytes. In time the bone becomes nonvital, which leads to limited remodeling and healing potential.

Surgical/Implant Implications

Osteoradionecrosis.

The most significant risk in placing implants into irradiated bone is osteoradionecrosis (ORN), which is an irreversible devitalization of

irradiated bone that is characterized by necrotic, soft bone that fails to heal properly. The pathophysiologic mechanism is an imbalance in oxygen demand and oxygen availability, which is caused by endarteritis of the blood vessels. Clinical symptoms include pain, exposed necrotic bone, pathologic fractures, and suppuration. Studies have shown the overall incidence of ORN after radiotherapy to be from 3% to 22%.[69]

Radiotherapy to previously placed implants.

There are very few studies on the effects of radiotherapy on preexisting dental implants. Short-term data show very minimal complications and failures. However, in longer-term studies, failure rates seem to be higher.[70] At this time, more studies need to be conducted for conclusive results.

Implant placement after radiotherapy.

The time between radiotherapy to implant placement seems to have effects on the prognosis of implants. Most studies have shown that the longer the period for implant placement after radiotherapy, the higher the success rate and the lower the risk of osteoradionecrosis (Box 2.5).[71]

Box 2.5

Treatment Protocol for Implant Placement in Radiation Sites

- For sites that have been previously treated with radiotherapy, the authors recommend referral to a dental school, hospital, or clinic that has experience in treating radiotherapy patients.
- If the clinician has experience or can treat the associated complications, the following is recommended:
  Ideal Implant Placement:

- Preradiation: more than 14 days before radiation
- During radiation: absolute contraindication[b]

- Postradiation: <6 month or >24 months—relative/absolute contraindication
- 6–24 months: relative contraindication[a]

[b]Radiation therapy medical consultation, possible >20 years ago referral to cancer institution or hospital treatments, for 90 minutes before placement followed by 10 minutes after placement.
[a]Medical consultation, hyperbaric oxygen, informed consent, aseptic technique (<20 Gy cumulative, approximately <50 Gy technique fractionation).

Irradiation patient prosthetics.

Because of the oral effects of radiotherapy (mucositis, xerostomia), an implant-supported prosthesis (FP-1, FP-2, FP-3) is recommended over a soft tissue prosthesis (RP-4, RP-5). This will reduce the possibility of soft tissue irritation that is associated with postradiotherapy patients wearing removable prostheses.

Complication Prevention

Past radiation treatment.

Caution must be emphasized to patients with past radiation therapy because earlier forms of radiation therapy (pre-1980s) were of lower energy, in contrast to current higher-energy levels that are less destructive. Because of this lower energy radiation and associated higher destructive radiotherapy, progressive endarteritis has been shown to take place, which increases over time.[72]

Amount of radiation exposure.

The presently available literature states that implant placement surgery may be completed on patients who have been irradiated at doses lower than 50 Gy.[73] Unfortunately, very few patients receiving doses above 50 Gy have been rehabilitated with implants.

Studies have shown that implants placed in patients with a cumulative radiation effect of 18 to 20 (approximately 48 to 65 Gy standard fractionation) have a rather high success rate. Other reports have shown that doses above a cumulative radiation effect of 40 (approximately 120 Gy standard

fractionation) exhibit a high degree of failure.[74]

Hyperbaric oxygen.

One treatment proposed to minimize the possibility of ORN is the use of hyperbaric oxygen. Prophylactic hyperbaric oxygen has been advocated to increase oxygen tension in irradiated bone, which will promote capillary angiogenesis and bone formation.[75] Recent data show that oxygen under hyperbaric conditions acts synergistically with growth factors, which stimulates bone growth and turnover and also may act as a growth factor itself. Hyperbaric oxygen has also been shown to act as a stimulator of osseointegration by increasing new bone formation, increasing bone turnover, and increasing the vascular supply to irradiated bone.[76]

Age Related Factors

Adolescents

- **Are you under the age of 20? Yes/No?**

Dental implants are commonly used to correct the congenital absence of teeth in adolescents, and studies have shown this to be a very reliable and predictable treatment option. When a clinician is presented with an adolescent patient, there must be a degree of caution as to the ideal time that implant therapy should be commenced. The concern is placement of implants too early may lead to the implants interfering with normal growth development and potential esthetic issues.

Surgical/Implant Implications

Surgery.

No age-related surgical issues exist unless systemic contraindications or psychologic issues.

Implant.

If placement is completed before craniofacial growth is complete, possible interruption of facial growth and esthetic (infraocclusion or labioversion) issues can result.

Complication Prevention

Early consultation.

In determining the ideal time for implant placement, the patient/family must be educated on craniofacial growth in comparison to chronologic age. Chronologic age is a poor indicator of dental development/facial growth; timing of implant placement should coincide with growth cessation.

Determination of growth cessation.

In the literature, there exist many methods of determining completion of craniofacial/skeletal growth: chronologic age, complete dental development, voice changes, hand-wrist radiographs, cervical vertebral maturation, and superimposition of lateral cephalometric radiographs. The most reliable method and safest (no radiation exposure) has been shown to be when the patient begins to exhibit a lack of growth in stature (<0.5 cm/year).

Cone beam computed tomography evaluation.

A comprehensive radiographic evaluation should be completed as close to growth cessation as possible. This is most important in the maxillary anterior region and congenitally missing edentulous sites to determine the ideal implant position for prosthetic longevity. Most likely these edentulous sites will be compromised in bone volume in the vertical and anteroposterior dimensions, thus requiring osseous augmentation prior to implant placement. Additionally, intraroot distances should be evaluated via axial cone beam computed tomography (CBCT) slices at the coronal, midroot, and apical areas. For longevity and esthetic requirements, implants should be no closer than 1.5 mm from any tooth structure. The importance of this evaluation cannot be overstated, including patients who have received adjunct orthodontic care. A patient may appear to have adequate space for implant placement in the coronal aspect of the edentulous site, only to have insufficient room in the apical segment due to orthodontic movement.

Treatment summary.

When implants are treatment planned in adolescents, clinicians must take into consideration the timing, site development, esthetics, and possible prosthetic limitations including malposition that may develop with age. Most importantly, the determination of growth cessation should be determined by the lack of growth in stature. This method involves no radiographs (decreased radiation exposure) and is the most benign method. The patient's pediatrician should be consulted in the determination of growth cessation

(Fig. 2.1).

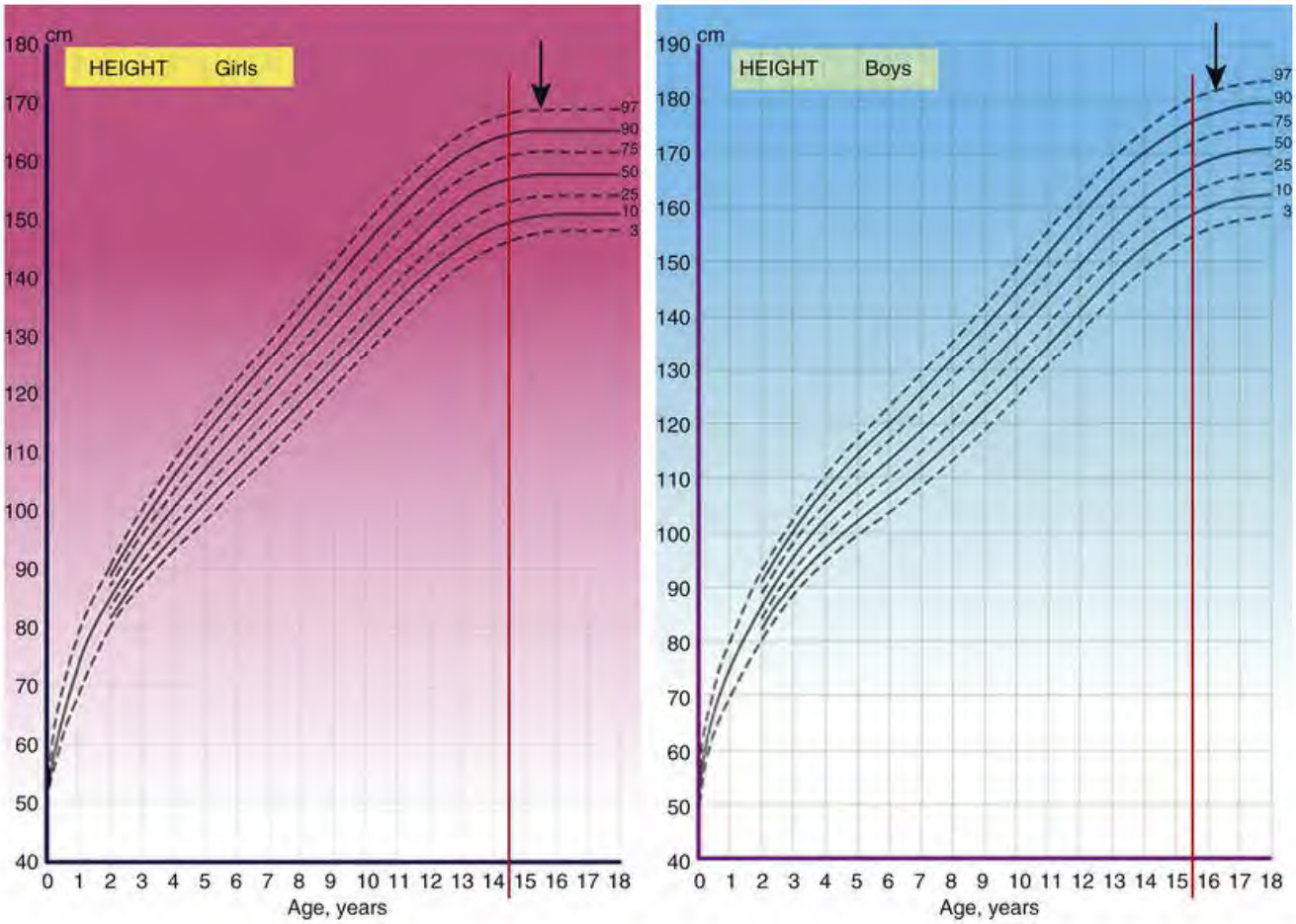

FIG 2.1 Growth cessation chart. Consultation with the patient's pediatrician should be completed to ascertain growth cessation, which usually coincides with <0.5 cm of growth in stature *(arrows)*.

Elderly

◆ **Are you 65 years old or older? Yes/No?**

According to the World Health Organization (WHO), most developed countries have accepted the chronologic age of 65 years as the definition of an "elderly" or "older" person.[77] The treatment of elderly patients is definitely challenging, and because more patients are living longer and are socially active, elderly patients will continue to be a significant part of the implant dentist's practice. Studies have shown that elderly patients are more prone to systemic diseases, more medically compromised, have potentially longer healing periods, challenging bone conditions (quality and quantity), increased susceptibility to drug interactions, and increased dental implant

morbidity.

Surgical/Implant Implications

Decreased renal function.

There is an age-related decline in renal functions that is accelerated by comorbid conditions like hypertension, heart disease, and diabetes. The age-related decline is more physiologic while the pathologic decline is associated with many medical conditions. In elderly patients, the glomerular filtration rate (GFR) and creatine will give insight into the patient's kidney function. As kidney function declines especially in Stage 3 (GFR 30–59) and above, there is a decreased metabolism and excretion of drugs (Table 2.11). Therefore, the intervals between drug administration should be longer and dosages should be decreased, except for liposoluble drugs and antibiotics, to compensate for the increase in body fat and the reduced immune response. In the presence of significant kidney disease (Stage 4 or above), antivirals (acyclovir), beta-lactams (amoxicillin), and cephalosporins should be reduced. Nonsteroidal analgesics should not be prescribed in those with Stage 3 or greater impairment without consultation with the patient's physician. Caution should be exercised with the use of sedation drugs because they can have more pronounced and longer-lasting effects.

TABLE 2.11

Age vs. Glomerular Filtration Rate

Stage	GFR	Description
1	90+	Normal kidney function
2	60–89	Mildly reduced kidney function
3	30–59	Moderately reduced kidney function
4	15–29	Severely reduced kidney function
5	<15 or dialysis	End stage kidney failure

Decreased gastric motility.

The decreased gastric motility of the elderly patient affects the use of oral analgesics such as hydrocodone and oxycodone. In addition, the use of narcotics in the elderly can cause significant changes in bowel habits especially constipation. If not contraindicated, a stool softener may be recommended concurrently with use of analgesics. Also, when using antibiotics for any prolonged period, the use of probiotics may help maintain normal gut flora.

Medications.

Medications and the number of prescribed drugs usually increase with age with over 75% of patients 65 and older taking medications. Many of these drugs are often the cause of adverse or significant drug reactions. Studies have shown more than 70% of drugs taken by elderly patients have potential adverse effects in the dental practice.[78] Although the incidence of severe drug interactions with commonly prescribed pain medications is relatively low, caution should be used in reviewing the elderly patient's complete medication history before prescribing any analgesics.

Isolated systemic hypertension.

A major cardiovascular health issue with the elderly is isolated systolic hypertension (ISH). In ISH, systolic blood pressure elevates above 140 mm Hg while the diastolic pressure remains below 90 mm Hg. The difference between the systolic and diastolic is termed the *pulse pressure,* which is a significant risk factor for stroke and heart disease. Recent metaanalysis studies have shown a 10 mm Hg increase in pulse pressure will increase the risk of major cardiovascular events by 20%.[79]

Bone healing.

Clinical studies have shown a direct correlation between delayed bone healing with increasing age. Most likely the etiology results from a reduced number of osteogenic cells and reduced systemic and localized blood flow to the healing site.[80] Therefore, longer healing periods along with progressive loading are recommended in older patients.

Bone quality/quantity.

Both the quality and quantity of bone is affected by aging. Histomorphometric and microradiographic studies have shown after the age of 50, a marked increase in the cortical porosity leading to decreased bone mass is present. Loss of bone mineral content has been estimated to be approximately 1.5% per year in females and 0.9% in males.[81]

Increased implant failure rate.

Studies have shown an increased risk of implant failure as a result of many age-related factors including compromised bone quality and quantity, implant length, treatment protocol, and edentulous locations. Other studies have shown patients older than 60 years were twice as likely to have adverse

outcomes.[82]

Prosthetic treatment.

Elderly patients have been shown to have increased difficulty in adapting to final implant prostheses. Postinsertion issues such as general adaptation, muscle control, hygiene difficulty, tissue inflammation, and overdenture seating were significant in the older population study. Patient education and final expectations should be discussed in detail prior to initiation of treatment.[83]

Complication Prevention

Intraoperative modifications.

A strict stress reduction protocol should be adhered to with elderly patients due to the potential frailty of their cardiovascular systems. Medication modifications including sedatives and CNS depressants are most important. Because of less competent immune systems, broad coverage with antibiotics is indicated and the use of probiotics should be considered. Elderly patients are less sensitive to pain, thus less analgesic medication is recommended, especially because gastric motility is reduced in these patients. Shorter surgical appointments are necessary to minimize exceeding patient tolerances.

Treatment summary.

The implant clinician must understand the physical, metabolic, and endocrine changes and the effects associated with the elderly patient before initiating implant treatment. Age is most certainly a prognostic factor in implant failure and morbidity. However, increased age is not an absolute contraindication to implant therapy. It is imperative the clinician obtain a detailed medical history and list of medications before devising the dental treatment plan. Patient education along with modification in medication use, surgical technique, soft and hard tissue healing times, and careful assessment of postoperative complications must be strictly enforced.

Psychosocial/Stress Related Factors

Psychological

- **Have you had any psychological problems? Yes/No?**

Providing dental implant care to patients with psychologic problems is very challenging for clinicians. This group of patients is prone to oral health issues because of poor oral hygiene, compliance, and medication effects. Providing comprehensive dental implant care to patients requires good communication skills, perseverance, and flexibility in both the surgical and prosthetic phases of treatment. Additionally, many patients are on tricyclic antidepressants, selective serotonin reuptake inhibitors (SSRIs), and monoamine oxidase inhibitors, which are associated with many interactions (see drug interactions). Oral manifestations of these diseases and medications include an increase in caries and periodontal disease, increased smoking, xerostomia, chronic facial pain, parafunction (bruxism/clenching), and temporomandibular joint dysfunction.

Surgical/Implant Implications

Medications.

Many psychotherapeutic drugs interact with medications that are commonly prescribed in implant dentistry. Clinicians must be aware of drug-drug and drug-disease interactions with respect to the patient's medical history. Most interactions are related to the potentiation of the sedative and anticholinergic actions of the psychotherapeutic drugs. It is important to identify patients taking monamine oxidase inhibitors or tricyclic antidepressants. Although these are no longer the mainstay of treatment for psychiatric illness, many patients will be placed on these medications to potentiate the effect of other medications. Common examples include amitriptyline, doxepin, nortriptyline, and imipramine. These medications are also being used to treat nonpsychiatric illnesses and can be used to treat chronic pain and sleep disorders. The main concern is the interaction of tricyclic medications and epinephrine because they produce anticholinergic effects on the heart. There is no contraindication to using them together, but patients should be followed more closely for adverse interactions. A physician consult as well as the implementation of a stress reduction protocol are recommended steps to follow when initiating treatment with these patients.

Clenching/Bruxism

- **Have you had any issues with clenching or bruxism? Yes/No?**

Parafunctional forces on teeth or implants are characterized by repeated or sustained occlusion and have long been recognized as harmful to the

stomatognathic system. There are two different types of parafunctional phenomena, bruxism and clenching. Bruxism primarily concerns the horizontal, nonfunctional grinding of teeth. The forces involved are in significant excess of normal physiologic masticatory loads. Clenching is a habit that generates a constant force exerted from one occlusal surface to the other without any lateral movement. The clench position most often is the same and rarely changes from one period to another. The direction of load may be vertical or horizontal. The forces involved are in significant excess of normal physiologic loads and are similar to bruxism in amount and duration. A positive feedback loop occurs with patients exhibiting parafunction because their muscles of mastication often hypertrophy, increasing the magnitude of force that they can produce during function. This leads to an overall musculoskeletal situation that must be closely monitored when initiating implant treatment with a patient.

Surgical/Implant Implications

Implant healing.

The most common cause of both early and late implant failure after successful surgical fixation is parafunction. Such complications occur with greater frequency in the maxilla because of a decrease in bone density and an increase in the moment of force. The lack of rigid fixation during healing is often a result of parafunction on soft tissue–borne prostheses overlying the submerged implant.

Implant prosthesis.

Parafunctional forces are most damaging when applied to implant prostheses, with lateral (shear) forces being the most catastrophic to the components of the restoration. This will most likely result in screw loosening, screw fracture, or prosthesis fracture.

Complication Prevention

Overengineering treatment.

When a patient is diagnosed as having parafunction, the treatment planning should include more implants, larger diameter implants, and the concept of progressive bone loading should be adhered to.

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Prosthetic design.

In an effort to minimize the effects of lateral (shear) loads on the implant system, especially in the posterior teeth, the clinician should seek restorations with narrow occlusal tables and minimal cusp heights. Furthermore, by splinting individual posterior implant units together, the impact of these forces is reduced.

Occlusal guards.

For any patient exhibiting signs or symptoms of parafunction, a hard, processed acrylic nightguard to dissipate the forces to the implant prostheses is paramount to protect the prostheses for long-term success (Table 2.12).

TABLE 2.12

Miscellaneous Patient Responses and Treatment Implications

Positive Response	Treatment Implications
Sinus disease	Possible sinus pathology leading to postoperative morbidity
Frequent headaches	Anxiety, migraine sinusitis, temporomandibular joint disorder, anemia
Intolerance to heat/warm rooms	Hypertension, hyperthyroidism
Seasonal allergies	Possible maxillary sinus disease
Pregnancy	Elective treatment (absolute contraindication)

Medications

Osteoporosis Medications

- **Have you ever taken bisphosphonates or osteoporosis drugs? Yes/No?**

Since the first reported cases of necrotic, exposed bone in patients taking bisphosphonates, there has been much debate over treatment implications with regards to dental implants. Bisphosphonates are a group of drugs that are widely used for several bone disorders and have been approved by the US Food and Drug Administration for treatment of osteoporosis, metastatic bone cancer, and Paget disease. However, what was once termed *bisphosphonate osteonecrosis* has now been renamed *drug-induced osteonecrosis of the jaws (DIONJ)* by the American Medical Association. The reason for this is the incidence of osteonecrosis cases involving additional drug classifications such as monoclonal antibody drugs, antiangiogenic drugs, and tyrosine kinase inhibitors (Table 2.13).

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TABLE 2.13
Medications Linked to DIONJ

Drug	Classification	Use	Dose	Route
Alendronate (Fosamax)	Bisphosphonate	Osteoporosis	70 mg/week	Oral
Risedronate (Actonel)	Bisphosphonate	Osteoporosis	35 mg/week	Oral
Ibandronate (Boniva)	Bisphosphonate	Osteoporosis	150 mg/month	Oral
Zoledronate (Reclast)	Bisphosphonate	Osteoporosis	5 mg/year	IV
Zoledronate (Zometa)	Bisphosphonate	Osteoporosis	4 mg/month	IV
Pamidronate (Aredia)	Bisphosphonate	Osteoporosis	90 mg/month	IV
Denosumab (Prolia, Xgeva)	Monoclonal antibody	Osteoporosis, Cancer	60 mg/6 months	Subcutaneous
Bevacizumab (Avastin)	Monoclonal antibody	Metastatic cancer	100–400 mg/14 days	IV
Sunitinib (Sutent)	Tyrosine kinase inhibitor	Cancer	5 mg/year	IV
Etidronate (Didronel)	Bisphosphonate	Paget disease	300–750 mg/6 months	Oral
Tiludronate (Skelid)	Bisphosphonate	Paget disease	400 mg daily/3 months	Oral

Bisphosphonates

Bisphosphonates are mainly used for the treatment of osteoporosis (oral form) and metastatic cancer (IV form) by inducing osteoclastic death or apoptosis at the cellular level. As an osteoporosis drug, they reduce bone resorption via a direct effect on the osteoclast. In osteoporotic patients undergoing bisphosphonate treatment, old bone is retained because bone turnover is suppressed, preventing normal remodeling in this area, which results in the formation of brittle bone. Additionally, bisphosphonates kill functionally resorbing osteoclasts not only at the peripheral sites but also in the bone marrow.

Monoclonal Antibodies

Monoclonal antibodies work by inhibiting RANKL (receptor activator of nuclear factor kappa-B ligand), which is a type II membrane protein that acts as a primary signal for bone removal. They have a direct effect on the immune system and control bone regeneration and remodeling. These drug molecules irreversibly bind to mineral matrix in bone and have a half-life of approximately 26 days, which is much shorter than bisphosphonates (11 years).

Tyrosine Kinase Inhibitors

Tyrosine kinase inhibitors directly inhibit tyrosine kinase receptors such as PDGF (platelet-derived growth factor) and VEGF (vascular endothelial growth factor), which regulate cellular replication in both tumor angiogenesis and tumor cell proliferation. Inhibiting these receptors reduces

tumor vascularization, leading to tumor shrinkage and death.

Surgical/Implant Implications

Diagnosis of DIONJ.

Marx has defined characteristics of patients who are diagnosed as having DIONJ. These include: (1) current or previous treatment with a systemic drug that affects bone homeostasis, (2) exposed alveolar bone in the jaws that persists for more than 8 weeks, (3) no history of radiotherapy to the jaws, and (4) no known diagnosis of osteopetrosis or cemento-osseous dysplasia. The definitive symptom of DIONJ is bone exposure in the mandible or maxilla that does not heal. Pain and inflammation is present with possible secondary infection of the soft tissue. In severe cases, drainage and progressive extension of bone involvement or sequestration results.[84]

Active lesions.

Osteonecrosis may remain asymptomatic for weeks and possibly months. Lesions usually develop around sharp, bony areas and previous surgical sites, including extractions, retrograde apicoectomies, periodontal surgery, and dental implant surgery. Symptoms include pain, soft tissue swelling, infection, loosening of teeth, and drainage. Radiographically, osteolytic changes are seen, and tissue biopsy has shown the presence of actinomyces, which is possibly caused by secondary infection.

Complication Prevention

CTx test.

It has been proposed that assays to monitor markers of bone turnover may help in the diagnosis and risk assessment of developing bisphosphonate-associated osteonecrosis. CTx are fragments of collagen that are released during bone remodeling and turnover. Because bisphosphonates reduce CTx levels, it is believed that serum CTx levels can be a reliable indicator of risk level. The CTx test (also called *C-terminal telopeptide* and *collagen type 1 C telopeptide*) is a serum blood test obtained by laboratories or hospitals (ICD9 diagnostic code 733.40). However, today, the use of the CTx test to determine the possibility of osteonecrosis is controversial.[85,85a]

CTx Value	Risk for DIONJ
300 to 600 pg/ml (normal)	None
150 to 299 pg/ml	None to minimal
101 to 149 pg/ml	Moderate
Less than 100 pg/ml	High

Drug holiday.

Marx has suggested a preoperative protocol for administering possible DIONJ drugs to patients who are undergoing oral surgical procedures. This protocol takes into consideration the type and duration of drug use as well as radiographic and clinical risk factors. Depending upon the laboratory values obtained, a "drug holiday" may be indicated, which includes temporary interruption of bisphosphonate treatment. However, improvement of bisphosphonate levels may not be observed because measurable levels have been shown to persist in bone for up to 12 years after cessation of therapy.[84]

Drug holiday recommendation[84a]

- **Presurgical:** Medication stoppage 9 months prior to surgery
- **Postsurgical:** Medication stoppage 3 months after surgery

Medical history.

A comprehensive medical history is essential before any elective treatment is initiated. The most important history of bisphosphonates is the use of intravenous nitrogen-containing bisphosphonates such as pamidronate (Aredia) and zoledronic acid (Zometa) and new osteoporotic drugs, which have very limited data on the association with DIONJ.

Bisphosphonate drugs.

In the dental setting, the most common bisphosphonates that implant dentists are exposed to will most likely belong to the family of oral nitrogen-containing bisphosphonates such as risedronate, ibandronate, and alendronate. The latest studies show that oral bisphosphonates has a very low probability of causing osteonecrosis.[86] However, because of the long half-life and short duration of the studies (3 years), future long-term complications may be less evident. With this in mind, the implant dentist should be cautioned regarding the possibility of developing osteonecrosis side effects. The risks vs. benefits of dental treatment must be discussed with the patient in detail. A well-documented consent form is recommended with possible medical consultation if the patient has been on this medication for

more than 3 years.

Reclast.

As stated, most drugs used to treat osteoporosis are oral, nitrogen-containing bisphosphonate drugs. Recently, Reclast (IV: Zoledronate) is given in 5-mg intravenous doses once a year. Studies have shown that a significant risk occurs after the fourth yearly dose. This is due to the accumulation of the medication and its 11-year half-life. Elective dental implant surgery or bone graft surgery are best scheduled 9 months after the most recent Reclast dose and 3 months before the next planned dose. However, at this time, very little research has been conducted on the relationship between Reclast and DIONJ.

Comorbidities.

Comorbidities are systemic diseases, medical conditions, medications, gender, and age, all of which can predispose the patient to a greater chance of developing DIONJ. Many chemotherapeutic drugs, diabetes, immune diseases, anemia, smoking, obesity, female gender and renal dialysis have been noted as comorbidities for DIONJ. Additionally, the use of glucocorticosteroids may be contraindicated in patients taking the DIONJ medications discussed above because these drugs have been associated with an increased occurrence of osteonecrosis.

New therapies for osteoporosis.

One of the newest therapies for osteoporosis is a biyearly subcutaneous injection of denosumab (Prolia). This is a human monoclonal antibody that functions as a RANK ligand inhibitor. Inhibition of the RANK ligand results in diminished osteoclast functional and bone resorption. Denosumab recognizes the specific protein that normally activates osteoclasts, thus inhibiting their activation and preventing them from breaking down bone. Denosumab has also been used to treat metastatic bone disease. These inhibitors do not bind to bone, and their impact on bone remodeling decreases after treatment is stopped. Osteonecrosis of the jaw has been observed in patients receiving denosumab, and all patients should receive an oral exam prior to therapy. The risk of developing osteonecrosis of the jaw is less studied in denosumab.

Treatment summary

- **Oral bisphosphonates:** Relative contraindication (informed consent, good surgical technique, CTx test, drug holiday)
- **IV bisphosphonates:** Absolute contraindication; Reclast: relative contraindication

Have you ever taken anticoagulants? Yes/No?

Oral antithrombotic medications have been used successfully to treat a variety of thrombotic diseases such as myocardial infarction, stroke, and deep venous thrombosis, while also having frequent use in the prevention of cardiovascular diseases. For decades, clinicians and patients have been conscious of the adverse side effects of these medications, primarily spontaneous or perioperative bleeding. Many have advocated for years to temporarily discontinue these medications prior to invasive dental treatments such as dental implant surgery. However, because discontinuation of these drugs may result in serious thrombus complications, a thorough knowledge of the mechanism of action needs to be understood (Table 2.14).

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TABLE 2.14
Common Anticoagulant Medications

Drug	ASA (81 mg)	ASA (325 mg)	Clopidogrel (Plavix)	Coumadin (Warfarin)	Dabigatran (Pradaxa)	Rivaroxaban (Xarelto)	Apixaban (Eliquis)
Test to determine coagulation status	Serum thrombin time, bleeding time	Serum thrombin time, bleeding time	Serum thrombin time, bleeding time	INR	No testing needed	No testing needed	No testing needed
Mechanism of action	Inhibiting platelet generation of thromboxane A2 results in inhibition of thrombus formation	Inhibiting platelet generation of thromboxane A2 results in inhibition of thrombus formation	Inhibits platelet aggregation and activation	Inhibits production of vitamin K–dependent clotting factors (II, VII, IX, and X)	Direct thrombin inhibitor	Factor Xa inhibitor	Factor Xa inhibitor
Dietary restrictions	None	None	None	Vitamin K	None	None	None
Dosing difficulty	None	None	None	Difficult	Reduce dose CrCl <30	Reduction CrCl <50 dosing different for different indications	Reduction CrCl <50 dosing different for different indications
Need for reduction/interruption	Usually not recommended	Case specific	Case Specific, usually not recommended can precipitate significant medical clotting issues	Case Specific, usually not recommended can precipitate significant medical clotting issues	Yes, MD Consult, usually 48–72 hrs.	Yes, MD Consult	Yes, MD Consult
Days of discontinuation prior to procedures	Not required in most cases, platelet function inhibited 10–14 days	10 days or more, MD Consult	MD consult especially if given with ASA	MD Consult, usually 5 days or more	Yes, usually 48–72 hours	Yes, usually 48–72 hours	Yes, usually 48–72 hours
Restarting Medication	If discontinued, after hemostasis	If discontinued, after hemostasis	If discontinued, dependent on MD recommendation	If discontinued, dependent on MD recommendation	Usually 24–48 hours and discussion with MD	Usually 24–48 hours and discussion with MD	Usually 24–48 hours and discussion with MD

CrCl, creatinine clearance.

Warfarin Sodium

Warfarin sodium (Coumadin) is used as an anticoagulant in a wide range of conditions such as ischemic heart disease, deep venous thrombosis, pulmonary emboli, and artificial heart valves. Warfarin sodium has a half-life of 40 hours, which has been known to vary among individuals from 20 to 60 hours. The mode of action of warfarin sodium is the interference of the synthesis of vitamin K, which is a cofactor in many reactions within the coagulation cascade. Coumadin has been the mainstay of anticoagulant treatment options; however, in the past 3 years there has been a shift to a new class of blood thinners in the treatment of nonvalvular atrial fibrillation and deep venous thrombosis. With an aging population the number of individuals diagnosed with nonvalvular atrial fibrillation continues to climb with over 2 million Americans now undergoing treatment. The major

concern of atrial fibrillation is the formation of blood clots, so most of these patients will be maintained on blood-thinning medications.

Surgical/Implant Implications

Medication modification.

Until recently most medical practitioners have believed that anticoagulants should be discontinued before dental surgery to prevent possible bleeding problems. However, there exist many documented cases of embolic complications in patients who discontinue the use of warfarin sodium and develop thrombosis from rebound hypercoagulability. In addition, studies have shown that dental surgery may be performed safely on patients receiving anticoagulant therapy as long as their INR values are within the therapeutic range (2.0–3.5). A brief periprocedural interruption of warfarin therapy is associated with a low risk of thromboembolism (0.7%) and risk of clinically significant bleeding (1.7%); however, the risk vs. benefit of interruption is not warranted in most cases.[87]

Complication Prevention

MD consultation.

Practitioners should consult with the patient's physician to determine the most recent INR before the surgery (ideally 24–48 hours before surgery). If the INR values are within the therapeutic range (2 to 3.5), there is no need to discontinue use of the anticoagulant. If the INR value is above the therapeutic range (especially higher than 4.0), the physician should take appropriate steps to lower the INR to a safer level or possibly discontinue the warfarin and supplement with heparin therapy or vitamin D. It is important to remember with all anticoagulant patients, special attention should be given to good surgical technique and use of appropriate local measures to control bleeding (hemostatic agents).

Aspirin

Aspirin or salicylic acid has been used as an antiinflammatory, analgesic, and antipyretic medication. However, in the 1980s it was discovered that aspirin also had an antiplatelet effect at very low doses (0.5 to 1 mg/kg) vs. higher doses needed for an antipyretic effect (5 to 10 mg/kg) and antiinflammatory response (30 mg/kg). Because of this research, low-dose aspirin has become a

secondary preventive drug for patients who have cardiovascular and peripheral vascular disease. Aspirin works by inhibiting the formation of prostaglandin thromboxane A2 within the platelet, thus affecting thrombus formation by irreversibly decreasing platelet aggregation.

Surgical/Implant Implications

Bleeding.

With aspirin there is a risk of potential bleeding from low platelet count. Studies have shown that this risk is minimal unless a 325-mg aspirin is being used. In a study of tooth extractions, 36 patients were randomized to 325 mg of aspirin or placebo for 2 days before and 2 days after. There was no significant association between those that took the aspirin and peri- or postoperative bleeding.[88]

Complication Prevention

Low dose (81 mg).

There exists no study supporting the recommendation of low-dose (<100 mg) aspirin discontinuation for routine dental implant procedures. In most patients, interruption is not warranted because it may expose the patient to the risk of developing thromboembolism, myocardial infarction, or cerebrovascular accident.

High dose (325 mg).

When patients are advised by their physician to take 325-mg aspirin or doses higher than 100 mg, a physician consultation is recommended. This is especially true of patients on aspirin (any dose) with other anticoagulants such as clopidogrel or dipyridamole. Bleeding times may be appropriate in these patients in combination with physician consultation.

Novel Anticoagulants

- **Plavix (Clopidogrel):** Clopidogrel is a platelet inhibitor that is approved for the reduction of atherosclerotic events in patients of recent stroke, MI, or peripheral arterial disease. The recent literature has supported longer treatment times for patients with coronary stents and acute coronary syndrome from 3 months to 12 months or more in combination with aspirin. The literature does not support the routine discontinuation of this

medication in relation to dental implant treatment, but it is important to remember that many patients treated with clopidogrel will be on aspirin or another antiplatelet medication, especially those with cardiac stents. This regimen should never be discontinued unless under the recommendation of a physician.

- **Pradaxa, Xarelto, Eliquis:** Orally administered anticoagulants have recently been developed to eliminate the disadvantages associated with warfarin. Dabigatran etexilate (Pradaxa) and rivaroxaban (Xarelto) have been shown to have a more favorable (wider) therapeutic index, fewer drug-drug and drug-food interactions, and a predictable anticoagulant response without the need for anticoagulants. Dabigatran reversibly inhibits thrombin, so the duration of action is predictable and correlates well with plasma drug concentrations. Rivaroxaban is a factor Xa (FXa) inhibitor that produces reversible inhibition of FXa activity.[89]

Surgical/Implant Implications

Bleeding.

In contrast to the many studies on oral surgery and the use of warfarin, no clinical trials have been completed to offer recommendations on the management of patients on these newer anticoagulants with relation to dental implant surgery. However, there exist several case studies suggesting that, with physician consultation, these drugs can be temporarily discontinued 24 hours prior to elective oral surgery and restarted the following day, resulting in minimal complications. Because of these drugs have a short half-life, brief interruption is usually acceptable. It is imperative that physician consultation be obtained prior any of these medications being temporarily discontinued. Good surgical technique and the use of hemostatic agents should be adhered to.

Treatment summary.

Currently, there is no accepted reduction protocol for these medications. Based on the information available, the clinician should consult the patient's physician concerning the proposed implant procedure and the invasiveness of the surgery, anticipated hemostasis complications, and amount of bleeding to be expected. If physician recommendation is for the temporary discontinuation of these drugs, the typical discontinuation recommendation is for 24 hours prior to surgery, and the drug should not be restarted until the

risk of postoperative bleeding is minimal (usually within 24 hours of surgery).[90]

Herbal Supplements

Over-the-counter herbal and dietary supplements are being consumed at a record pace for general health improvement and treatment of chronic conditions. Herbs have been known to be associated with unwanted side effects and cause drug interactions, as well as being associated with surgical complications. Many of these supplements contain active ingredients that exhibit strong biologic effects. The doses are usually unregulated and variable among patients. The *Journal of the American Medical Association* estimates that 15 million adults are at risk for adverse interactions between herbs and prescription medications.[91] The risks of these medications associated with dental implant surgery are increased bleeding, drug interactions, and possible infection. Patients should discontinue the use of these herbal supplements for at least 2 weeks prior to implant surgery (Box 2.6).

Box 2.6

Herbal Supplement and Adverse Effects

Increased Bleeding

Arnica

Barberry

Bilberry

Bromelain

Cayenne

Cat's claw

Chamomile

Chestnut

Cinnabar root

Devil's claw

Dong quai

Fennel

Feverfew

Garlic

Ginger

Ginkgo biloba

Ginseng

Grape seed

Green tea

Kudzu

Primrose

Red clover

Turmeric

Sweet woodruff

Vitamin E

Increased Inflammation

Celery

Dandelion

Elder

Goldenseal

Juniper

Interactions With NSAIDs

Feverfew

Gingko

Ginseng

St. John's Wort

Uva-Ursi

Interactions With Anesthesia

Green tea: Decrease effect of oral atropine

Dong quai: Increases sedation and lowers seizure threshold

Kava: Increases sedation

Valerian: Increases sedation, interacts with opioids

Vitamin C: In large doses can weaken anesthesia

Yohimbe: Can interact with some analgesics like morphine

Immunosuppressive Drugs

- **Have you ever received chemotherapy or been treated with immunosuppressive drugs? Yes/No?**

Immunosuppressive drugs are medications that are used to inhibit or prevent activity of the immune system. They are usually used to minimize rejection of transplanted organs and tissues and also for treatment of autoimmune diseases. These drugs have many side effects, with the majority of them acting nonselectively (acting on normal cells also). There are four classes of immunosuppressive drugs: glucocorticoids (prednisone),

cytostatics (chemotherapeutic agents), antibodies (polyclonal antibodies), and immunophilins (cyclosporine).

Glucocorticoids

Glucocorticoids have potent antiinflammatory and immunosuppressive properties. Because these drugs are widely used in the treatment of inflammatory and autoimmune diseases, special attention must be given to patients who are on long-term, high doses of glucocorticoids. These drugs impair many healthy anabolic processes in the body and suppress the immune system, which can lead to severe complications in dental implant patients.

Cytostatics

Cytostatics are common medications in the treatment of malignant disease. These drugs cannot discriminate between malignant and normal tissues and become cytoxic to normal tissue. Most chemotherapeutic agents are known to have cytoxic effects on bone, especially on grafted bone where the blood supply is compromised.[92] Because chemotherapeutic agents have a high affinity for cells that have a high turnover rate, the oral mucosa is often affected. These mucosal ulcerations have been known to become secondarily infected.

Several studies have shown that cyclosporine may negatively influence bone healing around dental implants and may even impair the mechanical retention of dental implants previously integrated in bone.[93]

Tamoxifen

Tamoxifen is a standard treatment for hormone receptor–positive breast cancer in premenopausal women. Because tamoxifen mimics the effects of estrogen, it has a very beneficial side effect that preserves bone mass and prevents bone loss. However, there exist drug-induced osteonecrosis concerns with the administration of this drug. However, studies show a very low prevalence.[94]

Aromatase Inhibitors

In postmenopausal women diagnosed with estrogen receptor–positive breast cancer, aromatase inhibitors are the mainstay of adjuvant therapy. These medications inhibit the conversion of androgens to estrogens, which results

in estrogen deficiency and may accelerate bone loss. There has been an association with an increase in drug-related osteonecrosis of the jaws with this class of medications.[95] However, in patients on aromatase inhibitors the incidence of osteonecrosis is still significant, and consultation with the treating physician should be considered in these patients.

Surgery/Implant Implications

Adverse effects.

Some of the most frequent side effects of chemotherapeutic drugs are bone marrow suppression, leukopenia, thrombocytopenia, and anemia. Therefore, patients are susceptible to increased infectious episodes, intraoperative bleeding, and compromised bone healing.

Complication Prevention

Medical consultation.

A medical consult and evaluation is highly recommended prior to any proposed implant treatment. For most chemotherapeutic medications, concurrent use and the placement of implants is an absolute contraindication. Additionally, patients on long-term corticosteroid use should be evaluated for possible adrenal insufficiency symptoms.

Treatment summary

- **Past chemotherapy:** Relative contraindication after MD consultation
- **Concurrent chemotherapy + implant therapy:** Absolute contraindication

Titanium Allergies

- **Do you have a titanium allergy? Yes/No?**

Titanium has been regarded as a biocompatible and inert material, though some studies have shown the material may encourage hematologic and metabolic toxicity.[96] Titanium alloys are commonly used in oral implantology because of their high strength, biocompatibility, and corrosion resistance. The most common titanium alloy, TiAl6V4, usually will contain many traces of other elements such as beryllium, cobalt, chromium, copper, iron, nickel, and palladium. These impurities are thought to potentially initiate type IV hypersensitivity allergic reactions.

Many case reports have shown dental implant–related allergic reactions that have resulted in dermal inflammatory reactions such as facial eczema, dermatitis, and rashes, along with localized erythema.[97] Sensitivity to titanium alloy has been characterized by the presence of macrophages and T lymphocytes, with the absence of B lymphocytes.[98] Studies have shown the incidence of this phenomenon to be approximately 0.6%.[99] Other reports have confirmed titanium allergies associated with pacemakers, surgical clips, and hip prostheses.[100] It is also important to note allergies to other metals because there has been some suggestion that allergy to other metals may increase the risk of a titanium allergy. This would also be of concern in patients who may have had a reaction to metals in jewelry. In these patients it may be advisable to consider additional testing. Unless a patient has direct exposure to titanium through an orthopedic procedure like hip or knee replacement or through the use of screws or plates to repair fractures, it is unlikely they would be aware of a titanium allergy. One study estimated the overall prevalence of titanium allergies to be very low at 0.6%.[101]

Complication Prevention

Evaluation of metal allergies.

A list of allergies must be examined as part of a thorough medical history evaluation. If an allergy to titanium is discovered, the treatment plan should be modified to test for titanium allergy or possible use of zirconia implants. Early study on ceramic implants shows promise because they possess good mechanical strength and excellent tissue compatibility and exhibit osseointegration comparable to that of titanium.[102]

Drug Interactions

- **Have you every had a drug interaction? Yes/No?**

In contrast to many years ago, patients who are seeking implant treatment are older and more medically compromised. Because of the advancement of pharmaceuticals, patients are on a wide range of medications that significantly increase the risk for drug interactions. Additionally, because oral implantology often involves invasive treatment, patients will require local anesthesia with vasoconstrictors, analgesics, anxiolytics, corticosteroids, and antibiotics, any of which on occasion could adversely interact with a variety of the medications they are on. The implant clinician must have a

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thorough understanding of the most common drugs prescribed with inherent interactions (Table 2.15).

TABLE 2.15

Most Common Medications Prescribed + Interactions[104]

	Interacting Drugs	Adverse Effects
All Penicillins		Static drug will impair action of Penicillin
	Bacteriostatic Antibiotics	
	Methotrexate (Rheumatrex)	Decreases secretion of Methotrexate
All Cephalosporins	Bacteriostatic Antibiotics	Static drug will impair action of Penicillin
	Anticoagulants	Risk of bleeding disorders might be increased in anticoagulated patients
Lincomycins Clindamycin (Cleocin)	Erythromycin	Possibility of antagonism. AVOID CONCURRENT USE.
Macrolides: dirithromycin (Dynabac) clarithromycin (Biaxin) erythromycin	Anticoagulants	Risk of bleeding disorders is increased in anticoagulated patients—Monitor patient
	Benzodiazepines	Possible increased benzodiazepine levels resulting in CNS depression, avoid in elderly
	CCBs diltiazem (Cardizem) and verapamil (Isoptin, Calan, Verelan)	QT interval prolongation, could cause sudden death
	Cyclosporine (Sandimmune, Neoral)	Increased cyclosporine renal toxicity
	"Statins" (Lipitor, Zocor, Mevacor)	Increased statin levels with possible muscle toxicity
Metronidazole (Flagyl)	Anticoagulants (Coumadin)	Risk of bleeding disorders is increased in anticoagulated patients
	Ethanol	Severe disulfiram-like reactions
	Tacrolimus (Prograf)	Metronidazole doubles Prograf levels
Quinolones: Ciprofloxacin (Cipro) Gatifloxacin (Tequin) Levofloxacin (Levaquin) Moxifloxacin (Avelox)	Antacids	Decreased quinolone absorption
	Anticoagulants (Coumadin)	Increased risk of bleeding disorders. Monitor INR
	Antineoplastics	Quinolone serum levels may be decreased
	Cyclosporine (Sandimmune, Neoral)	Cyclosporine renal toxicity may be enhanced
	NSAIDs	Enhanced CNS stimulation
	Caffeine	Increased caffeine effects
		Muscle Weakness—Tendon Damage
NSAIDs and Aspirin	Anticoagulants (warfarin, Coumadin)	Increase risk of bleeding disorders in anticoagulated patient, possible gastrointestinal (GI) hemorrhage
	Antihypertensives (all but CCBs) (ACEI, beta blockers, diuretics)	Decreased antihypertensive effect. Monitor blood pressure
	Bisphosphonates	GI toxicity
	Cyclosporine (Neoral, Sandimmune)	Nephrotoxicity of both agents may be increased
	Methotrexate (Rheumatrex, Mexate)	Toxicity of methotrexate may be increased, and increased possibility of stomatitis
	SSRIs	GI bleeding, depletion of platelet serotonin required for aggregation
	NSAID + Salicylates	Blockage of antiplatelet action with increased GI effects
Acetaminophen	Barbiturates, Carbamazepine, Phenytoin, Rifampin, Sulfinpyrazone	The hepatotoxicity of APAP may be increased by high dose or long-term administration of these drugs
	Sedatives/anxiolytics	Increased sedation and respiratory depression
	Ethanol	Increased hepatotoxicity of APAP with chronic ethanol ingestion
Tramadol (Ultram, Ultracet)	Any drug that enhances serotonin activity (SSRI antidepressants, "triptans" for acute migraine	Possible serotonin syndrome
	MAOIs (Marplan, Nardil, Parnate)	MAOI toxicity enhanced
	Quinidine	Tramadol increased/metabolite decreased
All Opioids	Alcohol, CNS depressants, local anesthetics,	Increased CNS and respiratory depression may

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	antidepressants, antipsychotics, antihistamines, cimetidine	occur. Use cautiously
Hydrocodone/Codeine	2D6 Inhibitors, Amiodarone, Cimetidine, Desipramine, Fluoxetine, Paroxetine, Propafenone, Quinidine, Ritonavir	Inhibition of biotransformation of Codeine to active analgesic form. Use different narcotic on 2D6 Inhibitor patients
	SSRI antidepressants and bupropion	Analgesic effect reduced
Amides (e.g., lidocaine)	Alcohol, CNS depressants, opioids, antidepressants, antipsychotics, antihistamines	Increased CNS and respiratory. Depression may occur
	Antiarrhythmic drugs	Increased cardiac depression
	Beta blockers, cimetidine	Metabolism of lidocaine is reduced
	Bupivacaine	Toxicity is additive, total dose should not exceed the combined maximum dosages
Vasoconstrictors (epinephrine, levonordefrin)	Tricyclic antidepressants-high dose (amitriptyline, desipramine, imipramine, nortriptyline, etc)	Increased sympathomimetic effects possible. Limit epi to 0.04 mg with high dose TCA's
	Beta blockers (nonselective) (e.g., propranolol, nadolol)	Hypertensive and/or cardiac rx possible Limit epi to 0.04 mg/2 hr. visit
	Phenothiazines (e.g., chlorpromazine)	Vasoconstrictor action inhibited, leading to possible hypotensive responses. Use cautiously
Antihistamines diphenhydramine (Benadryl) hydroxyzine (Atarax, Vistaril) Promethazine (Phenergan)	Anticholinergics	Increased dry mouth, tachycardia, urinary retention. Monitor
	CNS depressants (alcohol, narcotics)	Enhanced duration and intensity of sedation Reduce dosages
Benzodiazepines (Triazolam)	Rifampin, carbamazepine	Increased metabolism leading to decreased sedative response

Most of the reactions are the result of interactions with oral pain medications and with vasoconstrictors used to enhance local anesthetic pain control and control bleeding. Some of the more common interactions involve NSAIDs because these medications reduce the effectiveness of many blood pressure medications. The use of NSAIDs with anticoagulants can increase the anticoagulant effect and result in gastrointestinal (GI) bleeding. NSAIDs may increase the GI toxicity of bisphosphonates and SSRIs prescribed for patients with mental illness. SSRIs also interfere with the metabolism of codeine and hydrocodone, so the overall analgesic effect may be reduced (Table 2.16).[103,104]

TABLE 2.16
Diagnostic Lab Test Summary

Test Name	Description	Elevated Levels	Decreased Levels
Albumin (blood)	Is produced by liver and most abundant protein in blood; can be used to judge changes in overall health, liver, or kidney function	Dehydration	Inflammation, liver disease malnutrition, kidney disease, malabsorption
Alkaline phosphatase	Produced by several organs including liver, bone, and kidney	Bone disease such as metastatic cancer, Paget disease, multiple myeloma, liver disease	Malnutrition, hypophosphatemia, hypothyroid, B_{12} deficiency
Alanine transaminase (ALT)	Used to access function of the liver	Liver disease (hepatitis, necrosis, cirrhosis, tumor); medications (statins, antibiotics, chemotherapy, narcotics); mononucleosis, obesity (fatty liver)	N/A
Amylase	Enzyme produced by pancreas and used to detect issues with pancreas	Pancreatitis	N/A
Antinuclear antibody (ANA)	Used as a screen for connective tissue disease; positive test occurs in some individuals without	Requires further specific tests to confirm lupus, scleroderma, Sjögren	N/A

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	specific disease	syndrome, or myositis	
Aspartate aminotransferase (AST)	Used to detect liver disease and provide assessment of liver function	Liver disease, medications, mononucleosis, obesity (similar to AST) AST:ALT >2 : 1—alcoholic liver	Acute renal disease, beriberi, diabetic ketoacidosis, pregnancy, chronic renal dialysis
Basic metabolic panel (BMP)	Blood panel that measures sodium, potassium, glucose, BUN, creatinine, chloride, CO_2		Dependent on test (refer to each component)
Bilirubin indirect	Level of bilirubin that is product of liver that is not conjugated (have sugar molecules attached)	Hemolytic anemia, cirrhosis, transfusion reaction, Gilbert disease (lack enzyme to conjugate)	No low results available
Bilirubin direct	Level of bilirubin that is conjugated with a sugar molecule but cannot be secreted through blocked bile ducts	Viral hepatitis, drug reactions, alcoholic liver disease, gallstones, tumors, bile duct scarring	No low results available
Bleeding time	Measure clot time focused on function of platelets	von Willebrand disease, thrombocytopenia, DIC, medications	N/A
Blood urea nitrogen (BUN)	Measure urea nitrogen formed when protein is broken down. Help measure kidney and liver function	Kidney dysfunction, GI bleed, dehydration, shock, medications, CHF, or urinary outlet obstruction	Liver disease, SIADH (syndrome of inappropriate antidiuretic hormone), malnutrition
BUN/Cr ratio	Ratio of BUN to Creatinine, usually between 10 : 1 and 20 : 1	Dehydration, acute kidney failure or injury, diet high in protein (ratio can be normal in chronic kidney disease)	N/A
Calcium (Ca)	Checks blood level calcium not in bones and parathyroid function	Hyperparathyroidism, lung/breast cancer metastasis to bone, Paget disease, excessive intake of vitamin D	Chronic renal failure, vitamin D deficiency, magnesium deficiency, bisphosphonate therapy
Carbon Dioxide (CO_2)	Level of carbon dioxide in the blood and important buffer of acid/base regulation	Vomiting, COPD, anorexia, dehydration, hypoventilation	Diarrhea, hyperventilation, kidney or liver disease
Chloride (Cl)	Important in the monitoring of acid/base disorders	Dehydration, diarrhea, renal tubular acidosis, diuretics, hyperparathyroidism	Overhydration (SIADH), Addison disease, chronic vomiting, heart failure
Creatinine (Cr)	Important measurement of kidney function	Kidney disease, dehydration, diuresis, medication, radiocontrast induced, hypertensive kidney disease	Decreased muscle mass
Creatinine clearance (CrCl)	Used to estimate glomerular filtration rate and overall kidney function	90+: Stage 1 (normal kidney function) 60–89: Stage 2 (mildly reduced kidney function) 30–59: Stage 3 (moderately reduced kidney function) 15–29 Stage 4 (severe kidney disease) <15: End-stage kidney disease	
Erythrocyte sedimentation rate (ESR)	Nonspecific marker for inflammation	Collagen vascular disease (lupus, rheumatoid arthritis), vasculitis, infections, malignancy, renal failure, inflammatory bowel disease, anemias	Polycythemia, sickle cell anemia, spherocytosis
Ferritin	Measures amount of iron stored in body	Hemochromatosis, porphyria, liver disease, multiple blood transfusions, liver disease, Hodgkin lymphoma	Hemodialysis, iron deficiency anemia
Glucose	Measurement of blood sugar level that is best interpreted fasting <100	Diabetes, nonfasting level, illness, infection, stress response	Excess insulin secretion, excessive alcohol, Addison disease (adrenal insufficiency), reactive hypoglycemia
Hematocrit	Ratio of red blood cell volume to the total volume of the blood	Dehydration, diuresis, polycythemia vera, high altitude exposures	Anemia, pregnancy, excessive blood loss
Hemoglobin	Carries oxygen to tissues	Polycythemia, high altitude exposure, extreme exercise program	Anemia, hemolysis, excessive blood loss
Hemoglobin A1C (HbA_{1c})	Measurement of percentage of hemoglobin coated with sugar and provides average of blood sugar over 3-month period	Poorly controlled diabetes, iron deficiency anemia, vitamin B_{12} deficiency, uremia, alcoholism	Hemolysis, recent blood transfusion, chronic liver disease, excess treatment of diabetes, hypertriglyceridemia
Iron level (Fe)	Measures amount of iron in blood	Hemochromatosis, hemolysis, liver necrosis, hepatitis, vitamin B_{12} deficiency, excessive blood transfusions	Low dietary intake, heavy menstrual bleeding, GI blood loss, intestinal malabsorption, pregnancy
Lipase (LPL)	Enzyme produced by pancreas to help	Pancreatitis, tumors of pancreas, gall	May indicate chronic damage

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	breakdown fats and used to help determine disease of the pancreas	bladder infection, high triglycerides, excessive alcohol, gallstones or infection of gallbladder	to pancreas
Liver function tests (LFT)	Can give measurement of liver functioning (AST, ALT, bilirubin, albumin, alkaline phosphatase)		
Mean corpuscular volume (MCV)	Red blood cell average size	Vitamin B_{12} or folic acid deficiency, ETOH abuse, liver disease, bone marrow dysfunction, hypothyroidism	Anemias, iron deficient, chronic disease, sideroblastic, chronic renal failure, lead poisoning, thalassemia
Partial thromboplastin time (PTT)	Measures time for blood to clot for intrinsic pathway (factors IX, X, XI, XII)	Similar to prothrombin time (PT)	Similar to prothrombin time (PT)
Platelets	Number of circulating platelets	Acute bleeding, cancer, renal failure, infections, iron deficiency, splenectomy, inflammatory bowel disease, lupus	Hemolytic uremic syndrome, autoimmune disease, pregnancy, ITP, TTP
Potassium (K)	Measure level of potassium in blood, essential for proper function of organs and all cells	Acute/chronic kidney disease, Addison disease (adrenal insufficiency) rhabdomyolysis (breakdown of muscle), HTN medications (ACE/ARB), excessive intake, burn injury	Diabetic ketoacidosis, diarrhea, excessive alcohol or laxative use, hyperhidrosis (excessive sweating), diuretics, folic acid deficiency, primary aldosterone tumor, vomiting
Prostate-specific antigen (PSA)	Measure blood level of PSA released by prostate gland; PSA normally increases with age as prostate enlarges	Prostate cancer, prostatitis, catheter insertion, BPH, UTI, age-related, prolonged bike riding	<0.1 in patients treated for prostate cancer
Prothrombin time (PT)	Measures time for blood to clot by the extrinsic pathway (tissue factor, Xa); INR is standard measure	Liver disease, alcohol abuse, DIC, vitamin K deficiency, clotting factor deficiency, medication induced	Vitamin K supplementation, estrogen therapy, thrombophlebitis
RBC	Measures number of red blood cells	Thalassemia trait, altitude exposure, cigarette use, polycythemia	Anemia (including hemolytic), acute blood loss, bone marrow dysfunction
Rheumatoid factor (RF)	Measure autoantibody (RF antibody) level that attacks own tissue and can indicate rheumatoid arthritis	Rheumatoid arthritis, cancer, chronic infections or liver disease, lupus, scleroderma, Sjögren syndrome; also found in individuals with no disease	N/A
Sodium (Na)	Measure level of circulating sodium (important for fluid balance and functioning of nerves and muscles)	Increased dietary intake, Cushing syndrome	Medications (diuretics), CHF, liver disease, SIADH, chronic vomiting, adrenal insufficiency, drinking too much water
Thyroid-stimulating hormone (TSH)	Released by pituitary and causes thyroid gland to release thyroxine (T4) and triiodothyronine (T3); used to diagnosis thyroid disease	Hypothyroidism, Hashimoto thyroiditis (antibody attach thyroid), lithium, amiodarone	Hyperthyroidism, subacute thyroiditis (inflammation thyroid), excess thyroid replacement therapy, thyroid cancer (low normal)
Thyroxine (T4) free or total	Total T4 measures the amount of T4 in blood released by thyroid and used to diagnose hyper/hypothyroid disease and respond to thyroid replacement; total T4 is protein bound and can be abnormal because of protein levels; free T4 more accurate and not influenced by protein levels	Hyperthyroidism (Graves disease), pituitary adenoma, excessive thyroid replacement therapy, thyroiditis, birth control pills, pregnancy, excessive iodine intake	Hypothyroidism, pituitary insufficiency, malnutrition, chronic illness, low intake of iodine
Triiodothyronine (T3) free or total	Measure the amount of circulating T3 produced by thyroid; T3 is bound to thyroxine binding globulin; T3 not bound to protein is free T3 and this is thought to be responsible for biologic activities in the body	Hyperthyroidism (Graves disease), pituitary adenoma, excessive thyroid replacement therapy, thyroiditis, birth control pills, pregnancy, excessive iodine intake; free T3 levels stable in pregnancy and with birth control pills	Hypothyroidism, pituitary insufficiency, malnutrition, illness, medications (amiodarone, phenytoin)
WBC	Measures total number of white blood cells	Bacterial infection, sepsis, steroids very high in CLL	Immunosuppression, viral infections, chemotherapy, antibiotics
Types of White Blood Cells			
Neutrophils	Most abundant type of white blood cell	Bacterial infections "shift to left" more neutrophils acute infection	Malignancies, aplastic anemia, severe infections
Lymphocytes	Made up of B cells that produce antibodies and T cells produced in thymus and are part of immune response	Viral infections including mononucleosis and hepatitis	Bone marrow dysfunction, chemotherapy, TB, lupus, rheumatoid arthritis, drug induced

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Monocytes	Participate in phagocytosis; produce macrophages to help fight bacteria, fungi, and viruses	TB; chronic inflammatory disorders such as Crohn disease, ulcerative colitis, lupus	Vitamin B_{12} deficiency, bone marrow dysfunction, certain leukemias
Eosinophils	produced in response to allergens and diseases	Allergic reactions, parasites	Cushing disease, treatment with steroids, stress reactions
Basophils	Least abundant WBC; contain heparin and histamine related to hypersensitivity reactions	Viruses, lymphoma, hypothyroidism, inflammatory bowel disease	Pregnancy, steroid use, hyperthyroidism

Medical Consultation and Clearance

Oral implantology is a complex specialty with many factors that must be taken into consideration to decrease morbidity and increase the probability of successful treatment. Medical clearance is a necessity with respect to patients who present with complicated systemic conditions, medications, and predisposing factors that may lead to complications. The implant clinician must relay to the physician all necessary information, including: (1) a detailed summary of what the patient related as their medical history, (2) list of all current and recent medications, (3) allergies, (4) any medications that will be prescribed by the implant dentist, and (5) the invasiveness of the intended procedure (Fig. 2.2). The physician will provide answers to;

1. Most Recent Physical Exam: to determine if the patient is compliant with keeping up with their medical health.

2. Documentation of Medical Health: very important to determine if there exists any misinformation or missing health issues that the patient failed to represent on the medical/dental history.

3. Medication Modification: The physician will recommend any modifications to physician prescribed medications or dental surgery proposed medications.

4. Acceptable Candidate: The physician will clear the patient for dental implant treatment in writing.

5. Contacting the Physician: The physician will document whether their recommendation is for the implant dentist to contact them prior to treatment. And lastly, make sure the physician signs and dates the form.

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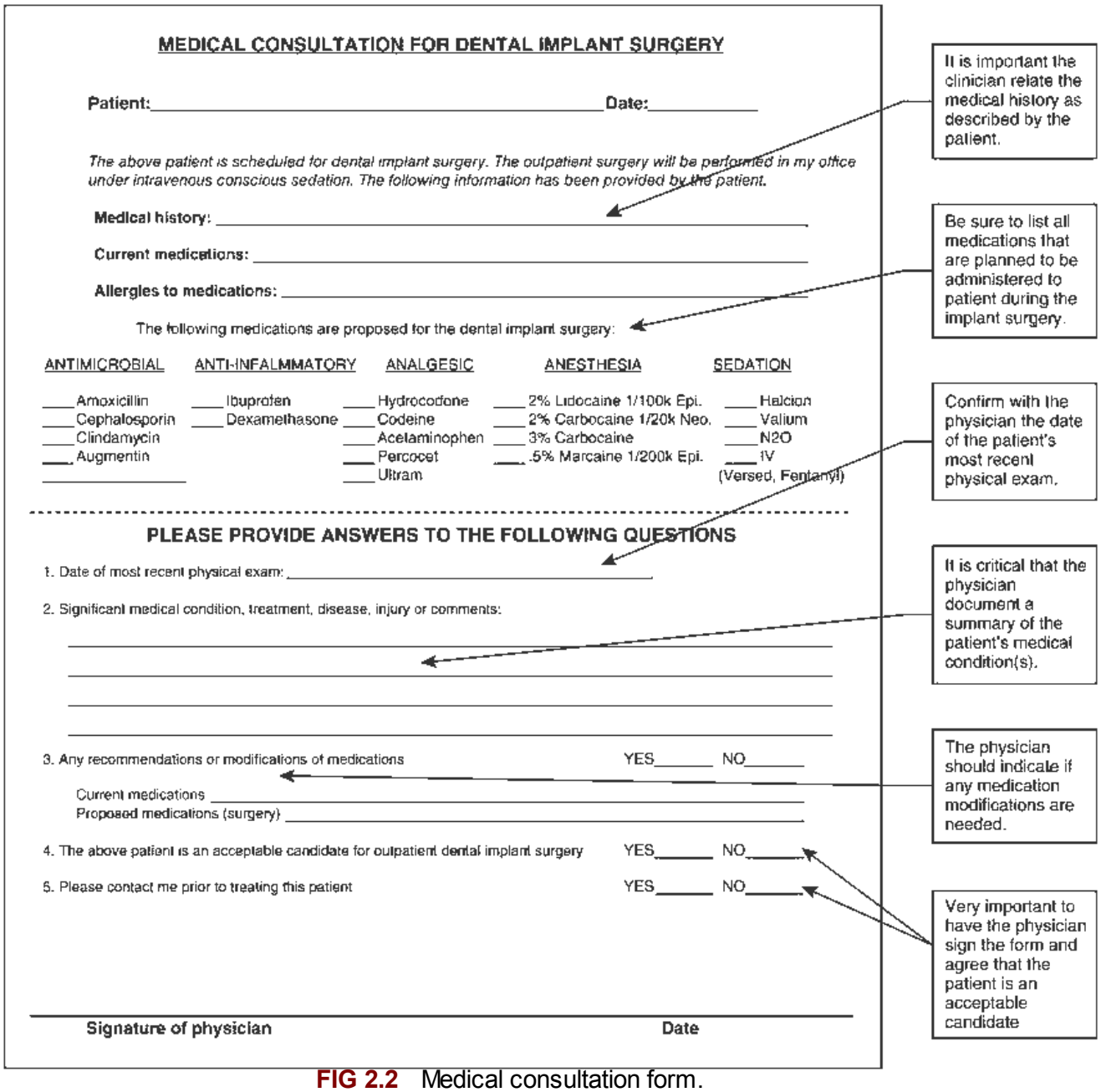

MEDICAL CONSULTATION FOR DENTAL IMPLANT SURGERY

Patient:_____ **Date:**_____

The above patient is scheduled for dental implant surgery. The outpatient surgery will be performed in my office under intravenous conscious sedation. The following information has been provided by the patient.

Medical history: _____

Current medications: _____

Allergies to medications: _____

The following medications are proposed for the dental implant surgery:

ANTIMICROBIAL	ANTI-INFALMMATORY	ANALGESIC	ANESTHESIA	SEDATION
____Amoxicillin	____Ibuprofen	____Hydrocodone	____2% Lidocaine 1/100k Epi.	____Halcion
____Cephalosporin	____Dexamethasone	____Codeine	____2% Carbocaine 1/20k Neo.	____Valium
____Clindamycin		____Acetaminophen	____3% Carbocaine	____N2O
____Augmentin		____Percocet	____.5% Marcaine 1/200k Epi.	____IV
_____		____Ultram		(Versed, Fentanyl)

PLEASE PROVIDE ANSWERS TO THE FOLLOWING QUESTIONS

1. Date of most recent physical exam: _____

2. Significant medical condition, treatment, disease, injury or comments:

_____

_____

_____

_____

3. Any recommendations or modifications of medications YES_____ NO_____

Current medications _____

Proposed medications (surgery) _____

4. The above patient is an acceptable candidate for outpatient dental implant surgery YES_____ NO_____

5. Please contact me prior to treating this patient YES_____ NO_____

Signature of physician **Date**

It is important the clinician relate the medical history as described by the patient.

Be sure to list all medications that are planned to be administered to patient during the implant surgery.

Confirm with the physician the date of the patient's most recent physical exam.

It is critical that the physician document a summary of the patient's medical condition(s).

The physician should indicate if any medication modifications are needed.

Very important to have the physician sign the form and agree that the patient is an acceptable candidate

FIG 2.2 Medical consultation form.

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Treatment Planning Complications

Randolph R. Resnik, Carl E. Misch

The introduction of the dental implant has greatly expanded the scope of services that clinicians can provide to restore patients to optimal form, function, and esthetics. Patients presenting with missing teeth or pathology that necessitate tooth extraction now have a wide range of treatment options beyond fixed bridges or removable prosthetics. The progressive loss of bone as a consequence of tooth extraction can now be minimized. Implant technology has allowed clinicians to come much closer to the ideal goal of restoring patients' dental health.

Patients present to dental offices every day with either an edentulous condition or pathology that necessitates tooth removal. Prior to the beginning of treatment, the clinician has an ethical and legal obligation to educate the patient as to the advantages and disadvantages of every therapeutic option available. The goal of this chapter is to provide clinicians with a comprehensive treatment protocol for the major edentulous conditions, including advantages and disadvantages of each. By informing the patient of each option available (including no treatment), the dental professional can aid the patient in forming an educated choice for treatment that meets their needs and values.

In this chapter the various aspects of treatment planning will be discussed. These include the prosthesis type, available bone, key implant positions, implant size, and force factors.

Type of Prosthesis

Treatment Planning

In implant dentistry, when a specific prosthetic result is desired, additional foundation units (support) may be created to obtain the end result. Both the psychologic and anatomic needs and desires of the patient should be first evaluated and determined. The prosthesis that satisfies the intended goals and expectations may then be designed.

Complications often arise when only one implant approach is used for all patients because the same surgical and prosthetic scenarios and flaws are invariably repeated. The benefits of implant dentistry can be realized only when the prosthesis is first discussed and determined in detail by the clinician and patient. An organized treatment approach based on the prosthesis permits predictable therapy results. Misch has postulated there are basically five various prosthetic options available in implant dentistry. Three restorations are fixed and vary in the amount of hard and soft tissue replaced; two are removable and are based on the amount of support for the restoration.[1]

The amount of support required for an implant prosthesis should initially be similar to that used in traditional tooth-supported restorations. After the intended prosthesis is designed, the implants and treatment surrounding this specific result can be established. The *prosthetic option* is the first factor to determine in the overall implant treatment plan.

Not Understanding and Communicating the Types of Prostheses

Complication.

When treatment planning for a fixed prosthesis, many inherent complications may occur. It is crucial for the clinician to have a thorough understanding of how the final fixed prosthesis is directly related to the amount of hard and soft tissue remaining, position of the implant, and the anatomic area of the oral cavity. If this is not understood, miscommunication may result leading to possible esthetic, biomechanical, or periodontal issues.

Prevention

Prosthesis treatment planning first.

To satisfy predictably a patient's needs and desires, the prosthesis should first be designed. In the stress treatment theorem postulated by Misch, the final restoration is first planned in a way similar to an architect designing a building before setting the foundation.[2] Implant dentistry is analogous to constructing a building. Prior to construction, detailed blueprints are obtained that explain in detail every aspect of the project. Similar guidelines should be used in implant dentistry treatment planning. Only after the prosthesis is envisioned and determined can the final abutments, implant size and location, and available bone requirements be determined to support the specific predetermined restoration.

Treatment plan according to finances.

Patients are too often treated as though cost is the primary factor in establishing a treatment plan. Patients should be presented with all viable treatment plans, regardless of cost. To determine the ideal final prosthetic design, the existing anatomy is evaluated after it has been determined whether a fixed or removable restoration is required to address the patient's desires. An axiom of implant treatment is to provide the most predictable, treatment that will satisfy the patient's anatomic needs and personal desires.

Patient should be educated on all viable treatment plans.

It is the clinician's obligation to educate the patient on the various treatment plans that are possible. In edentulous cases, fixed vs. removable should be explained. It is imperative that patients understand the advantages and disadvantages of each of these treatment modalities. In this way, patient expectation complications will be prevented. A good source of providing this information is via presentation books, videos, and online information. The education process should be documented and be part of the patient's records.

Understand the differences between the types of prostheses.

To prevent treatment planning complications, the implant clinician must understand there are three types of fixed prostheses and two types of removable prostheses, as postulated by Misch in 1989. When evaluating fixed prostheses, the three options may be used to replace one tooth or multiple teeth and may be cemented or screw retained. These types of fixed prostheses depend on the amount of hard and soft tissue structures replaced

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and the aspects of the prosthesis in the esthetic zone. Common to all fixed options is the inability of the patient to remove the implant prosthesis (Table 3.1 and Fig. 3.1).

TABLE 3.1
Prosthodontic Classification

Type	Definition
FP-1	**Fixed prosthesis;** replaces only the clinical crown; looks like a natural tooth with ideal contours
FP-2	**Fixed prosthesis;** replaces the clinical crown and a portion of the root; crown contour appears normal in the occlusal half but is elongated or hypercontoured in the gingival half
FP-3	**Fixed prosthesis;** replaces missing clinical crown and gingival color and a portion of the edentulous site; most common prosthesis is zirconia
RP-4	**Removable prosthesis;** overdenture supported completely by implants (usually with a superstructure bar) that is completely implant supported with no soft tissue support
RP-5	**Removable prosthesis;** overdenture supported by both soft tissue (primary support) and implants, which may or may not have a superstructure bar (secondary support)

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FIG 3.1 Fixed restorations have three categories: FP-1, FP-2, and FP-3. The restoration type is related to the contour of the restoration. (FP-1 is ideal, FP-2 is hypercontoured, and FP-3 replaces the gingiva drape with pink porcelain or acrylic.) The difference between FP-2 and FP-3 most often is related to the high maxillary lip position during smiling or the mandibular lip position during sibilant sounds of speech. FP-2 and FP-3 restorations often require more implant surface area support by increasing implant number or size. (From Misch CE: *Dental implant prosthetics,* 2e, St Louis, 2015, Mosby.)

Fixed Prostheses

FP-1

Definition.

An FP-1 is a fixed restoration and appears to the patient to replace only the anatomic crowns of the missing natural teeth (clinical crown). To fabricate

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this restoration type there must be minimal loss of hard and soft tissues. The volume and position of the residual bone must permit ideal placement of the implant in a location similar to the root of a natural tooth. The final restoration appears very similar in size and contour to the clinical crown or most traditional FPs used to restore or replace natural crowns on teeth (Figs. 3.2 and 3.3).

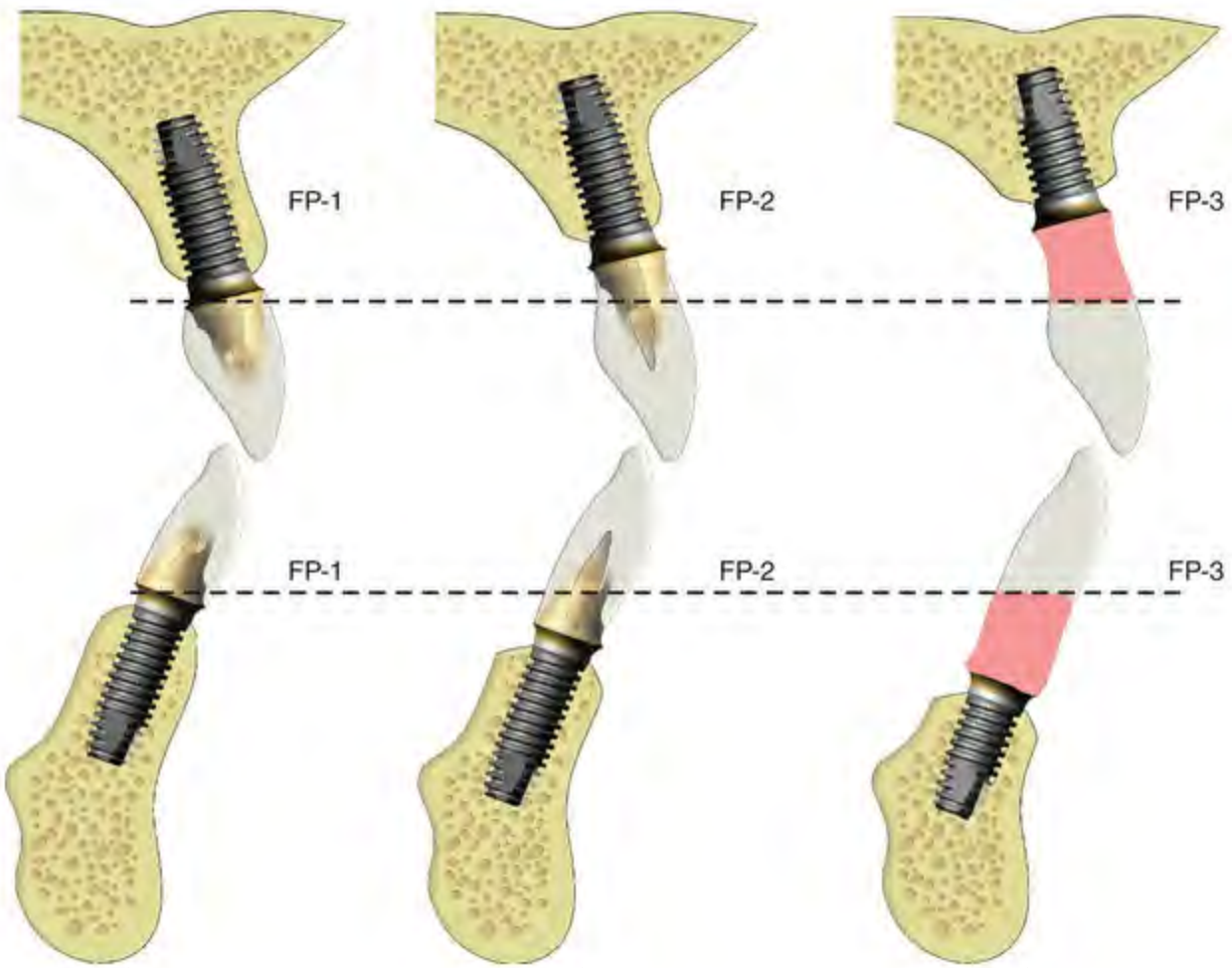

FIG 3.2 The Misch prosthesis classification is dictated by the amount of clinical crown height, hard and soft tissue replacement. FP-1 replaces the ideal clinical crown, FP-2 replaces the clinical crown + a hypercontoured replacement of the lost hard and soft tissue, and FP-3 that replaces the clinical crown + significant hard and soft tissue replacement (pink porcelain, acrylic, zirconia). (From Misch CE: *Dental implant prosthetics*, 2e, St Louis, 2015, Mosby.)

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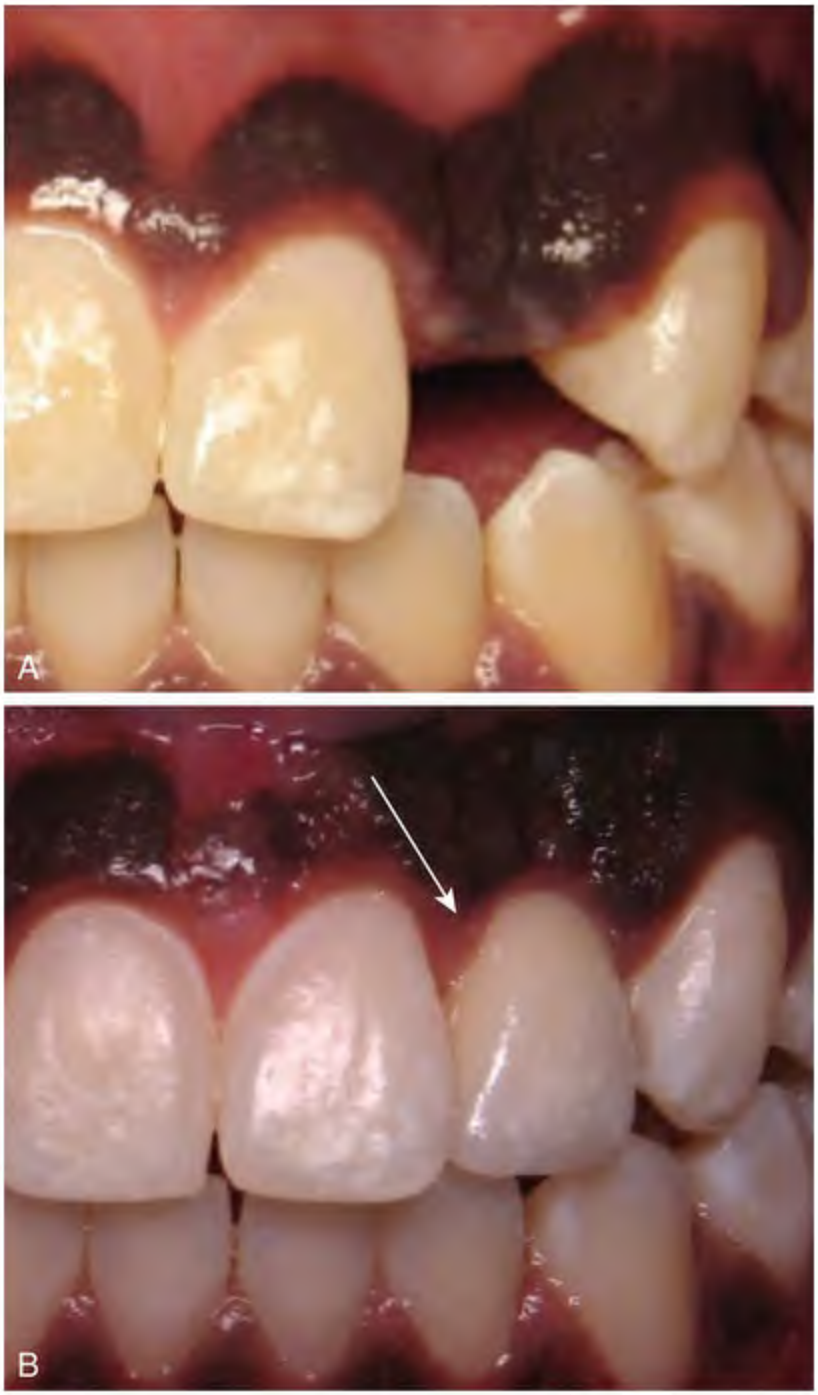

FIG 3.3 FP-1 prosthesis. (A) Preoperative image of missing # 10 (maxillary left lateral incisor); (B) Postoperative, depicting final prosthesis that is normal size to the adjacent clinical crowns.

Implant Criteria.

The FP-1 prosthesis is most often desired in the maxillary anterior region, especially in the esthetic zone during smiling. The final FP-1 restoration appears to the patient to be similar to a crown on a natural tooth. However, the implant abutment can rarely be treated exactly as a natural tooth

prepared for a full crown. The cervical diameter of a natural tooth is approximately 6.5 to 10.5 mm with an oval-triangular cross-section. However, the implant abutment is usually 4 to 5 mm in diameter and round in cross section. In addition, the placement of the implant rarely corresponds exactly to the crown–root position of the original tooth. For example, the thin labial bone lying over the facial aspect of a maxillary anterior root remodels after tooth loss, and the crest width shifts to the palate, decreasing 40% within the first 2 years.

Complication.

The most common complication with a patient requesting a FP-1 prosthesis is not recognizing preoperatively the limitations of the hard and soft tissue anatomy. If the final implant position is nonideal, it will be almost impossible to obtain a FP-1 prostheses without hard and soft tissue grafting.

Prevention.

The bone loss and lack of interdental soft tissue complicate the final esthetic result, especially in the cervical region of the crowns. FP-1 prostheses are especially difficult to achieve when more than two adjacent teeth are missing because of the need for hard tissue augmentation, soft tissue augmentation, and optimal implant positioning.

Hard tissue augmentation.

The width or height of the crestal bone is frequently insufficient after the loss of multiple adjacent natural teeth, and bone augmentation is often required before implant placement to achieve natural-looking crowns in the cervical region.

Soft tissue augmentation.

Because there are no interdental papillae in edentulous ridges, soft tissue augmentation is often required to improve the interproximal gingival contour. Ignoring this crucial step will result in open “black” triangular spaces (where papillae should usually be present) when the patient smiles.

Ideal implant positioning.

To obtain an FP-1 prostheses, the implant must be positioned ideally in the mesial-distal, buccal-lingual, and apicocoronal planes. The center of the

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osteotomy should be midway between the mesial-distal distance, provided the available space is ideal for the tooth being replaced. In a buccal-lingual position, the implant should be in a plane slightly lingual to the incisal edge of the tooth being replaced. In the apicocoronal plane, the implant should be approximately 3 mm apical to the free gingival margin of the adjacent teeth, provided that the adjacent teeth have ideal hard and soft tissue anatomy.

FP-2

Definition.

An FP-2 fixed prosthesis restores the anatomic crown and a portion of the root of the natural tooth and, therefore, is hypercontoured. The incisal edge of the restoration is in the correct position, but the gingival third of the crown is overextended, usually apical and lingual to the position of the original tooth. These restorations are similar to natural teeth exhibiting periodontal bone loss and gingival recession. In most situations an FP-2 is an acceptable prosthesis for patients. However, in the esthetic zone or in a patient with a high smile line, this may pose complication issues because the prosthesis may be deemed unesthetic by the patient (Fig. 3.4).

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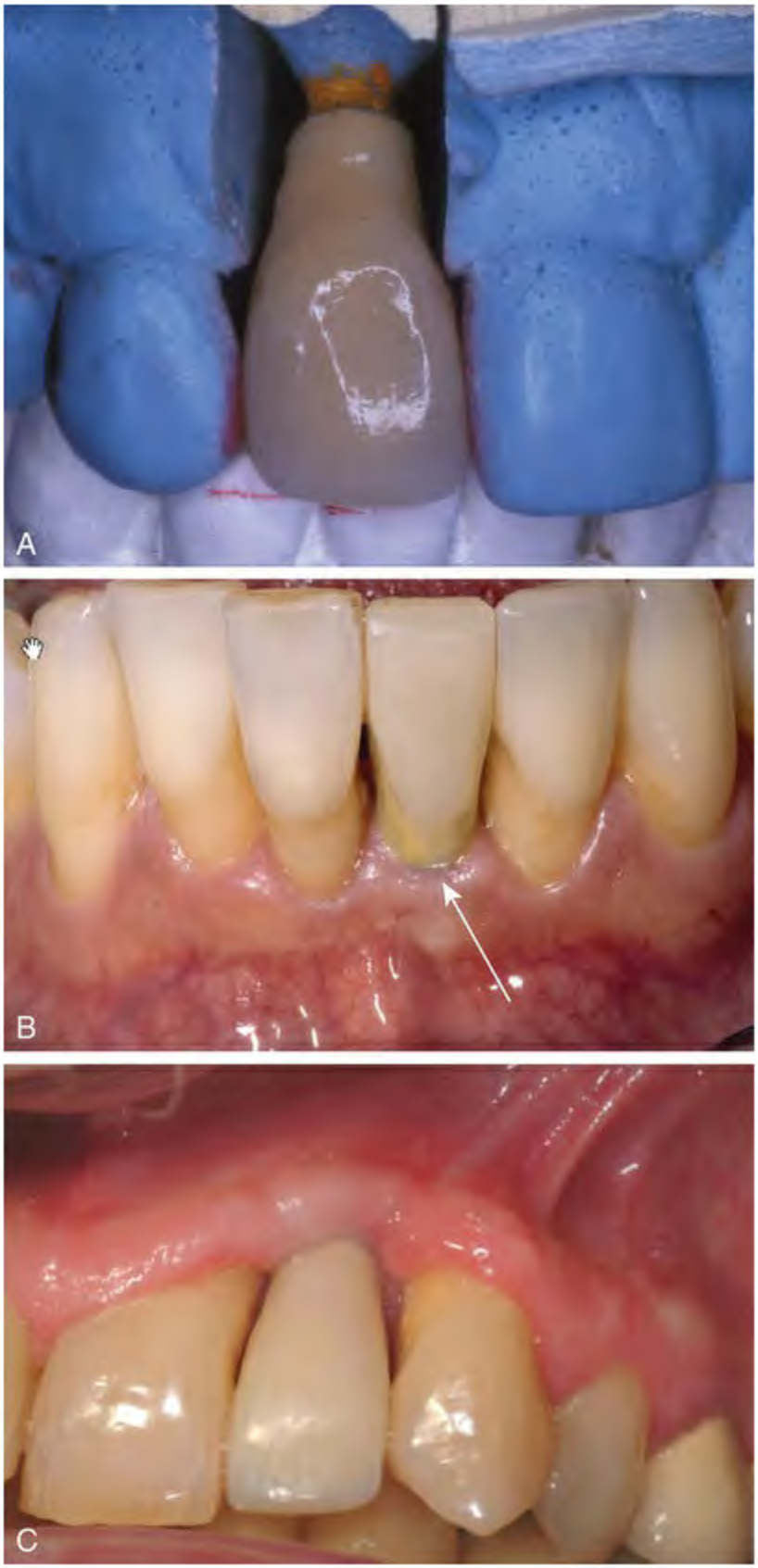

FIG 3.4 (A) and (B), FP-2 Prosthesis showing a hypercontoured or elongated tooth in comparison to the adjacent clinical crowns. (C), FP-2 prosthesis showing associated complications of bone loss and loss of papilla from implant positioning too deep or apical.

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Implant Criteria.

The volume and topography of the available bone are more apical compared with the ideal bone position of a natural root (1–2 mm below the cement-enamel junction) and dictate a more apical implant placement compared with the FP-1 prosthesis. This most commonly occurs because of implant placement in Division B ridges, and because of the lack of bone width, the final implant position will be too far apical in comparison to the adjacent teeth.

Complication.

The most common complications that occur with a FP-2 prosthesis are a result of not informing the patient of the hypercontouring of the final prosthesis or the need for the use of pink porcelain. Especially in the maxillary anterior region, this may pose an esthetic issue with the patient. The use of pink porcelain also increases laboratory expenses.

Prevention

Patient communication.

The patient should be well informed prior to the initiation of treatment that the final FP-2 prosthesis will appear longer than healthy natural teeth (without bone loss). The patient should be shown photo images or diagrams of an FP-2 prosthesis compared to an FP-1 prosthesis prior to treatment. Additionally, the surgical informed consent should be modified to explain and fully inform the patient of the overcontoured prostheses (FP-1 vs. FP-2) (Fig. 3.5).

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Consent for Implant Surgery

1. I have been informed and afforded the time to fully understand the purpose and the nature of the implant surgery procedure. I understand what is necessary to accomplish the placement of the implant under the gum or in the bone.

2. My doctor has carefully examined my mouth. Alternatives to this treatment have been explained. I have tried or considered these methods, but I desire an implant to help secure the replaced missing teeth.

3. I have further been informed of the possible risks and complications involved with surgery, drugs, and anesthesia. Such complications include pain, swelling, infection and discoloration. Numbness of the lip, tongue, cheek, or teeth may occur. The exact duration may not be determinable and may be irreversible. Also possible are thrombophlebitis (inflammation of the vein), injury to teeth present, bone fractures, sinus penetration, delayed healing, allergic reactions to drugs or medications used, etc.

4. I understand that if nothing is done any of the following could occur: bone disease, loss of bone, gum tissue inflammation, infection, sensitivity, looseness of teeth followed by necessity of extraction. Also possible are temporomandibular joint (jaw) problems, headaches, referred pain to back of the neck and facial muscles, and tired muscles when chewing. In addition, I am aware that if nothing is done an inability to place an implant at a later date due to changes in oral or medical conditions could exist.

5. My doctor has explained that there is no method to predict accurately the gum and bone healing capabilities in each patient following the placement of an implant.

6. It has been explained that in some instances implants fail and must be removed. I have been informed and understand that the practice of dentistry is not an exact science; no guarantees or assurances as to the outcome of the results of treatment or surgery can be made. I am aware that there is a risk that the implant surgery may fail, which might result in further corrective surgery or the removal of the implant with possible corrective surgery associated with the removal.

7. I understand that any amount of smoking, alcohol, or elevated blood sugar may effect gum and bone healing and may limit the success of the implant. I agree to follow my doctor's home care instructions. I agree to report to my doctor any complications and maintain regular examinations as instructed.

8. I agree to the type of anesthesia, depending on the choice of the doctor. I agree not to operate a motor vehicle or hazardous device for at least 24 hours or more until fully recovered from the effects of the anesthesia or drugs given to me for my care.

9. To my knowledge, I have given an accurate report of my physical and mental health history. I have also reported any prior allergic or unusual reactions to drugs, food, insect bites, anesthetics, pollens, dust, blood or body diseases, gum or skin reactions, abnormal bleeding or any other conditions related to my health.

10. I Have Been Informed And Understand The Existing Anatomy (Bone And Tissue) Which May Place Limitations On The Final Implant Crown Height And Position. The Implant Crown Will Most Likely Be Higher (Longer) Than The Adjacent Teeth (FP-2), With Lack Of Gum Tissue On Each Side. Pink Porcelain May Also Need To Be Used In Conjunction With The Final Crown.

11. I agree to notify the doctor's office of any and all changes to my address and/or telephone number within a reasonable time frame (two to four weeks)

12. I request and authorize medical/dental services for myself, including bone grafts and other surgery. I fully understand the contemplated procedure, surgery, or treatment conditions that may become apparent, which warrant, in the judgment of the doctor, additional or alternative treatment pertinent to the success of comprehensive treatment. I also approve any modifications in design, materials, or care, if it is felt this is for my best interest. If an unforeseen condition arises in the course of treatment which calls for performance of procedures in addition to or different from that now contemplated I further authorize and direct my doctor, associate, or assistant, to do whatever they deem necessary and advisable under the circumstances, including the decision not to proceed with the bone graft procedure.

Signature of Patient	Date
Signature of Witness	Date
Signature of Doctor	Date

FIG 3.5 Consent form for FP-2 or FP-3 prosthesis.

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Preoperative smile zone evaluation.

The esthetic zone of a patient is established during smiling in the maxillary arch. The number of teeth displayed when a patient smiles is highly variable. Less than 10% of the population limits their smile to the anterior six teeth. Almost 50% of people show up to the first premolar and approximately 4% of our patients display almost all the maxillary teeth during a smile.[3] The low lip position is ideally evaluated during sibilant sounds of speech (e.g., Mississippi, sixty-six). It is not unusual for patients to show fewer lower anterior teeth during smiling, especially in younger patients. Older patients are most likely to show the anterior teeth and gingiva during speech, with men showing more than women. Likewise, if the high lip line during smiling or the low lip line during speech does not display the cervical regions, the longer teeth are usually of no esthetic consequence, provided that the patient has been informed before treatment (Fig. 3.6).

FIG 3.6 High smile line. (A) Unfavorable smile line showing the entire clinical crown and tissue. This type of smile may contraindicate implant placement because of esthetic related issues. (B) Favorable smile line showing only one-half of the clinical crown and no tissue. This type of smile line is ideal for an FP-2 or FP-3 prosthesis.

Ideal implant position.

A multiple-unit FP-2 restoration does not require as specific an implant position in the mesial or distal position as does an FP-1 prosthesis. This is because the cervical contour is not displayed during function. The implant position may be chosen in relation to bone width, angulation, or hygienic considerations rather than purely esthetic demands (compared with the FP-1 prosthesis). On occasion, because of available bone, the implant may even be placed in an embrasure between the two teeth. This often occurs when replacing mandibular anterior teeth with a full-arch fixed restoration. If this occurs, the incisal two thirds of the two crowns should be ideal in width, as though the implants were not present. Only the cervical region is compromised (i.e., this is most likely out of the esthetic zone). Although the implant is not positioned in an ideal mesiodistal position, it should be placed in the correct facial-lingual position to ensure that contour, hygiene, and direction of forces are not compromised.

FP-3

Definition.

The FP-3 fixed restoration appears to replace the natural teeth crowns and has pink-colored restorative material (acrylic or pink porcelain) to replace a portion of the soft tissue, especially the interdental papillae. This is most commonly indicated when severe bone resorption has occurred.

Implant Criteria.

As with the FP-2 prosthesis, the original available bone height has decreased by natural resorption or osteoplasty at the time of implant placement. To place the incisal edge of the teeth in ideal position for esthetics, function, lip support, and speech, the excessive vertical dimension to be restored requires teeth that are unnatural in length. The soft and hard tissue loss requires replacement with pink porcelain or acrylic (Fig. 3.7).

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FIG 3.7 A splinted image of #8-#9 implants with pink porcelain. An FP-2 or FP-3 may not be indicated when a high smile line exists.

Complication.

The main complication associated with an FP-3 prosthesis is patient acceptance because of the hypercontoured crowns (i.e., pink porcelain or acrylic). Additionally, the clinician must be aware of the added laboratory costs associated with an FP-3 prosthesis. Most laboratories will charge a significantly higher fee for the application of pink porcelain. However, the clinician should be aware there exist various shades of pink porcelain. It is recommended that the color of the tissue be evaluated similar to tooth shade. Many pink shade guides are available for use in implant dentistry today (Fig. 3.8).

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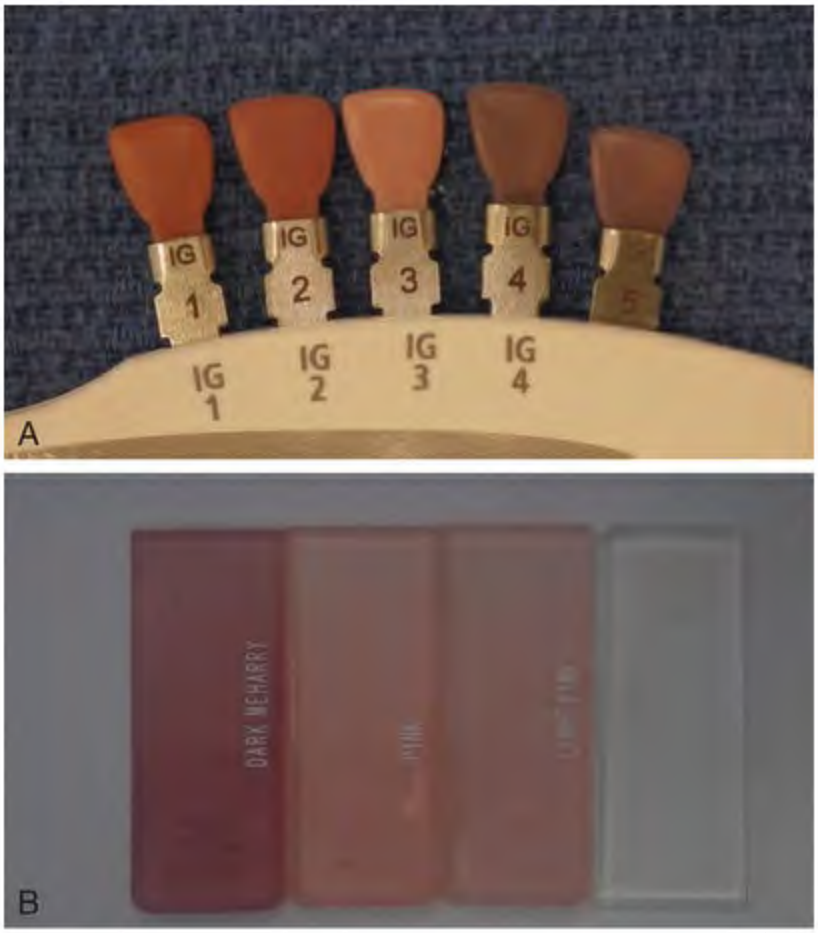

FIG 3.8 Pink tissue shading. (A) Pink shade guides. (B) Examples of pink porcelain and pink stained zirconia.

Prevention

Patient communication.

The patient should be well informed prior to any treatment that the final FP-3 prosthetic teeth will appear longer and also have pink restorative material associated with the prosthesis to replace the loss of hard and soft tissue. Photos or examples of the pink prosthesis should be shown to the patient.

Understanding of smile zone variations.

The ideal high smile line (i.e., not showing excessive soft tissue) occurs in almost 70% of the population. The maxillary lip displays the interdental papilla of the maxillary anterior teeth, but not the soft tissue above the mid cervical regions. A high smile or "gummy" smile will usually display the interdental papillae and at least some of the gingival tissues above the free gingival margin of the teeth. Patients in both of these categories of high lip

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line should have the soft tissue replaced by either the prostheses or augmentation. Additionally, the appearance of the mandibular teeth may be evaluated during sibilant sounds (Fig. 3.9).

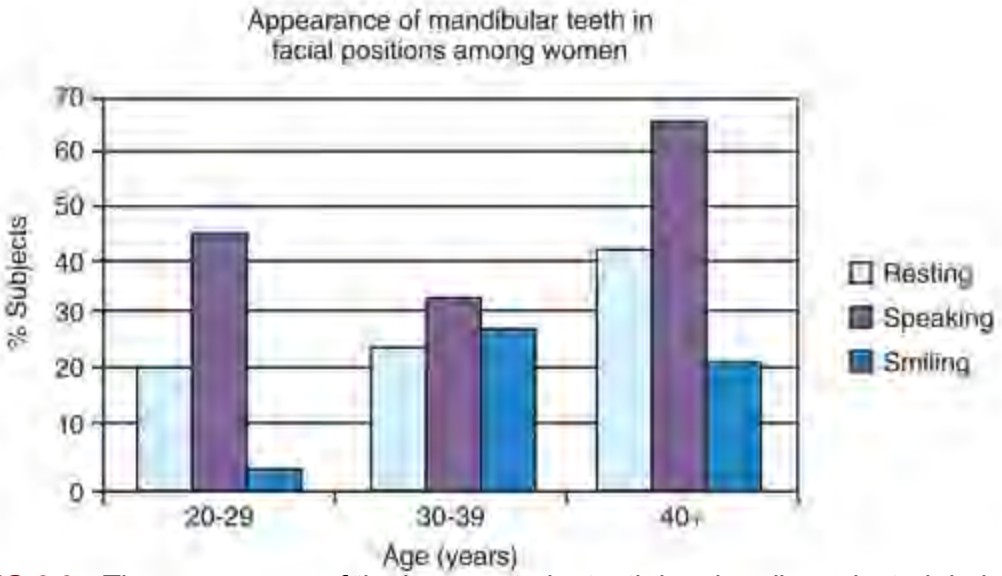

FIG 3.9 The appearance of the lower anterior teeth is primarily evaluated during sibilant sounds of speech, and older patients show more teeth than younger patients. (From Misch CE: *Dental implant prosthetics,* 2e, St Louis, 2015, Mosby.)

Color of the pink tissue.

Because the color characteristics of patient's gingiva vary greatly, the implant clinician should use a laboratory that has the capability to use a pink porcelain shade guide to match the tissue. However, patients should be informed of the tissue color changes that occur over time.

Understand the two types of FP-3 prostheses.

There are basically two approaches for an FP-3 prosthesis. (1) *A hybrid restoration of denture teeth and acrylic with a metal substructure*. The complications associated with this type of prosthesis are excessive wearing of the denture tooth or debonding from the prosthesis. (2) *A porcelain–metal/zirconia restoration*. An FP-3 porcelain-to-metal/zirconia restoration is more difficult to fabricate for the laboratory technician than an FP-2 prosthesis. The pink porcelain is more difficult to appear as soft tissue and usually requires more porcelain firing cycles. This increases the risk of potential porosity or porcelain fracture (Fig. 3.10).

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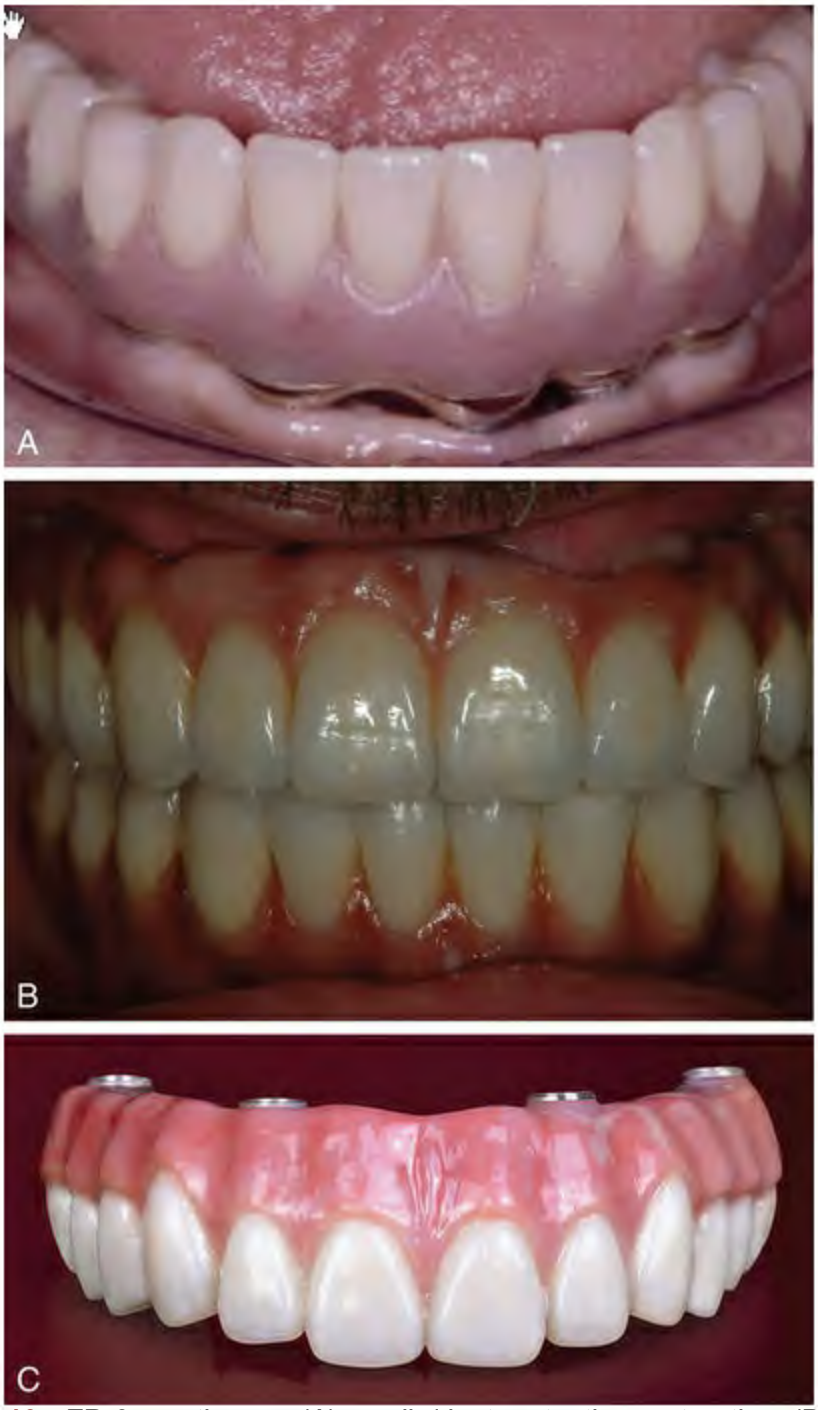

FIG 3.10 FP-3 prostheses. (A) acrylic/denture tooth construction; (B) pink porcelain; (C) pink zirconia.

Spacing of multiple implants.

For edentulous arches or larger spaces, implants should be placed a minimum of 3 millimeters apart. If they are less than 3 millimeters apart, difficulty with hygiene will result along with the possibility that bone loss on one will extend to the other, compromising both implants.

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Tissue space.

In the maxillary arch, wide open embrasures between the implants may cause food impaction or speech problems. These complications may be solved by using a removable soft tissue replacement mask or make the overcontoured cervical restorations. The maxillary FP-3 prosthesis is often extended or juxtaposed to the maxillary soft tissue so that speech is not impaired. However, this results in hygiene issues, which place the prostheses at risk. The mandibular FP-3 restorations may be left above the tissue, similar to a sanitary pontic. This facilitates oral hygiene in the mandible, especially when the implant is exposed through the soft tissue drape and is not visible during speech. However, if the space below the restoration is too great, the lower lip may lack support in the labio-mental region.

Removable Prostheses

When treatment planning, the patient's prosthetic requirements should be fully understood and an evaluation of the patient's anatomy is a priority. The most common removable implant prostheses are overdentures for completely edentulous patients. Complete removable overdentures have been reported with predictability and a high success rate for many decades; however, there is much confusion concerning this type of prosthesis because of the inherent variations.[4,5] Most often, patients do not understand the associated movement with overdentures (i.e., dependent on number of implants, attachments, A-P spread, posterior ridge form) because they don't understand the associated biomechanical factors with an overdenture prosthesis. The complications that may a occur may be significant.

There exist two types of removable prostheses that are based on support, retention, and stability of the restoration. Patients are able to remove the restoration but not the implant-supported superstructure or attachments to the abutments. The difference in the two categories of removable restorations are not in appearance (as it is in the fixed categories). Instead, the two removable categories are primarily determined by the amount of implant and soft tissue support (Fig. 3.11).

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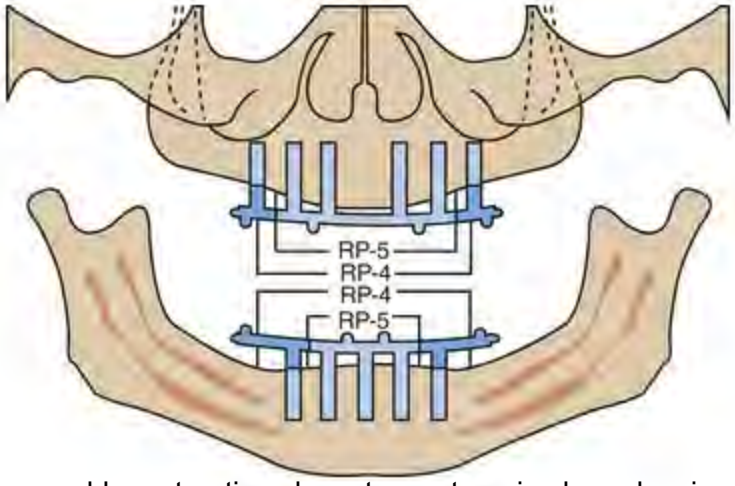

FIG 3.11 Removable restorations have two categories based on implant support. RP-4 prostheses have complete implant support in both the anterior and posterior regions. In the mandible, the superstructure bar often is cantilevered from implants positioned between the foramina. The maxillary RP-4 prosthesis usually has more implants and no cantilever (usually no palate present). An RP-5 restoration has primarily anterior implant support and posterior soft tissue support in the maxilla or mandible. Often fewer implants are required, and bone grafting is less indicated. (From Misch CE: *Dental implant prosthetics,* 2e, St Louis, 2015, Mosby.)

RP-4

Definition.

An RP-4 removable prosthesis is completely supported by implants with no soft tissue support. The RP-4 prosthesis is primarily a totally implant-supported prosthesis. The restoration is rigid when inserted, and the overdenture attachments usually connect the RP to single implant attachments or a low-profile tissue bar with attachments (Fig. 3.12).

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FIG 3.12 (A) RP-4—totally implant-supported prosthesis with no soft tissue support, note the lack of peripheral seal. (B) RP-5 prosthesis—soft tissue–supported with secondary implant support and peripheral seal.

Implant Criteria.

The implant placement criteria for an RP-4 prosthesis are different than that for an FP prosthesis. Denture teeth and acrylic require more prosthetic space for the removable restoration in comparison to a fixed prosthesis. The implants in an RP-4 prosthesis (and an FP-2 or FP-3 restoration) should be placed in the mesiodistal position for the best biomechanical and hygienic situation. Usually, in the mandible, implants are inserted between the two mental foramens in the A, B, C, D, and E positions.

Complication.

The most common complication occurring with a RP-4 prosthesis is lack of adequate implant support (e.g., insufficient number of implants) and food impaction. In the mandibular RP-4 prosthesis, because there exists no peripheral seal, often food becomes impacted underneath the prosthesis.

Prevention

Patient communication.

The patient should have a thorough understanding of the differences between a RP-4 and a RP-5 prosthesis. There exist distinct differences between RP-4 and RP-5 prosthesis with respect to number of implants, type of support, and prosthesis movement.

Treatment denture.

A preimplant treatment denture may be fabricated to evaluate the occlusal vertical dimension and ensure the patient's esthetic satisfaction. This technique is especially indicated for patients with demanding needs and desires regarding the final esthetic result or with severely reduced vertical dimensions with their present prosthesis. The implant dentist may also use the treatment denture as a surgical guide for implant placement and for use during the healing stage. After the implants are uncovered, the superstructure or prosthetic design is fabricated within the guidelines of the existing treatment restoration.

Implant position.

The positioning of implants for an RP-4 overdenture is critical to the successful outcome of the prosthesis. For example, a Hader clip requires the mesiodistal implant spacing to be greater than 6 mm from edge to edge of the implant bodies. Because of this space requirement, the number of implants is reduced, especially if placed between the interforaminal space of the mandible. Additionally, in the apicocoronal dimension, adequate interocclusal space is needed to allow for at least 2 mm of acrylic to retain the denture teeth with overdentures; approximately 15 mm is needed from the crest of the bone to the incisal edge.

Implant number.

For a totally implant-supported prosthesis (RP-4), four to five implants are required in the mandible and six to eight implants in the maxilla. Fewer

implants being utilized to support a RP-4 prosthesis will result in possible overloading of the prosthesis and/or implants leading to complications.

RP-5

Definition.

RP-5 is a removable prosthesis combining implant and soft tissue support. Predominately, the soft tissue is the primary support (primary stress-bearing areas) and implants are used for secondary support. The advantage of an RP-5 restoration is the reduced cost because fewer implants may be inserted compared with a RP-4 or fixed restoration. Additionally, there is less demand for bone augmentation, which decreases cost.

Implant Criteria.

Implants in the mandible are inserted within the mandibular interforaminal space with two, three, or four implants. These correspond to the Overdenture Treatment Planning options (e.g., OD-1–OD-5). In the maxilla, usually four to six implants are recommended depending upon force factors.

Complication.

The most common complication occurring with an RP-5 prosthesis is the associated movement. A common misconception of patients is they believe that implants, independent of the number, should have no associated movement. Because an RP-5 relies on the soft tissue for support, there will be inherent movement within the prosthesis. Additionally, with an RP-5 prosthesis, because of the primary implant support, soft tissue pressure is present, which may cause sore spots. If a patient's initial complaint is chronic posterior sore spots, an RP-5 is not the best prosthetic option.

Prevention

Patient communication.

The patient should have a thorough understanding of the differences between an RP-4 and an RP-5 prosthesis. A common problem with an RP-5 prosthesis is the possible associated movement, which some patients may not tolerate or expect. A preoperative explanation must allow the patient a full understanding of the advantages and disadvantages of the two types of

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prostheses. A common analogy is the use of a chair. A two-implant overdenture is similar to a chair with only two legs. The chair may be stabilized; however, it can easily be moved. A three-implant overdenture is similar to a three-legged chair because it is more stable than two-implant overdenture; however, it will still have some degree of movement. A four- to five-implant overdenture is similar to a four-legged chair, which is associated with minimal movement (Fig. 3.13).

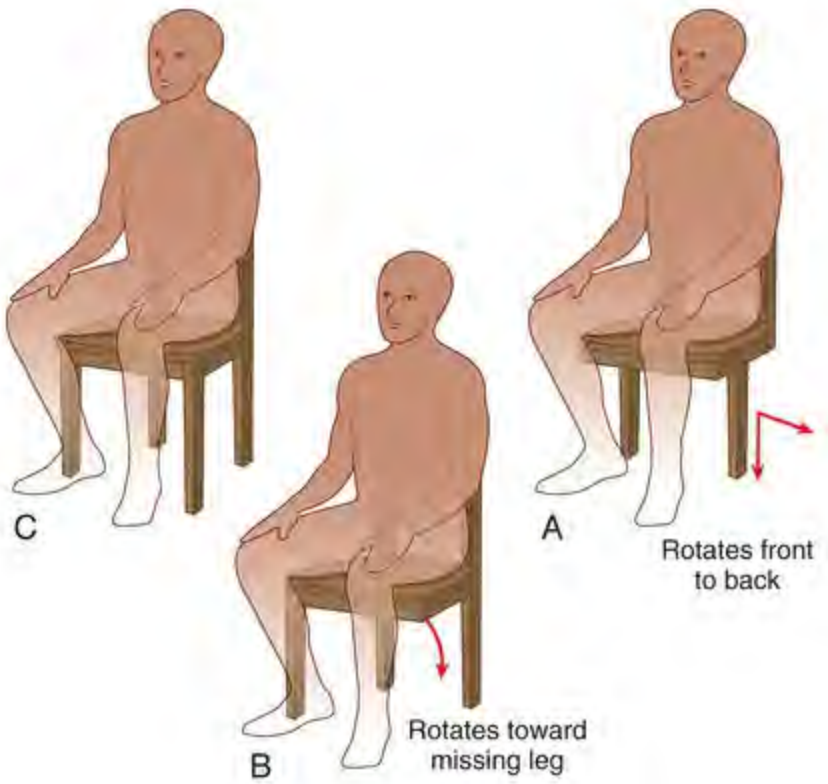

FIG 3.13 Overdenture type analogy; (A) Two-legged chair (2-implants) will rotate anterior and posterior, (B) Three-legged chair (3-implants) which is more stable than 2-implants, however still has movement, (C) Four-legged chair (4-5 implants) is the most stable with no movement.

Treatment denture.

A preimplant treatment denture may be fabricated to determine position and prosthesis thickness. However, this is usually less important than in a RP-4 type prosthesis.

Posterior ridge form.

If the patient has a poor posterior ridge form (mandible), especially in the

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posterior area, an RP-5 prosthesis might not be the ideal treatment option. In these cases, patient education and consent is mandatory so they fully understand the limitations of this type of prosthesis.

Implant position.

The positioning of implants for an RP-5 overdenture is critical to the successful outcome of the prosthesis. When a bar is not going to be utilized, great care should be exercised to make sure that adequate spacing between the implants is present. Lack of space between implants (<3 mm), will result in prosthetic attachment complications. Additionally, the implants should be placed at approximately the same height and as parallel as possible to prevent path of insertion complications.

Implant number.

For a totally implant-supported prosthesis, a minimum of two to four implants is required in the mandible and four to six implants in the maxilla. Fewer implants will result in additional mobility of the prosthesis or occlusal overloading.

Continuous residual ridge bone loss.

The clinician and the patient should realize that the residual bone will continue to resorb in the soft tissue–borne regions of the prosthesis. Relines and occlusal adjustments every few years are common maintenance requirements of an RP-5 restoration. Bone resorption in the posterior regions with RP-5 restorations may occur two to three times faster than the resorption found with full dentures.[6] This may be a determining a factor when considering this type of treatment in younger patients despite the decreased cost and lower failure rate (Fig. 3.14).

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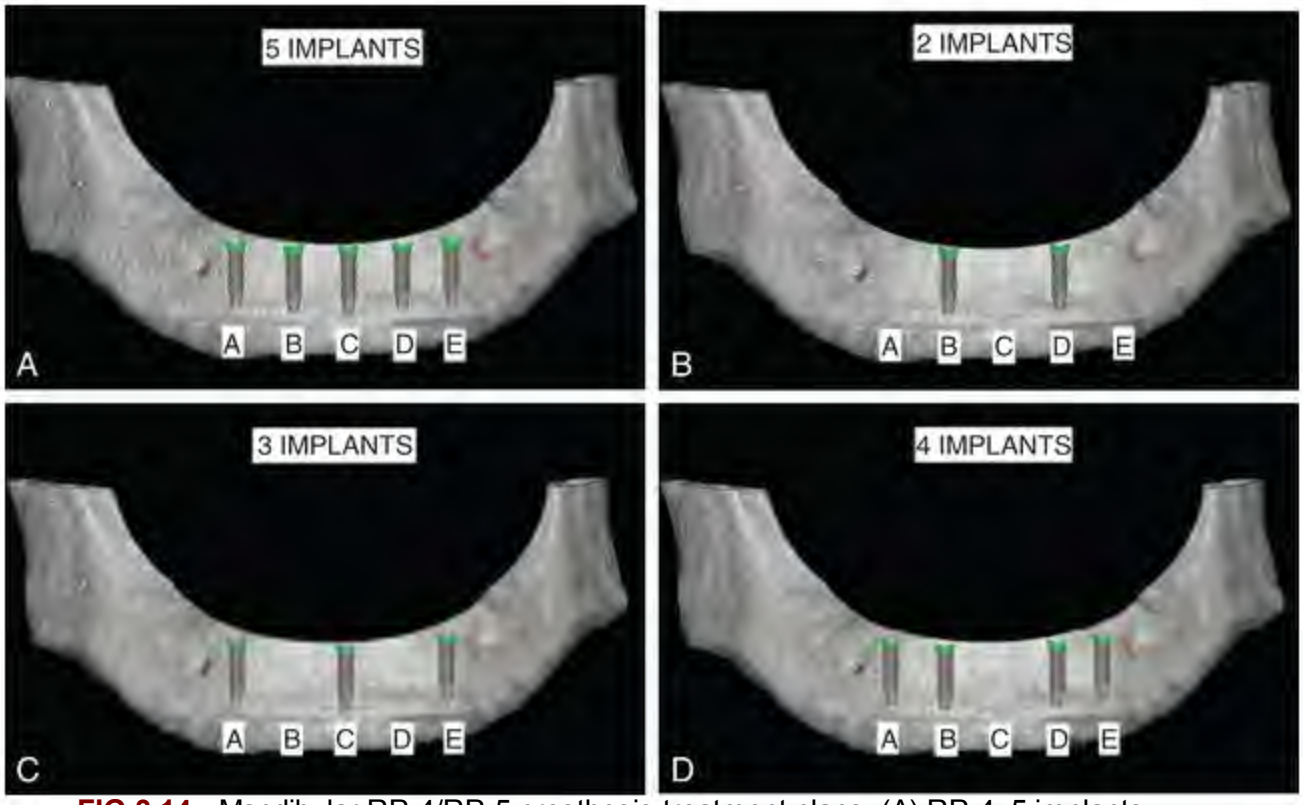

FIG 3.14 Mandibular RP-4/RP-5 prosthesis treatment plans. (A) RP-4; 5 implants between the mandibular foramen regions. (B) RP-5; 2 implants. (C) RP-5; 3 implants. (D) RP-5; 4 implants.

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Divisions of Available Bone

Quantity of Available Bone

After the type of prosthesis is determined, the available bone for implant placement is evaluated to determine the surgical approach necessary (i.e., bone augmentation, implant insertion, or both) to support the intended prosthesis. The available bone concept describes the amount of bone in the edentulous area considered for implantation. Available bone is measured in width, height, length, and angulation and crown height space (CHS) in relation to the remaining bone (Fig. 3.15). If the bone is inadequate to predictably support an implant, a bone graft is considered in the ideal site(s), or alternative sites may be considered when additional implant numbers are necessary.

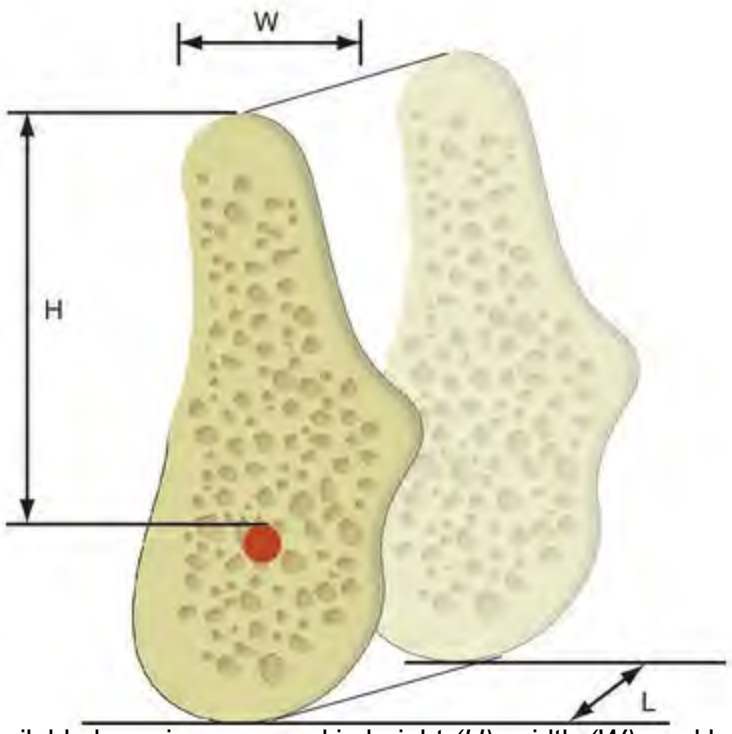

FIG 3.15 Available bone is measured in height *(H)*, width *(W)*, and length *(L)*. Also considered are crown height space and angulation of bone (which is related to the direction of force to the implant body). (From Misch CE: *Dental implant prosthetics*, 2e, St Louis, 2015, Mosby.)

Not Understanding the Parameters of the Available Bone

To avoid complications in assessing the available bone present, the implant

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clinician must understand the correct parameters in determining the bone height, width, and length.

Available Bone Height.

The available bone height is first determined by radiographic evaluation (preferably cone beam computed tomography [CBCT]) in the edentulous region by measuring from the crest of the edentulous ridge to the opposing anatomic landmark. The anterior regions of the jaws have the greatest height due to the pneumatization of the maxillary sinus and the inferior alveolar nerve limits this dimension in the mandibular posterior regions. The maxillary canine eminence region, just lateral to the lateral piriform rim of the nose, often offers the greatest height of available bone in the maxillary anterior (Fig. 3.16).[7]

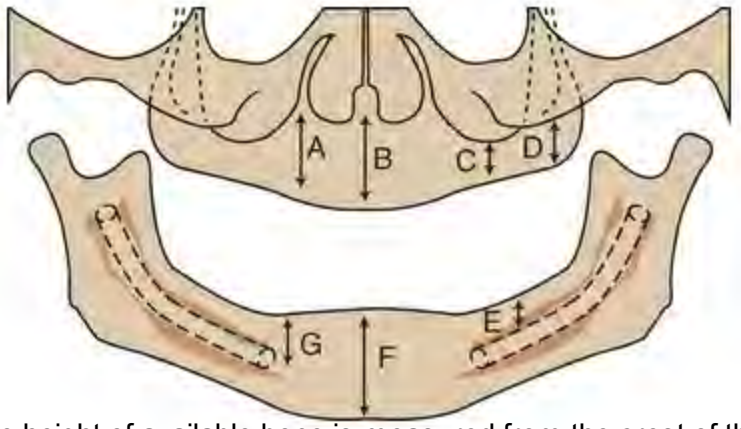

FIG 3.16 The height of available bone is measured from the crest of the edentulous ridge to the opposing landmark. The opposing landmark may be in the maxillary canine region *(A)*, floor of the nares *(B)*, maxillary sinus *(C)*, tuberosity *(D)*, mandibular canine region *(G)*, anterior mandible *(F)*, or bone above the inferior mandibular canal *(E)*. (From Misch CE: *Dental implant prosthetics*, 2e, St Louis, 2015, Mosby.)

As a general rule, the anterior mandible has the greatest bone height. There is more bone apical to the mandibular anterior teeth than any other region. Even after the resorption of the residual ridge after tooth loss, there is usually adequate bone to insert dental implants (Fig. 3.17). However, the crown height of the prosthesis may be extensive (e.g., FP-2, FP-3) because of the loss of bone. This region often has the most available bone but also may have the greatest crown height space.

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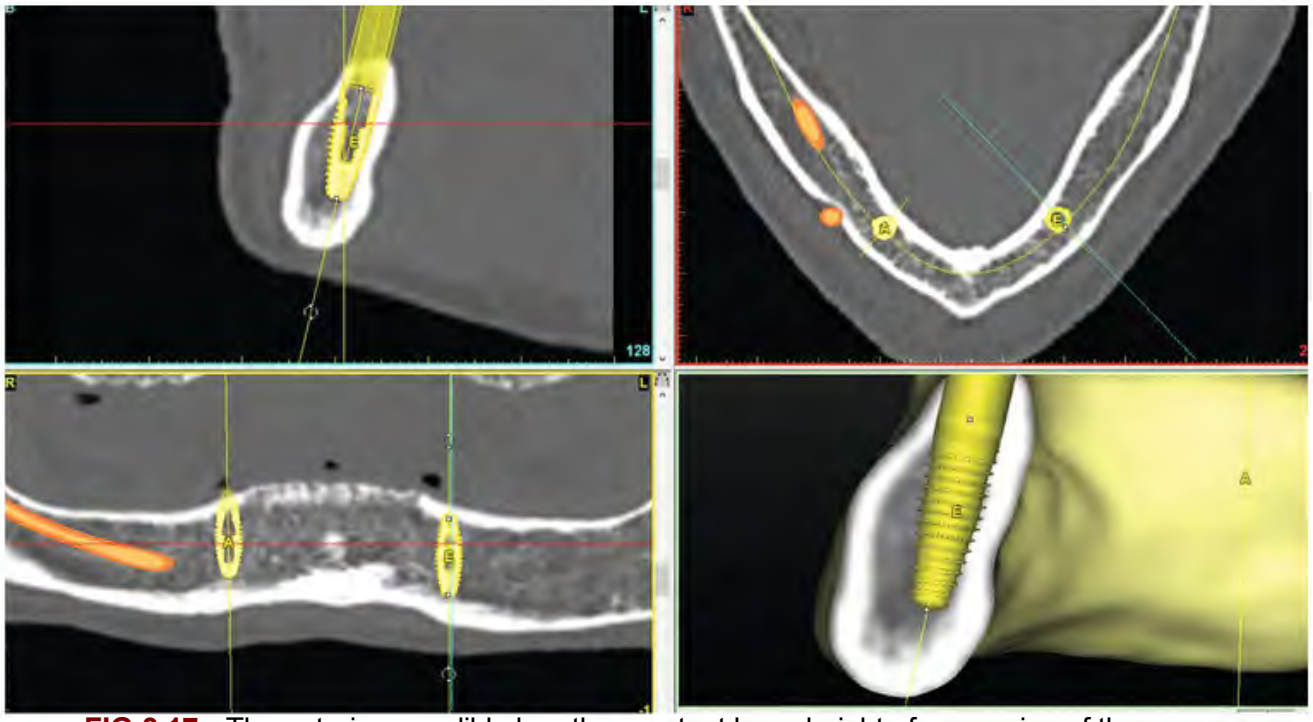

FIG 3.17 The anterior mandible has the greatest bone height of any region of the jaws. However, because of the variable osseous angulation in the anterior mandible, the implant often engages the lingual plate of bone.

The anterior bone region in the mandible extends between the right and left mental foramens. The mental foramen is most often found in close proximity to the two premolars. The anterior region of bone extends beyond the canines and to the first premolar region most often. The initial mandibular bone height is influenced by skeletal anatomy, with Angle Class II patients having shorter mandibular height and Angle Class III patients exhibiting the greatest height.

The opposing landmarks for both the maxilla and mandible of the initial available bone height are more limiting in the posterior regions distal to the first premolar. In the maxillary posterior jaw region, there is usually greater bone height in the first premolar than in the second premolar, which has greater height than the molar sites because of the concave morphology of the maxillary sinus floor. As a consequence, the existing bone anatomy of the implant patient often requires modification (e.g., sinus augmentation) to enhance long-term implant success (Fig. 3.21).

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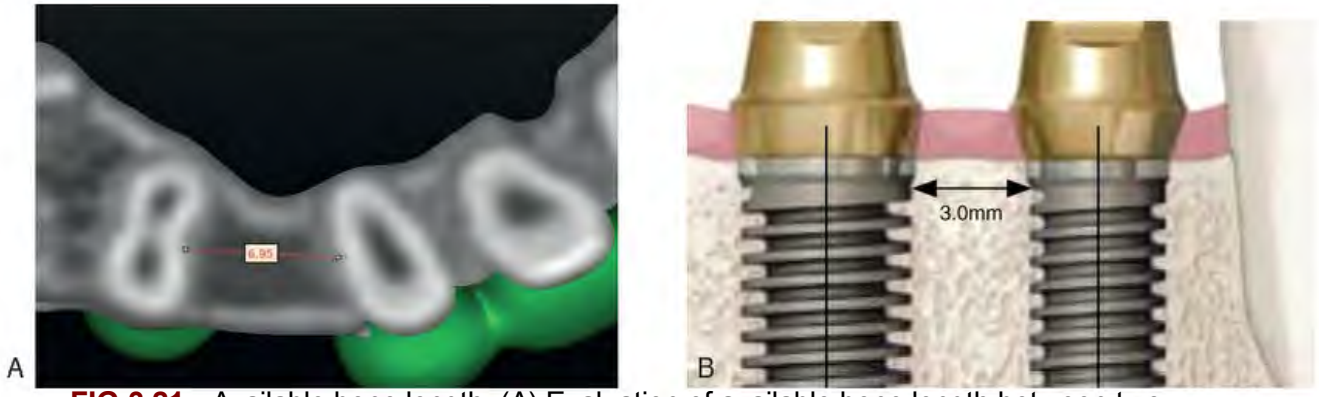

FIG 3.21 Available bone length. (A) Evaluation of available bone length between two teeth is most accurately determined with axial views. (B) In determining available bone length, a minimum of 3 mm is required for hard and soft tissue health.

The posterior height of bone in the mandibular region is reduced because of the presence of the mandibular canal, situated approximately 12 mm above the inferior border of the mandible (Fig. 3.18). Generally, less available bone is present in the higher force areas of the posterior mandible and maxilla; however, many treatment plans include shorter and fewer number of implants. Oikarinen et al found that more than 6 mm of bone height is found in less than 50% of posterior mandibles and 40% of posterior maxillae in partially edentulous patients.[8]

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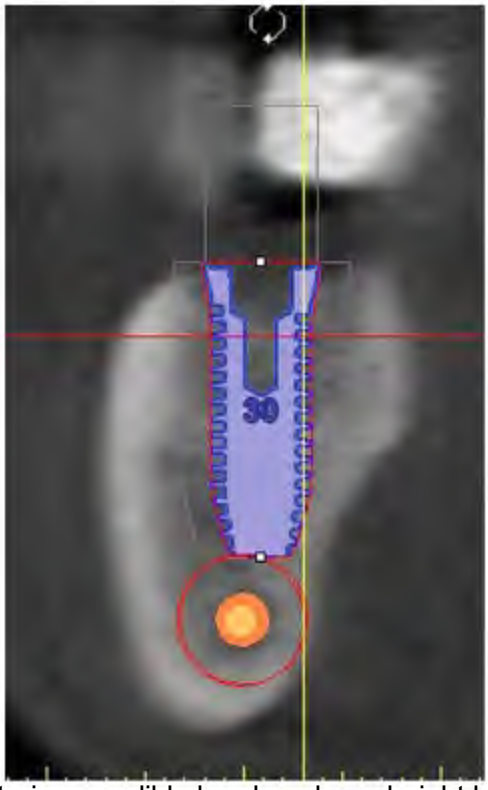

FIG 3.18 The posterior mandible has less bone height because the variable position of the inferior alveolar canal which dictates the size and positioning of the implant.

In the literature, the suggested minimum bone height for predictable long-term endosteal implant survival approaches 12 mm. Failure rates reported in the literature for implants shorter than 9 mm tend to be higher, independent of the manufacturer design, surface characteristic, and type of application.[9,10]

The available bone height in an edentulous site is the most important dimension for implant consideration because it affects both implant length and associated crown height. Crown height space directly affects force factors and esthetics. In addition, bone augmentation is more predictable in width than height, so even when the width is inadequate for implant placement, bone grafting may be used to create a site ideal for restorative and implant insertion requirements.

Available Bone Width.

The width of available bone is measured between the facial and lingual plates at the crest of the potential implant site. The crestal aspect of the residual ridge in the mandible is often cortical in nature and exhibits greater density than the underlying trabecular bone regions. This mechanical advantage permits immediate fixation of the implant, provided this cortical layer has

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not been removed by osteoplasty.

The crest of the edentulous ridge is most often supported by a wider base in the anterior mandible. In most mandibular situations, because of this triangular cross-section, an osteoplasty provides greater width of bone, although of reduced height (Fig. 3.19).

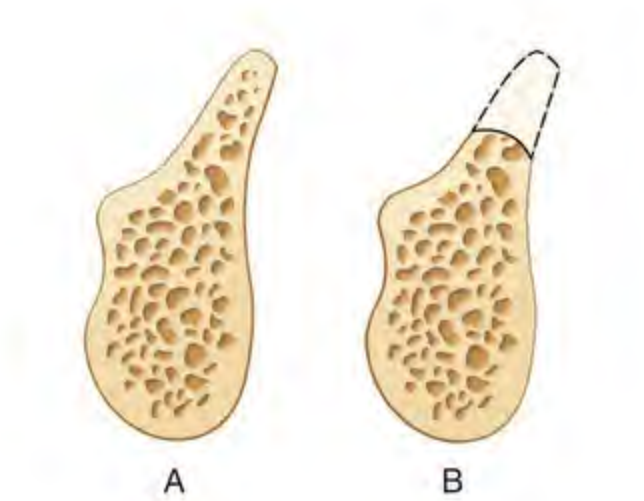

FIG 3.19 (A) The anterior mandible usually has a wider base than the crest of the ridge and often forms a triangular-shaped cross-section. (B) An osteoplasty to the narrow ridge in the anterior mandible increases the width of crestal bone (and reduces the available bone height). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

It should be noted that crest reduction (osteoplasty) affects the location of the opposing landmark, with possible surgical consequences, including implant size selection, implant position, and final prosthesis design. This is particularly important when a FP-1 prosthesis is planned, with the goal of obtaining a normal contour and proper soft tissue drape around a single tooth replacement.

Unlike the anterior mandible, the anterior maxilla often does not follow the triangular anatomy. The palatal plate of bone is more parallel to the facial plate in the maxilla (Fig. 3.20). In addition, many edentulous ridges exhibit a labial concavity in the incisor area, with an hourglass configuration. As a result, osteoplasty does not increase the width of bone as much as in the mandible. As a consequence, bone augmentation for width is more often indicated in the maxilla.

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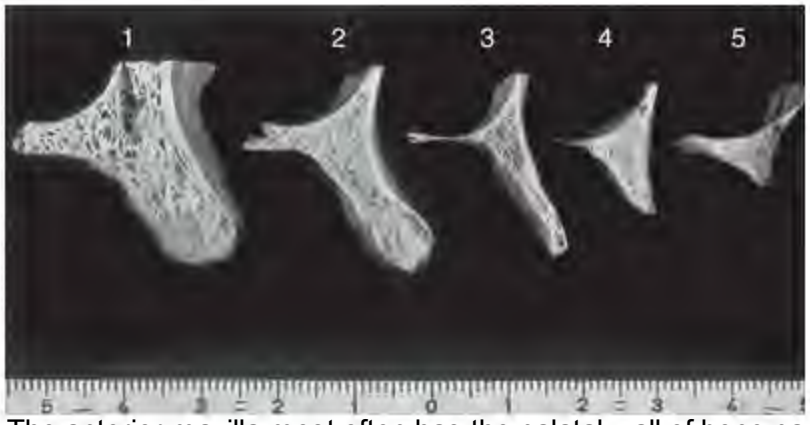

FIG 3.20 The anterior maxilla most often has the palatal wall of bone parallel to the facial cortical plate. Osteoplasty is less effective to increase the bone width. Augmentation procedures are most often warranted. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

After adequate height is available, the next most significant factor affecting the long-term survival of endosteal implants is the width of the available bone. Root form implants with crestal diameters of 4 mm usually require more than 6 mm of bone width to ensure sufficient bone thickness and blood supply around the implant for predictable survival. This dimension provides more than 1 mm of bone on each side of the implant at the crest. Because the bone usually widens apically in the mandible, this minimum dimension rapidly increases. For root form implants, the minimum bone thickness is located in the midfacial and midlingual contours of the crestal region exclusively (Fig. 3.21).

Available Bone Length.

The mesiodistal length of available bone in an edentulous area is often limited by adjacent teeth or implants. As a general rule, the implant should be at least 1.5 to 2.0 mm from an adjacent tooth and 3 mm from an adjacent implant. This dimension not only allows minor surgical error but also compensates for the width of an implant or tooth that acquires a crestal defect, which is usually less than 1.4 mm. As a result, if bone loss occurs at the crest module of an implant or from periodontal disease with a tooth, the vertical bone defect will not spread to a horizontal defect and cause bone loss on the adjacent structure.[11] In the case of a single-tooth replacement, the minimum length of available bone necessary for an endosteal implant depends on the width of the implant. For example, a 5-mm–diameter implant should have at least 8 mm of mesiodistal bone, so 1.5 mm is present on each side of the implant. A minimum mesiodistal length of 7 mm is usually

sufficient for a 4-mm–diameter implant.

The diameter of the implant is also related to the width of available bone and, in multiple adjacent sites, is primarily limited in this dimension. For example, a width of bone of 4.5 mm without augmentation requires a 3.5-mm or smaller implant, with inherent compromises (e.g., less surface area and greater crestal stress concentration under occlusal loads on abutment screw and marginal bone). In narrow ridges, it is often indicated to place two or more adjacent narrow-diameter implants (when possible) to obtain sufficient implant–bone surface area to compensate for the deficiency in width of the implant. Because the implants should be 3 mm apart and 1.5 to 2.0 mm from each tooth, 13 mm or more in available bone mesiodistal length may be required when the narrower implant dimensions are used to replace a posterior tooth.

The ideal implant mesiodistal width for single-tooth replacement is often related to the natural tooth being replaced in the site. The tooth has its greatest width at the interproximal contacts, is narrower at the cementoenamel junction (CEJ), and becomes even narrower at the initial crestal bone contact, which is 2 mm below the CEJ.[12] The ideal implant diameter corresponds to the width of the natural tooth, which may be measured 2 mm below the CEJ of the adjacent tooth. In this way the implant crown emergence (emergence profile) through the soft tissue may be similar to that of a natural tooth. For example, a maxillary first premolar is approximately 8 mm at the interproximal contact, 5 mm at the CEJ, and 4 mm at a point 2 mm below the CEJ. A 4-mm–diameter implant (at the crest module) would be the ideal if it is positioned at least 1.5 mm from the adjacent roots (2 mm below the CEJ).

Available Bone Angulation.

Bone angulation is the fourth determinant for the evaluation of available bone. The alveolar bone angulation represents the natural tooth root trajectory in relation to the occlusal plane. Ideally, this angulation is perpendicular to the plane of occlusion, which is aligned with the forces of occlusion and is parallel to the long axis of the prosthodontic restoration. The incisal and occlusal surfaces of the teeth follow the curve of Wilson and curve of Spee. As such, the roots of the maxillary teeth are angled toward a common point. The mandibular roots flare, so the anatomic crowns are more lingually inclined in the posterior regions and labially inclined in the anterior area compared with the underlying roots. The first premolar cusp tip is

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usually vertical to its root apex.

The maxillary anterior teeth are the only segment in either arch that does not receive a long-axis load to the tooth roots but instead are usually loaded at an approximate 12-degree angle. As such, their root diameter is greater than the mandibular anterior teeth. In all other regions of the mouth, the teeth are loaded perpendicular to the curves of Wilson and Spee.

Rarely does the bone angulation remain ideal after the loss of teeth, especially in the anterior edentulous arch. In this region, labial undercuts and resorption after tooth loss often mandate greater angulation of the implants or correction of the site before insertion (osseous augmentation). For example, in the anterior mandible, the implant insertion often engages the lingual cortical plate, rather than the inferior border of the mandible, as a consequence of the position of the incisal edge and the angulation of bone. In the posterior mandible, the submandibular fossa mandates implant placement with increasing angulation as it distally progresses. Therefore, in the second premolar region the angulation may be 10 degrees to a horizontal plane; in the first molar areas, 15 degrees; and in the second molar region, 20 to 25 degrees.

The limiting factor of angulation of force between the body and the abutment of an implant is the width of bone. In edentulous areas with a wide ridge, wider root form implants may be utilized. Implants may allow up to 30 degrees of divergence with the adjacent implants, natural teeth, or axial forces of occlusion with minimum compromise. However, angled loads to an implant body increases the crestal stresses to the implant components and bone, but the greater-diameter implant decreases the amount of stress transmitted to these structures. In addition, the greater width of bone offers some latitude in angulation at implant placement. The implant body may often be inserted so as to reduce the divergence of the abutments without compromising the permucosal site.

An acceptable bone angulation in the wider ridge may be as much as 30 degrees. The narrow yet adequate width ridge often requires a narrower design root form implant. Compared with larger diameters, smaller-diameter designs result in greater crestal stress to the system (abutment screws, crestal bone) and may not offer the same range of custom abutments. In addition, the narrower width of bone does not permit as much latitude in placement regarding angulation within the bone. This limits the acceptable angulation of bone in the narrow ridge to 20 degrees from the axis of the adjacent clinical crowns or a line perpendicular to the occlusal plane (Fig.

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3.22).

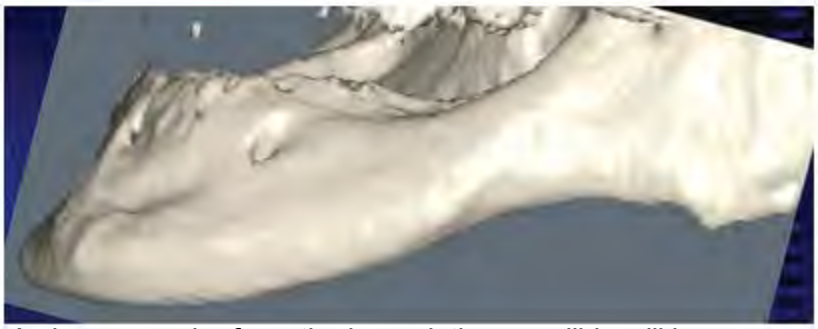

FIG 3.22 As bone resorbs from the buccal, the mandible will become more angled toward the lingual, resulting in an angulation complication for implant placement.

Crown Height Space.

The crown height space (CHS) is defined as the vertical distance from the crest of the ridge to the occlusal plane. It affects the appearance of the final prosthesis and may affect the amount of movement force on the implant and surrounding crestal bone during occlusal loading. Esthetically, the prosthesis is less likely to replace the sole anatomic crowns of natural teeth when a greater CHS is present.

The CHS may be considered a vertical cantilever. Any direction of load that is not in the long axis of the implant will magnify the crestal stresses to the implant-bone interface and to the abutment screws in the restoration. The greater the CHS, the greater the moment force or lever arm with any lateral force or cantilever (Fig. 3.23).

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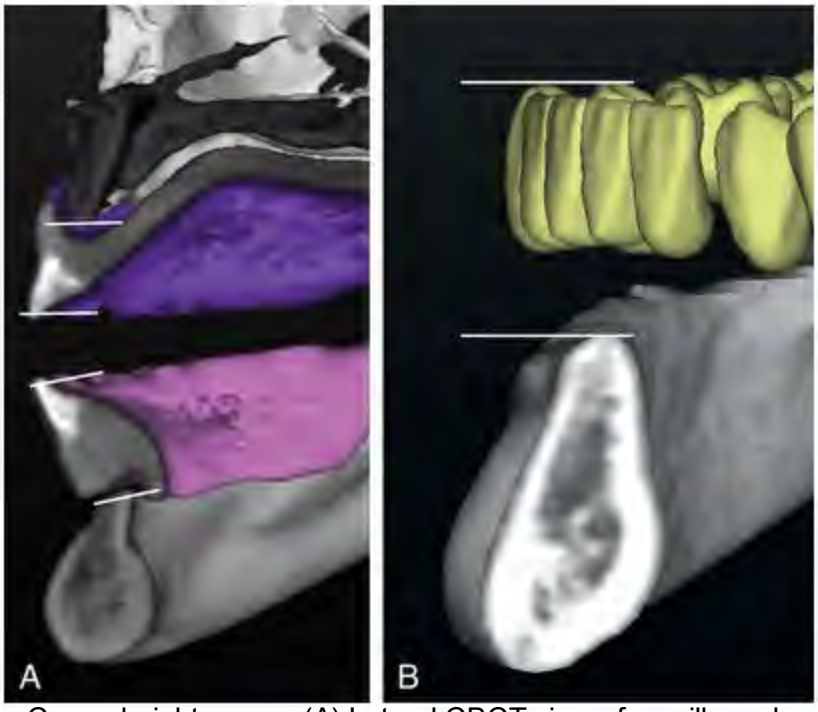

FIG 3.23 Crown height space. (A) Lateral CBCT view of maxilla and mandibular edentulous areas in relation to the incisal edge. The incisal edge does not change position; however, as bone loss advances, the CHS increases leading to greater potential for force-related complications. (B) Ideal crown height space varies with respect to the intended prosthesis (i.e., FP-3, RP-4, RP-5).

The absence of a periimplant ligament means that the bone-implant stresses cannot be reduced by increasing the implant height. Therefore, as the CHS increases and a cantilever or a lateral load is planned on the restoration, a greater number of implants or wider implants should be inserted to counteract the increase in stress. For an ideal treatment plan, the CHS should be equal to or less than 15 mm under ideal conditions.

Not Understanding the Divisions of Bone: Division A (Abundant Bone)

The Division A edentulous ridge exhibits abundant bone in all dimensions of height, width, and length. Division A root form implants are optimal and most often used as independent support for a fixed or removable prosthesis. Division A bone is the ideal type of bone to provide a natural looking FP-1 prosthesis.

Criteria Division.

Division A bone corresponds to abundant available bone in all dimensions; the height of 12 mm or more, width of >6 mm, angulation <30 mm, and crown

height space of <15 mm. Osteoplasty may often be performed to obtain additional bone width in the mandible when a larger diameter implant is desired. In rare instances, an angle abutment will be required; however, the direction of load is not excessive (Box 3.1).

Box 3.1

Division A Bone Dimensions

Width >6 mm

Height >12 mm

Mesiodistal length >7 mm

Angulation of occlusal load (between occlusal plane and implant body) <30 degrees

Crown height space ≤15 mm

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Surgical Treatment.

The implant choice in Division A bone is a Division A root form that is 4 mm or greater in diameter and 12 mm or longer in height (length). A larger-diameter implant is suggested in the molar regions (5 to 6 mm in diameter). Longer implants are suggested in immediate loading treatment options or when an implant is immediately inserted after the extraction of the tooth. As a general rule, Division A bone should not be treated with smaller-diameter implants for the final prosthesis, unless dictated by the specific tooth replacement (e.g., maxillary lateral incisors or mandibular incisors) (Fig. 3.24). There are several advantages to the use of implants equal to or greater than 4 mm in diameter compared with smaller-diameter implants (Box 3.2).

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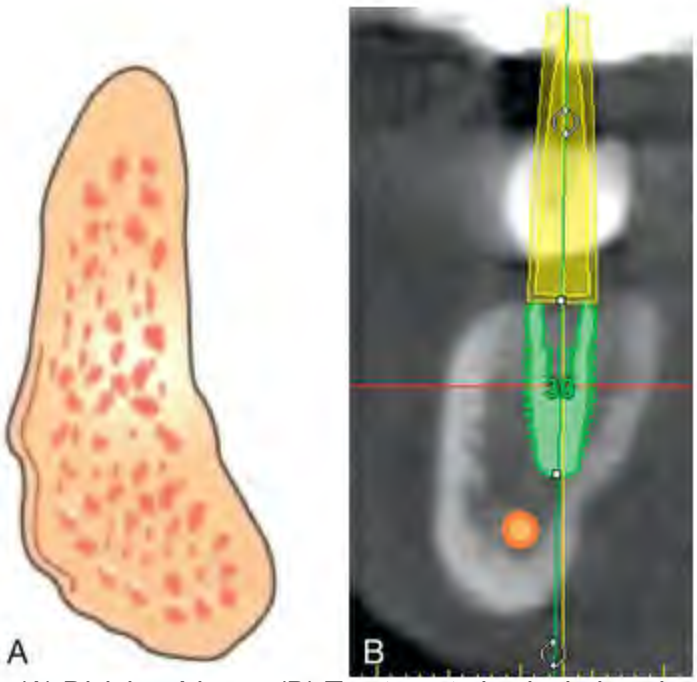

FIG 3.24 (A) Division A bone. (B) Treatment plan includes placement of conventional size implant.

Box 3.2

Division A Root Form Implant Advantages

- The larger the diameter of an implant, the greater the surface area and the less stress distributed through the crestal bone region.
- The larger-diameter implants are closer to the lateral cortical plates of bone, which have greater density and increased strength, modulus of elasticity, and bone-implant contact percentages.
- The larger-diameter implants are less likely to fracture because the strength of the material is increased by a power of four related to the radius of the implant (e.g., a 4-mm-diameter implant is 16 times stronger than a 2-mm-diameter implant).
- The smaller-diameter implants are often one-piece implants to decrease the risk of fracture.
- The one-piece implants require an immediate restoration rather than a submerged or one-stage approach. As such, micromovement may occur at

the bone-implant interface, with an increased risk of crestal bone loss and implant failure.

- The emergence profile angle of the crown is related to the implant diameter. The larger-diameter teeth can be most esthetically restored with a wider-diameter implant.
- The larger the implant diameter, the less stress applied to the abutment screw, and complications such as screw loosening or fracture are less likely.
- The larger-diameter abutment provides greater cement retention for the final restoration crown.
- Oral hygiene procedures are more compromised around smaller-diameter implants restored with greater emergence profile angles and over contoured restorations.
- The crest module and crestal portion of many two-piece, smaller-diameter implants are smooth metal to increase the interbody wall thickness, thus creating shear loads to the crestal bone and an increased risk of bone loss.
- Implant costs to the patient are related to implant number, not diameter. Increases in implant numbers for smaller-diameter implants increase the cost to the patient (and clinician).
- Division A root form implants can provide the greatest range of prosthetic options.

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prosthetic Treatment

Fixed.

FP-1 restorations require a Division A ridge. However, a FP-2 prosthesis most often also requires a Division A bone. A FP-2 restoration is the most common posterior restoration supported by multiple adjacent implants in partially edentulous patients because of either bone loss or osteoplasty prior to implant placement. A FP-3 prosthesis is most often the option selected in the anterior Division A bone when multiple adjacent teeth are missing and the

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maxillary smiling lip position is high, or a mandibular low lip line during speech exposes regions beyond the natural anatomical crown position.

Removable.

For removable implant overdentures in Division A bone, the final position of the tooth and superstructure bar must be evaluated before surgery. A limited CHS is more common in Division A bone, and an RP-4 or RP-5 restoration may require osteoplasty before implant placement. Division A bone may represent a contraindication for high-profile O-ring attachments or superstructures placed several millimeters above the tissue. This may result in difficulty in prosthesis fabrication, esthetics, hygiene, adequate strength of the prosthesis.

Complications.

Complications with Division A bone are minimal. The most common complication is not assessing the crown height space, which may impinge on the prosthetic rehabilitation. Many clinicians fail to educate the patient about the rapid decrease in bone volume width and the consequences of delaying treatment. When the bone volume is Division A, there is a decrease in treatment costs, with a reduction in the number and complexity of surgeries to the edentulous area (Fig. 3.25).

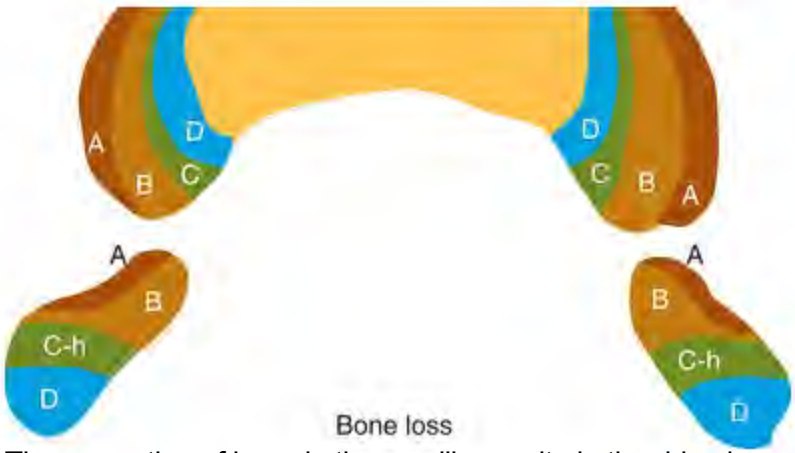

FIG 3.25 The resorption of bone in the maxilla results in the ridge becoming more narrow because it resorbs toward the midline. The initial mandibular bone loss also resorbs toward the midline. However, moderate to severe bone loss conditions result when the mandible is wider than the original mandibular crest. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

Not Understanding the Divisions of Bone: Division B (Barely Sufficient Bone)

The decreased width and surface area usually require additional implants to be included in the final prosthesis design. Division B may be changed to Division A by augmentation or osteoplasty. The treatment options may be selected in light of the area to be treated. For example, in the anterior maxilla, augmentation is most often selected because of esthetics. In the anterior mandible, osteoplasty is common because of the available bone height and low esthetic concerns. In the posterior mandible, multiple Division B implants may be used when the bone density is favorable, the available bone height is limited, and esthetics are not a primary factor. When stress factors are a concern, bone augmentation precedes Division B root form implants regardless of the anatomic location (Box 3.3).

Box 3.3

Division B Dimensions

2.5–6 mm wide

B+: 4–6 mm

B−w: 2.5–4 mm

Height >12 mm

Mesiodistal length >6 mm

Angulation <20 degrees

Crown height space <15 mm

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

As the bone resorbs, the width of available bone first decreases at the expense of the facial cortical plate because the cortical bone is thicker on the lingual aspect of the alveolar bone, especially in the anterior regions of the jaws. This may result in a 25% decrease in bone width the first year and a 40% decrease in bone width within the first 1 to 3 years after tooth

extraction.[13] The resulting narrower ridge is often inadequate for most 4-mm-diameter root form implants (Box 3.4).

Box 3.4

Disadvantages of Division B Root Forms

1. Almost twice the stress is concentrated at the top crestal region around the implant.

2. Reduced overall surface area results in increased lateral loads causing three times greater stress on the implant in comparison to Division A root form implants. This means the lateral loads on the implant are tripled.

3. Fatigue fractures of the implant, abutment, and abutment screw post are increased, especially under lateral loads.

- The crown emergence profile is less esthetic (except for maxillary lateral or mandibular incisors).

4. Periodontal conditions for daily care are compromised around the cervical aspect of the crown.

5. The implant design is most often poor in the crestal region. To increase implant body wall thickness and to reduce fracture, no threads or compressive force design are present; however, this further increases stress and the amount of shear loads to bone.

6. The angle of load must be reduced to less than 20 degrees to compensate for the small diameter biomechanical disadvantage.

7. Two implants are often required for proper prosthetic support unless anterior single-tooth replacement for maxillary laterals or mandibular incisors, thus surface area will be greater because of implant number, not diameter.

8. Implant costs are not related to diameter, so an increase in implant number results in greater cost to the doctor and patient.

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Complications

Division B root forms.

Division B bone offers sufficient available bone height with compromised bone width. The Division B available bone width may be further classified into ridges 4 to 6 mm wide and B minus width (B–w) 2.5 to 4 mm wide, where bone grafting is indicated most likely (Fig. 3.26). Because the ridge width and implant diameter are narrower, and forces increase as the angle of load increases, the angulation of occlusal load is also less and should be ideally within 20 degrees from the axis of the adjacent teeth or occlusal plane. A CHS of 15 mm or less (similar to Division A) is necessary in Division B to decrease the moment of forces with lateral or offset loads, especially because of the smaller width dimension.

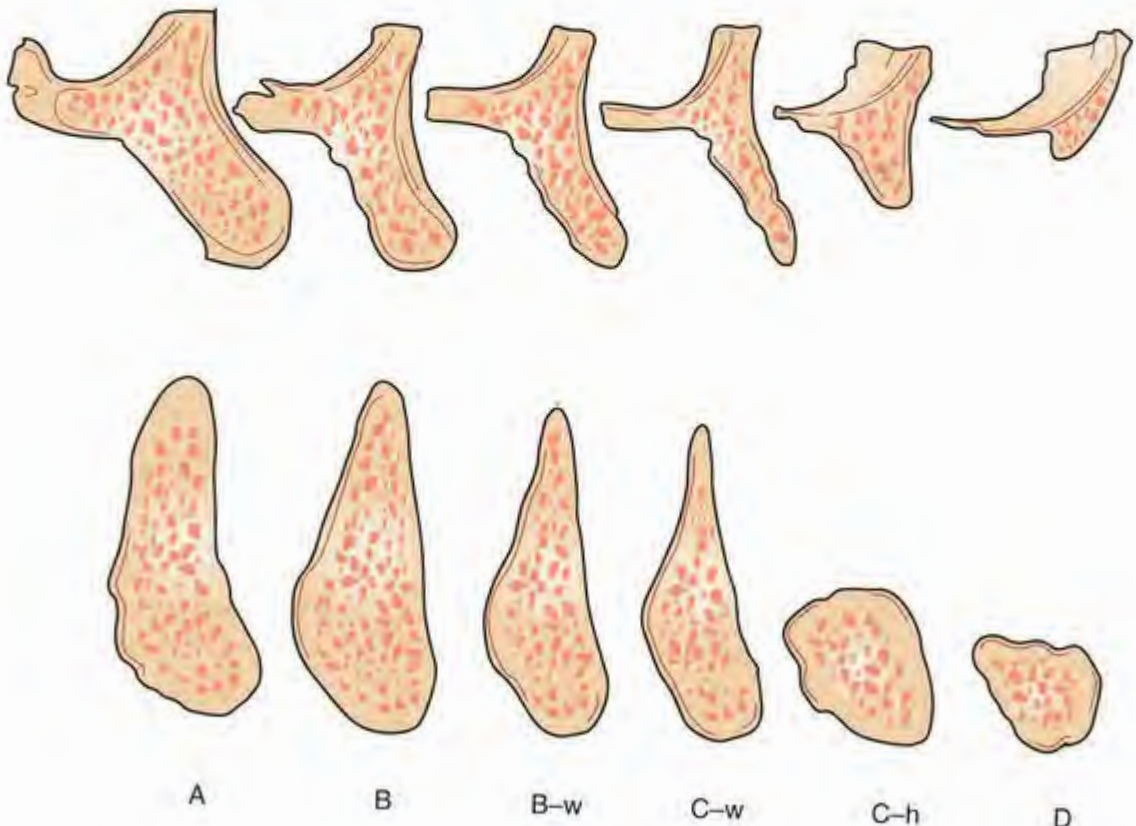

FIG 3.26 In 1985 Misch and Judy presented a classification of available bone (Divisions A, B, C, D), which is similar in both arches. Implant, bone-grafting methods, and prosthodontic-related treatment was suggested for each category of bone. *A,* Abundant; *B,* barely sufficient; *C,* compromised; *D,* deficient; *h,* inadequate height; *w,* inadequate width. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Not understanding the need for modification.

Three treatment options are available for the Division B edentulous ridge:

1. Modify the existing Division B ridge to Division A by osteoplasty to permit the placement of root form implants 4 mm or greater in width. When more than 12 mm of bone height remains after osteoplasty, the Division B bone is converted to Division A. When less than 12 mm of bone height remains after osteoplasty, a biomechanical disadvantage results due to the ridge being changed to a Division C–h (Fig. 3.27).

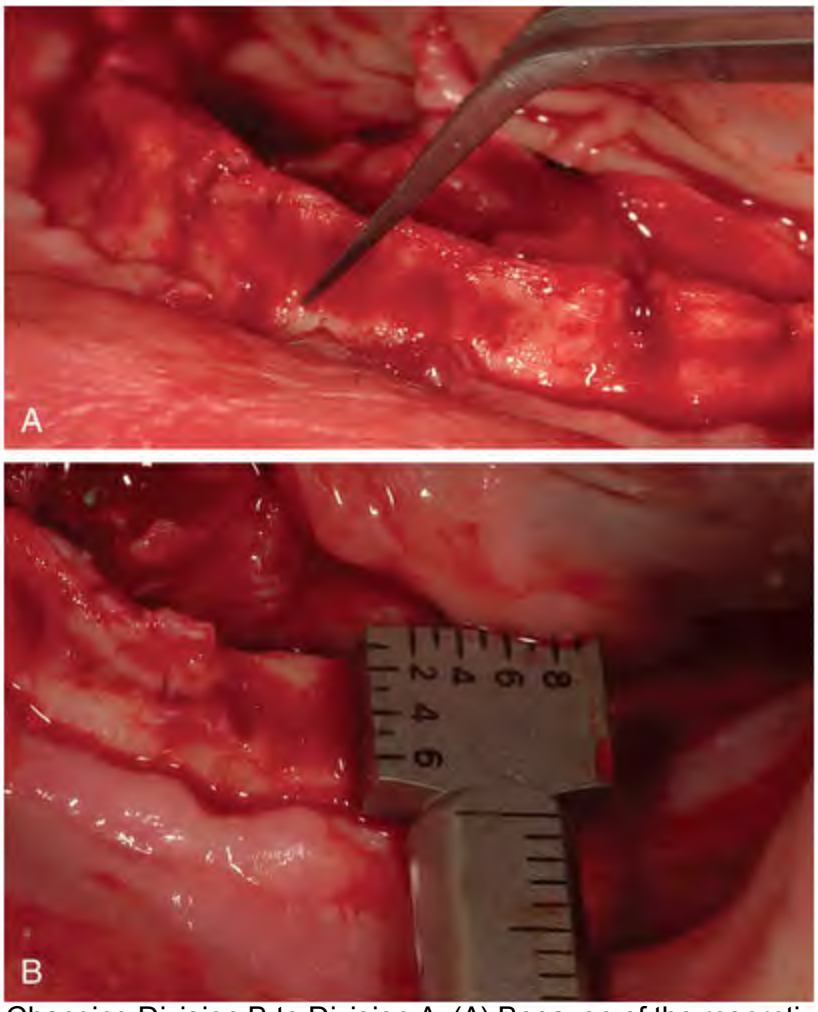

FIG 3.27 Changing Division B to Division A. (A) Because of the resorptive process, compromise in width occurs rather quickly. (B) Conversion to Division A via osteoplasty in the anterior mandible acquiring a minimum of 6 mm of width for placement of a 4 mm diameter implant.

2. The second treatment option is the placement of a narrow diameter

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implant (3–4 mm diameter and 12 mm or more in length; Fig. 3.28). Smaller-diameter root form implants (3.0–3.5 mm) are designed primarily for Division B available bone. Because Division B bone is compromised in width, there exists less margin of error in the ideal placement. The Division B root form implants present several inherent disadvantages compared with the larger-diameter implants.[14] As a result of these concerns for the Division B root form, this option is most often used for single-tooth replacement of a maxillary lateral incisor or mandibular incisors, where the restricted available bone is in mesiodistal width, or with multiple implants in the posterior mandible, where bone density is good and esthetic requirements are limited.

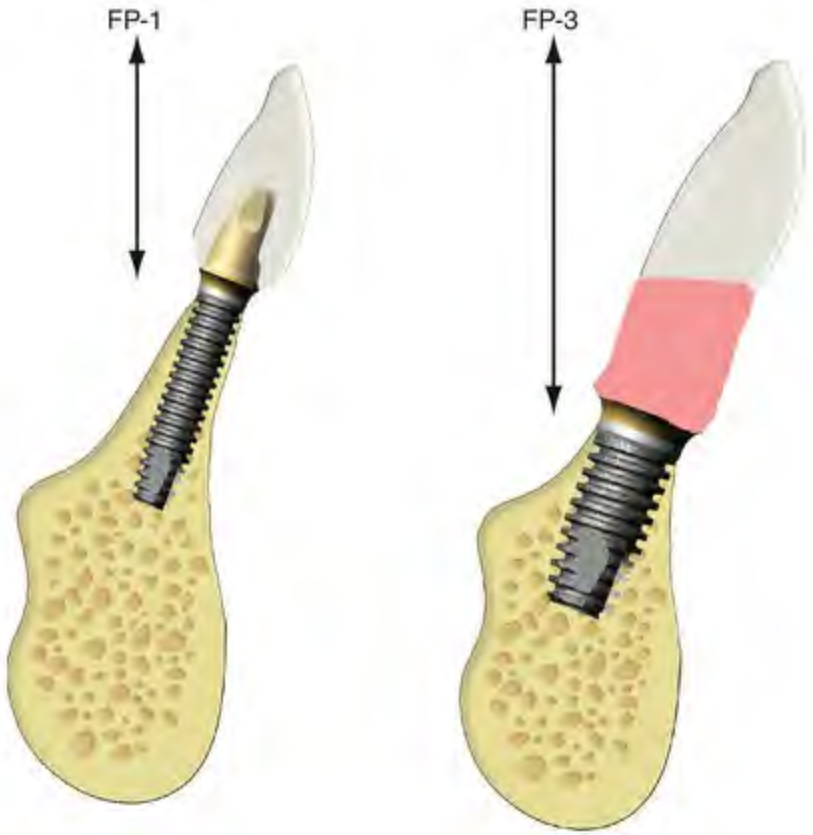

FIG 3.28 Options to treat a Division B ridge in the anterior mandible include a narrow implant with a final prosthesis closer to anatomic dimensions (FP-1) *(left)*, or osteoplasty with Division A root forms and extended crown heights (FP-2 or FP-3) *(right)*. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

3. The third alternative treatment for Division B bone is to change the Division B ridge into a Division A by grafting the edentulous ridge with autogenous bone or allogenic bone (Fig. 3.29). A disadvantage of this

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treatment plan includes the need for adequate bone healing. The emergence profile angle of the final crown, which does not compromise hygiene, requires a Division A root form implant (with the exception of maxillary lateral incisors or mandibular incisors). Stress factors may also dictate the augmentation approach to Division B bone in order to utilize larger-diameter implants. In the presence of unfavorable stress factors, the number and width of abutments should be increased without increasing the CHS to provide a greater surface area of resistance to the magnified forces, which most likely will require augmentation. To accomplish this goal, augmentation is most ideal in Division B bone.

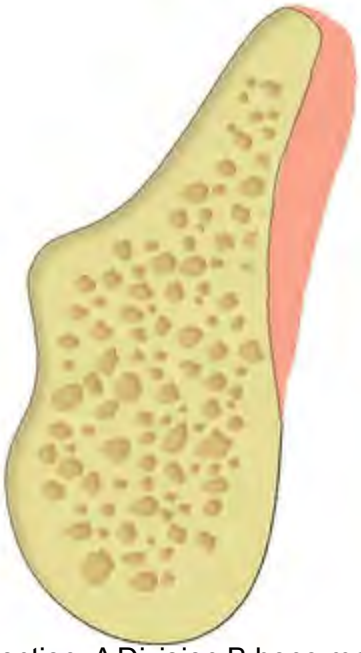

FIG 3.29 Ideal Division B option. A Division B bone may be modified to Division A by doing a bone augmentation. This treatment option is most often required for a FP-1 prosthesis. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

Modification from Division B to Division A may lead to a change in prosthesis.

When a Division B ridge is changed to a Division A by osteoplasty procedures, the final prosthesis design has to compensate for the increased CHS. For example, before surgery, the available bone height may be compatible with an FP-1 prosthetic design. If, at the time of surgery, the ridge is found deficient in width for implant placement, it is not unusual to remove crestal bone before reaching a Division A width. This means the final

restoration will require an additional height. It may result in an extended tooth (FP-2, FP-3) restoration, which may not be acceptable to the patient.

Insufficient osteoplasty.

The most common approach to modify the narrower Division B ridge into another bone division by osteoplasty is when the final restoration is a mandibular implant overdenture. Because of the resorptive process that occurs in the anterior mandible, an osteoplasty is usually indicated to allow for adequate bone width if the CHS is less than 15 mm; this maybe be advantageous for a fixed prosthesis and problematic for a removable prosthesis. When a RP-4 or RP-5 is planned, care should be noted to make sure adequate CHS is available. If insufficiency osteoplasty is performed, lack of space will be available for the prosthesis, which may lead to prosthesis fracture, tooth fracture, or tooth delamination. Ideally, greater than 2 mm of acrylic is required to secure an attachment or a denture tooth (Fig. 3.30).

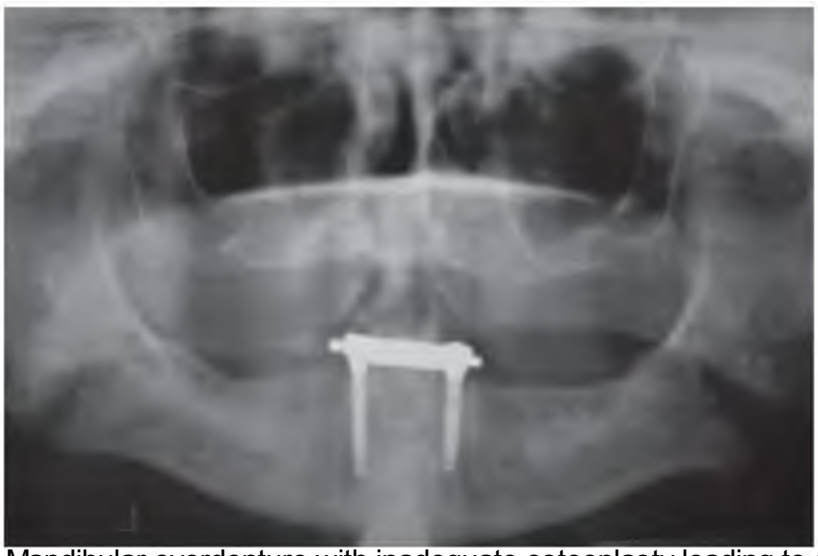

FIG 3.30 Mandibular overdenture with inadequate osteoplasty leading to decreased crown height space.

Not Understanding the Divisions of Bone: Division B–w (B Minus Width)

The distinction between Division B and Division B–w is especially important when augmentation is the method of choice. Bone augmentation is more predictable when the volume to augment is minimal and is for width and

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least predictable when additional bone height is desired. For example, a width increase of 1 to 2 mm may be obtained with an alloplast and guided bone regeneration, but more than 2 mm of width is more predictable with autologous bone as part of the graft.

Complications

More bone augmentation required.

The Division B–w ridge will usually require more than 2 mm of width increase, and therefore autologous bone or an autologous/allogenic graft is beneficial to predictably grow the additional bone width. If the Division B–w ridge contour requires alteration altered for improved prosthodontic relationships, an onlay particulate or block graft of autogenous bone is indicated. The autograft may be harvested from an intraoral region (e.g., the mandibular symphysis or ramus) and placed along the lateral aspect of the ridge that corresponds to ideal arch form. The implant placement is usually delayed for 4 to 6 months after the augmentation process to permit ideal implant placement and to ensure complete bone formation before placing the implant.

Bone resorption progression.

The patient delaying treatment with a Division B bone situation should be informed of the future bone volume resorption that presents from disuse atrophy. The augmentation of bone in height is much less predictable and requires more advanced techniques than augmentation of bone width alone (Fig. 3.31). For example, the patient may not be experiencing problems with a maxillary denture, but the Division B bone will resorb in height and decrease the stability and retention of the removable soft tissue–supported prosthesis. When treatment is delayed until patient problems begin, the overall result may be more difficult to achieve and more costly to the patient.

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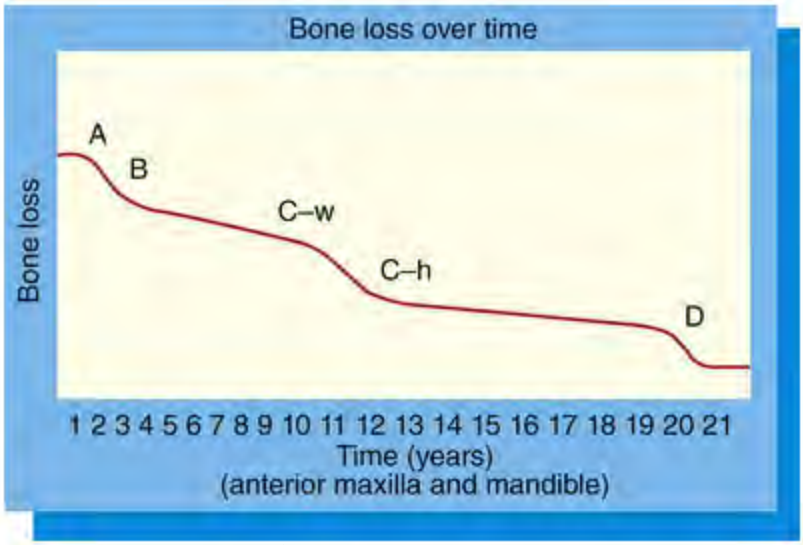

FIG 3.31 Bone rapidly resorbs from Division A to Division B then plateaus for many years before it is Division C–w. From Division C–w to C–h, it resorbs rapidly. Long plateaus are found for both Division B and Division C–h. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Final prosthesis.

The final prosthesis type for Division B ridges is dependent on the surgical option selected. Whereas grafted ridges will more often be used when a fixed prosthesis is desired, ridges treated with osteoplasty before implant placement are likely to be supporting removable prostheses. The treatment option may be influenced by the region to be restored. For example, in a partially edentulous anterior maxilla, augmentation is most often selected because of esthetics, and the parallel bony anatomy of the residual ridge is not conducive for osteoplasty to gain bone width. In the edentulous anterior mandible, osteoplasty is common. In the premolar region of the posterior mandible, Division B root form implants are often used because the bone density is adequate, available bone height is limited and may be reduced after osteoplasty, and esthetics are often not a major factor.

Not Understanding the Divisions of Bone: Division C (Compromised Bone)

The Division C edentulous ridge exhibits moderate resorption and presents more limiting factors for predictable endosteal implant placement. The decision to restore with endosteal implants or to change to a more favorable bone division via augmentation before implant placement is influenced by the prosthesis, patient force factors, and patient's desires.

The Division C ridge is deficient in one or more dimensions (width, length, height, or angulation) (Box 3.5) regardless of the position of the implant body into the edentulous site. The resorption pattern of bone occurs first in width and then in height. As a result, the Division C ridge continues to resorb in width, until it becomes inadequate for any design of endosteal implant.

Box 3.5

Division C Bone

Width (C–w bone): 0–2.5 mm

Height (C–h bone) <12 mm

Angulation of occlusal load (C–a bone) >30 degrees

Crown height space >15 mm

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Division C–w

The Division C-w is significantly compromised in width, and usually requires augmentation (facial and lingual) or osteoplasty to convert the ridge to C–h (adequate height). On occasion, the C–w ridge may be treated by osteoplasty in the anterior mandible, which converts the ridge to C–h and, in the anterior mandibular region, most often to a width suitable for root form implants. The most common available bone division after osteoplasty of C–w is C–h available bone, not Division A, because the CHS is greater than 15 mm. On occasion, the C–w osteoplasty may convert the ridge to Division D, especially in the posterior mandible or maxilla, which most likely contraindicates implant placement. Care should be exercised to prevent this from occurring because bone grafting procedures will be more challenging after the height has been reduced.

After the C–h ridge is augmented, it is treated with the options available in the acquired bone division. A patient who desires a fixed prosthesis often requires an autogenous graft before implant placement to acquire proper lip support and ideal crown height.

Augmentation of C–w is most often used when prosthetic guidelines

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require a fixed restoration or excess force factors require greater surface area implants and improved biomechanics for the prosthesis (Fig. 3.32).

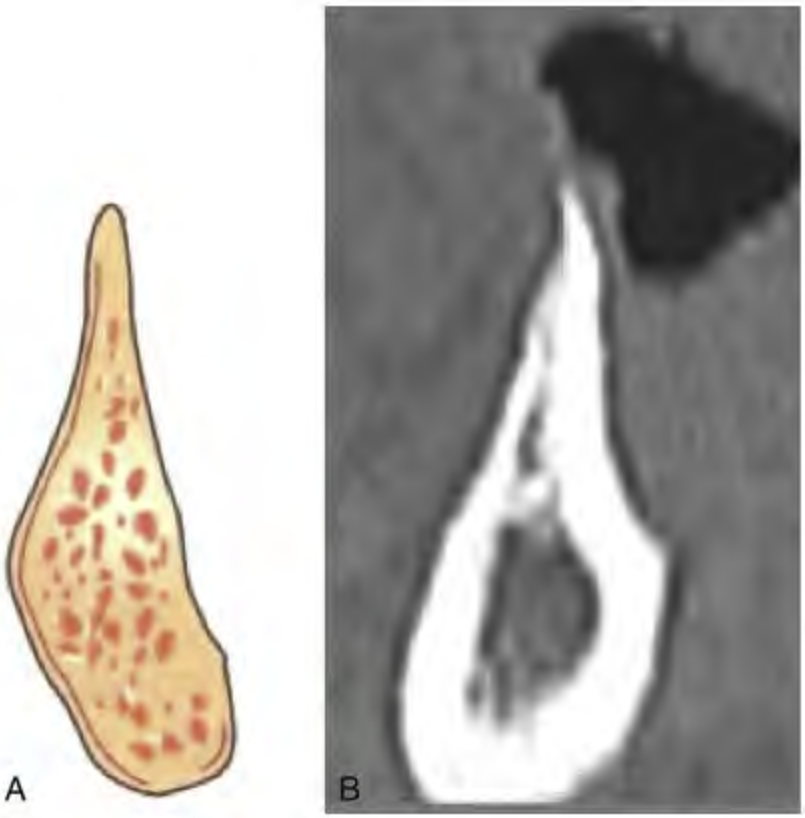

FIG 3.32 (A) and (B) Division C–w.

Complications of C–w

More difficult surgery.

The C–w augmentation is more difficult than for Division B bone because the need for bone volume is greater, yet the recipient bed is more deficient. Because less host bone is present, more difficulty in using fixation screws results. Additionally, there exists a decreased blood supply, which may compromise healing. Usually, block bone grafts are indicated with the use of bone graft factors. Soft tissue complications, such as incision line opening, are also more common in C–w augmentations than Division B because of compromised attached tissue (Fig. 3.33).

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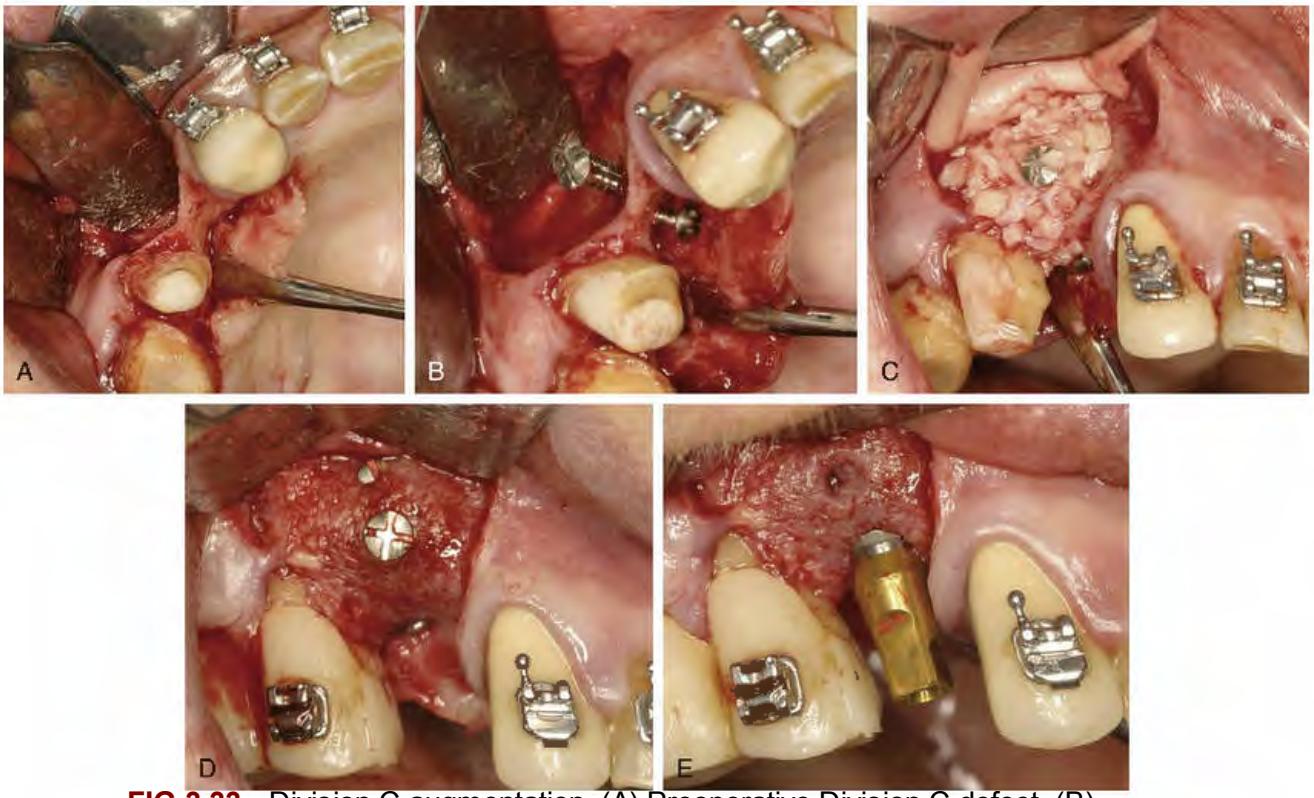

FIG 3.33 Division C augmentation. (A) Preoperative Division C defect. (B) Recipient site preparation. (C) Augmentation. (D) Five-month postoperative depicting bone growth on the buccal and lingual. (E) Ideal implant placement.

Fast resorption.

The clinician must be aware that the C–w bone will resorb to a C–h ridge as fast as A resorbs to B and faster than B resorbs to C–w. In addition, without implant or bone graft intervention, the C–h available bone will eventually evolve into Division D (severe atrophy). Care should be noted to prevent excessive force or pressure on the ridge via a removable prosthesis.

Division C-h

The Division C-h bone exhibits moderate to advanced atrophy vertical height of bone of 7 to 9 mm, or the crown height space of greater than 15 mm. Moderate to advanced atrophy may be used to describe the clinical conditions of Division C. The posterior maxilla and mandible are common areas for Division C–h bone. This is due to vital structures such as the maxillary sinus or mandibular canal, which limits vertical height sooner than the opposing cortical plates in the anterior regions.

The Division C edentulous ridge does not offer as many elements for predictable endosteal implant or prosthesis success as in Divisions A or B.

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Anatomic landmarks to determine implant angulations or positions in relation to the incisal edge are usually not present, and greater surgical skill is required. The clinician must realize that Division C ridge implant–supported prostheses are more complex and have slightly more complications in healing, prosthetic design, or long-term maintenance. On the other hand, the patients will usually have greater need for increased prosthodontic support. Despite the reduced bone volume, modifications of the treatment plan and prosthesis that decrease stress can provide predictable, long-term treatment (Fig. 3.34).

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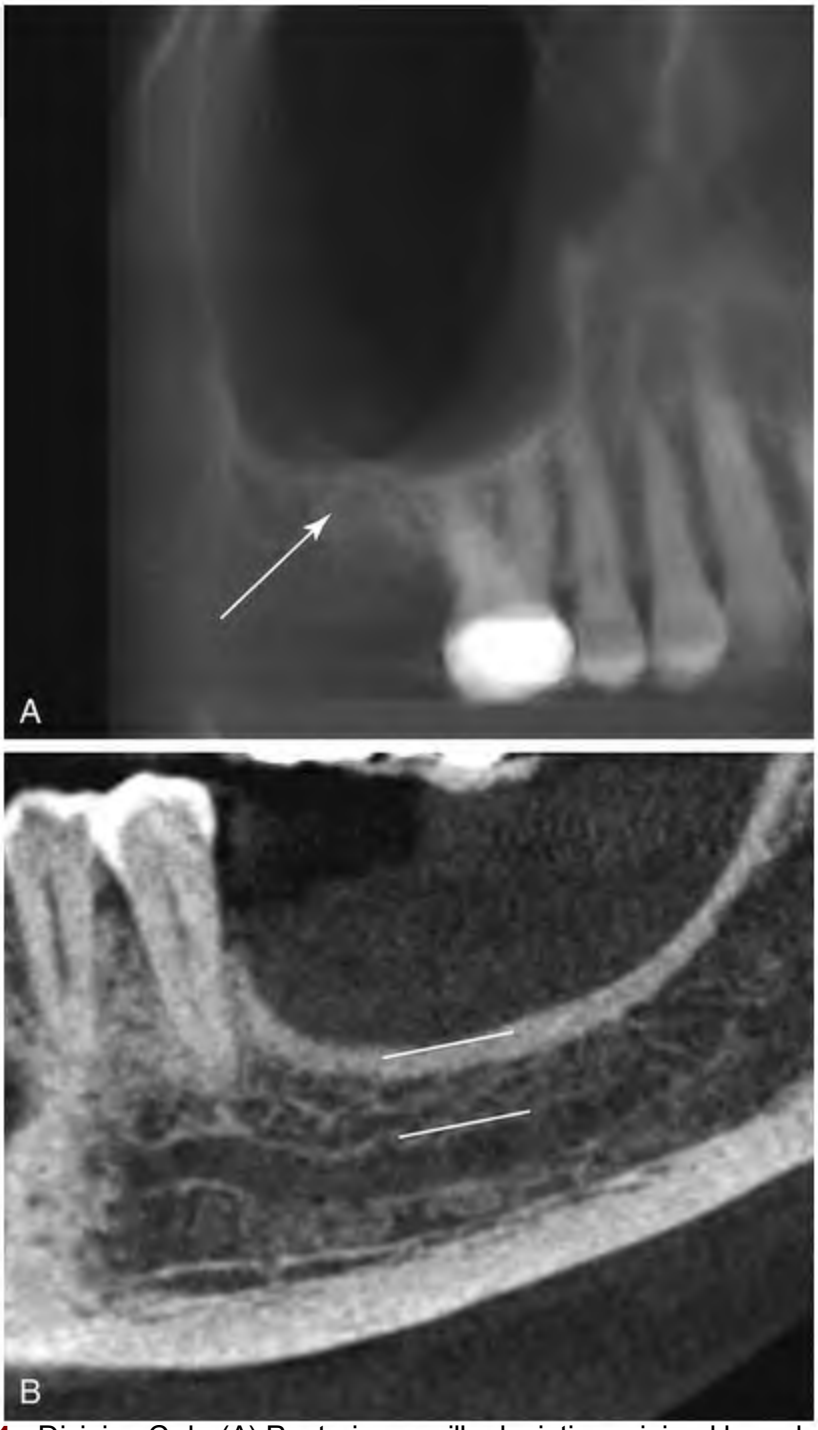

FIG 3.34 Division C–h. (A) Posterior maxilla depicting minimal bone below the sinus. (B) Posterior mandible, premolar area depicting minimal bone above the mandibular canal.

Complications C–h

Mandible-floor of mouth.

When the anterior mandible is C–h, the floor of the mouth is often level with

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the residual mandibular crest of the ridge, which present many potential complications. Additionally, less attached tissue is present, which may cause chronic tissue-related issues. During swallowing, it may prolapse over the residual crest and implant sites, causing constant irritation of the permucosal implant posts and impairing proper design of the prosthetic superstructures.

Short implants.

In C–h ridges, a common treatment option is the use of short implants. A C –h root form implant is usually 4 mm or greater in width at the crest module and 10 mm or less in height. Several studies indicate that implant survival is decreased when an implant is less than 10 mm in height. For example, a large multi-center study of 31 different sites and six different implant designs observed 13% failure with 10-mm implants, 18% failure with 8-mm implants, and 25% failure with 7-mm implants.[15] The implant failure did not occur after surgery but rather after prosthetic delivery. The loading failure is most likely due to an inadequate implant support combined with a magnification of force resulting from excessive CHS.

When endosteal root form implants are used in Division C–h bone with greater crown heights, additional implants should be placed to increase the overall implant-bone surface area, and the prosthesis should load the implants in an axial direction. Additionally, a narrow occlusal table is indicated to decrease force-related complications. Because the CHS is most likely greater than 15 mm, the design of a removable prosthesis should often reduce or eliminate cantilever length and incorporate a stress relief mechanism. Reduced long-term predictability is usually expected if additional implants or less stressful prostheses are not used because a greater moment force is transmitted to the implants and/or prosthesis.

Posterior maxilla: implant placement without sinus graft.

In addition to the residual alveolar bone resorption, the maxillary sinus expands after tooth loss (pneumatization). As a result, the available bone height is decreased from both the crestal and apical regions. Placing implants in the posterior maxilla predisposes the patient to increased morbidity and possible displacement of the implant into the maxillary sinus. Sinus grafting is often prescribed before placing endosteal implants in the C –h posterior maxilla.

Posterior mandible: vertical bone grafting.

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In adequate available bone, height is often found in the posterior mandible because of residual bone loss and the position of the mandibular nerve (i.e., especially with type 1 nerve position). Additionally, muscle pull from the buccinator muscles along with compromised interocclusal space make this area one of the most difficult to restore with dental implant prostheses.

Fixed prosthesis: excessive crown height space.

A fixed restoration in the Division C–h mandible may require both anterior and posterior implant support when force factors are greater than usual. The fixed prosthesis in Division C–h bone with greater than 15 mm CHS is most often a hybrid device, with denture teeth attached to a precious metal substructure with acrylic resin. In this way, the complications and costs of a porcelain-metal fixed restoration may be reduced and repair is easier. Additionally, fixed prosthesis with excessive CHS tend to be much heavier, which leads to common patient complaints.

Biomechanical disadvantages.

In general, Division C–h presents less favorable biomechanical factors to the implant support. Additional implants, cross-arch stabilization, soft tissue support, or an opposing removable prosthesis, often need to be considered in the prosthetic design to improve the long-term prognosis. The treatment of Division C–h ridges require greater clinician experience and training because the surgical and prosthetic principals are much different than Division A and B.

Division C–a

In the Division C–a category, available bone is adequate in height and width, but angulation is greater than 30 degrees. Mraiwa et al found that 28% of edentulous anterior mandibles had an angulation of 67.6 ± 6.5 degrees.[16] This condition is not uncommon and should be evaluated prior to any treatment. When present, this excessive angulation condition is most often found in the anterior mandible. Root form implants placed in this bone category may have the abutments positioned within the floor of the mouth and compromise prosthetic reconstruction, speech, and comfort. Other less observed regions for Division C–a include the maxilla with severe facial undercut regions or the mandibular second molar with a severe lingual undercut (Fig. 3.35).

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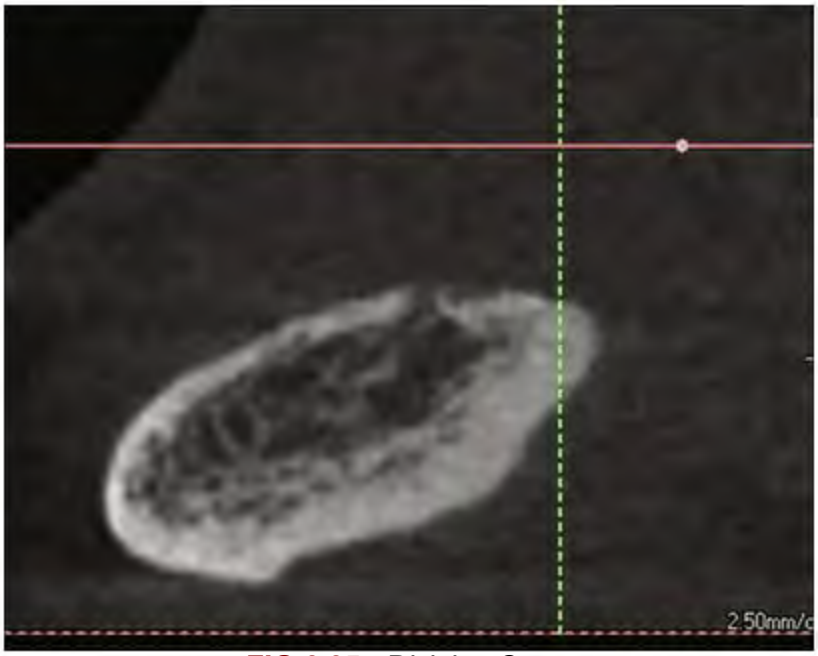

FIG 3.35 Division C–a.

Complications C–a

Malpositioned lingually.

When the anterior bone angulation is unfavorable, root form implants may be positioned too far lingually for prosthodontic support, speech, or hygiene. The patient will often complain of lack of tongue space and chronic tissue inflammation and soreness.

Perforate lingual plate.

Another complication related to the Division C–a is placement of implants that perforate the bony plates. The Division C–a anterior mandible is angled more than 30 degrees. If the clinician is unaware of this angulation, the implants may perforate the lingual plate and irritate the tissues of the floor of the mouth or cause significant bleeding episodes. If the clincian places the implants within the bone, they may enter the crest of the ridge at the floor of the mouth and make it almost impossible to restore (Fig. 3.36).

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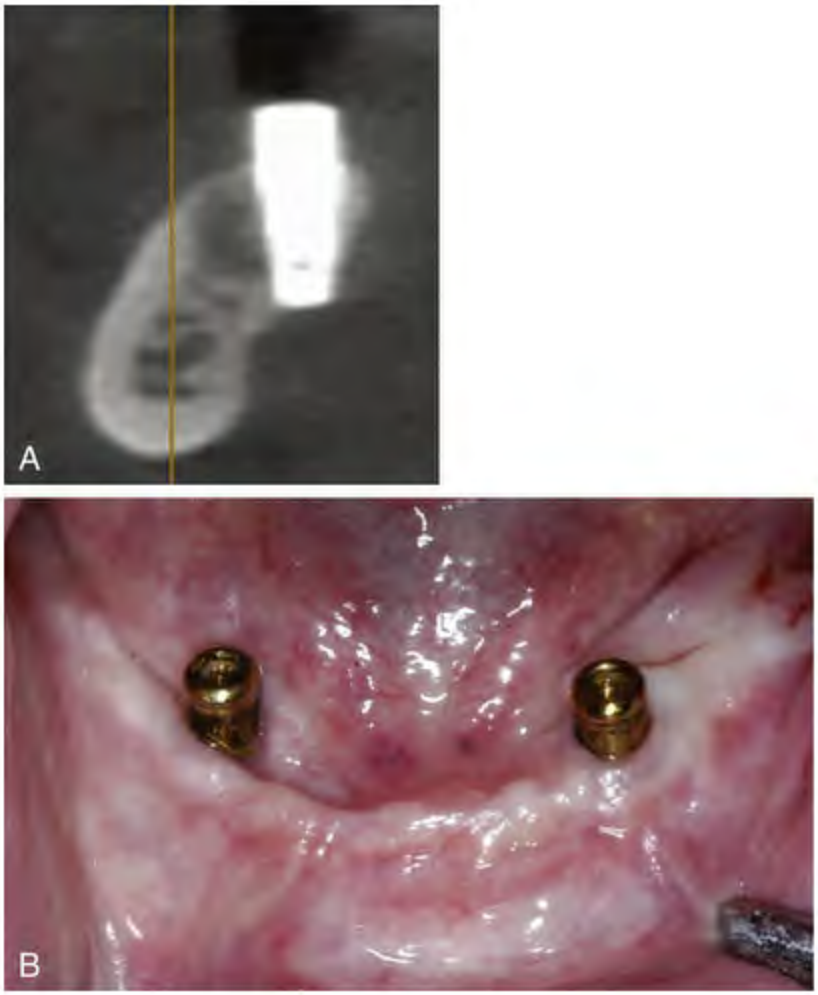

FIG 3.36 (A) Implant placed lingually in poorly angled mandible (e.g., sublingual undercut), which may lead to severe bleeding episodes. (B) Implant attachments protruding lingually in poor position for prosthetic rehabilitation and resulting in tongue impingement.

Difficult prosthetic rehabilitation.

The prosthetic options for Division C ridges more often consist of removable prostheses in the completely edentulous maxillary arch. A maxillary overdenture in a Division C ridge supports the upper lip without hygiene compromise. Ideally, an RP-5 prosthesis (full palate) is recommended to decrease biomechanical forces on the implants. In the Division C mandible, the greater CHS often mandates an overdenture design with some soft tissue support (RP-5). With the buccal shelf mandibular support, less force will be placed on the implant prosthesis.

Not Understanding the Divisions of Bone: Division D (Deficient Bone)

The Division D edentulous ridge corresponds to basal bone loss and severe atrophy, resulting in dehiscent mandibular canals or a completely flat maxilla. The patient often requires augmentation with autogenous bone before implant and prosthodontic reconstruction. Severe atrophy describes the clinical condition of the Division D ridge.

Division D Maxilla.

The Division D maxilla occurs when 6 mm or less of bone exists in the anterior maxilla below the floor of the nose, or less than 6 mm of posterior bone is present below the maxillary sinus. In the maxilla, basal bone loss eventually results in a completely flat maxilla. The partially or completely edentulous patient with a posterior Division D maxilla and healthy anterior teeth or implants may undergo sinus augmentation procedures to increase bone volume for implant placement. The CHS may be insufficient for onlay grafts in the posterior maxilla despite a lack of available bone height because the sinus expands faster than the crest of the ridge resorbs. Endosteal implants of adequate height can rarely be positioned in the posterior maxilla with Division D bone without a sinus graft. After 6 months post–sinus graft, the Division D posterior maxilla is restored to Division A or C–h, and root form implants may be inserted for posterior prosthodontic support (Box 3.6 and Fig. 3.37).

Box 3.6

Division D Bone

Severe atrophy

Basal bone loss

Flat maxilla

Pencil-thin mandible

>20 mm crown height

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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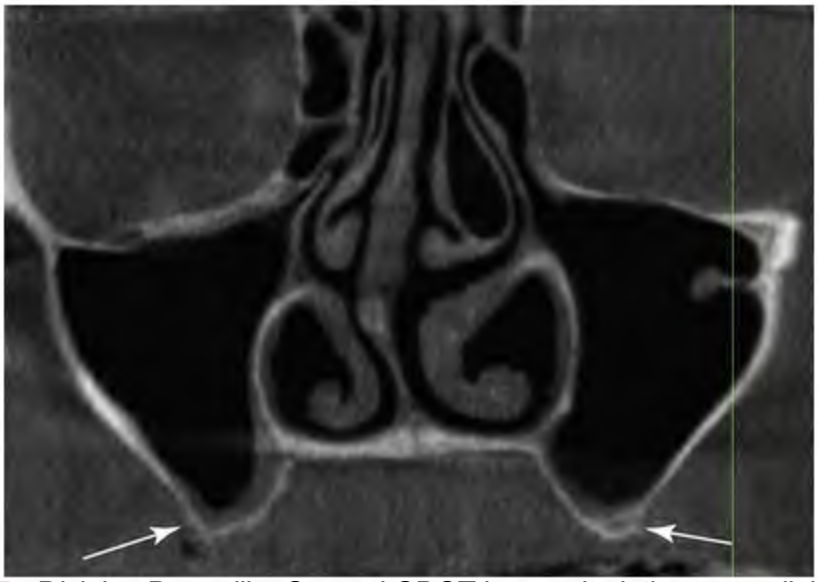

FIG 3.37 Division D maxilla. Coronal CBCT image depicting no available bone below the sinus.

Complications – maxilla.

The anterior maxilla rarely provides sufficient support in the Division D ridge for implants of any design. Autogenous iliac crest bone grafts to improve the anterior Division D are strongly recommended before any implant treatment is attempted.[73] After autogenous bone grafts are completed and allowed to heal for 5 or more months, the bone division is usually Division C–h (or possible Division A), and endosteal implants may be inserted.

The autogenous bone grafts are not intended for improved denture support (without future implant placement). If soft tissue–borne prostheses are fabricated on autogenous grafts, the bone will resorb at an accelerated rate. Additional augmentation to compensate for this resorption is not indicated. Repeated relines, highly mobile tissue, sore spots, and patient frustration are all consequences. However, autogenous bone grafts are maintained long term in conjunction with implant placement. Because of the stimulation of the augmented bone, bone supporting the implants will be maintained. The completely flat anterior Division D maxilla should not be augmented with only hydroxyapatite (nonresorbable) to improve denture support. Inadequate ridge form usually exists to guide the placement of the material. As a result, migration of the graft at the time of surgery or in the future after soft tissue loading is a frequent sequela leading to significant complications.

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Division D Mandible

Complications – mandible.

In the Division D mandible, the superior genial tubercles become the most superior aspect of the ridge. The mentalis muscle loses much of its attachment, even though the superior portion of the muscle attaches near the crest of the resorbed ridge. In the posterior mandible, the buccinator muscle may approach the mylohyoid muscle and form an aponeurosis above the body of the mandible. The mandibular arch also presents with mental foraminae and portions of the mandibular canal dehiscent. It is not infrequent that these patients develop neurosensory impairment of the lower lip, especially during mastication. The CHS is usually greater than 20 mm, which results in a significant force multiplier and can rarely be reduced enough to render long-term success of the prosthesis.

Prosthesis type.

The prosthetic result for anterior ridges with Division D without augmentation is the poorest treatment outcome of all the divisions of bone. Fixed restorations are nearly always contraindicated because the CHS is so significant resulting in a biomechanical disadvantage. When treated without augmentation, completely implant-supported overdentures are indicated whenever possible to decrease the soft tissue and nerve complications. An RP-5 restoration is not suggested because bone loss will continue in the soft tissue–supported region of the overdenture; usually there is lack of a buccal shelf (primary stress bearing area).

Pathologic fracture.

The mandibular completely edentulous Division D patient is the most difficult to treat in implant dentistry. Benefits must be carefully weighed against the risks associated with augmentation procedures. Although the clinician and patient often regard this condition as the most desperate, these patients may easily end up with pathologic fracture complications. If implant failure occurs, the patient may become a dental cripple—unable to wear any prosthesis. Idiopathic fracture during surgery or from implant failure or removal is a more likely complication than in other bone divisions. Clinicians treating anterior Division D mandibles should be able to manage future complications, which may be extensive.

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Implants without bone grafting.

Endosteal root form implants without autogenous grafts may be used on rare occasions in the anterior Division D mandible when the remaining bone is dense and the opposing arch is edentulous. Care must be taken during placement because mandibular fracture at insertion or during postoperative healing is a possible complication. Under these conditions the CHS is very great, and the number of implants is often four or fewer. Implant failure after loading is a greater risk. Implant failure results with circumferential bone loss, which may be associated with mandibular fracture through the implant site. An RP-5 removable restoration is usually indicated for Division D with only anterior implants. However, the RP-5 restoration allows continued bone resorption and atrophy to continue in the posterior regions. The prudent therapy is to educate the patient as to the risks of the situation and offer an autologous bone graft and implants to support a RP-4 restoration (Fig. 3.38).

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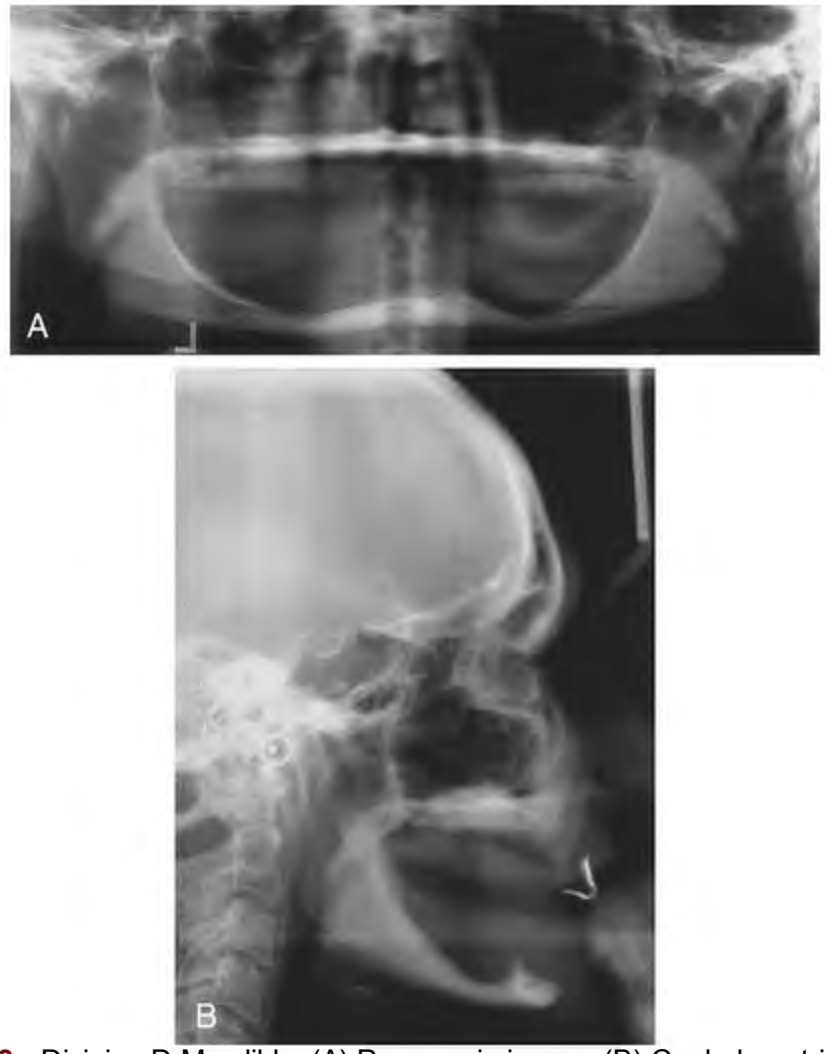

FIG 3.38 Division D Mandible: (A) Panoramic image. (B) Cephalometric image showing minimal available bone.

Lack of early treatment.

The Division D arch requires greater clinician training and results in more frequent complications related to grafting, early implant failure, and soft tissue management, and treatment options include a more guarded prognosis. It should be the goal of every clinician to educate and treat the patient before a Division D bone condition develops. For example, the profession treats periodontal diseases before pain in the region occurs, and carious lesions are removed from teeth before abscess formation. Bone loss is monitored around teeth in millimeters and requires continued care to reduce the risks of future tooth and bone loss. Likewise, prudent practitioners monitor bone loss in edentulous sites and offer education and treatment before deleterious effects occur.

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Key Implant Position

Treatment Planning

Implant positions are an important component of the dental implant treatment planning process, which is crucial to reduce force reduction to the implant system. The maximum number of potential implants that may be used in a fixed prosthesis is usually determined by allowing 1.5 to 2.0 mm or more from each natural tooth and a 3-mm space between each implant and adding the diameter of the implant (Fig. 3.39). This results in dividing the length of the span by 7 mm for the maximum number of implants (when the implants are 4 mm in diameter − 14 mm space divided by 7 = 2 × 4.0 mm implants). Hence, a 21- to 27-mm span may have three implants, and a 28- to 34-mm span may have four implants. The key implant positions are more important sites than the others to reduce biomechanical forces. When utilized, the key implant abutment locations will decrease biomechanical complications.

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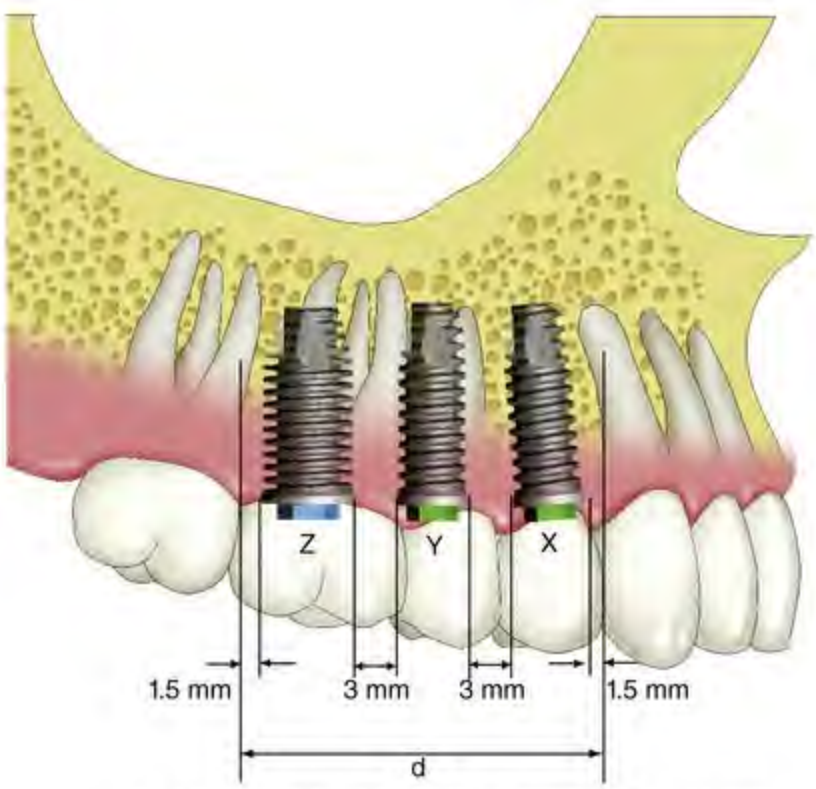

FIG 3.39 The maximum number of implants in an edentulous span may be determined by allowing 1.5 mm or more from an adjacent tooth and 3 mm between each implant and adding the diameter of the implants. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Misch has postulated four general guidelines to determine key implant positions for a fixed prosthesis in the edentulous site with multiple adjacent teeth missing:[17]

1. Cantilevers on prostheses designed for partially edentulous patients or completely edentulous maxillae should preferably be eliminated; the terminal abutments in the restoration are key positions.

2. Three adjacent pontics should not be designed in the prosthesis, especially in the posterior regions of the mouth.

3. When the canine is missing, the canine site is a key position, especially when other adjacent teeth are missing.

4. When the first molar is missing, the first molar site is a key implant position for all partially edentulous patients and completely edentulous maxillae.

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No Cantilevers

The first rule for ideal key implant positions is that no cantilever should be designed in the fixed prosthesis for partially edentulous patients or full-arch maxillary fixed restorations (unless favorable force factors). Cantilevers are significant force magnifiers, which result in excessive force to the cement or prosthesis screws, prosthesis superstructure, abutment screws, implant-bone interface, and the implants.[18]

Cantilevers on fixed partial dentures (FPDs) supported by teeth have a higher complication rate than prostheses with terminal abutments.[19] The primary causes of traditional three-unit FPD failure with natural tooth abutments are caries and endodontic complications (often related to the tooth preparation or decay). The 5-year survival rate of the traditional FPD is often above 95%.[20] However, when a cantilevered three-unit FPD supported by two teeth is used to replace a missing tooth, the failure rate is over 25% within the first 5 years, and the complication rate increases to 40% by 10 years; the primary cause of failure is biomechanics.[21]

When a load is placed on the cantilever portion of a prosthesis, the abutment farthest from the cantilevered pontic has a tensile and shear force applied to the cement seal because the tooth adjacent to the pontic acts as a fulcrum (Fig. 3.40). Cements are 20 times weaker to tension and shear compared with forces in compression.[22] Therefore, with a cantilevered prosthesis, the cement seal breaks on the most distal abutment, and then the abutment often decays. The abutment closest to the cantilever becomes mobile or fractures (especially when endodontics was performed) because it is the only retained abutment for the prosthesis. These biomechanical-related complications usually occur in a relatively shorter period of time compared with biologic complications (e.g., decay or periodontal disease).

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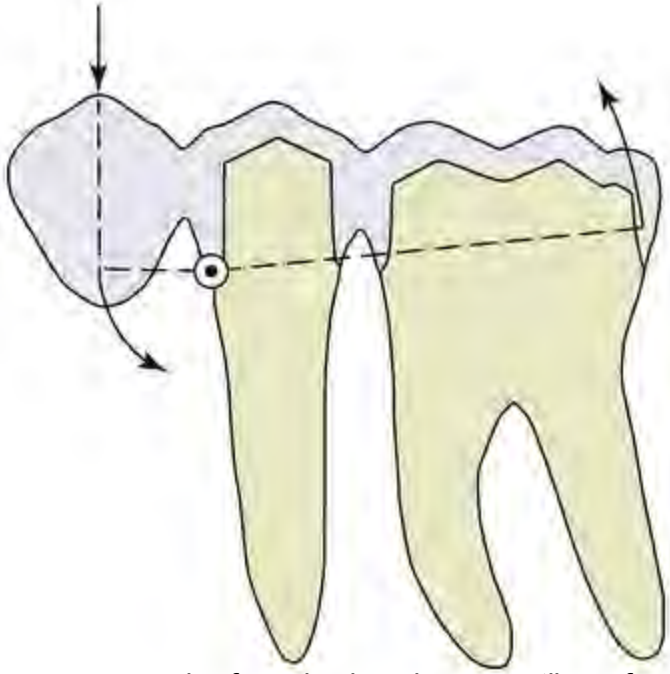

FIG 3.40 When a compressive force is placed on a cantilever from two (or more) natural teeth, the closest tooth acts as a fulcrum, and the distal tooth from the cantilever has a shear and tensile load applied to the cement seal. In this example, the compressive load is applied to a first premolar, the second premolar acts as a fulcrum, and the shear and tensile load is applied to the first molar. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

One Missing Tooth

Ideal placement.

When one tooth is replaced with an implant, the implant should be inserted into the mesiodistal center of the site. If the implant is positioned in the mesial-distal center, a cantliever will result. As a general rule, the implant should be 1.5 to 2 mm from an adjacent tooth. Care should be exercised to decrease the possibility of placing the implant too far from the natural teeth. This will also result in a cantilevered prosthesis.

Implant size.

A 4-mm implant requires 7 mm of space (4 mm + 1.5 mm + 1.5 mm). When a molar (~10–12 mm) is replaced, the implant should be larger in diameter to decrease the mesial and distal cantilever and placed in the mesiodistal center of the edentulous site. This decreases the biomechanical-related risks to the implant system. A common treatment planning problem is when the implant size is selected on the available bone with no emphasis on the space being replaced (Figs. 3.41 and 3.42).

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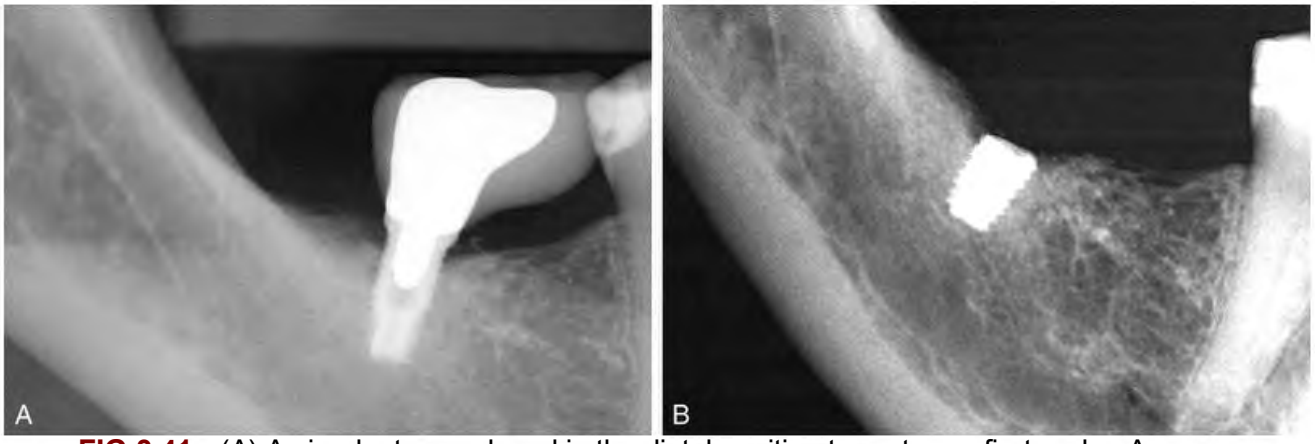

FIG 3.41 (A) An implant was placed in the distal position to restore a first molar. A mesial 7-mm cantilever was used to restore the crown. (B) The first molar implant fractured within a few years. Two implants should have been used to replace a molar tooth this large. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

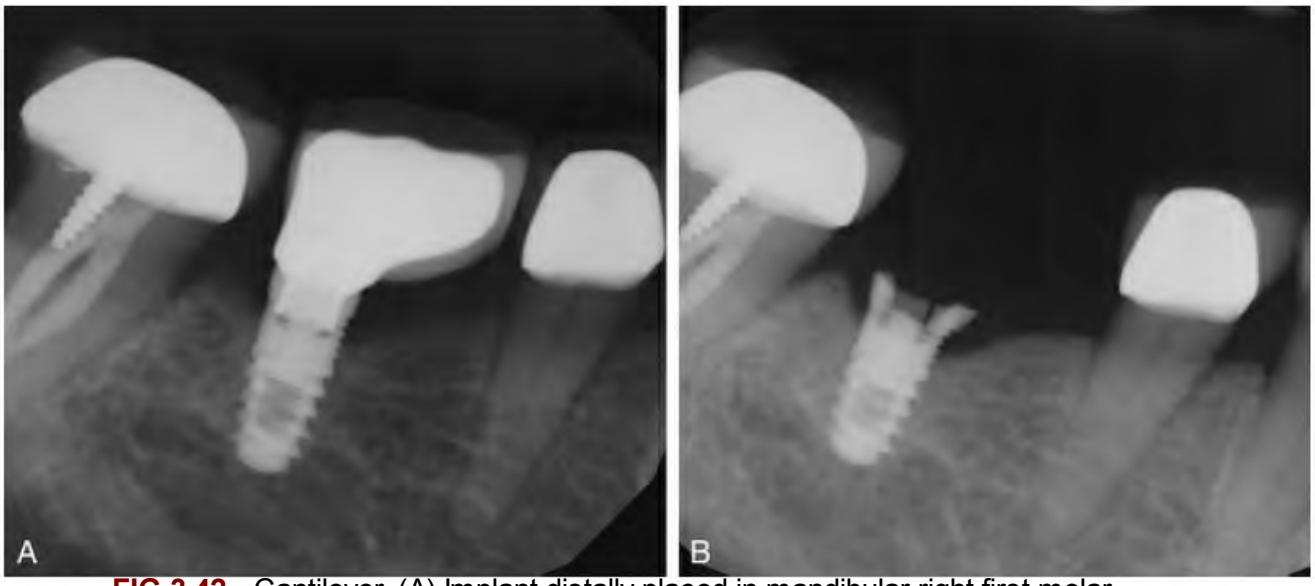

FIG 3.42 Cantilever. (A) Implant distally placed in mandibular right first molar position that resulted in a mesial cantilever. (B) Focre-related fatigue resulted in fracture of the implant body.

Two Missing Teeth.

When two adjacent teeth are missing, two implants should ideally support the implant restoration. As a result, whenever two adjacent teeth are missing and the space is 12 mm or more, two adjacent implants should be inserted, even in the esthetic zone.

To enforce the rule of no cantilever, the key implant positions indicate one

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implant per tooth when one or two adjacent teeth are missing with a span of more than 12 mm (when the implant diameter is 3 mm), 13 mm (when one implant is 3 mm and the other 4 mm), and so on (Fig. 3.43).

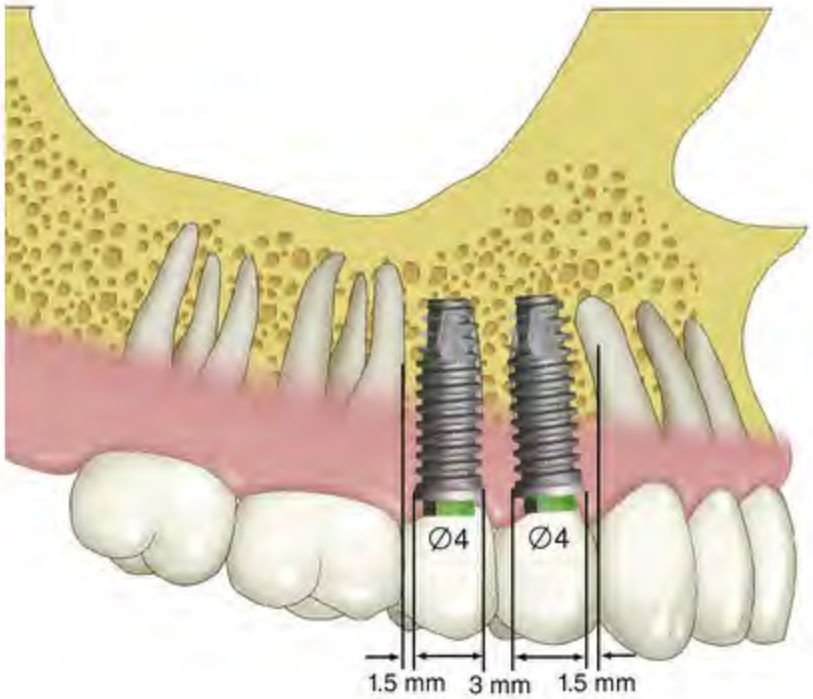

FIG 3.43 When two adjacent teeth are missing in the esthetic zone, the implants should be 1.5 mm from the teeth and 3 mm (or more) apart. This means a 12-mm space is required when the implants are 3 mm in diameter, and 14 mm is required for two 4-mm-diameter implants. *A-P,* anteroposterior. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

When one of the two (or more) missing teeth include a molar, one of the terminal implants should be positioned 1.5 mm from the anterior adjacent tooth and the other terminal implant at the distal of the last molar, not in the middle of the molar. In this fashion, the 3-mm cantilever from the midmolar to the marginal ridge is eliminated when the implants are splinted together. When the implant is not positioned in the distal molar position, the size of the last molar should be reduced to eliminate the cantilever. The clinician should be aware that the last molar should ideally be a premolar-size crown when the distal implant is positioned in the mesial to midmolar position.

Lower incisor option.

When missing two mandibular incisors, usually one implant may be placed interproximally, slightly lingual with a screw-retained prosthesis. If all four

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lower incisors are missing, two implants may be placed interproximally, distributing the cantilever amount equally (Fig. 3.44). This area involves lower force factors.

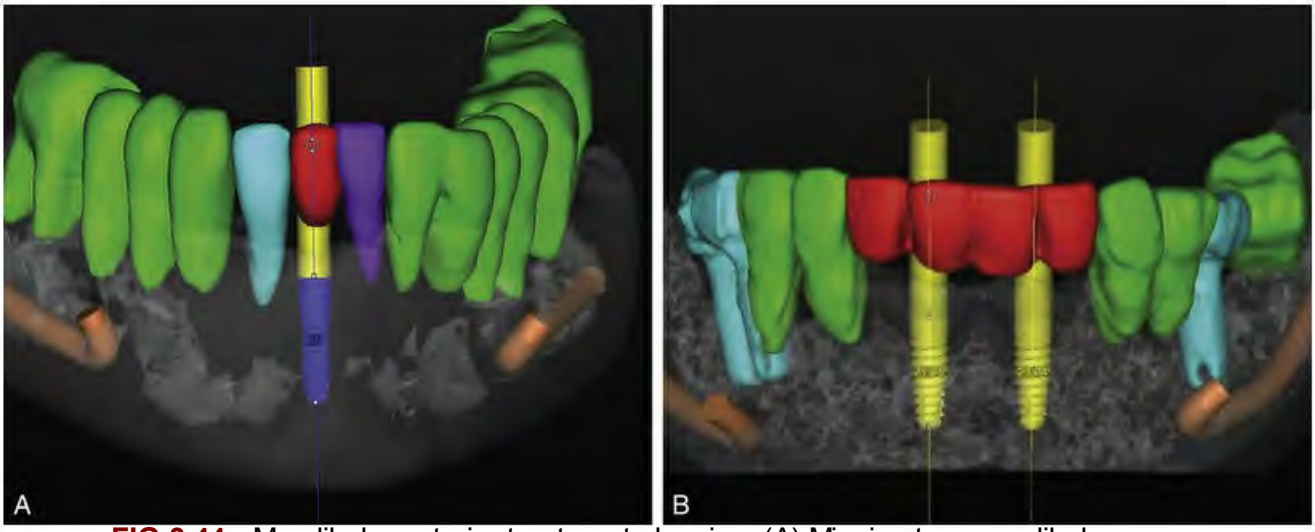

FIG 3.44 Mandibular anterior treatment planning. (A) Missing two mandibular incisors are ideally restored with a single implant. (B) Missing four mandibular incisors are ideally replaced with two implants and a screw-retained prosthesis.

Three Missing Teeth.

When three adjacent teeth are missing, the key implant positions include the two terminal abutments, one on each end of the prosthesis (Fig. 3.45). A three-unit prosthesis may be fabricated with only these abutments when most of the force factors are low to moderate and the bone density is favorable. A cantilevered restoration on multiple splinted implants may be compared to a class I lever.[18] The extension of the prosthesis from the last abutment is the effort arm of the lever. The last abutment next to the cantilever acts as a fulcrum when a load is applied to the lever. The distance between the last abutment and the farthest abutment from the end of the cantilever represents the resistance arm, and the distance between the implants may be called the *anteroposterior distance*, or *A-P spread*.

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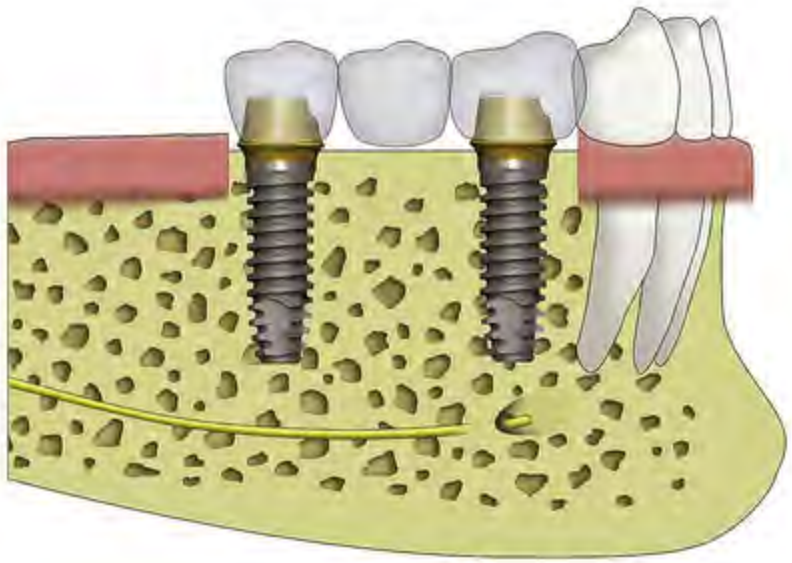

FIG 3.45 A three-unit prosthesis has key implant positions at each terminal end of the restoration. If force factors are high, a third implant is recommended.

The length (usually in millimeters) of the cantilever (effort arm) divided by the resistance arm represents the mechanical advantage. Therefore when two implants are 10 mm apart with a cantilever or extension of 20 mm, the mechanical advantage is 2 (20 mm/10 mm). In this example, a 25-lb force on the cantilever results in a 50-lb tensile force on the farthest abutment from the cantilever (25 lb × 2 = 50 lb). The abutment closest to the cantilever (fulcrum) receives a compressive force equal to the sum of the other two forces, or, in this example, 75 lb (25 lb + 50 lb). In other words, the force on the cantilever increases the force on the implants by two to three times (Fig. 3.46). Cantilevers magnify forces to all the abutments supporting the prosthesis.

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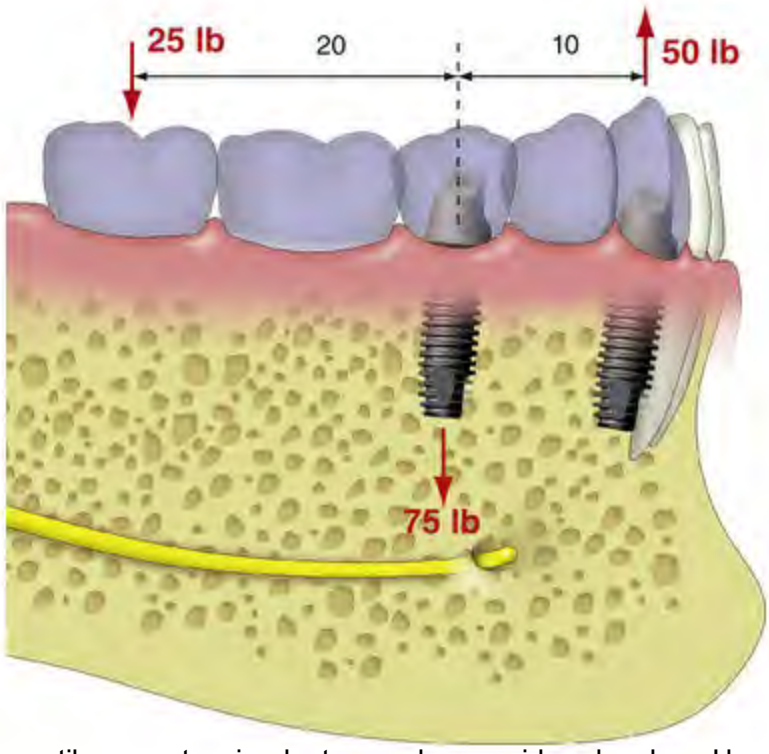

FIG 3.46 A cantilever on two implants may be considered a class I lever. When the implants are 10 mm apart, with a 20-mm cantilever, a mechanical advantage of 2 is created. A load on the cantilever will be multiplied by 2 on the most distal implant, and the implant close to the cantilever receives the sum total stress of the two other loads. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

When a cantilevered force exists, a greater load to the implant farthest from the cantilever results in a tensile or shear type of force, and any part of the implant system is at an increased risk of biomechanical failure (e.g., porcelain fracture, uncemented prosthesis, abutment screw loosening, crestal bone loss, implant failure, implant component or body fracture). This is especially observed when parafunction or increased CHS exists.

To eliminate posterior cantilevers, bone augmentation is often indicated to increase bone volume for implant placement. However, there does exist disadvantages of bone augmentation procedures. Bone augmentation often requires an additional surgery before implant placement. Additional training is required to learn bone augmentation procedures, the learning curve is longer, and it is more difficult to become accomplished in these techniques. Complications related to bone augmentation are more common than implant surgery in existing bone volumes and may be more extensive and even debilitating to the patient. However, cantilevered implant prostheses have a more frequently observed biomechanical risk than the surgical risks of augmentation, and these risks can cause the loss of the entire implant support and prosthesis. Additionally, bone loss and resultant defects from

implant failure may make the following bone augmentation procedures even more difficult to perform than when treatment was rendered in the original condition.

Four or More Adjacent Teeth Missing.

When four adjacent teeth are missing, the terminal abutments are the key implant positions (Fig. 3.47). Most often, one to two additional implants are required, especially when the missing teeth include a canine, a posterior teeth or when the bone density is poor. Restorations of 5 to 14 units require the key terminal positions plus additional abutments regardless of force factors or bone density. The number of additional abutments is determined by many biomechanical factors such as arch form, bone density, opposing occlusion, parafunctional habits, available bone, and type of prosthesis.

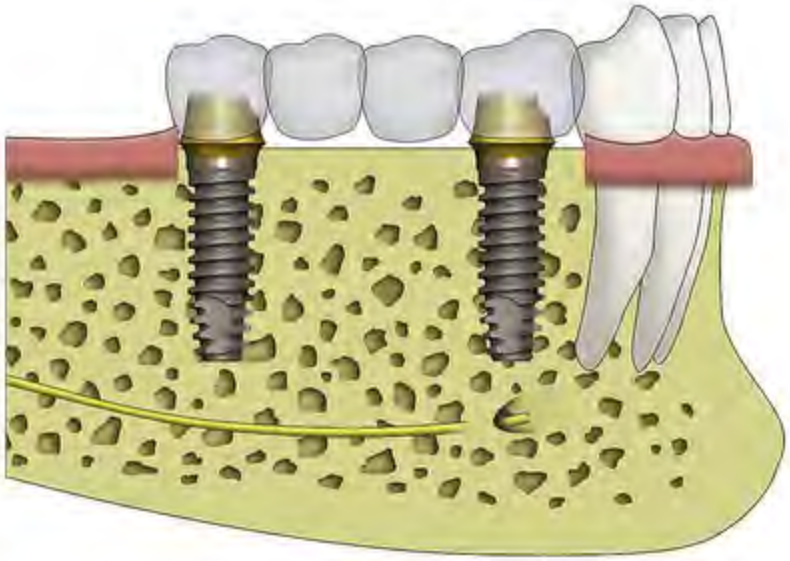

FIG 3.47 When four adjacent teeth are missing, the two terminal abutments are the key implant positions. Most often, one or two additional implants are required.

Cantilever Options.

The ideal implant treatment plan should eliminate cantilevers in partially edentulous patients and in complete arch maxillae. However, in completely edentulous mandibles, a cantilever is often the most prudent treatment option because of available anatomy. For example, in a completely edentulous mandible, available bone in the posterior regions may be insufficient for root form implant placement without advanced procedures (e.g., nerve

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repositioning, iliac crest bone grafts).

In addition, the dynamics of bone movement during opening and function is different for a mandible and maxilla. Upon opening, the mandible flexes distal to the mental foramen toward the midline (mandibular flexure). During heavy biting on the side of the jaw, the bottom of the mandible rotates to the buccal, and the crest slightly rolls toward the lingual, again, distal to the mental foramen (Fig. 3.48).[23] As a consequence of this flexure, splinting a molar implant across the arch to the contralateral molar may cause discomfort and lateral forces on the implant sites. With implant prostheses, uncemented restorations, bone loss, and even implant failure have been observed when there was cross-arch splinting of molars.

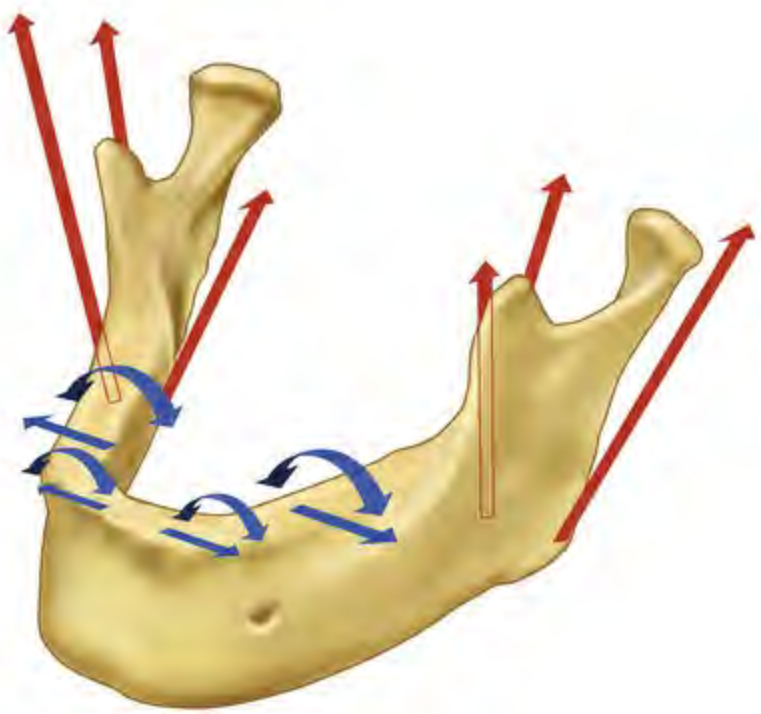

FIG 3.48 The mandibular bone has dynamic movement during function. Upon opening, the mandible flexes toward the midline. Parafunction or heavy biting on one posterior side results with a torsion of the mandible with the inferior border rolling buccal and the crest moving toward the tongue. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

No Three Adjacent Pontics

In most prostheses designs, three adjacent pontics are contraindicated on natural tooth abutments in the posterior regions of the mouth (Fig. 3.49). The adjacent abutments are subjected to considerable additional force when they

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must support three missing teeth, especially in the posterior regions of the mouth. When three adjacent posterior teeth are missing between remaining teeth (and the third molar is absent), the terminal abutments are the second molar and the canine. The forces in the posterior regions are three to four times greater than the anterior region, and the force on the canine is two times greater than on the anterior region. In addition, the canine receives a lateral load in most excursions. The lateral load increases the intensity of the force and places the cement seal and porcelain/zirconia under more tensile and shear loads.

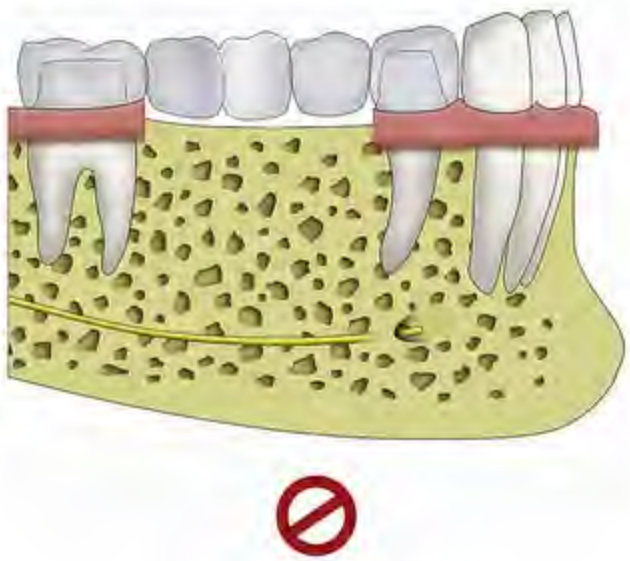

FIG 3.49 A posterior fixed prosthesis with three (or more) pontics is contraindicated with natural teeth abutments. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

In addition to the greater loads applied to the abutment teeth, all pontic spans between abutments flex under load. The greater the span between abutments, the greater the flexibility of the metal in the prosthesis. In a one-pontic prosthesis, minimal flexure results (8 μm or less with precious metal under a 25-lb load). In comparison, a two-pontic span flexes eight times more than a one-pontic span, all other variables being equal. Although the metal flexure is more for the two-pontic prosthesis, the failure rate of three- or four-unit prosthesis supported by natural teeth is similar for the first 5 years because the cause of failure is mostly biologic (e.g., caries).

The metal between abutments for a three-pontic span flexes 27 times more than that of a one-pontic span if all other factors are equal (Fig. 3.50).[24] In addition, the greater the load, the greater the flexure. With parafunction

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patients, the flexure is even greater, with an increased shear and tensile force on the abutments. The greater the flexure, the greater the risk of porcelain fracture, uncemented prostheses, and abutment screw loosening. As a result, not only is the magnitude of the force increased to the adjacent abutments when the prosthesis has three pontics (because they are supporting two abutments and three pontics) but the flexure of the metal also increases to a point that the incidence of complications makes the treatment plan contraindicated, especially when forces are greater (as in the posterior region). As a result, a three–adjacent-pontic prosthesis has an increased failure rate compared with a one- or two-pontic fixed prosthesis. The increased failure rate of long-span fixed prostheses is due largely to the increase in biomechanical complications (e.g., unretained restorations and fracture). As a consequence, it is well accepted in the literature that three pontics in the posterior regions are contraindicated for natural teeth.

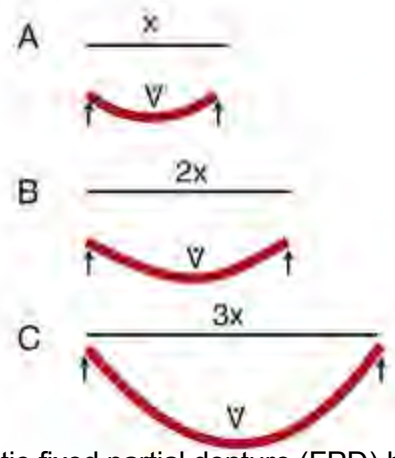

FIG 3.50 (A) A one-pontic fixed partial denture (FPD) has minimal flexure of the metal. (B) A two-pontic FPD flexes eight times more than a one-pontic span. (C) A three-pontic FPD has 27 times more flexure than a one-pontic span. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The flexure of materials in a long span is more of a problem for implants than natural teeth. Because natural roots have some mobility both apically and laterally, the tooth acts as a stress absorber, and the amount of material flexure may be reduced. Because an implant is more rigid than a tooth (and has a greater modulus of elasticity than a natural tooth), the risk for complications of increased load and material flexure are greater for an implant prosthesis. Because three posterior pontics are contraindicated in a natural tooth–fixed prosthesis, it is even more important not to have three

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pontics in an implant restoration.

The span of the pontics in the ideal treatment plan should be limited to the size of two premolars, which is 13 to 16 mm. When a molar is one of the teeth missing between existing teeth, the missing molar space alone may be 10 to 13 mm long. As a result, when a large second premolar and first molar are missing, this edentulous span is often treatment planned to replace three teeth, rather than two, and an additional implant is warranted in this span. This is especially appropriate for greater patient forces (i.e., moderate to severe parafunction) or softer bone types (i.e., D3 and D4).

To limit the effect of the complications of three adjacent premolar-size pontics, additional intraimplant key positions are indicated in prostheses missing five or more adjacent teeth. When 5 to 14 missing adjacent teeth are to be replaced, key implant positions are located in the terminal abutments, and additional pier or intermediary abutments are indicated to limit the pontic spans to two premolar-size pontics. Following this rule, a five- to seven- premolar–size unit prosthesis has three key abutments (two terminal and one pier) (Fig. 3.51).

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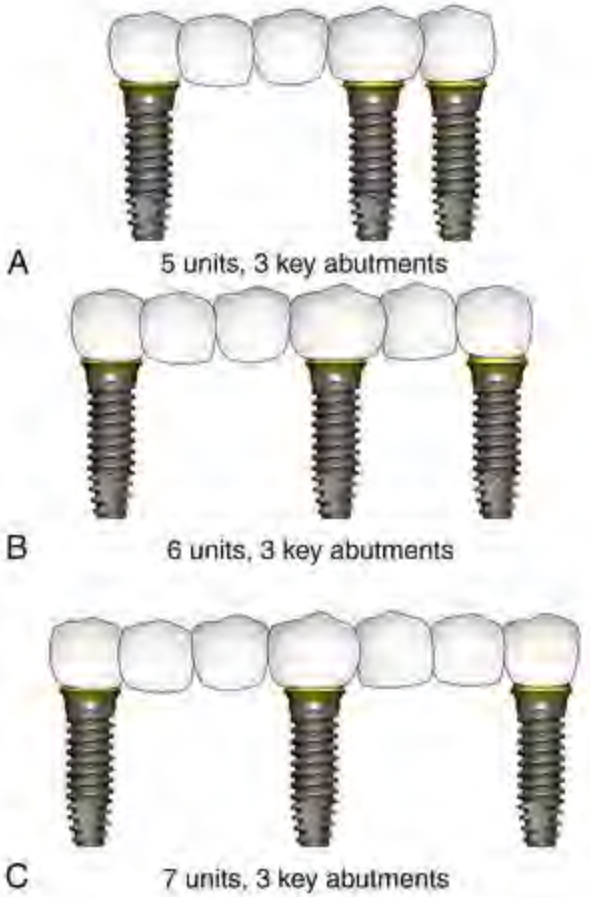

FIG 3.51 When five to seven adjacent teeth are missing, there are three key implant positions: the terminal abutments and another implant to limit the edentulous span to two teeth. Note additional implants are usually required, especially for six or seven missing teeth (translucent implants).

An 8- to 10-premolar–size unit prosthesis has four key implant positions (two terminal and two pier). An 11- to 13-unit prosthesis has five key abutments (two terminal and three pier), and a 14-unit prosthesis has six key abutment positions. In addition to these key abutments, additional abutments may be required to address patient force factors and bone density. Rarely is the force factor situation favorable and bone density ideal enough in a maxilla to be fulfilled with solely key abutments for a fixed prosthesis replacing more than five teeth.

Three-Pontic Options.

Angled forces to the premaxilla magnify the amount of the force to the implant system in both centric and excursive occlusal forces. Therefore, most maxillary anterior prostheses should also limit the number of pontics in the restoration. The exception to the no three-pontic rule is most often the anterior mandible, when the three adjacent missing teeth are mandibular

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incisors. As long as implants are placed in the canine position, the number of pontics may be increased because of the long axis angle of force, the reduced bite force, and the good bone quality. However, when the dentate arch position is tapered and the three anterior pontics are cantilevered to the facial, an additional implant is indicated even in the anterior mandible.

Canine Rule

In any arch, certain positions are more important sites than others. In the dental arch, these more important positions are represented by the canine and the first molar (Fig. 3.52).[25] The canine root has more surface area in either arch compared with any other anterior tooth, and the molar has more root surface area than any posterior teeth (Fig. 3.53).[26] The canine is a particularly interesting tooth. When a lateral force is placed on the natural canine and no posterior teeth are in contact, two thirds of the masseter and temporalis muscles do not contract, and the resultant force on the anterior teeth is less. In addition, because the mandible acts as a class III lever, with the temporomandibular joint behind the muscles of mastication, the force applied to the anterior teeth is less when the posterior teeth do not occlude. Therefore, both biologic and biomechanical factors make the canine position an important site in the dental arch.

FIG 3.52 In a dental arch, the two most important biomechanical positions are represented by the canine and the first molars. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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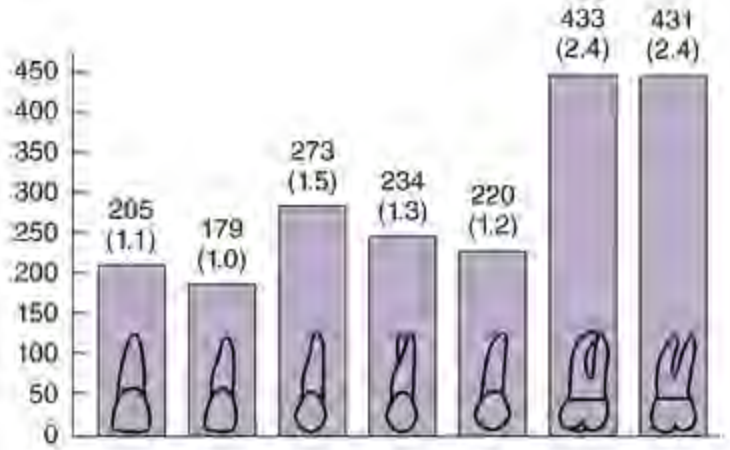

FIG 3.53 The canine has more root surface area than any anterior tooth and the first molar more area than any other posterior tooth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A fixed restoration replacing a canine is at greater risk than nearly any other restoration in the mouth. The maxillary or mandibular adjacent incisor is one of the weakest teeth in the mouth, and the first premolar is often one of the weakest posterior teeth. As a consequence, when a canine is missing, a single tooth implant replacing the canine is the ideal treatment of choice (Box 3.7).

Box 3.7

Arch Position

Canine

- Most surface area of any anterior tooth
- Canine-guided excursion of the mandible reduces masticatory muscle contraction
- Canine and anterior teeth farthest from the temporomandibular joint (less force magnitude)
- Adjacent teeth are less ideal for additional force

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

When two adjacent teeth are missing and include a canine, two implants

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are required. Even when a canine and lateral incisor are in the esthetic zone, it is better to reduce the size of the implants and place two implants with no cantilever rather than place a larger implant with a cantilever. The implants should be at least 3 mm apart so the base of the interimplant papilla can support the soft tissue drape.

A traditional fixed prosthetic axiom on natural teeth indicates it is contraindicated to replace a canine and two or more adjacent teeth.[24] If a patient desires a fixed prosthesis, implants are required whenever the following adjacent teeth are missing in either arch: (1) the first premolar, canine, and lateral incisor; (2) the second premolar, first premolar, and canine; and (3) the canine, lateral, and central incisors. Whenever these combinations of teeth are missing, implants are required to restore the patient because (1) the length of the span is three adjacent teeth, (2) the lateral direction of force during mandibular excursions increases the stress to the prosthesis, (3) the magnitude of the bite force is increased in the canine region compared with the anterior region, and (4) an implant in the canine region with implant-protected occlusion (mutually protected occlusion) distributes reduced lateral loads during mandibular excursions.

The canine is the most important position for the occlusal scheme of the patient. Canine guidance or mutually protected occlusion is the primary occlusal format in most fixed implant reconstructions or completely implant-supported removable restorations. The angled force of approximately 22 to 25 degrees in excursions should not be magnified on a canine pontic with an implant prosthesis supported by fewer implants.[27] Although the force reduction in excursions is not as great with an implant as with a natural canine tooth, there still is some force reduction as a consequence of the class III lever effect.[28] Whenever the canine and two or more adjacent teeth are missing, the canine is a critical site along with the terminal positions of the span (Fig. 3.54).

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FIG 3.54 A panoramic radiograph of a patient missing a maxillary right canine, lateral incisor, and central incisor. The key implant positions are the canine and central incisor to support a three-unit fixed partial denture. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

When the three adjacent teeth are the first premolar, canine, and lateral incisors, the key implant positions are the first premolar, the canine, and the lateral incisor when the overall intratooth space is greater than 19 mm because three implants with no cantilever reduce any increased force factor risks. The minimum implant sizes are usually 3.5 mm for the premolar and canine and 3 mm for the lateral incisor.

When the first premolar, canine, and lateral incisor are missing and the intratooth span is less than 19 mm, only two implants are used to support the prosthesis. In this scenario, it is better to place terminal abutments and have a canine pontic, especially when the prosthesis is within the esthetic zone. The size of the implants is slightly increased to compensate for the angled forces during a lateral excursion. In addition, the amount of the incisal vertical overbite is reduced to decrease the leverage effect on the canine. The incisal guidance should be as shallow as possible to decrease the force during excursions. However, it must be steep enough to separate the posterior teeth in the mandibular excursions.

When there are multiple missing teeth on each side of the canine site, the canine edentulous site is a key pier abutment position. The canine position is a key implant position to help disocclude the posterior teeth in mandibular excursions. As a result, when four or five adjacent teeth are missing, including a canine and at least one adjacent posterior premolar tooth, the key implant positions are the terminal abutments and the canine position. For

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example, when the first premolar, canine, lateral, and central incisor are missing, the key implant positions are the first premolar and central incisor (terminal abutments) and the canine (canine rule) (Fig. 3.55).

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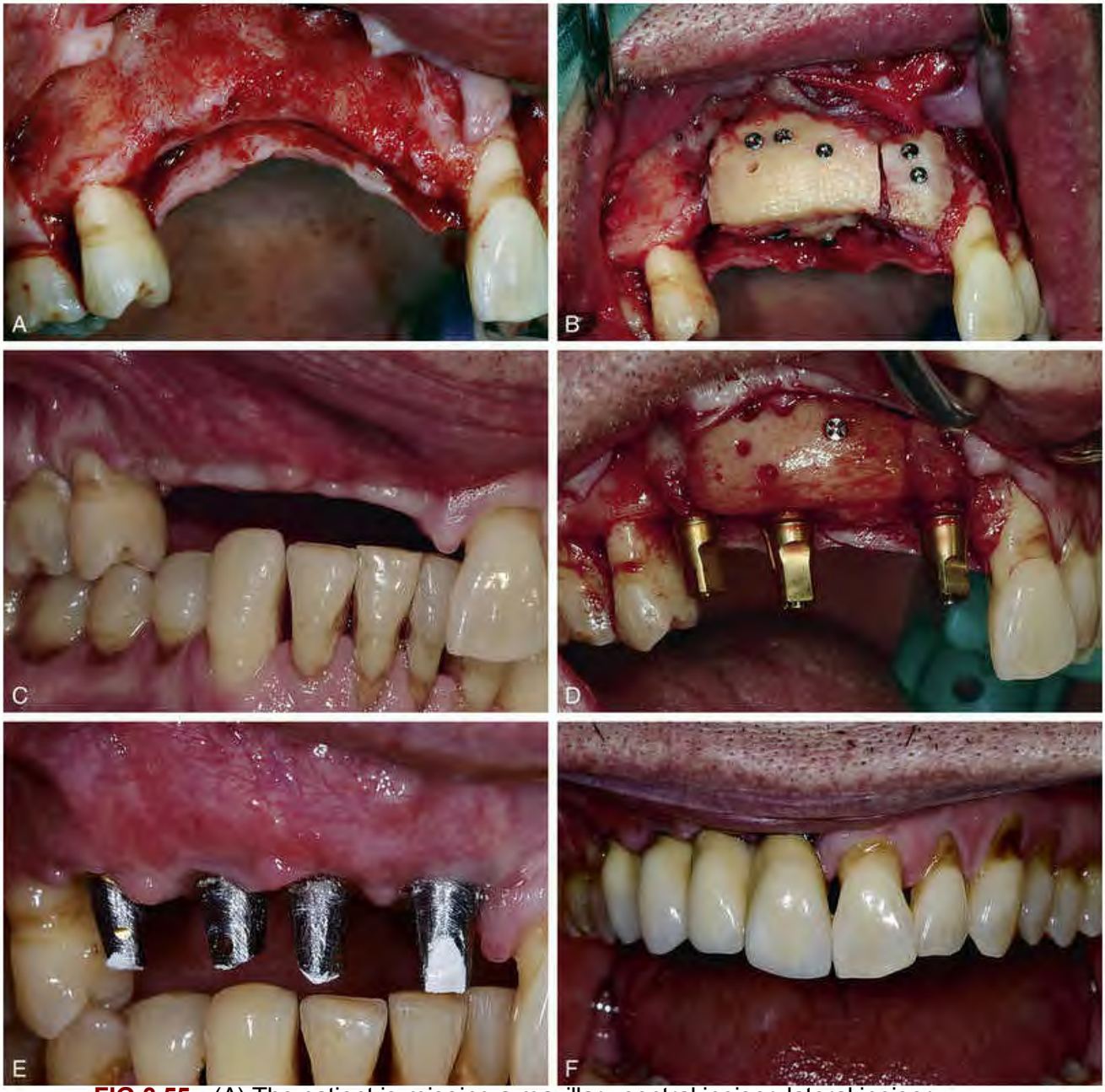

FIG 3.55 (A) The patient is missing a maxillary central incisor, lateral incisor, canine, and first premolar. There is inadequate bone volume in the canine position. (B) A block bone graft is positioned primarily in the canine region. (C) The block bone graft matures for 6 months. (D) The key implant positions are the central incisor, canine, and first premolar. (E) An additional implant was positioned in the lateral incisor region. (The patient is a man with deep vertical overbite.) (F) A four-unit fixed partial denture was cemented in place. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

When six or more adjacent teeth are missing, which include both canines, additional pier abutments (which limit the pontics' spans to no more than two teeth) are also indicated. For example, when the first premolar to first premolar are missing, five key implants are indicated, especially in the maxillary arch—the terminal abutments, the canines, and an additional

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implant in one of the central incisor positions. The same five key implant positions exist for the one-tooth span of second premolar to second premolar (Fig. 3.56).

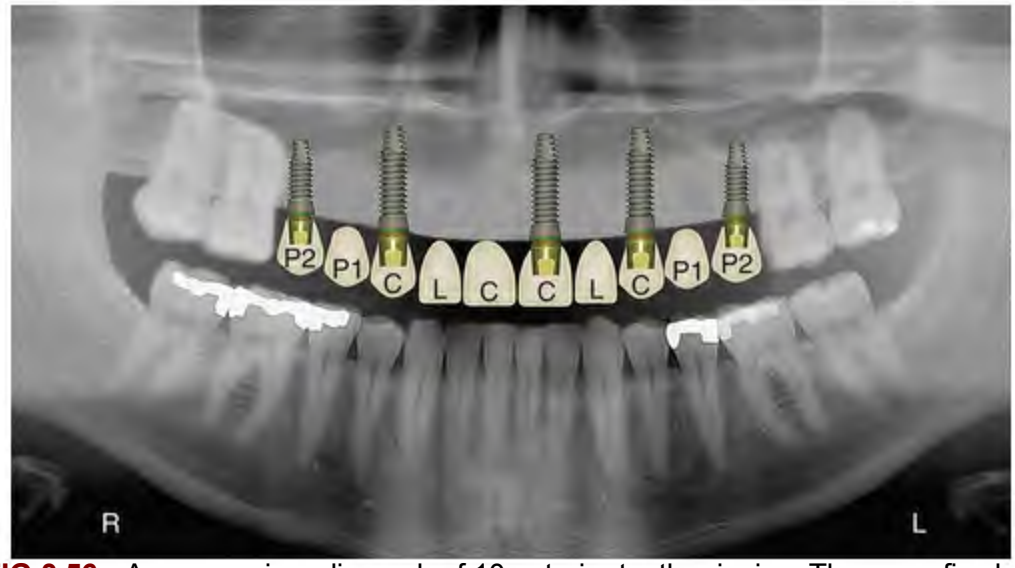

FIG 3.56 A panoramic radiograph of 10 anterior teeth missing. There are five key implants positions for this fixed prosthesis: the second premolars, the canines, and an anterior implant to limit the pontics to no more than two. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

First Molar Rule

The molars have the most root surface area of any natural tooth in the mouth and have two or three roots. The biomechanical rationale for this condition is that the bite force doubles in the molar position compared with that of the premolar position in both the maxilla and mandible. In addition, the edentulous span of a missing first molar is usually 10 to 12 mm compared with a 7-mm span for a premolar. As a result, the first molar is also a key implant position.[17]

As previously presented, cantilevers should not be used in partially edentulous patients to replace a first molar, especially when patient force factors are moderate to great (e.g., parafunction, opposing arch). The cantilever further increases the force of the molar region to the splinted abutments. As a result, uncemented restorations, bone loss, and failure are at greater risk.

When a first molar is missing, a 5- to 6-mm-diameter implant is indicated in the mid mesiodistal position of the edentulous site when the molar is less

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than 12 mm wide. When a first molar implant is indicated in the maxilla, a sinus bone graft is most always required. The maxillary sinus expands rapidly after tooth loss. More often than not, the sinus floor should be altered and grafted in conjunction with a first molar implant insertion.

When two adjacent teeth are missing, including a first molar, the key implant positions include the terminal abutments, including the distal molar position. When three posterior teeth are missing and include a first molar, a first molar implant is included. For example, in a patient missing the second premolar, first molar, and second molar, three key implant positions are required to restore the full contour of the missing molars teeth: the second premolar and second molar terminal abutments and the first molar pier abutment (Fig. 3.57). A similar scenario is present when all four posterior teeth are missing—first premolar, second premolar, first molar, and second molar. The key implant positions are the terminal abutments (first premolar and second molar) and the first molar (Fig. 3.58). In the maxilla, a sinus graft is most always indicated to replace these four adjacent teeth (Fig. 3.59). When one implant replaces a molar (with a span of 10–13 mm), the implant should be at least 5 mm in diameter. When a smaller-diameter implant is selected in a molar space of 14 mm or more, the molar may be considered the size of two premolars, and two smaller-diameter implants may be selected.[29]

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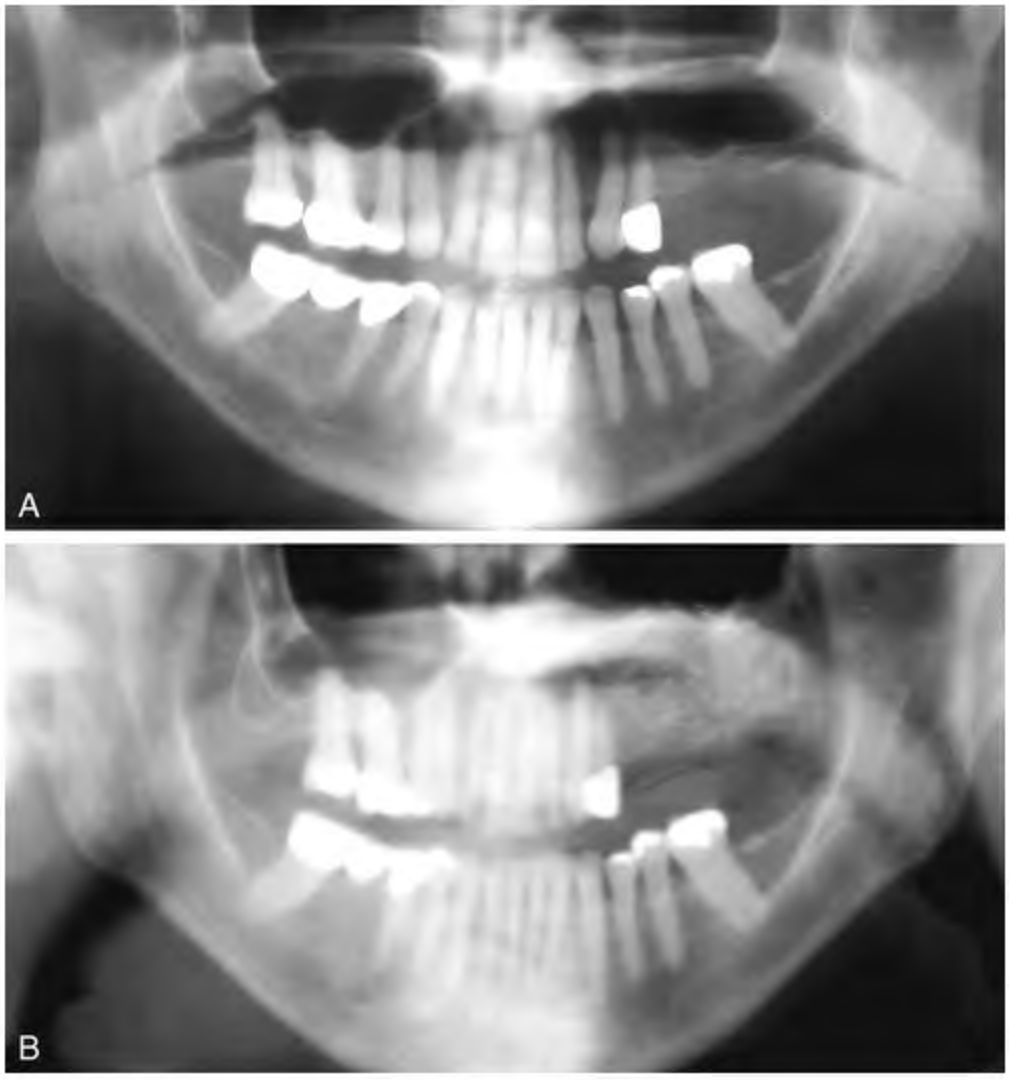

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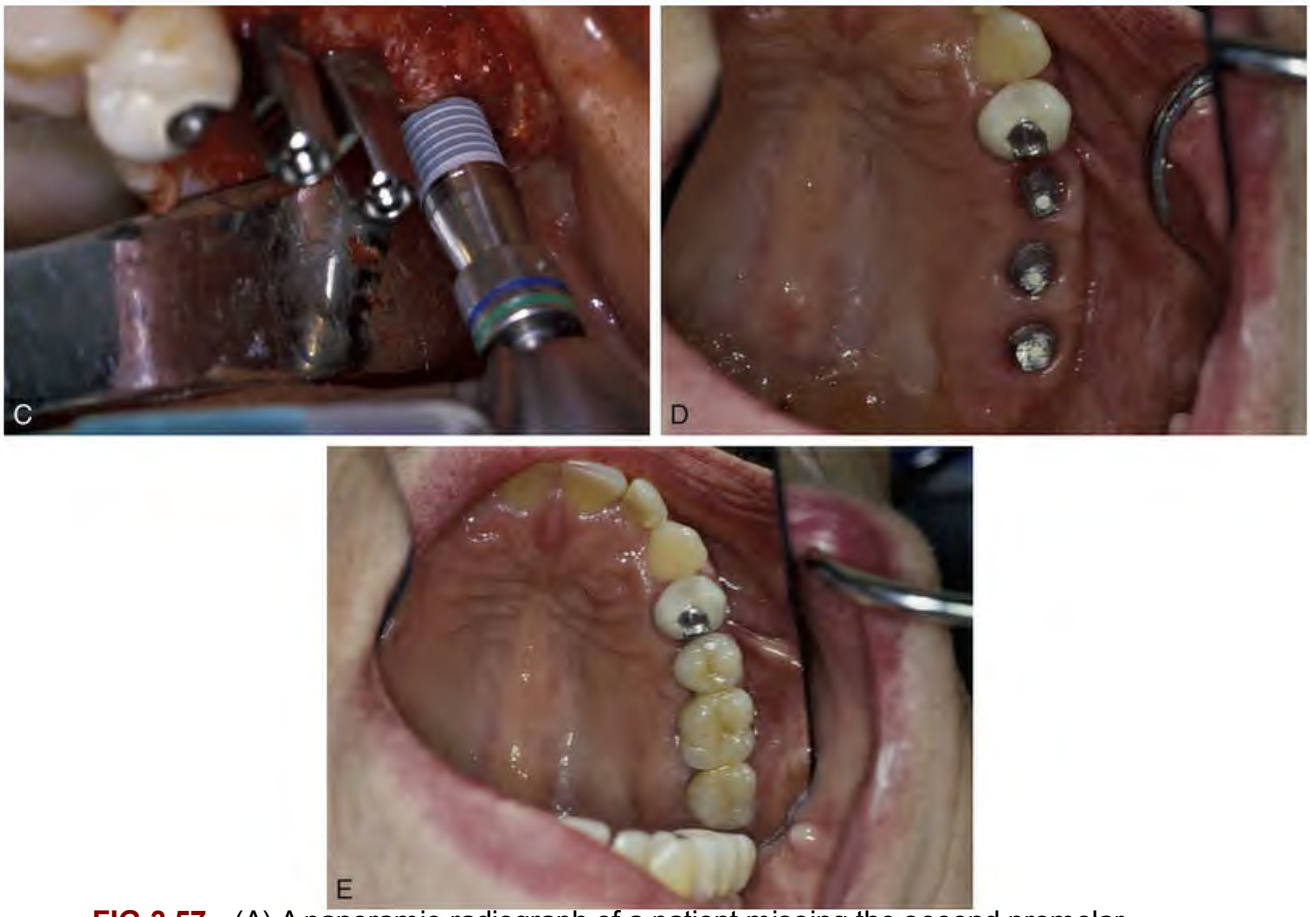

FIG 3.57 (A) A panoramic radiograph of a patient missing the second premolar, first molar, and second molar. There is inadequate bone height because of the pneumatization of the maxillary sinus. (B) A sinus graft restores the bone height to favorable limits for future implants in the second premolar, first molar, and second molar. (C) Three implants are inserted: the second premolar and the second terminal implants and a first molar implant. (D) The three implants after integration. (E) A three-unit fixed partial denture supported by three implants. Only the mesial half of the second molar is restored because there is no opposing mandibular second molar. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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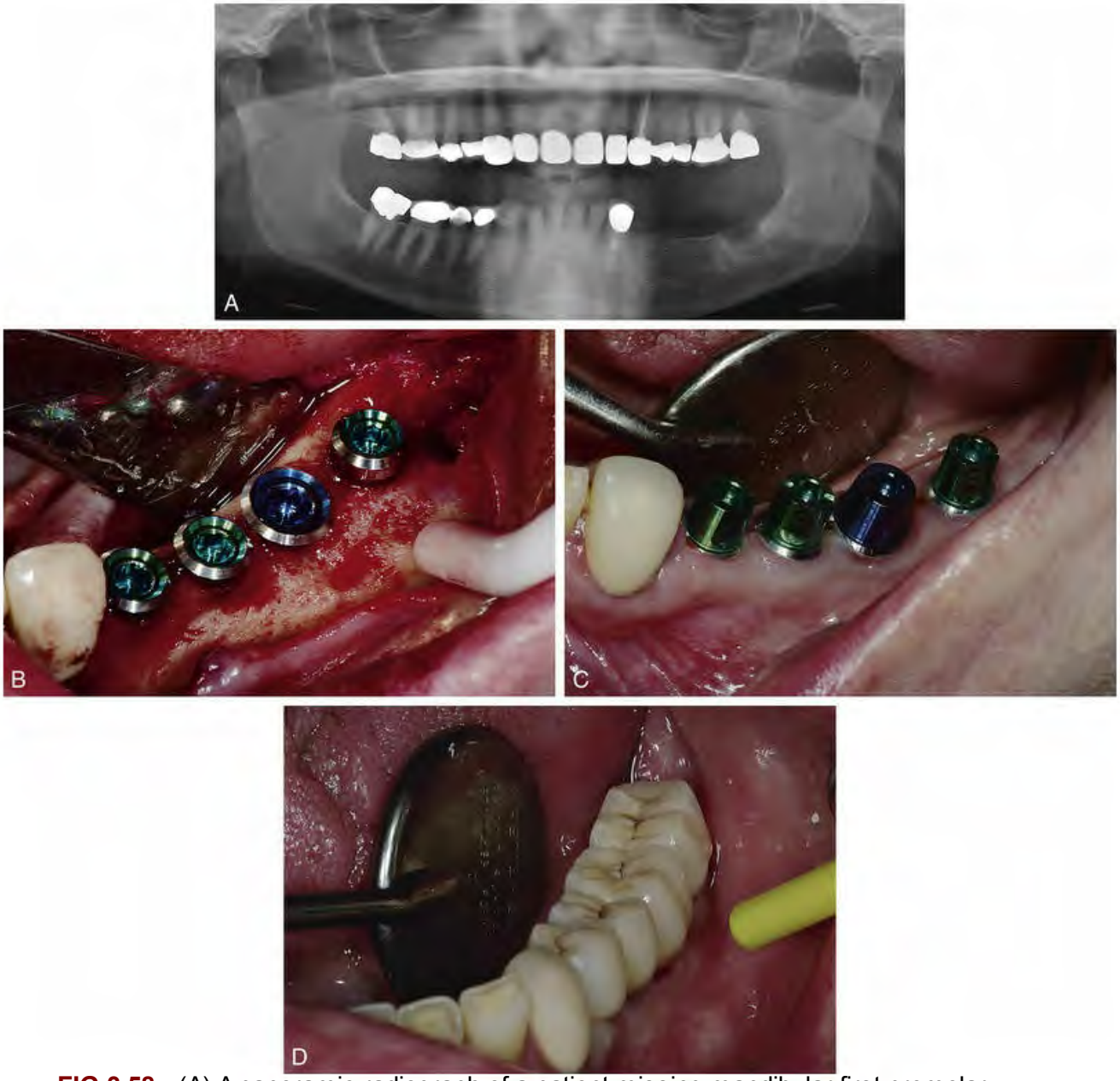

FIG 3.58 (A) A panoramic radiograph of a patient missing mandibular first premolar to second molar. (B) Four implants were used to restore the missing teeth. (C) The key implant abutments are the first premolar and second molar (no cantilever) and the first molar. (D) The four-unit splinted fixed partial denture restores the missing teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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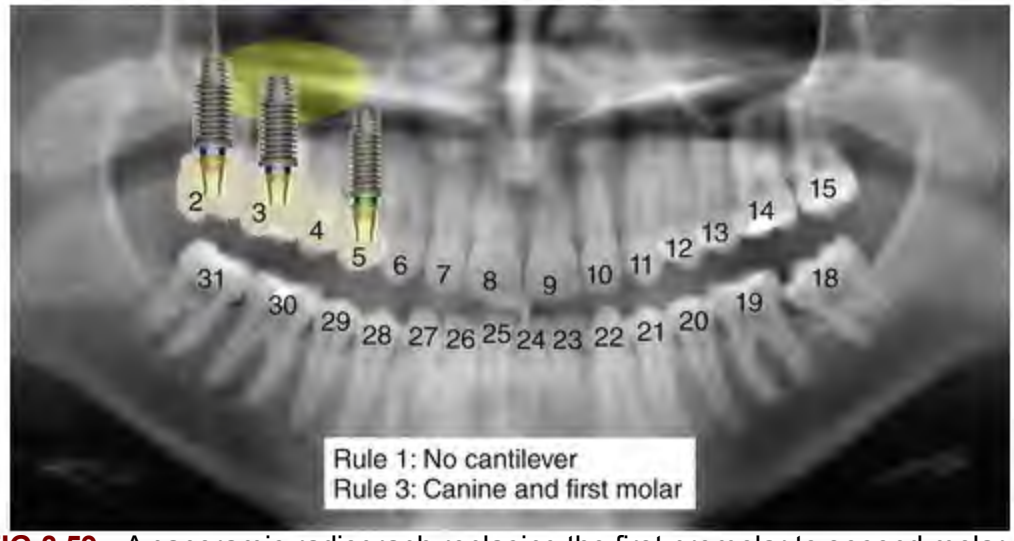

FIG 3.59 A panoramic radiograph replacing the first premolar to second molar. A sinus graft is most always required to place the molar implants. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Four to six implants in the anterior maxilla have been suggested in the complete edentulous maxilla, with posterior cantilevers (Fig. 3.60). Full-arch restorations for the edentulous maxillary arch should also have a first molar implant. In general, density of bone in the maxilla is less than the mandible in both the anterior and posterior regions. The anterior maxillary implants receive an angled load (compared with the anterior mandible) in both centric and mandibular excursions. The anterior maxillary arch usually has shorter implants than the anterior mandible because the vertical height of bone is less compared with the anterior mandible. The shorter implants have less surface area and higher stresses, especially in soft bone. Maxillary fixed restorations most often oppose an implant prosthesis (usually fixed) or natural teeth. This increases the force to the maxillary prosthesis. Therefore, the biomechanical risks associated with full-arch maxillary prostheses with a molar cantilever are greater than for mandibular restorations. A literature review of full-arch prostheses reports an implant failure rate three times higher in full-arch maxillary implant fixed restorations than with mandibular full-arch implant restorations.[30] The treatment plan should be different for the two arches.

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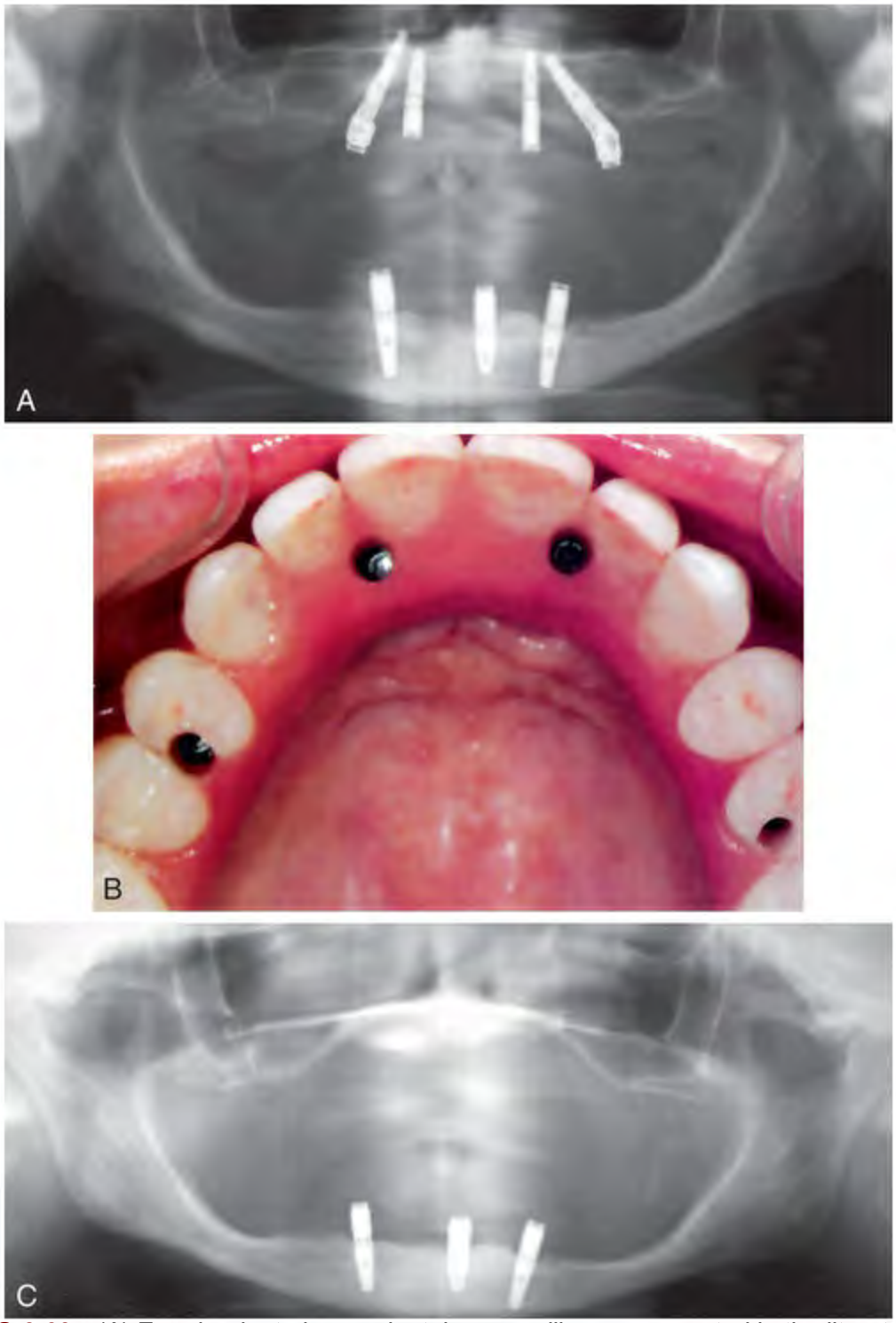

FIG 3.60 (A) Four implants in an edentulous maxilla are suggested in the literature to support a fixed prosthesis. (B) The fixed prosthesis supported by four anterior implants most often cantilevers the molars. In addition, there is also an offset cantilever to the facial in both the anterior and posterior regions. (C) The failure rate of the maxillary implants usually causes additional bone loss. The maxilla may be unable to be restored without advanced bone grafts, more implants, and a new prosthesis. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The key implant positions for an edentulous maxilla are the distal of the

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first molars bilaterally, the bilateral canines, and an implant in one of the central incisor positions between the canines. This permits the five sections of an arch to be splinted together and take advantage of the biomechanics of an arch (Fig. 3.61).

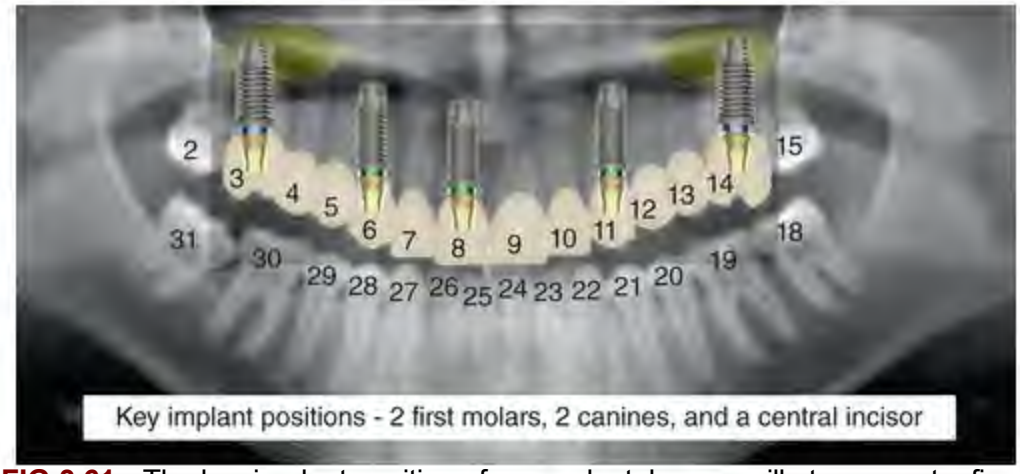

FIG 3.61 The key implant positions for an edentulous maxilla to support a fixed prosthesis (or RP-4 prosthesis) are the bilateral molars, the bilateral canines, and an implant in one of the central incisor positions. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Implant Number

Treatment Planning

In the past, the number of implants most often was determined in relation to the amount of available bone. This concept became popular in the mid 1980s, when the Brånemark philosophy of osseointegrations was introduced for completely edentulous arches. In an edentulous arch, four to six anterior implants were used in available bone situations between the mental foramina in the mandible and anterior to the maxillary sinuses in the maxilla for a full-arch fixed prosthesis. The prosthesis cantilevered the molars from the anterior implant positions. Four implants were used in moderate to severe atrophic ridges for a fixed full-arch prosthesis.[31] This concept has been expanded to include zygomatic implants in the posterior regions, which engage the palate and the apical 4 mm of the zygomatic process (passing through the maxillary sinuses) (Fig. 3.62). This treatment option does not consider the force magnifiers of CHS or the A-P spread of the implants in relationship to the anterior cantilever replacing the anterior teeth. In addition, when four implants support a 12-unit fixed prosthesis, the position of the implants cannot follow the four key implant position rules, and there are often no implants in the canine positions and more than three pontics between the anterior implants or three pontics cantilevered from the most distal implants.

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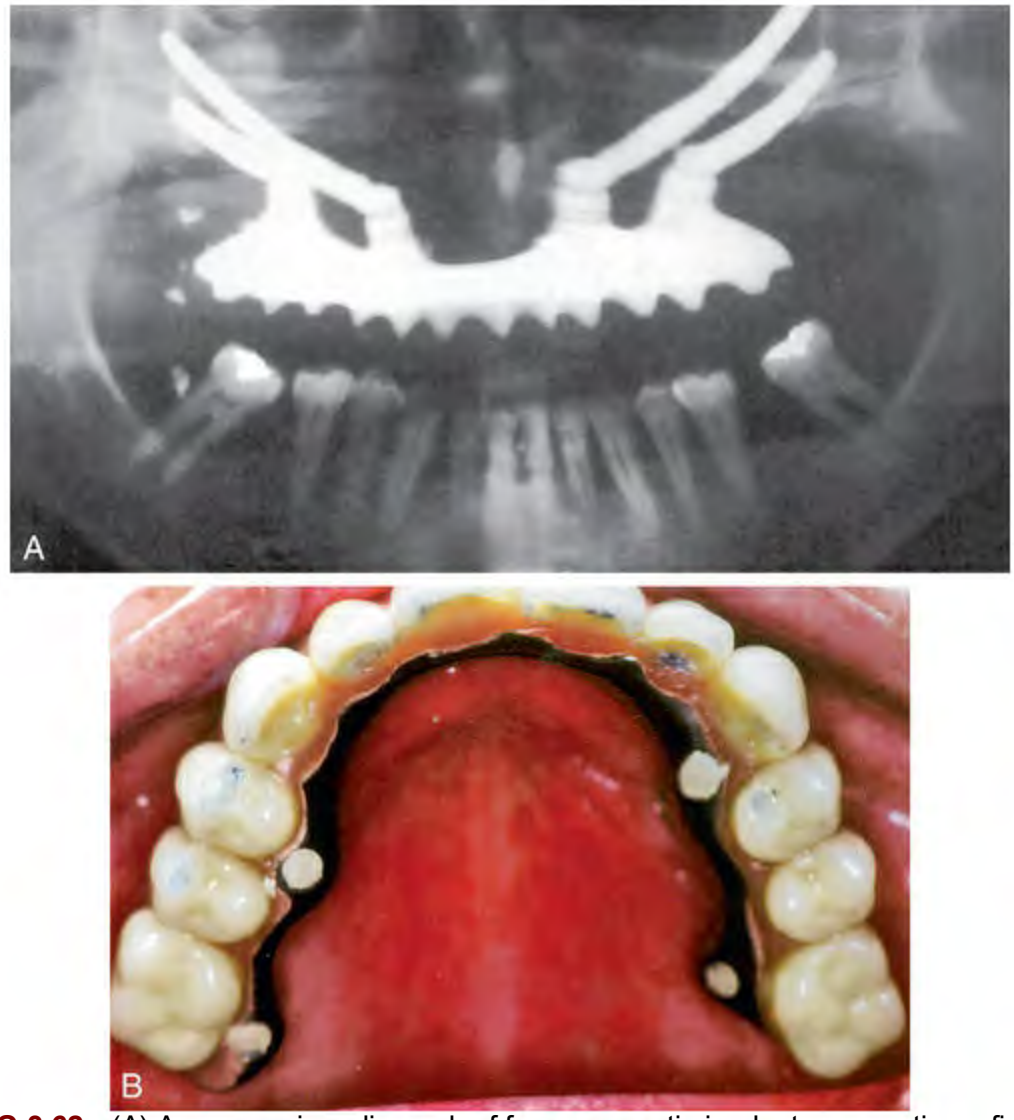

FIG 3.62 (A) A panoramic radiograph of four zygomatic implants supporting a fixed prosthesis in the maxilla. (B) The full-arch maxillary prosthesis is cantilevered to the facial, and there are six adjacent pontics in the anterior region, including a canine position. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In full-arch prostheses, studies comparing six implants to four- and three-implant abutments show better distribution and reduced stress on the six-implant system components (crown, cement, abutment, abutment screw, marginal bone, implant-bone interface, and implant components) (Fig. 3.63).[32] Silva et al evaluated, with three-dimensional finite element analyses, the difference in four vs. six implants to support a full-arch cantilevered prosthesis.[29] The cantilever length and crown height were similar in both models. The six-implant support model reduced the stress to the implant-bone regions between 7% to 29%, depending on the direction and position of the applied load.

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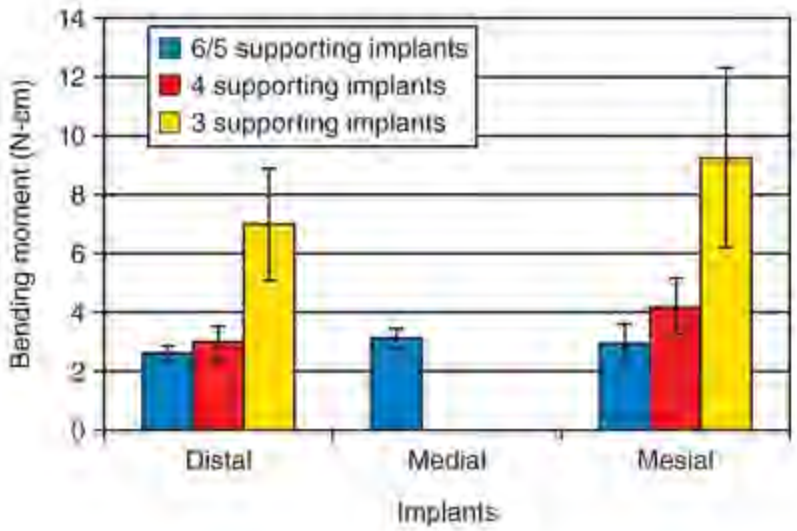

FIG 3.63 The more implants supporting a fixed prosthesis, the lower the bending movement and stress in the support system. (From Misch CE: *Dental implant prosthetics*, 2e, St. Louis, 2015, Mosby; Data from Duyck J, Van Doosterwyck H, Vandersloten J, et al: Magnitude and distribution of occlusal forces on oral implants supporting fixed prostheses: an in vivo study, *Clin Oral Implants Res* 2:465–475, 2000.)

In rare cases, four implants in the mandible between the foramen may be used to support a full-arch implant-supported prosthesis—fixed or RP-4. The implants are typically positioned in the first to second premolar positions, and the canines. However, the other patient force factors should be low (e.g., no moderate to severe parafunction, crown height space less than 15 mm, older woman, and opposing a maxillary complete denture). In addition, the bone density should be favorable (D2). When all of these conditions are not present, consideration is given to the five key implant positions, and more implants are indicated when stress factors are moderate to severe.

When a full-arch fixed implant restoration is the treatment for a maxillary arch, the suggested number of implants by some authors is often the same as the mandible. For example, "all on four" is a common treatment option presented to the profession in either arch along with similar fees for either arch to the patient (Fig. 3.64).[33] Yet a literature review reveals the failure rate of the full-arch maxillary restoration is three times greater than the mandible.[30] The hardness of the bone is related to its strength. The mandible more often has hard (strong) bone, and the maxilla more often has softer bone. In fact, the posterior maxillary bone may be 5 to 10 times weaker than the hard bone of the anterior mandible.[34] As a result, more implants should be used in the poorer-quality bone found in the maxilla. Increasing the implant number decreases the periimplant bone stress.

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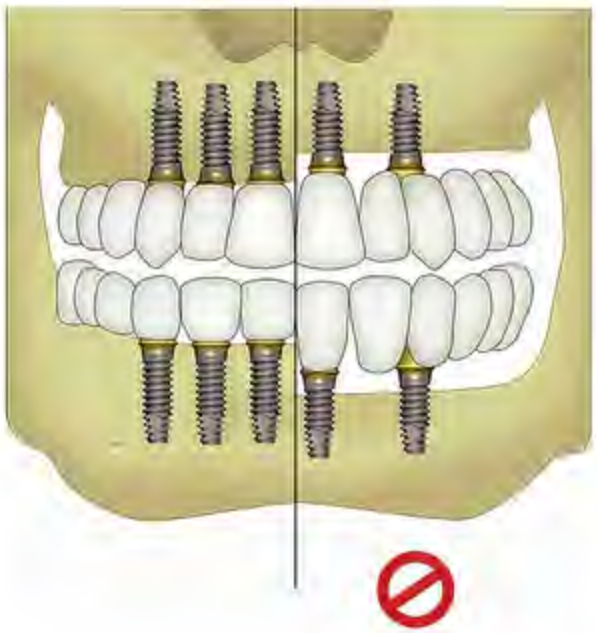

FIG 3.64 Full-arch implant fixed restoration by many authors uses the same number of implants in the maxilla and mandible. However, three times greater failure rates are observed in the maxillary arch. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The maxillary anterior arch receives a force at a 12- to 15-degree angle during occlusion and up to a 30-degree angle in excursions. A 15-degree angled force increases the force component on the implant by 25.9%, and a 30-degree force increases the force by 50%.[35] This is a biomechanical rationale for why maxillary anterior teeth are larger than the mandibular anterior teeth. Hence, the size or number of implants in the anterior maxilla should be greater than an anterior mandible.

The excursive forces in a maxillary restoration come from within the arch to push outside the arch. This force direction on the maxillary arch is more detrimental than in the mandible. The mandible receives a force from outside of the arch toward the inside of the arch, which is the mechanism of force the Roman or gothic arch was designed to resist. As a result of these biomechanical issues, more implants should be used in maxillary compared with mandibular restorations. It is probably not a coincidence that there are more roots for the teeth in the maxillary arch compared with those in the mandibular arch.

The minimum number of implants used to support a restoration should include all of the key implant positions. Yet the number of implants in a treatment plan should rarely be the minimum. There is no safety factor if an implant fails: the prosthesis becomes partially unretained, or the patient has a parafunctional episode. For example, if 25 patients receive four implants to

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support a fixed prosthesis, there would be 25 fixed prostheses and 100 implants in the report. This type of treatment planning may initially be less expensive for the patient, but an implant failure any time after implant surgery places the patient's restoration at considerable risk. If each patient lost one implant with this implant number per prosthesis, the overall implant success would be 75%, but there would only remain three implants in each patient. As a result, all 25 fixed prostheses would be at risk of overload failure. If 20% of the implants fail (with one failure per patient), only 5 of the 25 patients would have four implants to support the restoration (only 20% of the patients would be restored with a fixed prosthesis) (Table 3.2).[17]

TABLE 3.2

Implants vs. Prosthesis Success: Four Implants per Prosthesis for 25 Patients (100 Implants for 25 Prostheses)

Implant Number Success Rate	Prosthesis Number	Prosthesis Success Rate
100%	25	100%
90%	15	60%
80%	5	20%
75%	0	0%

(From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

If the 25 edentulous patients in this example have eight implants to support a full-arch, 12-unit fixed prosthesis, the risk of prosthesis failure is significantly reduced (Table 3.3). If each patient loses one implant, most likely all patients would still be able to function with their original prosthesis. Even if all 25 patients lost two implants, the 25 restorations may still function without risk (depending on the implant failure location). The additional implants also reduce the cantilever length and reduce the number of pontics in the prosthesis, providing more abutments for greater retention of the restoration, with reduced risk of screw loosening or uncemented prosthesis. As a general rule, it is better to err on the side of safety in numbers than on the side of too few implants. When in doubt, add an additional implant to the treatment plan.

TABLE 3.3

Implants vs. Prosthesis Success: Eight Implants per Prosthesis for 25 Patients (200 Implants for 25 Prostheses)

Implant Number Success Rate	Prosthesis Number	Success Rate
100%	25	100%
87.5%	25	100%
75%	25	100%

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Influence of Patient Force Factors on Implant Number

The additional number of implants, after the key implant sites are established, are related to the patient force factors and the bone density.[18] Five patient force factors determine the amount of stress transmitted to the prosthesis. They are:

1. Parafunction

Bruxism (severe, moderate, mild, absent; this is the most important stress factor)

Clenching (force magnitude may be as great as bruxism)

2. Masticatory muscle dynamics

Sex (men have greater force)

Age (younger patients have greater force and live longer)

Size (larger patients have greater force)

3. Crown height space

Double the crown height and double the force with any

angled load or cantilever (mesial, distal, facial, or lingual)

4. Arch position

a. Anterior regions: low forces

b. Canine and premolar: medium forces

c. Posterior regions: high forces

5. Opposing dentition

a. Denture: lowest force

b. Natural teeth: intermediate force

c. Implant fixed prosthesis: higher forces

Not all patient force factors have the same risk.

In conclusion, whenever the patient force factors are greater than usual, additional implants should be added to support the prosthesis. Of the patient force factors, severe bruxism is the most significant followed by clenching and CHS, region of the mouth, masticatory dynamics, and the opposing arch.

Influence of Bone Density on Implant Number

The additional number of implants after the key implant sites are established is also related to the density of bone. The softest bone type (D4) has (1) the lowest strength and may be 10 times weaker than the strongest bone type on a scale of 1 to 10 for bone strength (D4 bone is a 1 or 2); (2) the greatest biomechanical mismatch with its modulus of elasticity compared with titanium; (3) the lowest bone-implant contact (≈25%) and higher stresses

(stress = force/area); and (4) strains in the bone are transmitted not only at the crest but also along the entire bone-implant surface.

The soft bone type (D3) has (1) a low bone strength, which is 50% weaker than hard bone (D2) (on a 10-point scale, its strength is a 3 to 4); (2) intermediate difference of modulus of elasticity compared with titanium; (3) low bone-implant contact (≈50%); and (4) strain patterns at the crestal half of the implant.

The hard bone (D2) has (1) ideal strength (a 7 to 8 on a 10-point scale), (2) high bone-implant contact (≈75%), (3) more stiff modulus of elasticity, and (4) strain patterns primarily at the crestal region of the implant. The hardest bone (D1) has the best biomechanical features of (1) strength (9 to 10 on a 10-point scale), (2) highest bone-implant contact (above 85%), (3) stiffest modulus of elasticity, and (4) strain values above the first thread.

As the bone quality is reduced, the number of implants to support the prosthesis should increase. The risk factor scale for bone density is inversely related to the strength of the bone scale. D4 bone is a 10, D3 bone is an 8, D2 bone is a 4, and D1 bone is a 2. When the implants are inserted into D4 bone, a larger-diameter or another implant is suggested, depending on the number of teeth replaced. A full-arch fixed restoration in the mandible with D2 bone may often have five implants, but in D4 bone, nine implants may be appropriate. The total number of implants is related to the key implant positions plus the influence of the patient force factors and the quality of bone.

In conclusion, the decision for the number of implants in the treatment plan begins with the implants in the ideal key positions. Additional numbers are most often required and are primarily related to the patient force factors or to bone density in the edentulous sites. For example, a young, large man who bruxes severely with greater-than-normal CHS in the posterior regions of the mouth opposing an implant restoration will require one implant for each missing root (two implants for each molar). Likewise, patients with moderate force factors and poor bone density (D4 bone) in the implant sites may also require this many implants.

Implant Number: Full-Arch Mandibular Fixed Prosthesis

As a general observation, the number of implants to replace all of the mandibular teeth ranges from five to nine, with at least four between the mental foraminae. When the implants are limited to sites anterior to the mental foraminae to support a fixed prosthesis, a cantilever must be

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designed. Cantilevers in the mandible should ideally be projected in only one posterior quadrant to increase the A-P distance and reduce the force to the implants (Fig. 3.65). Whenever possible, at least one implant should be positioned in a first molar site. When implants are positioned in four of the five open pentagon positions in the mandible, a cantilever is at a reduced risk of overload because of favorable dynamics of an arch, increased A-P distance, and usually a more favorable bone density. When seven or more implants are used in the edentulous mandible with bilateral molar implants, two separate restorations may be fabricated with no posterior cantilever to permit mandibular flexure and torsion. Usually, the second molar is not replaced in the edentulous mandible.

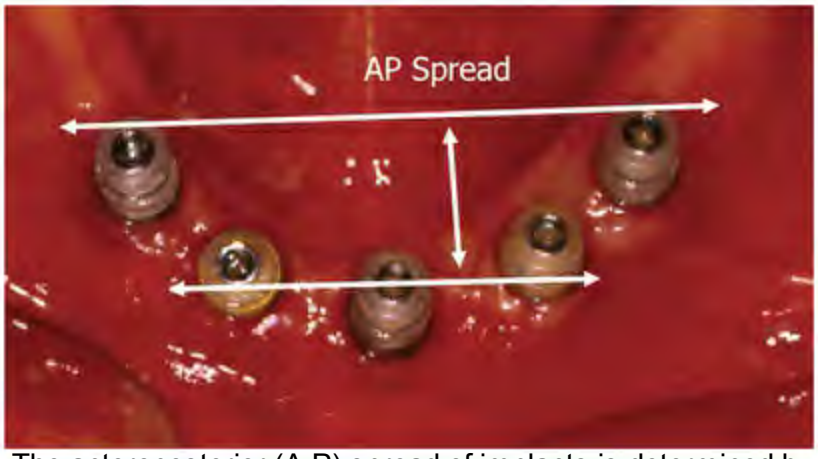

FIG 3.65 The anteroposterior (A-P) spread of implants is determined by drawing a line from the distal of the last implant on each side and a parallel line through the middle of the most anterior implant.

Implant Number: Full-Arch Maxillary Fixed Prostheses

The edentulous maxillary fixed prosthesis should usually not have a cantilever. The first seven ideal sites are often the bilateral first molars, bilateral second premolars, bilateral canines, and one implant between the canine positions (Fig. 3.66). These positions satisfy the key implant positions and add an implant in the posterior region because the bone density is often poor. Additional implants in the bilateral second molar sites are a benefit to increase the A-P distance of the implants, which counters the anterior bite forces that may be increased from parafunction and so on (Fig. 3.67). A greater number of implants are generally required in the maxilla to compensate for the less dense bone and more unfavorable biomechanics of

the premaxilla and range from 7 to 10 implants with at least three implants from canine to canine (Fig. 3.68).

FIG 3.66 In an edentulous maxilla, the most common additional implant site is in the second premolar region. Seven implants (or more) are most often used to support a fixed (or RP-4) prosthesis. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

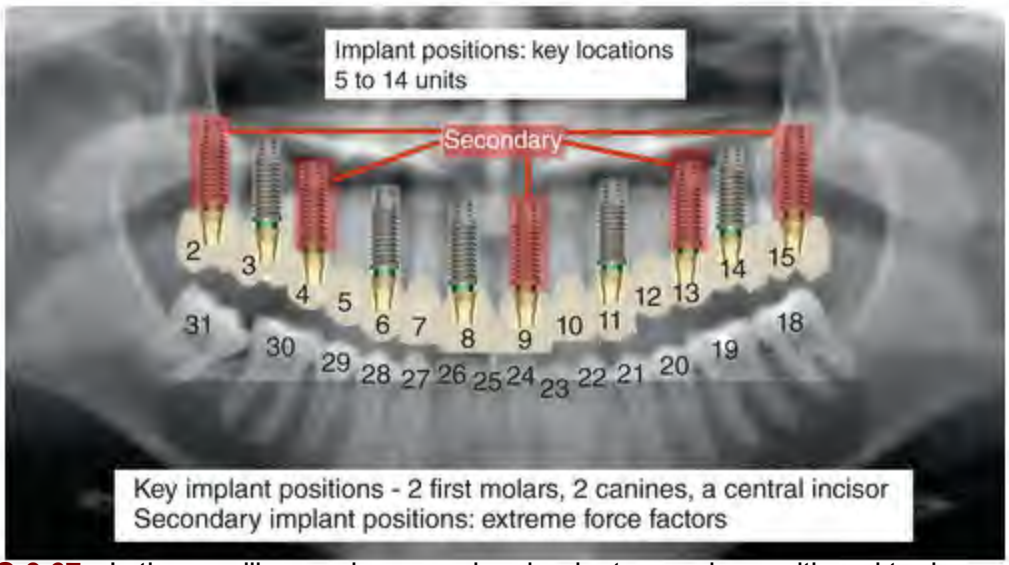

FIG 3.67 In the maxillary arch, secondary implants may be positioned to decrease the stress in soft bone or in patients with high force factors. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 3.68 (A) A panoramic radiograph of a maxillary bilateral sinus graft and maxillary and mandibular iliac crest bone grafts. Eight implants were used in the maxilla and seven implants in the mandible. (B) An intraoral view of the maxillary and mandibular implants. (C) FP-3 fixed restorations in situ. (D) A panoramic radiograph of the implants and fixed restorations. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Force-Related Issues

Parafunction

Definition

Parafunctional forces on teeth or implants are characterized by repeated or sustained occlusion (e.g., habitual movements) and have long been recognized as harmful to the stomatognathic system. These same forces, when applied to implant prostheses, have been shown to be very harmful.

General Complications

The lack of rigid fixation during implant healing may be a result of parafunction on soft tissue–borne prostheses overlying the submerged implant (e.g., interim prosthesis). The most common cause of both early and late implant failure after successful surgical fixation is the result of parafunction. Such complications occur with greater frequency in the maxilla because of a decrease in bone density and an increase in the moment of force. The presence of these parafunctional conditions must be carefully noted during the early phases of treatment planning.

Classification

The classification of parafunction involves (1) bruxism, (2) clenching, and (3) tongue thrust or increased size. The dental literature usually does not identify bruxism and clenching as separate entities. Although several aspects of treatment are similar, their diagnosis and treatment are in some ways different.

Bruxism and clenching are the most critical factors to evaluate in any implant reconstruction. Long-term success will not be achieved with severe parafunction of bruxism or clenching. The implant clinician should always try to diagnose the presence of these two conditions.

This does not mean that patients with moderate and severe parafunction are absolute contraindications to implant treatment. Because patients with moderate to severe parafunction represent so many additional risks in implant dentistry, one must be aware of these conditions and the methods to reduce their noxious effects on the entire implant-related system. Unfortunately, parafunction may be a difficult entity to diagnose, especially if the patient is completely edentulous and is wearing a recently fabricated prosthesis.

Bruxism.

Bruxism primarily concerns the horizontal, nonfunctional grinding of teeth. The forces involved are in significant excess of normal physiologic masticatory loads. Bruxism may affect the teeth, muscles, joints, bone, implants, and prostheses. These forces may occur while the patient is awake or asleep and may generate increased force on the system several hours per day. Bruxism is the most common oral habit and may be difficult to diagnosis.

The maximum biting force of bruxing patients is greater than average. Fortunately, the bite force does not continue to increase in most bruxing patients. When muscles do not vary their exercise regimen, their size and function adjust to the dynamics of the situation. As a result, the higher bite forces and muscle size usually do not continue in an unending spiral.

Diagnosis.

Bruxism does not necessarily represent a contraindication for implants, but it does dramatically influence treatment planning. The first step is to recognize the condition before the treatment is rendered. The symptoms of this disorder may be ascertained by a dental history and may include repeated headaches, a history (or presence) of fractured teeth or restorations, repeated uncemented restorations, or jaw discomfort upon awakening. When the patient is aware of muscle tenderness or the spouse is conscious of the noise of bruxism during sleep, the diagnosis is readily obtained. However, many patients do not attribute these problems to excessive forces on the teeth and report a negative history. A lack of these symptoms does not negate the possibility of bruxism (Box 3.8).

Box 3.8

Bruxism

Symptoms

Frequent headaches – Pain on opening/closing

History or presence of fractured teeth and/or restorations

Repeated uncemented restorations

Jaw tension and discomfort upon awakening

Muscle soreness and tenderness

Spouse awareness during sleep

Clinical signs.

Fortunately, many clinical signs of bruxism warn of excessive grinding. The signs of bruxism include an increase in size of the temporalis and masseter muscles. These muscles and the external pterygoid may also be tender during palpation. In addition, other signs include deviation of the lower jaw on opening, limited occlusal opening, increased mobility of teeth, cervical abfraction of teeth, fracture of teeth or restorations, and uncemented crowns or fixed prostheses (Box 3.9).

Box 3.9

Bruxism

Clinical Signs of Bruxism

1. Increase in muscle size of temporalis and masseter muscles

2. Temporalis, masseter, or external pterygoid muscles tender to palpation

3. Mandibular deviation while opening

4. Limited occlusal opening

5. Tooth mobility

6. Cervical abfraction of teeth

7. Fracture of teeth or restorations

8. Uncemented crowns or restorations

9. Wearing (attrition) of natural teeth

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. Tooth sensitivity

Clinical exam.

A physical examination for the implant candidate should include palpation of the muscles of mastication including the masseter, temporalis, and internal and external pterygoid muscles. Hyperactive or hypertrophied muscles are the most common sign of bruxing. The lateral pterygoid muscle is more often overused by the bruxing patient and is often difficult to palpate. The ipsilateral medial pterygoid muscle provides more reliable information in this region. It acts as the antagonist to the lateral pterygoid in hyperfunction and, when tender, provides a good indicator of overuse of the lateral pterygoid.[36] However, the most effective method to diagnose bruxism is to evaluate the wearing of the natural teeth. Nonfunctional wear facets on the incisal edges occur most often on natural teeth rather than on crowns made of porcelain or metal occlusal, especially in the anterior mandible and maxillary canines. Enamel opposing enamel causes more occlusal material wear than almost any other combination (e.g., enamel opposing metal, metal opposing metal, etc.).[37] As a result, in a partially edentulous patient, enamel wear is easily observed in the bruxing patient.

Not only is enamel wear the easiest method to determine bruxism in a dentate patient but Misch has noted the disorder may also be classified as absent, mild, moderate, or severe. No anterior wear patterns in the teeth signifies an absence of significant bruxism. Mild bruxism has slight wearing of anterior teeth but is not a cosmetic compromise (Fig. 3.69). Moderate bruxism has obvious anterior incisal wear facets but no posterior occlusal wear pattern (Fig. 3.70). Severe bruxism has an absence of incisal guidance as a result of the excessive wear, and posterior wearing of the teeth is obvious (Fig. 3.71).

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FIG 3.69 (A) Mild bruxism. Note the wear facet on the mandibular canine and the slight notch in the maxillary lateral incisor. (B) Patients often grind their teeth in a specific, repeated movement of the mandible, called an engram. When the opposing wear facets of the teeth are in contact, one should note the occlusal position of the teeth. The patient shown in A has a working contact on the mandibular premolar with the maxillary canine in this engram position. The slight cervical abfraction of the mandibular first premolar is a consequence of the parafunction. The patient's posterior teeth should not occlude in this position to decrease the amount of force on the anterior teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 3.70 (A) Moderate bruxism of the central incisors (there is an esthetic consequence). (B) The engram position placed the mandibular anterior teeth anterior to the maxillary incisal edge and caused the wear of the central incisors. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 3.71 This patient has severe bruxism because occlusal wear is both anterior and posterior (right). The incisal guidance should be reestablished before a maxillary arch fixed reconstruction. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Complications

Posterior wear facets.

Tooth wear is most significant when found in the posterior regions and changes the intensity of bruxism from the moderate to the severe category. Posterior wear patterns are more difficult to manage because they are usually related to a loss of anterior guidance in excursions, and when the posterior teeth contact in excursive jaw positions, greater forces against the teeth are

generated.[38] The masseter and temporalis muscles contract when posterior teeth contact. With incisal guidance and an absence of posterior contact in a lateral excursion of this jaw, two thirds of these muscles do not contract and, as a consequence, the bite force is dramatically reduced. However, when the posterior teeth maintain contact, the bite forces are similar in excursions, as during posterior biting. In a patient with severe bruxism, the occlusal plane or the anterior incisal guidance may need modification to eliminate all posterior contacts during mandibular excursions before the implant restoration.

Repeatable movement.

Bruxing patients often repeat the same mandibular movements, which are different from border movements of the mandible and are in one particular direction. As a result the occlusal wear is very specific and primarily on one side of the arch or even on only a few teeth (Fig. 3.72). This engram pattern usually remains after treatment. If the restoring dentist reestablishes incisal guidance on teeth severely affected by an engram bruxing pattern, the incidence of complications on these teeth will be increased. If the patient wears an occlusal guard, it is usually easy to see the repeatable excursive movements.

FIG 3.72 This patient exhibits an engram pattern of bruxism primarily toward the left premolar to central incisors. The right canine and lateral incisor have far fewer wear facets. Incisal guidance should be restored before any left posterior restoration. This "pathway of destruction" is specific. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Component fracture.

Because patients that exhibit bruxism have increased occlusal force, and much of the force results in lateral (nonaxial) loading, this may be very damaging to the implant system. An increased probability of crestal bone loss, implant fracture, abutment screw loosening, porcelain fracture, or unretained restorations.[17]

Clenching.

Clenching is a habit that generates a constant force exerted from one occlusal surface to the other without movement. The habitual clenching position does not necessarily correspond to centric occlusion. The jaw may be positioned in any direction and position before the static load; therefore a bruxing and clenching combination may exist. The clench position most often is in the same repeated position and rarely changes from one period to another. The direction of load may be vertical or horizontal. The forces involved are in significant excess of normal physiologic loads and are similar to bruxism in amount and duration; however, several clinical conditions differ in clenching.[39]

Diagnosis.

Many clinical symptoms and signs warn of excessive grinding. However, the signs of clenching are often less obvious. The forces generated during clenching are usually directed more vertically to the plane of occlusion, at least in the posterior regions of the mouth. Wearing of the teeth is usually not evident, and clenching often is not diagnosed during the intraoral examination. As a result, the clinician must be more observant to the diagnosis of this disorder.

Clinical signs.

Many of the clinical signs of clenching resemble bruxism. When a patient has a dental history or presence of muscle tenderness (often upon awakening) or tooth sensitivity to cold, parafunction is strongly suspected. In the absence of tooth wear, clenching is the prime suspect. Tooth mobility, temporalis, lateral pterygoid, or masseter muscle tenderness or hypertrophy, deviation of the mandible during occlusal opening, limited opening, stress lines in enamel, cervical abfraction, and material fatigue (enamel, enamel pits, porcelain and implant components) are all associated clinical signs of clenching.[40] When the clinical signs of excessive force appear on the teeth, muscles, or joint in the absence of incisal wear, clenching is strongly suspected.

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A most common clinical finding of clenching is a scalloped border of the tongue. The tongue is often braced against the lingual surfaces of the maxillary or mandibular teeth during clenching, exerting lateral pressures and resulting in the scalloped border. This tongue thrust position may also be accompanied by an intraoral vacuum, which permits a clench to extend for a considerable time, often during sleep. When the clinician asks the patient to open wide to evaluate maximum occlusal opening (while palpating the temporomandibular joint [TMJ]), the lateral tongue contour is observed to notice any scalloped border (Box 3.10).

Box 3.10

Clenching: Clinical Signs

- History or presence of temporalis, lateral pterygoid, or masseter muscle tenderness (often upon awakening)
- Tooth sensitivity
- Tooth mobility
- Temporalis, lateral pterygoid, or masseter muscle hypertrophy
- Deviation of mandible during opening
- Limited opening – pain on opening
- Stress lines in enamel
- Cervical abfraction
- Material fracture (enamel pits, restorations) – porcelain fracture
- Scalloped border of tongue – presence of antegonial notch at the angle of the mandible

Clinical exam.

Muscle evaluation for clenching (and bruxism) includes deviation during opening of the jaw, limited opening, and tenderness of the TMJ. Deviation to

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one side during opening indicates a muscle imbalance on the same side.[36] Limited opening is easily evaluated and may indicate muscular imbalance or degenerative joint disease. The normal opening should be at least 40 mm from the maxillary incisal edge to the mandibular incisal edge in an Angle Class I patient, taking into consideration an overjet or overlap. If any horizontal overjet or overlap exists, its value in millimeters is subtracted from the 40-mm minimum opening measurement.[41] The range of opening without regard for overlap or overjet has been measured in the range of 38 to 65 mm for men and 36 to 60 mm for women from incisal edge to edge.[42]

Increased mobility of teeth may be an indication of a force beyond physiologic limits, bone loss, or their combination. This requires further investigation in regard to parafunction and is very important if an implant may be placed in the region of the mobile teeth. The rigid implant may receive more than its share of occlusal force when surrounded by mobile teeth. Fremitus, a vibration type of mobility of a tooth, is often present in the clenching patient. To evaluate this condition, the dentist's finger barely contacts the facial surface of one tooth at a time and feels for vibrations while the patient taps the teeth together. Fremitus is symptomatic of a local excess of occlusal loads.

Cervical erosion is often a sign of parafunctional clenching (Fig. 3.73). The notched appearance of the cervical portion of the tooth directly correlates with the concentration of forces shown in three-dimensional finite analysis and photoelasticity studies.[43] Abfraction of teeth was also observed in cats, rats, and marmosets and was described in the literature as early as 1930. A study of a noninstitutionalized older human population revealed that cervical abrasion was present in 56% of the participants.[44]

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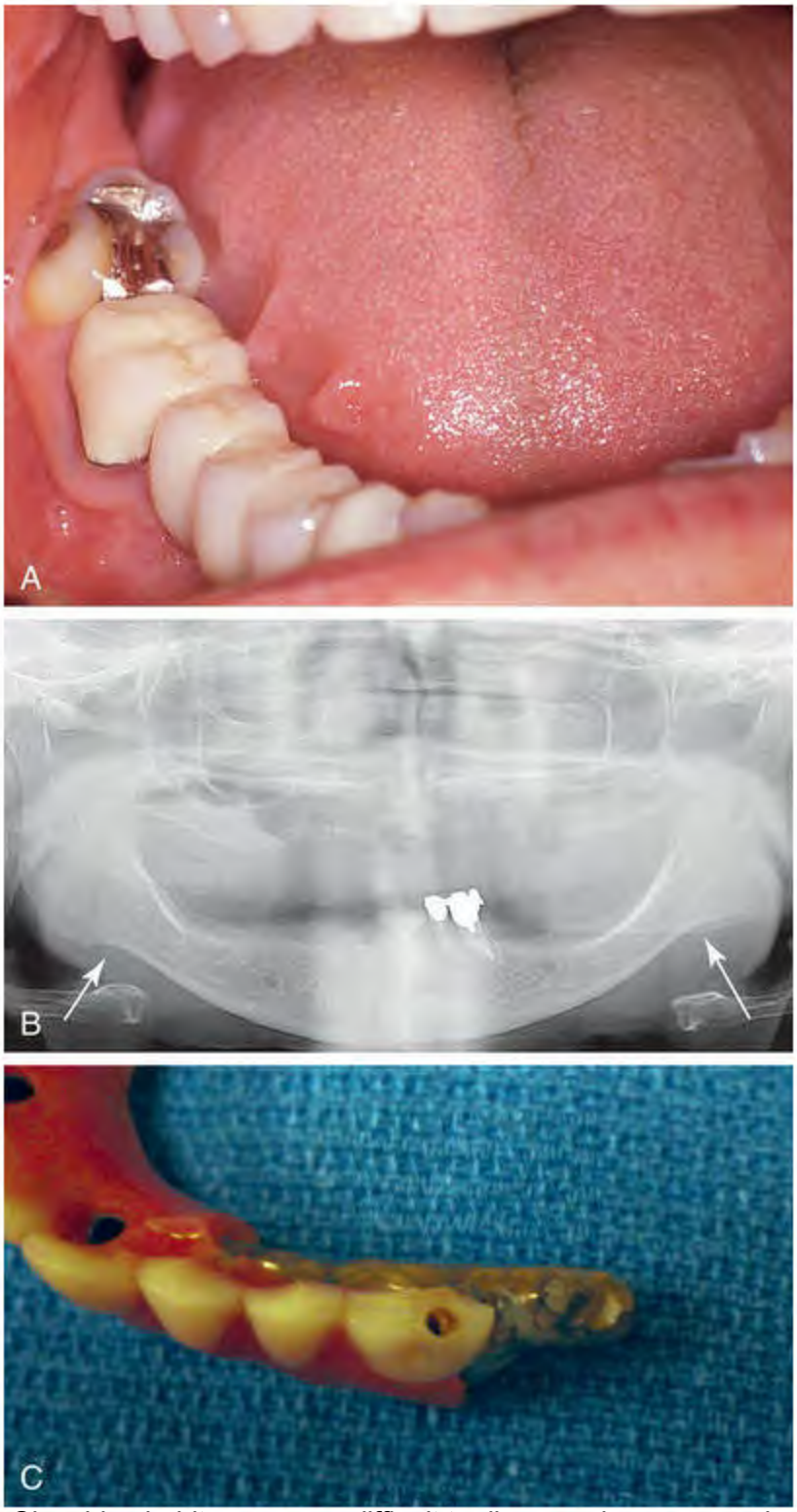

FIG 3.73 Clenching habits are more difficult to diagnose because occlusal wear is often absent. (A) A common sign is scalloping of the tongue, which results from tongue protrusion during clenching. (B) Antegonial notch, which results from massetter hypertrophy. (C) Prosthesis fracture resulting from excessive biomechanical force.

Complications

Postoperative care.

A common cause of implant failure during healing is parafunction in a patient wearing a soft tissue–supported prosthesis over a submerged implant. The tissue overlying the implant is compressed during the parafunction episode. The premature loading may cause micromovement of the implant body in the bone and may compromise osteointegration. When an overlying soft tissue–borne restoration exerts pressure as a result of parafunction, pressure necrosis causes soft tissue dehiscence over the implant. This condition is not corrected by surgically covering the implant with soft tissue, but the soft tissue support region of the prosthesis over the implant should be generously relieved during the healing period whenever parafunction is noted. With metal-free partial dentures, this may weaken the prosthesis leading to possible fractures.

Treatment Planning for Parafunction Patients (Clenching/Bruxism)

Progressive Bone Loading.

The time intervals between prosthodontic restoration appointments may be increased to provide additional time to produce load-bearing bone around the implants through progressive bone-loading techniques.[45] By utilizing the progressive bone loading technique, poorer bone density is transformed into better quality bone, which is more ideal for excessive occlusal loads.

Greater Surface Area.

Anterior implants that are subjected to parafunctional forces are problematic because they are usually nonaxial or shear forces. To counteract this excessive force the use of wider-diameter implants or additional number of implants (i.e., greater surface area) should be treatment planned.

Occlusion.

With parafunctional habits, the occlusion must be strictly designed and monitored. Ideally, the patient should be maintained in a canine guided occlusion, as long as the canines are healthy. Mutually protected occlusion, with additional anterior implants or teeth distributing forces, is developed if

the implants are in the canine position or if this tooth is restored as a pontic. The anterior teeth may be modified to recreate the proper incisal guidance and avoid posterior interferences during excursions.

The elimination of posterior lateral occlusal contacts (i.e., nonaxial loading) during excursive movements is recommended when opposing natural teeth or an implant or tooth-supported fixed prosthesis. This is beneficial in two aspects: (a) because lateral forces dramatically increase stress at the implant-bone interface, the elimination of posterior contacts diminishes the negative effect of angled forces during bruxism, and (b) the presence of posterior contacts during excursions, and almost all fibers of the masseter, temporalis, and the external pterygoid muscles contract and place higher forces on the anterior teeth and implants. On the contrary, during excursions in the absence of posterior contacts, fewer fibers of the temporalis and masseter muscles are stimulated, and the forces applied on the anterior implant–teeth system are reduced by as much as two thirds.

Prosthesis Design.

The prosthesis may be designed to improve the distribution of stress throughout the implant system with centric vertical contacts aligned with the long axis of the implant whenever possible. Narrow posterior occlusal tables to prevent inadvertent lateral forces and to decrease the occlusal forces are beneficial. Enamoplasty of the cusp tips of the opposing natural teeth is indicated to help improve the direction of vertical forces within the guidelines of the intended occlusion (i.e., improve plane of occlusion) newer occlusal materials (e.g., zirconia). Wider implant bodies, harder cement types (e.g., zinc phosphate vs. zinc oxide), titanium alloy implant bodies, and more implants splinted together are all beneficial.

Occlusal Guard.

The most important treatment for a patient with parafunctional habits is the use of an occlusal guard. Ideally, patients should wear a hard, processed acrylic occlusal guard at night. The guard will absorb the majority of the parafunctional forces, reducing the damaging forces to the implant system. Patients should also be instructed to wear the guard during any time they might exhibit parafunction, such as stressful time periods, driving, and working at a computer.

Tongue Thrust and Size.

Parafunctional tongue thrust is the unnatural force of the tongue against the teeth during swallowing. A force of approximately 41 to 709 g/cm^2 on the anterior and lateral areas of the palate has been recorded during swallowing.[46] These forces may cause clinical complications.

Types.

Several different types of tongue thrust have been identified; anterior, intermediate, posterior, and either unilateral or bilateral, which may be found and in almost any combination (Fig. 3.74). To evaluate anterior tongue thrust, the doctor holds the lower lip down, squirts water into the mouth with the water syringe, and asks the patient to swallow. A normal patient forms a vacuum in the mouth by positioning the tongue on the anterior aspect of the palate and is able to swallow without difficulty. A patient with an anterior tongue thrust is not able to create the vacuum needed to swallow when the lower lip is retracted because the seal and vacuum for the patient are achieved between the tongue and the lower lip. As a consequence, the patient is unable to swallow while the lower lip is withdrawn.

FIG 3.74 Patient with anterior openbite secondary to tongue thrust. Because of the openbite, the patient has no anterior guidance with mandibular excursions.

A posterior tongue thrust is evaluated by retracting one cheek at a time away from the posterior teeth or edentulous region with a mouth mirror, injecting water into the mouth with a water syringe and asking the patient to swallow. Visual evidence of the tongue during deglutition may also be accompanied by pressure against the mirror and confirms a lateral force.

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Complications

Early loading.

Although the force of tongue thrust is of lesser intensity than in other parafunctional forces, it is horizontal and can increase stress at the permucosal site of the implant. This is most critical for one-stage surgical approaches and immediate restoration of implants in which the implants are in an elevated position at initial placement and the implant interface is in an early healing phase. If the natural teeth in the region of the tongue thrust were lost as a result of an aberrant tongue position or movement, the implants are at increased risk during initial healing and early prosthetic loading (Box 3.11).

Box 3.11

Parafunction

Tongue Thrust and Size

1. Tongue thrust

a. Less force than bruxism or clenching

b. Is constant

c. Horizontal direction

2. Several types possible

a. Anterior

b. Intermediate

c. Posterior unilateral or bilateral

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3. Incision line opening after surgery

4. Early loading risk for one stage or immediate restorations

5. Prosthetic complications

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Incision line opening.

The tongue thrust may also contribute to incision line opening after bone grafting or implant surgery, which may compromise both the hard and soft tissues. This is especially noteworthy in a bone augmentation procedure.

Tooth movement.

A tongue-thrust habit may lead to tooth movement or mobility, which is of consequence when implants are present in the same quadrant. If the remaining teeth exhibit increased mobility, the implant prosthesis may be subject to increased occlusal loads.

Inadequate tongue room.

A potential prosthetic complication for a patient with a lateral tongue thrust is the complaint of inadequate room for the tongue after the mandibular implants are restored. A prosthetic mistake is to reduce the width of the lingual contour of the mandibular teeth to give the tongue more space. The lingual cusp of the restored mandibular posterior teeth should follow the curve of Wilson and have a proper horizontal overjet to protect the tongue during function. A reduction in the width of the mandibular posterior teeth often increases the occurrence of tongue biting and may not dissipate with time. When the lingual surface of the mandibular restoration is reduced, the entire prosthesis may need to be refabricated. The restoring dentist should identify the tongue position before treatment and inform the patient about the early learning curve for the tongue once the teeth are delivered on the implants (Fig. 3.75).

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FIG 3.75 In a patient with missing teeth and no prosthetic replacement, such as a complete or partial denture, the tongue often increases in size. The tongue does not transfer an active lateral force during swallowing. This tongue type will adapt most often to a mandibular posterior implant prosthesis. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Complication prevention.

Even in the absence of tongue thrust, the tongue often accommodates to the available space, and its size may increase with the loss of teeth. As a result, a patient not wearing a mandibular denture often has a larger-than-normal tongue. The placement of implants and prosthetic teeth in such a patient results in an increase in lateral force, which may be continuous. The patient then complains of inadequate room for the tongue and may bite it during function. However, this condition is usually short lived, and the patient eventually adapts to the new intraoral condition. However, it has been observed a fixed restoration is more advantageous for this type of patient. If the patient has a RP-5 prosthesis, it should be turned into an RP-4: An RP-5 restoration is much less stable in patients with tongue thrust or size issues, and patient complaints are more common with removable restorations in general.

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Crown Height Space (CHS)

Definition

The crown height space or interarch distance is defined as the vertical distance between the maxillary and mandibular dentate or dentate arches under specific conditions (e.g., the mandible is at rest or in occlusion).[47] The CHS for implant dentistry is measured from the crest of the bone to the plane of occlusion in the posterior region and the incisal edge of the arch in question in the anterior region (Fig. 3.76). In the anterior regions of the mouth, the presence of a vertical overbite means the CHS is larger in the maxilla than the space from the crest of the ridge to the opposing teeth incisal edge. In general, when the anterior teeth are in contact in centric occlusion, there is a vertical overbite. The anterior mandibular CHS is usually measured from the crest of the ridge to the mandibular incisal edge. However, the anterior maxillary CHS is measured from the maxillary crestal bone to the maxillary incisal edge, not the occlusal contact position.

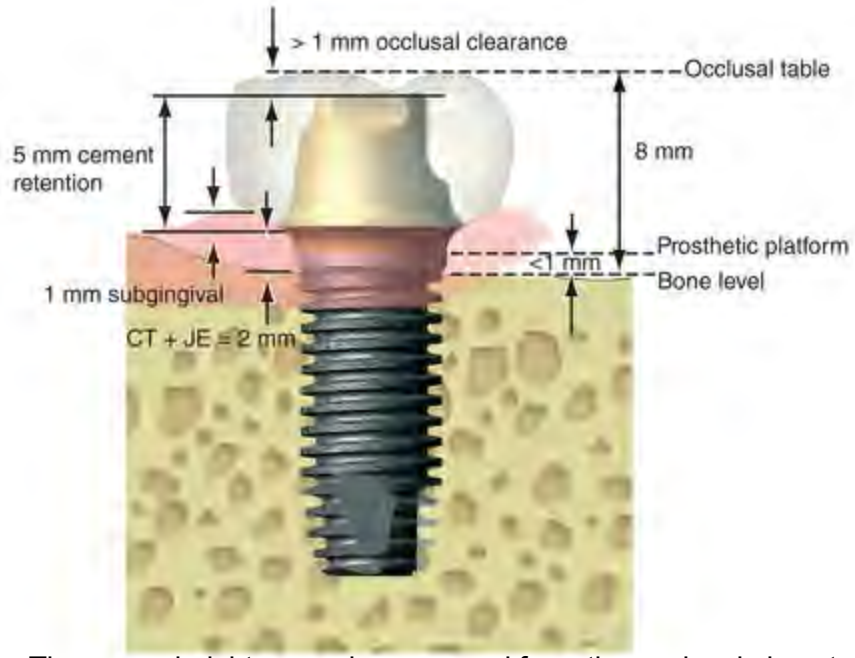

FIG 3.76 The crown height space is measured from the occlusal plane to the crest of the bone. The ideal space for a FP-1 prosthesis is between 8 mm and 12 mm. *CT,* Connective tissue attachment; *JE,* junctional epithelial attachment. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The ideal CHS needed for a fixed implant prosthesis should range between

8 and 12 mm. This measurement accounts for the "biologic width," abutment height for cement retention or prosthesis screw fixation, occlusal material strength, esthetics, and hygiene considerations around the abutment crowns. Removable prostheses often require a CHS greater than 12 mm for denture teeth and acrylic resin base strength, attachments, bars, and oral hygiene considerations (Box 3.12).[48]

Box 3.12

Crown Height Space

- The CHS is measured from the occlusal plane to the crest of the bone.
- CHS does not have a specific ideal dimension. With fixed restorations, the acceptable range for CHS is between 8 and 12 mm.
- Removable implant restorations often require a CHS of 12 mm or more, especially when a bar connects the individual implants.
- An increase in prosthetic complications occurs with either limited or excessive CHS.

CHS, crown height space.

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Complications

Increased Force.

By definition, force magnifiers are situations or devices that increase the amount of force applied to a system and include a screw, pulley, incline plane, and lever.[18] The biomechanics of CHS are directly related to lever mechanics. The properties of a lever have been appreciated since the time of Archimedes 2000 years ago. ("Give me a lever and a fulcrum and a place to stand and I can move the world.") The complex issues of cantilevers and implants have been demonstrated in the edentulous mandible, where the length of the posterior cantilever directly related to complications or failure of the prosthesis.[49] Rather than a posterior cantilever, the CHS is a vertical

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cantilever when any lateral or cantilevered load is applied and is also a force magnifier (Fig. 3.77). As a result, because CHS excess increases the amount of force, any of the mechanical complications related to implant prostheses may also increase, including uncemented prosthesis, screw loosening (prosthetic or abutment), overdenture attachment complications, and so on.

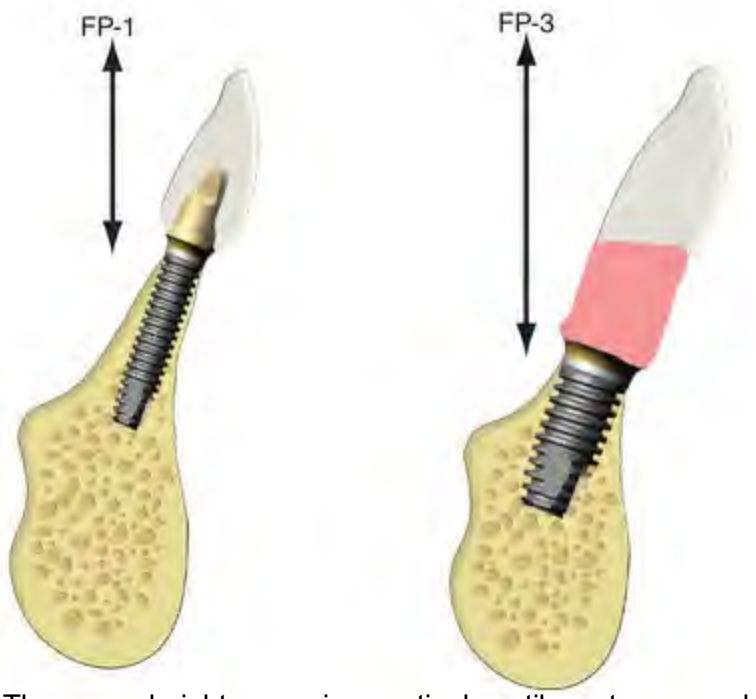

FIG 3.77 The crown height space is a vertical cantilever to any angled load or cantilever. The FP-3 on the right will deliver greater stresses to the implant compared with the implant on the left. A wider-diameter implant is of benefit to support the implant restoration on the right. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Cantilevers.

When the direction of a force is in the long axis of the implant, the stresses to the bone are not magnified in relation to the CHS (Fig. 3.78). However, when the forces to the implant are on a cantilever or a lateral force is applied to the crown, the forces are magnified in direct relationship to the crown height. Bidez and Misch evaluated the effect of a cantilever on an implant and its relation to crown height.[50] When a cantilever is placed on an implant, there are six different potential rotation points (i.e., moments) on the implant body (Fig. 3.79; Table 3.4). When the crown height is increased from 10 to 20 mm, two of six of these moments are increased by approximately 200%.

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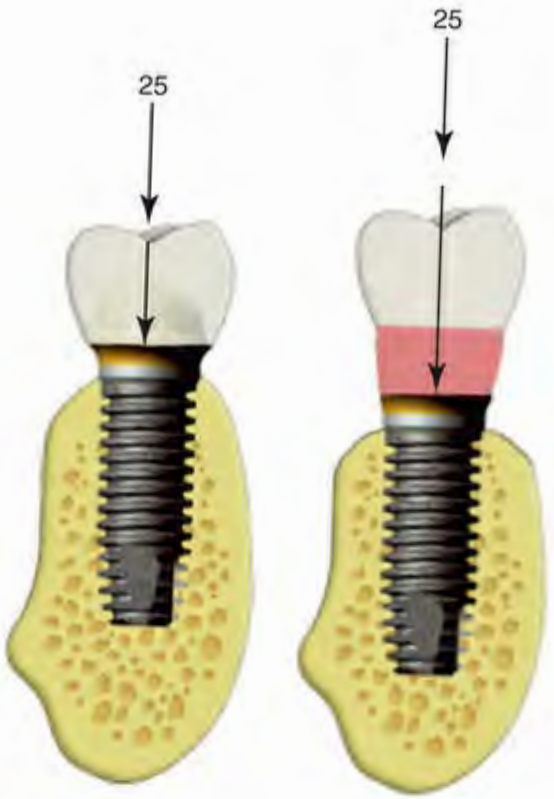

FIG 3.78 When a long axis load is applied to an implant, the crown height does not magnify the load. The implant on the left will have similar stress to the one on the right because the load is in the long axis. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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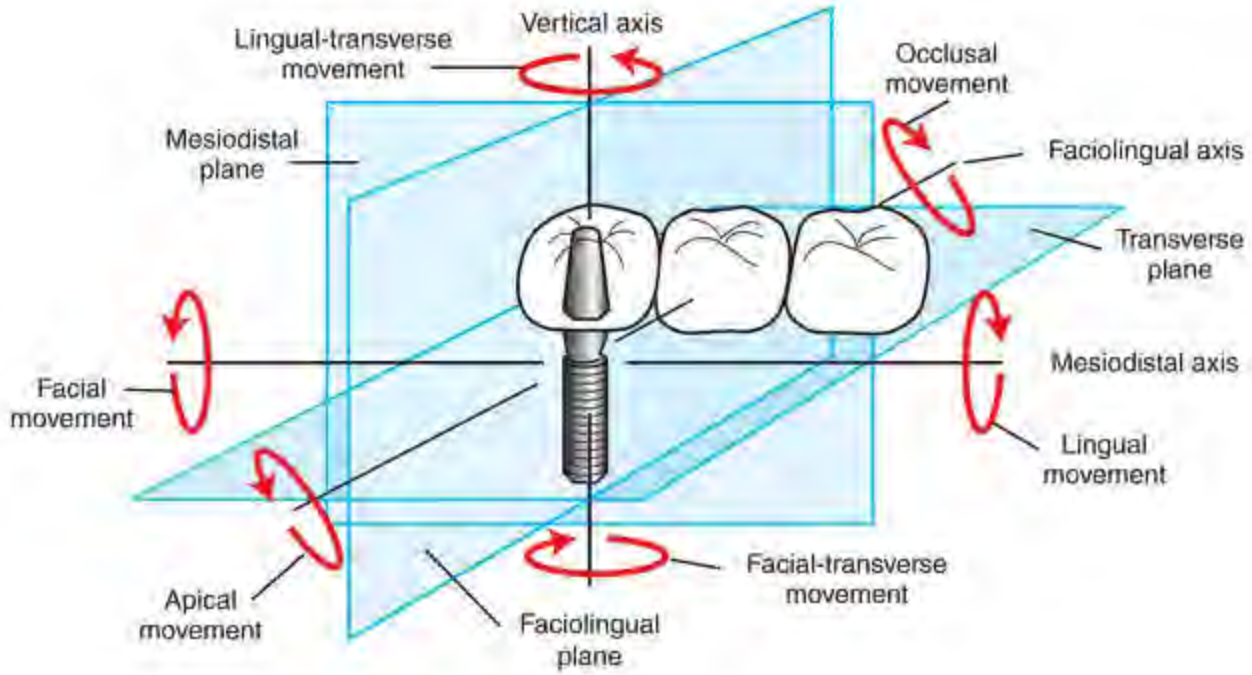

FIG 3.79 Moment loads tend to induce rotations in three planes. Clockwise and counterclockwise rotations in these three planes result in six moments: lingual-transverse, facial-transverse, occlusal, apical, facial, and lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

TABLE 3.4

Moment Load at Crest, When Subjected to Forces Shown in Fig. 3.79

Influences on Moment		Imposed Moments (N/mm) at Implant Crown-to-Crest Interface					
Occlusal Height (mm)	Cantilever Length (mm)	Lingual	Facial	Apical	Occlusal	Facial Transverse	Lingual Transverse
10	10	100	0	50	200	0	100
10	20	100	0	50	400	0	200
10	30	100	0	50	600	0	300
20	10	200	0	100	200	0	100
20	20	200	0	100	400	0	200
20	30	200	0	100	600	0	300

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A cantilevered force may be in any direction: facial, lingual, mesial, or distal. Forces cantilevered to the facial and lingual direction are often called *offset loads*. Because bone resorption proceeds from buccal to lingual and results in decreased width. Unless bone augmentation is completed, implants will be often placed more lingual than the center of the natural tooth root. This often results in a final restoration cantilevered to the facial. When the crest of the ridge resorbs, available bone height is also decreased, and the CHS is increased. The potential length of the implant is often reduced in excessive CHS conditions (i.e., because of vital structures), and

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the more lingual implant position results in offset loads (i.e., biomechanical disadvantage).

The vertical distance from the occlusal plane to the opposing landmark for implant insertion is typically a constant in an individual (with the exception of the posterior maxilla because the sinus cavity expands more rapidly than crestal bone resorption in height). As the bone resorbs, the crown height becomes larger, but the available bone height decreases (Fig. 3.80). An indirect relationship is found between the prosthesis and implant height. Moderate bone loss before implant placement may result in a crown height–bone height ratio greater than 1, with greater lateral forces applied to the crestal bone than in abundant bone (in which the crown height is less). A linear relationship exists between the applied load and internal stresses within the bone.[51] Therefore, the greater the load applied, the greater the tensile and compressive stresses transmitted at the bone interface and to the prosthetic components. And yet many implant treatment plans are designed with more implants in abundant bone situations and fewer implants in atrophied bone volume. The opposite scenario should ideally exist. The available bone present, the greater the crown height and the greater the number of implants indicated (Fig. 3.81).

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FIG 3.80 In the past, treatment plans included more and longer implants in abundant bone (top) but fewer and shorter implants in less available bone (bottom). However, crown height increases as bone height decreases, and this approach creates unfavorable mechanics when the bone height is reduced. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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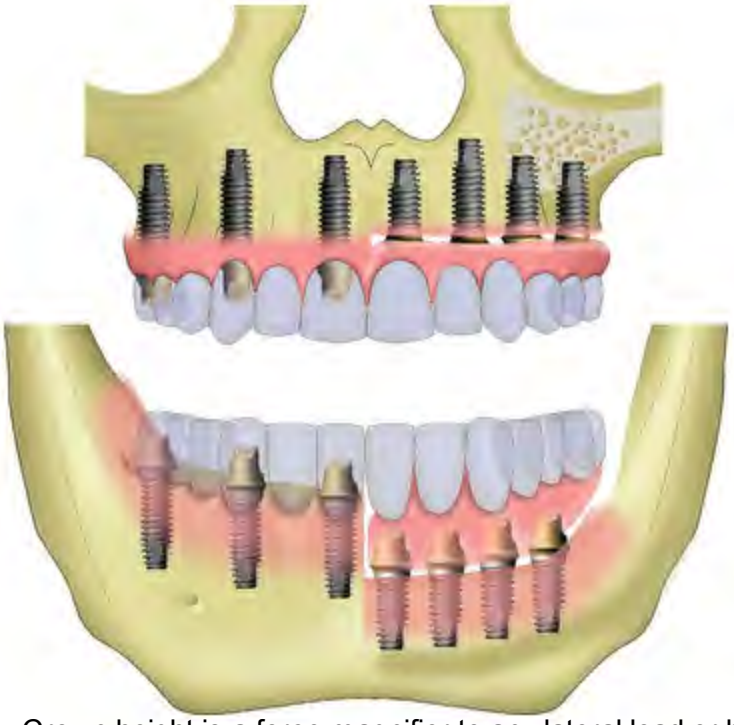

FIG 3.81 Crown height is a force magnifier to any lateral load or horizontal cantilever. When available bone height decreases with a greater crown height, more implants should be inserted and cantilever length reduced. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Treatment of Excessive Crown Space

Crown height space greater than 15 mm is considered excessive and is primarily the result of the vertical loss of alveolar bone from long-term edentulism. Other causes may include genetics, trauma, and past implant failure. Treatment of excessive CHS before implant placement includes orthodontic and surgical methods. Orthodontics in partially edentulous patients (i.e., especially in the growth and development state) is the method of choice because other surgical or prosthetic methods are usually more costly and have greater risks of complications. Several surgical techniques may also be considered, including block onlay bone grafts, particulate bone grafts with titanium mesh or barrier membranes, interpositional bone grafts, and distraction osteogenesis. A staged approach to reconstruction of the jaws is often preferred to simultaneous implant placement, especially when large-volume gains are required. Significant vertical bone augmentation may even require multiple surgical procedures.

In case of excessive CHS, bone augmentation may be preferred to prosthetic replacement, especially in type C–h or D bone volumes. Surgical augmentation of the residual ridge height reduces the CHS and improves

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implant biomechanics by both position and number. Augmentation often permits the placement of wider-body implants with the associated benefit of increased surface area (Fig. 3.82). Prosthetics is the most commonly used option to address excess CHS; however, it should be the last choice. Using gingival-colored prosthetic materials (pink porcelain, acrylic resin, or stained zirconia) on fixed restorations or changing the prosthetic design to a removable restoration should often be considered when the prosthesis is used to restore excessive CHS (Fig. 3.83).

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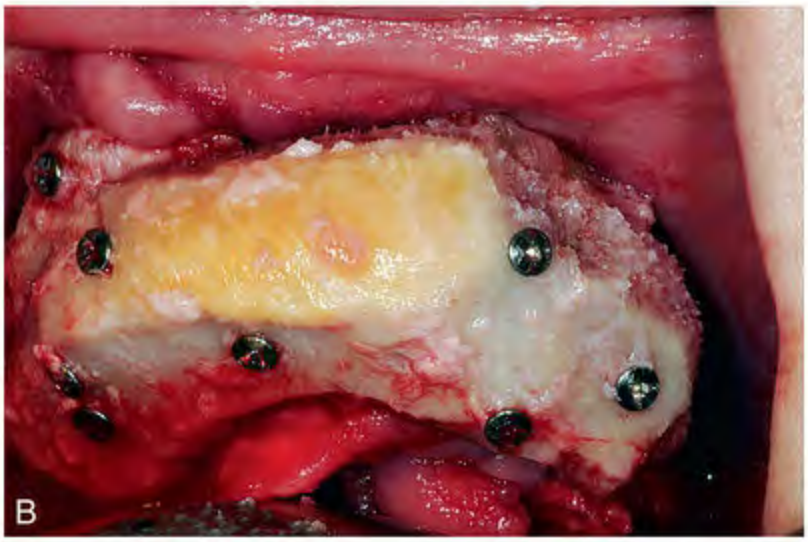

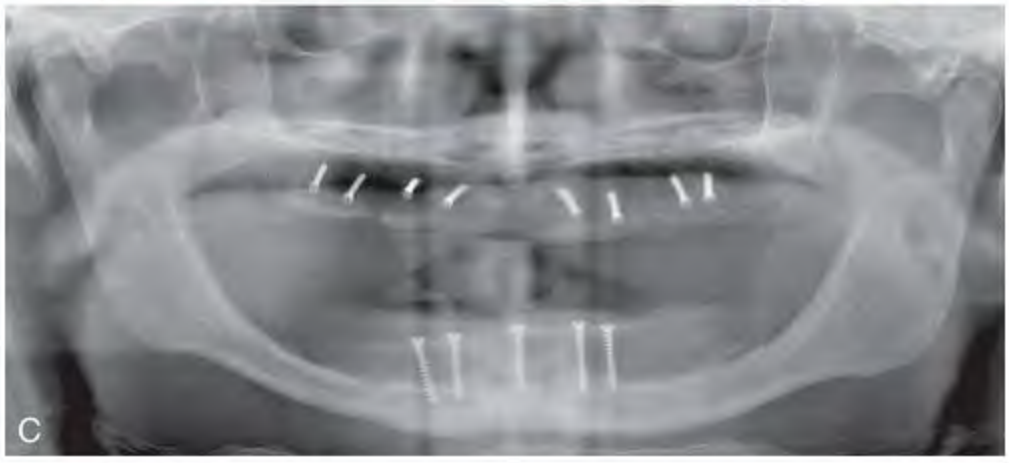

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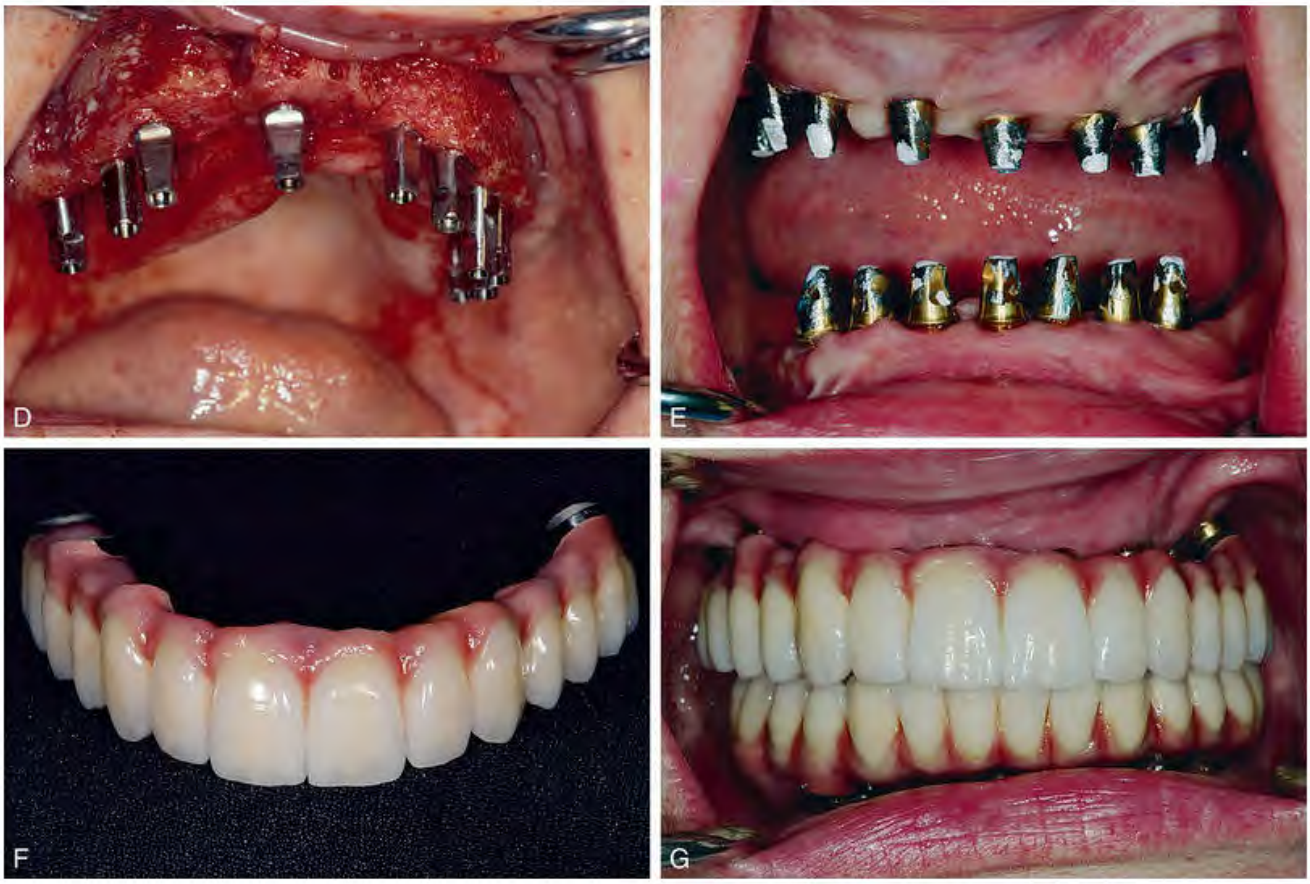

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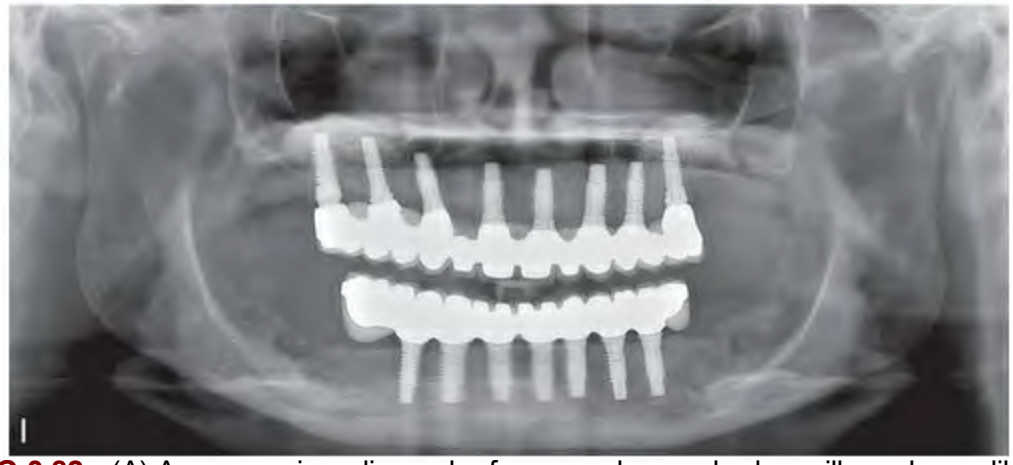

FIG 3.82 (A) A panoramic radiograph of a severely resorbed maxilla and mandible. (B) An autologous bone graft may be used to increase the available bone height and reduce the crown height in a Division C or D bone volume. (C) A panoramic radiograph after the iliac crest bone graft to the maxilla and mandible. (D) Implants may be inserted into the bone graft after 6 months. (E) The implants are prepared to support a cemented prosthesis. (F) A FP-3 fixed restoration is fabricated. (G) The maxillary and mandibular FP-3 prosthesis in place. (H) The high smile line of the patient. (I) A panoramic radiograph of the iliac crest, implants, and prostheses. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 3.83 When the crown height space is greater than 12 mm, pink porcelain (or acrylic) is often used to replace the soft tissue drape in the prosthesis. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In the maxilla, a vertical loss of bone results in a more palatal ridge position. As a consequence, implants are often inserted more palatal than the natural tooth position. Removable restorations have several advantages under these clinical circumstances. The removable prosthesis does not require embrasures for hygiene. The removable restoration may be removed during sleep to decrease the effects of an increase in CHS on nocturnal parafunction. The removable restoration may improve the lip and facial support, which is usually deficient because of the advanced bone loss. The overdenture may have sufficient bulk of acrylic resin to decrease the risk of prosthesis fracture and allow for ease of repair. The increase in CHS permits ideal denture tooth placement without infringement of the implant-prosthetic substructure.

The excessive CHS on a RP-5 prosthesis often makes the restoration more unstable and often requires more soft tissue support. In RP-5 overdentures, there are two different components of the CHS: (1) the distance from the crest of the ridge to the height of the overdenture attachment and (2) the distance from the overdenture attachment to the occlusal plane. The greater the distance from the attachment to the occlusal plane, the more force on the prosthesis to move or rotate on the attachment and the greater the prosthesis mobility (and less the stability). Therefore, more tissue support, (i.e., buccal shelf) is required during function. If the prosthesis loads the soft tissue incorrectly, sore spots may occur and may accelerate the posterior bone loss (Fig. 3.84).

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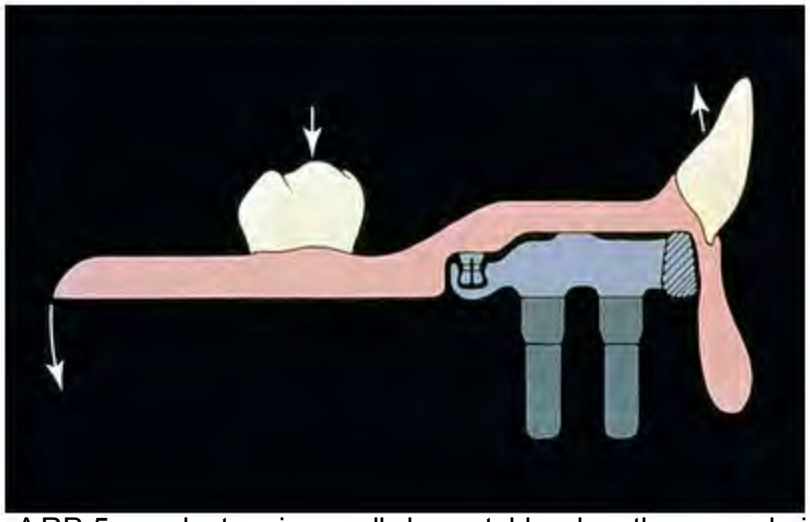

FIG 3.84 A RP-5 overdenture is usually less stable when the crown height space (CHS) is large. The CHS of the prosthesis is measured from the occlusal plane to the height of the overdenture attachments. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

An increase in the biomechanical forces is in direct relationship to the increase in CHS. The treatment plan of the implant restoration should consider stress-reducing options whenever the CHS is increased. Methods to decrease stress include:

1. Shorten cantilever length.

2. Minimize offset loads to the buccal or lingual.

3. Increase the number of implants.

4. Increase the diameters of implants.

5. Utilize implants with maximum surface area.

6. Fabricate removable restorations that are less retentive and incorporate soft tissue support (e.g., buccal shelf).

7. Remove the removable restoration during sleeping hours to reduce the noxious effects of nocturnal parafunction.

8. Splint implants together, whether they support a fixed or removable prosthesis.

Crown height space is a considerable force magnifier; the greater the

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crown height, the shorter the prosthetic cantilever that should extend from the implant support system. When the CHS is greater than 15 mm, no cantilever should be considered unless all other force factors are minimal. The occlusal contact intensity should be reduced on any offset load from the implant support system. Occlusal contacts in centric relation occlusion may even be eliminated on the most posterior aspect (or offset region) of a cantilever. In this way a parafunction load may be reduced because the most cantilevered portion of the prosthesis is only loaded during functional activity (e.g., chewing).[52]

Arch Position

Posterior Has Higher Forces

The arch position is an important part of the treatment planning process and has a significant impact on the amount of force generated to an implant prosthesis. In general, the maximum biting force is greater in the molar region and decreases as measurements progress anteriorly. Maximum bite forces in the anterior incisor region correspond to approximately 35 to 50 psi, those in the canine region range from 47 to 100 psi, and those in the molar area vary from 127 to 250 psi (Fig. 3.85).[53] Mansour et al evaluated occlusal forces and moments mathematically using a class III lever arm, the condyles being the fulcrum and the masseter and temporalis muscles supplying the force.[54] The forces at the second molar were 10% higher than at the first molar, indicative of a range from 140 to 275 psi.

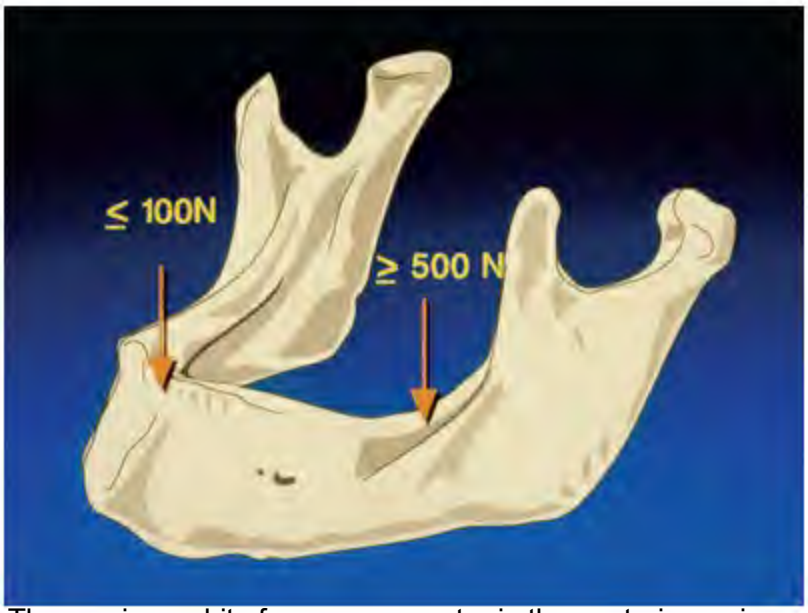

FIG 3.85 The maximum bite forces are greater in the posterior regions of the jaws compared with the anterior regions. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Arch position should also consider the anterior maxilla versus the anterior mandible. Not only is the bone generally denser in the anterior mandible, but the direction of force is also more in the long axis for the lower anterior teeth. The angled load of 12 to 15 degrees in maxillary anterior implants increases the force by approximately 25%. Note that the maxillary anterior

teeth are wider in diameter and have greater surface area compared with the smallest teeth in the mouth, the mandibular incisors. The amount of force is similar, but the direction of force places the maxillary teeth more at risk.

Arch position includes the maxillary arch vs. the mandibular arch. As previously mentioned the bone in the mandible is more often more dense than that of the maxilla, especially in the posterior regions. The edentulous maxilla with a poorer bone density requires more implants or larger widths compared with the edentulous mandible. It is interesting to note that the maxillary dentition has more roots and greater surface area roots than the mandibular counterparts (Box 3.13). Yet, in the edentulous maxilla, there is less available bone height than any region because the maxillary sinus quickly expands to decrease bone height.

Box 3.13

Arch Position

Posterior Regions

1. Significantly higher biting force in the molar regions.

a. Mechanical component: class III lever

b. Biologic component: amount of muscle mass contraction

2. Posterior region is associated with long-term crestal bone loss of integrated implants

3. Bone density poorer than in anterior regions of mouth (e.g., D3/D4 - maxilla vs. D2 - mandible)

4. Posterior maxilla more at risk than posterior mandible because of poorer bone quality

5. Posterior maxilla has least bone volume

a. Crestal bone loss

b. Sinus expansion

c. Close approximation and root apexes extending into maxillary sinus (e.g., palatal and MB root of first molar)

6. Posterior mandible less bone height than anterior regions

a. Position of mandibular canal and foramen

b. Angulation issues because of the buccal bone resorption

c. Sublingual undercuts

Complications

Greater Bone Loss.

In a study by Chung et al with 339 implants in 69 patients in function for an average of 8.1 years (range, 3–24 years), the posterior implants (even with keratinized mucosa) showed a 3.5-fold greater average bone loss per year than anterior implants.[55] In the region of higher bite forces, greater bone loss may be evident. The anterior biting force is decreased in the absence of posterior tooth contact and greater in the presence of posterior occlusion or eccentric contacts. Besides the mechanical properties of a class III lever function, there also is a biologic component to decrease bite force in the anterior regions. When the posterior teeth are in contact, the large masticatory muscles contract. When the posterior teeth are not in contact, two thirds of the temporalis and masseter muscles do not contract their fibers, which result in the biting force being reduced.

Decreased Surface Area.

In the anterior regions with less force, the anterior natural tooth roots are smaller in diameter and root surface area compared with posterior teeth. The greatest increase in natural tooth surface area occurs in the molar region, with a 200% increase compared with the premolars. Yet in implant dentistry, we primarily determine the implant length by existing bone volume and place longer implants in the anterior region and shorter implants in the posterior regions (or cantilever off the anterior implants, which results in posterior bite forces magnified by the cantilever length). This approach should be corrected to conform to the biomechanical load similar to that observed with natural teeth. However, the length of an implant is less effective to dissipate force. Instead, implant width and design are more effective. The best option to decrease stress is to increase implant number. Implants in the posterior regions should often be of greater diameter or greater number (because molars have more roots), especially in the presence of additional force factors.

Poorer Bone Density Resulting in Less Support.

The natural teeth are surrounded by a thin cortical plate of bone and periodontal complex, which is similar for all teeth and arch positions. However, after the teeth are lost, the bone density in the edentulous site is reduced and is often different for each region of the mouth. The posterior regions, in general, form less bone density after tooth loss than the anterior regions, with the anterior maxilla less dense than the mandible. The mandibular anterior implant sites benefit from denser bone than the maxillary anterior implant sites. The denser the bone, the greater its resistance to stress applied at the implant-bone interface. In other words, the edentulous bone density is inversely related to the amount of force and surface area of the natural tooth roots generally applied in that arch position. As a result, the posterior maxilla is the most at-risk arch position followed by the posterior mandible and then the anterior maxilla. The most ideal region for implant stress transfer within the physiologic loading zone for bone is the mandibular anterior region.[56]

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Opposing Arch

An often overlooked factor in the treatment planning process is the opposing arch. In general, natural teeth transmit greater impact forces through occlusal contacts than soft tissue–borne complete dentures. In addition, the maximum occlusal force of patients with complete dentures is limited and may range from 5 to 26 psi.[57] The force is usually greater in recent denture wearers and decreases with time. Muscle atrophy, thinning of the oral tissues with age or disease, and bone atrophy often occur in edentulous patients as a function of time.[58] Some denture wearers may clench on their prosthesis constantly, which may maintain muscle mass, but will usually result in bone loss.

The maximum force generated against an implant prosthesis is related to the number of teeth or implants supporting the prosthesis in the opposing arch. Partially edentulous dentate patients have less force than dentate patients with all of their teeth. Patients with partial dentures may have forces intermediate between those of natural teeth and complete dentures, depending on the location and condition of the remaining teeth, muscles, and joints. In partially edentulous patients with implant-supported fixed prostheses, force ranges are more similar to those of natural dentition, but lack of proprioception may magnify the load amount during parafunctional and functional activity (Fig. 3.86).

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FIG 3.86 Opposing arch. Greatest forces from high to low. (A) Implant-supported fixed prosthesis. (B) Conventional fixed porcelain fused to metal. (C) Natural Dentition. (D) Overdenture/conventional denture.

A complete implant fixed prosthesis does not benefit from proprioception as do natural teeth, and patients chew food with a force four times greater than with natural teeth. The highest forces are created with implant prostheses in the opposing arch. An RP-4 overdenture may have some movement compared with a fixed prosthesis and is more likely to have acrylic or resin teeth. Hence, the bite force is slightly less than for a full arch fixed implant prosthesis. In addition, premature contacts in occlusal patterns or during parafunction on the implant prostheses do not alter the pathway of closure because occlusal awareness is decreased with implant prostheses compared with natural teeth. Continued stress increases can be expected to occur with the implant restoration (Box 3.14).

Box 3.14

Opposing Arch

Force Generated (Lowest to Highest)

1. Soft tissue–borne denture (conventional complete denture)

2. RP-5 overdenture (primary support - soft tissue)

3. Partially edentulous arch

4. Dentate arch

5. RP-4 overdenture (primary support - implants)

6. Fixed implant prosthesis (full-arch implant-supported)

The opposing arch is not as major a factor to alter an implant treatment plan as parafunction, masticatory dynamics, or excessive CHS, but is a major factor for the risk of porcelain or prosthesis fracture. In a report by Kinsel and Lin, the opposing dentition varies the incidence of porcelain fracture to an implant crown.[59] When the opposing arch was a denture, 0% fracture of the implant crowns in the opposing arch was found. The opposing dentition of a natural tooth found 3.2% fracture of implant crowns. The opposing dentition of a crown on a natural tooth found a 5.7% fracture of the opposing implant crown. A 16.2% fracture was observed when an implant crown opposed an implant crown. When the percentage of patients with major fractures of porcelain were compared to the percentage with no fractures, the incidence of patients with porcelain fractures of implant crowns was 19.4% for natural teeth and 69.5% of patients with implant crowns in the opposing arch. Therefore, the opposing dentition may increase the impact force, and the greater the force, the higher the risk of porcelain fracture (Box 3.15).

Box 3.15

Implant Crown Porcelain Fracture Related to Opposing Arch

Least to Highest Risk

1. Complete denture (0%)

2. Natural teeth (3.2%) (19.4% of patients)

3. Crown on a natural tooth (5.7%)

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4. Implant crown (16.2%) (69.5% of patients)

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

As a consequence of the opposing arch affecting the intensity of forces applied to an implant prosthesis, the treatment plan may be modified to reduce the risk of fatigue fracture and overload. Rarely should the opposing arch be maintained in a traditional denture as a method to decrease the stress to the implant arch. Unfortunately, many edentulous patients opt to remain in a denture for the maxillary arch as a consequence of the increased costs associated with implant prostheses. However, the patient should be aware of the continued bone loss in the maxillary edentulous arch, and a preferred treatment is an implant-supported prosthesis in both arches in order to maintain the existing bone volume.

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Arch Form

The patient's arch form should always be evaluated in the treatment planning process, especially in the mandibular arch. There exist many variations on the size and shape of patients' arch forms. The distance from the center of the most anterior implant to a line joining the distal aspect of the two most distal implants on each side is called the anteroposterior (A-P) distance or the A-P spread (Fig. 3.87).[60] The greater the A-P spread (Fig. 3.87),[60] theorectically the farther the distal cantilever may be extended to replace the missing posterior teeth, which minimizes force-related issues. As a general rule, when five to six anterior implants are placed in the anterior mandible between the foramina to support a fixed prosthesis, the cantilever should not exceed two times the A-P spread, with all other stress factors being low.

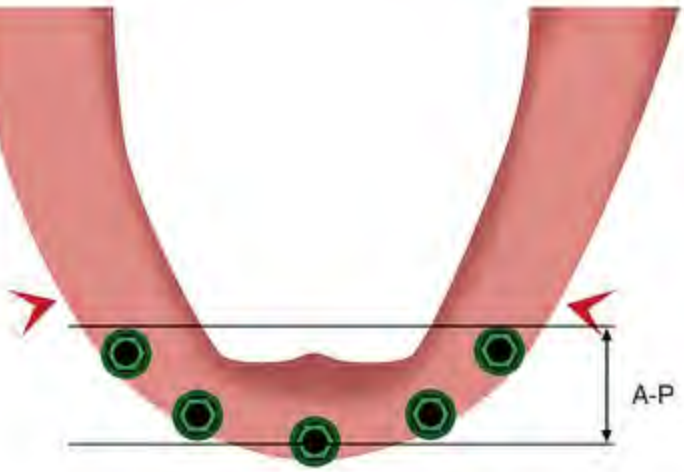

FIG 3.87 The anteroposterior (A-P) distance is determined by a line drawn from the distal portion of the distalmost implant on each side of the arch and another parallel line drawn through the center of the anteriormost implant from the cantilever. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

The A-P distance is directly affected by the arch form. The types of arch forms may be separated into square, ovoid, and tapering. A square arch form in the anterior mandible has a 0- to 6-mm A-P spread between the most distal and most anterior implants (Fig. 3.88). An ovoid arch form has an A-P distance of 7 to 9 mm and is the most common type (Fig. 3.89). A tapering arch form has an A-P distance greater than 9 mm (Fig. 3.90). Whereas a tapering arch form may support a 20-mm cantilever, a square arch form requires the cantilever to be reduced to 12 mm or less. A tapering arch form is most ideal, and a square arch form is susceptible to force-related

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complications.

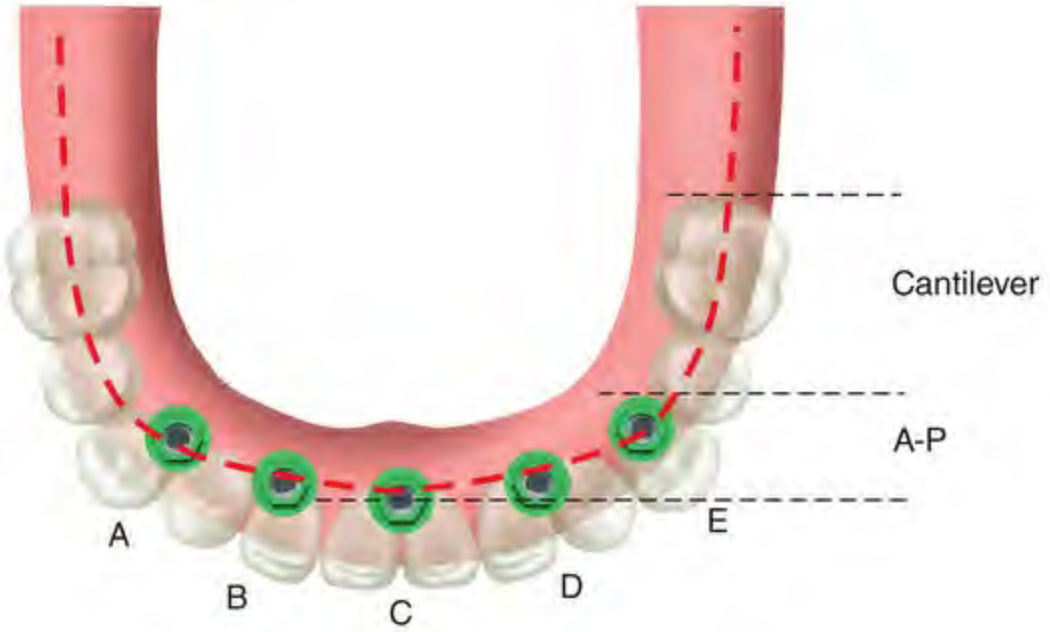

FIG 3.88 A mandibular square arch form has an anteroposterior (A-P) distance of 0 to 6 mm. As a result, a cantilever is limited. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

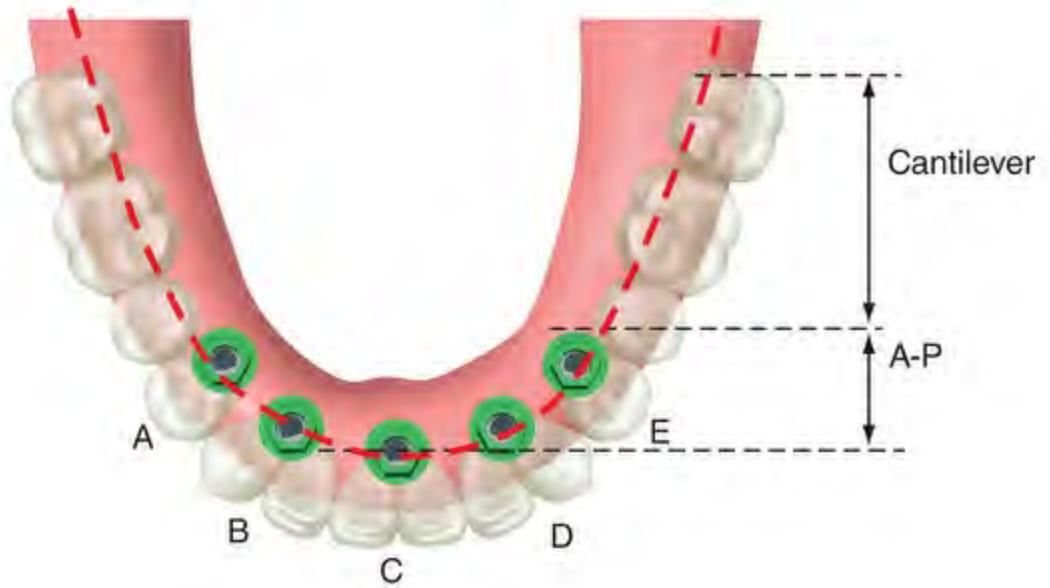

FIG 3.89 A mandibular ovoid arch form has an anteroposterior (A-P) distance of 7 to 9 mm and is the most common type. A cantilever may extend to 18 mm with the ovoid-type arch. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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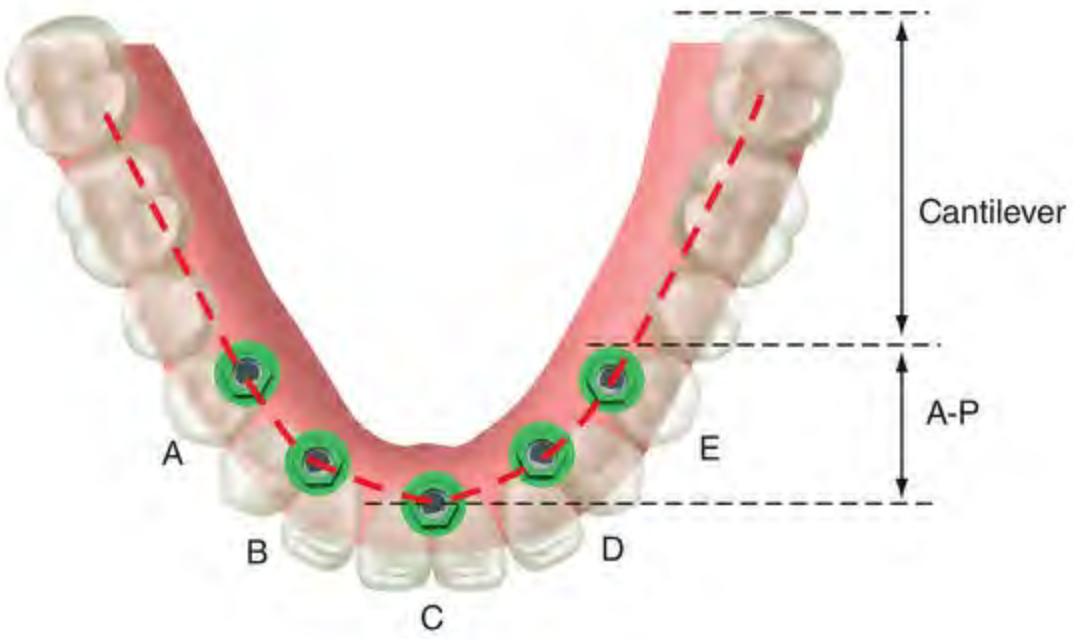

FIG 3.90 A mandibular tapered arch form has an anteroposterior (A-P) distance of greater than 9 mm, and is the type least observed. A cantilever is least at risk for this arch form. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

The A-P spread is only one of the force factors to be considered for the extent of the distal cantilever. If the stress factors are high (e.g., parafunction, crown height, masticatory musculature dynamics, opposing arch), the cantilever length of a prosthesis should be reduced and may even be contraindicated.

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Bone Density

Treatment Planning

The external (cortical) and internal (trabecular) structure of bone may be described in terms of quality or density, which reflects a number of biomechanical properties, such as strength, modulus of elasticity, bone-implant contact (BIC) percent, and stress distribution around a loaded endosteal implant (Box 3.16). The external and internal architecture of bone controls and dictates virtually the surgical and prosthetic protocol for the patient. The density of available bone in an edentulous site is a determining factor in treatment planning, surgical approach, implant design, healing time, and the need for initial progressive bone loading during prosthetic reconstruction.[56]

Box 3.16

Bone Quality Reflects

- Strength of cortical/cancellous bone
- Modulus of elasticity
- Bone-implant contact percent (interface)
- Stress contours around a loaded endosteal implant
- Surgical protocol
- Healing time
- Need for progressive bone loading

The bone density has a significant impact on the treatment planning of an implant patient. The initial treatment plan is presented to the patient using the anatomic location as an index of the bone density: anterior mandible and single tooth replacement is D2, anterior maxilla and posterior mandible is D3, and posterior maxilla is D4. After the initial treatment evaluation of the osseous structures are taken into consideration (e.g., prosthesis type and

design, implant key position, and patient force factors), a more complete treatment plan relative to bone density is obtained by a CBCT scan or modified during the surgical procedure using the tactile method to determine bone density.

Understanding the Basics of Bone

Bone is an organ that is able to change in relation to a number of factors, including hormones, vitamins, and mechanical influences. However, biomechanical parameters, such as the amount of strain transmitted to bone, are predominant. Awareness of this adaptability in the skeletal system has been reported for more than a century. In 1887, Meier qualitatively described the architecture of trabecular bone in the femur.[61] In 1888 Kulmann noticed the similarity between the pattern of trabecular bone in the femur and tension trajectories in construction beam concepts used by Eiffel (Fig. 3.91).[62] Wolff, in 1892, further elaborated on these concepts and published: "Every change in the form and function of bone or of its function alone is followed by certain definite changes in the internal architecture, and equally definite alteration in its external conformation, in accordance with mathematical laws."[63] It has been widely reported that, in the structural skeleton, the external architecture of bone (cortical bone) changes in relation to function, and the internal bony structure (trabecular bone) is also modified (Wolff's Law).

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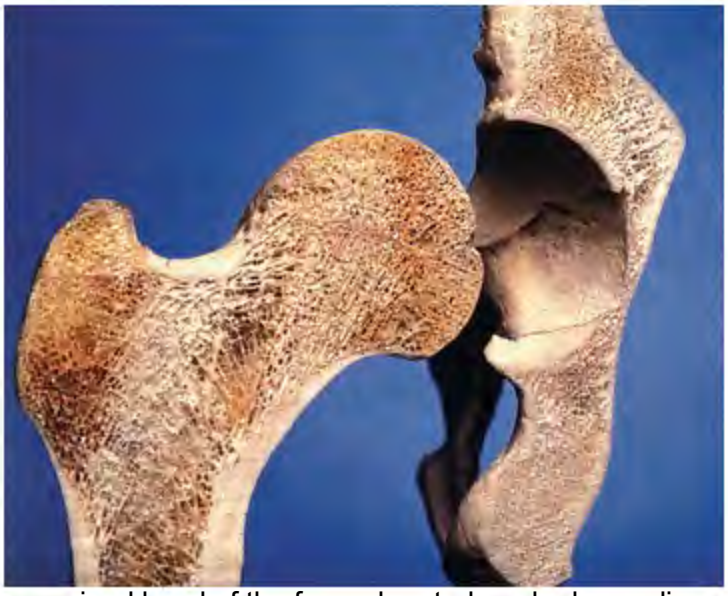

FIG 3.91 The proximal head of the femur has trabecular bone aligned along stress pathways, similar to beams for a bridge or tower. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The structural changes in bone as a consequence of mechanical influences have also been noted in the jaws. As an example, both MacMillan and Parfitt have reported on the structural characteristics and variation of trabeculae in the alveolar regions of the jaws.[64] The maxilla and mandible have different biomechanical functions (Fig. 3.92). The mandible, as an independent structure, is designed as a *force-absorption unit*. When teeth are present, the outer cortical bone is much denser and thicker, and the trabecular bone is more coarse and dense (Fig. 3.93). This bony architectural make-up is in direct relation to the force applied. On the other hand, the maxilla is a *force-distribution unit*. Stresses to the maxilla are transferred by the zygomatic arch and palate away from the brain and orbit. As a consequence, the maxilla has a thin cortical plate and fine trabecular bone surrounding the teeth (Fig. 3.94). When evaluating bone quality around natural teeth, Neufeld noted that the bone is most dense around the teeth (cribriform plate) and more dense around the teeth at the crest compared with the regions around the apices (Fig. 3.95).[65]

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FIG 3.92 The maxilla and mandible vary in their bony make-up. The maxilla is a force distribution unit, and the mandible is a force absorption unit. As a consequence, the cortical and trabecular bone are different. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 3.93 The trabecular bone in a dentate mandible is coarser than that in the maxilla. The cortical bone is thick and dense. The mandible, as an independent structure, is a force-absorbing element. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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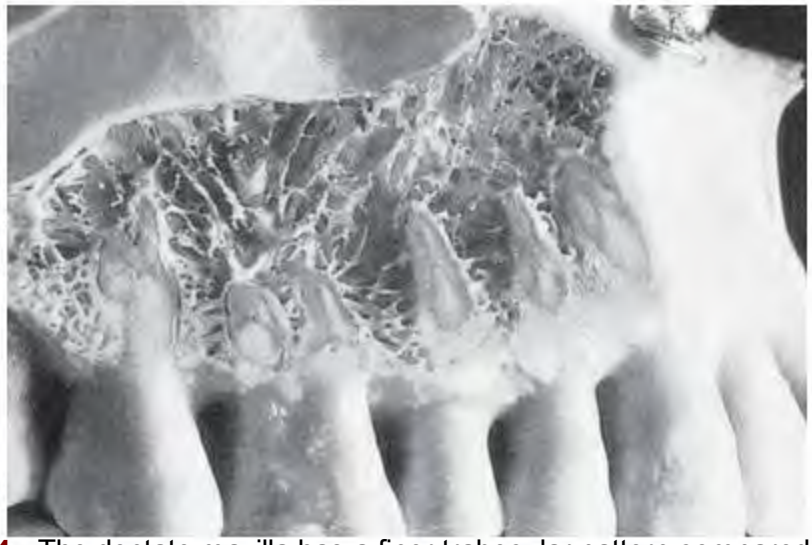

FIG 3.94 The dentate maxilla has a finer trabecular pattern compared with the mandible. The cortical bone is more thin and porous. The maxilla is a force distribution unit and is designed to protect the orbit and brain. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 3.95 The trabecular bone of each jaw has structural variations. The trabecular bone is densest next to the teeth, where it forms the cribriform plate. Between the teeth, the bone is usually densest near the crest and least dense at the apex. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Orban demonstrated a decrease in the trabecular bone pattern around a maxillary molar with no opposing occlusion compared with a tooth with occlusal contacts on the contralateral side (Fig. 3.96).[66] Bone density in the jaws also decreases after tooth loss. This loss is primarily related to the length of time the region has been edentulous and not loaded appropriately, the initial density of the bone, flexure and torsion in the mandible, and parafunction before and after tooth loss. In general, the density change after

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tooth loss is greatest in the posterior maxilla and least in the anterior mandible.

FIG 3.96 On the left, the opposing mandibular tooth was removed. A lack of occlusal contact resulted in loss of trabecular bone around the maxillary tooth. The tooth on the right is from the same monkey, with the opposing mandibular tooth in place. The trabecular bone is much denser around the tooth. The disuse atrophy observed on the left is from inadequate microstrain conditions to maintain the bone. (From Orban B: *Oral histology and embryology,* ed 3, St Louis, 1953, Mosby.)

Cortical and trabecular bone throughout the body is constantly modified by either modeling or remodeling. Modeling has independent sites of formation and resorption and results in the change of the shape or size of bone. Remodeling is a process of resorption and formation at the same site that replaces previously existing bone and primarily affects the internal turnover of bone, including that region where teeth are lost or the bone next to an endosteal implant. These adaptive phenomena have been associated with the alteration of the mechanical stress and strain environment within the host bone.[67]

Stress is determined by the magnitude of force divided by the functional area over which it is applied. Strain is defined as the change in length of a material divided by the original length. The greater the magnitude of stress applied to the bone, the greater the strain observed in the bone.[18] Bone modeling and remodeling are primarily controlled, in part or whole, by the mechanical environment of strain. Overall, the density of alveolar bone evolves as a result of mechanical deformation from microstrain.

Frost proposed a model of modeling/remodeling patterns for compact bone as it relates to mechanical adaptation to strain.[68] Spontaneous fracture, the pathologic overload zone, mild overload zone, adapted window, and acute disuse window were described for bone in relation to the amount of the microstrain experienced (Box 3.17). These categories also may be used to describe the trabecular bone response next to a dental implant in the jaws.

Box 3.17

Mechanical Adaptation of Bone Categories[68]

1. Spontaneous fracture
2. Pathologic overload zone
3. Mild overload zone
4. Adapted window
5. Acute disuse window

With disuse atrophy, bone loses mineral density, and *disuse atrophy* occurs because modeling for new bone is inhibited and remodeling is stimulated, with a gradual net loss of bone. The microstrain of bone for trivial loading is reported to be 0 to 50 microstrain.[68] This phenomenon may occur throughout the skeletal system, as evidenced by a 15% decrease in the cortical plate and extensive trabecular bone loss consequent to immobilized limbs for 3 months.[69] A cortical bone density decrease of 40% and a trabecular bone density decrease of 12% also have been reported with disuse of bone (Fig. 3.97).[70]

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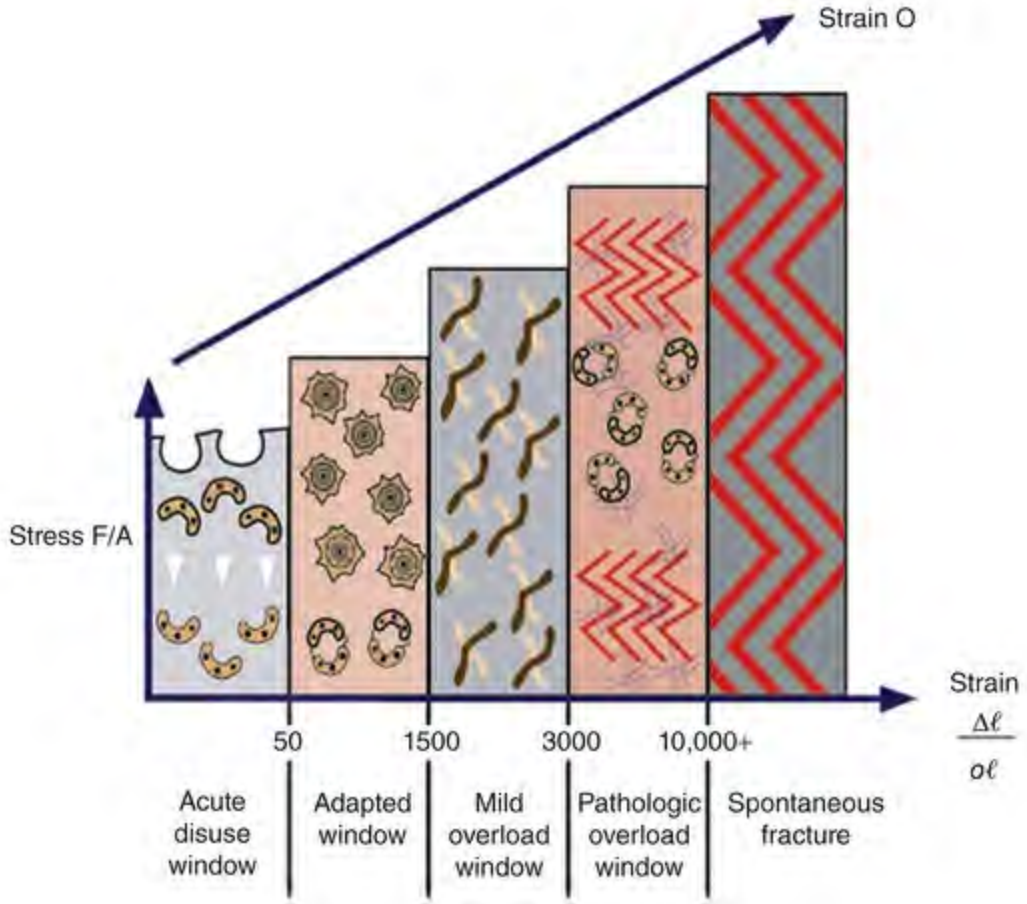

FIG 3.97 Four zones for bone related to mechanical adaption to strain before spontaneous fracture. The acute disuse window is the lowest microstrain amount. The adapted window is an ideal physiologic loading zone. The mild overload zone causes microfracture and triggers an increase in bone remodeling, which produces more woven bone. The pathologic overload zone causes increase in fatigue fractures, remodeling, and bone resorption. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The *adapted window* (50–500 microstrain) represents an equilibrium of modeling and remodeling, and bone conditions are maintained at this level. Bone in this strain environment remains in a steady state, and this may be considered the homeostatic window of health. The histologic description of this bone is primarily lamellar or load-bearing bone. Approximately 18% of trabecular bone and 2% to 5% of cortical bone is remodeled each year in the physiologic loading zone, which corresponds to the adapted window.[71] This is the range of strain ideally desired around an endosteal implant after a stress equilibrium has been established. Bone turnover is required in the adapted window; Mori and Burr provide evidence of remodeling in regions of bone microfracture from fatigue damage within the physiologic range.[72]

The *mild overload zone* (1500–3000 microstrain) causes a greater rate of fatigue microfracture and increase in the cellular turnover rate of bone. As a

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result, the bone strength and density decrease. The histologic description of bone in this range is usually woven or repair bone. Woven bone is able to form faster but is less mineralized and less organized than lamellar bone. This may be the state for bone when an endosteal implant is overloaded and the bone interface attempts to adapt to the greater strain environment. During the repair process, the woven bone is weaker than the more mature, mineralized lamellar bone.[73] Although bone is loaded in the mild overload zone, care must be taken because the "safety range" for bone strength is reduced during the repair.

Pathologic overload zones are reached when microstrains are greater than 3000 units. Cortical bone fractures occur at approximately 10,000 to 20,000 microstrain (1%–2% deformation). However, pathologic overload may begin at microstrain levels of only 20% to 40% of the ultimate strength or physical fracture of cortical bone. The bone may resorb and form fibrous tissue or, when present, repair woven bone is observed in this zone because a sustained turnover rate is necessary. The marginal bone loss evidenced during implant overloading may be a result of the bone in the pathologic overload zone. Implant failure from overload may also be a result of bone in the pathologic overload zone.

Understanding Different Bone Densities

In 1988, Misch proposed four bone density groups independent of the regions of the jaws based on macroscopic cortical and trabecular bone characteristics.[74] This bone density classification allows for different treatment protocols according to the type of bony anatomy. Suggested treatment plans, implant design, surgical protocol, healing time, and progressive loading time spans have been described for each bone density type.[17] Following this regimen, similar implant survival rates have been observed for all bone densities.[75]

Dense or porous cortical bone is found on the outer surfaces of bone and includes the crest of an edentulous ridge. Coarse and fine trabecular bone types are found within the outer shell of cortical bone and occasionally on the crestal surface of an edentulous residual ridge. These four macroscopic structures of bone may be arranged from the most dense to the least dense, as first described by Frost and by Roberts: dense cortical bone, porous cortical bone, coarse trabecular bone, and fine trabecular bone (Fig. 3.98).

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FIG 3.98 The macroscopic structure of bone may be described, from the least dense to the most dense, as *(1)* fine trabecular, *(2)* coarse trabecular, *(3)* porous cortical, and *(4)* dense cortical. (Courtesy E. Roberts; from Misch CE: *Dental implant prosthetics,* 2e, St Louis, 2015, Mosby.)

In combination, these four macroscopic densities constitute the four bone categories described by Misch (D1, D2, D3, and D4) located in the edentulous areas of the maxilla and mandible (Table 3.5; Fig. 3.99). The regional locations of the different densities of cortical bone are more consistent than the highly variable trabecular bone.

TABLE 3.5
Misch Bone Density Classification Scheme

Bone Density	Description	Tactile Analog	Typical Anatomic Location
D1	Dense cortical	Oak or maple wood	Anterior mandible
D2	Porous cortical and coarse trabecular	White pine or spruce wood	Anterior mandible Posterior mandible Anterior maxilla
D3	Porous cortical (thin) and fine trabecular	Balsa wood	Anterior maxilla Posterior maxilla Posterior mandible
D4	Fine trabecular	Styrofoam	Posterior maxilla
D5	Immature, non-mineralized bone	—	Early healed grafted bone

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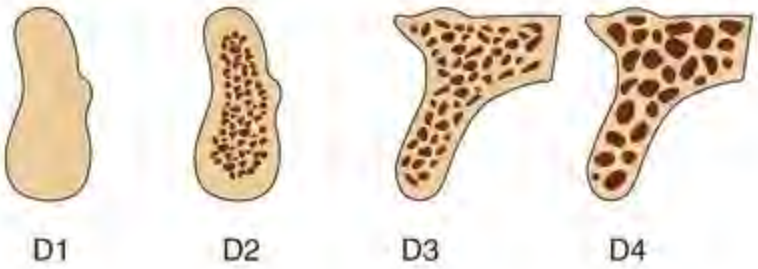

FIG 3.99 Misch described four bone densities found in the anterior and posterior edentulous regions of the maxilla and mandible. D1 bone is primarily dense cortical bone, D2 bone has dense to thick porous cortical bone on the crest and coarse trabecular bone underneath, D3 bone has a thinner porous cortical crest and fine trabecular bone within, and D4 bone has almost no crestal cortical bone. The fine trabecular bone composes almost all of the total volume of bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

D1 bone is primarily dense cortical bone. D2 bone has dense to porous cortical bone on the crest and lateral to the implant site. The bone within this cortical housing has coarse trabecular bone (Fig. 3.100). D3 bone types have a thinner porous cortical crest and facial/lingual regions, with fine trabecular bone in the region next to the implant (Fig. 3.101). D4 bone has almost no crestal cortical bone and porous cortical lateral plates. The fine trabecular bone comprises almost all of the total volume of bone next to the implant (Fig. 3.102). A very soft bone, with incomplete mineralization and large intratrabecular spaces, may be addressed as D5 bone (Fig. 3.103). This bone type is found often in the immature bone of a developing bone graft site. The bone density may be determined by the general location, tactile sense during surgery, or computerized radiographic evaluation.

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FIG 3.100 A cross section of a D2 mandible in the region of the midline. A dense to porous cortical plate exists on the crest and lateral borders, and a coarse trabecular bone pattern exists within. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 3.101 A posterior mandible with D3 bone. A thin porous cortical bone is at the crest and fine trabecular bone is in the body of the mandible. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 3.102 An anterior maxilla demonstrating D3 bone with a thin porous cortical plate on the crest with fine trabecular bone underneath. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 3.103 In a D4 posterior maxilla, the posterior crestal region has little to no cortical bone on the crest and is composed primarily of fine trabecular bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Complications Related to Bone Density

D1.

Dense cortical bone also presents several disadvantages. The implant height is often limited to less than 12 mm in the atrophic mandible, and the crown height space is often greater than 15 mm. As a result, additional force-multiplying factors (such as cantilevers or lateral forces) are further magnified on the implant-prosthetic system. Stress-reducing factors may be incorporated in the prosthesis design to reduce these effects, not only on the bone, but also on the prosthetic components (Fig. 3.104).

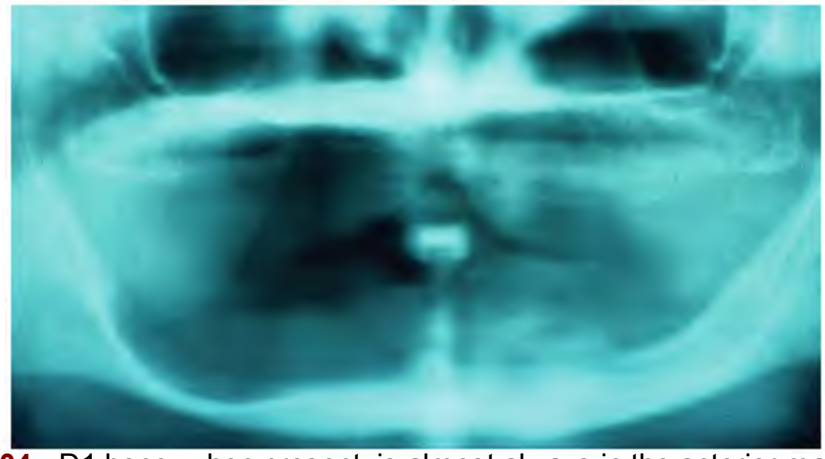

FIG 3.104 D1 bone, when present, is almost always in the anterior mandibular area in the severely atrophic mandible. This type of bone has a high BIC (~80%) and is susceptible to surgical complications (i.e., overheating the bone during osteotomy preparation).

D1 bone has a more compromised vasculature with fewer blood vessels than the other three types, and it is more dependent on the periosteum for its nutrition. The cortical bone receives the outer one third of all its arterial and venous supply from the periosteum.[76] This bone density is almost all cortical, and the capacity of regeneration is impaired because of the poor blood circulation. Delicate and minimal periosteal reflection is indicated. When D1 density is present, the bone width is usually abundant (i.e., as bone is lost in height, the mandible exhibits greater width). Fortunately, there are few occurrences when facial or lingual undercuts are observed with D1 bone densities, and flap reflection can be safely kept to a minimum. The precise closure of the periosteum and the overlaying tissue has been shown to help recover the blood supply and is encouraged (Box 3.18).

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Box 3.18

D1 Bone: Surgical Modifications

1. Overheating During Osteotomy

- Abundant external or internal irrigation
- Cooled saline irrigation
- Intermittent pressure on drill (e.g., bone dancing)
- Maintain irrigation while pausing every 3-5 seconds
- Utilize new, sharp drills
- Incremental drill sequence (use more drills; pass same drill more than once to widen osteotomy)

2. Blood Supply

- Primarily from periosteum, results in longer healing times
- Minimal reflection to decrease blood compromise

3. Final Osteotomy Drill

- Greater width to minimize pressure necrosis
- Greater depth
- Slower drill speed
- Verify no bone debris remaining

4. Bone Tap

- Short of full osteotomy depth
- Allows passive implant fit to minimize pressure necrosis

- Prevents internal implant-body–implant-bone interface microfracture
- Removes drill remnants

5. Final Implant Placement at or Above Bone Level

- After final insertion, unthread ½ turn to relieve internal stresses

6. Slower Healing Rate

- Lamellar bone – fewer blood vessels
- Five months to achieve mature interface – anterior mandible

7. Stage II Uncovery

- May initiate stage II surgery after 3 to 4 months
- May often use immediate loading (when prosthesis is biomechanically stable)

D2.

D2 bone provides excellent implant interface healing, and osteointegration is very predictable. There exist basically no disadvantages to this type of bone. Most implant systems refer to this density of bone for their ideal surgical protocol. The dense to porous cortical bone on the crest or lateral portions of the implant site provides a secure initial rigid interface. Osteoplasty to gain additional width of bone before implant placement or countersinking below the crestal bone does not compromise support because the lateral cortices and coarse internal trabecular bone provide rigid fixation. The implant may even be placed slightly above the crest of the ridge with decreased compromise or risk of movement at the interface during healing, compared with softer bone types. The intrabony blood supply allows bleeding during the osteotomy, which helps control overheating during preparation and is most beneficial for bone-implant interface healing (Figs. 3.105 and 3.106).

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FIG 3.105 D2 bone has a dense to porous cortical crest, and inner trabecular bone is coarse. It is found most often in the mandible. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

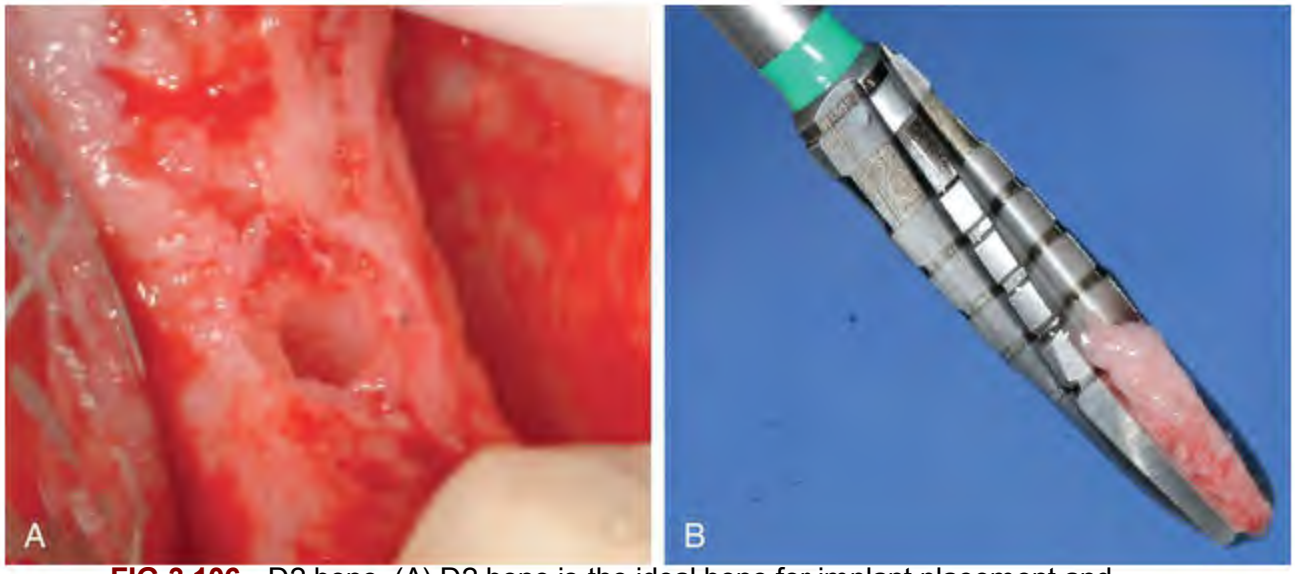

FIG 3.106 D2 bone. (A) D2 bone is the ideal bone for implant placement and healing with a high success rate. (B) This type of bone also allows for the accumulation of bone from the osteotomy that can be used to augment defects.

D3.

D3 bone also presents several disadvantages (Box 3.19). It is more difficult to

manage than the previous two bone density types (D1 and D2) because its preparation is completed easily. Bone preparation in D3 bone completed with constant care of direction to avoid enlargement or elliptical preparation of the site.

Box 3.19

D3 Bone: Surgical and Prosthetic Modifications

1. Bone Anatomy

- Most common in anterior maxilla; usually deficient in width

2. Osteotomy

- Lateral perforation may occur because of width deficiency
- Osteotomy is commonly overprepared
- Ideal angulation to prevent apical perforation

3. Bone-Implant Contact

- Approximately 50%, which compromises initial stability and increases bone healing
- Additional implant may need to be placed for biomechanical advantage

4. Implant Placement

- One time, no removal and reinsertion
- Level with thin crestal cortical bone or slightly below
- Greater risk of load during healing, verify no interim prosthesis pressure
- Use high-torque handpiece to insert self-tapping threaded implant – avoid using insertion ratchet as this tends to widen osteotomy or redirect implant

5. Implant Design

- Titanium plasma spray (TPS) or hydroxyapatite (HA) coated
- Larger-thread design
- Only threaded implants should be placed
- Increased diameter implants, results in greater surface area

6. Healing Period

- Six months to increase lamellar bone and mineralization
- Prosthetic progressive loading more important than for D1 or D2

7. Prosthetic Rehabilitation

- Splint implants for biomechnical stress distribution
- Narrow occlusal table
- Progressive bone loading

A common mistake that causes an elliptical site to form is the use of a finger rest during the osteotomy. Because the drill is often longer than 20 mm, a finger rest results in an arched pathway of the drill into the bone. In dense bone, the side of the drill encroaches upon the dense cortical crest, which opposes the movement and stops the rotation before the crestal osteotomy is enlarged. In D3 bone the arc pathway is not stopped and the osteotomy at the level of the crestal bone is of greater diameter than the drill. If the implant design does not increase at the crestal region, the surgical defect created around the top of the implant may heal with fibrous tissue rather than bone and cause an initial bony pocket. Additionally, the direction for the osteotomy may be changed (see Box 3.19).

To improve rigid fixation of traditional root form designs during healing, the opposing thin cortical bone of the nasal or antral floor is often engaged in the maxilla or the apicolingual plate in the mandible, when immediate loading is considered. If the original implant height determined before

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surgery does not engage the opposing cortical bone, the osteotomy is increased in depth until it is engaged and even perforated. Slightly longer implants are placed in this approach to further increase surface area of support with rigid fixation being of utmost importance. However, it should be noted this technique improves stability during healing but does not decrease the crestal loads to bone after healing. Instead, implant crest module design and the crestal one-third of the implant body design are necessary to decrease stress when the implant prosthesis is loaded (Fig. 3.107).

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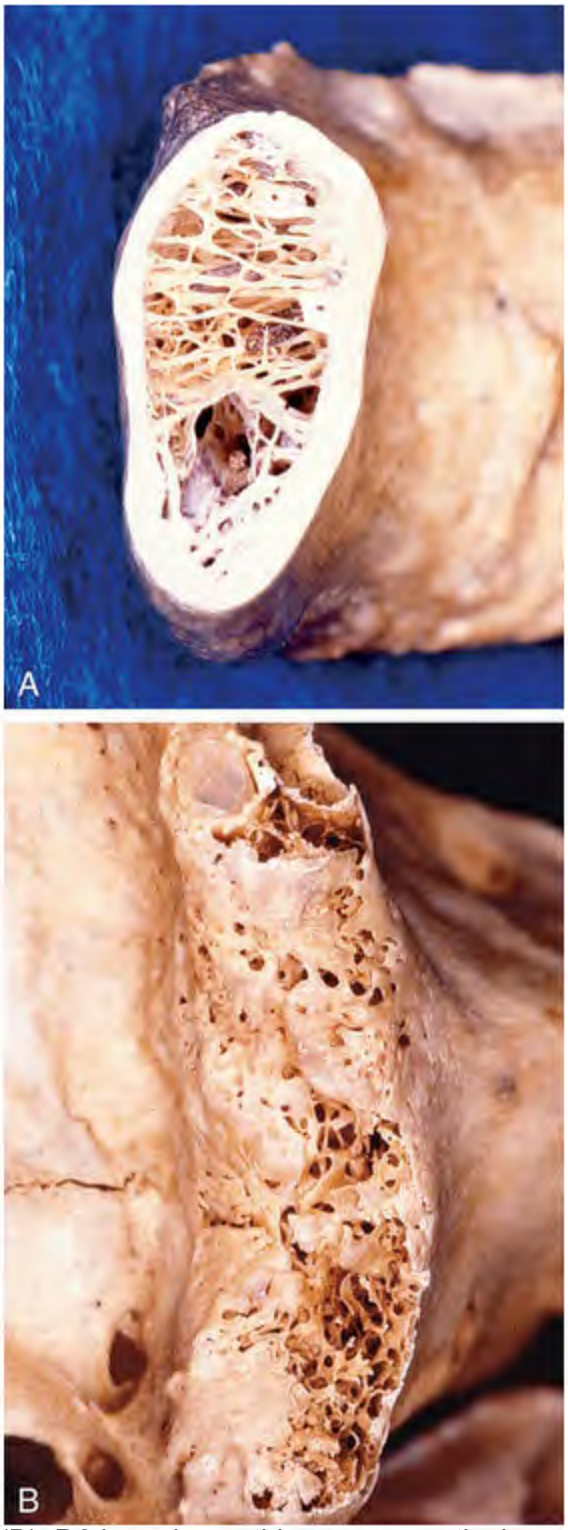

FIG 3.107 (A) and (B), D3 bone has a thin, porous cortical crest and fine trabecular bone within the alveolus. It is frequently found in a posterior mandible. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

D4.

Fine trabecular bone presents the clinician with the most difficult and

greatest possibilty for rigid fixation problems. Bone trabeculae are sparse and, as a result, initial fixation of any implant design presents a surgical challenge (Box 3.20). The implant surgeon should not prepare D4 bone with rotating drills, which use an extraction technique to remove bone preparation of the osteotomy. The initial drill to determine site depth and angulation is the only drill to be used in this bone type, after which osteotomes may be used with a surgical mallet or hand piece to compress the bone site, rather than remove bone, as the osteotomy increases in size. The compaction technique of the site is prepared with great care. The bone site is easily distorted, resulting in reduced initial stability of the implant. The final osteotomy diameter is similar to the D3 preparation. The residual ridge is easily expanded in this bone type. The osteotomy may both compress the bone trabeculae and expand the osteotomy site resulting in an improved bone density (Fig. 3.108 and Box 3.20).

Box 3.20

D4 Bone: Surgical and Prosthetic Modifications

1. Bone Anatomy

- Location is usually posterior maxilla, which results in surgical difficulty
- No cortical crest results in compromised initial fixation
- Decreased height because of maxillary sinus pneumatization
- Bone augmentation is usually indicated

2. Osteotomy

- Easily overprepared, surgical site should be underprepared
- Use of osteotomes is highly recommended
- Angulation should be strictly monitored and misdirection often occurs

3. Bone-Implant Contact

- Approximately 25% resulting in poor initial fixation

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- Additional implant indicated for biomechanical stress distribution

4. Implant Placement

- No removal and reinsertion
- Placement below the crestal bone to minimize loading during the healing phase
- Implant design with greater surface area
- Placement with handpiece is recommended to maintain path of insertion
- Insertion ratchet should not be used

5. Prosthesis Fabrication

- Progressive loading highly recommended
- Narrow occlusal table decreases force-related issues
- Splinting of implants for force distribution

(From Misch CE: *Contemporary Implant Dentistry*, ed 3, St Louis, 2008, Mosby.)

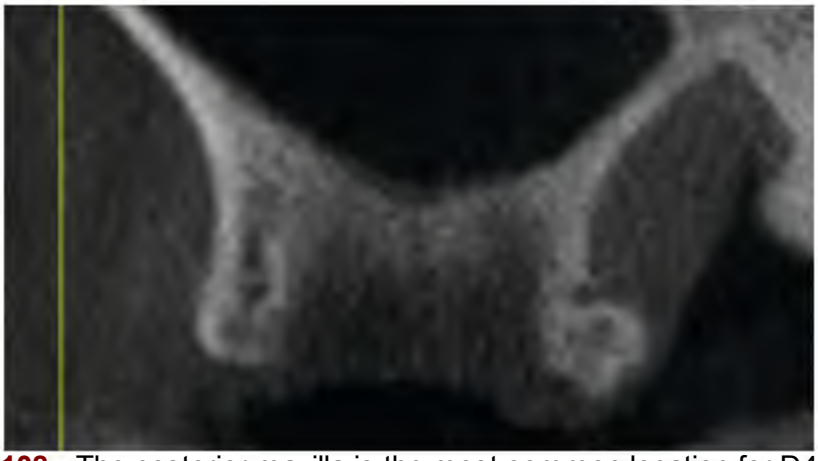

FIG 3.108 The posterior maxilla is the most common location for D4 bone. Because of the poor bone implant contact (~25%), modifications of the surgical and prosthetic procedures need to be implemented to decrease complications.

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Prevention Of Bone Density Complications

Understanding Bone Strength and Density

To understand how the direct effect bone density has on dental implant success and morbidity, the clinician must have knowledge of the make-up and biomechanics of bone. Bone density is directly related to the strength of bone before microfracture. Misch et al. reported on the mechanical properties of trabecular bone in the mandible using the Misch bone density classification.[77] A 10-fold difference in bone strength may be observed from D1 to D4 bone (Fig. 3.109). D2 bone exhibited a 47% to 68% greater ultimate compressive strength compared with D3 bone (Fig. 3.110). On a scale of 1 to 10, D1 bone is a 9 to 10 relative to strength, D2 bone is a 7 to 8 on this scale, D3 bone is 50% weaker than D2 bone and is a 3 or 4 on the strength scale, and D4 bone is a 1 to 2 and up to 10 times weaker than D1 bone. It should be noted that the studies of bone strength were performed on mature bone types. Bone is 60% mineralized at 4 months after implant surgery, and the strength of bone is related to the amount of mineralization. It is prudent to increase healing time prior to loading in D3 and D4 bone densities. A period of 3 to 4 months is adequate for D1 and D2 bone. A healing period of 5 to 6 months is beneficial in D3 to D4 bone. The bone densities that originally relied on clinical impression are now fully correlated to quantitative objective values obtained from CBCT scans and bone strength measurements. These values can help prevent failure in specific situations of weak densities.

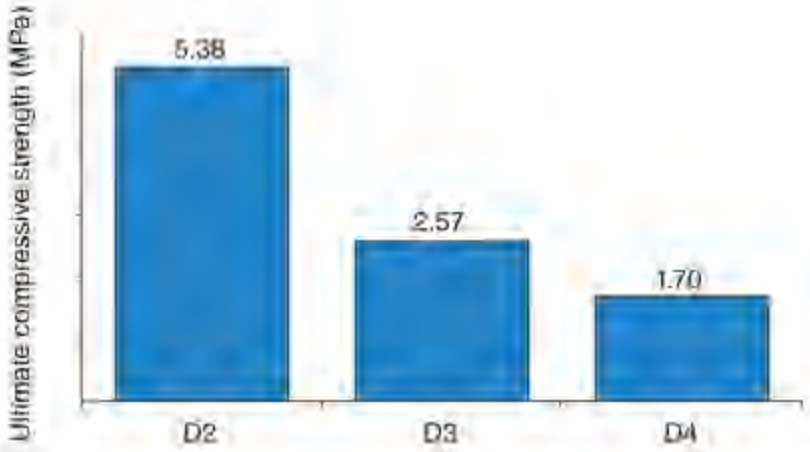

FIG 3.109 The strength of bone is related directly to the density of bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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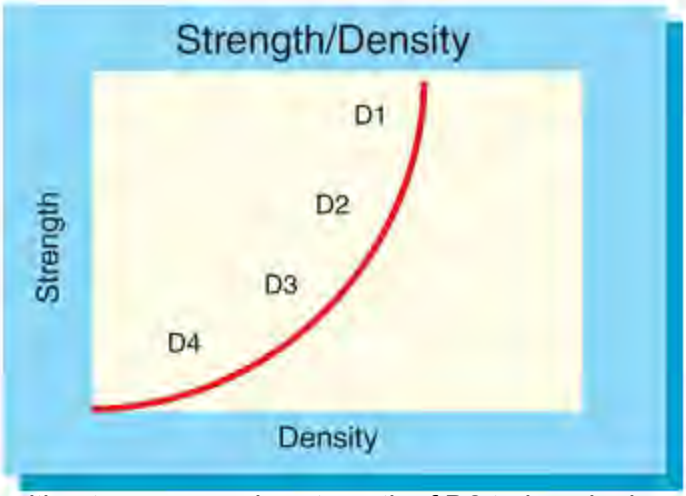

FIG 3.110 The ultimate compressive strength of D2 trabecular bone is greater than D3 trabecular bone, and D4 trabecular bone is the weakest. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Elastic Modulus and Density

By definition, elastic modulus describes the amount of strain (changes in length divided by the original length) as a result of a particular amount of stress. This has been shown to be directly related to the apparent density of bone.[78] The elastic modulus of a material is a value that relates to the stiffness of the material. The elastic modulus of bone is more flexible than titanium. When higher stresses are applied to an implant prosthesis, the titanium has lower strain (change in shape) compared with the bone. The difference between the two materials may create microstrain conditions of pathologic overload and cause implant failure. When the stresses applied to the implant are low, the microstrain difference between titanium and bone is minimized and remains in the adapted window zone, maintaining load-bearing lamellar bone at the interface.[79]

Misch et al. found the elastic modulus of the trabecular bone in the human jaw to be different for each bone density (Fig. 3.111). As a result, when a stress is applied to an implant prosthesis in D1 bone, the titanium-D1 bone interface exhibits very little microstrain difference. In comparison, when the same amount of stress is applied to an implant in D4 bone, the microstrain difference between titanium and D4 bone is greater and may be in the pathologic overload zone (Fig. 3.112). As a result, D4 bone is more likely to cause implant mobility and failure. Clinicians must take into consideration that poorer quality of bone is inherently more susceptible to implant complications.

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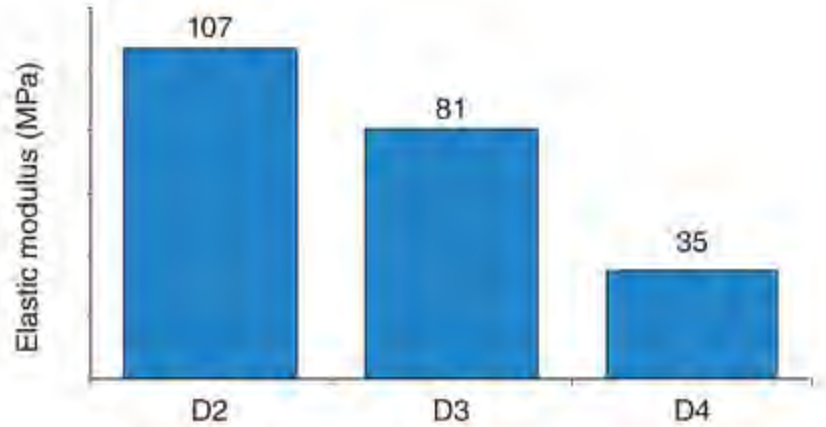

FIG 3.111 The elastic modulus for D2 trabecular bone is greater than that for D3 trabecular bone, and D4 trabecular bone has the lowest elastic modulus. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

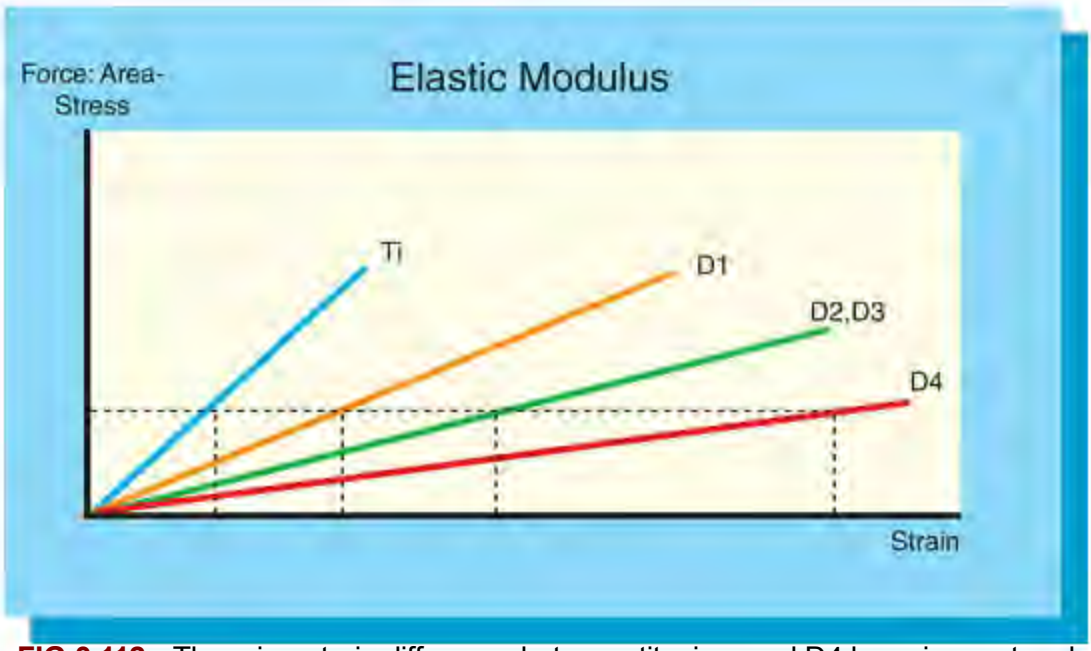

FIG 3.112 The microstrain difference between titanium and D4 bone is great and may be in the pathologic overload zone, whereas at the same stress level, the microstrain difference between titanium and D2 bone may be within the ideal adapted window zone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Bone-Implant Contact Percentage

The initial bone density not only provides mechanical immobilization of the implant during healing but after healing also permits distribution and transmission of stresses from the prosthesis to the implant-bone interface.

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The mechanical distribution of stress occurs primarily where bone is in contact with the implant. Open marrow spaces or zones of unorganized fibrous tissue do not permit controlled force dissipation or microstrain conditions to the local bone cells. Because stress equals force divided by the area over which the force is applied, the less the area of bone contacting the implant body, the greater the overall stress, other factors being equal. Therefore, the BIC percent has a significant influence on the amount of stress and strain at the interface.

In 1990, Misch noted that the bone density influences the amount of bone in contact with the implant surface, not only at first-stage surgery but also at the second-stage uncovery and early prosthetic loading.[80] The BIC percentage is significantly greater in cortical bone than in trabecular bone. The very dense D1 bone of a C–h resorbed anterior mandible or of the lingual cortical plate of a Division A anterior or posterior mandible provides the highest percentage of bone in contact with an endosteal implant and may approximate more than 85% BIC (Fig. 3.113). D2 bone, after initial healing, usually has 65% to 75% BIC (Fig. 3.114). D3 bone typically has 40% to 50% BIC after initial healing (Box 3.21). The sparse trabeculae of the bone often found in the posterior maxilla (D4) offer fewer areas of contact with the body of the implant. With a machined-surface implant, this may approximate less than 30% BIC and is most related to the implant design and surface condition. Consequently, greater implant surface area is required to obtain a similar amount of BIC in soft bone compared with a denser bone quality. As a result, many anterior mandibles with denser bone have less importance with respect to the implant number, size, or design compared with posterior maxillae with less dense bone.

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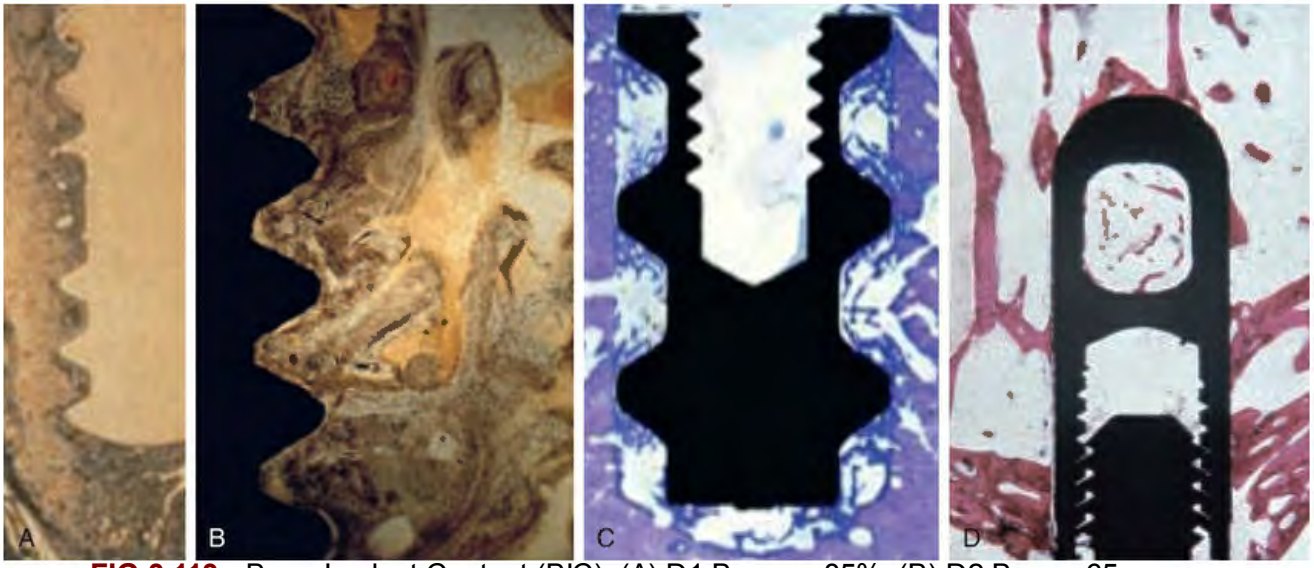

FIG 3.113 Bone-Implant Contact (BIC): (A) D1 Bone - ~85%, (B) D2 Bone - 65–75%, (C) D3 Bone - 40–50%, (D) D4 Bone - ~30%.

FIG 3.114 Bone density. An alternative material to evaluate bone density is: D1 bone = maple wood; D2 bone = white pine wood; D3 bone = balsa wood; D4 bone = Styrofoam.

Box 3.21

Initial Bone-Implant Contact Percent (BIC %)

D1: 85%

D2: 65%–75%

D3: 40%–50%

D4: <30% (% = bone-implant contact)

Studies have shown the BIC is directly related to the bone density and the healing time. For example, in a study by Carr et al.,[80a] the BIC was greater in the mandible than the maxilla (i.e., because of the greater bone density in the mandible in comparison to the maxilla). In addition, the BIC was greater at 6 months compared with 3 months in both jaws (Fig. 3.115). Thus, the healing time before implant loading is related to the density of bone because the strength of bone increases and the BIC increases with a longer time period. Three to 4 months of healing for D1 to D2 bone and 5 to 6 months for D3 to D4 bone has less risk than a shorter time period for all bone types.

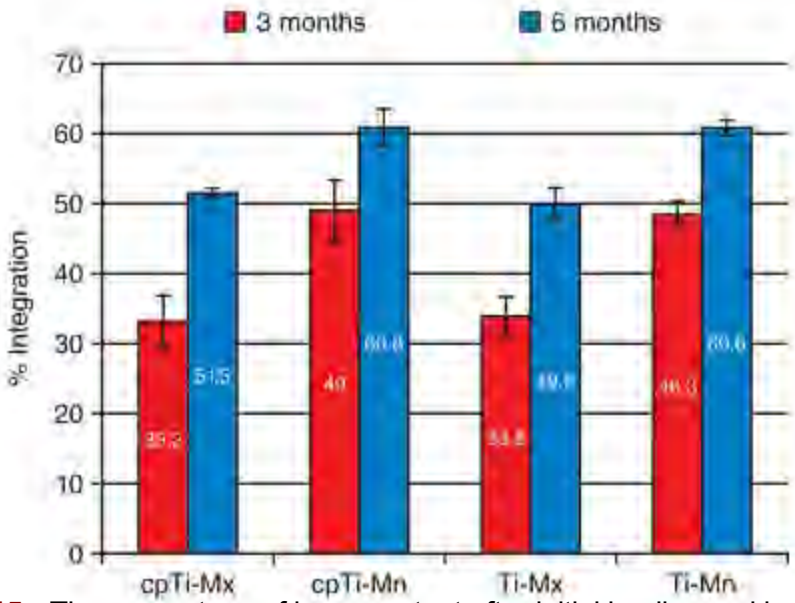

FIG 3.115 The percentage of bone contact after initial healing and before any occlusal load may be related to bone density (e.g., mandible vs. maxilla) and healing time. Longer healing periods may increase bone-implant contact. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Stress Transfer

Crestal bone loss and early implant failure after loading results may occur from excess stress at the implant-bone interface. A range of bone loss has

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been observed in implants in different bone densities with similar load condition.[81] Bidez and Misch noted in 1990 that part of this phenomenon may be explained by the evaluation of finite element analysis (FEA) stress contours in the different volumes of bone for each bone density.[82] Each model reproduced the cortical and trabecular bone material properties of the four densities described. Clinical failure was mathematically predicted in D4 bone and some D3 densities under occlusal loads (Fig. 3.116). Other studies using FEA models with various implant designs and bone quality have also evaluated the stress-strain distribution in the bone around the implants.[83] For example, Tada et al. evaluated the three-dimensional changes around different length implants in different bone qualities (Fig. 3.117).[84] The type 3 and 4 bone categories had four to six times more strain around all implants, with the highest strains around the shortest implants. As a result of the correlation of bone density to the elastic modulus, bone strength, and BIC percent, when a load is placed on an implant, the stress contours in the bone are different for each bone density.[85] In D1 bone, the highest strains are concentrated around the implant near the crest, and the stress in the region is of lesser magnitude. D2 bone, with the same load, sustains a slightly greater crestal strain, and the intensity of the stress extends farther apically along the implant body. D4 bone exhibits the greatest crestal strains, and the magnitude of the stress on the implant proceeds farthest apically along the implant body.

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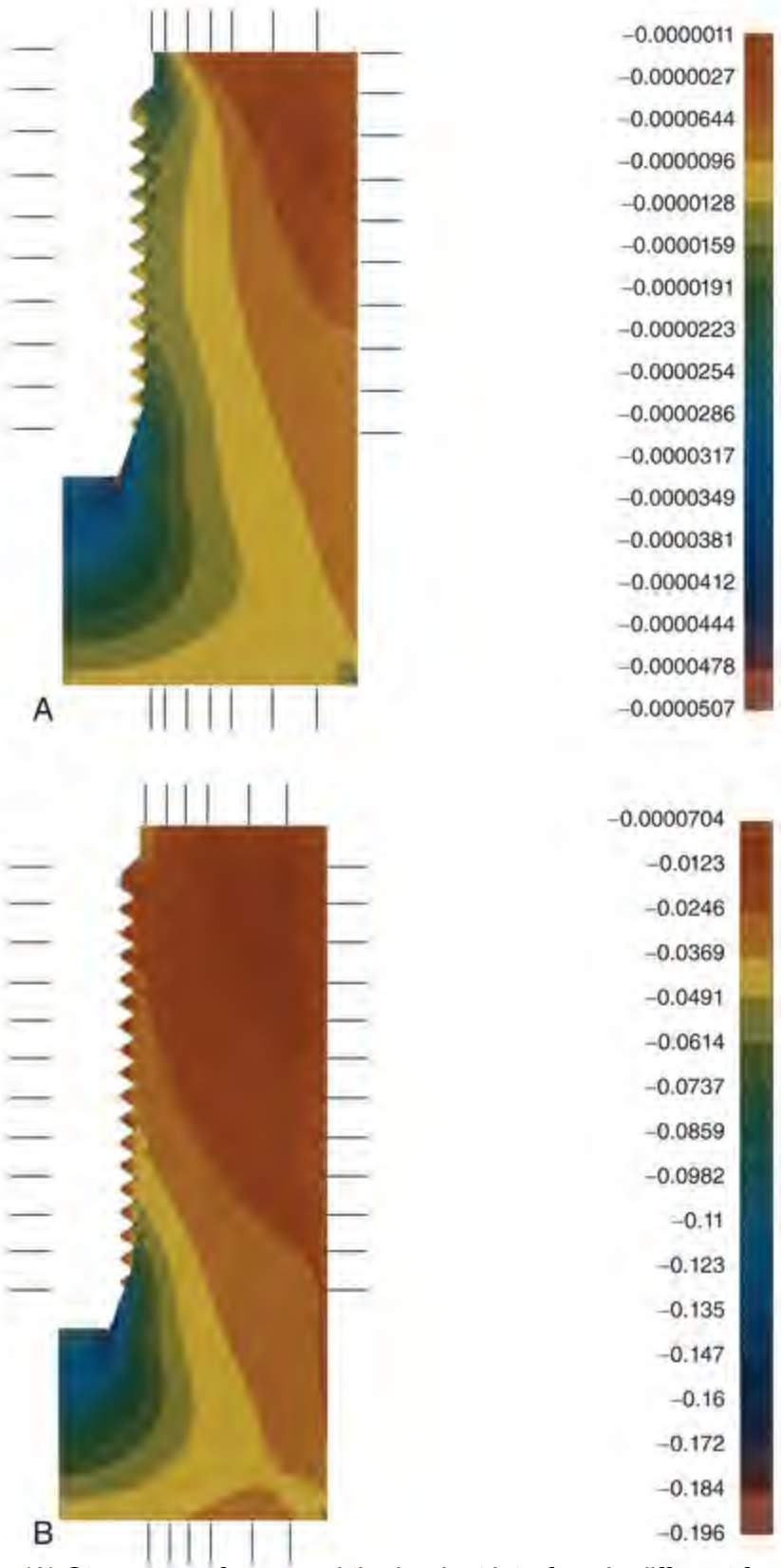

FIG 3.116 (A) Stress transfer around the implant interface is different for each bone density. In this two-dimensional finite element analysis, D2 bone has an intermediate stress intensity around the implant. (B) A two-dimensional finite element analysis demonstrates that D4 bone has a higher stress intensity around the implant, and the higher intensity even extends to the zone around the apical threads. (From Misch CE:

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Dental implant prosthetics, ed 2, St Louis, 2015, Mosby.)

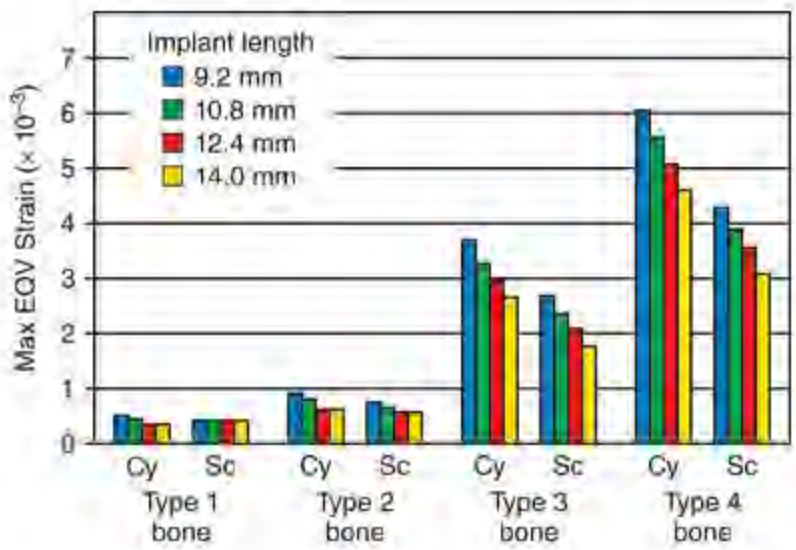

FIG 3.117 The softer bone types (types 3 and 4) have higher strain values around implants regardless of their length compared with harder bone types (types 1 and 2). (From Misch CE: *Dental implant prosthetics,* 2e, St Louis, 2015, Mosby; Data from Tada S, Stegaroiu R, Kitamura E, et al.: Influence of implant design and bone quality on stress/strain distribution in bone around implants: a 3-dimensional finite element analysis, *Int J Oral Maxillofac Implants* 18:357–368, 2003.)

As a consequence of different strain regions present around implants with different bone densities, the magnitude of a prosthetic load may remain similar, and yet give one of the following three different clinical situations at the bone-implant interface based on the bone density around the implant: (1) physiologic bone loads in the adapted window zone and no marginal bone loss; (2) mild overload to pathologic overload bone loads and crestal bone loss; or (3) generalized pathologic overload and implant failure. To obtain a similar clinical result in each implant prosthesis, the variables in each patient must be either eliminated or accounted for in the treatment plan. Because the myriad of variables cannot be eliminated relative to bone density, the treatment plans (including implant number, size, and design) should be modified.

Bone Density Treatment Planning

The first component of the treatment planning process should include the use of a radiographic evaluation, preferably a CBCT x-ray. Initially, an idea of the potential bone density can be determined by the anatomic position;

anterior mandible and single tooth replacement is D2, anterior maxilla and posterior mandible is D3, and posterior maxilla is D4. Secondly, a more accurate representation of the bone density may be determined by evaluation of the hounsfield units (Hu) on a medical CT scan or a CBCT scan (i.e., linear correlation with the corresponding hounsfield units). A third technique would be to use prior experience (i.e., if surgery has been completed prior in the area) as a guideline for the determination of bone density.

Treatment Planning Modification.

When utilizing bone density in the treatment planning process, the clinician must take into consideration these four facets of bone quality: (1) each bone density has a different strength; (2) bone density affects the elastic modulus; (3) bone density differences result in different amounts of BIC percent; and (4) bone density differences result with a different stress-strain distribution at the implant-bone interface. Bone density is an implant treatment plan modifier in several ways—prosthetic factors, implant number, implant size, implant design, implant surface condition, and the need or method of progressive loading (Box 3.22).

Box 3.22

Treatment Plan Modifiers

↓Bone density = ↑ Implant area

↑Implant number

↑Implant width

↓Cantilevers

↑Implant body surface area

↑Implant length (D4 bone)

↑Implant surface condition

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Increase Surface Area.

As the bone density decreases, the strength of the bone also decreases. In order to decrease the incidence of microfracture of bone, the strain to the bone should be reduced. Because strain is directly related to stress, the stress to the implant system should be reduced as the bone density decreases. Stress may be reduced by increasing the functional surface area over which the force is applied. Increasing implant number is an ideal way to reduce stress by increasing functional loading area. For example, three implants rather than two may decrease applied implant moments in half and bone reaction forces by two thirds, depending on implant position and size. An implant prosthesis with normal patient forces in D4 bone should have at least one implant per tooth. In the molar region, two implants for each missing molar may even be appropriate. In D3 bone, one implant per tooth is often appropriate in the posterior region, where fewer implants are required in the anterior location. In D2 bone with normal patient forces, one or more pontic may replace a tooth between two implants in both posterior and anterior regions.

Implant Design.

The surface area of the implant macrogeometry may be increased to decrease stress to the implant-bone interface. The easiest technique is to increase the implant diameter, which will decrease stress by increasing the surface area. This may also reduce the length requirement. For example, when a 0.5-mm increase in width occurs, there is an increased surface area between 10% and 15% for a cylinder implant (i.e., even more difference is found with threaded implant body designs). Because the greatest stresses are concentrated at the crestal region of the implant in favorable bone types, width is more significant than length for an implant design after adequate length has been established. D4 bone should often require wider implants compared with D1 or D2 bone. This may require onlay grafts or bone spreading to increase the width of bone when other stress factors are high. Based on long-term clinical experience of V-shaped threaded implant bodies, the minimum bone height for initial fixation and early loading for D1 bone is 7 mm; for D2 bone, 9 mm; and for D3 bone, 12 mm using the classic V-thread screw implant design and titanium surface condition. Because the crestal region is the location of pathologic overload of bone most often occurs after prosthetic loading, after initial healing is complete, the length of the implant is not as significant to solve crestal bone loss (i.e., and the quality of implant health) as other factors

(e.g., implant design, implant width). In contrast, D4 bone benefits from relatively longer implants for initial fixation and early loading compared with other bone densities. This is not only for initial fixation but also because the stress-strain transfer of occlusal forces extends farther down the implant body.

Implant Coatings.

Coatings or the surface condition on an implant body can increase the BIC percentage and the functional surface area. A rougher surface is strongly suggested in soft bone (e.g., D3, D4) and has resulted in improved survival rates compared with machined titanium. However, after 1 to 2 years, the mechanical load on the overall implant design is more critical to the amount and type of bone contact compared with the surface condition on the implant body. Rough surface conditions also may have some disadvantages. Plaque retention when exposed above the bone, contamination, and increased cost are a few of the concerns with roughened surfaces. The benefit and risk of surface conditions suggests that the roughest surfaces are most often used in only softer bone types.

Direction of Force.

The consequences of the direction and amount of occlusal force is directly related to the bone density. A load directed along the long axis of the implant body decreases the amount of stress in the crestal bone region compared with an angled load (i.e., nonaxial load). As the bone density decreases, axial loads on the implant body become more critical as crestal bone loss may occur. Bone grafting or bone spreading to increase the width of bone and to better position the implant relative to the intended load is considered for soft bone types. Additionally, adhering to progressive bone loading in poorer bone qualities will decrease the possibility of force-related bone loss.

Progressive Bone Loading.

Progressive bone loading provides for a gradual increase in occlusal loads, separated by a time interval to allow the bone to mature and accommodate to the local strain environment. If proper techniques are utilized, progressive bone loading changes the amount and density of the implant-bone contact (i.e., a D4 bone may be changed to a D3 bone density). The increased density of bone at the implant interface improves the overall support system

mechanism. The poorer quality of the bone, the more important the need for progressive loading.

Bone Density Summary

A key determinant for clinical success is the diagnosis of the bone density in a potential implant site. The strength of bone has been shown to be directly related to bone density. The modulus of elasticity and the percentage of BIC is related to bone density. The occlusal force and direction of force with the consequences are affected by the density of bone. As a consequence, the clinician must take into consideration altering the protocol of treatment related to bone density to decrease morbidity and increase survival rates. Studies and clinical experience has shown that altering the treatment plan to compensate for soft bone types has provided similar survival rates in all bone densities. After the prosthetic option, key implant position, and patient force factors have been determined, the bone density in the implant sites should be evaluated to modify the treatment plan. The treatment plan may be modified by reducing the force on the prosthesis or increasing the area of load by increasing implant number, implant size, implant design, or implant body surface condition. Of these possibilities, the number of implants (i.e., adding additional implants) is often the most effective method to decrease the stress to the implant system.

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Size of Implants

Narrow-Diameter (Mini) Implants

In the 1970s, narrow-diameter implants smaller than 2 mm in diameter were very popular in Europe and South America. These "pin" implants were often used in two or three sets for each tooth (Fig. 3.118). They did not maintain crestal bone, often would fail or fracture, and became unpopular after the 3.75-mm-diameter root form implants were developed. More recently, these implants have reemerged in the marketplace (Fig. 3.119).

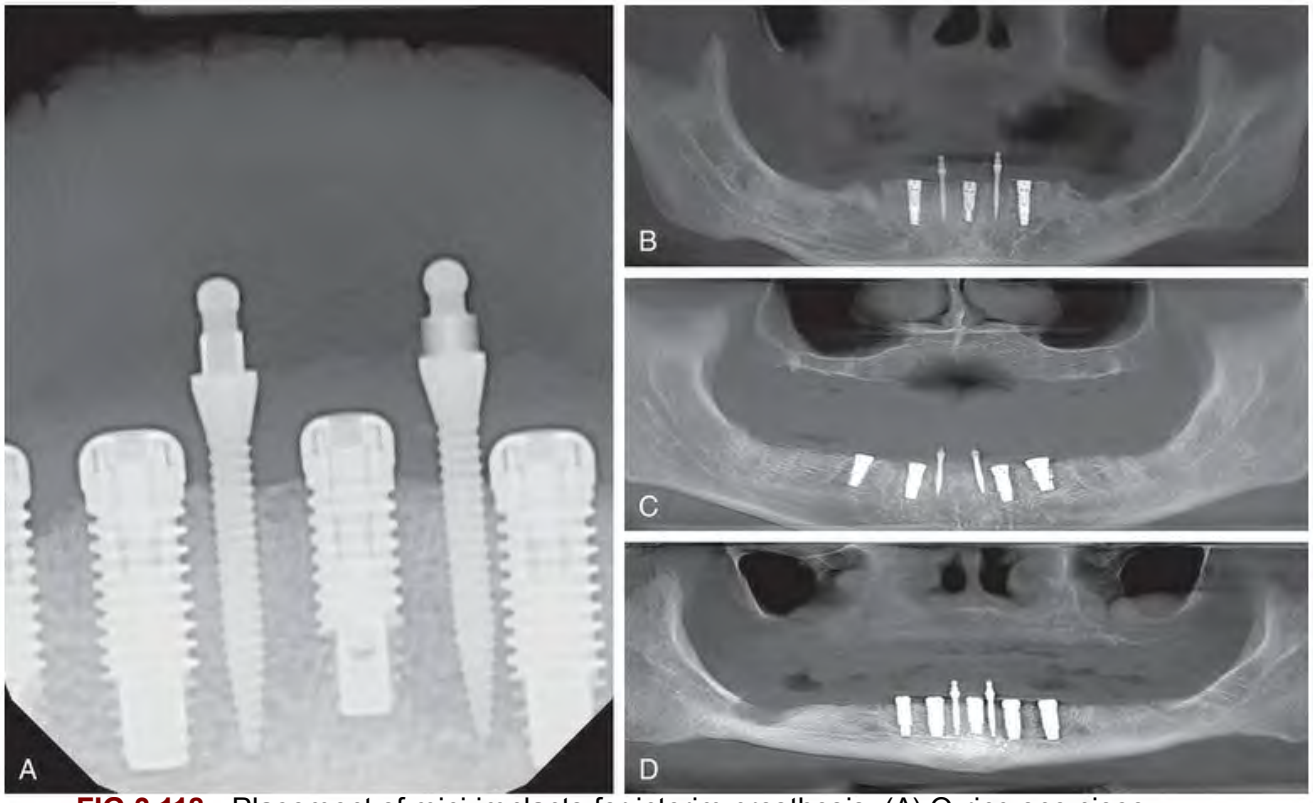

FIG 3.118 Placement of mini-implants for interim prosthesis. (A) O-ring one piece mini-implant. (B) 3–implants overdenture. (C) 4–implants overdenture. (D) 5–implants fixed prosthesis.

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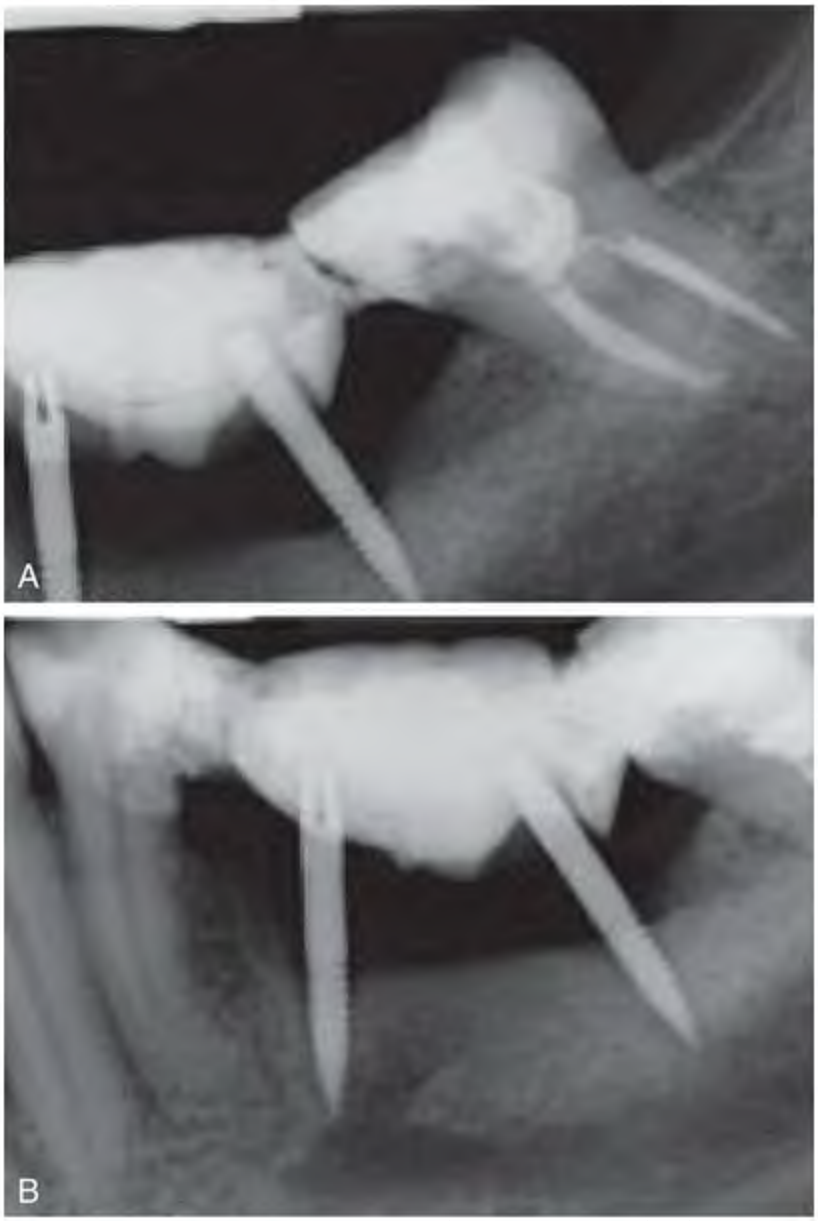

FIG 3.119 Mini-implants. (A–B) The use of mini-implants for fixed prostheses is associated with a high surgical and prosthetic morbidity.

The initial reentry of the mini-implant was for a transitional prosthesis; the diameter of these implants ranged from 1.8 to 2.4 mm. After the final implant positions and numbers were inserted in a two-stage healing process, additional mini-implants were used to immediately restore and support a transitional prosthesis. This approach still has validity when patients do not want to wear a removable restoration during the initial healing process or to protect a bone graft site during augmentation. Although the transitional mini-implants may fail in some clinical situations, the regular-size implants are not affected, and the final restoration is not at risk.

After a few years, the mini-implants were suggested for implant

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overdenture support. The concept (as presented) places multiple mini-implants with O-ring or other overdenture attachment systems and immediately is used to retain and support the prosthesis (Fig. 3.120). It is also presented as a "simple solution for denture comfort because of flapless implant installation." This concept also encourages a reduced fee to have greater patient acceptance.

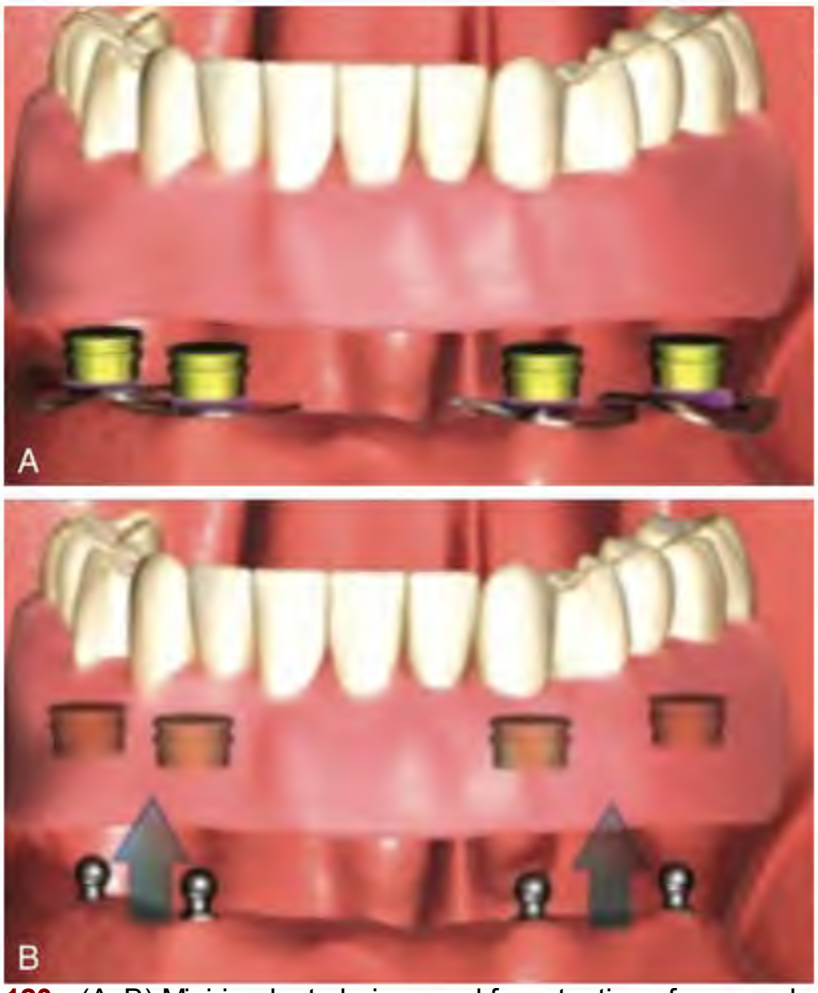

FIG 3.120 (A–B) Mini-implants being used for retention of an overdenture.

Disadvantages of "Mini" Implants

Compared with implants 3.75 mm or larger, with thousands of clinical reports, the small-diameter implant has almost no long-term studies. Even studies longer than 3 years are limited in numbers. Because implants smaller than 3 mm in diameter are usually too narrow for a two- or three-piece implant body abutment design, a one-piece implant is most often designed

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(Fig. 3.121). This requires the implant abutment portion to extend into the mouth upon insertion. Hence, the implant most often is immediately placed into more function compared with the one- or two-stage approach. This increases the risk of failure during the healing period of bone because the surgical healing and the early loading period occur at the same time.

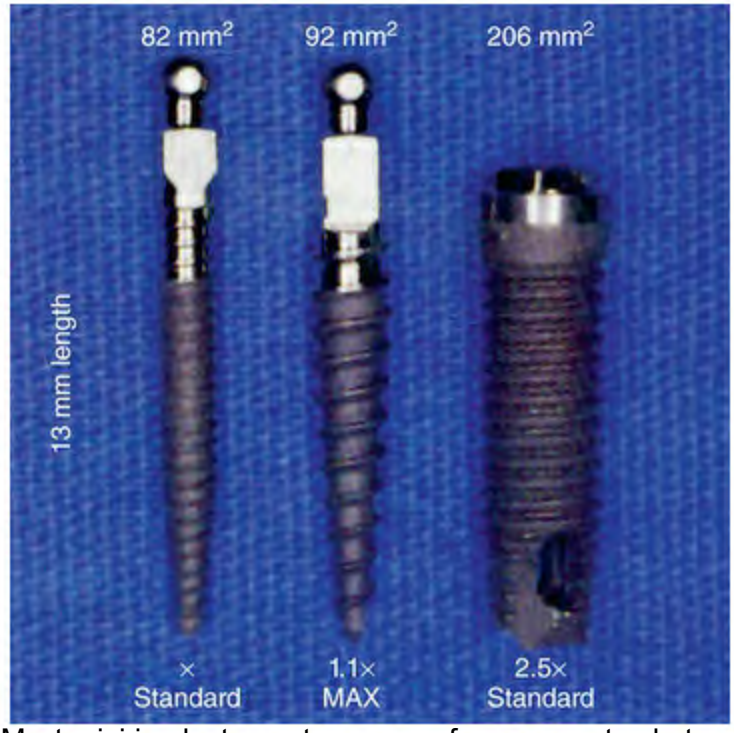

FIG 3.121 Most mini-implants are too narrow for a separate abutment-to-implant connection. As a result, they are one-piece implants with the abutment connected to the implant body and often placed in function after insertion. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

An implant has an increased risk of healing and early loading failure of 5% to 30% when used for an immediate restoration, in part related to a number of factors, including the implant diameter and design. The mini-implant is usually less than 2 mm in width. In a study by Misch, the small-diameter implant (2.2–2.4 mm) had a 75.7% survival rate after 6 weeks when used immediately for retention of a mandibular denture using four to five implants per patient.[86]

To decrease the risk of healing and early loading failure, a wider-diameter implant with an implant body with more surface area is of benefit. Because the mini-implants are too narrow to increase the depths of each thread, they act more as a "nail" than a screw. The surface area for initial fixation, early loading, and mature loading is reduced.

The mini-implant designs are usually deficient in seven ways: (1) decreased diameter and less surface area for loading; (2) a decreased thread depth; (3) less initial fixation; (4) greater risk of fracture; (5) narrow range of prosthetic abutment options; (6) difficult to splint implants together; and (7) immediate restoration often required (Box 3.23).

Box 3.23

Narrow "Mini" Diameter Implants

Disadvantages

1. Few long-term studies
2. Immediate restoration often required
3. Less surface area for loading
4. Decreased initial fixation
5. Higher associated failure rates
6. Poor emergence profile for fixed prosthesis
7. Greater risk of fracture
8. Higher risk procedure
9. Often associated with flapless surgery resulting in increased morbidity

. Removal process of fractured implants more difficult

The "flapless" surgical approach is often suggested with the mini-implant and has a perceived benefit of surgical ease and less patient discomfort. However, there is an increased risk of bone perforations in the areas of concavities or minimal thickness regions of the crestal bone. If a CBCT scan is not performed before surgery, it is almost impossible to evaluate most edentulous maxillae and many edentulous mandibles without reflecting the tissue. Additionally, this places the patient at risk in the posterior mandible

for possible neurosensory impairment issues. In a study by Misch, there was no difference in the postoperative pain medication requirements of patients with a "flapless" surgery compared with the regular reflection surgical technique. It is suggested to directly observe the bone region before and during implant insertion unless abundant bone and CT scans are available.

Less risk of early implant failure is present when the implants can be splinted together. The mini-implant is most often used as an independent unit because angled abutments are not available (because the implant-abutment is all one piece). Therefore, the stresses are generally greater and the failure rate risk is greater because the implants are independent units.

In addition to a higher risk of failure, the bending fracture resistance and fatigue fracture of the mini-implant is 16 times less than that of a regular 4-mm-diameter implant. Cycles to fracture may be as few as 11,000 to 20,000 cycles at 200 N (1350 lb). The teeth often have 440 cycles/day of function and parafunction with 314 cycles/day of maximum bite force.[87] Thus, the mini-implant is at risk of fracture even within the first year of loading (Fig. 3.122).

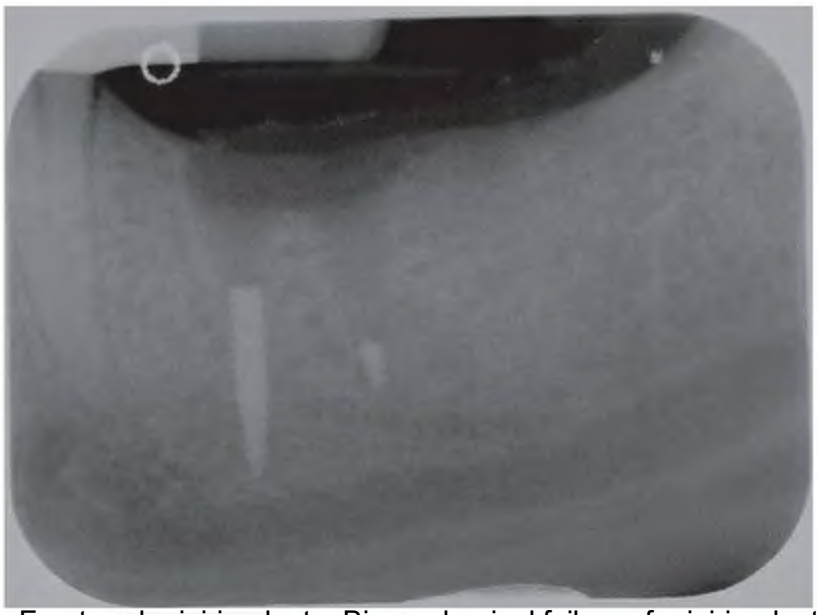

FIG 3.122 Fractured mini-implants. Biomechanical failure of mini-implants resulting fractured implant bodies.

A mini-implant is often promoted as a less expensive option for the patient. The product cost to the clinician of a "mini" implant is approximately half that of a regular-size implant. It is safer to reduce the fee in half and then add the extra cost of a regular implant than to reduce the fee; use a mini-implant; and have a greater risk of early failure, greater risk of

fracture, greater risk with independent units, and limited prosthetic options. A two-stage implant system may have confirmation of successful integration healing without a prosthetic load. A range of abutments permits individual loading or splinting the implants together after integration is confirmed. However, the mini-implants do have a benefit for transitional prostheses and transitional solutions to protect a bone graft, especially when the patient does not accept a transitional removable restoration. The clinician must be conscious of the type of removable prosthesis used with mini implants either on a intreim basis or for the final prosthesis. An RP-5 prosthesis should always be used (i.e., completely soft tissue–supported) to minimize stress on the implants.

Ideal Implant Width

The natural teeth may be used as a guideline to determine the ideal implant width for function loads and esthetics. The roots of the natural dentition optimize the amount and direction of forces found with the mouth. The smallest-diameter roots are located in the mandibular anterior region, where the forces are less and the direction of force is along the long axis of the root. The maxillary anterior teeth have larger roots and a different cross-section shape to compensate for the off-axis loading that increases lateral forces on the structure. The canines have a greater root surface area (i.e., maxilla compared to mandibular) in response to the higher bite forces (90 lb/in^2 compared with 35 lb/in^2) and the direction of force during mandibular excursions.

The premolars have less surface area than the canines because they do not receive a lateral load in excursions. The molars have multiple roots splinted together in one crownmainly due to the amount of force received. The maxillary posterior region has the least bone density; the mandibular counterpart has coarser trabecular bone. The maxillary molars have more roots than the mandibular components and have more surface area to dissipate loads in the fine trabecular bone located in this region of the mouth. The molar crowns are almost twice as large in diameter, and the root surfaces are twice those of the premolars. This compensates for the amount of load increase by two to three times and decreases the risk of damaging stresses (Fig. 3.123).

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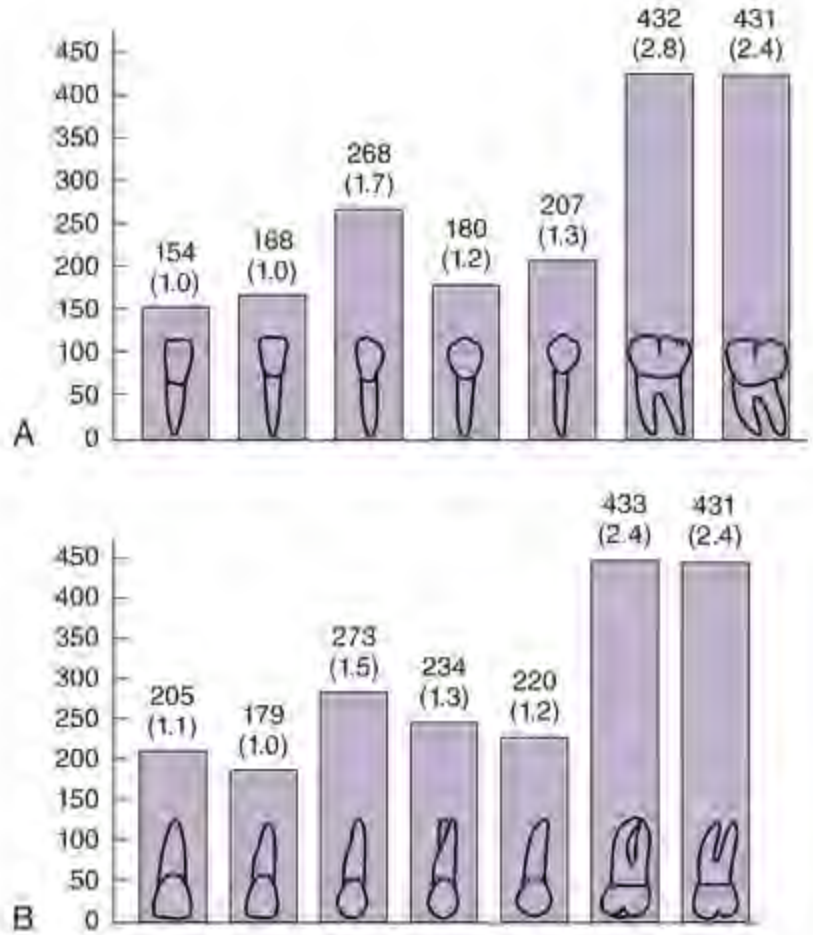

FIG 3.123 (A) The root surface area of the mandibular teeth is greater in the posterior regions, where the bite forces are greater. (B) The root surface area of the maxillary teeth is greater than that of the mandibular teeth because the surrounding bone is less dense. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

In this light, the mandibular incisors region and the maxillary lateral incisor may be replaced with 3- to 3.5-mm-diameter implants; the maxillary centrals, canines, and premolars in both arches may use 4-mm-diameter implants. The molars may be restored with 5- or 6-mm-diameter implants in both arches. When larger-diameter implants cannot be used in the molar region, two 4-mm-diameter implants for each molar should be considered, especially in the maxilla (Box 3.24).

Box 3.24

Ideal Implant Diameters

Function and Esthetics (Diameter)

Maxillary centrals: 4.0 mm

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Maxillary laterals: 3.0–3.5 mm

Maxillary cuspids and premolars: 4.0 mm

Maxillary molars: 5.0–7.0 mm

Mandibular incisors: 3.0 mm

Mandibular cuspids and premolars: 4.0 mm

Mandibular molars: 5.0–7.0 mm

The ideal size of the implant body should be incorporated into a treatment plan rather than the surgeon determining this dimension at the time of surgery. The initial size of an implant is determined in both length and diameter. In a two-stage healing protocol the ideal implant length should be at least 12 mm. The poorer quality of the bone, the longer the implant requirements. The greater the bite force, the longer the implant dimension. Therefore, the shortest implant length may be treatment planned in the anterior mandible, the anterior maxilla may have a slightly longer implant, the posterior mandible may have a longer implant, and the longest implant requirement for an ideal treatment plan is usually found in the posterior maxilla.

The diameter of an implant has surgical, loading, and prosthetic considerations. In the initial treatment plan, the loading and prosthetic components are most important. The width of the implant is directly related to the overall functional surface area. Where the forces are greater or the bone is less dense, the implant is wider, ranging from 3 to 6 mm. As a general rule, the narrowest implant is found in the anterior mandible followed by the anterior maxilla and the posterior mandible; the widest-diameter requirements are found in the molar region of the posterior maxilla.

The prosthetic aspects of the implant width are primarily related to the esthetics of the emergence profile, the force on an abutment screw, and the strength of the implant components. As a result, wider-diameter implants are selected in the molar regions; standard diameters in the canines, premolars, and maxillary central incisors; and the smallest-size implants in the maxillary lateral and mandibular incisors.

The natural dentition follows the guidelines established in the implant-size treatment plan considerations. The correlation is most likely found

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because of the biomechanical relationship of the amount and type of the forces in the location of the jaws and the type of the bone in the region. In the maxilla, fine trabecular bone is used to dissipate forces, and the amount of force is the greatest in the molar region. The mandible is a force-absorbing unit and has coarse trabeculae and dense cortical bone. The tooth size difference is reflected in the diameter of the tooth, not in the overall length dimension. These guidelines are consistent for both teeth and implants when engineering principles determine tooth and implant size.

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Splinting Implants to Teeth

Treatment Planning

Treatment planning a splinted implant-tooth prosthesis is very controversial in implant dentistry today. The connection of a natural tooth (i.e., with a periodontal ligament) with a dental implant (i.e., direct bone interface) poses a biomechanical challenge. To date, studies have been equivocal on the success of this treatment mainly due to the differential support mechanisms.

Although rare, the most common scenario for which a root form implant may be joined to a natural tooth as a terminal abutment is in the posterior regions of the mouth. For example, if a patient is missing the first and second molars in a quadrant (with no third molar present), the segment requires at least two implants of proper size and design to independently restore these two teeth. If adequate bone exists in the second molar and distal half of the first molar but inadequate bone exists in the mesial half of the first molar, a premolar-size pontic is required. The pontic may be cantilevered from the anterior natural teeth or the posterior implants. Either of these options may result in complications because of tensile forces on the cement seal of the abutment farthest from the pontic.

An alternative may be to join the implant to a natural tooth, if all other factors are favorable. This plan is more likely in the presence of a Division C –h ridge in the pontic region, when inadequate bone height adjacent to the natural tooth decreases the prognosis of a vertical bone graft. Another scenario in favor of this treatment plan is when the posterior implants are of a narrower diameter than usual. When two Division B root forms are used in the posterior mandible to replace molars, there should be no cantilever to magnify the force on the implants. Posterior pontics should not be cantilevered from even two splinted Division B root form implants. An additional root form implant or natural tooth is required as an abutment for the fixed prosthesis. When an additional implant insertion is not an option, the posterior implants may be joined by a rigid connector (i.e., a solder joint) to natural teeth within the prosthesis, provided all dental factors are favorable (Fig. 3.124).

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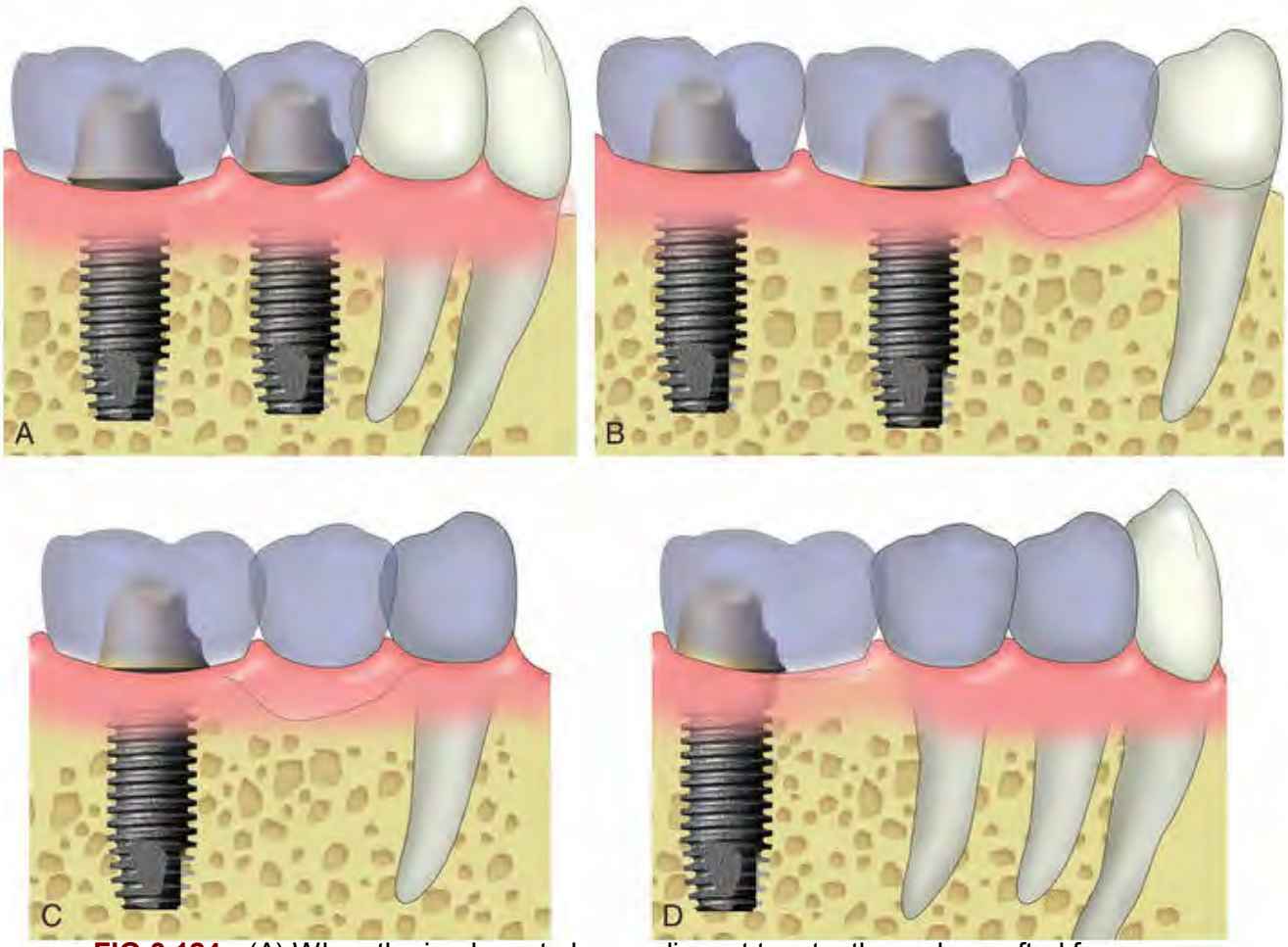

FIG 3.124 (A) When the inadequate bone adjacent to a tooth can be grafted for implant placement and an independent prosthesis, this is the treatment of choice. (B) When the inadequate bone adjacent to a tooth cannot be grafted, one option is to cantilever the missing tooth from the anterior teeth or from posterior implants. The posterior implants permit the replacement of more than one tooth but require at least two implants. (C) When the inadequate bone adjacent to a tooth cannot be grafted, another option is to insert an implant more distal and make a three-unit fixed partial denture by connecting the implant to the nonmobile tooth. (D) When the inadequate bone adjacent to a tooth cannot be grafted and the tooth is slightly mobile, one option is to insert an implant more distal and make a four-unit fixed partial denture by connecting the implant to two anterior teeth (when the most anterior tooth is nonmobile). (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

The connection of natural teeth and osteointegrated implants within a single rigid prosthesis has generated concern and publications, with studies and guidelines for both extremes (Fig. 3.125). In other words, some articles report problems, whereas others state that no problem exists. To be more specific to a particular situation, more information is required to design a successful treatment plan. Two designs are available for the connection of implants and teeth within the same prosthesis: a conventional fixed partial denture or a fixed partial denture with a nonrigid connector. To address this

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issue, the mobility of the natural abutment must be assessed.

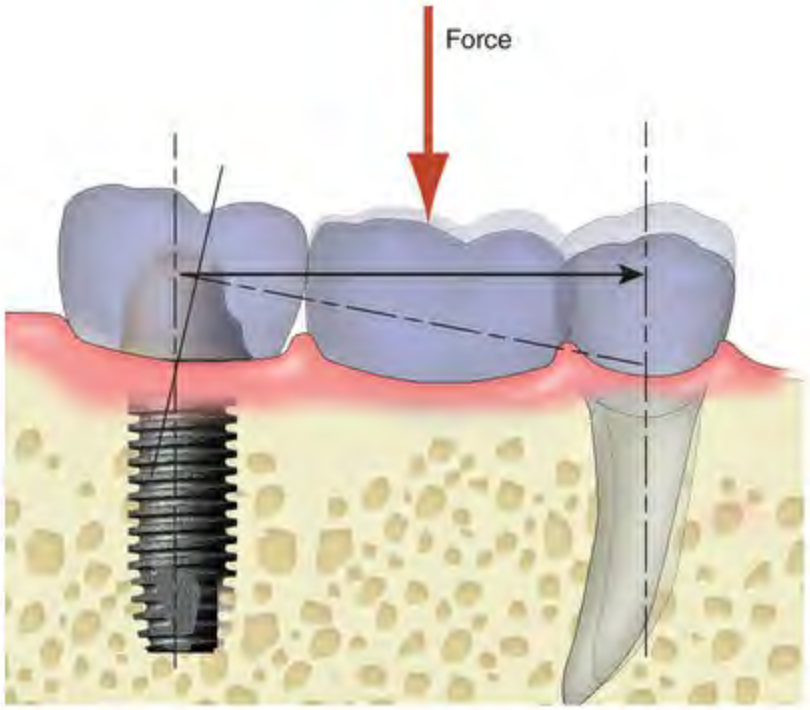

FIG 3.125 Splinting a rigid implant to a natural tooth has caused concerns relative to the biomechanical differential in movement between the implant and tooth. Because the tooth moves more than the implant, the implant may receive a moment force created by the "cantilever" of the prosthesis. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Mobility

The mobility of potential natural abutments influences the decision to join implants and teeth more than any other factor. In the implant-tooth rigid fixed prosthesis, five components may contribute movement to the system: the implant, the bone, the tooth, the prosthesis, and implant/prosthetic components.

Vertical Movement.

A natural tooth exhibits normal physiologic movements in vertical, horizontal, and rotational directions. The amount of movement of a natural tooth is related to its surface area, root design, and bone support. Therefore, the number and length of the roots; their diameter, shape, and position; and the health of the periodontal ligament primarily influence tooth mobility. A healthy tooth exhibits no clinical mobility in a vertical direction. Actual

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initial vertical tooth movement is about 28 mm and is the same for anterior and posterior teeth. The immediate rebound of the tooth is about 7 mm and requires almost 4 hours for full recovery, so additional forces applied within this time period depress the tooth less than the original force. The vertical movement of a rigid implant has been measured as 2 to 3 mm under a 10-lb force, and is due mostly to the viscoelastic properties of the underlying bone (Fig. 3.126).

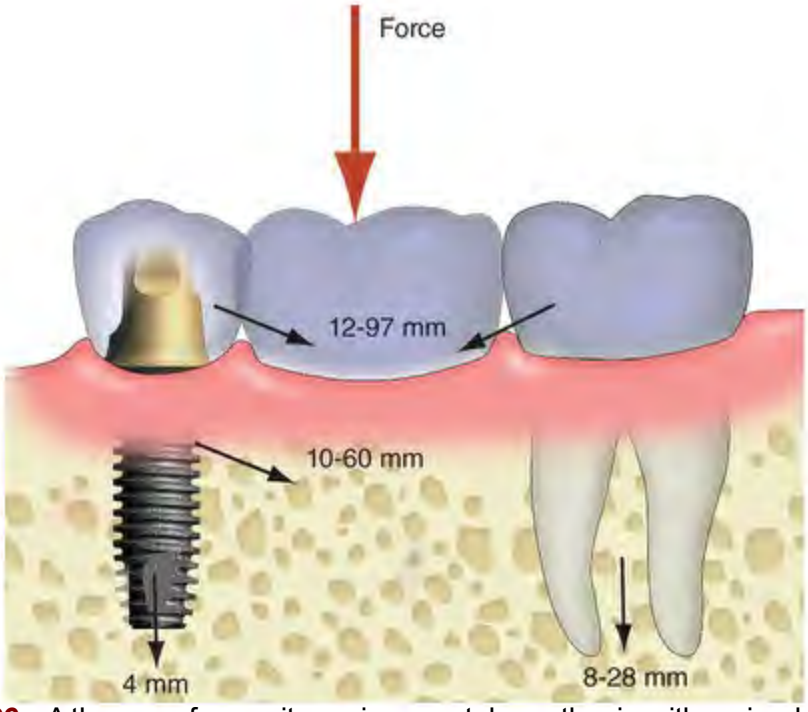

FIG 3.126 A three- or four-unit precious metal prosthesis with an implant and a posterior tooth rigidly splinted has some inherent movement. The implant moves apically 0 to 5 μm, and the tooth moves apically 8 to 28 μm but can rotate up to 75 μm toward the implant because of a moment force. The metal in the prosthesis can flex from 12 to 97 μm, depending on the length of the span and the width of the connecting joints. The abutment-to-implant component movement may be up to 60 μm because of abutment prosthetic screw flexure. As a result, a vertical load on the prosthesis creates little biomechanical risk when joined to a nonmobile tooth because of the design. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Prosthesis Movement.

The fixed prosthesis that connects a tooth and implant also illustrates movement. Under a 25-lb vertical force, a prosthesis with a 2-mm connector fabricated in noble metal results in a 12-mm movement for one pontic and 97-mm movement for a two-pontic span. The fixed partial denture movement

helps compensate for the difference in vertical mobility of a healthy tooth and implant. A fixed prosthesis supported by one implant and one natural tooth will have the abutment/gold cylinder screw joint of the system act as a flexible element. The inherent flexibility will match the vertical mobility of the natural tooth. The minimal movement of the tooth and the fact that implant, prosthesis, and abutment components have some mobility indicate the risk is small in the vertical direction with the biomechanical difference of implant and tooth in the same prosthesis when one or two pontics separate these units.

Horizontal Movement.

With natural teeth, horizontal tooth mobility is greater than vertical movement. A very light force (500 g) moves the tooth horizontally 56 to 108 mm (Fig. 3.127). The initial horizontal mobility of a healthy, nonmobile posterior tooth is less than that of an anterior tooth and ranges from 56 to 75 mm, which is two to nine times the vertical movement of the tooth. Initial horizontal mobility is even greater in anterior teeth and ranges from 90 to 108 mm in healthy teeth.

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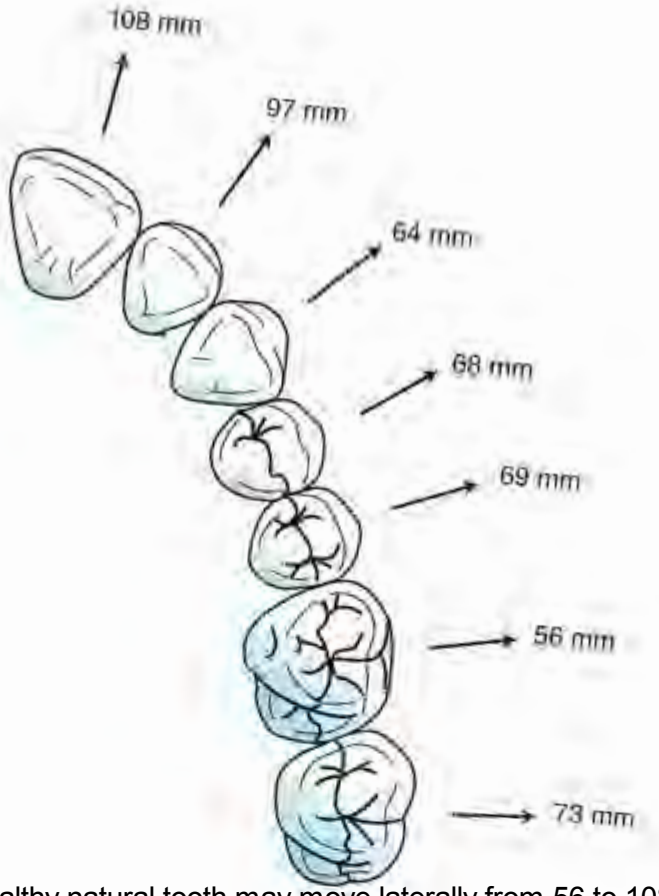

FIG 3.127 A healthy natural tooth may move laterally from 56 to 108 µm, with anterior teeth moving more than posterior teeth. (From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.)

Muhlemann found that tooth movement may be divided into initial mobility and secondary movement.[88] The initial mobility is observed with a light force, occurs immediately, and is a consequence of the periodontal ligament. If an additional force is applied to the tooth, a secondary movement is observed, which is related directly to the amount of force. The secondary tooth movement is related to the viscoelasticity of the bone and measures up to 40 mm under considerably greater force.

Implant Movement.

The implant-bone interface also exhibits lateral movement. Sekine et al. evaluated the movement of endosteal implants with rigid fixation and found a range of 12 to 66 mm of movement in the labiolingual direction.[89] Komiyama measured 40 to 115 mm of implant movement in the mesiodistal direction under a force of 2000 g (about 4.5 psi) and a labiolingual range of 11 to 66 mm.[90] The greater implant movement in the mesiodistal dimension corresponds to the lack of cortical bone between the implants in this

direction compared with the thicker lateral cortical plates present in the labiolingual dimension. The mobility of implants varies in direct proportion to the load applied and the bone density and reflects the elastic deformation of bone tissue.

An interesting note in implant mobility is that no significant difference was related to implant length. This finding further confirms that implant length is not the primary factor for implant support, even in the presence of lateral loads. Bone density affects this condition more than implant length. These mobility characteristics corroborate the findings of Fenton et al., who applied a 500-g load for 4 seconds to maxillary anterior teeth and osseointegrated implants. The implants were displaced a mean 10 mm with a rapid elastic return (less than 1 millisecond), whereas the teeth showed a mean displacement of 57 mm with a prolonged viscoelastic return.[91] When all factors are considered, an implant moves vertically and horizontally, the abutments and prosthesis flex, and the tooth has apical and lateral movements.

Guidelines for Joining Implants to Teeth

A vertical movement/force placed on a posterior implant joined to a healthy posterior tooth causes mesial tension on the implant. The implant can move vertically 3 mm and mesially 40 to 115 mm, and a noble metal-fixed prosthesis with one pontic allows mesiodistal movement of 6 mm. A natural tooth with no clinical mobility could be connected rigidly to an osseointegrated implant because the implant, bone, and prosthesis compensate for the slight tooth movement. There is extensive documentation that implants can be connected rigidly to stable teeth. However, the occlusion should be modified to allow the initial occlusal contacts on the natural tooth so that the implant does not bear the major portion of the initial load.

No Mobility of Natural Tooth Abutment.

The mobility of healthy anterior incisor teeth often is recorded as 1 with a range of movement from 90 to 108 mm. Visual clinical evaluation by the human eye can detect movement greater than 90 mm. When the mobility of a natural tooth can be observed, mobility is greater than 90 mm and too great to be compensated by the implant, bone, and prosthesis movement. When the vertical posterior tooth movement, vertical implant movement, mesiodistal implant movement, and prosthesis movement are compared

with the same conditions of an anterior tooth with lateral loads, the biomechanical risk factors do not correlate. One primary condition for joining an implant to natural teeth is the lack of observable clinical movement of the natural abutment.

No Lateral Forces on Prosthesis.

Another requisite to join an implant to a natural tooth is that no lateral force should be designed on the prosthesis. Lateral forces increase the amount of tooth movement and decrease the amount of implant movement (faciolingual vs. mesiodistal). Horizontal forces placed on an implant also magnify the amount of stress at the crestal bone region. Implants should rarely be connected to anterior teeth because (1) anterior teeth often exhibit greater clinical mobility than the implant can tolerate and (2) the lateral forces applied to the restoration during mandibular excursions are transmitted to the natural tooth and implant abutments (Fig. 3.128).

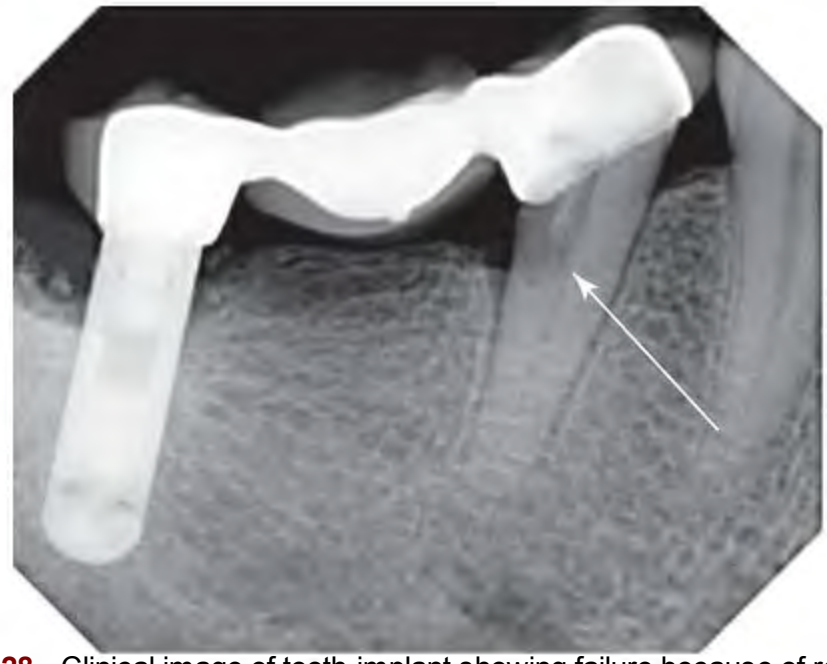

FIG 3.128 Clinical image of tooth-implant showing failure because of recurrent decay.

Additional Treatment Options.

When the natural abutment exhibits clinical horizontal movement or conditions promote horizontal forces against the abutment tooth, two

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options can be selected for the final prosthesis. The first, and the option of choice, is to place additional implants and to avoid the inclusion of natural abutments in the final prosthesis. The other option is to improve stress distribution by splinting additional natural abutments until no clinical mobility is observed.

Guidelines for Splinting Dental Units

Splinting natural teeth does not decrease the mobility of a tooth significantly after the prosthesis is removed; however, the overall prosthesis movement is decreased, especially when the splinted units form an arch. If posterior contacts cannot be eliminated in lateral excursions as a result of skeletal relationships or when opposing a removable prosthesis, splinting often is safer to reduce the risk of long-term complications. In addition, splinting natural abutments also decreases the amount of load to each abutment (when a 150-psi load is distributed to all splinted abutments, the resultant force on each abutment is decreased) (Fig. 3.129).

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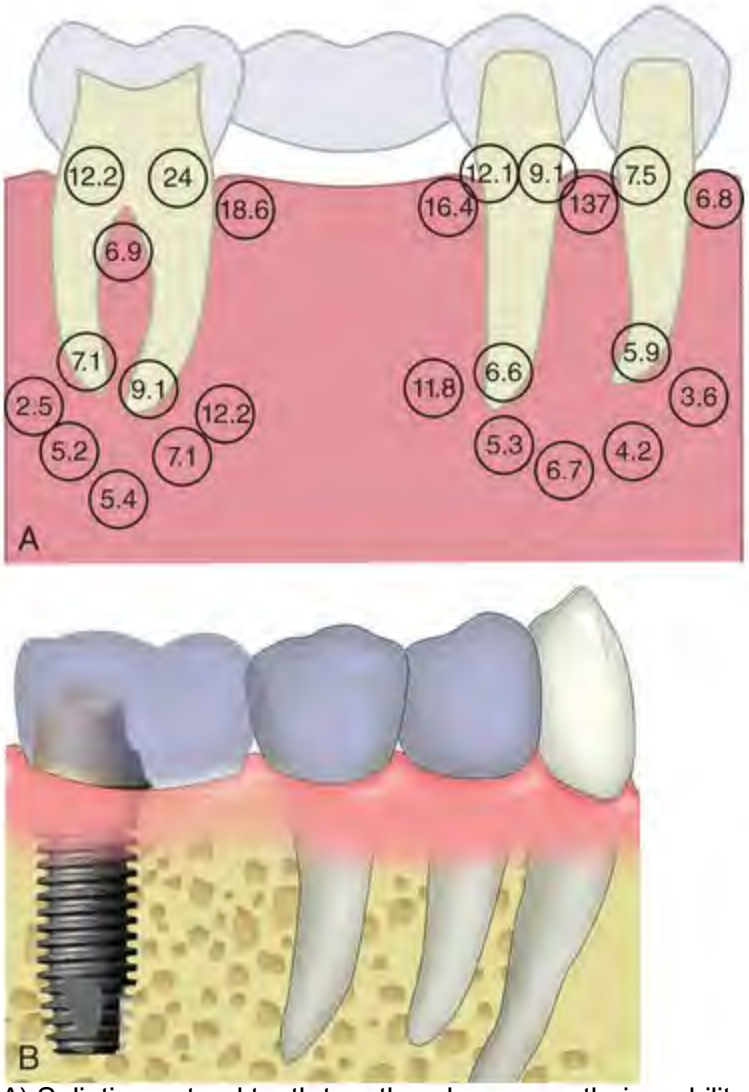

FIG 3.129 (A) Splinting natural teeth together decreases their mobility and reduces the amount of stress transferred to the support system. (B) When the terminal natural tooth is slightly mobile, splinting an adjacent tooth is indicated. ([A] Courtesy Y. Ismail, Pittsburgh, PA. [B] From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The number of teeth to splint together is the number required to eliminate prosthesis movement. The initial dental evaluation may include acid etching and bonding potential mobile natural abutments to each other to determine how many teeth must be joined to reduce the prosthesis clinical mobility to zero. The dentist applies the following prosthetic guidelines:

1. The last tooth connected in the splint should not be mobile. In other words, to decrease mobility, at least the last tooth in the splint (and sometimes more) should be rigid.

2. The terminal abutments in the splint should not have poor retention form.

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3. Adjacent teeth splinted together should be parallel enough to have the same path of insertion for the prosthesis.

4. Adjacent teeth should not be crowded or overlapped and should have enough room for splinted crowns to have adequate interproximal hygiene.

A classic axiom for splinting teeth in prosthodontics reads, "It is unadvisable to employ the last tooth as a splinted abutment if it lacks a degree of firmness comparable to its healthy neighbor because the strain on the firm abutment could be destructive."[92] Implant prostheses may use additional secondary natural abutments to decrease the movement of the prosthesis so that rigid fixation of the implant will not be compromised. However, if the last abutment is mobile, it does not serve the intended purpose. A general guideline is to not end a fixed prosthesis on the weakest splinted abutment. The weak tooth does not offer additional support and further burdens the healthier abutments. In addition, if cement failure occurs or the restoration needs retrieval, the partially retained prosthesis is more difficult to retrieve from the mobile abutment, resulting in more frequent coronal fracture and other complications.

The natural teeth exhibit some faciolingual movement, which varies from 56 to 108 μm in health. The discussion here is to reduce tooth movement when it is visible so that the mobile teeth may be connected to the implants. Although the teeth move in a faciolingual direction, different regions of the arch have different directions of movement relative to each other. In other words, the faciolingual direction of the anterior teeth corresponds to the mesiodistal direction of the posterior teeth, and if these dental units are splinted to each other, the splint may become nonmobile.

A dental arch may be described as a five-sided structure. The posterior teeth on one side move in a similar direction to each other, the canine moves in a different direction, the anterior teeth move in a third direction, the contralateral canine moves in yet another direction in comparison, and the other posterior component of the arch moves in a similar direction as the first. The more dental sections are connected, the more rigid the structure. As a general rule, three or more sections rigidly connected create an overall nonmobile dental structure. Even mild to moderate individual mobile dental units may become a nonmobile single unit.

The approach of joining implants to mobile teeth in several different arch positions is usually limited to conditions when the multiple sections of the

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dental arch already require restoration. Rarely would one consider crowning eight or more teeth solely to splint to the implant component. Instead, the use of a natural tooth pier abutment may be indicated.

The last tooth in a splinted prosthesis should not have poor retentive form. When a force is applied to the terminal region of a multiple-splinted restoration, the pier abutments may act as a fulcrum. As a consequence, tensile and shear forces may be applied to the cement seal. Because the cements are 20 times weaker in shear compared with compressive forces, the cement seal may break. As a consequence, the natural abutment often decays and may be lost. The most distal tooth in a splinted restoration should have adequate height and retentive form.

The adjacent teeth should be able to have the path of insertion as all the dental units in the prosthesis. It may be necessary to perform endodontics or even extract an offending tooth to accomplish the goal of splinting across an arch.

The adjacent teeth that are splinted together should not be overlapped or crowded. It may be necessary to have orthodontics or selective extractions to prepare the teeth for a similar path of insertion as the implant prosthesis. When the adjacent teeth are splinted, enough interproximal tooth tissues must be removed to permit adjacent metal crowns, connectors, and porcelain to be applied and maintain interproximal hygiene.

In conclusion, the natural abutment connected to a rigidly fixated implant should not exhibit clinical mobility or poor retentive form. These same two criteria should be considered for the natural tooth used as a secondary abutment when splinting teeth in a FPD.

Nonrigid Connectors.

Although nonrigid connectors have been advocated in the literature,[93] a nonrigid connector in a unilateral prosthesis rarely is indicated for implant-fixed prostheses and may be detrimental. Nonrigid connection does not improve the stress distribution between the different abutments[94] and has been reported to have caused migration of the natural teeth.[95] If the nonrigid connector exhibits any clinically observed mobility, it moves more than the implant. As such, the implant-supported part of the restoration is cantilevered to the attachment. In addition, the nonrigid (or mobile) attachment adds cost, creates overcontoured abutments, impairs daily hygiene, and does not decrease the clinical tooth movement.

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Intrusion.

Reports of intrusion of the natural tooth connected to an implant usually include the use of temporary cement to lute a coping to the natural abutment, leaving the final restoration uncemented on the coping, or the use of a nonrigid connector.[96] When implants are joined to teeth that act as a terminal abutment, a definitive cement should be used for the natural tooth. The tooth cannot intrude unless it becomes unretained from the abutment (or has a nonrigid connector between the units).

A possible explanation for tooth intrusion may be that the tooth is pushed vertically 28 μm but wants to rebound only 8 μm. The fixed prosthesis rebounds immediately and pulls on the tooth. The cement seal eventually breaks, causing a space to develop, which is first occupied by air. The prosthesis then acts as an orthodontic appliance and continually pushes the tooth in a vertical direction. Eventually, the space is occupied by saliva, and hydraulics continue the downward force during mastication. The tooth eventually submerges or intrudes from the prosthesis (Fig. 3.130).

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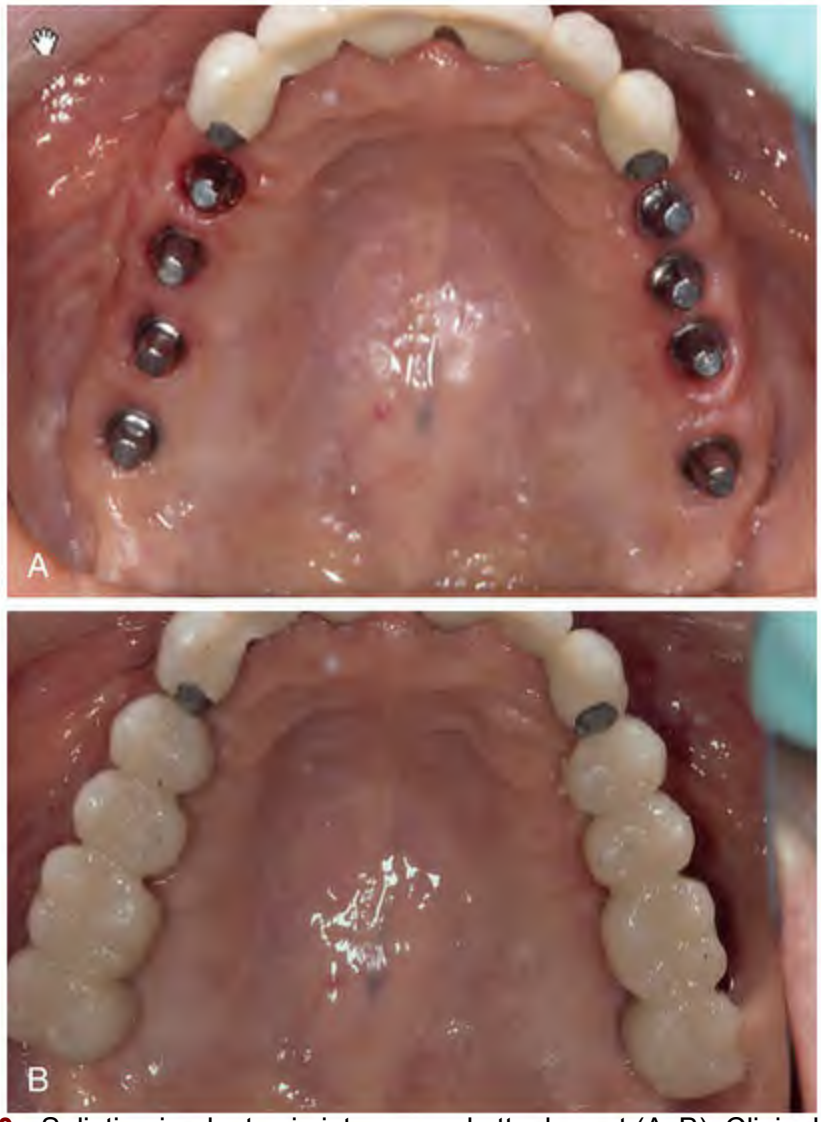

FIG 3.130 Splinting implants via intracoronal attachment (A, B). Clinical image of nonrigid attachment, which is contraindicated. Ideally, the implants should be splinted together, independent of the natural teeth.

Implant Pier (Intermediary) Abutments

A pier abutment is one between two other abutments, sometimes referred to as an intermediate abutment. The intermediate abutment may be an implant or a natural tooth, and each type plays a different role in the overall treatment. When an implant serves as a pier abutment between two natural teeth, the difference in movement between implant and tooth may increase the complication rate compared with one intermediate tooth joined to two terminal implants (Fig. 3.131). The pier implant abutment exhibits less movement than the natural teeth terminal abutments and acts as the fulcrum of a class I lever. As a consequence, a compressive force on one end of the

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prosthesis is converted to a tensile or shear force on the other terminal abutment. The cement tensile strength is often 20 or more times less than the compressive strength. When the implant acts as a fulcrum, an uncemented abutment (usually the least mobile tooth or least retentive crown) is a common consequence, with decay being the next most common occurrence.

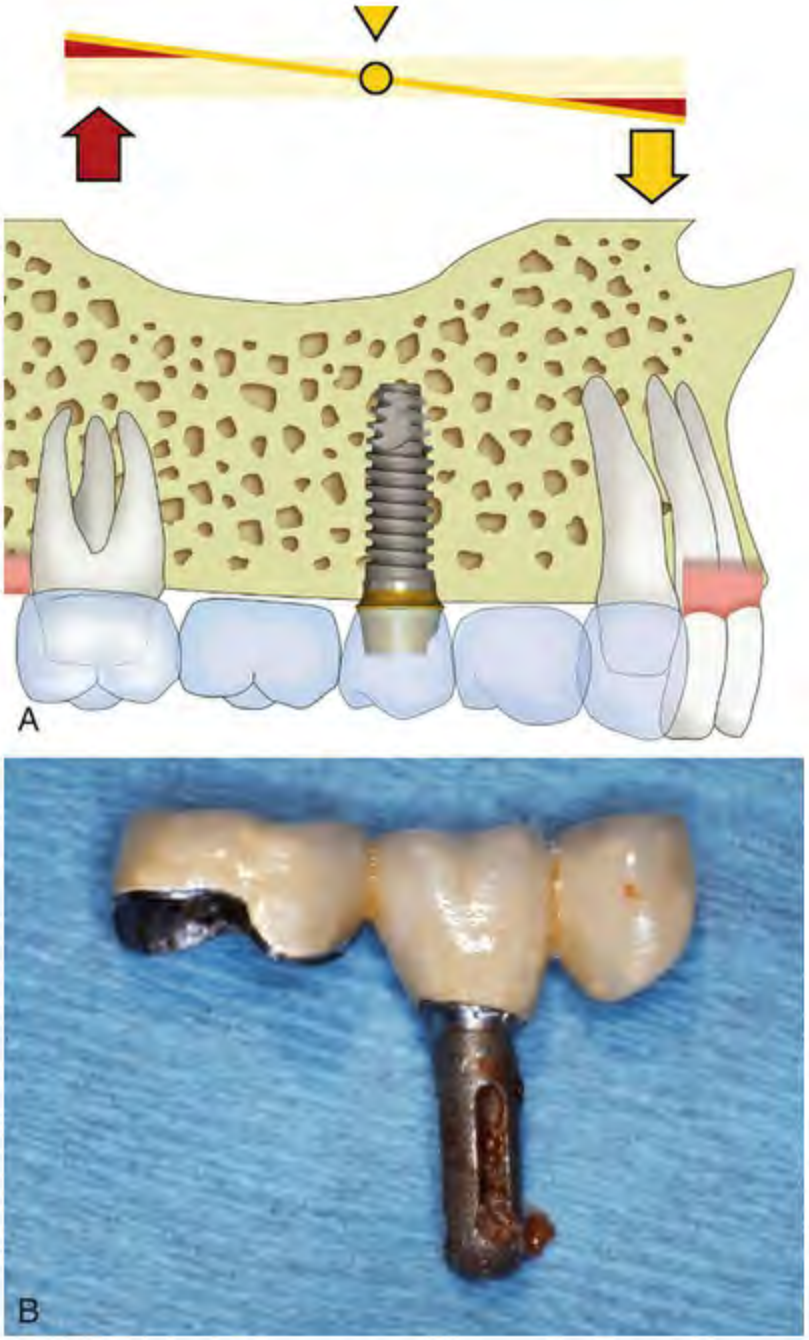

FIG 3.131 A pier implant abutment between two natural teeth may cause a cement seal to break on the teeth, especially if one is more mobile than the other. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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This problem is magnified by a longer lever arm such as a pontic between the implant and tooth. When the natural tooth or teeth have clinical mobility, the force is lateral on the prosthesis, or the forces are greater than usual. A pier implant abutment may cause complications even when joined to nonmobile teeth as terminal abutments (Fig. 3.132).

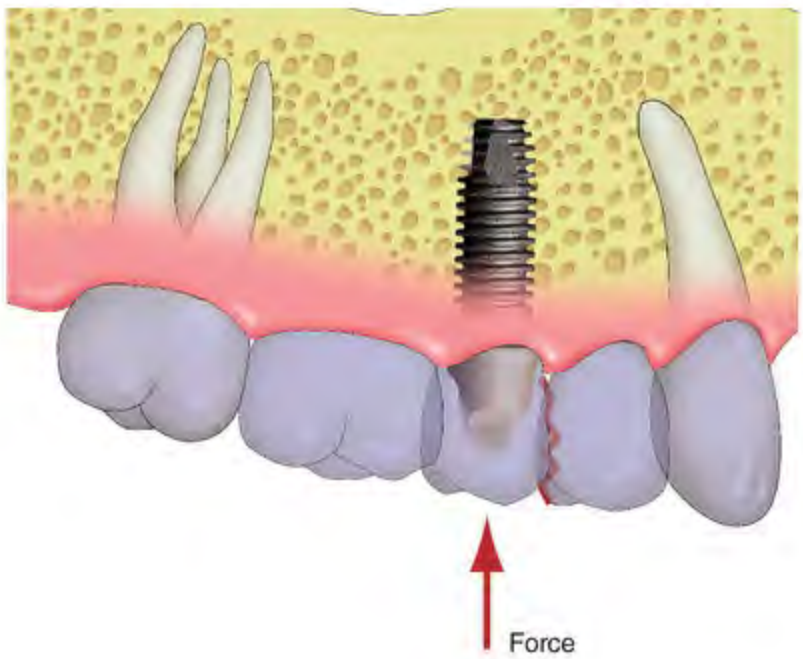

FIG 3.132 When grafting and additional implants are not an option, a mobile attachment may be used to prevent the pier implant from acting as a fulcrum. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Uncemented restorations are a common complication in FPDs even when all aspects of treatment are within acceptable limits. Any condition that may increase this problem, such as the one presently addressed, should be carefully avoided.

Patient Treatment Planning

Failure to Provide to the Patient Comprehensive Treatment Options

When discussing a treatment plan with a patient, it is quite easy to get mentally focused on a certain treatment option based on the actual needs and perceived values of the patient. Implant clinicians sometimes favor certain treatments (e.g., overdenture vs. fixed prosthesis) according to their learning curve, training, or their personal preferences. It is imperative from an ethical and legal perspective that the clinician discuss all treatment options, including a conversation concerning each option's advantages and disadvantages. Most state dental boards in the United States require as part of their dental law code that all patients be given all possible and viable options, including advantages and disadvantages.

To prevent complications and treatment misunderstandings, a comprehensive treatment planning protocol should be developed with every patient. The next section of this chapter will discuss various edentulous site treatment situations along with the associated advantages and disadvantages of each treatment.

Single Missing Tooth

No Treatment.

Even though in most cases the option of “no treatment” is not ideal, the patient should always be given an explanation of the possible ramifications that may occur if no treatment is rendered. Proposing this treatment option may seem counterintuitive to clinicians because the goal of dentistry is to restore a patient to optimal function. However, the presentation of this option does allow the clinician to enter into a discussion as to the various consequences of tooth loss, bone loss, and lack of masticatory efficiency.

Advantages.

The only advantages of no treatment are the patient will not have to undergo further procedures to address the situation, and secondly, there will be no financial demands for the patient.

Disadvantages

Movement of adjacent teeth.

When a patient loses a single tooth, there are numerous consequences that may result to create an occlusal disharmony and the potential for further dental complications. If a tooth is extracted in any position anterior to the second molars, the patient can expect for the tooth distal to it to begin tilting mesially into the vacant space. This will most likely result in a change of the occlusal plane on that side. As the teeth experience this mesial tilt, the direction of load changes, which may cause excessive stress to the periodontal ligament. The contacting teeth in the opposing arch will begin to supraerupt in relation to the changes in the occlusal plane. The correction of future supraerupted teeth may require orthodontic or endodontic/crown therapy. In some situations, extraction may be necessary.

Occlusal force issues.

Another consequence of the single missing tooth is the patient will typically favor the fully dentate side to chew with, due to a decreased masticatory efficiency on the partially edentulous side. This situation results in the overuse of the fully dentate side, leading to fatigue-related issues with the teeth. Examples of these issues would be porcelain fracture of crowns, fractures of enamel/fillings, significant occlusal wear, or myofascial pain complications (Box 3.25).

Box 3.25

Missing Single Tooth

No Treatment Option

Advantages

- No treatment time for the patient
- No financial outlay for the patient

Disadvantages

- Supraeruption of the opposing teeth
- Drifting/tilting movement of the adjacent teeth

- Decrease masticatory function
- Food impaction
- Adjacent teeth will receive a higher occlusal load
- Occlusal overuse of contralateral side

Removable Partial Denture

Advantages.

The main advantages of the removable partial denture (RPD) in restoring a single missing tooth are based on convenience. The patient can receive a tooth-borne RPD after a few appointments, and there is a lack of invasive treatment in this modality. There is also a lower associated cost in comparison to most other treatment options.

Disadvantages

Decreased acceptance.

Removable partial dentures, even those that are primarily tooth borne, have a low patient acceptance rate compared to other treatment options. Patients experience difficulty in eating, as food debris may become trapped under the prosthesis. Speech patterns are often disrupted, as the patient must acclimate to the partial framework in the mouth. The prosthesis is often bulky, covering part of the palatal tissue on the maxilla or the lingual tissue on the mandible.

Increased morbidity to abutment teeth.

Reports of removable partial dentures indicate the health of the remaining dentition and surrounding oral tissues often deteriorates. In a study that evaluated the need for repair of an abutment tooth as the indicator of failure, the “success” rates of conventional removable partial dentures were 40% at 5 years and 20% at 10 years.[97] Patients wearing the partial dentures often exhibit greater mobility of the abutment teeth, greater plaque retention, increased bleeding upon probing, higher incidence of caries, speech inhibition, taste inhibition, and noncompliance of use. A report by Shugars et al. found abutment tooth loss for a removable partial denture may be as high

as 23% within 5 years and 38% within 8 years.[98]

Increased bone loss.

The natural abutment teeth, on which direct and indirect retainers are designed, must submit to additional lateral forces. Because these teeth are often compromised by deficient periodontal support, many partial dentures are designed to minimize the forces applied to them. The result is an increase in mobility of the removable prosthesis and greater soft tissue support. These conditions protect the remaining teeth but accelerate the bone loss in the edentulous regions.[99] It should be noted that bone loss is accelerated in the soft tissue support regions in patients wearing the removable prosthesis compared with no prosthesis (Box 3.26).

Box 3.26

Missing Single Tooth

Removable Partial Denture Treatment Option

Advantages

- Minimal treatment minimal cost compared to other options

Disadvantages

- Poorly tolerated
- Decreased survival rate
- Increased mobility
- Plaque accumulation
- Bleeding on probing caries on abutment teeth
- Increased need for abutment teeth loss or repair
- Food impaction
- Accelerated bone loss in edentulous area

Fixed Partial Denture

Advantages

Common type of treatment.

A fixed prosthesis is a conventional and common type of procedure that most clinicians are comfortable performing. The prosthesis can be fabricated rather quickly because a laboratory can generate a complete restoration in 1 to 2 weeks that satisfies the criteria of normal contour, comfort, function, esthetics, speech, and health. Most patients have an increased compliance with this type of treatment, especially because no surgical intervention is needed.

Minimal need for soft and hard tissue augmentation.

With a fixed partial denture, augmentation of the edentulous area is very uncommon. Because the pontic may be modified to encompass most defects, surgical augmentation procedures are usually not indicated. In some instances, lack of attached tissue will be present on abutment teeth; however, this is rather rare.

Disadvantages

Increased caries rate.

Despite the many advantages that an FPD has over its removable counterpart, the treatment modality does have inherent disadvantages. Caries and endodontic failure of the abutment teeth are the most common causes of fixed partial denture prosthesis failure.[100] Caries occur more than 20% of the time and endodontic complications to the abutments of a FPD 15% of the time. Recurrent decay on the abutment crown primarily occurs on the margin next to the pontic. Fewer than 10% of patients floss on a regular basis, and those using a floss threader are even fewer.[101] As a result, the pontic acts as a large overhang next to the crown and a reservoir for plaque and bacteria. The long-term periodontal health of the abutment teeth may also be at greater risk as a result of the plaque increase, including bone loss.

Increased endodontic treatment.

When a vital tooth is prepared for a crown, a 3% to 6% risk of irreversible pulpal injury and subsequent need for endodontic treatment exists.[102] Not

only does tooth preparation present a risk for endodontics on each of the vital abutment teeth, the crown margin next to the pontic is also more at risk of decay and the need for endodontics as a result. Studies have shown up to 15% of abutment teeth for a fixed restoration require endodontic therapy compared with 3% to 6% of nonabutment teeth with crown preparations.[103]

Unfavorable outcomes of FPD failure.

There exist many issues that may result when a fixed partial denture fails. These may include not only the need to replace the failed prosthesis but also the loss of an abutment tooth and the need for additional pontics and abutment teeth in the replacement bridge. Because 15% of FPD abutment teeth require endodontics, many abutment teeth may be lost. In addition, an endodontic posterior tooth abutment is at a greater risk of fracture. Reports indicate that abutment teeth for a FPD fail from endodontic complications (e.g., fracture) four times more often than those with vital pulps.[104] The fracture of the tooth may result in failure of the prosthesis and abutment tooth.

The abutment teeth of an FPD may be lost from caries, endodontic complications, or root fracture at rates up to 30% for 8 to 14 years.[105] Recent reports indicate 8% to 18% of the abutment teeth supporting a FPD are lost within 10 years. This is most disturbing because 80% of abutments have no previous decay or are minimally restored before the fabrication of the FPD (Box 3.27).[106]

Box 3.27

Missing Single Tooth

Fixed Partial Denture Treatment Option

Advantages

- Most common treatment (doctor friendly)
- Reduced time (two appointments, 1 to 2 weeks apart)
- Restores function, esthetics, and intraarch health
- Few bone and soft tissue considerations

- Proven long-term survival
- Reduced cost—dental insurance covers procedure (reduced patient cost)
- Indicated when minimal mesiodistal space (<6 mm space)
- Potential abutments have clinical mobility; will benefit from being splinted
- Increases patient compliance and reduces fear

Disadvantages

- Mean life span approximates 10 to 15 years
- Caries and endodontic failure of abutment teeth most common complication
- Increased plaque retention of pontic increases caries and periodontal disease risk
- Hygiene difficulty
- Damage to healthy teeth (removing undamaged tooth structure)
- Failure of prosthesis related to loss of abutment teeth (8% to 18% within 10 years)
- Fracture complications (porcelain, tooth)
- Esthetic complications (crowns less esthetic than natural teeth)
- Uncemented restoration

Single Tooth Implant (Box 3.28)

Advantages

Higher success rate.

The single tooth implant provides numerous advantages when compared to the other treatment options. Most studies to date have shown a single tooth

implant to be the most predictable method of single tooth replacement. Most long-term studies report success rates exceeding 90%.

Box 3.28

Missing Single Tooth

Dental Implant Treatment Option

Advantages

- Adjacent teeth do not require splinted restorations
- Less risk of caries
- Less risk of endodontics
- Less risk of porcelain fracture
- Less risk of uncemented restoration
- Less fracture of tooth
- Psychologic need of patient addressed: patient does not desire two adjacent teeth (often virgin) prepared and splinted to restore missing tooth
- Improved hygiene conditions
- Less decay risk
- Floss vs. floss threader
- Less pontic “plaque trap overhang”
- Decreased cold or contact sensitivity
- Prepared teeth more temperature sensitive
- Cementum of tooth removed by tooth preparation; toothbrush or scaler sensitive

- Maintains bone in site: 30% decreasing bone width within 3 years after extraction
- Decreases adjacent tooth loss: 30% vs. 0.05% risk at 10 years

Disadvantages

- Increased treatment time
- Need for surgical treatment
- May need hard and soft tissue augmentation
- Possibly less esthetic
- Retained cement
- Peri-implantitis
- Increased laboratory fees

Hygiene.

The dental implant treatment plan will usually allow for easier hygiene access because the proximal surfaces can be reached for flossing. This acts as a preventive measure against peri-implatntitis issues.

No alteration of adjacent teeth.

Adjacent teeth do not have to be altered with the implant option, which decreases the risk of recurrent caries or endodontic possibilities with these teeth. Because of these advantages the patient is at a much lower risk of losing further teeth in the future.

Better cost comparison.

Cost comparison studies conclude that the implant restoration demonstrates a more favorable cost-effectiveness ratio.[30] Even when the adjacent teeth are not lost, the conventional FPD often needs to be replaced more frequently because of decay, endodontic complications, porcelain fracture, or unretained restoration (i.e., which most likely results in decay and the need for endodontic treatment).

Improved maintenance of bone.

With a fixed partial denture replacing a single missing tooth, continued bone resorption will occur. Therefore, placing an implant into the edentulous site will help maintain the existing host bone. Additionally, this will decrease the possibility of soft tissue recession.

Disadvantages

Increased treatment time.

The single tooth implant procedure will take a considerably longer time for treatment in comparison to a RPD or FPD. From the initial surgical placement, the average implant will require an average of 4 to 6 months for osseointegration to occur. This time frame is dependent on the patient's bone density in that area as well as the volume of bone that was present at placement. In an effort to address this issue, techniques have been proposed to immediately place and at times immediately provisionalize implants. However, in certain circumstances, these techniques present disadvantages, especially when the patient criteria for these procedures is not met.

Need for additional treatment.

In esthetic areas, modifications to the soft tissue may be necessary as well in an effort to change the soft tissue drape or to enhance the patient's tissue biotype. This usually will lead to more complex procedures that are needed for tissue augmentation. In addition, bone augmentation procedures may be indicated to increase bone volume for implant placement. In some cases, this may increase the cost significantly as well as the treatment time.

Esthetics.

Based on available bone and crown height space, the final prosthesis may feature a traditional tooth contour (FP1), a longer crown form (FP2), or may require the addition of pink porcelain to mimic normal soft tissue contours (FP3). The patient must be aware of these possibilities as their esthetic demands may contraindicate implant placement or will dictate dictate the need for adjunctive bone grafting procedures.

Multiple Missing Teeth

No Treatment.

The patient should always be given an explanation of the possible ramifications that may occur if no treatment is rendered. No treatment is more of a concern in comparison to a single edentulous site as esthetic issues, decrease in masticatory efficiency, and food impaction issues may arise.

Advantages.

When a patient is missing multiple teeth, the education and communication to the patient is even more important. Although there is no financial or time commitment for the patient, the disadvantages are more significant in comparison to a single missing tooth.

Disadvantages

Decreased masticatory function.

The main disadvantage of not replacing multiple missing teeth is the decreased masticatory function. Patients will place more force and stress on their remaining teeth, which leads to increased morbidity. The forces of mastication are transmitted to the remaining teeth, which results in a greater possibility of decay, mobility, periodontal issues, and loss of teeth. The longer the edentulous ridge remains without stimulation, the greater chance bone loss will occur. This may lead to the future need for hard and soft tissue augmentation procedures to increase hard and soft tissue volume for implant placement.

Tooth movement.

The remaining teeth may continue to shift in relation to the stresses of mastication, causing movement and tilting. Teeth in the opposing arch will supraerupt due to the lack of stimulation by an opposing tooth, causing root exposure and occlusal disharmony. These phenomena combine to potentially complicate or contraindicate future implant placement.

Esthetics.

If no treatment is rendered for the edentulous area, obvious esthetic issues will result. In most cases, patient acceptance of the edentulous areas is low, and esthetics is usually a motivating factor in seeking rehabilitation.

Removable Partial Denture

See the advantages and disadvantages for RPD in Box 3.26.

Implanted-Supported Crowns

See the advantages and disadvantages for RPD in Box 3.28.

Completely Edentulous

No Treatment.

The patient should always be given an explanation of the possible ramifications that may occur if no treatment is rendered.

Advantages.

There exist few advantages other than no treatment time or financial outlay for the patient.

Disadvantages

Continued bone loss.

Most clinicians overlook the insidious bone loss that will occur after tooth extraction. The patient is often not educated about the anatomic changes and the potential consequences of continued bone loss. The bone loss accelerates when the patient wears a poorly fitting soft tissue–borne prosthesis. Most patients do not understand that bone resorption occurs over time and at a greater rate beneath poorly fitting dentures. Patients do not return for regular visits for evaluation of their condition; instead, they return after several years when denture teeth are worn down or can no longer be tolerated. In fact, studies have shown that the average denture wearer sees a dentist every 14.8 years after having a complete denture. The traditional method of tooth replacement (dentures) often affects bone loss in a manner not sufficiently considered by the clinician and the patient. The clinician should inform the patient that a denture replaces more bone and soft tissue than teeth, and every 3 to 5 years a reline, or new denture is suggested to replace the additional bone loss by atrophy that will occur (Fig. 3.133 and Box 3.29).

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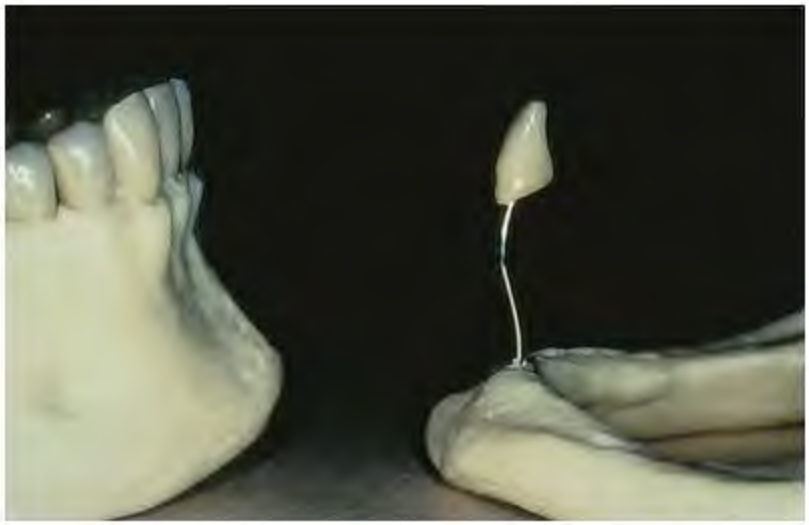

FIG 3.133 A dentate mandible on the left and a long-term edentulous mandible on the right. Note the amount of bone loss in height. Loss of bone height in the mandible may be measured by the centimeter and often is ignored. Such bone loss is often more significant than the bone loss (in millimeters) from periodontal disease. The patient should understand that a denture often replaces more bone than teeth to restore the proper dimensions of the face. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Box 3.29

Consequences of Bone Loss in Fully Edentulous Patients

- Decreased width of supporting bone
- Decreased height of supporting bone
- Prominent mylohyoid and internal oblique ridges with increased sore spots
- Progressive decrease in keratinized mucosa surface
- Prominent superior genial tubercles with sore spots and increased denture movement
- Muscle attachment near the crest of the ridge
- Elevation of prosthesis with contraction of mylohyoid and buccinators muscles serving as posterior support

- Forward movement of prosthesis from anatomic inclination (angulation of mandible with moderate to advanced bone loss)
- Thinning of mucosa with sensitivity to abrasion
- Loss of basal bone
- Paresthesia from dehiscent mandibular neurovascular canal
- More active role of tongue in mastication
- Effect of bone loss on esthetic appearance of lower third of face
- Increased risk of mandibular body fracture from advanced bone loss
- Loss of anterior ridge and nasal spine, causing increased denture movement and sore spots during function

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Soft tissue consequences.

As bone loses width, then height, then width and height again, the attached gingiva gradually decreases. A very thin attached tissue usually lies over the advanced atrophic mandible or is entirely absent. The increasing zones of mobile, unkeratinized gingiva are prone to abrasions caused by the overlying prosthesis, which will lead to bone loss. In addition, unfavorable high muscle attachments and hypermobile tissue often complicate the situation. The continued atrophy of the posterior mandible eventually causes prominent mylohyoid and internal oblique ridges covered by thin, movable, unattached mucosa. The anterior residual alveolar process also continues to resorb, and the superior genial tubercles (which are 20 mm below the crest of bone when teeth are present) eventually become the most superior aspect of the anterior mandibular ridge. There is little to prevent the prosthesis from moving forward against the lower lip during function or speech. This condition is further compromised by the vertical movement of the distal aspect of the prosthesis during contraction of the mylohyoid and buccinator muscles and the anterior incline of the atrophic mandible compared with that of the maxilla.[107] The thickness of the mucosa on the atrophic ridge is also related to the presence of systemic disease and the physiologic changes that

accompany aging. Conditions such as the patient's age, hypertension, diabetes, anemia, and nutritional disorders have deleterious effects on the vascular supply and soft tissue quality under removable prostheses. These disorders result in a decreased oxygen tension to the basal cells of the epithelium. Surface cell loss occurs at the same rate, but the cell formation at the basal layer is slowed. As a result, thickness of the surface tissues gradually decreases, and sore spots and uncomfortable removable prostheses result. The tongue of a patient with edentulous ridges often enlarges to accommodate the increase in space formerly occupied by teeth. At the same time, it is used to limit the movements of the removable prostheses and takes a more active role in the mastication process. As a result, the removable prosthesis decreases in stability. The decrease in neuromuscular control, often associated with aging, further compounds the problems of traditional removable prosthodontics. The ability to wear a denture successfully may be largely a learned, skilled performance. An aged patient who recently became edentulous may lack the motor skills needed to adjust to the new conditions (Box 3.30).

Box 3.30

Soft Tissue Consequences of Edentulism

- Attached, keratinized gingiva is lost as bone is lost
- Unattached mucosa for denture support causes increased soft spots
- Thickness of tissue decreases with age and systemic disease that causes more sore spots for dentures
- Tongue increases in size, which decreases denture stability
- Tongue has more active role in mastication, which decreases denture stability
- Decreased neuromuscular control of jaw in elderly adults

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Esthetic consequences.

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The facial changes that naturally occur in relation to the aging process can be accelerated and potentiated by the loss of teeth (Fig. 3.134). There exist many esthetic consequences that result from the loss of alveolar bone. A decrease in facial height from a collapsed vertical dimension will causes several facial changes (Fig. 3.135). The loss of the labiomental angle and deepening of vertical lines in the area create a harsh appearance. As the vertical dimension progressively decreases, the occlusion evolves toward a pseudo class III malocclusion. As a result, the chin rotates forward and creates a prognathic facial appearance (Fig. 3.136). These conditions result in a decrease in the horizontal labial angle at the corner of the lips; the patient appears unhappy when the mouth is at rest (Fig. 3.137). People with short facial types have higher bite forces, greater bone loss, and more dramatic facial changes with edentulism compared with others. A thinning of the vermilion border of the lips results from the poor lip support provided by the prosthesis and the loss of muscle tone. The maxillary retruded position is related to the loss of the premaxillary ridge and the loss of tonicity of the muscles involved in facial expression. The contraction of the orbicularis oris and buccinator muscles in a patient with moderate to advanced bone atrophy displaces the modiolus and muscles of facial expression medially and posteriorly. As a result, a narrowing of the commissure, inversion of the lips, and hollowing of the cheeks are characteristic findings.

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FIG 3.134 Esthetic aspects of the inferior third of the face are not only related to the position of the teeth but even more important is the position and amount of bone in the jaws and include the muscles that attach to the bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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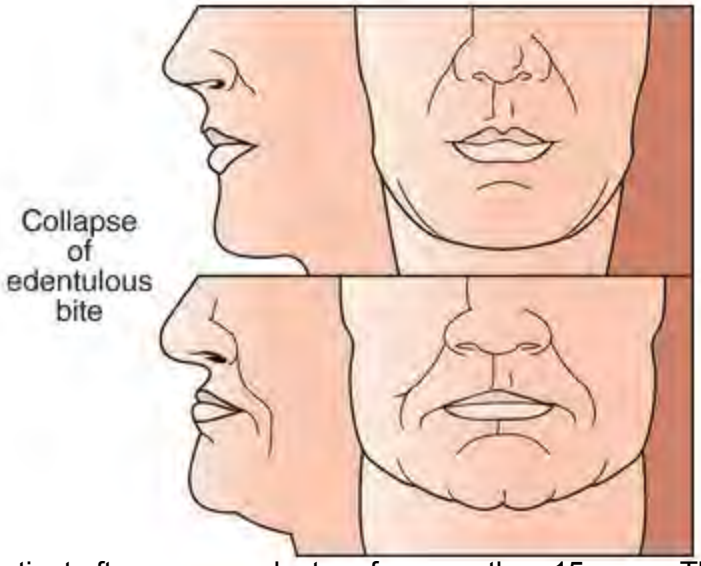

FIG 3.135 A patient often wears a denture for more than 15 years. The loss of bone height during this time is associated with many extraoral facial changes as a closed bite, a mandible that rotates forward, a receding maxilla, a reverse smile line, increased number and depth of lines in the face, more acute angle between the nose and the face, loss of vermilion border in the lips and jowls, and witch's chin from loss of muscle attachment. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 3.136 Loss of bone height can lead to a closed bite with rotation of the chin anterior to the tip of the nose. This picture represents the face of someone without teeth and advanced bone loss. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 3.137 This patient has severe bone loss in the maxilla and mandible. Although she is wearing her 15-year-old dentures, the facial changes are significant. The loss of muscle attachments leads to ptosis of the chin (witch's chin), loss of vermilion border (lipstick is applied to the skin), reverse lip line (decrease in horizontal angles), increased vertical lines in the face and lips, increased lip angle under the nose, and a lack of muscle tonicity in the masseter and buccinator muscles. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A deepening of the nasolabial groove and an increase in the depth of other vertical lines in the upper lip are related to normal aging but are accelerated with bone loss. This usually is accompanied by an increase in the columella-philtrum angle. This can make the nose appear larger than if the lip had more support (Fig. 3.138). Men often grow a moustache to minimize this effect. The maxillary lip naturally becomes longer with age as a result of gravity and loss of muscle tone, resulting in less of the anterior teeth shown when the lip is at rest. This has a tendency to "age" the smile because the younger the patient, the more the teeth show in relation to the upper lip at rest or when smiling. Loss of muscle tone is accelerated in edentulous patients, and the lengthening of the lip occurs at a younger age and is longer (showing less teeth) than dentate patients of a similar age. The upper lip often rolls over the incisal edge of the maxillary dentures, which further decreases the size of the vermilion border.

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FIG 3.138 Profile view. Note the maxillary bone loss effect on the lack of vermilion border of the lip, deep labial folds, and the columella–philtrum angle. Yet the lower lip has a normal vermillion border and the muscles to the anterior lower jaw are still attached, providing a normal contour. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The attachments of the mentalis and buccinator muscles to the body and symphysis of the mandible also are affected by bone atrophy. This will result in sagging of the tissue or "jowls" or a "witch's chin." This effect is cumulative because of the loss in muscle tone with the loss of teeth, the associated decrease in bite force, and the loss of bone in the regions where the muscles used to attach (Box 3.31). Patients are usually unaware the hard and soft tissue changes are from the loss of teeth. Among denture wearers, studies have shown that 39% have been wearing the same prosthesis for more than 10 years.[87] The profession is unable to evaluate patients unless they return yearly. It is important that the consequences of tooth loss be explained to partially or completely edentulous patients during the early phases of treatment.

Box 3.31

Esthetic Consequences of Bone Loss

- Decreased facial height

- Loss of labiomental angle
- Deepening of vertical lines in lip and face
- Chin rotates forward—gives a prognathic appearance
- Decreased horizontal labial angle of lip—makes patient look unhappy
- Loss of tone in muscles of facial expression
- Thinning of vermilion border of the lips from loss of muscle tone
- Deepening of nasolabial groove
- Increase in columella-philtrum angle
- Increased length of maxillary lip, so less teeth show at rest and smiling—ages the smile
- Ptosis of buccinators muscle attachment—leads to jowls at side of face
- Ptosis of mentalis muscle attachment—leads to "witch's chin"

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Complete Upper Denture

Advantages.

Compared to no treatment, the complete upper denture will usually satisfy esthetic and some functional requirements. The patient will have landmarks to use for pronunciation of words, and they will retain the appearance of facial height, although superficially.

Disadvantages

Masticatory function.

The difference in maximum occlusal forces recorded in a person with natural teeth and one who is completely edentulous is dramatic. In the first molar region of a dentate person, the average force has been measured at 150 to 250

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psi.[108] A patient who grinds or clenches their teeth may exert a force that approaches 1000 psi. The maximum occlusal force in an edentulous patient is reduced to less than 50 psi. The longer patients are edentulous, the less force they are able to generate. Patients wearing complete dentures for more than 15 years may have a maximum occlusal force of less than 6 psi.[57]

As a result of decreased occlusal force and the instability of the denture, masticatory efficiency also decreases with tooth loss. Ninety percent of the food chewed with natural teeth fits through a no. 12 sieve; this is reduced to 58% in the patient wearing complete dentures.[109] A study of 367 denture wearers (158 men and 209 women) found that 47% exhibited a low masticatory performance. The 10-fold decrease in force and the 40% decrease in efficiency affect the patient's ability to chew. In patients with dentures, 29% are able to eat only soft or mashed foods, 50% avoid many foods, and 17% claim they eat more efficiently without the prosthesis.[110] Lower intakes of fruits, vegetables, and vitamin A by females were noted in this group. Denture patients also take significantly more drugs (37%) compared with those with superior masticatory ability (20%), and 28% take medications for gastrointestinal disorders. The reduced consumption of high-fiber foods could induce gastrointestinal problems in edentulous patients with deficient masticatory performance. In addition, the coarser bolus may impair proper digestive and nutrient extraction functions.[111]

Systemic consequences.

The literature includes several reports suggesting that compromised dental function causes poor masticatory performance and swallowing poorly chewed food, which in turn may influence systemic changes favoring illness, debilitation, and shortened life expectancy.[112] In another study, the masticatory performance and efficiency in denture wearers were compared with those of dentate individuals. This report noted that when appropriate corrections were made for different performance norms and levels, the chewing efficiency of a denture wearer was less than one sixth of a person with teeth.[113]

Several reports in the literature correlate a patient's health and life span to dental health. Poor chewing ability may be a cause of involuntary weight loss in old age, with an increase in mortality rate.[114] In contrast, patients with a substantial number of missing teeth were more likely to be obese. After conventional risk factors for strokes and heart attacks were accounted for, there was a significant relationship between dental disease and

cardiovascular disease, the latter still remaining as the major cause of death.[115]

Satisfaction of prosthesis.

A dental survey of edentulous patients found that 66% were dissatisfied with their mandibular complete dentures. Primary reasons were discomfort and lack of retention causing pain and discomfort.[116] Past dental health surveys indicate that only 80% of the edentulous population are able to wear both removable prostheses all the time.[117] Some patients wear only one prosthesis, usually the maxillary; others are only able to wear their dentures for short periods. In addition, approximately 7% of patients are not able to wear their dentures at all and become "dental cripples" or "oral invalids." They rarely leave their home environment, and when they feel forced to venture out, the thought of meeting and talking to people when not wearing their teeth is unsettling.

Speech effects.

A report of 104 completely edentulous patients seeking treatment was performed by Misch and Misch.[118] Of the patients studied, 88% claimed difficulty with speech, with one fourth having great difficulty. This most likely occurs with the mandible, which rests upon the buccinator muscle and mylohyoid muscle when the posterior mandible resorbs. When the patient opens his or her mouth, the contraction of these muscles acts like a trampoline and propels the lower denture off the ridge. As a result, the teeth often click when the patient talks, not from vertical dimension issues, but from the lack of stability and retention of the prosthesis. Speech problems may be associated with a concern for social activities. Awareness of movement of the mandibular denture was cited by 62.5% of these patients, although the maxillary prosthesis stayed in place most of the time at almost the same percentage.

Psychologic aspects of tooth loss.

The psychologic effects of total edentulism are complex and varied and range from very minimal to a state of neuroticism. Although complete dentures are able to satisfy the esthetic needs of many patients, some believe their social lives are significantly affected. They are concerned with kissing and romantic situations, especially if a new partner in a relationship is unaware of their oral handicap. Fiske et al., in a study of interviews with edentulous subjects,

found tooth loss was comparable to the death of a friend or loss of other important parts of a body in causing a reduction of self-confidence ending in a feeling of shame or bereavement (Box 3.32).[119]

Box 3.32

Negative Effects of Complete Dentures

- Bite force is decreased from 200 psi for dentate patients to 50 psi for edentulous patients
- 15-year denture wearers have reduced bite force to 6 psi
- Masticatory efficiency is decreased
- More drugs are necessary to treat gastrointestinal disorders
- Food selection is limited
- Healthy food intake is decreased
- The life span may be decreased
- Reduced prosthesis satisfaction
- Speech difficulty
- Psychologic effects

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Implant-Supported Overdenture (Removable-RP4/RP5)

Advantages

Reduction in soft tissue coverage.

The overdenture (RP4) may reduce the amount of soft tissue coverage and extension of the prosthesis. This is especially important for new denture wearers, patients with tori or exostoses, and patients with low gagging

thresholds. Also, the existence of a labial flange in a conventional denture may result in exaggerated facial contours for a patient with recent extractions, which can result in chronic soreness. Implant-supported prostheses (RP4) do not require labial extensions or extended soft tissue coverage. *Note:* An RP-5 prosthesis would have full peripheral acrylic extensions in the maxilla and mandible (i.e., mandible, buccal shelf support; maxilla, full palatal coverage).

Increased retention.

In general, an implant overdenture prosthesis will have significant retention in comparison to a conventional complete removable prosthesis. For example, a complete mandibular denture moves during most mandibular jaw movements in function and speech. Studies have shown a mandibular denture may move approximately 10 mm during function. Under these conditions, specific occlusal contacts and the control of masticatory forces are nearly impossible. An IOD provides improved retention and stability of the prosthesis, and the patient is able consistently to reproduce a determined centric occlusion.[120]

Increased biting forces.

Higher bite forces have been documented for mandibular overdentures on implants. The maximum occlusal force of a patient with dentures may improve 300% with an implant-supported prosthesis.[121] A study of chewing efficiency compared wearers of complete dentures with wearers of implant-supported overdentures (IODs). The complete denture group needed 1.5 to 3.6 times the number of chewing strokes compared with the overdenture group.[122] The chewing efficiency with an IOD is improved by 20% compared with a traditional complete denture.[123]

Better speech.

The contraction of the mentalis, buccinator, or mylohyoid muscles may lift a traditional denture off the soft tissue. As a consequence, the teeth may touch during speech and elicit clicking noises. The retentive IOD remains in place during most mandibular movements. The tongue and perioral musculature may resume a more normal position because they are not required to limit mandibular denture movement. However, most patients will obtain better speech with a RP-4 prosthesis, as a RP-5 overdenture tends to have longer flanges, which impinge on the musculature.

Decreased number of implants.

An overdenture also provides some practical advantages over an implant-supported complete fixed partial denture. Fewer implants may be required when a RP-5 restoration is fabricated because soft tissue areas may provide additional support. The overdenture may provide stress relief between the superstructure and prosthesis, and the soft tissue may share a portion of the occlusal load. Regions of inadequate bone for implant placement may be eliminated from the treatment plan rather than necessitating bone grafts or placing implants with poorer prognosis. As a result of less bone grafting and fewer implants, the cost to treat the patients is dramatically reduced. An RP-4 prosthesis requires more implants than an RP-5; however, less than a fixed prosthesis.

Esthetics.

The esthetics for many edentulous patients with moderate to advanced bone loss are improved with an overdenture compared with a fixed restoration. Soft tissue support for facial appearance often is required for an implant patient because of advanced bone loss, especially in the maxilla. Interdental papilla and tooth size are easier to reproduce or control with an overdenture. Denture teeth easily reproduce contours and esthetics compared with time-consuming and technician-sensitive porcelain metal fixed restorations. The labial flange may be designed for optimal appearance, not daily hygiene. In addition, abutments do not require a specific mesiodistal placement position for an esthetic result because the prosthesis completely encompasses the implant abutments.

Hygiene.

Hygiene conditions and home and professional care are improved with an overdenture compared with a fixed prosthesis. Periimplant probing is easier around a bar than a fixed prosthesis because the crown contour often prevents straight-line access along the abutment to the crest of the bone. The overdenture may be extended over the abutments to prevent food entrapment during function in the maxilla. With a fixed implant prosthesis, hygiene is usually complicated because of the contours of the prosthesis in comparison to the implant position.

Less trauma from parafunction.

An overdenture may be removed at bedtime to reduce the noxious effect of

nocturnal parafunction, which increases stresses on the implant support system. In addition, a fixed prosthesis is not desired as often for a long-term denture wearer. Long-term denture patients do not appear to have a psychologic problem associated with a removable implant prosthesis vs. a fixed prosthesis.

Ease of repair.

The overdenture prosthesis is usually easier to repair than a fixed restoration. Reduced laboratory fees and fewer implants allow the restoration of patients at reduced costs compared with a fixed prosthesis. If a fixed prosthesis fractures (i.e., porcelain), remediation usually will include refabrication of the prosthesis.

Decreased bone loss.

In the areas of implant placement, bone atrophy will be reduced greatly in comparison to areas of edentulism. It has been shown in numerous studies that the stimulation from the implants and/or prosthesis maintains posterior bone volume.

Prosthesis may be upgraded.

In most cases, an overdenture may be upgraded to a fixed prosthesis (i.e., as long as there exist no positioning or bone deficiency issues) (Box 3.33; Box 3.34). For example, a two-implant RP-5 mandibular overdenture may be changed to a RP-4 by adding 2 to 3 additional implants or an FP-3 fixed prosthesis by adding 3 to 4 additional implants in the mandible.

Box 3.33

Mandibular Implant Overdenture Advantages

- Prevents anterior bone loss
- Improved esthetics
- Improved stability (reduces or eliminates prosthesis movement)
- Improved occlusion (reproducible centric relation occlusion)
- Decrease in soft tissue abrasions

- Improved chewing efficiency and force
- Increased occlusal efficiency
- Improved prosthesis retention
- Improved prosthesis support
- Improved speech
- Reduced prosthesis size (reduces flanges)
- Improved maxillofacial prostheses

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Box 3.34

Implant Overdenture Advantages vs. Fixed Prosthesis

- Fewer implants (RP-5)
- Less bone grafting required before treatment
- Less specific implant placement
- Improved esthetics
- Denture teeth
- Labial flange
- Soft tissue drape replaced by acrylic
- Soft tissue considerations
- Improved periimplant probing (follow-up)
- Hygiene

- Reduced stress
- Nocturnal parafunction (remove prosthesis at night)
- Stress relief attachment
- Lower cost and laboratory cost (RP-5)
- Fewer implants (RP-5)
- Less bone grafting (RP-5)
- Easy repair
- Laboratory cost decrease (RP-5)
- Transitional device is less demanding than a fixed restoration

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Disadvantages

Patient expectations.

The primary disadvantage of a mandibular overdenture is related to the patient's desire, primarily when he or she does not want to be able to remove the prosthesis. A fixed prosthesis often is perceived as an actual body part of the patient, and if a patient's primary request is not to remove the prosthesis, an implant-supported overdenture would not satisfy the psychologic need of the patient.

Food impaction.

Unlike the labial flange of a maxillary denture, the labial flange of a mandibular overdenture rarely is required for esthetics. A mandibular overdenture often traps food below its flanges, similar to a denture. Dentures and RP-5 IODs are border molded to the muscle attachment level to allow the floor of the mouth to raise during swallowing. As a consequence, food accumulates below the denture flange while the muscles are at rest and then is compressed under the restoration during deglutition. The contour of a fixed restoration is less prone to food entrapment. The daily care for a bar

IOD (RP-4) may be similar to that for a fixed mandibular restoration because ridge lap pontics are not required for esthetics or speech, as with some maxillary fixed prostheses.

More maintenance.

Removable overdentures require greater maintenance and exhibit more frequent prosthetic-related complications than fixed restorations. For example, Walton and McEntee noted that there were three times more maintenance and adjustments for removable prostheses compared with fixed restorations.[124] IODs often require attachments to be changed or modified every 6 months to 2 years, and denture teeth often wear, requiring a new prosthesis to be fabricated every 5 to 7 years.[125] In a review of literature by Goodacre et al., IODs have retention and adjustment problems 30% of the time, relines 19% of the time, clip or attachment fracture 17% of the time, and fracture of the prosthesis 12% of the time.[30] Fixed prostheses need less repair and less maintenance and often last the life of the implant support. Although porcelain fractures with a fixed restoration may occur and be costly to repair, over a lifetime the implant-supported removable prosthesis is often more expensive.

Denture teeth attrition.

Denture teeth wear faster on an IOD (i.e., hybrid) than with a traditional denture because bite force and masticatory dynamics are improved. A new overdenture often is required at 5- to 7-year increments because of denture tooth wear and changes in the soft tissue support. Patient education regarding the long-term maintenance requirement and the associated costs should be outlined at the onset of implant therapy (Box 3.35).

Box 3.35

Overdenture Disadvantages

- Psychologic (need for nonremovable teeth)
- Greater abutment crown height space required
- More long-term maintenance required

- Attachments (change)
- Relines (RP-5)
- New prosthesis every 7 years
- Continued posterior bone loss
- Food impaction
- Movement (RP-5)

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Implant-Supported Fixed Prosthesis (Fixed)

Advantages

Ideal prosthesis.

The implant-supported fixed prosthesis is the closest available treatment option for an edentulous patient to return to optimal form, function, and esthetics. Most patients receiving a fixed prosthesis will state that it "feels like normal teeth," which carries a profound psychologic impact. The prosthesis does not require removal and is less likely to impact food in comparison to a removable prosthesis.

Less bone loss in cantilevered areas.

Wright et al. have evaluated posterior mandibular bone loss in IODs (type 5 removable prosthesis [RP-5]) compared with cantilevered fixed prostheses from anterior implants.[121] The annual bone loss index observed in the RP-5 overdentures ranged from +0.02 to −0.05 with 14 of 20 patients losing bone in the posterior regions. The fixed prostheses group had a range from +0.07 to −0.015 with 18 of 22 patients gaining posterior bone area. Reddy et al. also found a similar clinical observation in 60 consecutively treated cantilevered fixed prostheses supported by five to six implants placed between the foarmina.[126] The mandibular body height was measured 5, 10, 15, and 20 mm distal to the last implant. The baseline measurements up to 4 years after function increased from 7.25 ± 0.25 mm to 8.18 ± 0.18 mm. Nearly all of the bone growth occurred during the first year of function. An important role for

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the complete implant-supported restoration is the maintenance and even regeneration of posterior bone in the mandible.

Decreased maintenance.

Because there are no attachments utilized with a fixed implant prosthesis, there is far less maintenance required. Less maintenance is associated with less financial outlay that the patient must commit to in comparison to an overdenture treatment (Fig. 3.139 and Box 3.36).

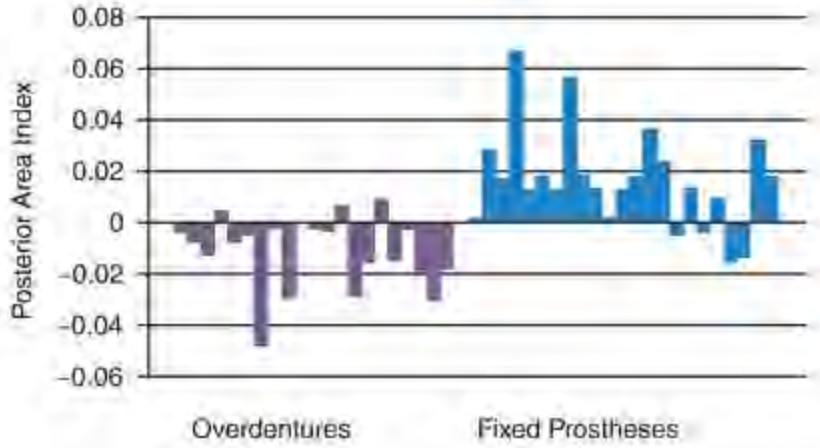

FIG 3.139 Implant overdentures with posterior soft tissue support lose bone in the posterior regions almost 75% of the time *(purple bars)*. Fixed prostheses cantilevered from anterior implants gain bone in the posterior regions more than 80% of the time *(blue bars)*. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby; Data from Wright PS, Glastz PO, Randow K, et al: The effects of fixed and removable implant-stabilized prostheses on posterior mandibular residual ridge resorption, *Clin Oral Implants Res* 13:169–174, 2002.)

Box 3.36

Advantages of a Full-Arch Fixed Partial Denture vs. Overdenture

- Psychologic: "feels like teeth"
- Less prosthetic maintenance (e.g., attachments, relines, new overdenture)
- Less food entrapment

- Posterior mandibular bone gain

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Disadvantages

Cost.

The cost of a fixed prosthesis is higher than other treatment plans, which may serve as a barrier to acceptance. In patients with severe parafunction, the argument does arise for fabrication of a removable overdenture as opposed to the porcelain fixed restoration as it is removable and is easily repaired if needed.

Esthetics.

The esthetics for a fixed detachable prosthesis may be inferior to an overdenture. Because soft tissue support for facial appearance often is required for an implant patient with advanced bone loss, a fixed prosthesis will usually not be as soft tissue supportive as an overdenture. Because there is no labial flange with a fixed prosthesis, compromises in the soft tissue may result. If overcontouring of the prosthesis is completed by the laboratory, this will often result in decreased hygiene.

Food impaction.

With a fixed prosthesis, a common complaint exists with an increase in food impaction. This will most likely result when custom abutments are used to offset nonideal implant positioning. Because the prosthesis is fixated, removing the prosthesis, whether cement or screw, is time-consuming and increases potential complications.

Summary

The foundation of a successful treatment outcome is to fully inform the patient as to the advantages and disadvantages of every possible treatment option for their respective condition. Even with superior clinical skill and perfect execution, a clinician may encounter patient dissatisfaction with the finished treatment due to unmet expectations. With a firm understanding of every possible treatment option, the practitioner can effectively educate the patient, agree on a treatment plan based on the patient's values, and manage

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expectations throughout the process. By doing this, both the clinician and patient will enjoy the benefits of their relationship.

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Radiographic Complications and Evaluation

Randolph R. Resnik, John W. Preece

The use of diagnostic imaging in implant dentistry has changed dramatically over the years. Comprehensive and accurate radiographic assessment is a crucial aspect of dental implant treatment planning. Various imaging techniques have been used to evaluate bone quality, quantity, and location of anatomic structures in relation to proposed implant sites. Traditionally, implant clinicians have relied on two-dimensional conventional radiographic modalities in implant dentistry. However, with the advent of computed tomography (CT) and cone beam computed tomography (CBCT), a new era in all phases of the radiographic imaging survey of implant patients has become available. These technologic advances have significantly increased the level of detailed information available to implant clinicians in the diagnosis, treatment planning, surgical, and prosthetic phases of dental implant treatment. This chapter will comprehensively review the use of various radiographic modalities and technologies to avoid complications related to the presurgical evaluation, treatment planning, and postoperative assessment of implant treatment.

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Radiographic Modalities

2-Dimensional

Periapical Radiograph

Periapical radiography, one of the most commonly used radiographic modalities in dentistry, has many advantages such as high resolution, low radiation, convenience, and image modification via digital software capability. However, the implant clinician must understand the inherent disadvantages of this radiologic technique when used in oral implantology.

Limitations

- **Image Distortion:** Intraoral radiographs are inherently susceptible to image distortion and magnification because the object of interest does not have the same focal spot-to-object distance. When determining the location of anatomic structures, the clinician should note that the image may contain distortion and that relying on exact measurements from these images should be cautioned against. If the x-ray beam is perpendicular to the image receptor (film or sensor) but the object is not perpendicular to the image receptor and object, dimensional changes such as foreshortening and elongation will occur (Fig. 4.1). Edentulous sites/quadrants are especially predisposed to these errors because flat maxillary palatal vaults along with high muscle attachments in the mandible make accurate positioning of the image receptor difficult.

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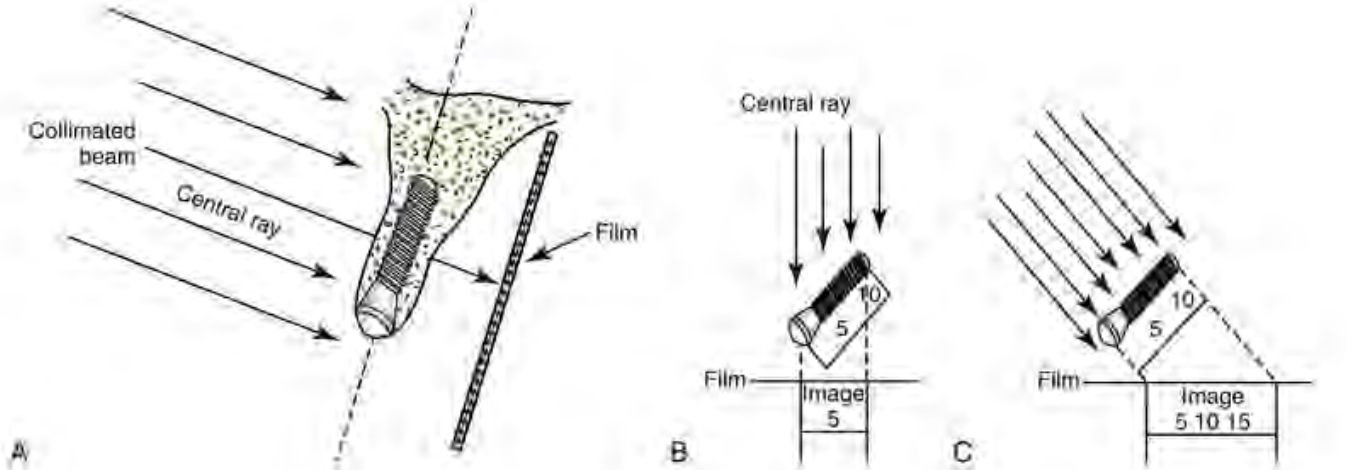

FIG 4.1 Film positioning. (A) The central ray is perpendicular to the bone, object, and film, resulting in no distortion. (B) The central ray is perpendicular to the film, but not to the implant, resulting in foreshortening. (C) The central ray is perpendicular to the object, but not the film, resulting in elongation. (From Misch CE: *Dental implant prosthetics,* ed 2, St. Louis, 2015, Mosby.)

- **Two-Dimensional Radiographic Modality:** For ideal site assessment for dental implants, a true evaluation and determination of the buccal-lingual available bone must be determined. Because periapical radiography anatomically compresses the width dimension into a two-dimensional radiograph, important information cannot be obtained. Therefore when attempting to estimate width distances in close approximation to maxillary and mandibular anatomic structures with two-dimensional radiographs, the implant clinician must be continuously conscious of the inherent inaccuracies associated with two-dimensional images.
- **Identification of Vital Structures:** When evaluating the position of vital structures with intraoral radiographs, extreme caution should be exercised. In the evaluation of the true location of the mental foramen, studies have shown less than 50% of periapical radiographs depict the correct location of the mental foramen.[1] Other studies have concluded that, because of insufficient cortical bone around the mandibular canal, only 28% of periapical radiographs will accurately identify the mandibular canal.[2] Therefore periapical radiographs exhibit high false-positives and false-negatives with respect to the identification of vital anatomic structures.

Complication Implications.

Periapical radiographs have many inherent disadvantages, the most notable being that they provide only a two-dimensional image of a three-dimensional object. The inability to determine the buccal-lingual bony dimensions is a

major shortcoming with respect to implant treatment planning. These radiographs are of little value in determining quantity and quality of bone, identifying vital structures, and depicting the spatial relationship between structures within proposed implant sites. Thus, periapical radiographs should be limited to an initial evaluation of a proposed implant site, intraoperative evaluation, and postoperative assessment.

Panoramic Radiograph

Panoramic radiography is a curved-plane tomographic radiographic technique used to depict the body of the mandible, maxilla, and the maxillary sinuses in a single image. Its convenience, speed, and ease have made this type of radiography a popular technique in evaluating the gross anatomy of the jaws. However, the implant clinician must understand the inherent fundamental limitations characteristic of this type of radiograph.

Limitations

- **Magnification/Distortion:** All panoramic radiographs suffer from vertical and horizontal magnification, along with a tomographic section thickness that varies according to the anatomic position. Because the x-ray source exposes the jaws utilizing a negative angulation (~8%) to avoid superimposing the occipital bone/base of the skull over the anterior dental region, variable magnification will always be present on panoramic radiographs. Increased magnification stems from variances in patient positioning, focal object distance, and the relative location of the rotation center of the x-ray system and variations in normal anatomic form and size from one patient to the next. Zarch et al. have shown that 83% of panoramic measurements are underestimated, with the greatest magnification being present in the anterior region (Fig. 4.2).[3]

- **Horizontal magnification:** Horizontal magnification is determined by the position of the object within the focal trough. The degree of horizontal magnification depends on the distance of the object from the focal trough center and is influenced by the patient's anatomy and positioning within the panoramic

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machine. In the anterior region the horizontal magnification will increase significantly as the object moves away from the focal trough. This results in anterior magnification being far greater and more variable than posterior magnification.

- **Vertical magnification:** Vertical magnification is determined by the differences between the x-ray source and object. Because the beam angle is directed at a negative (upward) angulation, structures positioned closer to the source are projected higher within the image in relation to structures positioned farther from the x-ray source. Therefore the spatial relationships between objects projected on a panoramic radiograph are inaccurate (see Fig. 4.3).

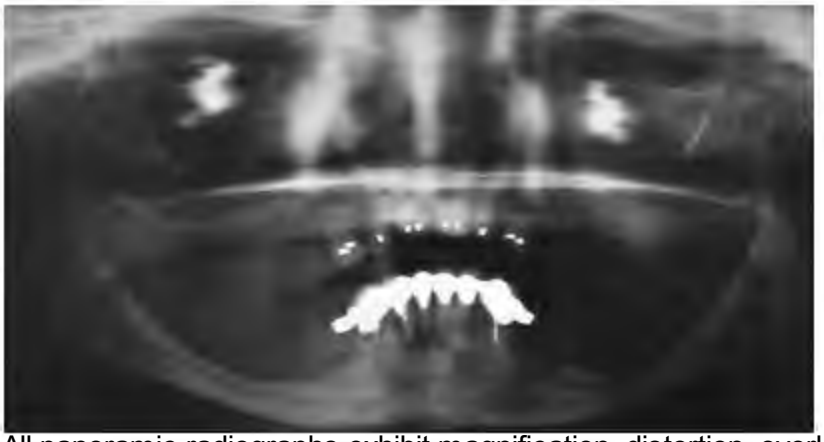

FIG 4.2 All panoramic radiographs exhibit magnification, distortion, overlapping of images, and ghost images, making these images inaccurate as the sole determination for dental implant diagnosis.

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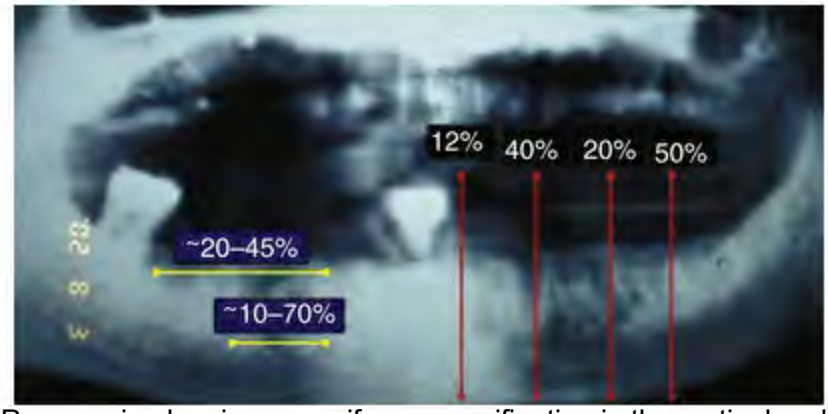

FIG 4.3 Panoramic showing nonuniform magnification in the vertical and horizontal plane depicting inaccurate measurements. Vertical magnification can be determined; however, horizontal magnification is entirely inaccurate.

- **Two-Dimensional Radiographic Modality:** The panoramic radiograph is a two-dimensional (2-D) image depicting 3-dimensional (3-D) structures. Accordingly, it does not demonstrate the buccal-lingual dimension of maxillofacial structures; therefore bone width and vital structures cannot be determined. Additionally, it produces a flattened, spread-out image of curved structures, which results in significant distortion of the vital structures and their relationship in space.
- **Identification of Vital Structures:** Panoramic radiography does not exhibit an accurate assessment of bone quality/mineralization, and it does not truly identify and locate vital structures accurately.

- **Visibility of mandibular canal:** Lindh has shown that the mandibular canal cortical walls were visible in only 36.7% of panoramic radiographs.[4]

- **Mental foramen location:** Yosue et al, in evaluation of the mental foramen, concluded that over 50% of radiographs will not depict the true location of the mental foramen.[1]

- **Linear measurements:** Sonic et al have shown an inaccuracy rate of 24% in determination of linear

measurements for bone assessment with respect to vital structures.[5]

- **Anterior loops:** Studies completed by Kuzmanovic et al of anterior loops (mental nerve courses anteriorly to the mental foramen), concluded panoramic radiographs exhibit a high incidence of false positives and false negatives, making them totally inaccurate.[6]

- **Location of septa:** In evaluation of maxillary sinus floor bony septa by Krenmair et al, correct identification and location has been shown to be approximately 21.3%.[7]

- **Identification of accessory foramina:** Accessory (double) foramina have been shown to accurately identified in less than 50% of panoramic radiographs.[8]

Complication Implications.

Although panoramic radiographs have historically been the gold standard in evaluating potential implant sites, many disadvantages are associated with these types of radiographs. A lower resolution prevents evaluation of the fine detail that is required for the assessment of osseous structures and anatomy. The magnification in the horizontal and vertical planes is nonuniform; thus linear measurements are inaccurate (Fig. 4.3). Often the image has superimposition of real, double, and ghost images, which result in difficulty in visualizing anatomic and pathologic details. The true positions of important vital structures, which are crucial in dental implant treatment, are not easily seen or incorrectly depicted. Therefore panoramic radiographs have value for initial evaluation; however, they predispose the implant clinician to many surgical, prosthetic, and medicolegal complications.

Cone Beam Tomography

3-Dimensional

To overcome some of the disadvantages of two-dimensional radiographs and conventional medical CT scanners, a new type of computed tomography specific for dental applications has been developed. This type of advanced tomography is termed cone beam volumetric tomography (CBVT) or cone beam computed tomography (CBCT). In the past, conventional computerized tomography, when used for dental implant treatment planning, has been underutilized due to concerns related to potentially high radiation dose and lower resolution. Because of the low radiation dose inherent with cone beam technology, the limitations of medical computerized tomography have been overcome. Additionally, this scanning technology has advantages including potential "in-office" installation and use, which allow the clinician and patient the convenience of onsite scanning capabilities and treatment planning. In addition, for clinicians not wishing to invest in a personal CBCT unit, many major cities have specialized dental scanning centers for referral for appropriate CBCT imaging.

Today, CBCT imaging has become the gold standard for dental implant treatment planning. However, many implant clinicians lack the background and knowledge in evaluating and treatment planning with CBCT, thus predisposing to possible complications. Therefore the implant clinician must have a thorough understanding of inherent disadvantages of CBCT scans along with knowledge of applied head and neck anatomy, anatomic variants, incidental findings, and pathologic conditions with respect to implant treatment planning.

CBCT Technology Complications

Sensor (Detector) Type.

The x-ray sensor receives the x-rays and converts them into electrical data that are then converted to various images via special computer programs. There exist two types of sensors used today in CBCT technology: (1) image intensifiers (IIs) with charged coupling devices (CCD) and (2) flat panel detectors (FPDs). Image intensifiers have many disadvantages in comparison to flat panel detectors including poorer resolution, larger size, and a higher patient radiation dose requirement. Flat panel detectors, although more

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expensive than image intensifiers, produce images with much higher quality and resolution. Most FPDs used today in CBCT units utilize cesium iodide (CsI) as the scintillator crystal screen. Cesium iodide scintillators produce the highest spatial resolution possible among various CBCT screens.

Voxel Size.

The unit element in the 3-D image is termed the voxel, which is analogous to the 2-D pixel. Images composed of multiple voxels are stacked in rows or columns that are isotropic (i.e., they have equal dimensions in the x, y, and z planes) and range in size from 0.075 to 0.6 mm. Each individual voxel is assigned a grayscale value that corresponds to the anatomic structures attenuation value. The smaller the voxel size, the greater the resolution and quality of the image, but also the greater the resultant radiation dose. A voxel size of 0.2 to 0.3 mm is considered ideal because it allows for an equitable trade-off between image quality and absorbed radiation dose (Fig. 4.4).

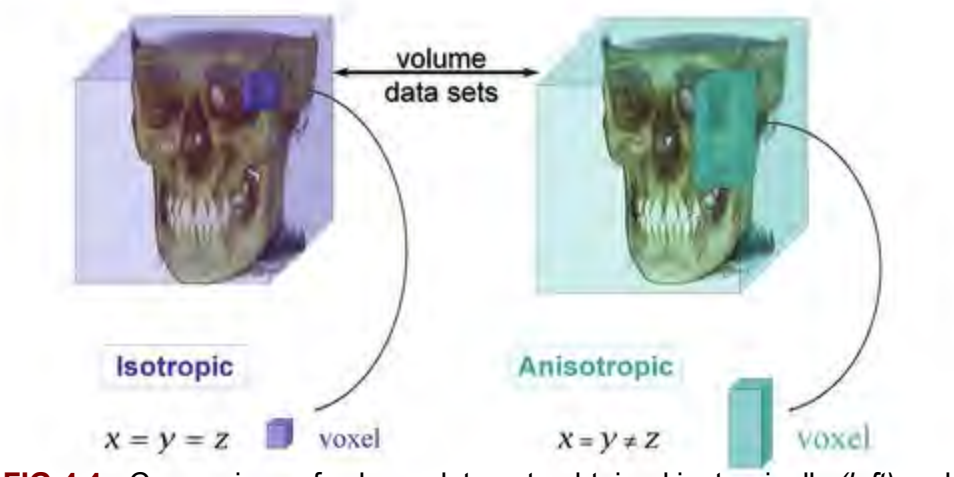

FIG 4.4 Comparison of volume data sets obtained isotropically *(left)* and anisotropically *(right)*. Because CBCT data acquisition depends on the pixel size of the area detector and not on the acquisition of groups of rows with sequential translational motion, the compositional voxels are equal in all three dimensions, rather than columnar, with height being different from the width and depth dimensions. (From Scarfe WC, Farman AG: What is cone-beam CT and how does it work? *Dent Clin North Am* 52(4):707–730, 2008.)

Spatial Resolution.

Spatial resolution is measured in lines/millimeter (lp/mm) and relates to the ability to distinguish two anatomically close objects. On a CBCT image, the

higher the spatial resolution, the greater the ability to delineate two different objects from one another. Normally, CBCT scanners (voxel size 0.075–0.6 mm) are most commonly associated with higher spatial resolution than medical grade scanners (voxel size 0.6–1 mm). However, decreased spatial resolution on CBCT images may result from: (1) the use of a higher voxel size (> 0.4) (i.e., use of voxel sizes > 0.3 mm for implants is not recommended due to the lower spatial resolution), (2) decreased radiation (kVp or mA), which results in increased noise, (3) metallic restorations resulting in artifacts, and (4) increased focal spot size.

Contrast Resolution.

Contrast resolution is defined as the ability to differentiate tissues of different radiodensities. In implant dentistry, the ability to produce different shades of gray is important for a clearly diagnostic image. Because CBCT images utilize less radiation and are produced with lower kVp (peak kilovoltage) and mA (milliamperage) settings in comparison to MDCT units, dental CBCT images are associated with slightly higher image contrast, modifiable through software settings. Dental CBCT images generally have increased noise and image scatter compared to medical units. To minimize noise and scatter, a smaller FOV may be used. However, smaller FOVs are usually associated with slightly higher radiation settings.

Bit Depth.

The quality of CBCT images is directly related to the number of shades of gray (bit depth). Currently, CBCT units produce up to 16-bit images, which corresponds to (2^{16}) 65,536 shades of gray. However, computer monitors may display up to only 8 bits (2^{8}) 256 shades of gray. To increase the quality of the image, the monitor brightness and contrast may be adjusted to display 8 bits per image.

Bone Density: MDCT.

Medical CT data permit differentiating between tissues that have a physical density of less than 1%. In contrast, conventional radiography requires a minimum of 10% difference in physical density to be seen.[9] Each medical CT image is composed of pixels and voxels, which are characterized by a given numeric value, which reflect the x-ray beam attenuation. These values are directly affected by the density and thickness of the tissue. The Hounsfield

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units (HU), or CT numbers, correlate with the density of the medical CT image and range in value from −1000 (air) to +3000 (enamel). A specific shade of gray or density number is assigned to each CT number, which ultimately forms the image. The correlation of these CT numbers has been used to associate the density of the area of interest with various bone densities used for surgical and prosthetic treatment planning. Thus the gray values depicted on medical CT images are considered true attenuation x-ray values (HU) (Fig. 4.5).

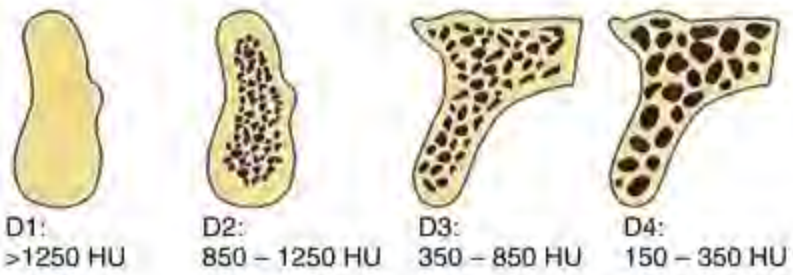

FIG 4.5 Hounsfield units correlation with bone density classification.

Bone Density: Dental CBCT.

When evaluating dental CBCT images in regards to bone density, there does not exist a direct correlation (accuracy of measurement) as compared with medical CT. Most dental CBCT systems inherently have an increased variation and inconsistency with density estimates. The density estimates of gray levels (brightness values) are not true attenuation values (HU); thus, inaccuracies in bone density estimates result.[10] This is mainly due to the high level of noise in the acquired images and the slight inconsistencies in the sensitivity of the CBCT detectors. Dental imaging software frequently provides attenuation values (HU); however, such values should be recognized as approximations lacking the precision of HU values derived from medical CT units.

Artifact Complications

Beam Hardening.

Because metallic objects in the oral cavity are associated with higher attenuation coefficients than soft tissue, dental CBCT images inherently are

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predisposed to these artifacts. One of the most common types of artifacts is termed *beam hardening*. Beam hardening occurs when x-rays travel through the bone/implant, resulting in more low-energy photons being absorbed than high-energy photons. Because of this the image will have compromised image quality.[11] The titanium alloy surface is highly susceptible to these types of artifacts because of the high-density nature of the metal. This results in inaccuracies, especially when viewing periimplant bone levels. Conventional intraoral images will not exhibit these beam-hardening artifacts and may appropriately be used to better evaluate the quality and quantity of bone mesial and distal to an implant when beam-hardening artifacts may obliterate visualization of interproximal bone, especially when multiple implants are present in the same quadrant. Additionally, higher-density materials commonly found in the oral cavity (e.g., amalgam, gold) will lead to complete absorption of the beam and beam-hardening artifacts.[12] There exist two types of beam-hardening artifacts that result in linear areas of dark bands or streaks between dense objects and cupping artifacts. Cupping artifacts occur when x-rays pass through the center of a highly dense object and are absorbed more than the peripheral x-rays. This results in an image in which a uniformly dense object appears to be less dense (darker, lower CT numbers) at its center and appears as a “cup” (Fig. 4.6).

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FIG 4.6 Beam hardening, which results in radiolucency surrounding the implant that frequently is misdiagnosed as a failing implant. This is caused by the dense nature of titanium implants and the exposure of more low-energy photons.

Motion-Related Artifacts.

Motion artifacts are usually the result of patient movement and result in the inaccurate depiction of bony landmarks, measurements, and implants.[13] Patient movements and incorrect patient positioning create blurring problems, double density line artifacts adjacent to major bony structures that result in nondiagnostic images. Patients should be instructed to not move and avoid swallowing throughout the scan. The motion blurring causes "double contours" of anatomic structures that result in decreased scan quality and spatial resolution. This may lead to improper implant placement and possible damage to neural structures.[14] Motion-related artifacts may be decreased by using sit-down CBCT units or head restraints, or by decreasing scanning times (Fig. 4.7).

FIG 4.7 Motion artifact due to movement of the patient leading to overlapping "double images."

Streak Artifacts.

CBCT images are susceptible to streak artifacts caused by x-rays traveling through objects with a high atomic number (metallic restorations). Streak artifacts usually are seen as light and dark lines that arise from the source object, resulting in images with decreased quality and obscuring of anatomic structures (Fig. 4.9).

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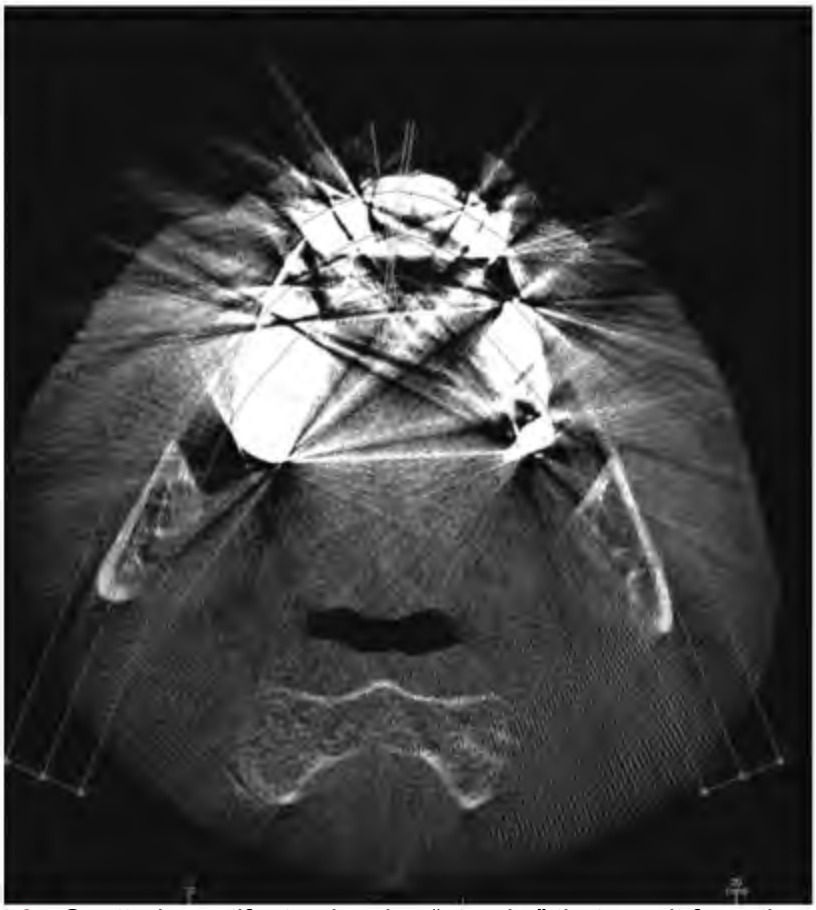

FIG 4.9 Scattering artifacts showing "streaks" that result from the metal restorations.

Scatter.

Another disadvantage inherent with CBCT images is scatter, which is most commonly produced from metallic restorations. This is caused by photons (x-rays) that are deflected from their original path by metallic objects. When these deflected photons reach the sensor (detector), the intensity of the signal is magnified in a nonuniform magnitude. The end result is an image with decreased resolution and image quality, which ultimately leads to inaccuracies in the reconstructed CT number or voxel density.[15] The field of view (FOV) of the CBCT is proportional to the amount of scattering; thus smaller FOVs are associated with less scattering. CBCT images have inherently greater scatter radiation than medical-grade CT images (Fig. 4.9).[16]

Noise.

There are two types of noise associated with CBCT images: additive (results from electrical noise) and photon-count (quantum noise). Because CBCT

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operate at much lower amperage (mA) settings than MDCT scanners, CBCT images are associated with greater quantum noise. The noise is displayed as a "graining" of the image and is the result of inconsistent distribution of the signal, which results in inconsistent attenuation (gray) values in the projection images (see Fig. 4.8).

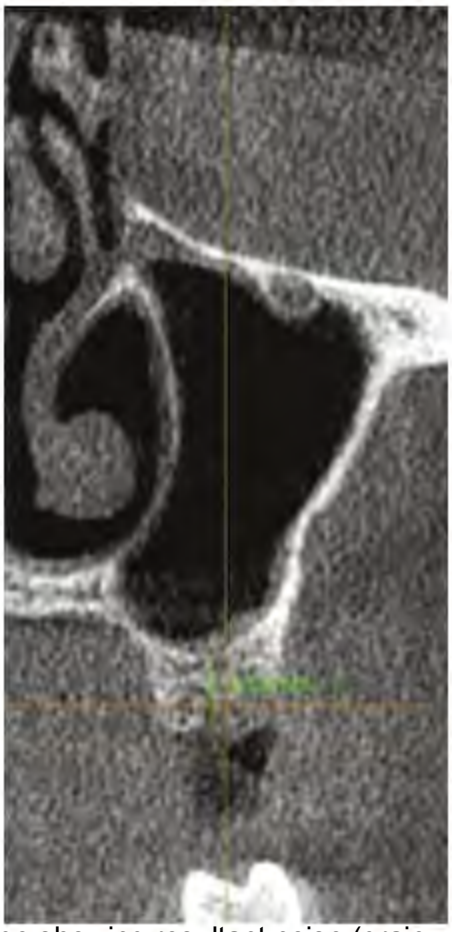

FIG 4.8 Image showing resultant noise (grainy appearance).

Bone Dehiscence on 3-D Reformatted Images.

MDCT and dental CBCT data have the ability to be reformatted by software algorithms to represent 3-D images by only projecting the voxels that represent the surface of the object (surface rendering), resulting in a "pseudo-3D rendering of the facial skeleton." The pixels are illuminated on the screen as if a light source is present in the front of the object. The closer the pixels, the brighter they appear. This shading effect allows the object to be projected as a 3-D object with depth. However, some 3-D images appear to

have large voids or no bone present on the surface because the software averages volume elements, and the voids appear when the software attempts to reconstruct portions of the image covered by a very thin layer of bone. When evaluating the cross-sectional images, bone will be present. This is a direct result of the reformatting process, which usually selects a higher HU reformation, resulting in decreased scatter on the 3-D image. Therefore the implant clinician should be aware 3-D images do not accurately depict the quantity and quality bone, but provide only a stylized representation of the facial skeleton (Fig. 4.10).

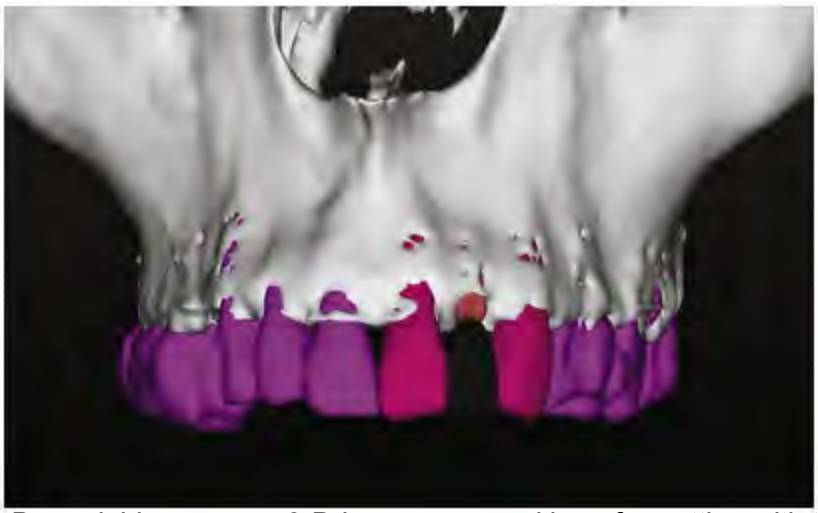

FIG 4.10 Bone dehiscence on 3-D images caused by reformatting with too high of Hounsfield unit threshold, which is done to decrease scattering of the image.

Scanning Technique Complications

Imaging Protocol.

The patient should be positioned within the CBCT unit as per manufacturer's recommendations. When taking the scan, the teeth should be slightly separated so that the different arches may be easily differentiated upon reformation. Cotton rolls, tongue depressors, or a bite registration may be used. Additionally, cotton rolls may be placed in the vestibule to separate the lips and cheeks from the buccal mucosa. This will allow for a more accurate representation of the contour and thickness of the gingival tissues.

Position of the Scanning Template.

The position of the scanning template/radiographic markers in the mouth during CBCT examination is crucial for the accuracy of fabrication of the surgical template. First, it is recommended that an index be used to position the scanning template in the correct position. The ideal index includes a radiolucent bite registration, which will allow for the teeth to be separated and maintain the patient in centric relation. This will prevent inaccuracies and help stabilize the template in the mouth. Additionally, denture adhesive should be used with the CBCT template to keep it in the ideal position.

Mucosal Thickness.

When fabricating mucosa-supported surgical guides, the thickness of the mucosa may have a direct effect on the accuracy of the of the planning of the implant sites. Increased mucosa thickness may lead to inaccurate placement of the mucosa-borne guides during the surgical placement procedure. Vasek showed a 1.0-mm buccal mucosa thickness may result in a buccal-lingual deviation of over 0.41 mm.[17] This will inevitably cause inaccurate measurements and possible misalignment of the surgical guide when placing the implants. When significant atrophy is present in the premaxilla, usually there will be excessive tissue thickness, which will result in rocking of the template.

CBCT Anatomic Radiographic

Anatomy

Incidental Findings

The role of CBCT is rapidly emerging in all aspects of diagnosis and treatment planning with dental implants. Because of varying FOVs, the implant clinician is placed in a position to evaluate maxillofacial areas that they may not be familiar with. Therefore it is crucial the implant clinician be able to interpret anatomic structures and pathology outside their primary area of interest. In radiology, an incidental finding is defined as an unexpected discovery found on a radiologic examination performed for an unrelated reason. Unfortunately, many normal anatomic variants, developmental anomalies, and imaging artifacts may be misidentified as possible pathologic conditions by inexperienced clinicians.[18] This may lead to unnecessary concern and stress for patients and embarrassment for the clinician. Additionally, possible significant pathologies may exist that go undiagnosed. This problem results in many professional, ethical, clinical, and potential legal issues for the implant clinician.

Complication Prevention

Understanding Incidence of Incidental Findings.

Incidental findings on CBCT scans have been well documented in the literature. The exact frequency of incidental findings varies from study to study depending on age, gender, race, and FOV. Price et al showed a high incidence (3.2 findings/scan) of incidental findings with approximately 16% requiring intervention or referral.[19] These incidental findings ranged from common benign findings to significant pathologic conditions. Miles reported a minimum of two reportable findings per CBCT and also showed a high incidence of periapical lesions that went undetected on conventional radiographs.[20] Cha determined after evaluation of 500 scans an incidence of 24.6% of incidental findings, most in the airway region.[21] Arnheiter showed patients 40 to 49 years old had the largest percentage of reportable incidental findings (70%), with patients aged 20 to 29 years old with the lowest percentage (40%).[22]

Obtaining a Radiology Report.

Radiology reports immediately after CBCT exams, prior to surgery, minimize the liability that may present to the implant clinician. Formal radiology reports may be obtained from many sources, preferably from an appropriately qualified, board-certified maxillofacial radiologist. Unfortunately, the geographic distribution of maxillofacial radiologists is not uniform within states or regions within a state, and a careful search will be required. Several, but not all, states require that the report be made by a maxillofacial radiologist licensed in the state, and it is therefore crucial to check with your local dental board or dental practice act to determine if in-state licensure is required. The implant clinician must be able to recognize and evaluate variations from normal and refer for appropriate medical consultation any significant incidental finding that may be contained in the radiology report.

Use of the Smallest FOV as Possible.

Ideally, the smallest FOV should be utilized for scans when treatment planning for dental implants (Fig. 4.11). A smaller FOV (~Mid FOV) will reduce radiation dose to the patient, thus adhering to the ALARA (As Low As Reasonably Achievable) principle. However, caution should be exercised to not take an inadequate FOV that includes insufficient view of the anatomic area of concern. The most common anatomic area for this to occur is the maxillary posterior region because many practitioners will set the limits of the scan superiorly/coronally to exclude the maxillary ostium. When placing implants or bone grafting in the posterior maxilla area, confirming the patency of the ostium is important to minimize complications associated with an obstructed osteomeatal complex.

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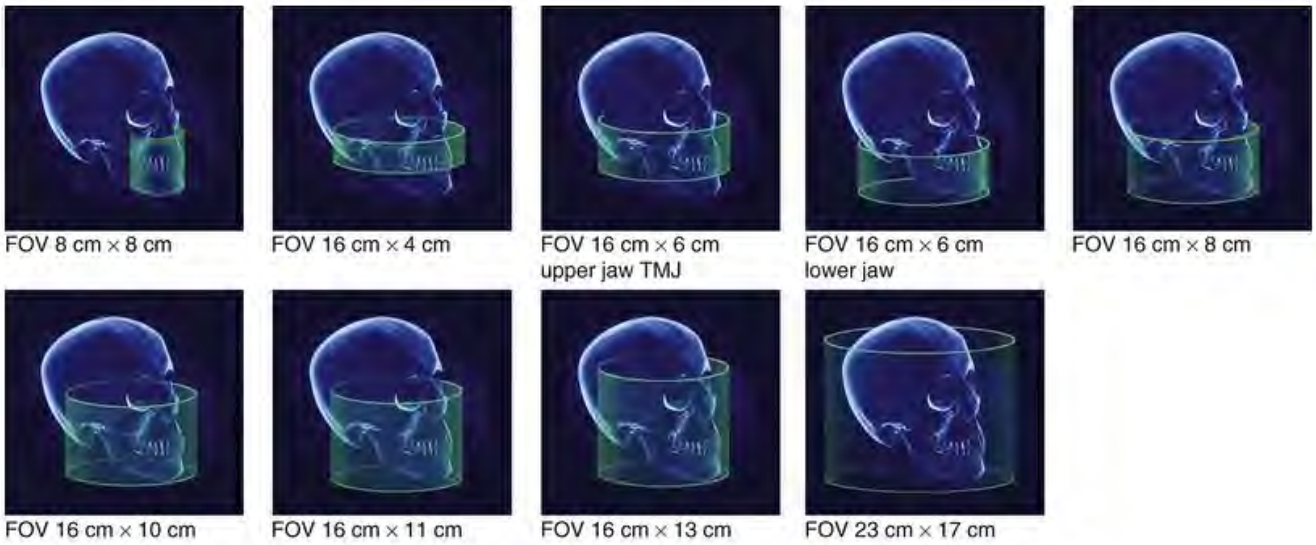

FIG 4.11 Examples from the i-CAT FLX Cone Beam 3D system depicting of different field of views for specific areas of interest. Ideally, the smallest FOV should be selected as long as the areas of interest are fully depicted on the images. (Images courtesy Imaging Sciences International, LLC, Hatfield, PA.)

Normal Radiographic Anatomy

Due to the complex nature of implant treatment and the potential for complications throughout the surgical and prosthetic phases, the clinician must have a thorough understanding of the normal anatomy of the maxillofacial region. Traditional dental education has focused on the interpretation of conventional 2-D radiographic images for diagnosis, but with the introduction and rise of CBCT images, a deeper understanding of anatomy is necessary to examine the patient's structures in three dimensions. This section of the chapter will address the basic radiographic anatomy as viewed in the three planes (axial, coronal, sagittal) typically seen on a CBCT image.

Mandibular Anatomy

Location of the Mandibular Canal in the Mandible

The position of the mandibular canal as it courses through the mandible from posterior to anterior is highly variable. Although the pathway of the inferior alveolar nerve and the mental nerve have been well described in the literature, it is paramount that the implant clinician have a clear understanding of their anatomic features and variations. When evaluating the intraosseous course of the mandibular canal buccal-lingually and inferior-superiorly within the mandible, many variations exist based on gender, ethnicity, amount of bone resorption, and age.

Buccal-Lingual Mandibular Canal Locations

Radiographic evaluation.

In the posterior region of the mandible, the inferior alveolar nerve enters the mandibular foramen on the lingual surface of the mandible and progresses anteriorly in the body of the mandible. In between the mandibular canal and the mental foramen, the buccal-lingual position is extremely variable. Studies have shown the buccal-lingual location is dependent on such variables as the amount of bone resorption, age, and ethnicity.[23] The buccal-lingual position of the mandibular canal is easily depicted on cross-sectional images after canal location is verified and highlighted (Fig. 4.12).

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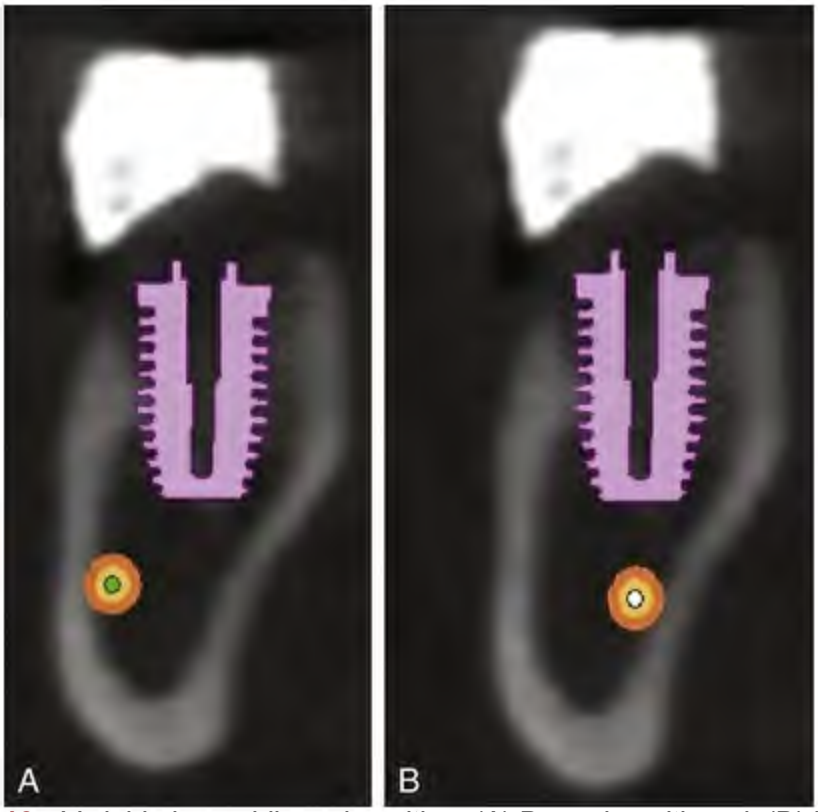

FIG 4.12 Variable buccal-lingual position. (A) Buccal positioned; (B) lingual positioned.

Clinical significance.

The intraosseous path of the mandibular canal is variable in the buccal-lingual position within the mandible, and a comprehensive radiographic survey (CBCT) ideally should be completed prior to implant osteotomy initiation to determine the anatomic path. A 2-millimeter safety zone between the implant and the mandibular canal should always be adhered to. Attempting to place an implant buccal or lingual to the neurovascular bundle may result in neurosensory impairment.

Inferior-Superior Mandibular Canal Locations

Radiographic evaluation.

The vertical position of the mandibular canal below the apices of the natural teeth within the mandible is also highly variable. Therefore, generalizations cannot be made as to a constant inferior-superior position because the distance of the canal to the root apices is not consistent.[24] An early classification of the vertical positions of the course of the alveolar nerve was reported by Carter and Keen.[25] They described three distinct types: (1) in

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close approximation to the apices of the teeth, (2) a large nerve approximately in the middle of the mandible with individual nerve fibers supplying the mandibular teeth, and (3) a nerve trunk close to the inferior cortical plate with large plexuses to the mandibular teeth. After the mandibular canal is located and drawn on the reconstructed panoramic image using CBCT viewing software, the vertical position of the intraosseous path may be determined by scrolling through the cross-sectional images. The vertical position is then easily seen on individual cross sections or CBCT-generated reconstructed panoramic images (Fig. 4.13).

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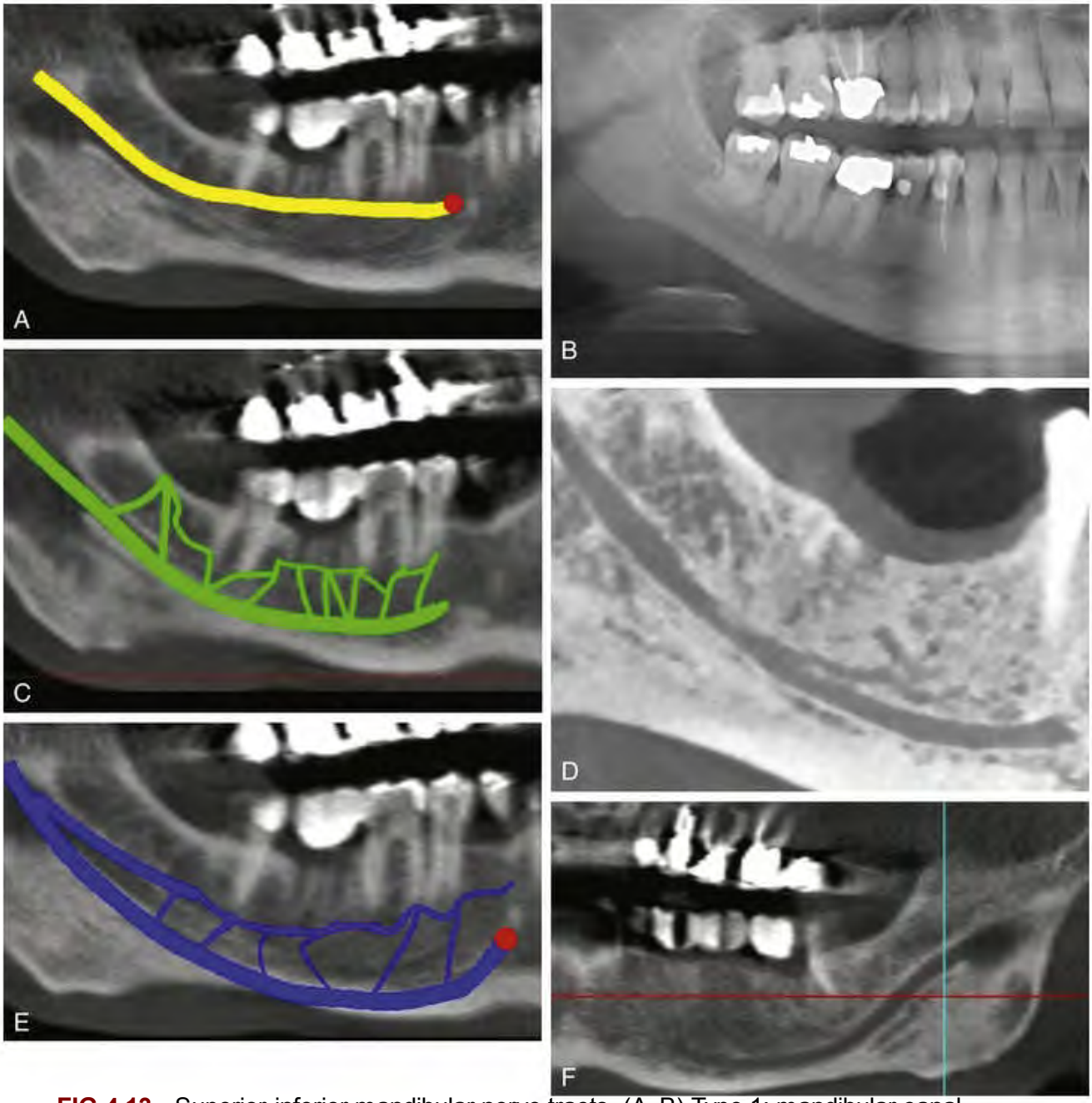

FIG 4.13 Superior-inferior mandibular nerve tracts. (A–B) Type 1: mandibular canal in close proximity to tooth roots. (C–D) Type 2: mandibular canal in center of mandible (most common). (E–F) Type 3: mandibular nerve close to inferior border of mandible.

Clinical significance.

The intraosseous path of the mandibular canal is variable in the inferior-superior position within the mandible, and a comprehensive radiographic survey (CBCT) ideally should be completed prior to implant osteotomy. Special care should be exercised in type 1 nerves because their close approximation to the root apexes results in compromised bone height for

implant placement. Immediate implant placement in the mandibular posterior when a type 1 nerve exists is not recommended. Type 3 nerves are most favorable for implant placement in the posterior mandible because the mandibular canal is positioned low in the mandible, therefore having increased available bone in height.

Mandibular Canal

The inferior alveolar canal (IAC), or mandibular canal (MC), contains the neurovascular bundle, which consists of the inferior alveolar nerve, artery, vein, and lymphatic vessels. The inferior alveolar nerve bundle enters the mandibular foramen, where it transverses anteroinferiorly from lingual to buccal within the body of the mandible. A 3-D evaluation of the MC position is recommended when implant placement is going to be completed in proximity to the nerve. The most accurate assessment of the anatomic position is with CBCT because images may be enhanced via viewing software adjustments for contrast, brightness, and gray scale to help depict the anatomic location of the MC.

Image Evaluation.

Radiographically, the MC appears as a linear, radiolucent shadow with or without inferior and superior radiopaque borders. Studies have shown the total length to be approximately 62.5 mm, with slightly longer measurements in males (+~2.5 mm).[26] The average diameter of the MC is approximately 2.0 to 3.4 mm with the diameter being the greatest in the posterior near the mandibular foramen (entrance of inferior alveolar nerve on the lingual surface of the ramus).[27] The mandibular canal becomes more ovoid as it progresses anterior towards the mental foramen.[28] Location is variable depending on the patient's race, gender, and amount of bone resorption. Usually, the MC is located on a bony ledge, the lingula, which is located on the medial surface of the ramus. Studies have shown the foramen to be located approximately 19.7 mm from the anterior border of the ramus.[29] The CBCT data are used with appropriate viewing software to identify and trace the MC. The depiction of the MC enables the implant clinician to assess the position in various multiplanar and 3-D reformations. Initially, the MC is most easily drawn on the CBCT reconstructed panoramic view with location confirmation on the cross-sectional images. In most cases, the endpoints are first identified (e.g., mandibular foramen, mental foramen), then the location

of the MC is extrapolated between these two landmarks.

Radiographic Complication.

In many instances the mandibular canal may not be easily depicted on the CBCT image; thus identification can be extremely challenging. The visibility of the MC varies significantly, even within the same individual.

The mandibular canal walls usually are not made up of compact bone, showing only a coalescence of trabecular bone with varying degrees of density.[2] This complicates the determination and location of the true identification of the canal. Studies have shown that the unreliability of identifying the entire MC course is a direct result of minimal to no dense cortical plates surrounding the nerve bundle, which has been shown to occur in approximately 30% of cases. The MC has an increased wall density in the posterior region (mandibular foramen > third molar region) in comparison to the anterior region.[30]

With CBCT, images are susceptible to noise and artifacts, with resulting low contrast. Because of these inherent quality issues, distinguishing the mandibular canal from other aspects of the internal trabecular components of the mandibular image may be difficult. Thus, the clinician should be be proficient at utilizing available tools within the software programs to be able to identify the mandibular canal.

Mental Foramen

The mental foramen is an opening in the anterolateral aspect of the mandible, commonly in the apical space in the first and second premolar area; however, individuals may rarely exhibit the position of the foramen as anterior to the cuspid area and as far posteriorly as the bifurcation of the first molar. One of the two terminal branches of the inferior alveolar nerve is the mental nerve, which exits the mental foramen with sensory innervation to the chin, lip, and anterior gingiva. The mental foramen completes in formation after the 12th gestational week, when the mental nerve separates into several fascicles. If the mental nerve separates prior to the formation of the mental foramina, the formation of a accessory foramen may result.[31] The mental foramen location, size, and number is highly variable with many dependent factors including gender, ethnic background, age, skeletal makeup.

Image Evaluation.

The mental foramen may be most easily identified on axial, coronal and cross-sectional images. The relationship between the mental foramen and teeth or vital structures can be evaluated most easily on volumetric 3-D images.

Radiographic Complication.

The location of the mental foramen on 2-D periapical and conventional panoramic radiographs has been shown to be inaccurate because they do not show the true location in most cases. Additionally, when placing immediate implants in the premolar region, angulation and avoidance of the foramen should be noted because the mental foramen has been shown to be located coronal to the root apex of premolars in 25% to 38% of patients. In most cases when an implant is to be treatment planned in approximation of the foramen, a CBCT evaluation is recommended. A CBCT image will always provide excellent visualization of the mental foramen because it exits the buccal cortical plate regardless of how poorly the canal may be visualized prior to the exit point. The identification difficulty occurs when the canal is poorly visualized by an absence of cortication or in D3 or D4 bone quality, where very little internal trabeculation is visible. Such a bony pattern makes it difficult to trace the canal posterior from the mental foramen (Fig. 4.14).

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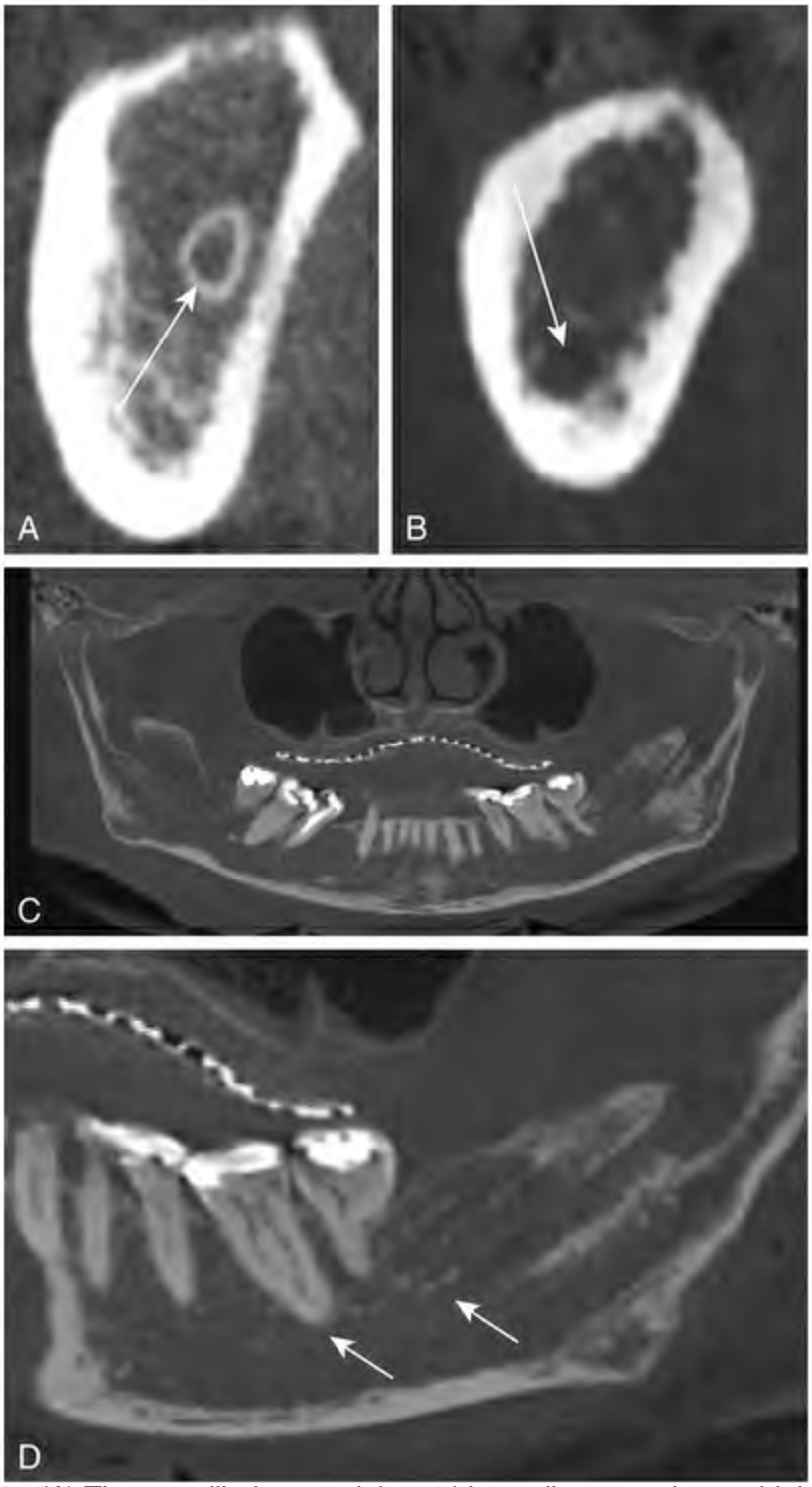

FIG 4.14 (A) The mandibular canal *(arrow)* is easily seen when a thick cortical component is present. (B) However, in 30% of patients, the mandibular canal will not have a cortical component *(arrow)*. (C) CBCT panoramic view depicting thin cortical outline with poorly defined internal bony trabecular pattern indicative of osteoporosis/osteopenia. (D) Poorly defined mandibular canal *(arrows)*.

Mandibular Ramus (Donor Site for Autogenous Grafting)

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The mandibular ramus area has become a very popular donor site for autogenous onlay and trephine bone grafting. This anatomic area of the mandible is extremely variable in the amount of bone present, as well as the buccal-lingual and inferior-superior position of the mandibular canal. Most commonly, the lateral aspect of the ramus is harvested as a block graft, which is used for ridge augmentation procedures.

Image Evaluation.

The mandibular ramus is quadrilateral and contains two surfaces, four borders, and two processes. The lateral surface is flat with two oblique ridges, the external and internal. The masseter muscle attaches on the entire lateral ramus surface. The medial surface gives rise to the lingula, which is the entrance of the inferior alveolar nerve and associated vessels. When present, the antegonial notch, anterior to the angle of the mandible, is significant for the presence of parafunction.

The relationship between the lateral cortical plate in the ramus area and the position of the mandibular canal is easily seen on cross-sectional images after nerve location identification. Additionally, 3-D images and bone models assist in the determination of the osseous morphology in this region to help the clinician select the most appropriate graft site.

Radiographic Complication.

Historically, standard 2-D radiographs for evaluation of the ramus area as a donor site included conventional panoramic images, in which the location of the external oblique and the mandibular canal may be noted. However, 2-D evaluation of this area can be very difficult to use for determination of the amount of bone present and position of the mandibular canal. With this procedure it is vital that the implant clinician be able to completely determine the exact position of the mandibular canal with respect to the external oblique ridge and the lateral cortical bone. Overestimation of available bone can result in increased morbidity, so a more accurate representation of this area is with the use of CBCT (Fig. 4.15).

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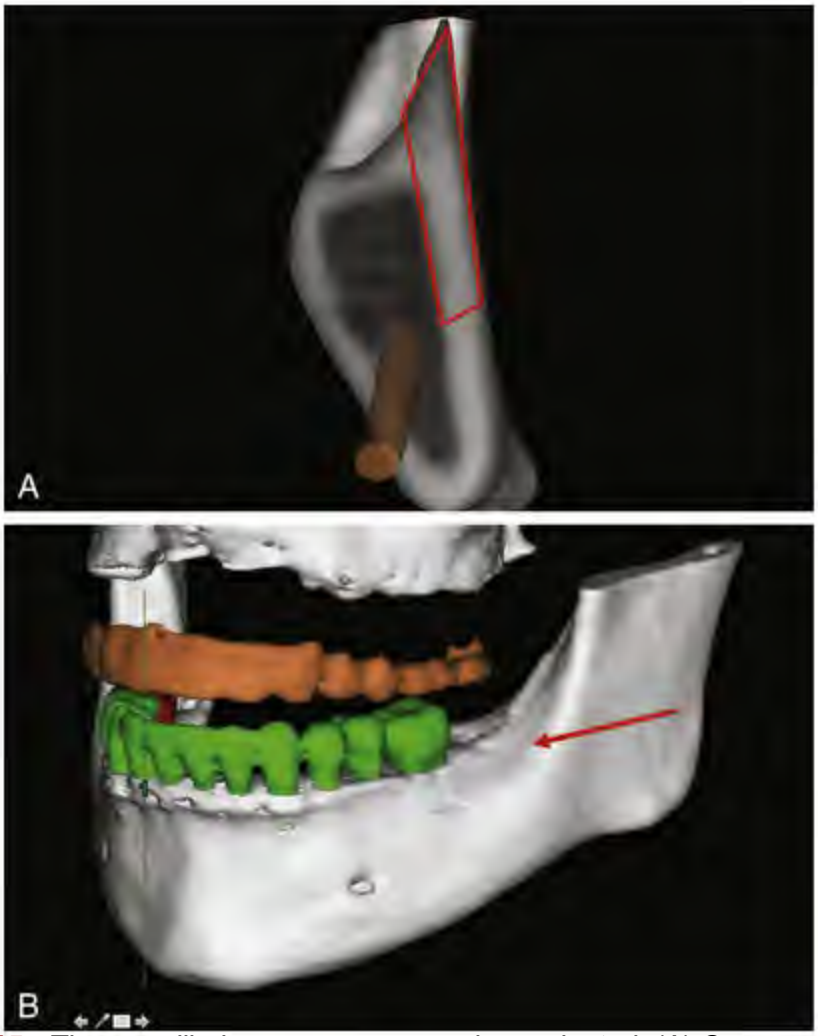

FIG 4.15 The mandibular ramus area can be evaluated. (A) Cross-sectional (outline for ramus block graft) and (B) 3-D images (depicting the ramus area in relation to the adjacent teeth).

Mandibular Symphysis (Implant Placement and Bone Donor Site)

The mandibular symphysis area is a common area for implant placement as well as a donor site for autogenous block grafting. This anatomic region has been shown to be one of the most ideal intraoral donor sites for bone harvesting. However, the mandibular symphysis is susceptible to nonuniform bone resorption and contains various anatomic variations that may lead to surgical complications.

Image Evaluation.

The anterior surface of the mandible is termed the *mandibular symphysis*. A ridge divides the right and left side and inferiorly forms the triangular

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eminence of the mental protuberance. The elevated center of this depressed area forms the mental tubercle, which is the origin of the mentalis muscles. This area should be evaluated on cross-sectional, axial, and 3-D images.

Radiographic Evaluation.

Two-dimensional imaging of this area should only be used as a preliminary evaluation for bone quantity determination. Poor angulation, bony undercuts, and measurements cannot be determined with 2-D radiography. CBCT imaging is highly recommended to prevent implant malposition or overestimation of available bone for harvest procedures, which may lead to increased complications (Fig. 4.16).

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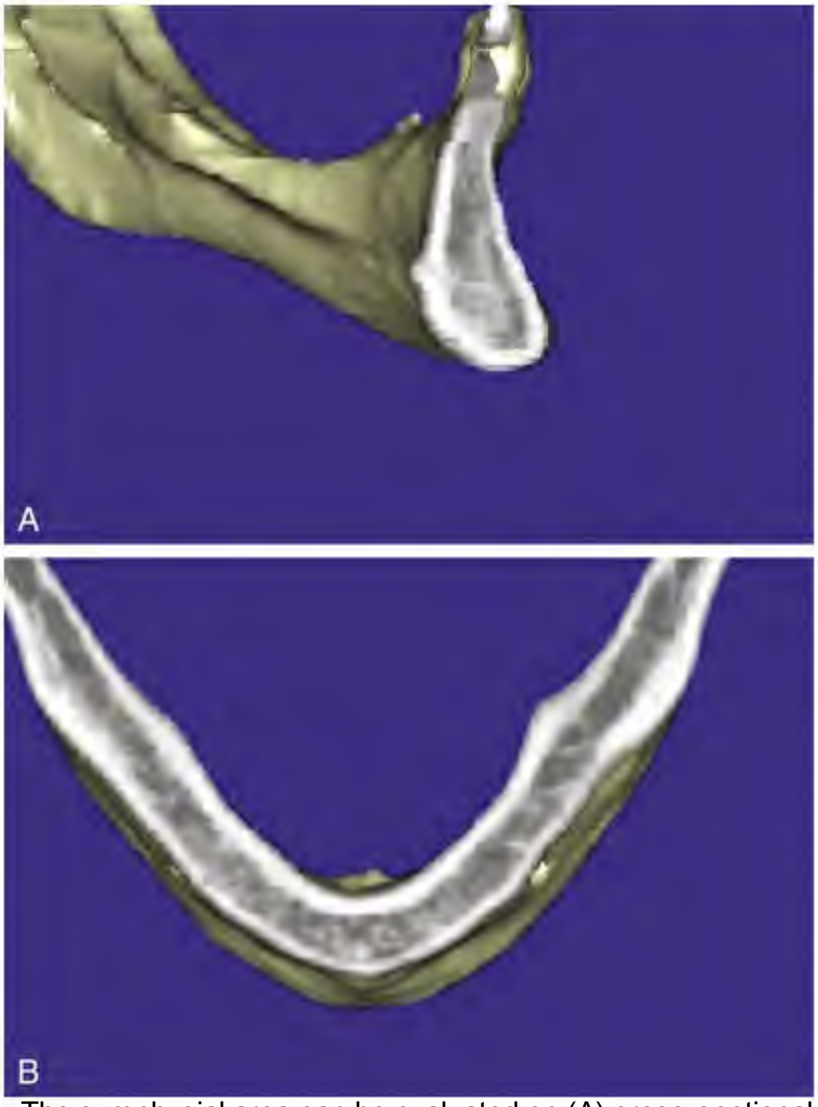

FIG 4.16 The symphysial area can be evaluated on (A) cross-sectional image(s) along with (B) axial slices.

Anatomic Variants of the Mandibular Anatomy

Anterior Loop

As the mental nerve proceeds anteriorly in the mandible, it may on occasion extend beyond the anterior boundary of the mental foramen. This endosteal curved loop is proximal to the mental foramen and exits distally through the mental foramen and is termed an "anterior loop." Studies have shown a prevalence of approximately 35% to 50 %, with a mean distance of 1.16 mm anteriorly to the foramen.[32] Clinically, an anterior loop may be determined by probing within the mental foramen in a posterior direction; however, this necessitates full reflection of the mental foramen.

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Radiographic Evaluation.

An anterior loop is difficult to identify and cannot be determined accurately with 2-D radiography. High false-positive and false-negative results have been noted on conventional panoramic and periapical radiographs. To identify an anterior loop on a reformatted CBCT image, the mandibular canal must be highlighted, including the cross-sectional image depicting the mental foramen slice. The anterior part of the mental foramen is marked with a constant perpendicular line (line will remain constant throughout all the images). In sequential axial images, scrolling from superior to inferior, any component of the nerve anterior to the constant line is considered a anterior extension. If an anterior loop exists, the highlighted nerve will be anterior to the perpendicular line (Fig. 4.17).

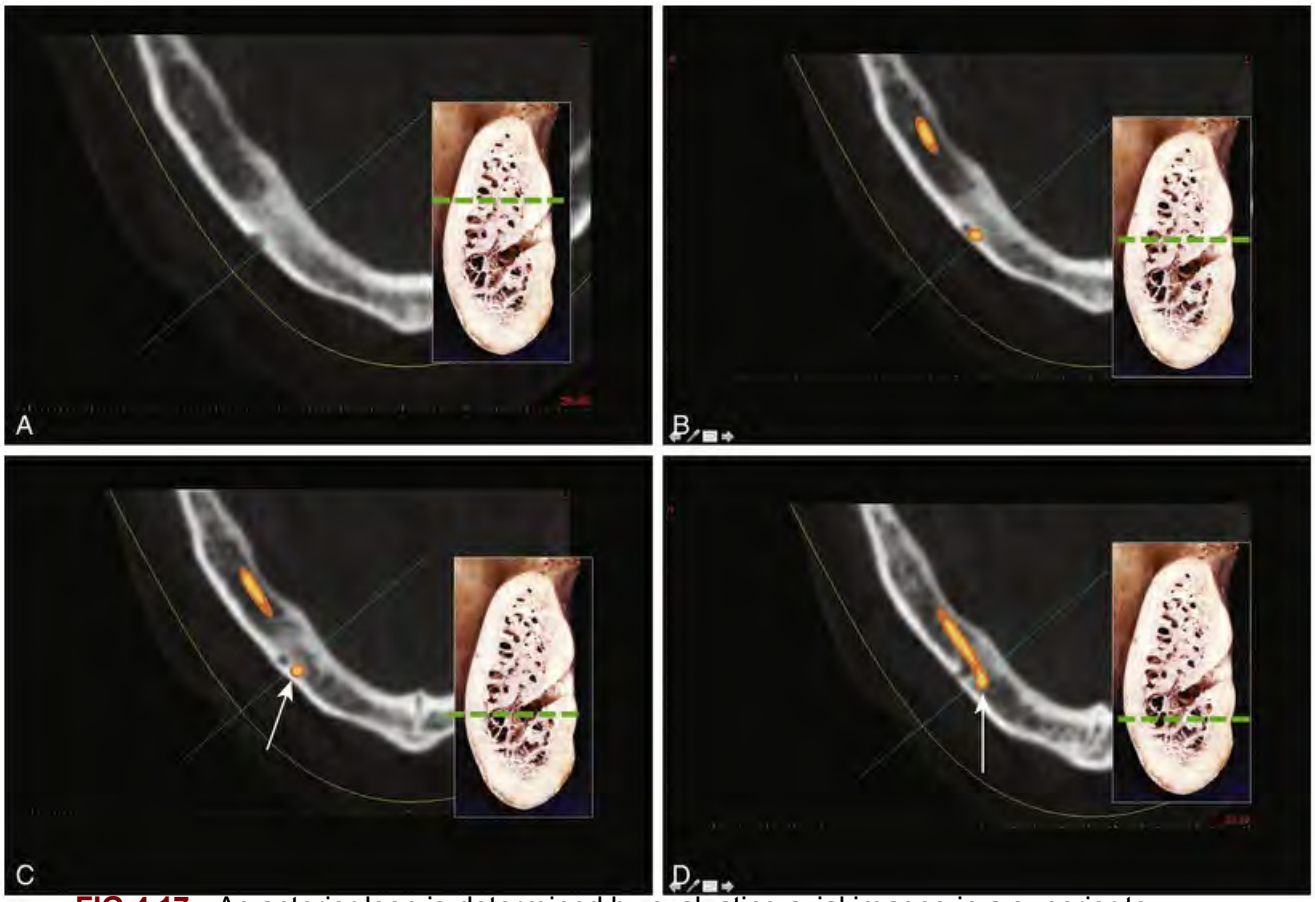

FIG 4.17 An anterior loop is determined by evaluating axial images in a superior to inferior direction. (A) The anterior aspect of the foramen should be marked (line that remains constant in the vertical plane). (B) As the axial images are sequentially evaluated from superior to inferior, if any part of the marked canal extends anterior to the line (C–D, *arrows*), a anterior loop exists.

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Clinical Significance.

Determining the presence of an anterior loop is critical when placing implants anterior to the mental foramen. Inability to establish the existence of an anterior loop may result in implant placement too close to the mental nerve, resulting in possible neurosensory impairment and related complications.

Accessory Foramens

In approximately 6.6% to 12.4 % of patients, an accessory (double) foramen is present with an average diameter of 1.0 mm.[33-35] Special care should be noted to evaluate for an accessory canal because it may contain components of one of the three branches of the mental nerve. Accessory foramens are believed to be the result of early branching of the inferior alveolar nerve, prior to exiting the mental foramen during the 12th week of gestation.[36]

Radiographic Evaluation.

The ideal technique to determine an accessory foramen is evaluation of coronal images along with evaluation of the 3-D image. In the coronal image, the mandibular foramen will be shown bifurcating into two canals, resulting in the presence of two foramina. The evaluation of 3-D images will easily depict two canals. Normally, accessory canals are located superior and distal to the mental foramen (Fig. 4.18).

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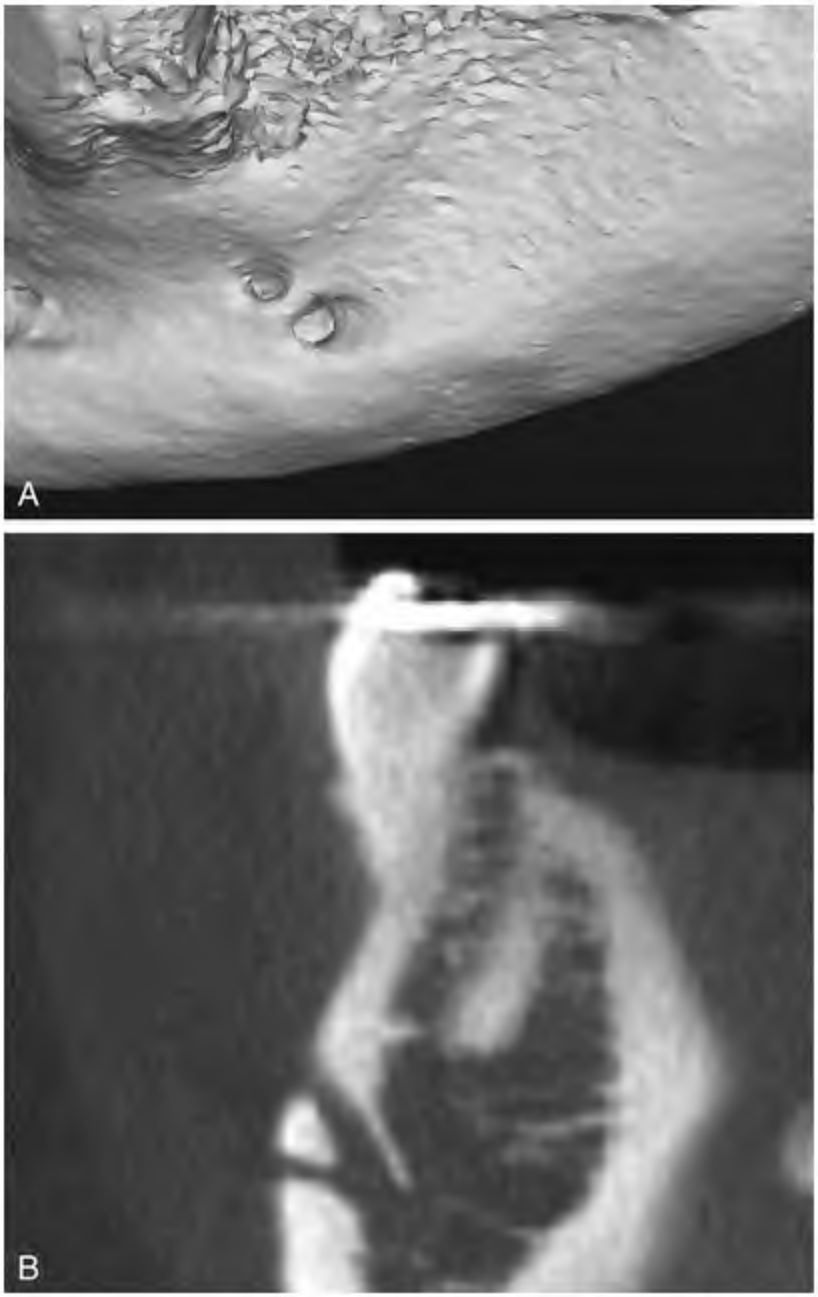

FIG 4.18 Accessory (double) foramina can be evaluated on (A) 3-D images or (B) coronal images.

Clinical Significance.

In the majority of patients, small accessory foramina usually contain a small branch of the mental nerve, which is not problematic because of cross innervation. However, in some cases, a larger branch of the mental nerve (equal or larger size foramen) may exit the mental foramen. If a larger accessory foramen is present and resultant damage to the nerve exists, possible neurosensory impairment is possible. The larger accessory foramens

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are sometimes termed “double foramens.”

Lingual Concavities (Anterior/Posterior)

The trajectory/angulation of the mandible along with inherent undercuts pose a significant problem to the implant clinician. Lingual concavities may occur in the anterior region as an hourglass or constriction of the mandibular bone. Butera has shown the incidence to be approximately 4% of patients, which is most likely genetic or developmental in origin.[37] In the posterior region, concavities are much more common, resulting in undercuts in approximately 35% of patients.[38] Because of these undercuts, implant placement may be difficult and perforation of the lingual plate may result.

Anterior

Radiographic evaluation.

Anterior undercuts are most easily seen in cross-sectional and 3-D images (Fig. 4.19A).

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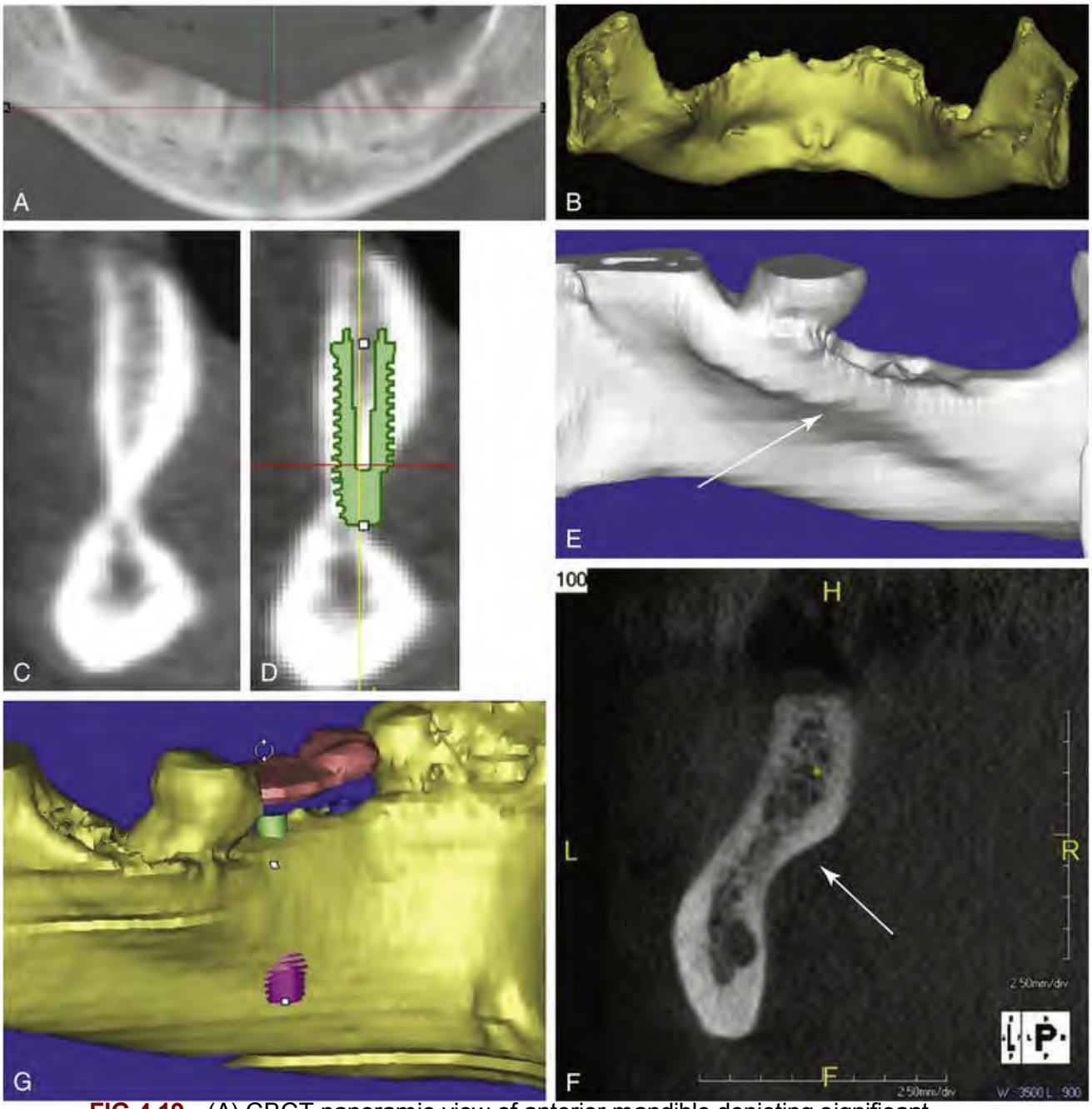

FIG 4.19 (A) CBCT panoramic view of anterior mandible depicting significant quantity of bone; (B–C) however, when viewed three-dimensionally, resultant hourglass concavities present in the anterior mandible; (D) complication of sublingual perforation which may lead to bleeding complications. (E) 3-D images depicting sublingual undercut; (F) cross section depicting significant undercut; and (G) complication of sublingual perforation.

Clinical significance.

In the anterior region, perforation of the bony plates of the mandible during implant osteotomies may lead to extensive bleeding from sublingual vessels. A significant plexus of sublingual and submental arteries may lead to life-

threatening floor-of-the-mouth hematoma formation. Therefore, a thorough CBCT examination will, with interactive treatment planning, determine the exact location and angulation for safe implant placement.

Posterior

Radiographic evaluation.

Posterior undercuts are most easily seen in cross-sectional and 3-D images.

Clinical significance.

In the posterior region, overestimation of available bone is a common complication. If an implant osteotomy is completed in this area, perforation of the lingual plate may result, leading to possible bleeding and possible implant morbidity. Life-threatening lingual bleeding may occur as a result of blood vessel injury leading to bleeding into the soft tissues. Additionally, damage to the lingual nerve may occur upon perforation of the lingual cortical plate. Case reports have been published revealing loss of the implant body into the sublingual space when large undercuts are present (see Fig. 4.19B).

Hypomineralization of the Mandibular Canal

Studies have shown in 20.8% of CBCT scans the mandibular canal walls are hypomineralized.[39] This often results in poor localization of the mandibular canal and is sometimes an early indication of osteopenia or osteoporosis. A thin cortical outline, poorly defined internal bony trabecular pattern, and variable density within the cortical layer are potential indications of osteoporosis/osteopenia. In 30% of cases, no superior cortical plate is present, which complicates the identification of the true location (see Fig. 4.14 C–D).

Radiographic Evaluation.

The brightness and contrast may be altered using imaging software to more clearly define the canal walls. Ideally, the mandibular canal may be seen easiest in the panoramic or cross-sectional images.

Clinical Significance.

Lack of identification of the MC may result in placement of implants too

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close to the nerve resulting in possible nerve damage. Additionally, when hypomineralization is present, usually the bone density throughout the mandible will be poor and compromised (~D4).

Incisive Canal

The mandibular incisive canal is a bony canal within the anterior mandible that is a continuation of the MC. This canal contains the terminal branch of inferior alveolar nerve, which travels inferiorly to the mandibular anterior teeth and terminates in the midline. In approximately the first molar region, the inferior alveolar nerve bifurcates into the mental and incisive nerves. The mandibular incisive canal terminates as nerve endings within the anterior teeth or bone near the lateral incisor region and will extend only to the midline in 18% of patients, and in some cases will anastomosis with the contralateral side.[40]

Radiographic Evaluation.

The incisive canal is not always seen radiographically on CBCT. The incisive nerve may be differentiated from the mental nerve by determination of any canal that is anterior to the mental nerve/foramen exit. When present, this radiolucent canal will continue anteriorly from the mental foramen and can be seen as a bifurcation with branches in the superior direction (Fig. 4.20).

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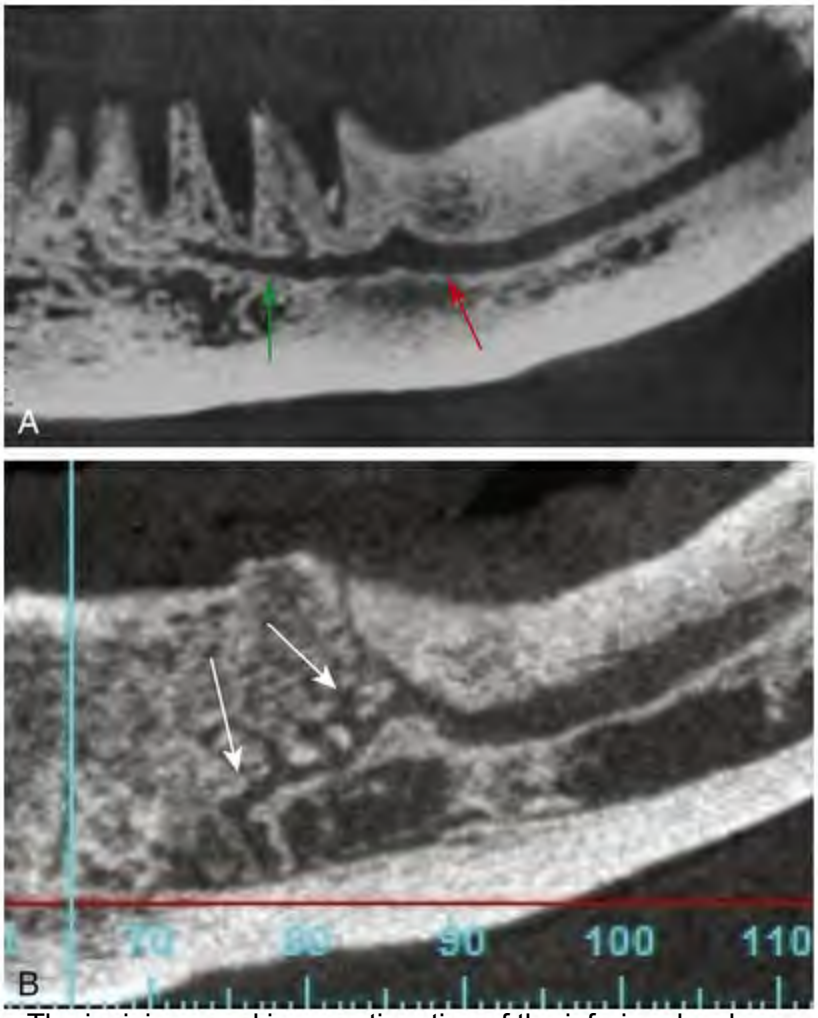

FIG 4.20 The incisive canal is a continuation of the inferior alveolar canal, which contains the incisive nerve, which innervates the mandibular anterior teeth (red shows the inferior alveolar canal; green shows the incisive canal). (A) CBCT image showing incisal canal extension from mandibular canal, and (B) CBCT panoramic image showing branching of incisive canal *(arrows)*.

Clinical Significance.

The incisive canal is often mistaken for an anterior loop of the mental nerve, but this nerve innervates the anterior teeth and has no sensory innervation to the soft tissue. However, if the incisive canal is traumatized, cases of excessive bleeding have been reported. Usually the canal and its branches will become necrotic after the teeth are extracted.

Retromolar Foramen

The retromolar fossa of the mandible forms a triangular depression that borders the temporal crest medially and the anterior border of the mandibular ramus laterally. Within this fossa, an anatomic variant termed the

retromolar foramen (RMF) is present in approximately 14% of patients.[41] The RMF on the alveolar surface is the terminal end to the retromolar canal, which branches from the mandibular canal.

Radiographic Evaluation.

RMFs are not located in a constant position and usually are not bilateral. Most commonly, RMFs should be initially evaluated via CBCT sagittal slices and then verified with cross-sectional images.

Clinical Significance.

It is important to confirm the RMF and canal locations prior to surgical procedures because this area is a common donor site for bone grafts. If perforation of the retromolar canal results, excessive bleeding may result.

Lingual Foramen/Canal

The interforaminal region in the anterior mandible is usually a relatively safe area for implant placement and bone grafting procedures. However, on the lingual aspect of the mandible, in the midline, lies the lingual foramen or foramina. This anatomic structure houses the terminal branches of the lingual artery (sublingual artery), facial artery (submental artery), or the anastomosis of both. As the blood vessels enter within the mandible, they are termed the *mandibular median vascular canal*.

Radiographic Evaluation.

Lingual canals and foramina may be seen radiographically as a radiolucent canal in the midline of the mandible and easily depicted on cross-sectional or axial views. Studies have verified the median vascular canal is present in 96% to 100% of patients. The median vascular canal size is proportional to the diameter of the arteries entering the foramen. The average diameter has been shown to be approximately 0.84 mm, with the average distance from the inferior mandibular border to be 11.2 mm. With consideration to the extent of penetration within the mandible, 19.4% of canals end within the lingual third, 52.8% reach the middle one third of the mandible, and 27.8 % penetrate to the buccal one third (Fig. 4.21).[42]

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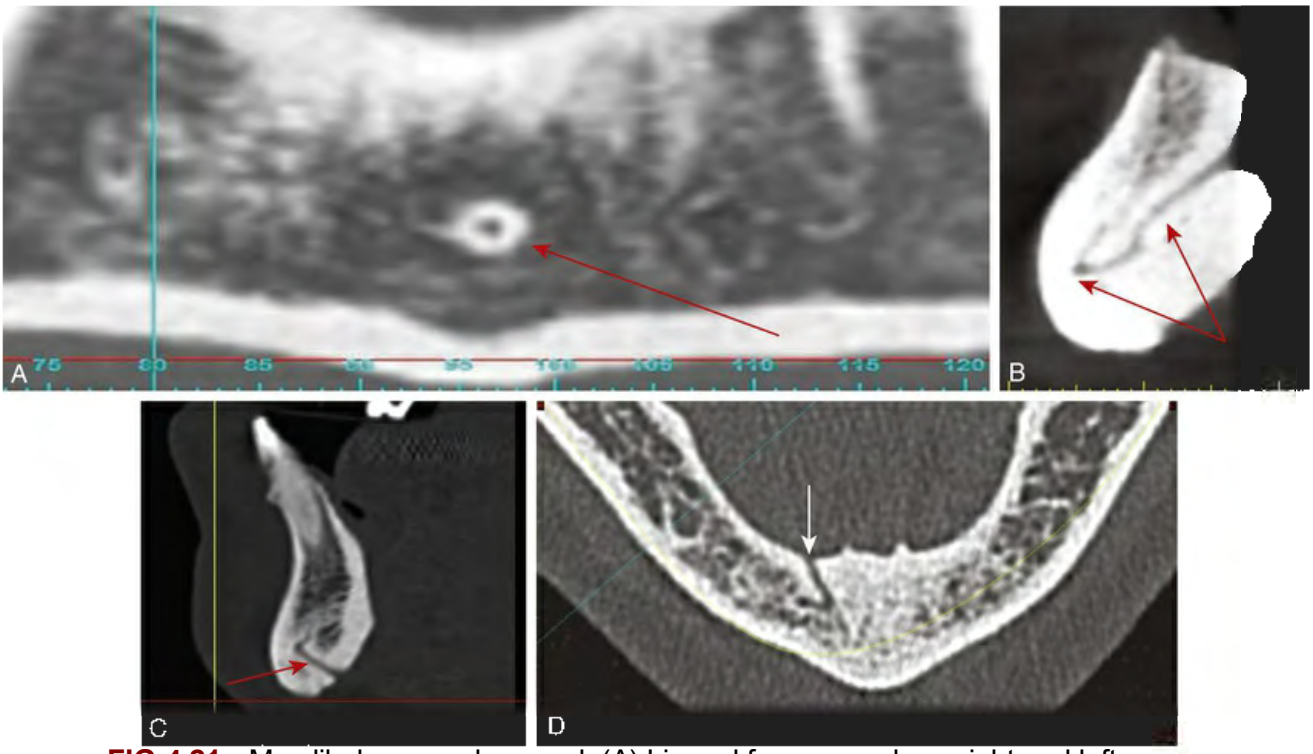

FIG 4.21 Mandibular vascular canal. (A) Lingual foramen, where right and left sublingual arteries enter the mandible *(arrow)*; (B–C) mandibular vascular canal that contains the sublingual artery anastomosis; and (D) off midline lingual vascular canal *(arrow)*.

Clinical Significance.

Potentially, these vessels may cause extensive bleeding in the mandible during endosseous implant placement or symphysial bone grafts. When larger lingual canals exist (>1.0 mm), significant bleeding issues may present with a possible compromised integration because of a potential soft tissue interface with the implant. Usually bleeding may be slowed or stopped by inserting a surgical drill, direction indicator, or implant into the osteotomy site.

Calcified Carotid Artery Atheroma

Calcified carotid artery atheromas are calcifications found in the common carotid usually located near the bifurcation of the internal and external carotid arteries. These calcifications give radiographic evidence of atherosclerosis, which is an indicator of possible stroke or metabolic disease. It has been shown that approximately 80% of strokes are ischemic and due to atherosclerotic disease in the carotid bifurcation.[43]

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Radiographic Evaluation.

Carotid artery calcifications are small, multiple radiopacities in the carotid space anterior and lateral to cervical vertebrae C3-C4. These multiple and irregularly shaped calcifications may be vertical in orientation and are usually easily distinguished from the adjacent soft tissue. They can be easily seen on axial and 3-D images (Fig. 4.22 A–B). An additional common site to evaluate for carotid artery calcifications in large-volume CBCT images is lateral to the pituitary fossa.

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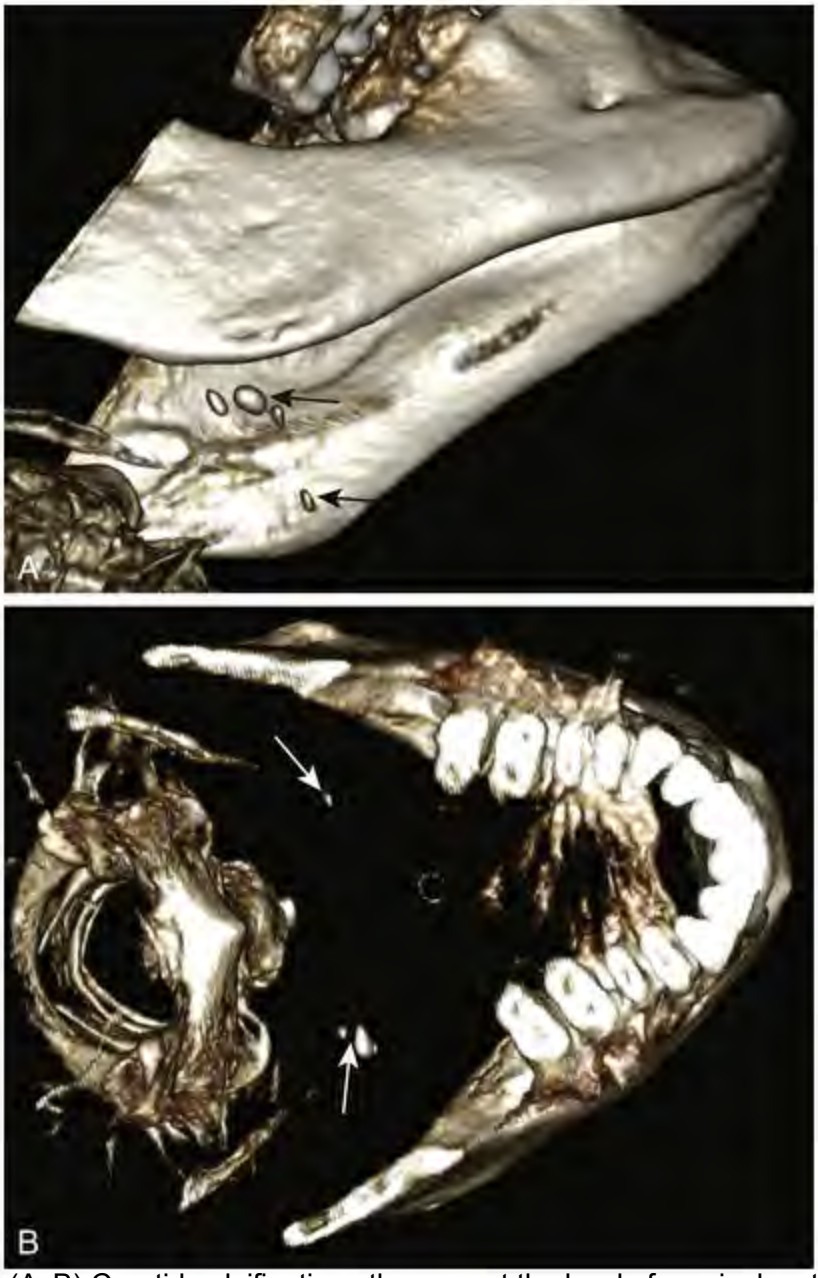

FIG 4.22 (A–B) Carotid calcification atheroma at the level of cervical vertebrae C3-C4 *(arrows)*.

Clinical Significance.

Because of the significant complications that may arise from the presence of carotid calcifications (ischemic cerebrovascular disease is the second leading cause of death in most developed countries), the patient should be referred to their physician for assessment of carotid artery stenosis and possible ultrasound evaluation.

Maxillary Anatomy

The maxilla is composed of paired bones (right and left) that unite to form the upper jaw and is composed of four processes: posterolateral (zygomatic, horizontal, and medial); palatine, arch and inferior; alveolar; and the superior projecting frontal process. In oral implantology, the maxilla presents a difficult and demanding challenge in the treatment and placement of implants with its complex osseous makeup, anatomy, and anatomic variants.

Premaxilla

The anterior premaxilla is one of the most difficult areas for the implant clinician in preoperative assessment, surgical placement, and esthetic and prosthodontic demands. Numerous factors affect the anatomic makeup of the premaxilla that may predispose to surgical complications and result in a decrease in implant survival.

Radiographic Evaluation.

The premaxilla is a difficult and complex region of the oral cavity to evaluate clinically and radiographically. Many factors complicate this area, such as the trajectory of the anterior maxilla, rapid buccal bone resorption after tooth loss, decreased bone density, and a highly esthetic demanding area. The premaxilla may be easily evaluated via cross-sectional, sagittally, and 3-D.

Clinical Significance.

As a result of the alveolar ridge resorption after tooth loss, the residual available bone migrates to a more palatal position.[44] This leads to difficulties in implant positioning that place the implant clinician at risk due to esthetic issues. Because bone resorption occurs at the result of the buccal plate, implant placement usually occurs in a more palatal position. This results in a greater moment force leverage on the bone-implant interface, abutment screws, and implants. Coupled with an angled force in both centric and excursions, more stress is transmitted to premaxillary implants than those in anterior mandibles. This often dictates more implants and larger-diameter implants with bone augmentation by bone-spreading or bone graft procedures before or in conjunction with implant placement.

In most patients, the bone is less dense in the anterior maxilla than in the anterior mandible. The maxilla most often presents thin porous bone on the labial aspect, very thin porous cortical bone on the floor of the nasal and

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sinus region, and a denser cortical bone on the palatal aspect.[45] The trabecular bone in the premaxilla is usually fine and less dense than the anterior region of the mandible. Due to this poor bone quality, increased difficulty in implant placement and a higher probability of overload implant failures or crestal bone loss may result.

Because of the poor bone quality in the premaxilla, preexisting bone after extractions is predisposed to significant resorption. After tooth loss, the facial cortical plate rapidly resorbs during initial bone remodeling, and the anterior ridge has been shown to lose up to 25% of its width within the first year, as well as 40% to 50% within the next 3 to 5 years, mostly at the expense of the labial contour (Fig. 4.23A–B). Therefore, it is imperative that when radiographically evaluating the premaxilla, a radiopaque template be utilized to ascertain the ideal implant position with respect to the teeth being replaced.

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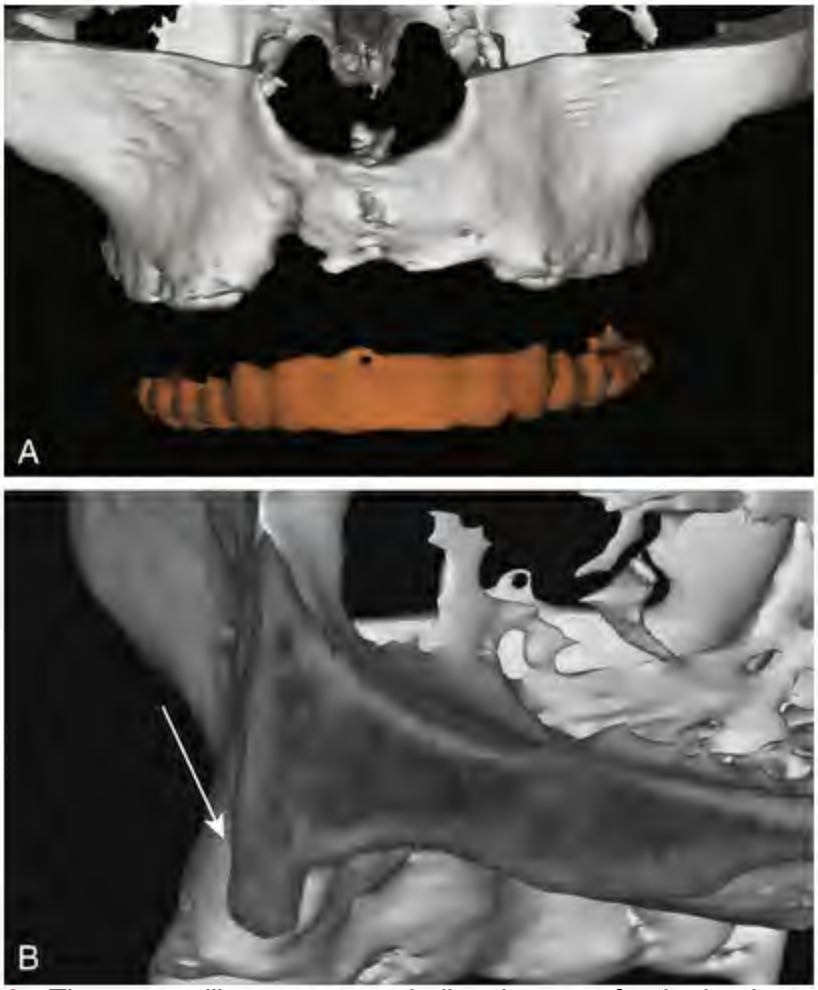

FIG 4.23 The premaxilla presents a challenging area for the implant clinician because of the (A) hard and soft tissue resorption and (B) advanced buccal plate resorption, which complicates implant placement because of compromised width and trajectory of bone *(arrow)*.

Nasopalatine Canal/Incisive Foramen

The nasopalatine canal (also termed the *incisive canal* or *anterior palatine canal*) is a passageway within the anterior maxilla midline that connects the palate to the floor of the nasal cavity. The entrance of the canal into the oral cavity is via the incisive foramen, which is posterior to the central incisor teeth. The vital structures passing through the canal include the terminal branch of the internal maxillary artery and the nasopalatine nerve, which communicates with the sphenopalatine artery and the greater palatine nerve. The anatomic structures (e.g., nerve artery, vein) in the nasopalatine canal may present with wide variation in the location, shape, and dimensions.

Radiographic Evaluation.

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The location and dimension of the nasopalatine canal is most likely seen on axial and coronal images. Cross-sectional and 3-D images may also depict the size, shape, and location of the nasopalatine canal along with evaluation of implant impingement on this space.

Clinical Significance.

Determining the morphology of the nasopalatine canal via CBCT images allows the clinician to ascertain if available bone is present for dental implantation. Placing implants in the anterior maxilla (central incisor area) is the most challenging anatomic location for the implant dentist because of biomechanical, functional, esthetic, and phonetic demands. Especially with immediate implant placement, consideration must be given to the presence of the nasopalatine canal, including a careful evaluation of its morphology and position to minimize implant placement complications.

The incisive foramen often expands laterally within the palatal bone, and the central incisor implant osteotomy may inadvertently encroach on this structure, resulting in the formation of fibrous tissue at the interface in the mesiopalatal region. If the osteotomy invades the incisive canal, treatment options include tissue removal within the canal with and bone graft and/or implant placement. When a large nasopalatine canal exists, a more distally placed implant in the central incisor region prevents encroachment on this area. Because most restorations in an edentulous premaxilla are FP-2 or FP-3, the most favorable sites for bone width are selected, even when they are in the interproximal region of central and lateral incisor sites.

When there exists an enlarged canal, the lack of available bone will most likely not permit ideal implant placement. However, it is important to differentiate enlarged canals from incisive canal cysts. Incisive canal cysts are known to cause localized dilation of the canals with possible displacement of the teeth. In edentulous patients, the nasopalatine canal has been shown to be significantly larger in comparison to that of dentate patients (Fig. 4.24).

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FIG 4.24 The nasopalatine canal area should be evaluated as to the size and location because implant placement in this area may predispose to placement within soft tissue. (A) Implant placement impinging on nasopalatine canal; (B) very large canal leading to minimal available bone *(arrow)*.

When implants are positioned in contact with neural tissue, lack of osseointegration and failure of the implant may result. Additionally, placement of implants in close approximation to nasopalatine blood vessels may cause excessive bleeding during surgical procedures; however, such bleeding episodes are usually self-limiting and controlled by local hemostatic techniques.

Infraorbital Foramen

The infraorbital foramen (IOF) is located in the anterior aspect of the maxillary bone below the infraorbital margin (IOM) of the orbit. The

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infraorbital artery, vein, and nerve exit the foramen. On average, the IOF-IOM distance is approximately 6.1 to 10.9 mm.[46]

Radiographic Evaluation.

The infraorbital foramen is easily seen on coronal images along with 3-D reformatted images.

Clinical Significance.

Anatomic variants have been reported to be as far as 14 mm from the orbital rim in some individuals. In the severely atrophic maxilla, the infraorbital neurovascular structures exiting the foramen may be close to the intraoral residual ridge and should be avoided when performing sinus graft procedures to minimize possible nerve impairment. This is of particular concern on soft tissue reflection and the bone preparation of the superior aspect of the window. Because the infraorbital nerve is responsible for sensory innervations to the skin of the upper cheek, mucosa of the maxillary sinus, maxillary incisors, canines, and premolars, as well as of the gingiva, skin, and conjunctiva of the eyelid, lateral nose, and mucosa of the upper lip, damage to this nerve may cause significant discomfort to the patient. Most often, the nerve is not severed, and a neurotmesis presents that usually resolves within 1 month after the surgery (Fig. 4.25 A–B).

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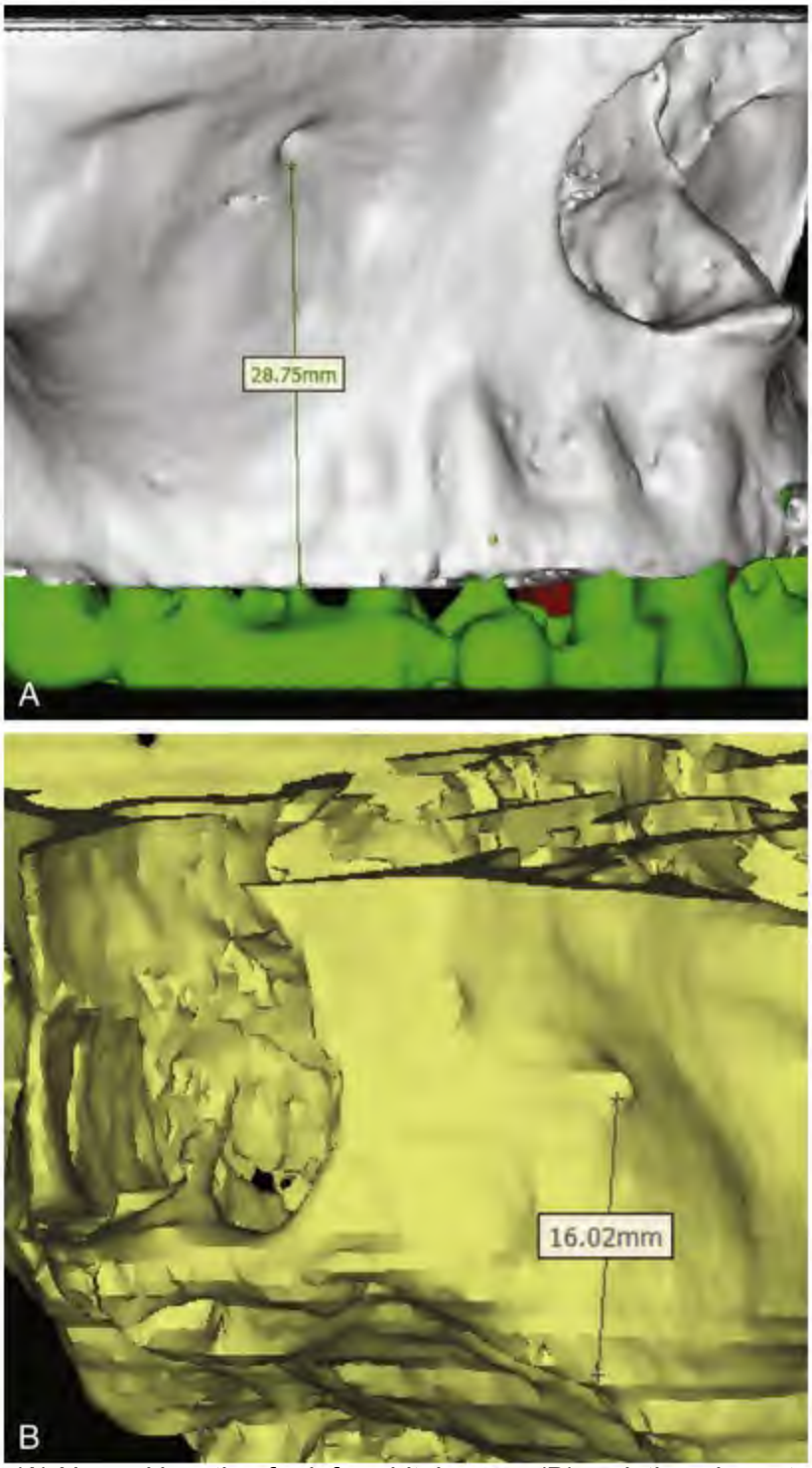

FIG 4.25 (A) Normal location for infraorbital nerve; (B) variation closer to ridge that may result in neurosensory impairment from retraction or possible transection upon reflection of the tissue.

Paranasal Sinuses

Frontal.

The frontal sinuses are bilateral and funnel-shaped and located on each side of the midline superior to the orbital bones. The borders of the frontal sinus are: inferior (orbital portion of the frontal bone), posterior (separates the dura of the frontal lobe from the lining mucosa), and posterior (separates the dura of the frontal lobe from the lining mucosa). The frontal sinuses extend to the middle meatus and drain through the nasofrontal duct and into the frontal recess. The frontal ostia are located approximately two-thirds high on the posterior medial wall, which anatomically complicates clearing of the sinus after infection.[47] The frontal recess, which is the drainage pathway of the frontal sinus, drains into the middle meatus or ethmoid infundibulum. On coronal CBCT images the frontal recess is superior and medial to agger nasi cells.

Ethmoid.

The ethmoid sinuses are within the ethmoid bone and are divided into two compartments, the anterior and posterior. The anterior ethmoid sinus drains into the middle meatus, and the posterior ethmoids drain into the sphenoethmoidal recess. The borders of the ethmoid sinuses include: anterior ethmoid (lateral): lamina papyracea of the orbit (medial); middle turbinate (superior): fovea ethmoidalis (cribriform plate); posterior ethmoid (lateral): lamina papyracea of the orbit (medial); superior turbinate (superior); fovea ethmoidalis (cribriform plate). The ethmoid sinuses have various radiographic anatomic markers that are termed *air cells*. The ethmoid bulla are the largest and most prominent radiographically in the anterior region. *Agger nasi cells* are usually the most anterior of the anterior air cells and are located in anterior/superior to the middle turbinate. Along the inferior border of the orbits are the *Haller cells,* which may impair mucociliary clearance when they enlarge and impinge of the ethmoid infundibulum. The *Onodi cells* derive from the posterior ethmoid and are located lateral and superior to the sphenoid sinus.[48]

Sphenoid.

The sphenoid sinus, located within the sphenoid bone, contains superiorly the pituitary fossa and olfactory nerves. Inferiorly, the pterygoid canal courses beneath the mucosa with the cavernous portion of the internal carotid artery within the lateral wall. The ostium lies in the superior aspect and drains into the sphenoethmoidal recess.[49]

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Maxillary.

The maxillary sinuses are the largest of the paired paranasal sinuses and an often problematic area for implant clinicians. The posterior maxilla has many inherent disadvantages including poor bone density, minimal interocclusal space, and insufficient bone quantity for ideal implant placement. Thus, the implant clinician must have a comprehensive knowledge of normal vs. abnormal anatomy in association with the maxillary sinus and paranasal sinus anatomy. The maxillary sinus has a high prevalence of anatomic variants and pathology, which predispose the patient to increased morbidity during procedures in the posterior maxilla. Thus, a comprehensive knowledge and understanding of this area is important for implant clinicians. Radiographically, the maxilla sinus has the following borders: Superiorly, the maxillary sinus is bordered by the orbital floor, which houses the infraorbital canal. Inferiorly, the floor of the maxillary sinus approximates the roots of the maxillary teeth. The medial wall coincides with the lateral wall of the nasal cavity and is the location of the maxillary ostium, the area of drainage of the ethmoid infundibulum (Fig. 4.26).

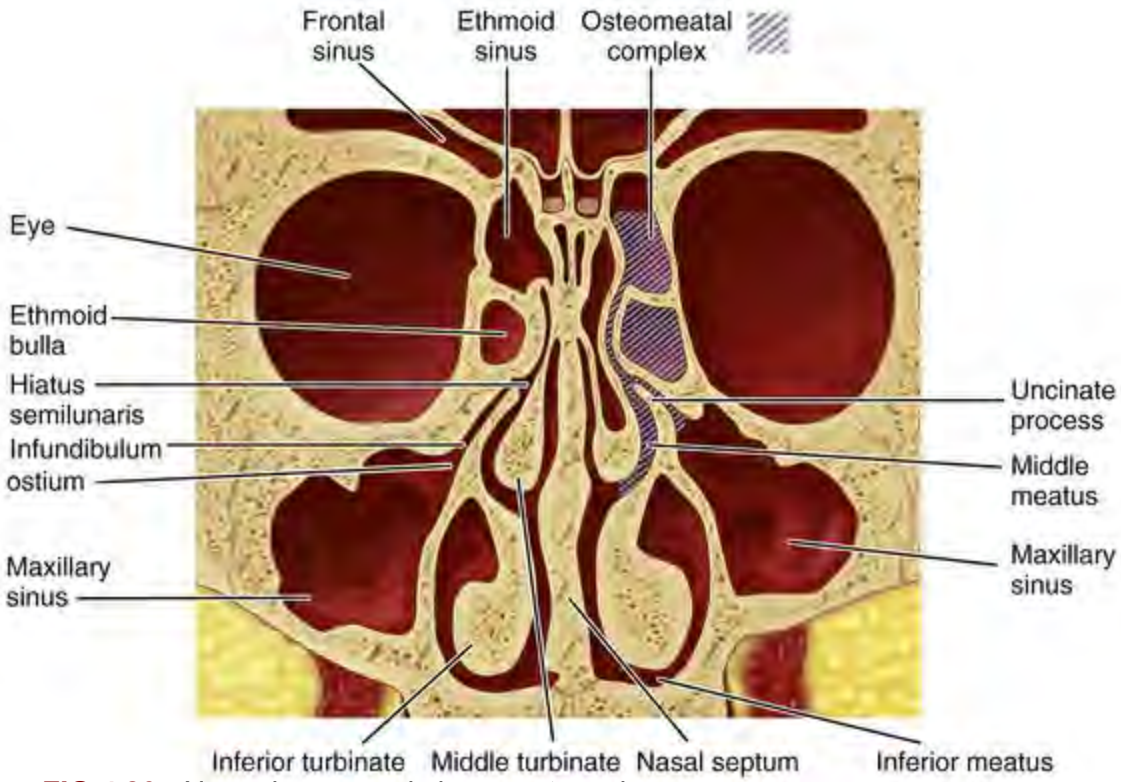

FIG 4.26 Normal paranasal sinus anatomy images. (From Misch CE: *Contemporary implant dentistry*, ed 3, St. Louis, 2008, Mosby.)

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Nasal Cavity

The borders of the nasal cavity are: hard palate (inferior); medial walls of the right and left maxillary sinus (lateral); nasal, ethmoid, and sphenoid bones (superior); and nasal septum (medial). The lateral walls of the nasal cavity are made up of turbinates (concha), which are epithelium-lined bony structures that protrude into the nasal cavity and function to warm, cool, and filter inspired air. Below each turbinate are spaces termed *meatuses*. The middle meatus is most important because this is the area of drainage for the frontal, anterior ethmoid, and maxillary sinuses. The inferior meatus is the drainage site for the nasolacrimal duct. The superior meatus interconnects with the posterior ethmoid and sphenoid sinuses through the sphenoethmoidal recess.[50]

Maxillary Sinus Membrane

The maxillary sinus is lined by the Schneiderian membrane, which is identical to respiratory epithelium. This pseudostratified columnar epithelium is continuous with the nasal epithelium through the maxillary ostium in the middle meatus. The membrane has an average thickness of 0.8 mm and is usually thinner and less vascular than nasal epithelium.[51]

Radiographic Evaluation.

A CBCT scan of normal, healthy paranasal sinuses reveals a completely radiolucent (dark) maxillary sinus. Any radiopaque (whitish) area within the sinus cavity is abnormal, and a pathologic condition should be suspected. The normal sinus membrane is radiographically invisible, whereas any inflammation or thickening of this structure will be radiopaque. The density of the diseased tissue or fluid accumulation will be proportional to varying degrees of gray values (Fig. 4.27).

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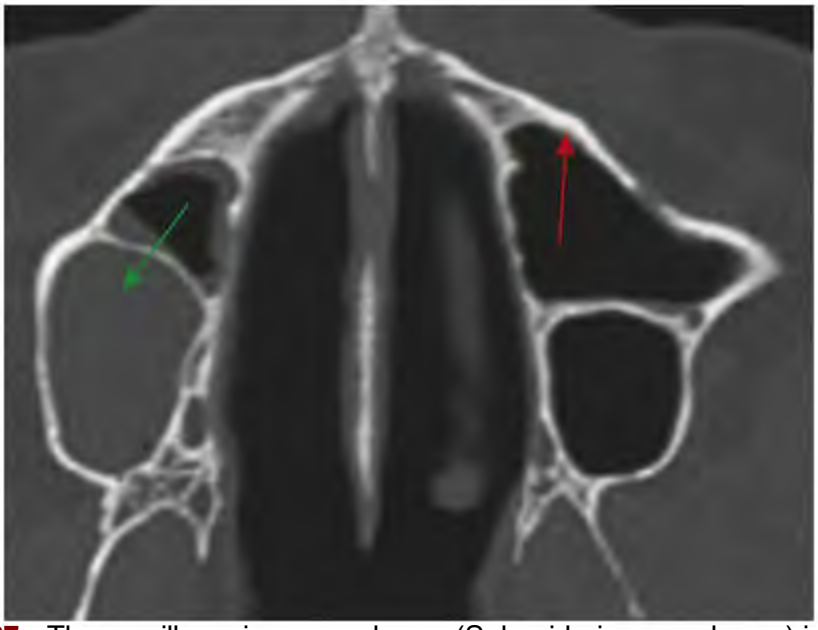

FIG 4.27 The maxillary sinus membrane (Schneiderian membrane) in health should be invisible *(red arrow)*. When inflammation or pathology is present, it will be depicted as an increase in density/radiopacity or a visible increase in thickness *(green arrow)*.

Clinical Significance.

Ideally, when evaluating the maxillary sinus, it should be completely radiolucent. If any radiopaque areas are present, this is most likely the result of a disease process (e.g., inflammation, cystic, polyps). Therefore, if implant placement into the maxillary sinus is planned, the degree of radiopacity is significant to the long-term success and morbidity. In some cases, treatment may be indicated prior to entry (i.e., implant placement or bone grafting) into the maxillary sinus.

Ostiomeatal Complex

The ostiomeatal unit is composed of the maxillary ostium, ethmoid infundibulum, anterior ethmoid cells, uncinate process, and the frontal recess. This anatomic area allows air flow and mucociliary drainage into the middle meatus.

Radiographic Evaluation.

The osteomeatal complex can be evaluated radiographically most easily on a coronal scan, which includes the following structures:

1. Maxillary sinus ostium

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2. Infundibulum

3. Ethmoid bulla

4. Uncinate process

5. Hiatus semilunaris

Maxillary Ostium.

The main drainage avenue of the maxillary sinus is through the ostium. The maxillary ostium is bounded superiorly by the ethmoid sinuses and inferiorly by the uncinate process. The maxillary sinus ostium is on the superior aspect of the medial wall of the sinus, approximately half-way between the anterior and posterior walls. The ostium is usually oval shaped and oriented horizontally or obliquely.[52]

Radiographic evaluation.

The maxillary ostia are visualized on coronal images, usually in the anterior one third of the maxillary sinus. This opening is located in the superior aspect of the maxillary sinus medial (lateral wall of nasal cavity). The patency of the maxillary ostium should always be ascertained when placing implants or bone grafts into the maxillary sinus. By scrolling through various coronal images, the opening can be verified (Fig. 4.28).

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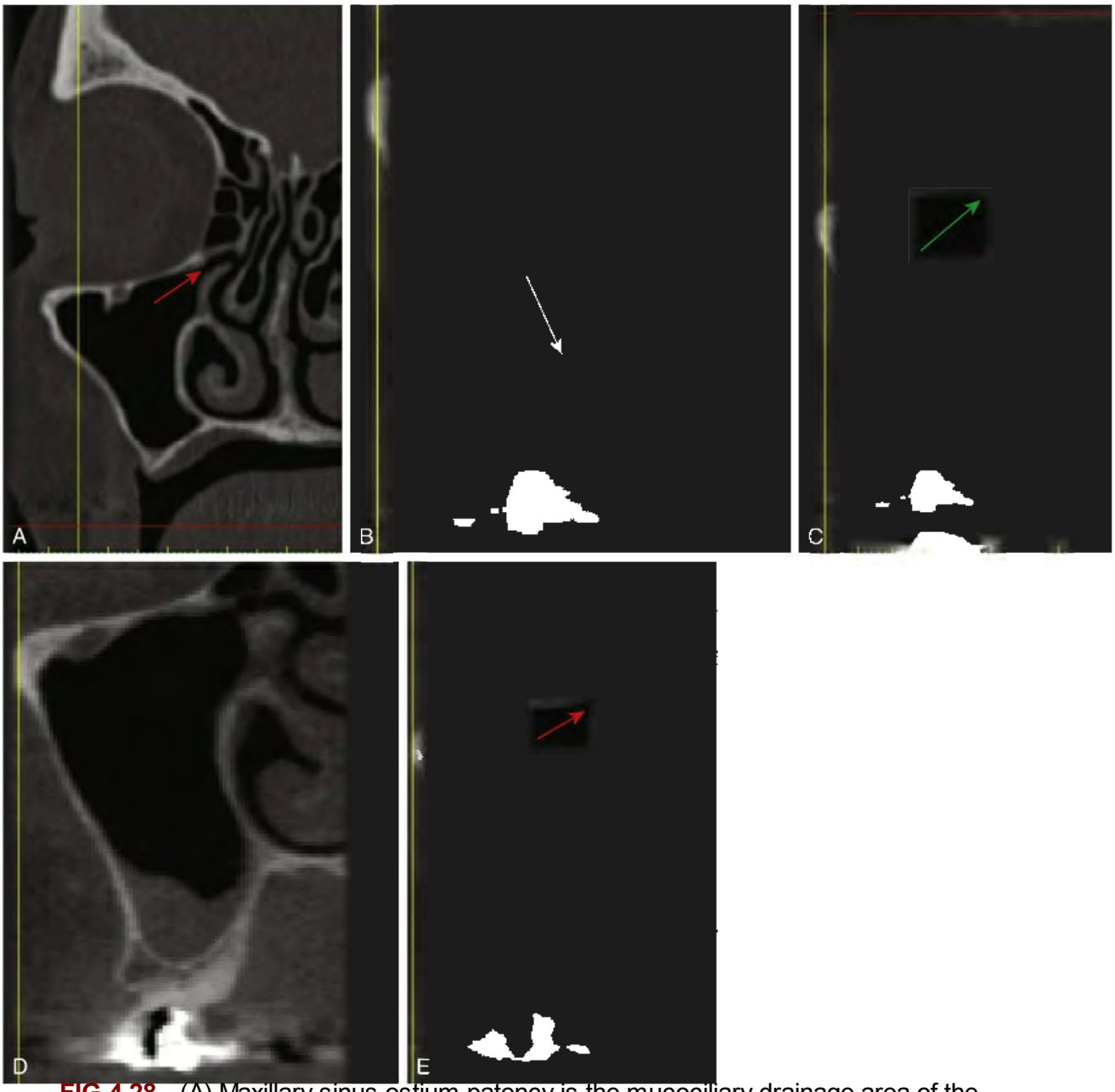

FIG 4.28 (A) Maxillary sinus ostium patency is the mucociliary drainage area of the maxillary sinus; (B) nonpatent ostium; (C) suspected nonpatent ostium; (D–E) scrolling through cross section depicts patency of ostium. *Red arrows*, patent ostium; *white arrow*, membrane inflammation; *green arrow*, nonpatency.

Clinical significance.

If the maxillary ostium is nonpatent, the mucociliary clearance of the maxillary sinus may be affected. This can lead to an increased morbidity in implant-related procedures.

Infundibulum/Hiatus Semilunaris.

Vital structures within the osteomeatal complex that allow for mucociliary drainage of the sinuses are the maxillary infundibulum and the hiatus semilunaris. Drainage through the maxillary ostium enters the maxillary infundibulum, which is a pathway that leads to the hiatus semilunaris. The hiatus semilunaris is a crescent-shaped space or opening in the lateral wall of the nasal cavity, which is inferior to the ethmoid bulla that is the location for the openings of the frontal sinus, maxillary sinus, and anterior ethmoid sinus. These sinuses drain through this area into the middle meatus.

Radiographic interpretation.

The maxillary infundibulum and hiatus semilunaris are easily seen on coronal sections of the patient's maxillary anatomy. These crucial areas of the maxillary osteomeatal complex is bounded anteriorly and inferiorly by the uncinate process of the ethmoid bone, superiorly by the ethmoid bulla, and posterior by the inferior nasal concha.

Clinical significance.

Any blockage of the infundibulum or hiatus semilunaris will lead to inflammation, congestion, or infection in the maxillary, ethmoid, or frontal sinuses. Therefore, prior to any procedures that may violate the maxillary sinus (e.g., implant, bone graft), the patency of infundibulum and hiatus semilunaris must be verified to decrease the possibility of postoperative complications.

Uncinate Process.

The uncinate process is an important structure in the lateral wall of the nasal cavity. This finger-like bony projection helps form the boundaries of the hiatus semilunaris and ethmoid bulla, which allow the draining of the frontal and maxillary sinuses.

Radiographic evaluation.

On coronal or cross-sectional CBCT images the uncinate process is bordered by the medial wall of the maxillary sinus and articulates with the ethmoid process and inferior nasal turbinate. Inferiorly, it borders the semilunar hiatus and posteriorly it has a free margin.

Clinical significance.

A deflected uncinate process (either laterally or medially) can narrow the

ethmoid infundibulum, thus affecting the osteomeatal complex. Perforations may also be present within the uncinate process, leading to communication between the nasal cavity and ethmoid infundibulum. In addition, the uncinate process may be pneumatized. Although this is rare, it may compromise adequate sinus clearance. Uncinate process variations should be evaluated and treated prior to any procedure in which the physiology of the maxillary sinus is altered (implant placement or bone grafting).

Ethmoid Bulla: the ethmoid bulla is the largest and most prominent ethmoid air cell. The ethmoid bulla is caused by bulging of the middle ethmoidal cells and may be a pneumatised cell or a bony prominence.

Radiographic Interpretation: The ethmoid bulla are usually evaluated on coronal images. These air cells are part of the anterior ethmoid sinuses and make up the superior border of the hiatus semilunaris and maxillary infundibulum and laterally bounded by the lamina papyracea.

Clinical Significance. The degree of pneumatization within the ethmoid bulla varies. When enlarged, the bulla may encroach upon the uncinate process and middle turbinate, resulting in nonpatency of the osteomeatal complex. The patency of this area should be verified prior to any procedures involving the maxillary sinus.

Anatomic Variants of the Maxillary Anatomy

Concha Bullosa

The middle turbinate plays a significant role in proper drainage of the maxillary sinus. Normally, the middle turbinate is a thin, boney structure; however, it can be aerated, in which case it is termed a *concha bullosa*. This anatomic variant can be unilateral or bilateral and has been shown to have a prevalence of up to 53.6% of the population.[53] Additionally, there is a strong association with the concha bullosa and a deviated septum of the contralateral side.[54]

Radiographic Evaluation.

Concha bullosa are easily identified on a CT/CBCT coronal image as a radiolucent air space in the center of the middle meatus and surrounded by an ovoid bony rim.

Clinical Significance.

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In most cases of concha bullosa, no paranasal sinus pathology results. The larger the concha bullosa, the more likely the probability of compromising the drainage of the middle meatus. When enlarged, pressure against the uncinate process may occur, decreasing the infundibulum drainage, and thus affecting the physiology of the maxillary sinus leading to increased drainage problems. Caution must be exercised because concha bullosa patients are more predisposed to postoperative complications from bone grafting and implants in the sinus area (Fig. 4.29).

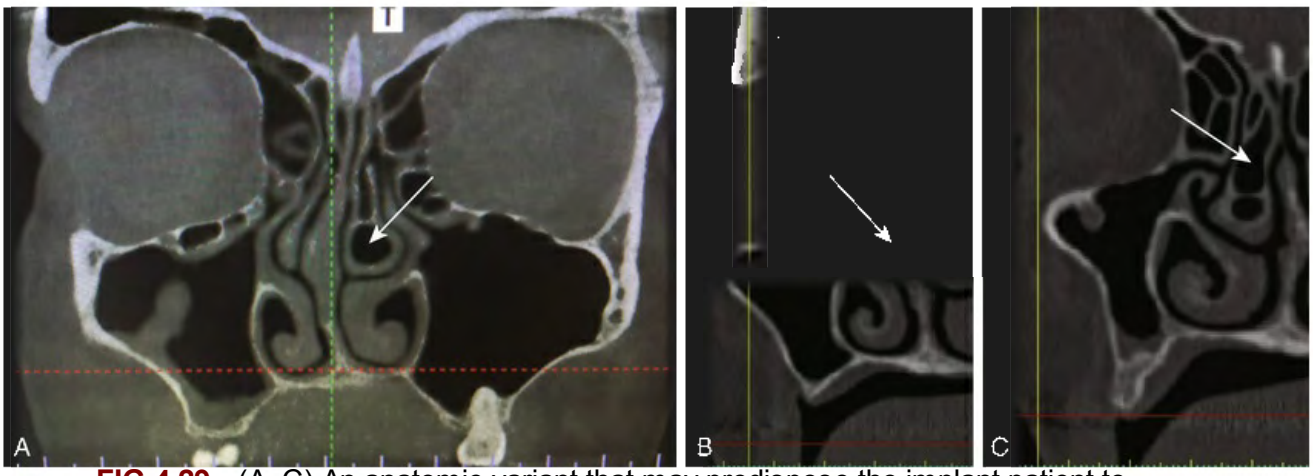

FIG 4.29 (A–C) An anatomic variant that may predispose the implant patient to postoperative mucociliary impairment is a concha bullosa *(arrows)*, which is an aerated middle turbinate.

Paradoxical Middle Turbinate

A paradoxical middle turbinate is an anatomic variant of the middle turbinate with a prevalence of approximately 15% of the population.[55] This anatomic variant is a reversal of the normal medially directed convexity of the middle turbinate (middle turbinate convexity is towards the lateral instead of medial). The inferior edge of the middle turbinate may have various shapes exhibiting excessive curvature that may predispose the patient to blockage in the nasal cavity, infundibulum, and middle meatus.[56]

Radiographic Evaluation.

A paradoxical middle turbinate is most easily seen on a coronal CT/CBCT scan image. It may also be seen in certain cross-sectional images. The convexity of the paradoxical middle turbinate is directed laterally, instead of

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medially toward the nasal septum.

Clinical Significance.

When a paradoxical middle turbinate is present, the implant clinician must take into consideration the possibility of postoperative mucociliary complications after bone grafting or implant placement in the maxillary sinus from blockage of the ostium (Fig. 4.30).

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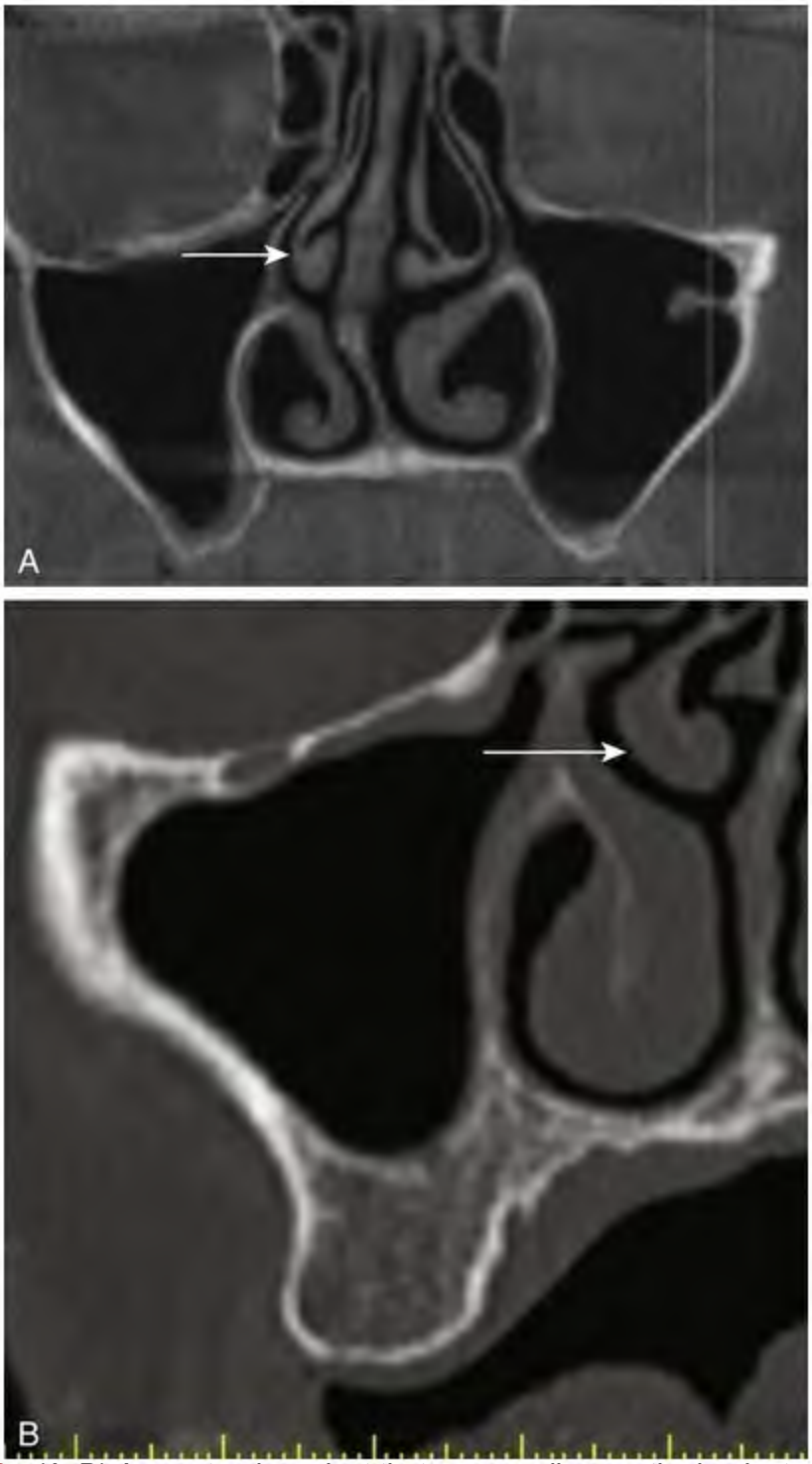

FIG 4.30 (A–B) An anatomic variant that may predispose the implant patient to postoperative mucociliary impairments is a paradoxical middle turbinate. The convex side of the middle turbinate is directed laterally, instead of medially. Note the concha bullosa on the left side *(arrows)*.

Deviated Septum

One of the most common anatomic variants in the oral region is a deviated

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septum, which may be congenital or traumatic in origin. Studies have shown a prevalence of 70%, which increases the possibility of osteomeatal complex blockage. This occurs when the nasal septum is displaced laterally towards one side of the nasal cavity. When the deviation is severe, the flow of air through the nasal cavity is redirected and may cause nasal obstruction, hypoplasia of the ipsilateral turbinates, or hyperplasia of the contralateral turbinates.

Radiographic Evaluation.

A deviated septum can be seen most easily via the coronal and axial image scans. Additionally, a 3-D image of the midline structure will allow direct evaluation. The nasal septum will be displaced toward one side of the nasal cavity (Fig. 4.31).

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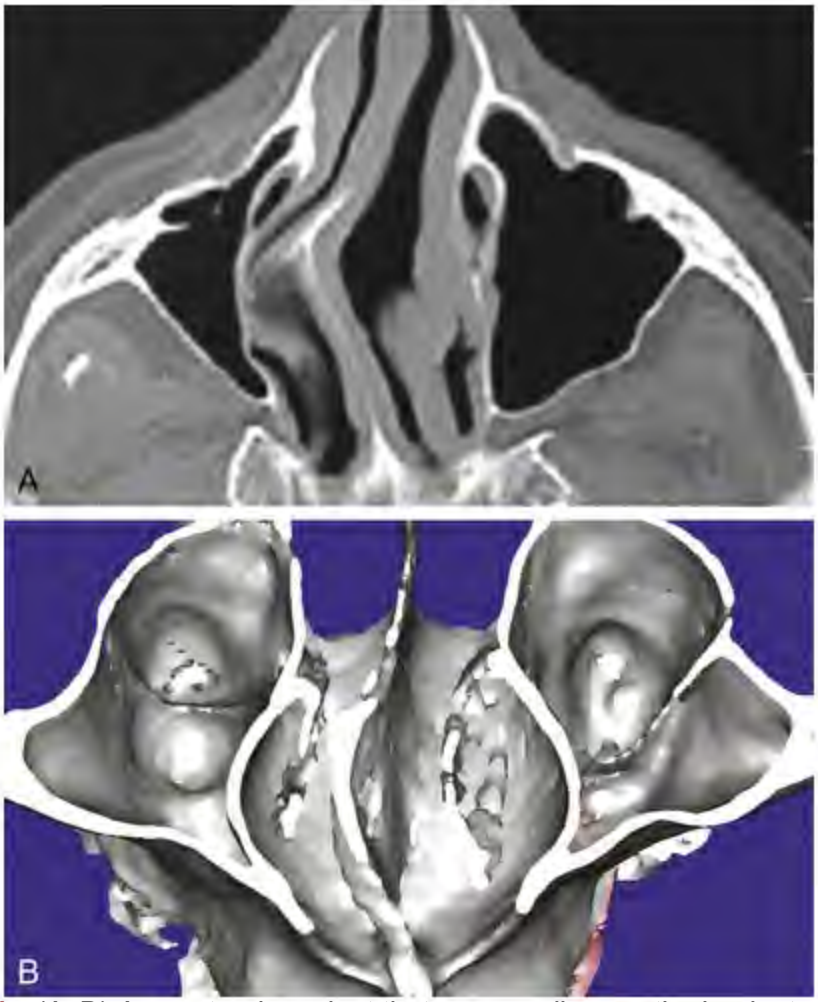

FIG 4.31 (A–B) An anatomic variant that may predispose the implant patient to postoperative mucociliary impairments is a deviated septum. The side of deviation may cause blockage of the maxillary ostium.

Clinical Significance.

When the deviation is severe, the air flow through the nasal cavity is compromised, manifesting as nasal congestion. Patients with deviated septa are predisposed to sinus clearance issues, which increase morbidity of bone grafting and implant placement procedures in the maxillary posterior area on the side of deviation. Usually, the contralateral side will have normal mucociliary clearance.

Haller Cells

Haller cells are infraorbital ethmoidal air cells that project from the maxillary sinus roof and the most inferior portion of the lamina papyracea. They are usually present unilaterally with a prevalence of approximately 6% of the population.[57] The origin of Haller cells is the anterior ethmoid (88%) and

posterior ethmoid (12%).[58]

Radiographic Evaluation.

Haller cells are identified on coronal images that are located inferior to the ethmoid bulla and adhering to the medial roof of the orbit, lateral to the uncinate process.

Clinical Significance.

These air cells may expand into the orbit and narrow the ostium of the maxillary sinus, especially in the presence of an infection. Haller cells have been associated with a high incidence of chronic rhinosinusitis because they may impinge on the patency of the maxillary ostium, thus inhibiting ciliary function. Procedures (implants, bone grafts) that may involve the maxillary sinus have an increased morbidity when Haller cells are present.

Agger Nasi Cells

Agger nasi cells are the most anterior ethmoidal air cells, extending anteriorly into the lacrimal bone. They can be identified on CT/CBCT in over 90% of patients and have a high incidence of frontal sinusitis.[59]

Radiographic Evaluation.

Agger nasi cells are most easily seen in CT/CBCT coronal images as they lie anterior, lateral, and inferior to the frontal recess and borders the primary ostium of the frontal sinus (Fig. 4.32).

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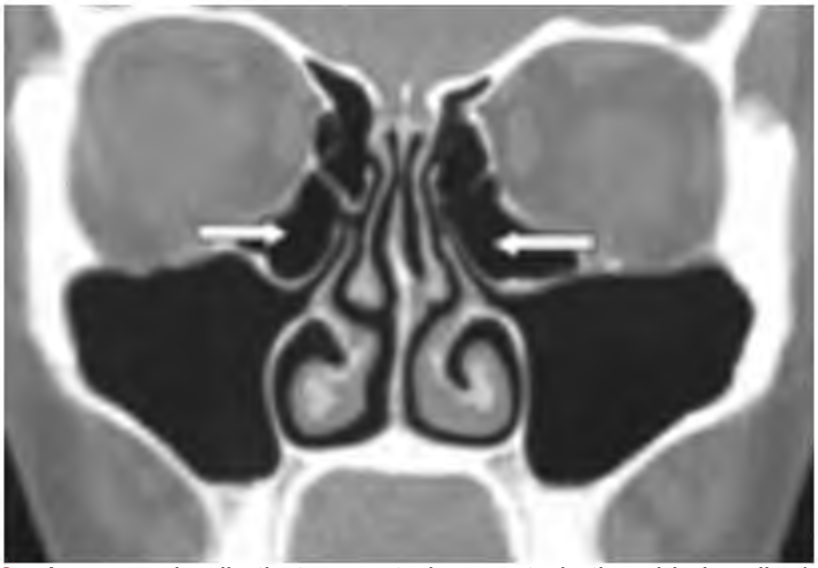

FIG 4.32 Agger nasi cells that are anterior aerated ethmoid air cells *(arrows)*.

Clinical Significance.

These cells may predispose the patient to postoperative sinus complications. Their size may directly influence the patency of the frontal recess and the anterior middle meatus, thus indirectly affecting the patency of the osteomeatal complex.

Maxillary Sinus Septa

Antral septa (buttresses, webs, and struts) are the most common osseous anatomic variants seen in the maxillary sinus. Underwood, an anatomist, first described maxillary sinus septa in 1910. Krennmair et al further classified these structures into two groups: primary, which are a result of the development of the maxilla, and secondary, which arise from the pneumatization of the sinus floor after tooth loss.[7] The prevalence of septa has been reported to be in the range of 33% of the maxillary sinuses in the dentate patient and as high as 22% in the edentulous patient. The most common location of septa in the maxillary sinus has been reported to be in the middle (second bicuspid–first molar) region of the sinus cavity. CT scan studies have shown that 41% of septa are seen in the middle region, followed by the posterior region (35%) and the anterior region (24%). For diagnosis and evaluation of septa, CT scans are the most accurate method of radiographic evaluation.[60]

Radiographic Evaluation.

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3-D images depict the anatomic features of septa most easily on CBCT images. They may also be easily seen on reformatted panoramic and axial and sagittal images (Fig. 4.33).

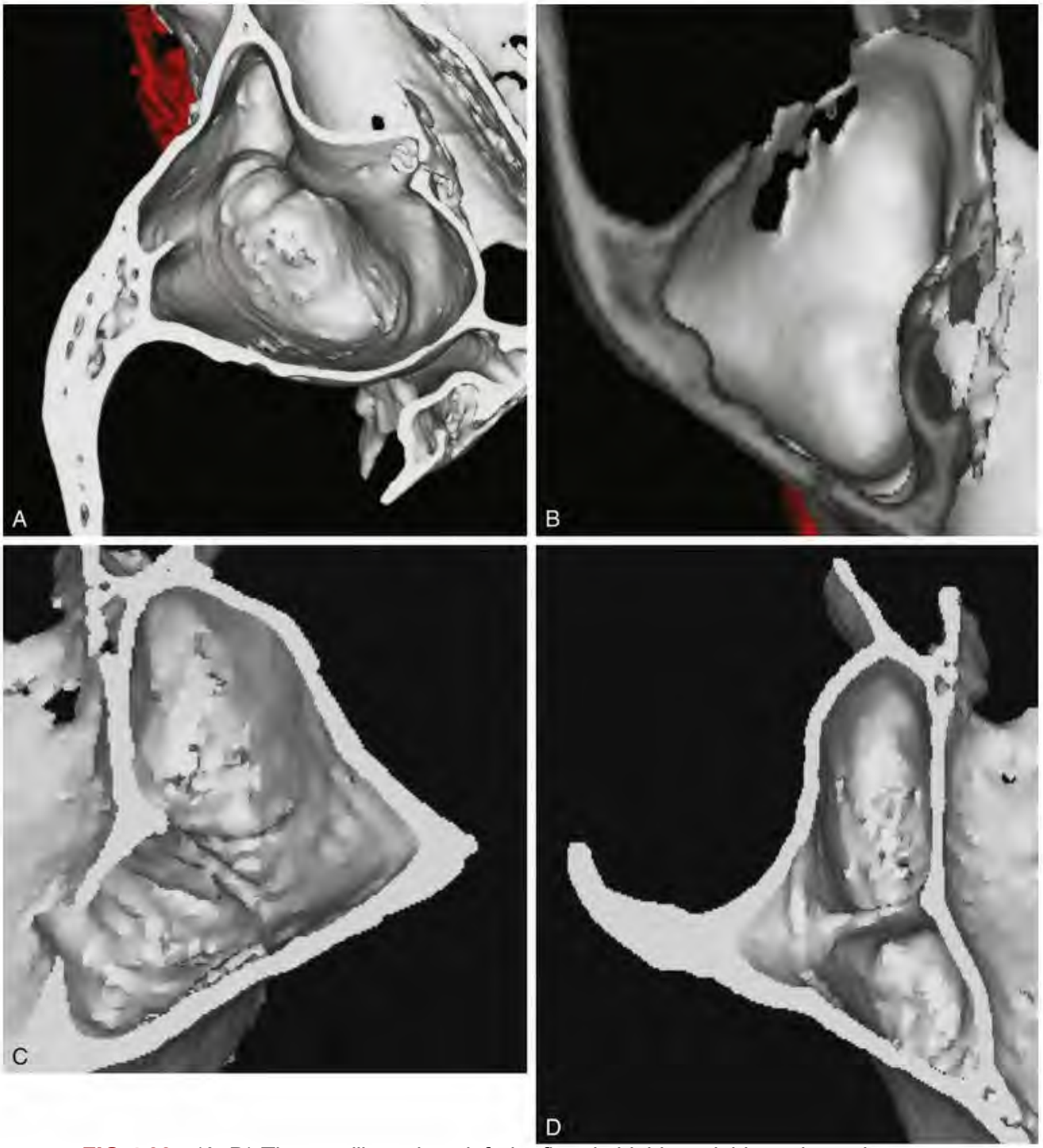

FIG 4.33 (A–D) The maxillary sinus inferior floor is highly variable and may be problematic with respect to the sinus graft procedures.

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Clinical Significance.

Maxillary septa complicate sinus graft surgery and can prevent adequate access and visualization to the sinus floor; therefore inadequate or incomplete sinus grafting is possible. Additionally, a higher incidence of membrane perforation results when septa are present.

Maxillary Sinus Hypoplasia

Hypoplasia of the maxillary sinus may be a direct result of trauma, infection, surgical intervention, or irradiation to the maxilla during the development of the maxillary bone. These or other congenital developmental conditions interrupt the maxillary growth center, thus producing a smaller-than-normal maxilla. A malformed and positioned uncinate process is associated with this disorder, leading to chronic sinus drainage problems.

Radiographic Evaluation.

Smaller-than-normal maxillary sinus volume can be seen on panoramic, cross-sectional, coronal, axial, or 3-D images.

Clinical Significance.

Most often, these patients have adequate bone height for endosteal implant placement, and a sinus graft is not required to gain vertical height. If implant placement or bone grafting involves the maxillary sinus, caution should be exercised, as this condition has been associated with chronic sinus disease. (Fig. 4.34A–B)

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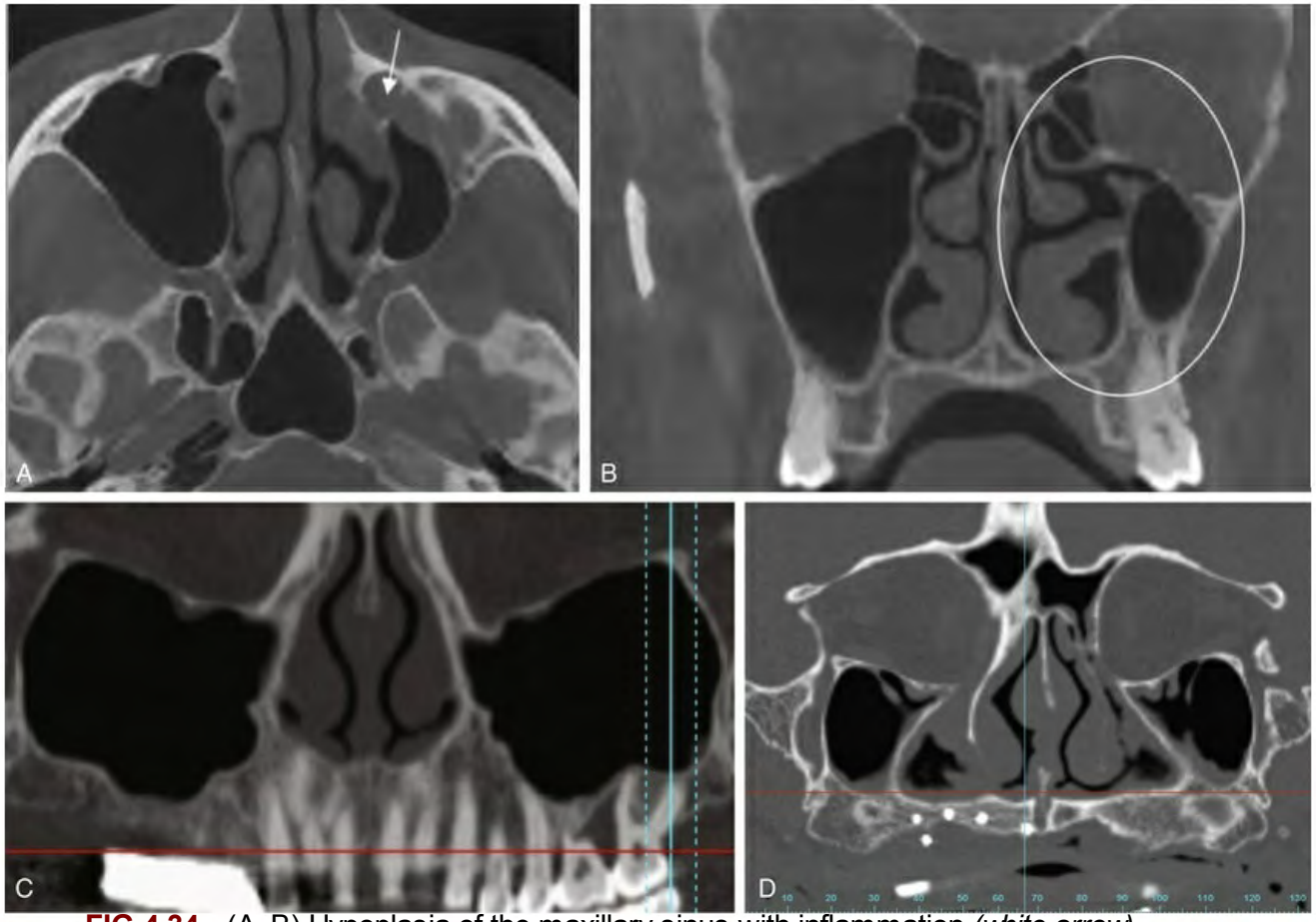

FIG 4.34 (A–B) Hypoplasia of the maxillary sinus with inflammation *(white arrow)*. (C) Normal relationship of nasal cavity and maxillary sinus. (D) Big-nose variant, which results in the nasal cavity extending into the first molar region leaving inadequate bone for implants in the bicuspid region.

Inferior Turbinate and Meatus Pneumatization (Big-Nose Variant)

A rather uncommon anatomic variant, the big-nose variant, occurs when the inferior third of the nasal cavity exhibits pneumatization within the maxilla and resides over the alveolar residual ridge. Studies have shown an incidence of approximately 3%. Because the maxillary sinus is lateral to the edentulous ridge, there exists inadequate bone height.

Radiographic Evaluation.

Big-nose variants may be determined by evaluation on conventional or reconstructed panoramic images because the nasal cavity will extend distal or posterior to the premolar area.

Clinical Significance.

If this condition is not taken into account, the implant may be placed into the nasal cavity above the residual ridge and often may penetrate into the inferior meatus and contact the inferior turbinate. A sinus graft is contraindicated with this patient condition because the sinus is lateral to the position of the implants. Instead, an onlay graft is required to increase bone height (Fig. 4.34C–D).

Buccal Thickness of Bone in Premaxilla

On average, maxillary buccal cortical plates are less than 1-mm thick, significantly thinner than the mandibular alveolar bones, which are greater than 1 mm. Thin cortical plates (similar to voxel size) tend to become indistinguishable from adjacent cementum or titanium implants on CBCT images.

Radiographic Evaluation.

Studies have shown that spatial resolution limitations of CBCT limit bone visibility of thickness less than 0.6 mm, meaning this is the minimum thickness required for bone to be measureable. Additionally, clinical studies show that when bone dehiscence is suspected, a true dehiscence is present only 50% of the time and a fenestration is present 25% of the time.[61]

Clinical Significance.

Because of the high degree of false positives, diagnosis and treatment planning can be problematic. The bone thickness should be correlated with all CBCT images, especially the cross-sectional views (not 3-D views).

Intraosseous Anastomosis

Within the lateral wall of the maxilla sinus is the intraosseous anastomosis, which is composed of the posterior superior alveolar and infraorbital arteries. The vertical component of the lateral-access wall (lateral wall osteotomy) for the sinus graft often severs these blood vessels.

Radiographic Evaluation.

The intraosseous anastomosis is easily seen on cross-sectional or coronal views of a CBCT scan as a discontinuation of the lateral wall with a radiolucent notch (opening). On average, this structure is approximately 15 to 20 mm from the crest of a dentate ridge.

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Clinical Significance.

When lateral wall sinus augmentation is indicated, evaluation of the CBCT should be completed to determine location and size. If bleeding does occur during the lateral wall osteotomy, it can be addressed by cauterization by the hand piece and diamond bur without water, electrocautery, or pressure on a surgical sponge while the head is elevated (Fig. 4.35).

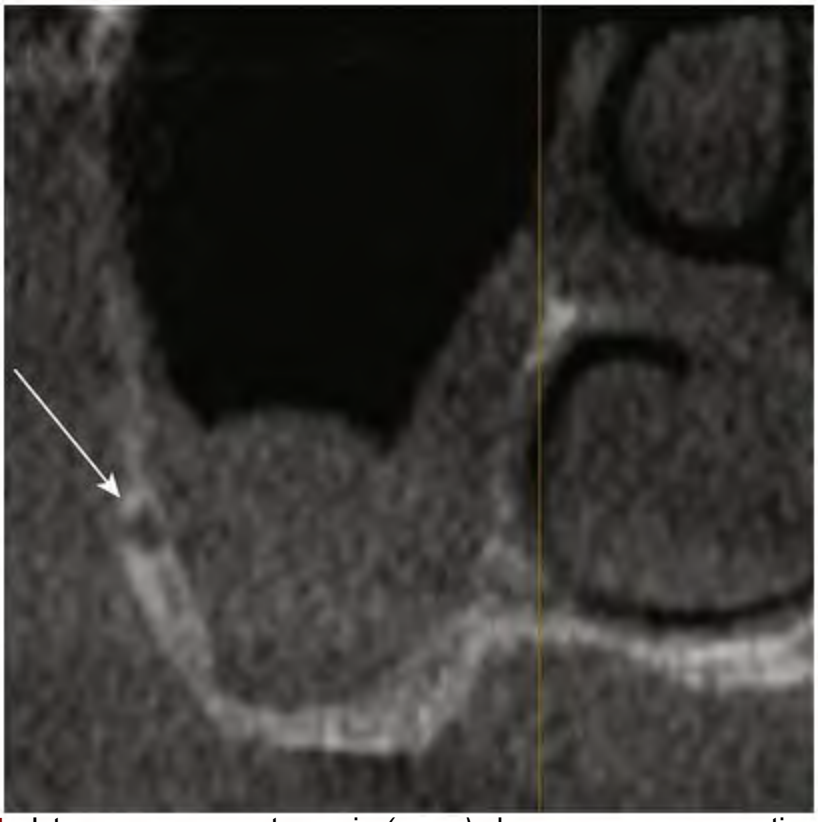

FIG 4.35 Intraosseous anastomosis *(arrow)* shown on a cross-sectional image seen as discontinuity of the lateral wall.

Canalis Sinuosus

The anterior superior alveolar nerve branches from the infraorbital canal, just lingual to the cuspid area. This radiolucent canal is called the *canalis sinuosus*. The canal runs forward and inferior to the inferior wall of the orbit and follows the lower margin of the nasal aperture and opens to lateral to the nasal septum.[62] The canalis sinuosus transmits the anterior superior alveolar nerve, artery, and vein.

Radiographic Evaluation.

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If the clinician is unaware of the canalis sinuosus, the anatomic structure may be misinterpreted as apical pathology on 2-D radiographs. Therefore, on CBCT scans, the bilateral anatomic structure should be evaluated for its presence. It may be depicted on axial, cross-sectional or 3-D images. Studies have shown the canalis sinuosus to be present on 87.5% of CBCT scans (Fig. 4.36).[63]

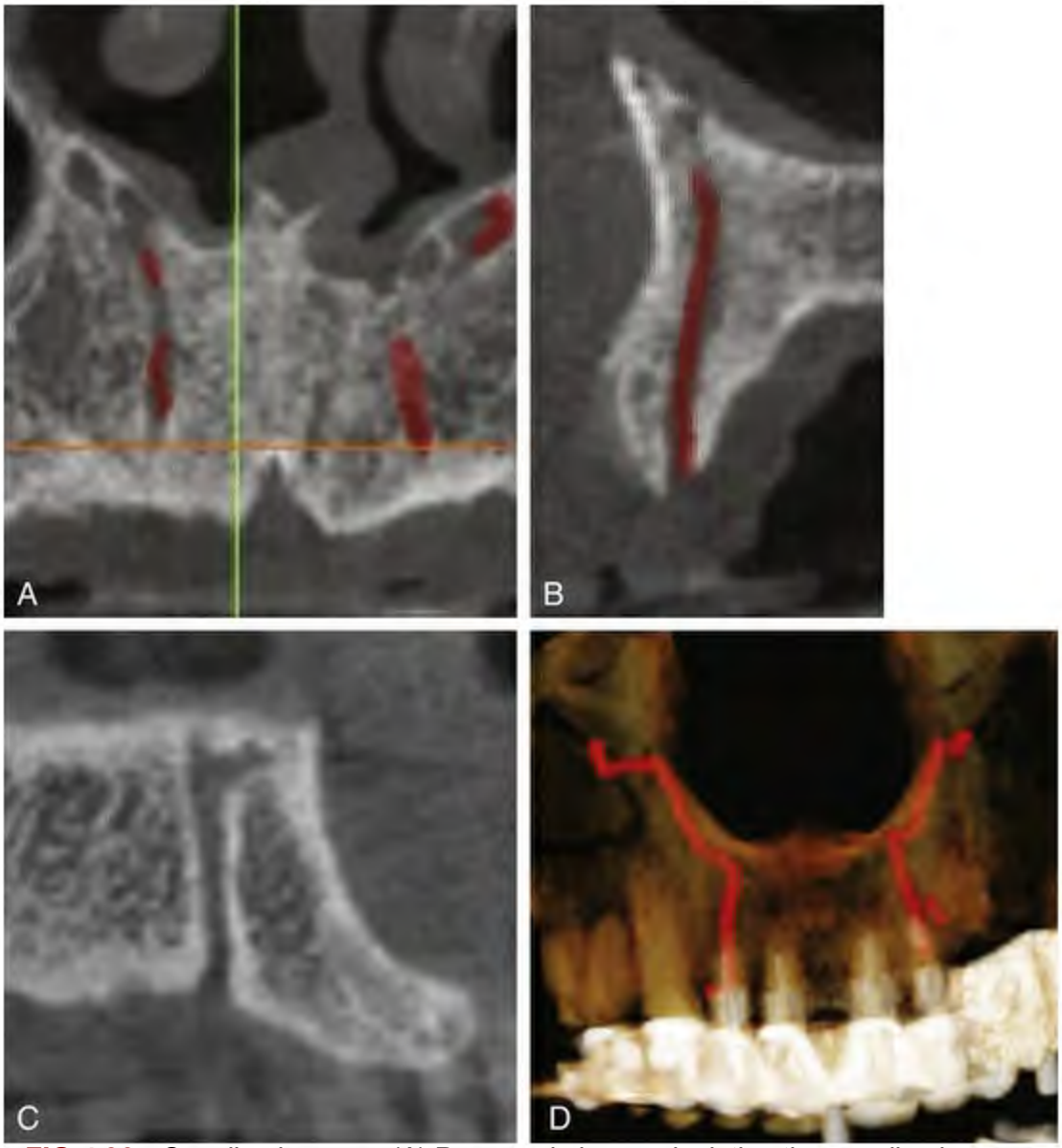

FIG 4.36 Canalis sinuosus. (A) Panoramic image depicting the canalis sinuosus which transmits the anterior superior alveolar vessels; (B–C) cross-sectional image; (D) 3-D image showing course of the canal.

Clinical Significance.

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Because the anterior maxillary region is a common area for dental implant placement, the presence of canalis sinuosus may lead to a high degree of implant morbidity. Impingement into the canal may lead to a soft tissue interface and failure of the implant, as well as temporary or permanent sensory dysfunction and possible bleeding issues.[64] However, significant sensory impairments are rare because of cross innervation.

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Pathologic Conditions in the Paranasal Sinuses

Rhinosinusitis

Odontogenic Sinusitis (Periapical Mucositis)

Odontogenic rhinosinusitis occurs when the sinus membrane is violated by infection of teeth and pathologic lesions of the jaws. The intimate approximation of the roots of the maxillary posterior teeth to the floor of the sinus results in inflammatory changes of the periodontium or surrounding alveolar bone, which promotes the development of pathologic conditions in the maxillary sinus.

Radiographic Appearance.

Odontogenic rhinosinusitis will usually produce generalized sinus mucosal hyperplasia, which is seen as a radiopaque band that follows the contours of the sinus floor. A localized periapical mucositis reveals a thickening of the mucous membrane adjacent to the offending tooth and, on occasion, a perforation through to the floor of the sinus. This radiographic appearance has been termed a *halo effect* (Fig. 4.37).

FIG 4.37 Odontogenic rhinosinusitis associated with a pathologic tooth (red arrow shows the thickened membrane; green arrow shows expansion into sinus cavity secondary to diseased tooth).

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Differential Diagnosis.

This condition may be confused with acute rhinosinusitis or mild mucosal thickening. However, in odontogenic rhinosinusitis, the patient will most likely have pathology associated with an existing tooth (e.g., pain from a posterior tooth or a recent extraction, exudate around the existing natural posterior teeth) and radiographic evidence of communication between the teeth and the maxillary sinus.

Acute Rhinosinusitis

A nonodontogenic pathologic condition may also result in inflammation in the maxillary sinus in the form of a rhinosinusitis. The most common type of rhinosinusitis in the maxillary sinus is acute rhinosinusitis. The signs and symptoms of acute rhinosinusitis are rather nonspecific, making it difficult to differentiate from the common cold, influenza type of symptoms, and allergic rhinitis. However, the most common symptoms include purulent nasal discharge, facial pain and tenderness, nasal congestion, and possible fever. Acute maxillary rhinosinusitis results in 22 to 25 million patient visits to a physician in the United States each year, with a direct or indirect cost of 6 billion US dollars. Although four paranasal sinuses exist in the skull, the most common involved in sinusitis are the maxillary and frontal sinuses.[65]

Radiographic Appearance.

The radiographic hallmark in acute rhinosinusitis is the appearance of an air-fluid level. A line of demarcation will be present between the fluid and the air within the maxillary sinus. If the patient is supine (CBCT), the fluid will accumulate in the posterior area; if the patient is upright during the imaging, the fluid will be seen on the floor and accumulate horizontally. Additional radiographic signs include smooth, thickened mucosa of the sinus, with possible opacification. In severe cases the sinus may fill completely with supportive exudates, which gives the appearance of a completely opacified sinus. With these characteristics, the terms *pyocele* and *empyema* have been applied (Fig. 4.38).

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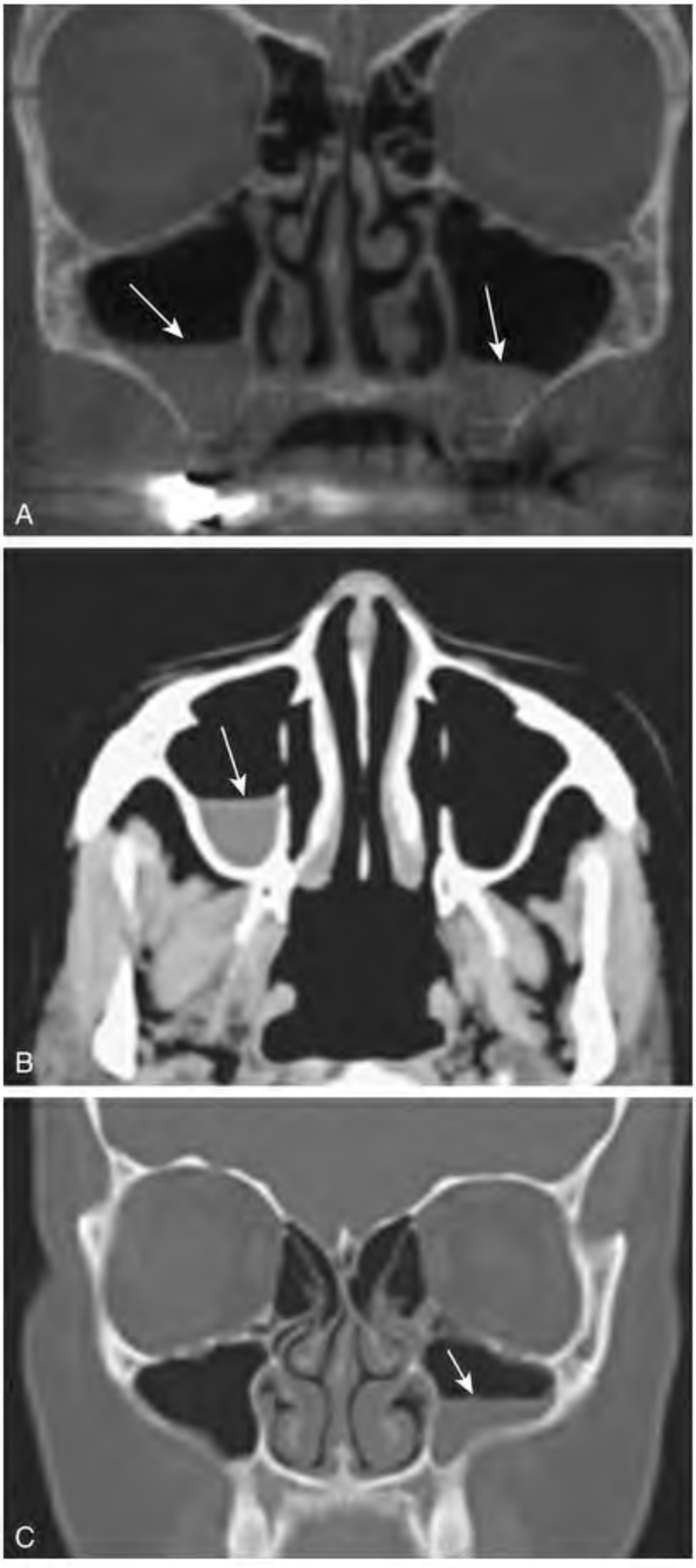

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FIG 4.38 Acute bacterial rhinosinusitis. (A) Coronal scan showing bilateral air-fluid level. (B) Axial image showing air-fluid level on the right side, the scan is most likely taken with the patient in a supine position. (C) Left-sided air-fluid level. *Arrows*, air-fluid level. (From Som PE and Curtin HD: *Head and neck imaging*, ed 5, St. Louis, 2012, Mosby.)

Differential Diagnosis.

The differential diagnosis of acute rhinosinusitis and prolonged viral upper respiratory infection are very similar. However, a classic air-fluid level in the maxillary sinus will give rise to the confirmation of acute rhinosinusitis. Additionally, viral rhinosinusitis will usually improve within 7 to 10 days, whereas acute bacterial rhinosinusitis persists for longer than 10 days.[66]

Chronic Rhinosinusitis

Chronic rhinosinusitis is a term used for a rhinosinusitis that does not resolve in 6 weeks and also has recurrent episodes. It is the most common chronic disease in the United States, affecting approximately 37 million people. Symptoms of chronic rhinosinusitis are associated with periodic episodes of purulent nasal discharge, nasal congestion, and facial pain.

Radiographic Appearance.

Chronic rhinosinusitis has the characteristic feature of sclerotic, thickened cortical bone from long-lasting mucoperiosteal inflammation. Additionally, it may appear radiographically as thickened sinus mucosa to complete opacification of the antrum.

Allergic Rhinosinusitis

Allergic rhinosinusitis is a local response within the maxillary sinus caused by an irritating allergen in the upper respiratory tract. The allergen may be the cause of the allergic rhinosinusitis. This category of rhinosinusitis may be the most common form, with 15% to 56% of patients undergoing endoscopy for sinusitis showing evidence of allergy. Allergic rhinosinusitis leads to chronic rhinosinusitis in 15% to 60% of patients.[67] The sinus mucosa becomes irregular or lobulated, with resultant polyp formation.

Radiographic Appearance.

Polyp formation related to allergic rhinosinusitis is usually characterized by multiple, smooth, rounded, radiopaque shadows on the walls of the maxillary

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sinus. Most commonly, these polyps are located near the ostium and are easily observed on a CBCT scan. In advanced cases, ostium occlusion, along with displacement or destruction of the sinus walls, may be present, with a radiographic image showing a completely opacified sinus (Fig. 4.39).

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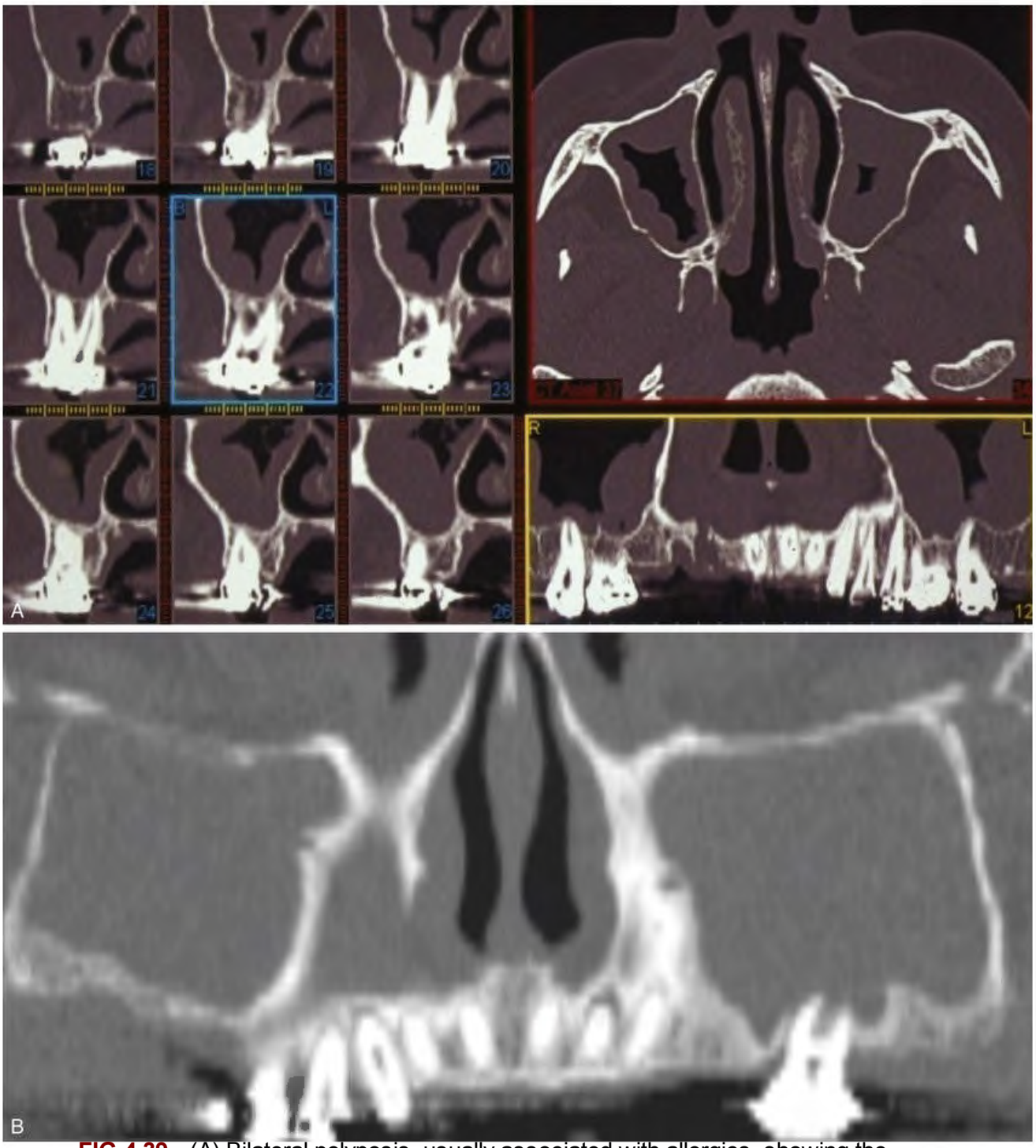

FIG 4.39 (A) Bilateral polyposis, usually associated with allergies, showing the circumferential, polypoid nature of the lesions. (B) Bilateral opacified sinuses representing a severe case of allergic rhinosinusitis; severe cases may lead to complete opacification.

Differential Diagnosis.

Although the radiographic signs of allergic rhinosinusitis may be similar to acute/chronic rhinosinusitis, a thorough medical history may be used to

differentiate. Most patients with allergic rhinosinusitis will have systemic systems (e.g., bilateral involvement) and also have a past history of allergy issues.

Fungal Rhinosinusitis (Eosinophilic Fungal Rhinosinusitis)

Granulomatous rhinosinusitis is a very serious (and often overlooked) disorder within the maxillary sinus. Patients who have fungal sinusitis are thought to have had an extensive history of antibiotic use, chronic exposure to mold or fungus in the environment, or are immunocompromised.

Radiographic Appearance.

Fungal rhinosinusitis is usually unilateral (78% of cases) with bony destruction very rare. Within the sinuses the presence of mild thickening to complete opacification may be present. In most cases, varying degrees of density ("double-densities") are seen. The majority of maxillary sinuses exhibiting fungal disease will radiographically show near complete opacification. Depending on the invasiveness of the disease, expansion of the involved sinus may occur and possibly remodeling, thinning, or erosion of the sinus walls may be seen radiographically (Fig. 4.40).

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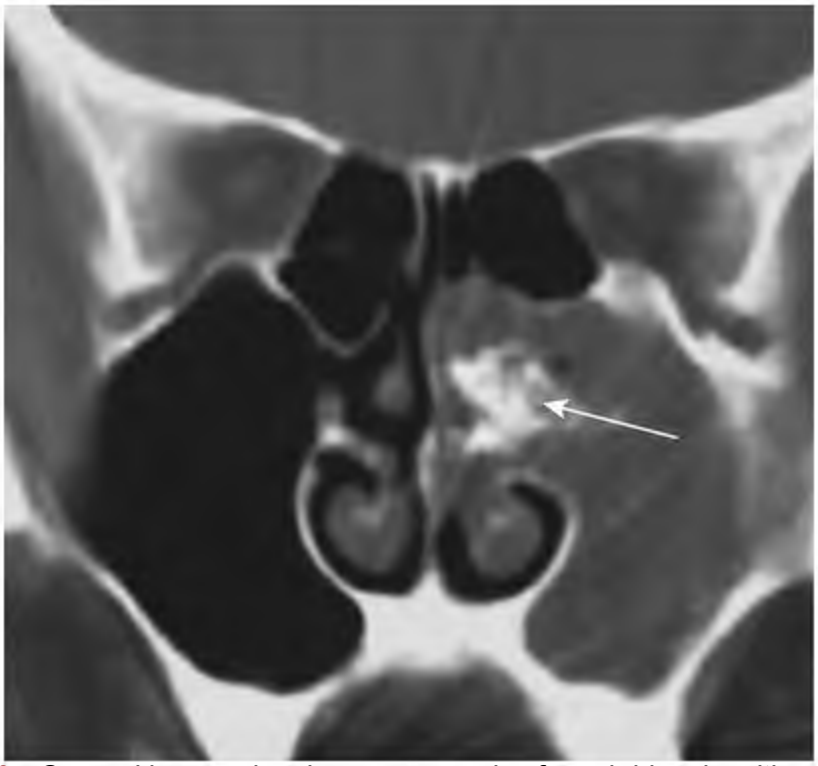

FIG 4.40 Coronal image showing a progressive fungal rhinosinusitis of the left paranasal sinus area. Note the dense radiopacity, which is termed a *fungal ball (arrow)*.

Differential Diagnosis.

Three possible clinical signs may differentiate fungal sinusitis from acute or chronic rhinosinusitis: (1) no response to antibiotic therapy, (2) soft tissue changes in sinus associated with thickened reactive bone, with localized areas of osteomyelitis, and (3) association of inflammatory sinus disease that involves the nasal fossa and facial soft tissue. In some cases a positive diagnosis may require mycologic and histologic studies.

Cystic Lesions

Cystic lesions are a common occurrence in the maxillary sinus, and studies have reported a prevalence range of 2.6% to 20%.[68] They may vary from microscopic lesions to large, destructive, expansile pathologic conditions that include pseudocysts, retention cysts, primary mucoceles, and postoperative maxillary cysts.

Pseudocysts (Mucous Retention Cyst)

The most common cysts in the maxillary sinus are mucous retention cysts.

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After much controversy, in 1984, Gardner[69] distinguished two categories of these cysts: (1) pseudocysts and (2) retention cysts. Pseudocysts are more common and of much greater concern during sinus graft surgery compared with retention cysts. Pseudocysts reoccur in approximately 30% of patients and are often unassociated with sinus symptoms. As a consequence, many physicians do not treat these lesions. However, when their size is larger than 10 mm in diameter, pseudocysts may occlude the maxillary ostium during a sinus graft procedure and increase the risk of postoperative infection.

Radiographic Appearance.

Pseudocysts are depicted radiographically as smooth, homogenous, dome-shaped, round-to-ovoid, well-defined homogeneous radiopacities. Pseudocysts do not have a corticated (radiopaque) marginal perimeter and are always on the floor of the sinus cavity. As their name states, they are not true cysts (e.g., pseudocyst), therefore do not have an epithelium lining (Fig. 4.41).

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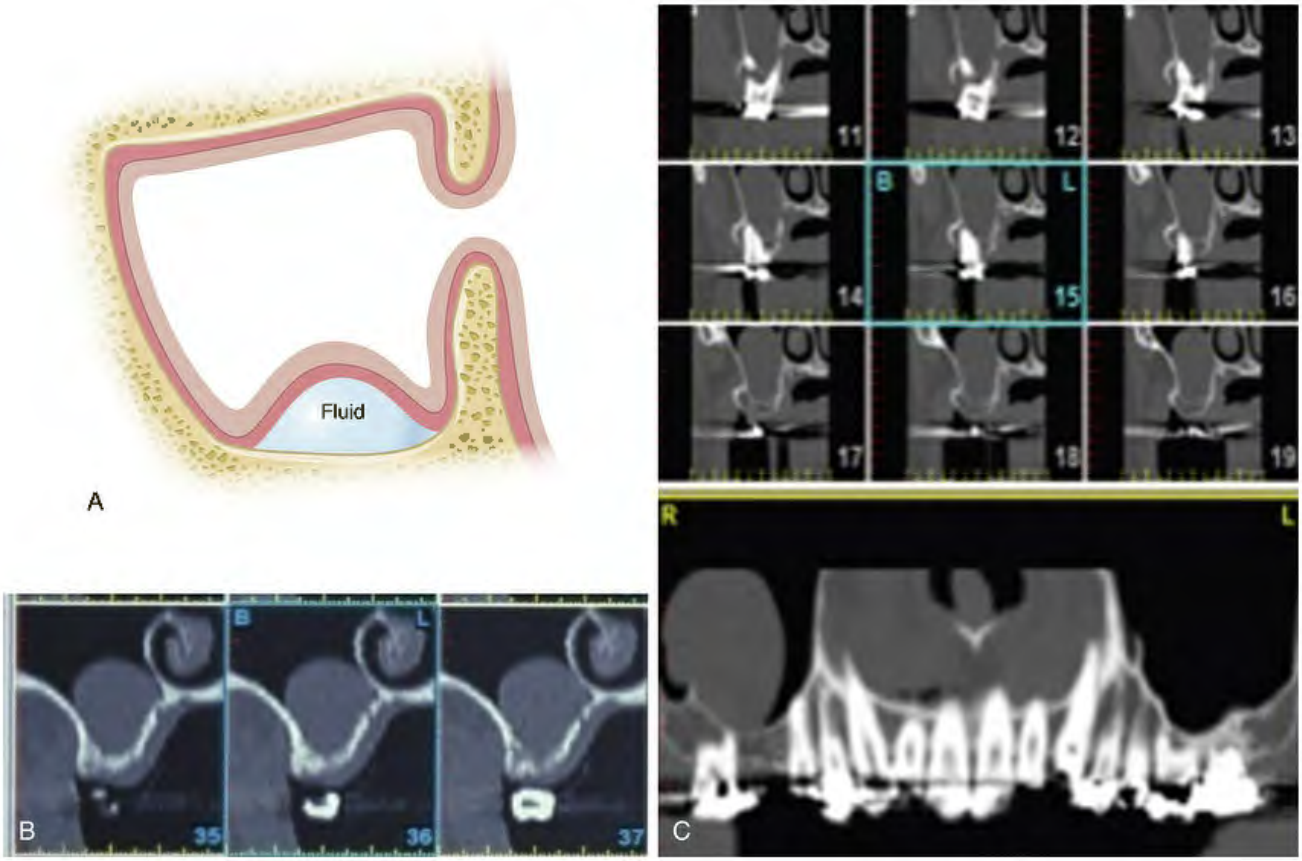

FIG 4.41 (A) Pseudocyst, also termed a *mucous retention cyst*. (B) Cross sections showing the dome-shaped lesion on the floor of the maxillary sinus. (C) Maxillary right large pseudocyst, which has expanded to encompass most of the sinus proper. Note in the cross sections, a pathologic tooth is present, which is most likely the etiologic factor because of the communication with the sinus.

Differential Diagnosis.

The pseudocyst is easily identified in comparison to other cystic lesions (e.g., retention, mucocele, polyps) by being dome-shaped and only located on the floor of the sinus.

Retention Cysts

Retention cysts may be located on the sinus floor, near the ostium, or within antral polyps. Because they contain an epithelial lining, researchers consider them to be mucous secretory cysts and "true" cysts. Retention cysts are often microscopic in size.

Radiographic Appearance.

Retention cysts are usually very small and not seen clinically or radiographically. In rare instances, they may achieve adequate size to be seen

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in a CT image and may resemble the a small pseudocyst.

Differential Diagnosis.

Retention cysts are very uncommon, rarely seen clinically or radiographically, and no treatment is indicated. Therefore, these lesions are of no consequence.

Primary Maxillary Sinus Mucocele

A primary mucocele is a cystic, expansile, destructive lesion that may include painful swelling of the cheek, displacement of teeth, nasal obstruction, and possible ocular symptoms.[70]

Radiographic Appearance.

In the early stages, the primary mucocele involves the entire sinus and appears as an opacified sinus. As the cyst enlarges, the walls become thin and eventually perforate. In the late stages, destruction of one or more surrounding sinus walls is evident (Fig. 4.42).

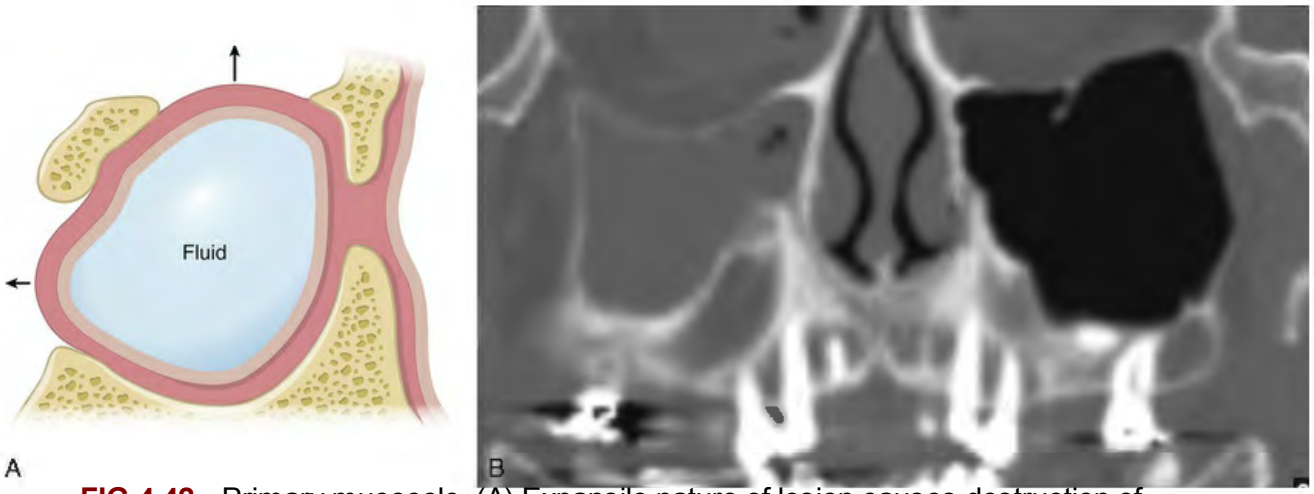

FIG 4.42 Primary mucocele. (A) Expansile nature of lesion causes destruction of sinus walls. (B) Clinical image depicting right side of a complete radiopaque sinus with expansion of walls.

Differential Diagnosis.

The primary maxillary sinus mucocele has clinical and radiographic similarities to chronic rhinosinusitis, fungal rhinosinusitis, or neoplasm.

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Patients that present with these signs and symptoms should be referred for proper diagnosis and treatment.

Postoperative Maxillary Cyst

A postoperative maxillary cyst of the maxillary sinus is a cystic lesion that usually develops secondary to a previous trauma or surgical procedure in the sinus cavity. It has also been termed a *surgical ciliated cyst, postoperative maxillary sinus mucocele*, or a *secondary mucocele*.[71]

Radiographic Appearance.

The cyst radiographically presents as a well-defined radiolucency circumscribed by sclerosis. The lesion is usually spherical in the early stages, with no bone destruction. As it progresses, the sinus wall becomes thin and eventually perforates. In later stages, it will appear as two separated anatomic compartments (Fig. 4.43).

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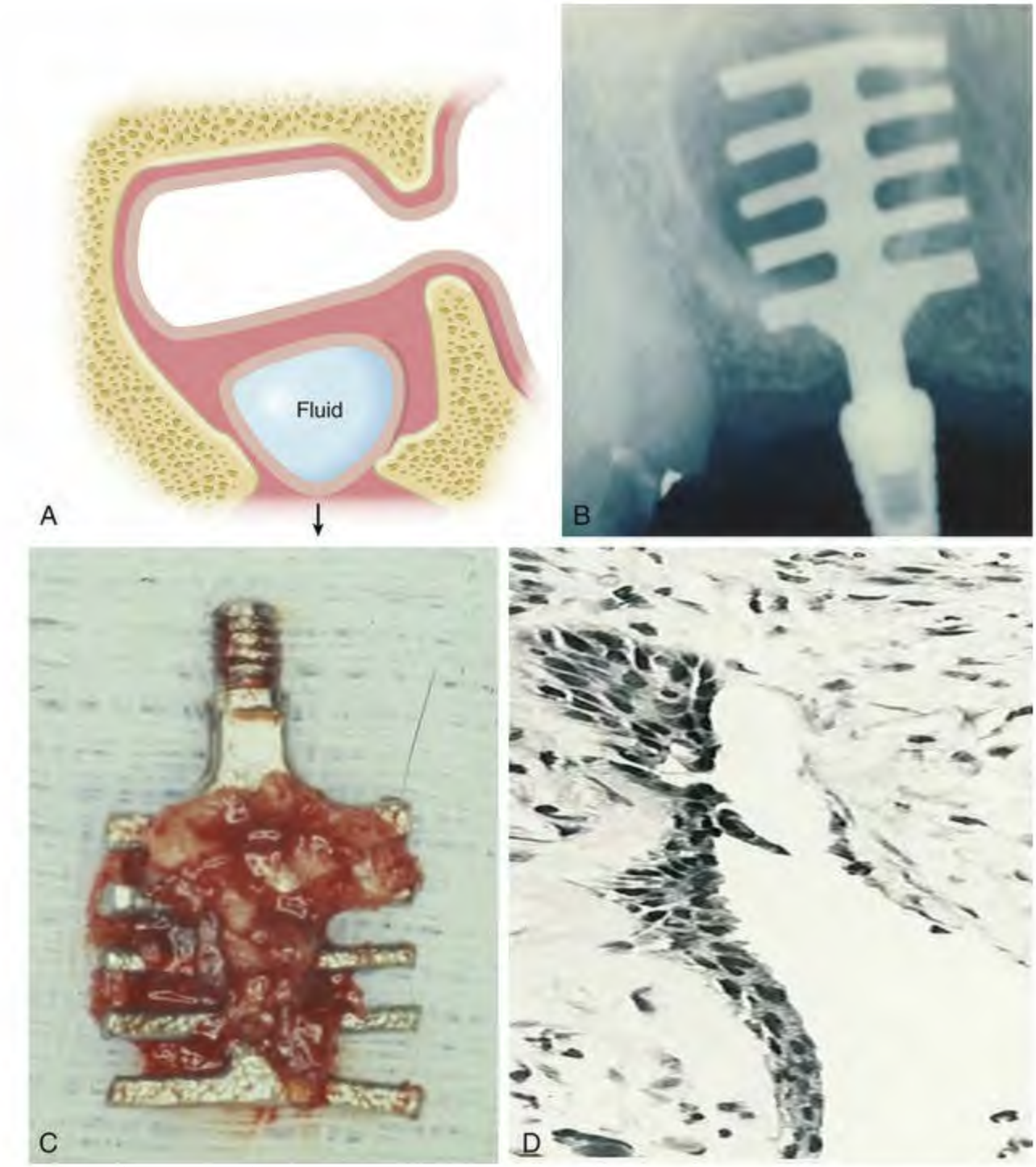

FIG 4.43 (A) Secondary mucocele is a well-defined radiolucent lesion that separates the sinus cavity into two separate compartments, which is usually fluid filled. (B) Radiograph depicting cystic area surrounding implant. (C) Blade implant after removal which is fully encompassed by lesion. (D) Histologic section confirming secondary mucocele diagnosis.

Differential Diagnosis.

The postoperative maxillary cyst is easily differentiated from other lesions

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present in the maxillary sinus as the patient will have had a past history of sinus surgery and radiographically there will be two distinct radiolucent cavities.

Neoplasms

Squamous Cell Carcinoma, Adenocarcinoma

Malignant tumors of the paranasal sinuses are rare, with a poorly differentiated squamous cell carcinoma comprising approximately 80% of tumors. Seventy percent of these tumors are found in the maxillary sinus.[72] Symptoms can vary; however, neoplasms of the maxillary sinus usually include nasal obstruction, rhinorrhea, epistaxis, cranial neuropathies, and pain. Advanced cases may include visual disturbances, paresthesias, and possible malocclusion.

Radiographic Appearance.

Radiographic signs of neoplasms may include various-sized radiopaque masses, complete opacification, or bony wall changes. A lack of a posterior wall on a radiographs should be a sign of possible neoplasm (Fig. 4.44).

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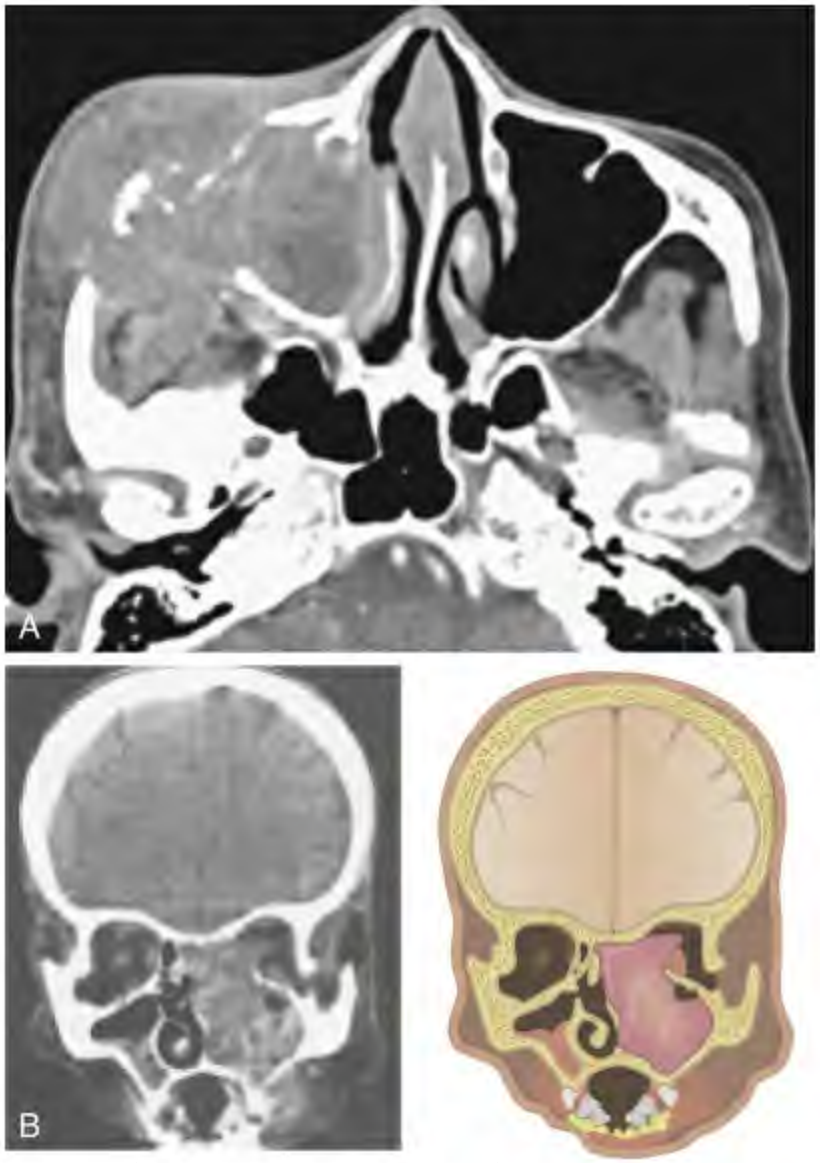

FIG 4.44 (A–B) Squamous cell carcinoma of the right maxillary sinus showing complete radiopacity with associated expansion and destruction of sinus walls.

Differential Diagnosis.

A maxillary sinus neoplasm may show signs and symptoms similar to chronic rhinosinusitis, primary maxillary sinus mucocele, fungal rhinosinusitis, or allergic rhinosinusitis. An opacified sinus or bony expansion should result in immediate referral.

Antroliths

Maxillary Sinus Antroliths

Maxillary sinus antroliths are the result of complete or partial encrustation of

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a foreign body that is present in the sinus. These masses found within the maxillary sinus originate from a central nidus, which can be endogenous or exogenous.[73]

Radiographic Appearance.

The radiographic appearance of a maxillary antrolith resembles either the central nidus (retained root) or appears as a radiopaque, calcified mass within the maxillary sinus (Fig. 4.45).

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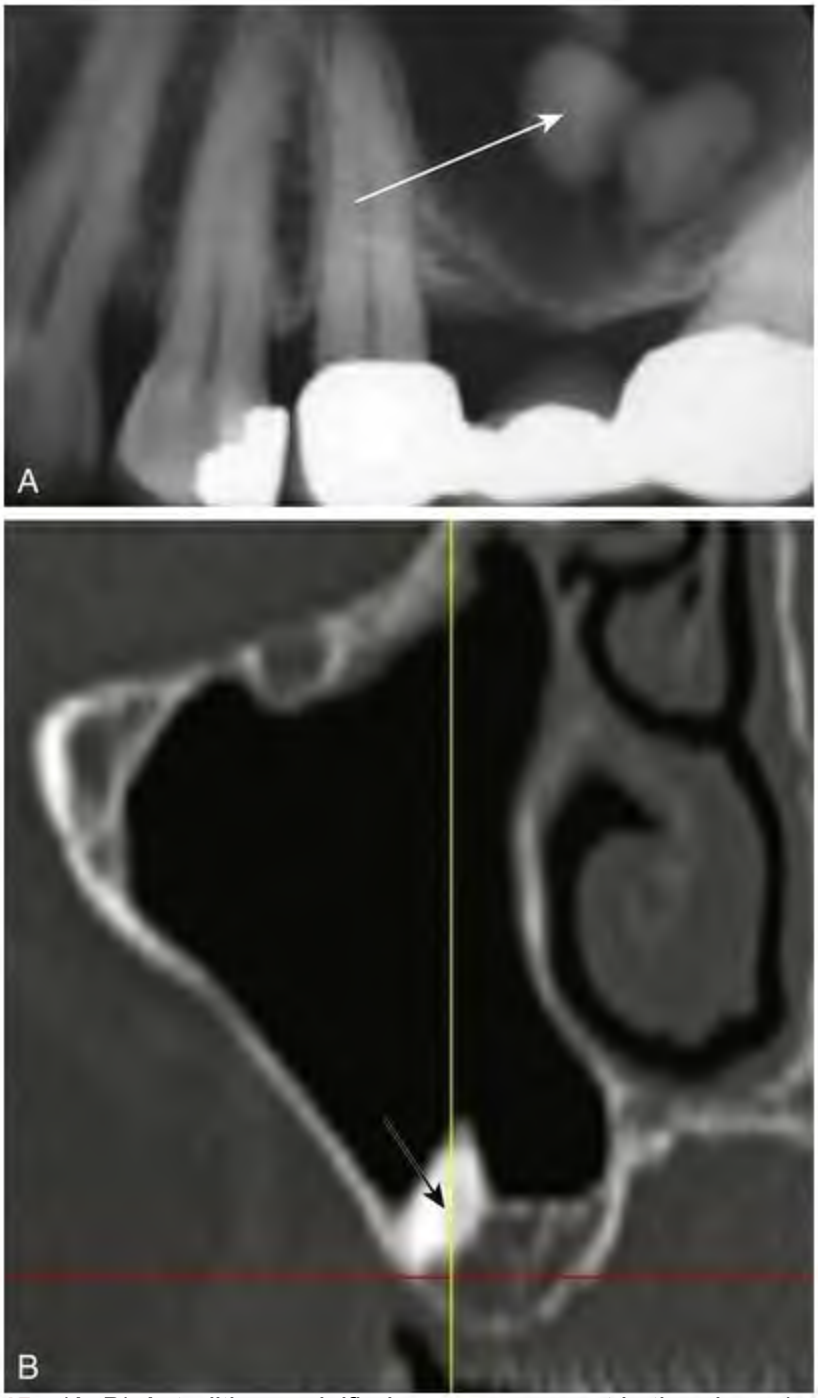

FIG 4.45 (A–B) Antrolith or calcified masses present in the sinus *(arrows)*.

Differential Diagnosis.

Because the calcified antrolith is composed of calcium phosphate ($CaPO_4$), calcium carbonate salts, water, and organic material, it will be considerably more radiopaque than an inflammatory or cystic lesion.[74] The central nidus of the antrolith is similar to its usual radiographic appearance (e.g., implant, tooth root).

Miscellaneous CBCT Complications

Diagnostic Factors

Patient Positioning

Improper positioning of patients during CBCT examinations may lead to inaccuracies in image quality that can cause incorrect measurements during interactive treatment planning. Therefore it is important that a standardized protocol for all patients be completed by staff taking the scans. Especially if guided surgery is to be utilized, strict evaluation and protocol of patient positioning must be verified. Additionally, the patient should be instructed to not move, as any movement (even minor) may lead to blurring and errors with the interactive treatment planning.

Lack of Radiopaque Template

For ideal implant placement, anatomic and prosthetic considerations of the planned tooth or prosthesis must be determined. A radiographic template must be used during the scanning process to simulate the information into the final treatment plan. There exist various techniques to fabricate radiographic templates. These include: (1) the existing or duplicate prosthesis with radiopaque markers, (2) a thermoplastic template with radiographic markers, and (3) use of radiopaque teeth in a mucosa or tooth-supported template. Care should be taken if the existing prosthesis is utilized, and any esthetic or functional changes should be made prior to scanning.

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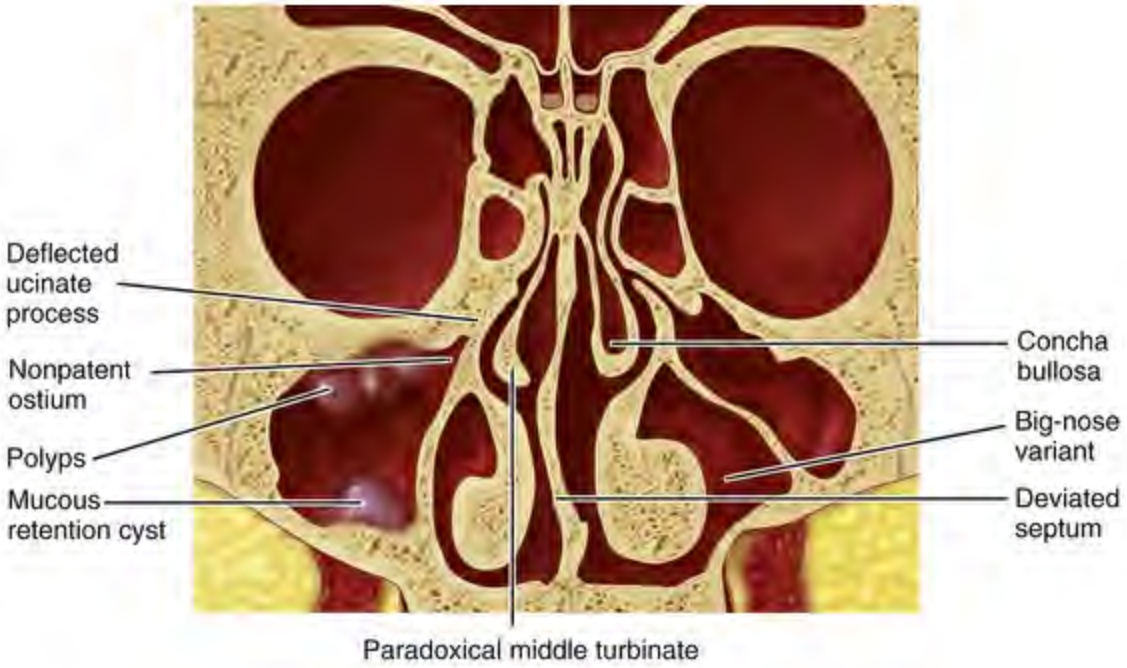

FIG 4.46 Summary of the most common pathologic conditions occurring in the paransal sinuses. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Clinical Complication.

If a radiopaque template is not utilized, the ideal positioning may not be determined. For cases involving minimal edentulous sites, interactive treatment planning software may be used to fabricate the position of the replacement teeth (e.g., Virtual Teeth, Materialize Dental). For full-arch edentulous cases, a radiopaque template or a dual scan protocol should be utilized (Fig. 4.47 A–B).

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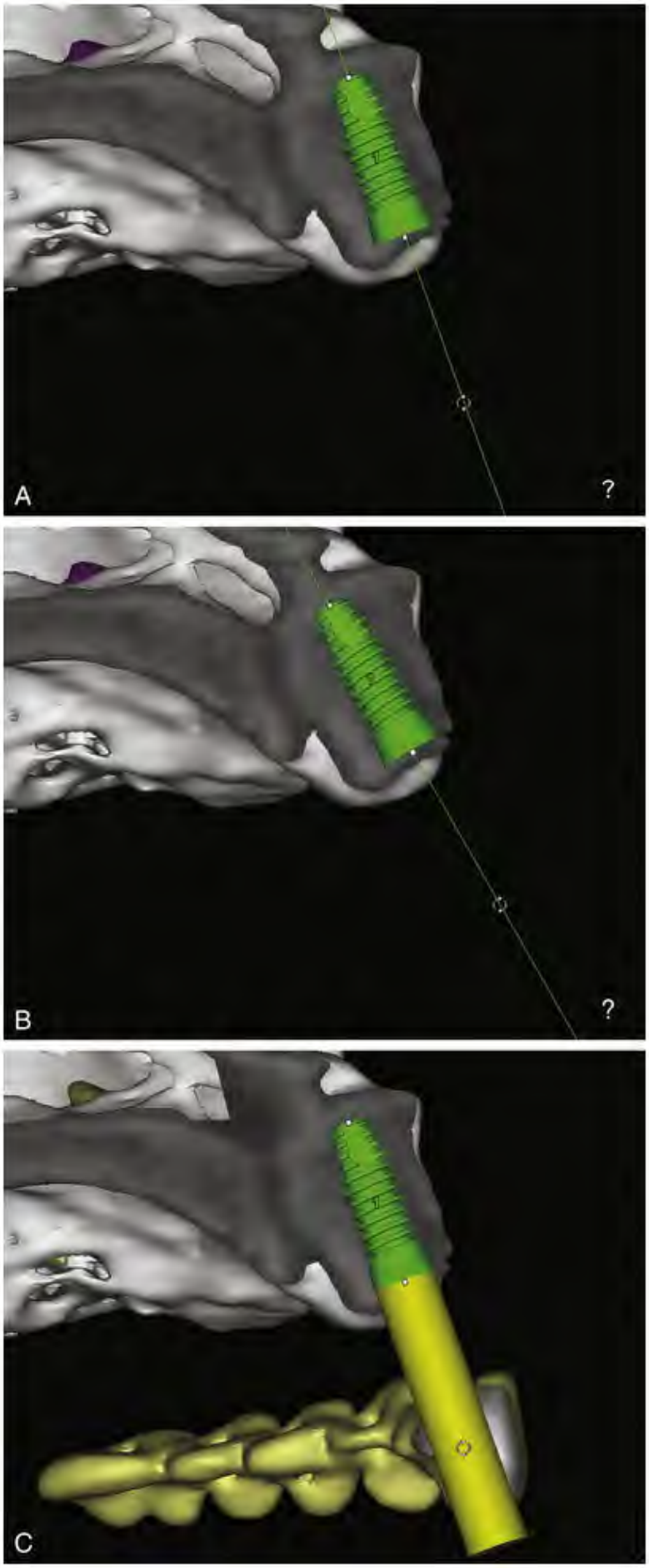

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FIG 4.47 (A–B) Without a radiopaque template, ideal angulation may not be determined. (C) A radiopaque template allows for the correct placement of the implant.

Lack of Radiopaque Template Stability

If any instability is present in the radiopaque template, inaccuracies may result with the interactive treatment planning. The final positioning of the implants and the final prosthesis may be compromised. Because of the need for ideal implant placement, denture adhesive or reline of the prosthesis should be used for the scan. If not, the prosthesis might be canted, thus altering the anatomy and placement of the implants. On CBCT images, a radiolucent space will be present showing a void and improper positioning of the prosthesis.

Complications Prevention.

The radiopaque template should always be evaluated for midline verification, ideal occlusal plane, and approved esthetics. This will minimize the possibility of transferring incorrect information to be used for the implant placement position and surgical guide preparation. A well-fitting prosthesis with denture adhesive or reline should be used to help stabilize the prosthesis along with a bite registration. The patient should maintain the teeth in together (i.e., slightly out of occlusion) during the scan (Fig. 4.48).

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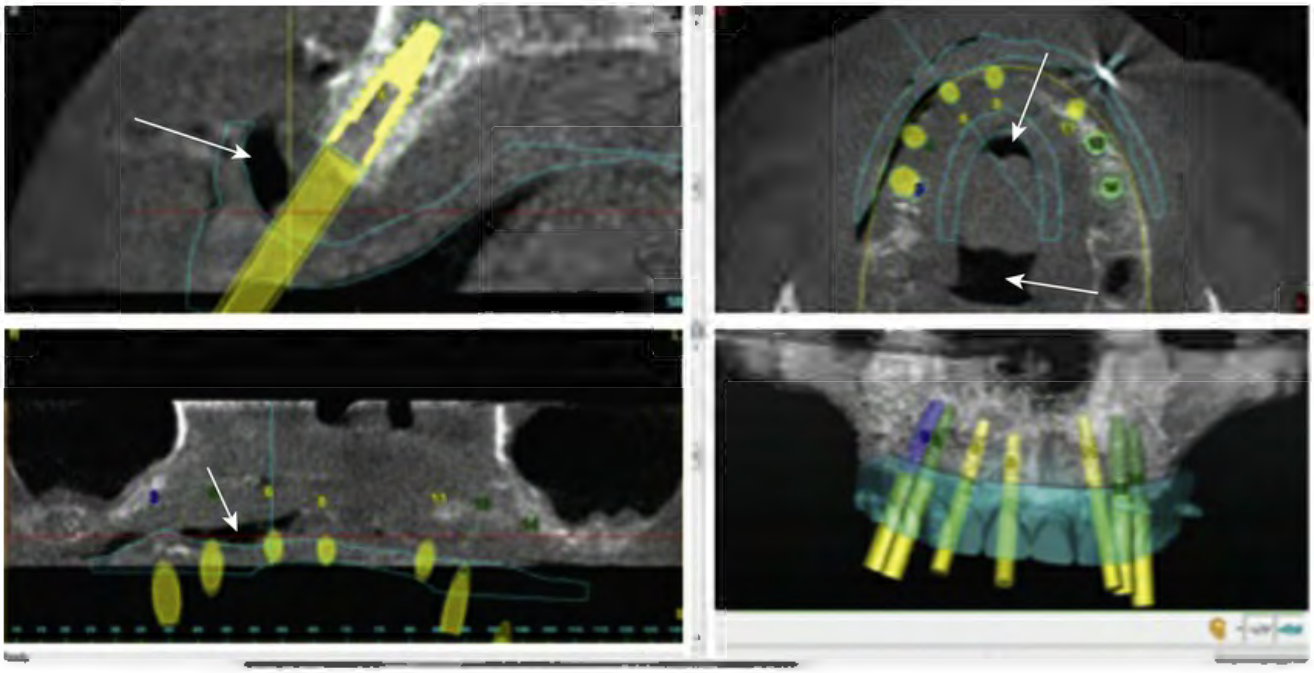

FIG 4.48 Radiolucent air spaces exhibiting improper positioning or ill-fitting of the prosthesis during the CBCT scan. The air spaces represent no contact between the prosthesis and the soft tissue.

Inability to Identify Mandibular Canal

Identification of Mandibular Canal Methods.

The accurate identification of the mandibular canal is crucial for preoperative treatment planning for implant placement in the posterior mandible. Because the amount of available bone height present between the alveolar ridge and the mandibular canal dictates the positioning and size of the dental implant, any inaccuracies may lead to an increased morbidity. Because of the inability to ascertain cortical borders in the MC and with varying trabeculation, in some cases it may be difficult to determine the exact location. Studies have shown the visibility of the MC decreases towards the mental foramen. This unreliability of visualization of the MC near the mental foramen is due to the lack of definite walls in the anterior portion of the canal. Even with the wide variation of CBCT images, the ability to identify this structure is dependent on the density of the bone and MC.

Lofthag-Hansen et al determined that the mandibular canal is only visible on one third of cross-sectional images. However, when other images (sagittal and axial) were evaluated, the visibility of the MC increased significantly to approximately 87%. Therefore, assessing every sequential image available increases the localization of the MC (Box 4.1 and Figs. 4.49 and 4.50).[75]

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Box 4.1

Technique to Localize Mandibular Canal

Manipulation of Images (See Fig. 4.50)

1. Select the reconstructed panoramic view using the CBCT software to access the mandibular canal (MC).

2. If the mandibular canal is not seen clearly, manipulate the mandibular curve in the axial view buccal-lingually (Fig. 4.49B).

3. When the mandibular canal can be seen clearly, the nerve is drawn (main nerve canal) from the posterior to the mental foramen.

4. In the cross-sectional views, scroll until the mental canal/foramen is seen. Draw the *first* nerve (green) from the mandibular canal to the exit of the mental foramen. Draw the *second* nerve (orange) from anterior to posterior.

5. If mandibular canal cannot be seen clearly, mark the posterior and anterior limits of the mandibular canal and extrapolate via cross-sectional images. The MC can then be drawn connecting the extrapolating points on the panoramic image (see Fig. 4.49)

Additional Techniques

If the CBCT examination does not depict the mandibular canal clearly, an MRI examination may be completed to more easily see the cortical and cancellous bone, nerve, and blood vessels. Studies have shown that MRI images provide less variability in determining the locations of the mandibular nerve, the mental foramen, and the mandibular foramen than CBCT images. Even though there exists no ionizing radiation, MRI technology is limited in dentistry due to cost, availability, and no cross referencing.[76]

CBCT, cone beam computed tomography; *MC,* mandibular canal; *MRI,* magnetic resonance imaging.

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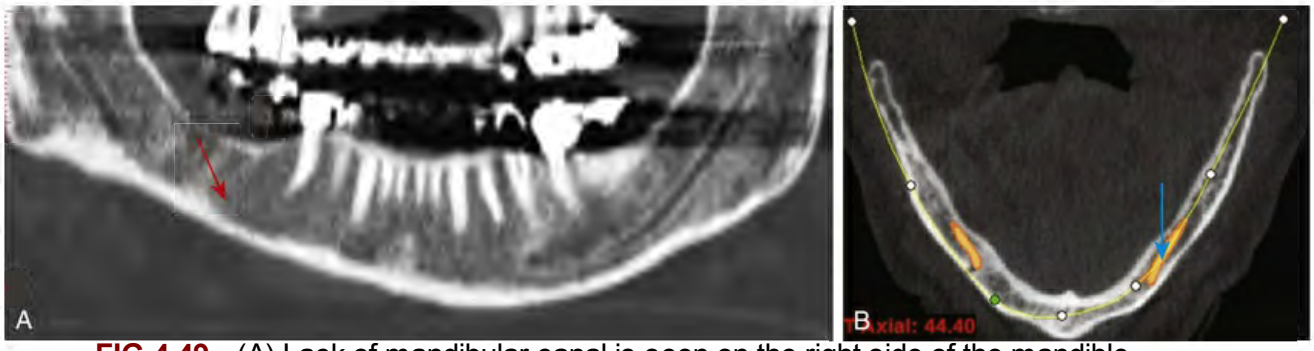

FIG 4.49 (A) Lack of mandibular canal is seen on the right side of the mandible because the panoramic curve is outside the focal trough of the canal *(red arrow).* (B) On the left side, the canal is easily depicted as the panoramic curve is in the center of the focal trough *(blue arrow).*

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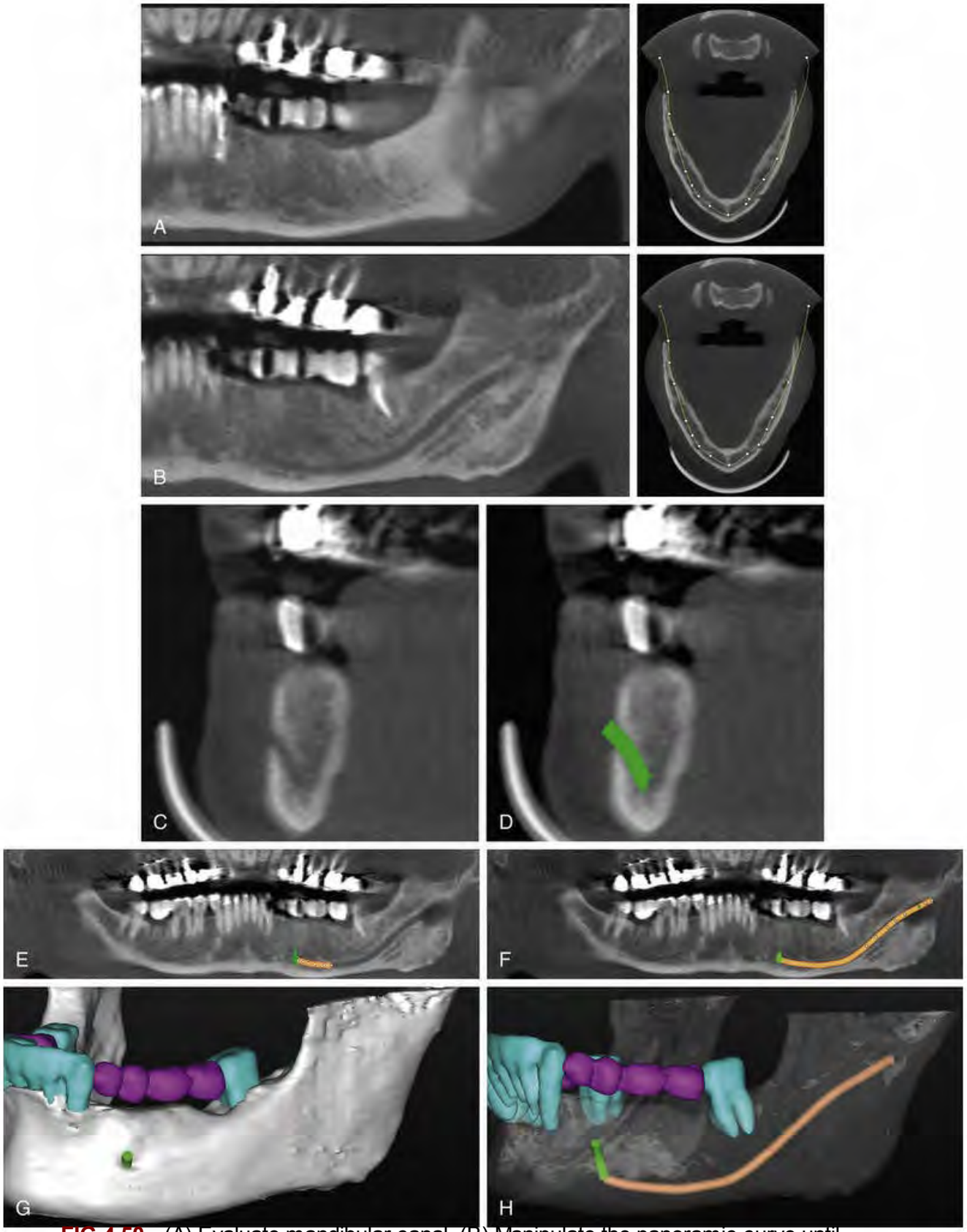

FIG 4.50 (A) Evaluate mandibular canal. (B) Manipulate the panoramic curve until the entire mandibular canal may be seen clearly. (C) Scroll until cross section identifies the mental canal/foramen. (D) Draw the mental nerve and extend through foramen. (E–F) Draw mandibular nerve from anterior to posterior. (G–H) 3-D images.

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Inadequate Field of View (Maxillary Posterior)

It is imperative to determine the patency of the maxillary ostium when placing implants or bone grafting into the maxillary sinus area. If pathology exists, there is possible need for referral to an otolaryngologist for examination and treatment. If the ostium is not seen on the CBCT, this will result in the need for an additional scan, which ends up being embarrassing for the implant clinician as a new scan will need to be taken (Fig. 4.51).

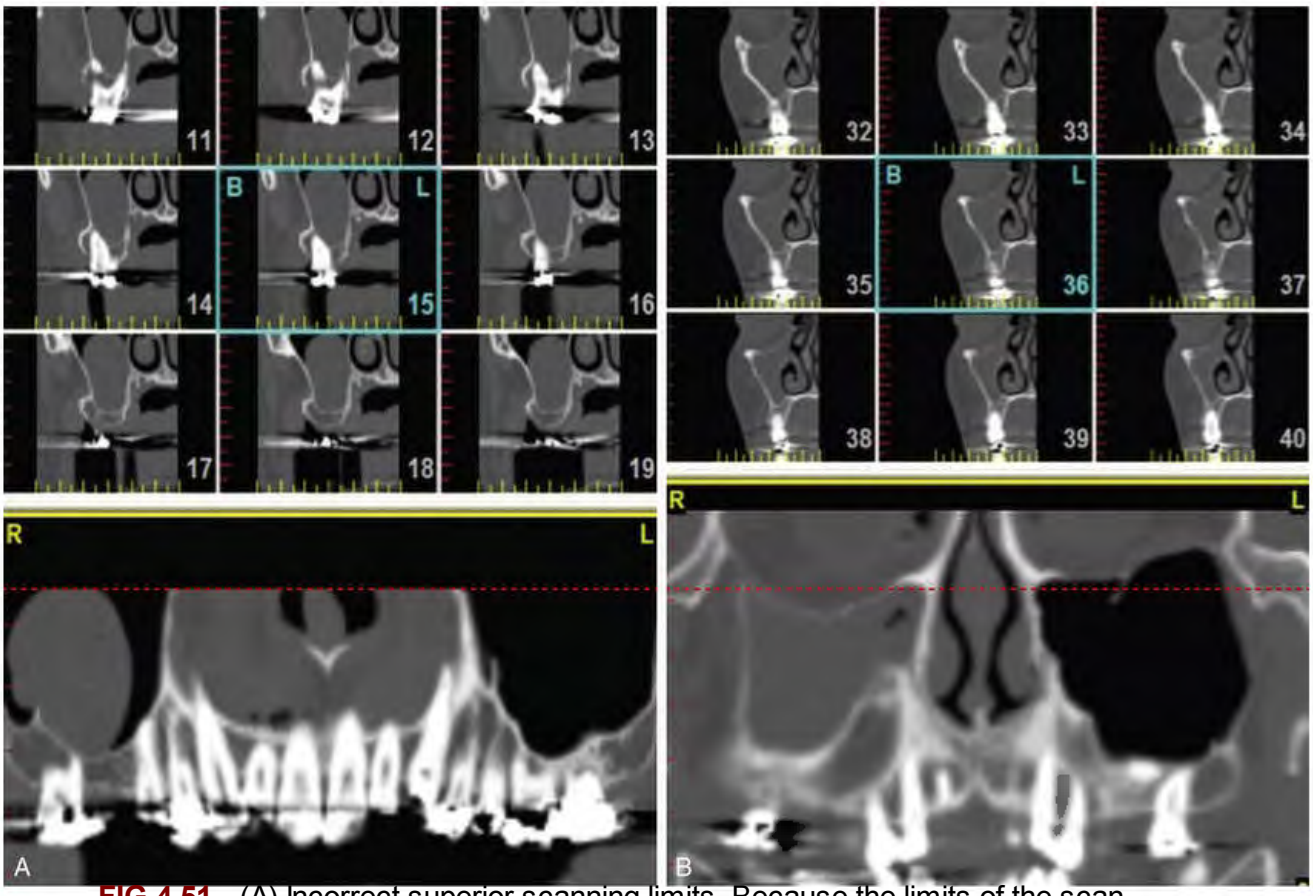

FIG 4.51 (A) Incorrect superior scanning limits. Because the limits of the scan were not high enough, the ostium cannot be evaluated. (B) Correct superior limit depicting maxillary ostium.

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Radiology Reports

Interpretation

In dentistry, a practicing, licensed dentist is considered by the licensing board to be competent to interpret commonly utilized radiographs. When evaluating a medium-to-large-volume CBCT capturing more than one quadrant or one arch above or below the root apices, it is helpful to use some type of radiographic template as a guide. The use of a report template makes sure the anatomic structures that have been included within the volume have been thoroughly evaluated and deviations from normal symmetry commented upon. In general, the radiologist will be performing an "over read" of the volume on your behalf, meaning you have looked at the volume and the radiologist has validated your observations and findings in a formal report. Each radiologist may use a slightly different reporting form to fit their style of reporting, but the common elements of a report are described below.

Basic Information Elements

A typical radiographic report template will include the following basic information elements:

Patient/Office Identification Section.

This section records date of report, patient name, date of birth, gender, name of the referring doctor, date of the scan, and the name of the scanning center or dental office taking the scan/volume.

- **Clinical Significance:** Critical/patient record information.

Images Provided.

Enter the type of images provided for review. A typical entry would be: "Cone beam CT images with bone window; axial, coronal and sagittal planes." Optional information would include: the name of the CBCT unit, pixel resolution, (e.g., 0.3 mm, size of the volume—small, medium, large).

- **Clinical Significance:** Critical/patient record information; when volume size and pixel resolution are included, patient dose reconstruction is possible when the specific CBCT unit is identified.

Clinical Information.

This section would include a brief relevant history and/or clinical note. Entries might include such elements as: “Implant evaluation for edentulous areas of maxilla,” “Relationship of endosseous implant to the mandibular canal,” etc.

- **Clinical Significance:** Critical/patient record information providing the clinician’s rationale for taking the diagnostic image.

Diagnostic Objectives.

The referring clinician enters their specific objectives for the report such as: 1) sinus evaluation; 2) rule out pathology; 3) implant measurements #3, 10, 14, 19, 29, 4) rule out osteomyelitis; 5) mandibular/maxillary pathology.

- **Clinical Significance:** Clinician’s specific request or potential concern for the radiologist to look for as a priority.

Radiographic Findings.

This section of the template provides the radiologist/volume interpreter with a list of specific areas within the volume to be evaluated. A standard listing would include:

- Maxilla
- Paranasal Sinuses
- Nasal Cavity
- Air Space
- TMJ
- Other Findings

Dental Findings.

The radiologist will provide limited comments in this section and typically WILL NOT report on caries, calculus, or periodontal disease associated with individual teeth. Typically, third molar positions will not be reported unless specifically requested by the clinician because the interpretation of these anomalies are within the diagnostic skill-set of the dentist.

- **Clinical Significance:** Provides a summary of radiographic findings for the clinician to quickly identify areas of normality and abnormality within the patient volume. *Note:* With a digital template for reports, these areas may have a “normal” response listed and subsequently edited as necessary when

variations from the normal appearances are identified. For example, maxilla: no abnormalities detected; sinuses: no abnormalities detected, the right and left osteomeatal complexes were patent; nasal cavity: no abnormalities detected, etc. for each area on the list.

Radiographic Impression.

This section of the report template will identify specific variations and deviations from "normal" for each of the areas listed under the radiographic findings and provide the radiologist's impression of the deviation from normal.

- **Clinical Significance:** Provides a summary of radiographic findings providing the clinician with a differential radiographic interpretation of deviations from normal.

Recommendations.

This section may be combined with the radiographic impression noted above. However, it may be separated to provide general recommendations for clinician guidance related to the findings listed within the radiographic impression section. The "Recommendations" section would most likely include statements such as "Physician referral for more thorough evaluation of ¼." Included here would be any anomaly NOT within the dental scope of practice as defined by your state licensing board. Other recommendations might include: "Biopsy suggested/recommended for more thorough evaluation of the biologic processes involved in ¼." For example: a large cystlike lesion in the anterior dental area could represent a cyst of the incisive canal/foramen, large radicular/periapical cyst, ameloblastoma, or central giant cell tumor, and a biopsy would be helpful in identifying the specific biologic nature of the lesion.

- **Clinical Significance:** Provides the clinician with general guidance related to a specific anomaly. *Note:* In general, the radiologist WILL NOT recommend a specific type of treatment for any finding because this is a consultative report that the clinician must integrate into the patient's overall treatment plan and outcome assessment.

Radiologist Name and Signature

- **Clinical Significance:** Critical/patient record information.

Typical Radiographic Descriptions

Mucositis/sinusitis: "The right maxillary and sphenoid sinuses exhibited an increase in the thickness and density of the sinus lining."

Mucous retention pseudocyst: "A homogeneous ovoid/dome-shaped increase in density was noted within the left maxillary sinus."

Sinusitis: "The right maxillary sinus was partially occupied by homogeneous area of increased density containing bubbles."

Osteomeatal complex: if the opening is not clearly visible, it should be reported as obstructed/blocked.

Other, less common sinus findings: a thickening, irregularity, and sclerosis of the walls of the sinus may potentially represent a longstanding chronic inflammation of the sinuses. Small irregular calcifications within the homogeneous density of the tissues of the sinus may be an indication of antrolith formation, and an indication of a longstanding chronic sinusitis and small osteomas within the ethmoid sinus.

Radiographic Findings

Maxilla.

Asymmetries between right and left maxilla or sinuses, changes in bone pattern or texture.

Typical report findings might read: "An asymmetry was noted between the right and left maxillary sinuses; the right maxillary sinus and maxilla exhibits a smaller volume and size than the left, potentially suggestive of maxillary hypoplasia. Correlation of the radiographic observation with the patient's clinical evaluation is suggested."

- **Clinical Significance:** Identification of possible hemimaxillary hypoplasia, previous trauma, fibrous dysplasia.

Sinuses.

This section will report on findings within all major sinus groups: right and left maxillary, ethmoid, frontal and sphenoid sinuses. Under "normal" circumstances the linings of the sinuses are not radiographically visible and

are reported as “no abnormalities detected.” When the lining becomes visible, sinus pathology is present and reported if the lining is 3 mm or more in thickness.

Typical report findings might read: “The radiographic findings appear consistent with a mild chronic sinusitis of the right and left maxillary sinuses. Review of patient's history for chronic sinusitis/allergy is suggested. Physician referral for more thorough evaluation is suggested if merited by clinical findings and symptoms.”

- **Clinical Significance:** Identification of potential changes on the sinus region meriting potential physician referral in the presence of symptoms.

Nasal Cavity.

This section will include any findings of asymmetry associated with the nasal cavity including: inferior, middle, and superior turbinates; deviations of the nasal septum; absence of internal nasal structures potentially associated with previous ENT surgery. A variation in normal anatomy is a dilation within the middle turbinate referred to as a *concha bullosa*.

Typical report findings might read: “A mild deviation the nasal septum to the right; enlargement of the middle turbinate consistent with a concha bullosa, is considered a variation in normal anatomic form. Deviation of the nasal septum is considered a variation in normal anatomy; referral and treatment is not indicated unless the patient provides a history of difficulty breathing through their nose.”

- **Clinical Significance:** Identification of possible changes in the nasal cavity potentially influencing breathing patterns.

Air Space.

Variations in the size of the airway are noted in the section as well as potential enlargements of the adenoid and pharyngeal tonsils.

Typical report findings might read: “Narrowing of the airway has been associated with a variety of respiratory disorders including an increased risk of obstructive sleep apnea. Correlation of the radiographic observation with the patient's clinical history is suggested. Clinical evaluation of the soft tissues of the oral pharynx is suggested.”

- **Clinical Significance:** Identification of possible airway changes affecting patient breathing patterns.

TMJ.

This section reports on variations and deviations in symmetry between the right and left condyles, articular fossae, and joint spaces.

Typical report findings might read: "The right condyle, articular fossa, and joint space exhibited normal bony profiles and contours; the left articular fossa and joint space exhibited normal radiographic contours; the left condyle exhibits a localized discontinuity the cortical outline, the presence of resorption lacunae, and sclerosis of the underlying bony trabecular pattern consistent with DJD. Correlation of the radiographic observation with the patient's clinical findings and symptoms, if any, is suggested."

- **Clinical Significance:** Identification of possible radiographic changes within the bony structures of the TMJ region affecting patient symptoms/occlusion. TMJ-positive findings may predispose the patient to prosthetic rehabilitation complications.

Other Findings.

This section is used to report radiographic changes in anatomic structures not associated with the maxilla and mandible but included within the volume including, but not limited to: calcifications within the carotid artery lateral to the pituitary fossa and within the lower neck; radiographically visible changes within the cervical vertebra including osteophyte formation, sclerosis, narrowing, and irregularity of intervertebral disk space width with potential bone to bone contact; generalized loss or thinning of cortical bone and an absence of internal bony trabeculation suggestive of systemic metabolic disorders of bone/osteoporosis; increased density noted within one or both mastoid processes. Common incidental radiographic findings included here would be: calcification the stylohyoid ligament, calcifications of pineal gland and cavernous sinus (middle cranial fossa area), idiopathic soft tissue calcifications within the soft tissues of the skin or soft tissues of the oral pharynx (tonsilloliths), salivary gland/duct calcifications, metallic foreign bodies, ear wax, etc.

Styles of Radiology Reports

Each radiologist has their own style and format they use to construct a report, and it is appropriate for the referring clinician to do their "due diligence" and select the radiologist who will provide the kind of report they are comfortable using as a basis for treatment planning decisions. Examples

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of radiology report templates are shown in Fig. 4.52. For example, some radiologists specify that their review of the volume is through the assessment of "axial cross sections only," which limits the potential of visualization of radiographic anomalies when CBVT volumes and the software used easily provide axial, coronal, and sagittal cross sections. Our suggestion is to identify a radiologist who provides interpretation based on a complete analysis of the volume utilizing axial, coronal, and sagittal cross sections.

A. Minimal Information Report:

Patient Name: xxxx xxxxxxx DOB: 8/20/1991 Date: xx-xx-xxxx
Scanning Center: or dental office taking volume Gender: xxxx
Referring Doctor: xxxx xxxxxx Date of Scan: 5/26/15

Images provided: Cone Beam CT images in the bone window. Axial, coronal and sagittal planes. Closed and open scans provided.

Clinical Info: chronic headaches, jaw pain
Relevant History: not available
Client Notes: implant #3

Diagnostic Objectives:
Rule out pathology

Findings:
Axial, coronal, and sagittal cross-sections of the patient volume were reviewed. Radiographic findings potentially affecting your proposed treatment objectives were not identified.

Radiologist name and signature:
Thank you for the referral of this patient and the opportunity to serve your practice.

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B. Medical Style [written only, no illustrations] Report:

Patient Name: xxxx xxxxxxx DOB: 8/20/1991 Date: xx-xx-xxxx
Scanning Center: or dental office taking volume Gender: xxxx
Referring Doctor: xxxx xxxxxx Date of Scan: 5/26/15

Images provided: Cone Beam CT images in the bone window. Axial, coronal and sagittal planes.

Clinical Info: chronic headaches, jaw pain
Relevant History: not available
Client Notes: implant #3

Diagnostic Objectives:
Rule out pathology

Findings:
Maxilla: no abnormalities detected
Sinuses: a small dome shaped area of increased density was noted within the right maxillary sinus; the right and left osteomeatal complexes were patent.
Nasal Cavity: a deviation the nasal septum to the left was noted.
Mandible: no abnormalities detected
Air Space: no abnormalities detected
TMJs: Both condyles, their articular fossae and eminences exhibit good symmetry and apparently normal bony anatomy; no abnormalities of the bony structures were noted.
Other findings: Sclerosis and osteophyte formation, narrowing and irregularity of intervertebral disc space width with bone to bone contact was noted within the cervical vertebra.
Dental findings: no abnormalities detected

Radiographic Impression:
Sinuses: the radiographic findings appear consistent with a mild chronic mucositis/sinusitis/mucus retention pseudocyst. Review of patient's history for chronic sinusitis/allergy is suggested. Physician referral if merited by clinical findings and symptoms.
Nasal Cavity: deviation of the nasal septum is considered a variation in normal anatomy; referral and treatment is not indicated unless the patient provides a history of difficulty breathing through their nose.
Other Findings: Sclerosis and osteophyte formation, narrowing and irregularity of intervertebral disk space width with bone to bone contact within the cervical vertebra may be indications of DJD of the cervical spine. Correlation of the radiographic observation with the patient's clinical findings and symptoms of chronic neck/muscle pain/headache or other neurological symptoms is suggested. Physician referral is suggested for more thorough evaluation if merited by clinical findings and symptoms.

Radiologist name and signature:
Thank you for the referral of this patient and the opportunity to serve your practice.

Comment: Using the medical model style of radiology report, the radiologist provides a written description of radiographic findings but does not provide illustrations of the various findings or implant measurements.

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C. Hybrid Medical with Illustrations

Patient Name: xxxx xxxxxxx DOB: 8/20/1991 Date: xx-xx-xxxx
Scanning Center: or dental office taking volume Gender: xxxx
Referring Doctor: xxxx xxxxxx Date of Scan: 5/26/15

Images provided: Cone Beam CT images in the bone window. Axial, coronal and sagittal planes.

Clinical Info:
Relevant History:
Client Notes:

Diagnostic Objectives:
1. TMJ Evaluation
2. Rule Out Pathology
etc.

Findings:
Maxilla: no abnormalities detected
Sinuses: no abnormalities detected
Nasal Cavity: no abnormalities detected
Mandible: no abnormalities detected
Air Space: no abnormalities detected
TMJs: no abnormalities detected
Other findings: no abnormalities detected
Dental findings: no abnormalities detected

Radiographic Impression:

Recommendations:

Radiologist name and signature:
Thank you for the referral of this patient and the opportunity to serve your practice.

Comment: Many maxillofacial radiologists provide a hybrid medical model style of report that will include selected images illustrating various radiographic findings. The referring clinician values this kind of report because the illustrations provided allow them to evaluate the severity of the conditions the radiologist has identified and can be used to educate the patient with regard to the radiographic findings.

Patient referral to a physician for additional evaluation based on a radiology report does not have clearly defined guidelines and clearly professional clinical judgment is the key, taking into consideration and integrating clinical findings and patient symptoms. We as healthcare providers have an underlying responsibility to refer patients for additional evaluation when considered appropriate; however, we cannot force our patients to go to physicians if they do not choose to. As a result, documenting in the patient's chart that the radiology report indicated the presence of potential pathology in an area outside of our scope of practice and that the patient was requested to seek a more thorough examination from a physician regarding the condition is prudent and critical.

FIG 4.52 Sample radiology report. (A) Minimal information report. (B) Medical style (written only, no illustrations). (C) Hybrid medical style with illustrations.

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Summary

One of the keys to preventing potential complications during the surgical and prosthetic phases of implant treatment is to have as clear a picture of the patient's current anatomic makeup as possible. Identifying deficiencies of bone allows the clinician to modify the bony architecture to achieve optimal implant location for prosthetic success. Knowing the exact locations of vital structures allows clinicians to plan safe zones during treatment to avoid potentially catastrophic complications. Proper planning is absolutely paramount to success in any endeavor, and having a strong plan in place prior to the initiation of implant treatment is no exception.

Cone beam technology has ushered in a new era of accuracy in treatment planning. Clinicians are no longer having to rely on “guesswork” by extrapolating anatomical measurements from a distorted 2-D image. Templates may be made based on these new 3-D images to assist clinicians during tough surgical cases, especially early on respective learning curves. CBT is closer to becoming the standard of care across the board.

With the combination of 3-D imaging and a thorough knowledge of the anatomic areas that are focused on in this chapter, a clinician can acquire a further degree of confidence that the likelihood of complications has been reduced, which makes the implant treatment process less stressful for both patient and provider.

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Dental Implant Intraoperative Complications

Randolph R. Resnik

The surgical placement of dental implants, once a very specialized treatment modality, has become a very mainstream component of contemporary dentistry. This has been made possible by advancements that have made dental implant procedures very predictable with high success rates. Despite this level of success, there still exist many potential complications that can occur at any phase of the implant surgical procedure. During any implant surgery the potential for a complication exists, ranging from simple issues to situations that could potentially place the patient at increased risk. The goal of this chapter is to provide the implant clinician with a knowledge base to properly address many of the common and uncommon complications that may occur during the implant surgical phase.

Implant Placement: Surgical Related

Placement of Implants Into Sites With Preexisting Pathology

Infection or bacteria at or adjacent to a potential implant site is a significant source for future implant morbidity. Placement of an implant close to an infected site or into a previous extraction site with bacterial contamination may lead to the loss of the implant and/or loss of the adjacent tooth. Ayangco et al reported that teeth with failed endodontic lesions that were extracted, debrided, and sufficiently healed, are at risk of possible retrograde peri-implantitis after implant placement.[1]

Etiology

Bacteria present at the time of surgery places the implant at risk. Endodontically infected teeth have involved bacteria, which are most commonly *Propionibacterium acnes, Staphylococcus epidermidis, Streptococcus intermedius, Wolinella recta,* and *Porphyromonas* and *Prevotella* spp.[2] *Bacteroides* spp bacteria have been shown to inhabit natural tooth periapical lesions that are encapsulated in a polysaccharide that enhances its virulence and survival ability. *Bacteroides forsythus* has been shown to be present in asymptomatic periradicular endodontic lesions and may survive encapsulated in bone even after extraction and debridement.[3]

Prevention

The surgical site should be evaluated radiographically prior to the surgery for any possible apical pathology. The adjacent teeth should be assessed for the presence of periodontal ligament (PDL) thickening or radiolucent areas that may impinge on the area of implant placement. Brisman et al reported that even asymptomatic endodontically treated teeth with normal radiographic appearance could result in implant morbidity. They relate the possibility of inadequate obturation with an incomplete seal on the tooth root that may contain bacteria, even when they are free of symptoms.[4] Nelson and Thomas revealed in studies that bacteria persist and are reactivated upon implant placement even after debridement of apical infection, complete extraction socket healing, and alveolar bone remodeling.[5] Kassolis et al reported that edentulous jaws will contain regions of bacterial biofilm and nonvital bone

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for over 1 year after extraction, and healing may pose a significant risk for future implant failure.[6]

Treatment

Endodontic therapy, apical surgery, or extraction of the adjacent tooth should be completed prior to placement of dental implants in this area. Even in the absence of infection, extraction sites should be thoroughly debrided and bleeding initiated to reduce the bacteria count and increase bone growth factors to the site. If granulation tissue remains, bacteria and a resultant inflammatory response will persist. Special curettes may be used to assist in the removal of the granulation tissue and small round burs (#2 or #4) can be used to perforate the alveolar walls to increase bleeding areas (Fig. 5.1).

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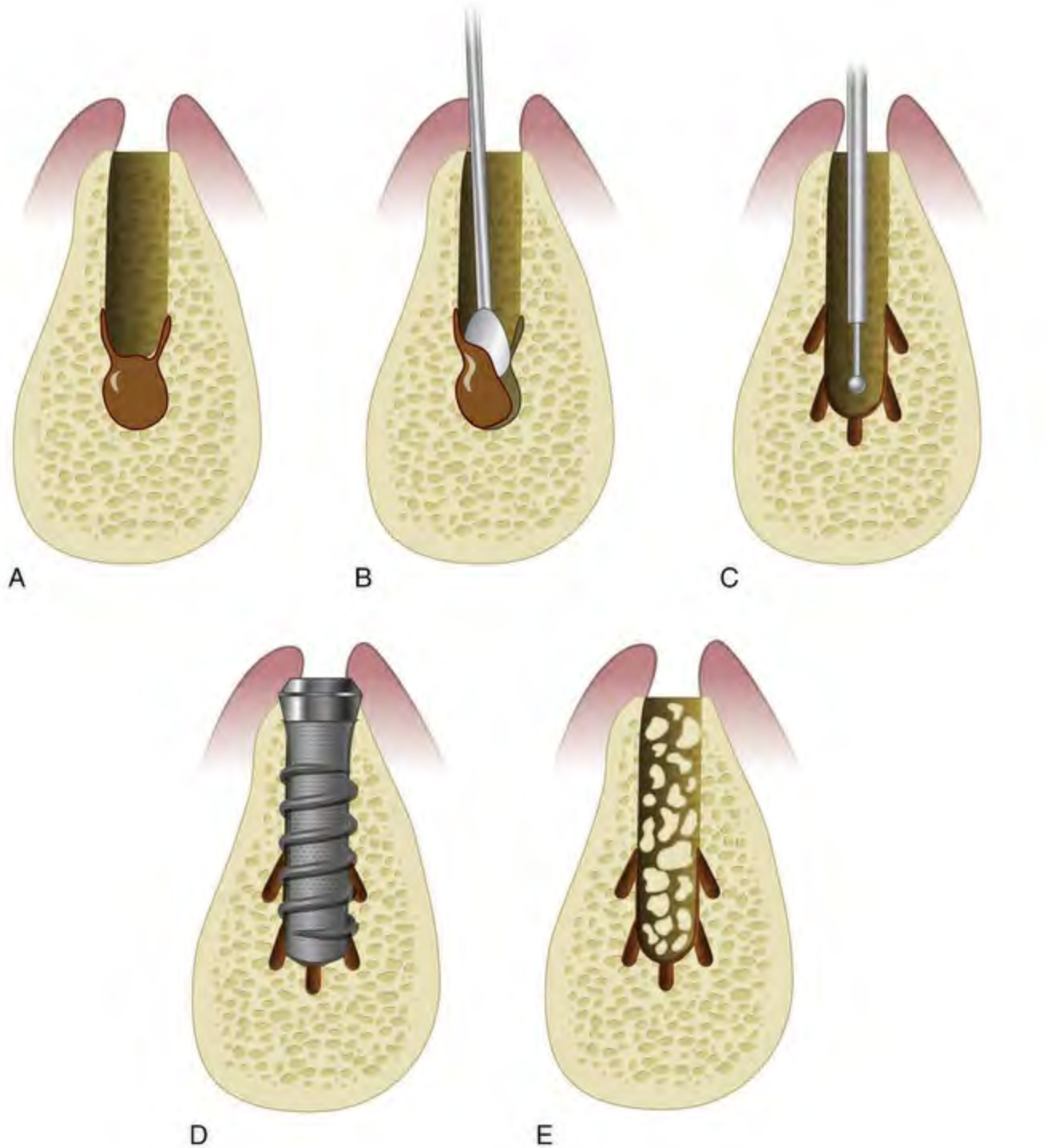

FIG 5.1 Postextraction socket. (A) With existing pathology. (B) Removal of fibrous and granulation tissue with serrated spoon curette. (C) Walls of extraction site are decorticated with #2 or #4 round bur to initiate regional acceleratory phenomenon (RAP). (D) After complete removal of all bacteria and tissue, implant placement. (E) If the extraction site is compromised, a bone graft procedure is recommended.

Retained Root Tips in Implant Site

Placement of dental implants into extraction sites that contain retained tooth roots may lead to inflammation and retrograde peri-implantitis. Unfortunately, in some cases, root tips are difficult to diagnosis preoperatively, the condition may go unnoticed until after implant placement.

Etiology

Placement of dental implants, especially after immediate extraction, may lead to undiagnosed retained root tips at the site of implantation. Gray et al, in an animal study, evaluated the intentional placement of dental implants into tooth roots. Histologically, there was no inflammation, and in some of the specimens a calcified material was deposited on the implants. Buser et al also supported the same findings in animal studies. However, implants should never be placed in contact with tooth structure because this may be a source of infection and place the practitioner at risk for possible medicolegal issues.

Prevention

To prevent retained tooth roots, atraumatic and careful extraction of teeth should be completed. Special care should be exercised with multirooted teeth and tooth roots with dilacerations. Preoperative evaluation should include a CT evaluation with the following Hounsfield numbers as a guide (Fig. 5.2):

Air = − 1024 Hu

Water = 0 Hu

Trabecular bone ≅ 200 Hu

Cortical bone ≅ 1500 to 2000 Hu

Tooth structure—Enamel ≅ 3072 Hu

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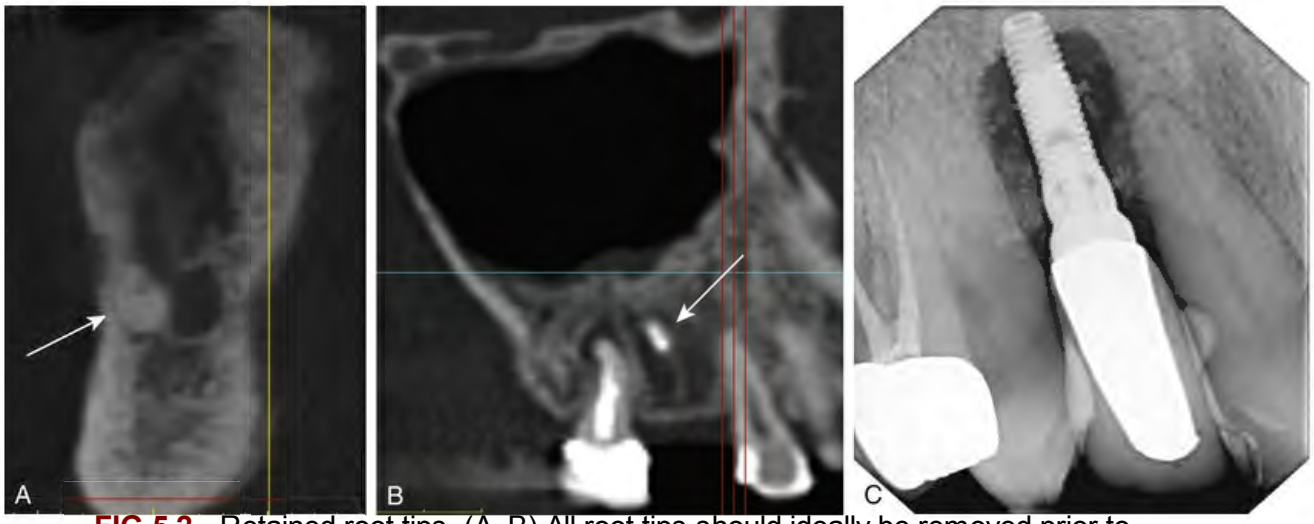

FIG 5.2 Retained root tips. (A–B) All root tips should ideally be removed prior to bone graft or implant placement. (C) Retained bacteria, granulation tissue, or tooth root may lead to increased morbidity after implant placement.

Treatment

Prior to Placement.

Root tips should be removed and the site evaluated for implant placement. If an inadequate amount of bone is present, grafting should be completed followed by implant placement at a later date.

After Implant Placement.

If a root tip is discovered after implant placement, the site should be evaluated on a strict recall basis. If any signs of inflammation develop, the implant and root tip should be removed, grafted, with implant placement at a later date (Figs. 5.2 and 5.3).

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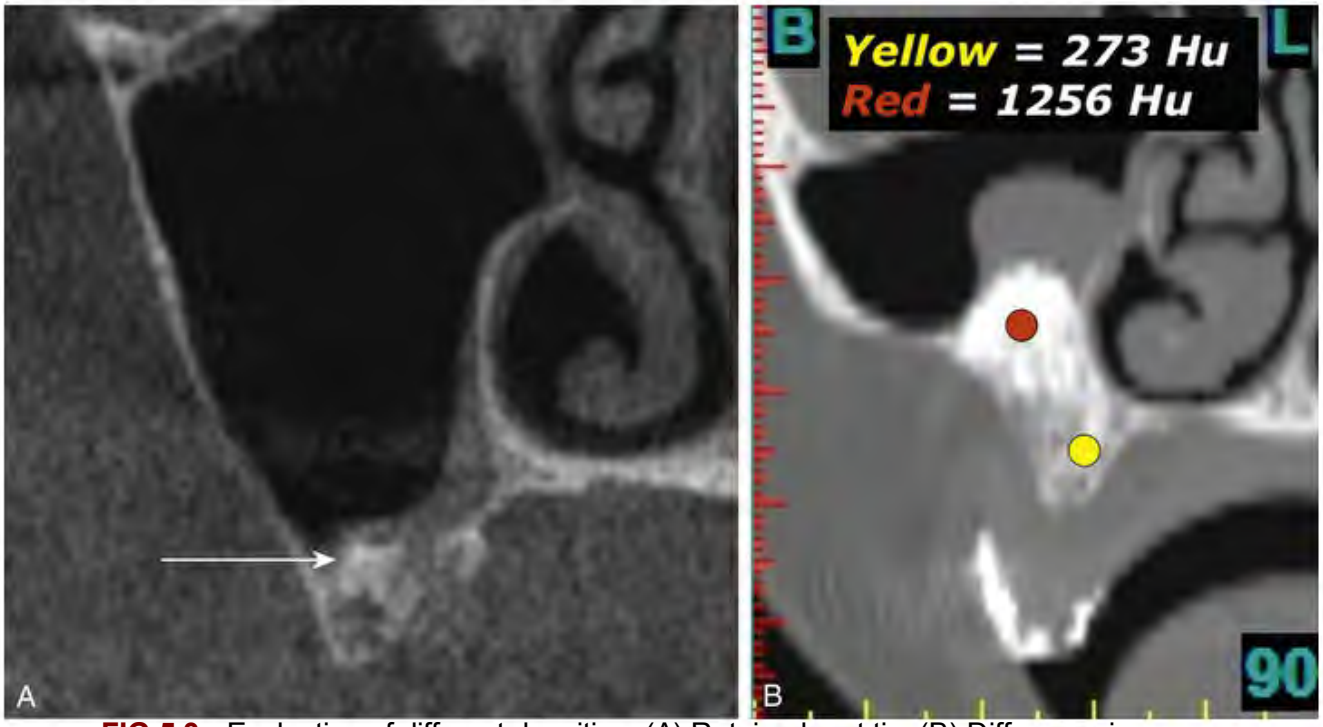

FIG 5.3 Evaluation of different densities. (A) Retained root tip. (B) Difference in host bone vs. grafted bone utilizing medical grade CT imaging (Hounsfield units) and showing different bone densities.

Flapless Surgery

Flapless surgery has become very popular today in implant dentistry. This technique entails no reflection of the crestal soft tissue and placement of the implant through the opening for the osteotomy. The advantages of flapless surgery are: (1) no soft tissue reflection, decreasing the invasiveness of the surgery; (2) minimizes bleeding; (3) reduces inflammation and pain; (4) hard and soft tissue preservation, which maintains vascular supply and soft tissue drape; and (5) no suturing.

Etiology

However, flapless surgery does have disadvantages that may be detrimental to the prognosis of dental implants. These include: (1) inability to assess the bone volume before or during the implant osteotomy and insertion; (2) inability to ascertain perforation of the cortical plates; (3) tissue punches are often used, which may result in decreased keratinized tissue; (4) difficulty in visualizing crestal bone area, resulting in the inability to determine apicocoronal positioning; (5) possibility of overheating the bone and causing thermal damage, especially if a tissue borne surgical template is used; and (6)

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possibility of soft tissue entrapment into the osteotomy site, which may lead to a retrograde infection (Fig. 5.4).

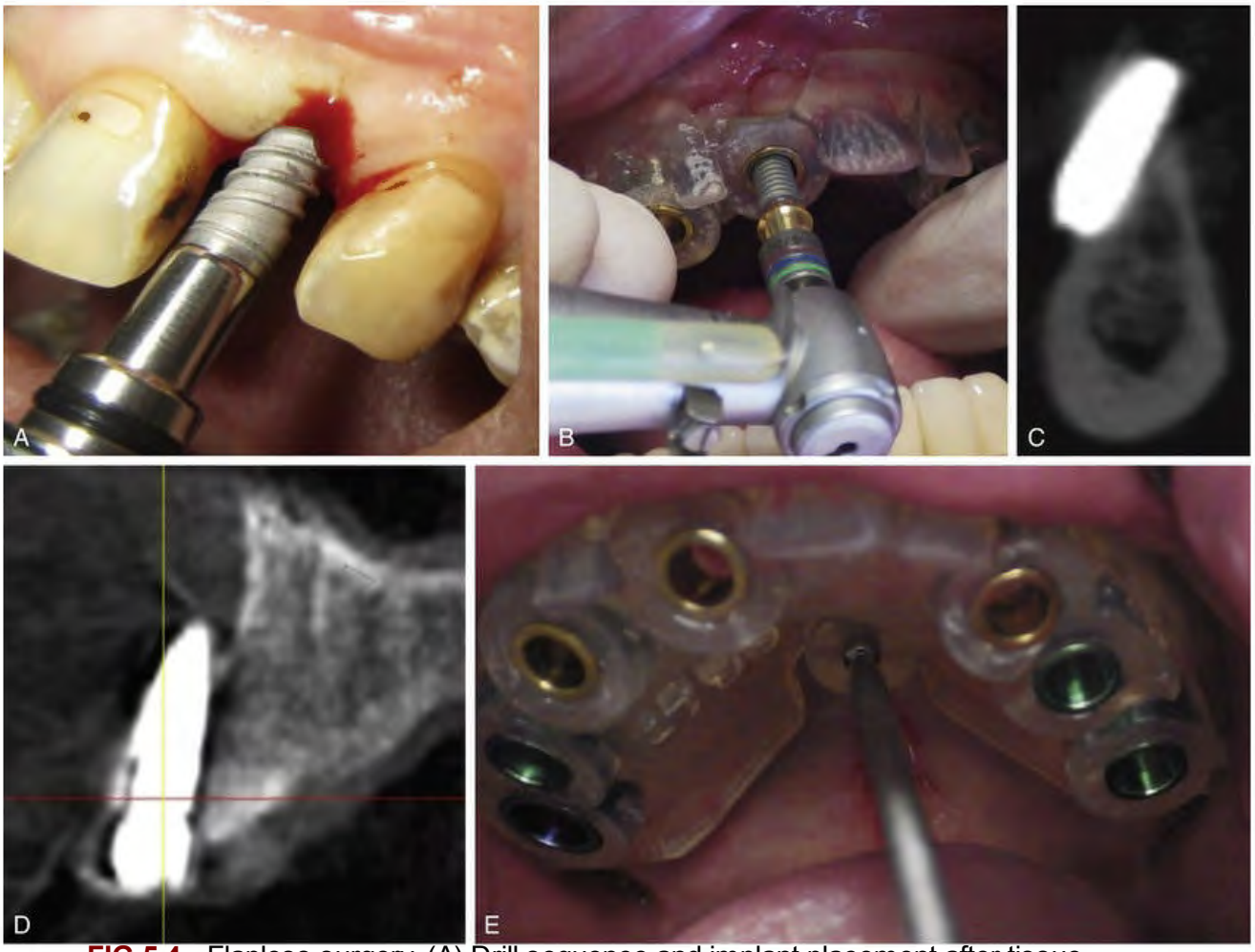

FIG 5.4 Flapless surgery. (A) Drill sequence and implant placement after tissue punch. (B) Osteotomy preparation and implant placement through surgical template. (C) Flapless surgery leading to lingual position of implant, with the complication of traumatizing the lingual tissue and vital structures in the mandible. (D) Maxillary anterior flapless surgery leading to implant placed facially, completely out of the bone. (E) Tissue surgical templates should be fixated with bone screws to minimize possibility of malposition.

Prevention

A thorough preoperative evaluation should be completed including a three-dimensional analysis of the available bone and anatomic variants. Use of cone beam computed tomography (CBCT)–generated surgical templates is recommended. Care should be noted in Division B or Division C ridges because ideal placement is difficult.

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Treatment

Flapless implant placement should only be completed in the presence of adequate keratinized tissue and sufficient bone quantity and angulation, where root approximation is not an issue. If bone quantity is compromised, the surgical approach should be changed to an exposure (flap) procedure to verify ideal placement and angulation.

Malpositioned Initial Osteotomy Site

In certain initial osteotomies, the initial implant position may not be placed in the ideal location. The osteotomy may need to be repositioned to allow for ideal placement. The use of a Lindemann bur is ideal for the repositioning of an osteotomy because of its side-cutting capabilities. Lindemann burs are side-cutting burs, which allow easy positional change with minimal trauma to the bone.

Etiology

Once the initial osteotomy is prepared, it is assessed for proper position with a direction indicator. If incorrect, the osteotomy site may need to be "stretched" or repositioned to a more ideal location.

Prevention

Use of surgical templates or implant-positioning devices for ideal implant positioning to decrease the possibility of changing the osteotomy position.

Treatment

To horizontally reposition an osteotomy site, the use of conventional drills is difficult because of the end-cutting capabilities of the burs. The use of a side-cutting Lindemann bur will allow for repositioning to a new, corrected site. The new osteotomy position should be deepened so that subsequent end-cutting drills will not reposition back into the original osteotomy site. However, when using the Lindemann bur, always use copious amounts of saline because this bur will generate a significant amount of trauma and heat to the bone[7] (Fig. 5.5).

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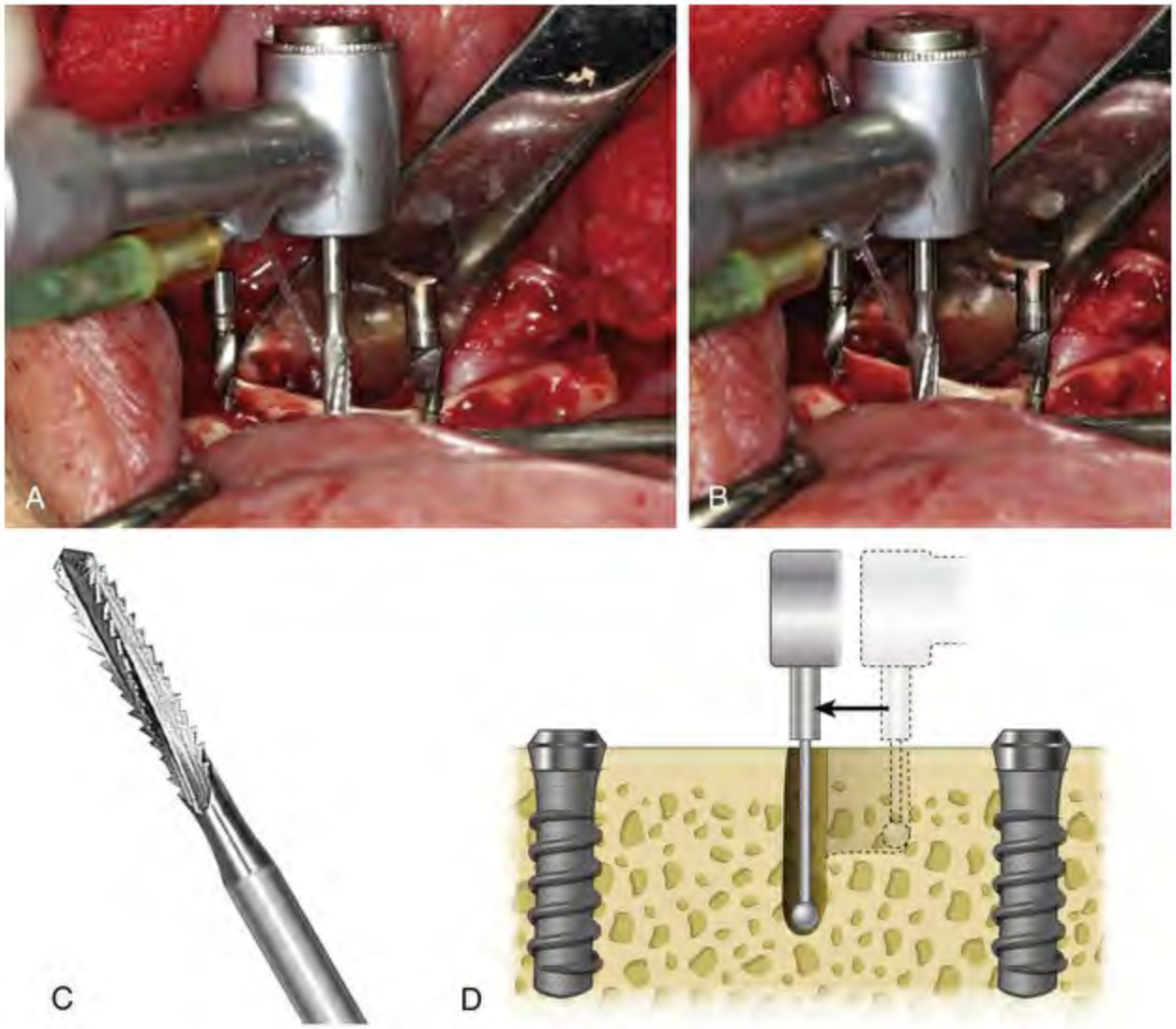

FIG 5.5 Malpositioned initial osteotomy site (i.e., not equidistant between implants). (A) Implant position too close to center implant. (B) Use of Lindemann bur to move the implant site posteriorly. (C) Side-cutting Lindemann bur. (D) Lindemann bur used to reposition osteotomy site by increasing osteotomy depth to prevent from entering back into original malpositioned site.

Lack of Keratinized Tissue at Surgical Site

The presence of keratinized tissue is a controversial subject in oral implantology. However, there appear to be greater benefits with having this tissue in relation to an implant when compared to a natural tooth. Some reports indicate the lack of keratinized tissue may contribute to implant failure.[8]

Etiology

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Mobile, nonkeratinized mucosa has been shown to exhibit greater probing depths, which has been confirmed histologically. The absence of keratinized mucosa also increases the susceptibility of periimplant regions to plaque-induced destruction.[9] Additional studies have shown that mobile mucosa may disrupt the implant-epithelial attachment zone and contribute to an increased risk of inflammation from plaque.[10] For larger edentulous ridges, the zone of attached tissue on the facial flap (mandible) provides greater resistance for the sutures against tension of the mentalis muscle in the anterior region and the buccinator muscle in the molar-premolar regions, which often cause incision line opening. As a result, an incision made facial to the attached tissue may cause partial ischemia to some of the crestal tissue. In addition, the incision in unkeratinized facial tissue also severs larger blood vessels, which increases bleeding and decreases vision during surgery, while also potentially complicating final suturing (Fig. 5.6).

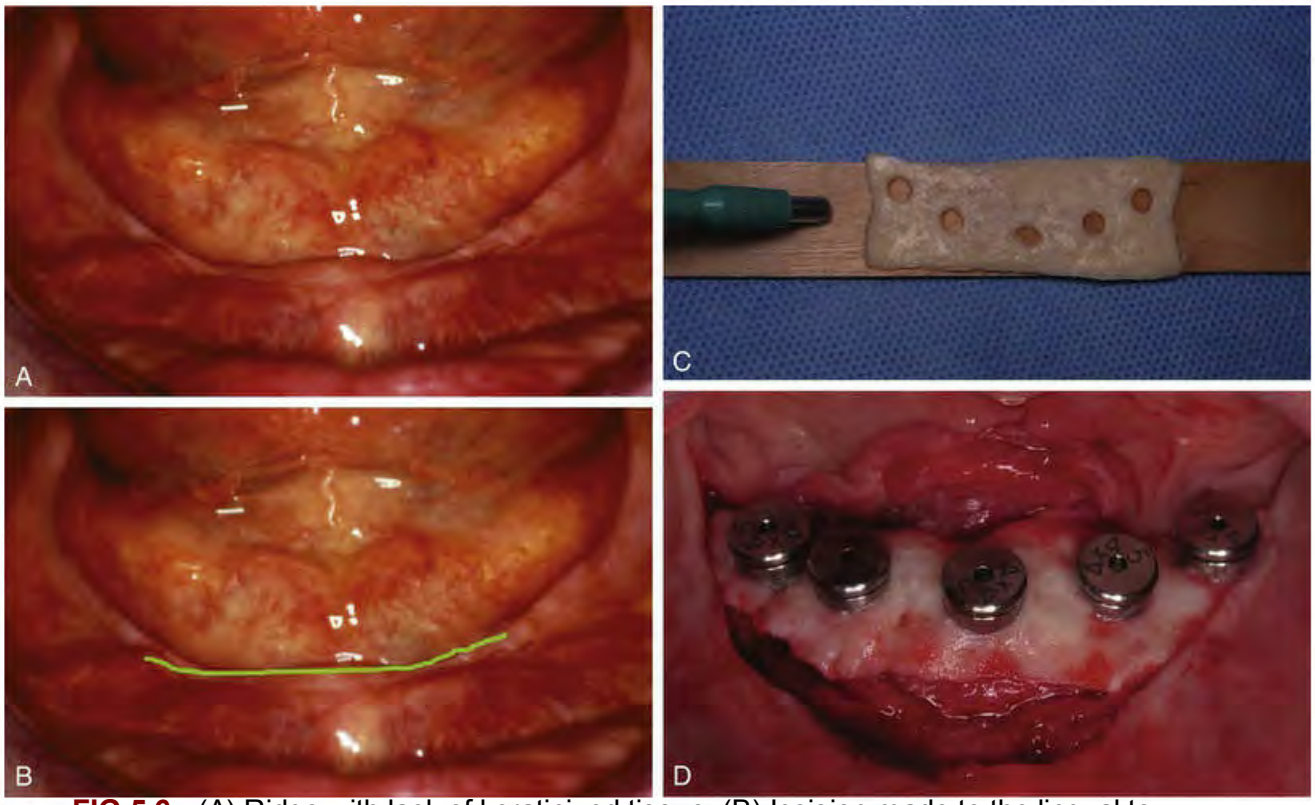

FIG 5.6 (A) Ridge with lack of keratinized tissue. (B) Incision made to the lingual to maintain as much attached tissue on facial as possible. (C) Dermal accelular matrix (e.g., OraCELL [Salvin Dental Specialties, Inc.]) modified with a tissue punch. (D) Dermal matrix placed over implants prior to closure.

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Prevention

A thorough clinical examination to determine the amount of host-attached tissue prior to surgery and the possible implementation of tissue grafting prior to implant placement.

Treatment

For implant sites intended for crown restorations, an evaluation of attached tissue should be done. If insufficient attached tissue is present, tissue augmentation procedures should be completed prior to implant placement. For larger edentulous sites, especially in the mandible, the incision may be modified to maintain the attached tissue in some cases. If the crest of the ridge is above the floor of the mouth, and there exists greater than 3 mm of attached, keratinized gingiva on the crest of the ridge, a full-thickness incision is made, bisecting the attached tissue. If less than 3 mm of attached gingiva exists on the ridge, the full-thickness incision is made more to the lingual so that at least 1.5 mm of the attached tissue is to the facial aspect of the incision line. Additionally, AlloDerm may be used as a membrane and to increase the amount of attached tissue.

Bur “Stuck” in Bone During Osteotomy

Etiology

Often in hard bone (≈D1–D2 bone), if the handpiece is stopped with the surgical drill in the bone, it may be difficult to remove out of the osteotomy. Attempting to remove the bur with the handpiece (either forward or reverse) will result in damage to the handpiece gears (Fig. 5.7).

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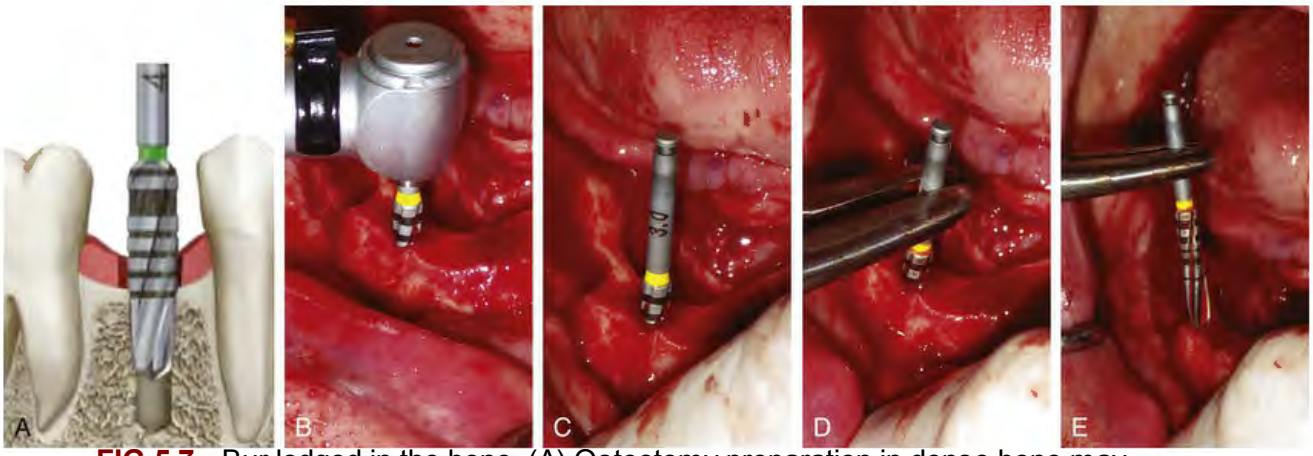

FIG 5.7 Bur lodged in the bone. (A) Osteotomy preparation in dense bone may result with internal stress within the prepared site leading to difficulty in bur removal. (B) When bur cannot be removed, do not attempt to use handpiece in reverse direction because this may cause damage to the handpiece. (C) Handpiece disengaged from bur. (D) Bur gently removed with forceps in counterclockwise direction. (E) Bur removed carefully to minimize possibility of fracturing buccal plate.

Prevention

To avoid this complication, in dense bone small (minimal) increments of bone should be removed at a time. When performing the osteotomy, "bone dancing" should be performed, which will result in less stress to the bone and will allow for ease of widening the osteotomy. Also, by using intermediate burs (more burs close in diameter), smaller amounts of bone are removed at a given time, decreasing the possibility of burs being lodged in the bone ("bur integration").

Treatment

If a bone drill becomes lodged in the bone during preparation, the hand piece should not be wiggled back and forth to disengage the drill. This may increase the size of the bone preparation, cause injury and necrosis to the bone, or separate the drill above or below the bone. Instead, the drill is disengaged from the handpiece and gently rotated counterclockwise with forceps or rongeurs.

Overpreparation of Final Drill

Etiology

The final drill is the most critical surgical step in the osteotomy preparation. The bone surrounding this drill will be in direct contact with the implant.

When the final drill preparation is not precise, the implant-bone region may be irregular with gaps that may decrease initial stability and lead to early implant failure. A decreased initial bone contact of the host bone and dental implant also decreases the percentage of new bone-implant contact formation (Fig. 5.8).

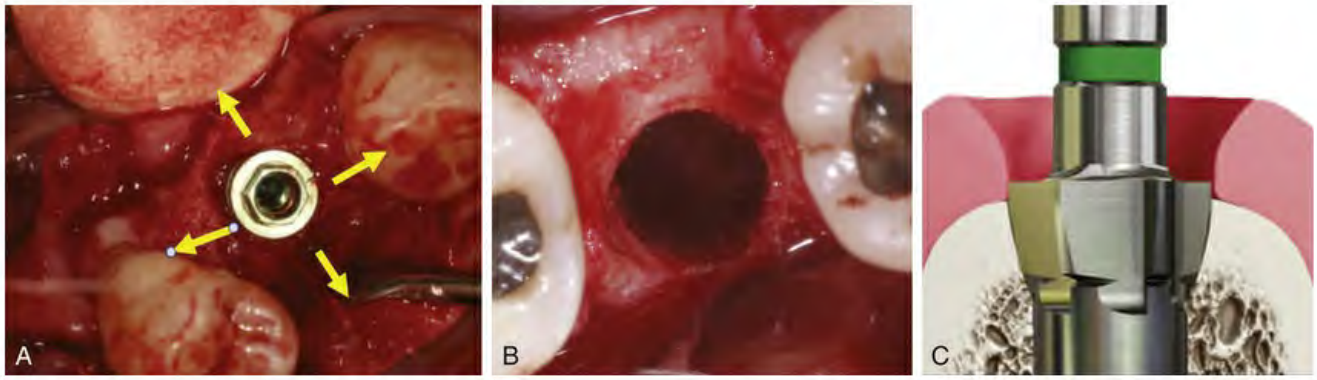

FIG 5.8 (A) Overpreparation of the osteotomy site that results in mobility and lack of bone implant contact. (B) Irregular osteotomy site showing overpreparation of site. (C) In less dense bone (lack of cortical bone), no crestal bone drill should be used because this will result in lack of stability of the implant.

Prevention

A constant pressure and angulation is used with the final drill to ensure that a precise, round osteotomy is prepared. The most important factor is the use of the final drill only once to avoid over preparation, most importantly in less dense bone (≈D3–D4). In D4 bone the final bur is often not used to increase bone-implant contact (BIC) around the implant. Additionally, in less dense bone a crestal bone drill should never be used because of increased loss of initial fixation.

Treatment

If overpreparation of the osteotomy site occurs, clinical evaluation should be completed to determine if mobility of the implant exists. If mobility does exist, the following are possible options; however, it is imperative that the final placement of the implant not have any micromovement:

Compress Buccal and Lingual Cortical Plates.

In less dense bone, the buccal and lingual cortical plates can be depressed to

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reduce movement of the implant. The implant should then be evaluated for micromovement. If movement exists, the implant should be removed.

Remove Implant, Deepen Osteotomy.

The mobile implant may be removed, and the osteotomy deepened so that rigid fixation is obtained. However, care should be exercised to not allow encroachment on any vital structures (e.g., mandibular canal) or compromise the prosthesis by increasing the crown-implant ratio.

Remove Implant, Place Wider Implant.

If sufficient width of bone is present, the implant may be removed and a wider implant placed to obtain rigid fixation. Usually, the osteotomy site does not need to be further prepared for the wider implant. However, a minimum of 1.5 mm of bone should be present on the facial aspect of the ridge after implant placement.

Remove Implant, Graft, Let Heal.

Usually, the ideal technique for a mobile implant, which will lead to decreased implant morbidity, is to remove the mobile implant, graft the site, and allow for sufficient healing prior to implant placement.

Remove Implant, Graft, Replace Implant.

An often-used technique, which has the highest possibility of complications, is removing the mobile implant, replacing the implant, and grafting the areas with little bone contact.

Facial Dehiscence After Implant Placement

After implant placement, it is not uncommon to have facial plate dehiscence on the buccal aspect of the implant. Because bone resorbs from the facial aspect, usually less than 1.5 mm of facial bone is present after final implant placement. Thus, if inadequate bone is present, this may lead to future soft tissue complications and increased implant morbidity.

Etiology

Bony defects at the crest after implant placement will usually result in lack of available bone width at the ridge level (Fig. 5.9) (e.g., a division B ridge that is

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compromised in width ~<6 mm).

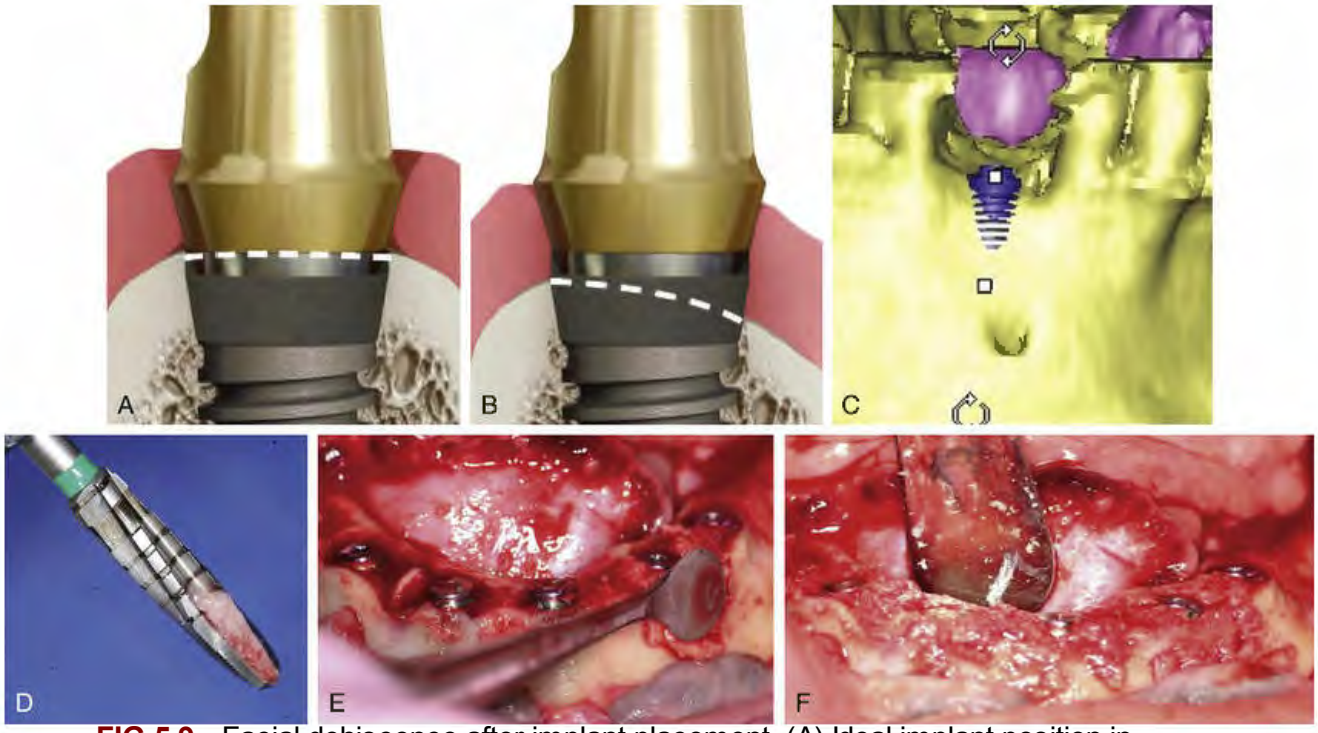

FIG 5.9 Facial dehiscence after implant placement. (A) Ideal implant position in relation to ridge. (B) When lingual bone is higher than buccal bone, implant placement will result in a facial bony dehiscence. (C) 3-D image of implant placement in division B bone. (D) Autograft from osteotomy site. (E) Defects packed with autograft. (F) All sites grafted with bone retained within surgical drills prior to closure.

Prevention

All ridges should be modified to obtain a division A bone (e.g., >6 mm width and >12 mm of bone height) before osteotomy initiation. After implant placement, 1.5 mm of facial bone should be present or the area should be grafted.

Treatment

After implant placement, if there exists less than 1.5 mm of bone on the facial aspect of the ridge, the site may be grafted with autogenous bone (ideally). The autogenous bone may be obtained from fragments gathered from the flutes of the surgical drills during the osteotomy preparation. The consistency of this bone allows for ease of packing, and the graft will have less of a chance of migrating. Allograft bone is not preferred because it tends

to migrate easily after placement and is an added expense.

Loss of Facial Plate When Placing an Implant

When placing implants in bone that is compromised in width (~division B), it is not uncommon to fracture or lose the facial plate of supporting bone. This leads to a compromise in the healing of the implant and the longevity of the implant and prosthesis.

Etiology

Ideally, the width of bone needs to exceed 6.0 mm for placement of a 4.0-mm diameter implant. When compromised width of bone exists, the trauma of the osteotomy or the placement of the implant may fracture or "pop off" the buccal plate. This is most likely the result of the buccal plate being thinner than the lingual plate, which results in the facial plate being more susceptible to fracture (Fig. 5.10).

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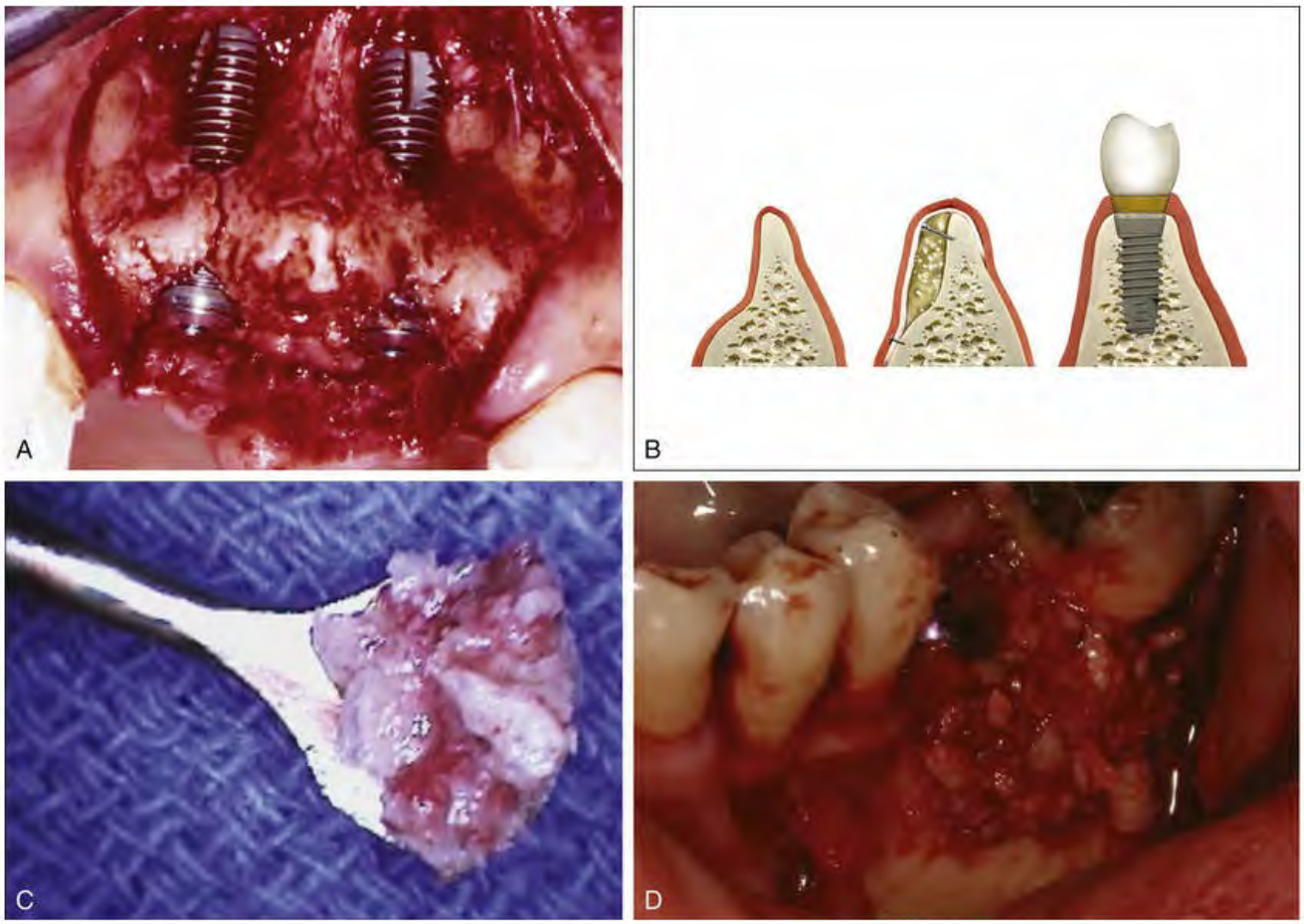

FIG 5.10 (A) Facial plate fracture leading to exposure of the implants after placement. (B) Prevention includes grafting site prior to implant placement to restore site to ideal dimensions prior to implant placement. (C–D) Grafting facial aspect of implant with autogenous bone harvested from surgical burs.

Prevention

Determine the available bone prior to implant placement. If nonideal width of bone is present, site development, including grafting, is indicated to obtain a division A bone. The osteotomy preparation should be in one plane, and care should be exercised to not deviate from the original angulation. If division B bone is present, ridge augmentation is recommended to achieve a division A ridge prior to implant placement.

Treatment

After implant placement, if a fracture or loss of the buccal plate exists, treatment will depend on the extent of the deficit.

Loss of Entire Buccal Plate.

If the entire buccal plate is lost or if mobility of the implant exists, the ideal treatment should include grafting then allowing for sufficient healing before implant placement.

Partial Buccal Plate Still Intact.

If no mobility of the implant is present and the facial plate is partially intact, the facial area can be grafted, ideally with autogenous bone from the osteotomy site (e.g., surgical drill).

Not Altering Surgical Protocol in Poorly Dense Bone

Many studies have shown the greatest risk of surgical failure is observed in the softest bone type (D4), especially when found in the maxilla. To combat this problem, Misch developed a different surgical protocol for the various bone qualities in 1988. The implant design, surgical protocol, healing times, treatment plans, and progressive loading time spans are unique for each bone density type.

Etiology

Fine trabecular (D4) bone has very little density with minimal to no cortical crestal bone. The most common locations for this type of bone are the posterior molar region of the maxilla in a long-term edentulous patient, in an augmented ridge (grafted for height and width with particulate bone or substitutes), or in a sinus graft.

The tactile sense during osteotomy preparation of this bone is similar to stiff, dense Styrofoam or soft balsa wood. The bone trabeculae may be up to 10 times weaker than the cortical bone of D1. The BIC after initial loading is often less than 25%. A CBCT scan with reformatted images of D4 bone has a Hounsfield number (or equivalent) of less than 375 units (Fig. 5.11).

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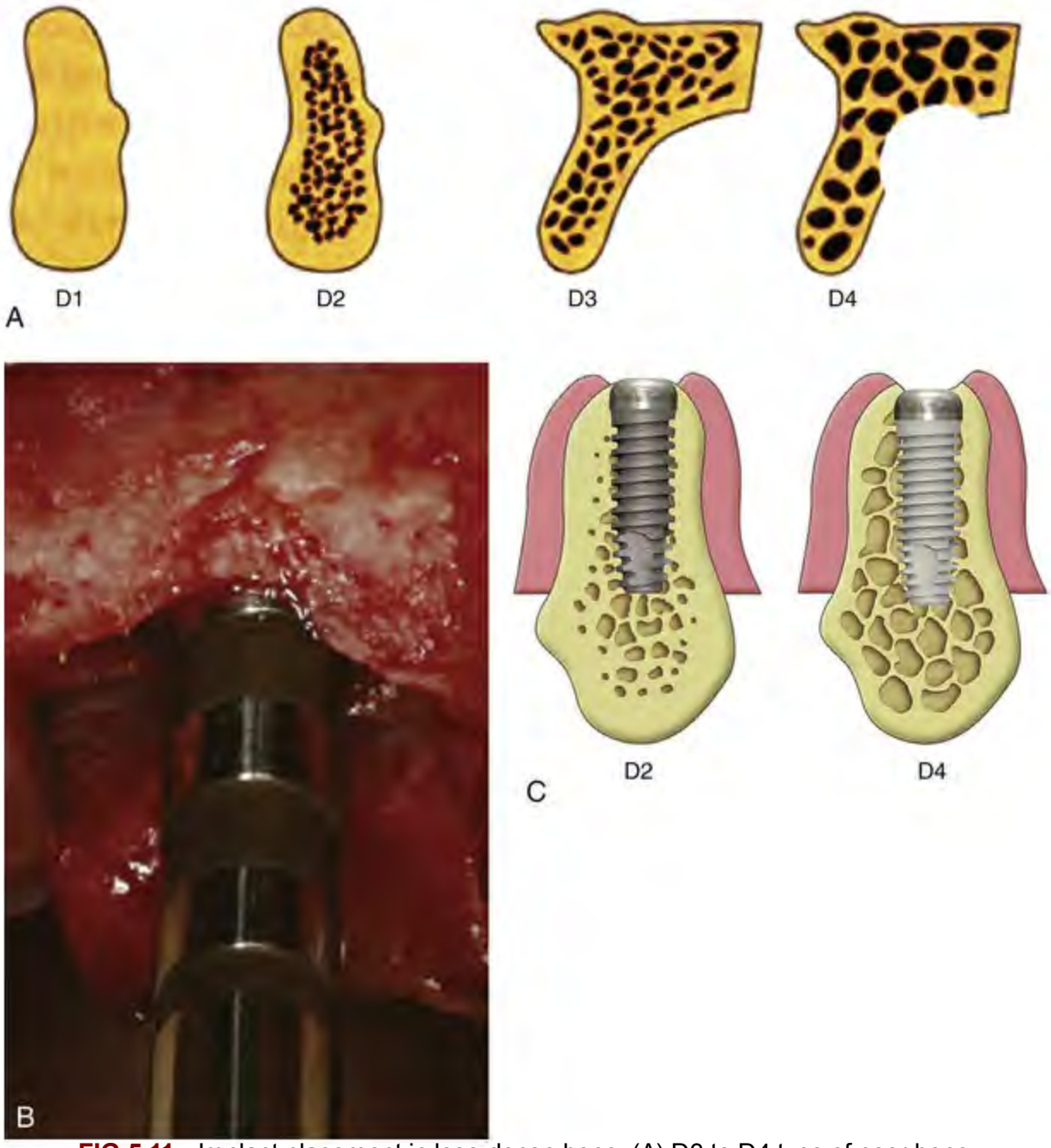

FIG 5.11 Implant placement in less dense bone. (A) D3 to D4 type of poor bone density showing lack of cortical bone and fine trabeculae. (B) Osteotomes to compact the existing bone, increasing bone implant contact, should be used in D3 and D4 bone quality of bone. (C) Implant in D4 type of bone should be countersunk in comparison to better-quality bone (D2). (C, From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Prevention

Osteotomy Drills.

The implant surgeon should not prepare D4 bone with rotating drills, which

use an extraction technique to remove bone during preparation of the osteotomy. These types of drills in D4 bone will result in distortion of the osteotomy site (enlargement). Ideally, a compaction technique should be used with osteotomes, which expands the bone by compressing the trabecular bone.

Insertion With Handpiece.

The implant should be allowed to self-tap with the use of a slow-speed, high-torque hand piece. A hand wrench is contraindicated because it will widen the osteotomy (i.e., make elliptical) and possibly result in a lack of rigid fixation of the implant. The pressure on the implant during insertion corresponds to the speed of rotation, and the implant proceeds to self-tap the soft bone.

One-Time Placement.

Once inserted, the implant should not be removed and reinserted. Instead, a one-time placement is mandatory because removal of an implant in this bone will lead to less bone at the interface.

Countersink.

The implant is countersunk in this bone if any risk of loading is expected during healing (e.g., under a soft tissue–borne denture). Countersinking the implant below the crest reduces the risk of micromovement during healing in this very soft bone. No countersink drill is used before implant placement because this decreases the density of bone at the crestal area.

Treatment

When a poorer type of bone exists, increased healing times and progressive bone loading should be adhered to. Increased healing time is indicated to allow for more bone to remodel at the surface and to intensify its trabecular pattern. The additional time also allows a more advanced bone mineralization and increased strength. Six or more months of undisturbed healing is suggested. The compression technique for surgery (e.g., osteotomes), the extended healing time, and progressive bone loading protocol allow the remodeling of the poor quality bone into a more organized and load-bearing quality similar to D3 bone before the final prosthetic loading of the implants.

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Overheating the Bone

One of the most common complications that has been associated with early implant failure and bone loss is overheating of the bone during osteotomy preparation. This usually is a result of the surgical osteotomy protocol.

Etiology

The amount of heat produced in the bone is directly related to the amount of bone removed by each drill.[11] A 3-mm pilot drill has been shown to generate greater heat than a 2-mm pilot drill.[12] As a result most manufacturers suggest the first drill be 2 mm or less in diameter. In a similar fashion, the amount of heat generated by successive drills is also directly related to the increase in drill diameter. A 3-mm drill after a 2-mm drill removes 0.5 mm of bone on each side of the drill. A 2.5-mm drill after a 2-mm drill removes only 0.25 mm of bone on each side of the osteotomy. The smaller incremental drill size allows the surgeon to prepare the site faster, with less pressure and less heat. In addition, when large increases in drill diameter are used to prepare bone, the surgeon may inadvertently change the angulation of the drill because the larger drill is removing a greater bone volume and the tactile sense is decreased. As a result, an elliptical osteotomy may be prepared that does not correspond accurately to the round implant diameter. The gradual increase in osteotomy size also reduces the drill chatter at the crestal opening, which can inadvertently chip away pieces of bone on the crest, where complete bony contact is especially desired. The gradual increase in drill diameter also keeps each drill sharper for a longer period, which also reduces the heat generated (Fig. 5.12).

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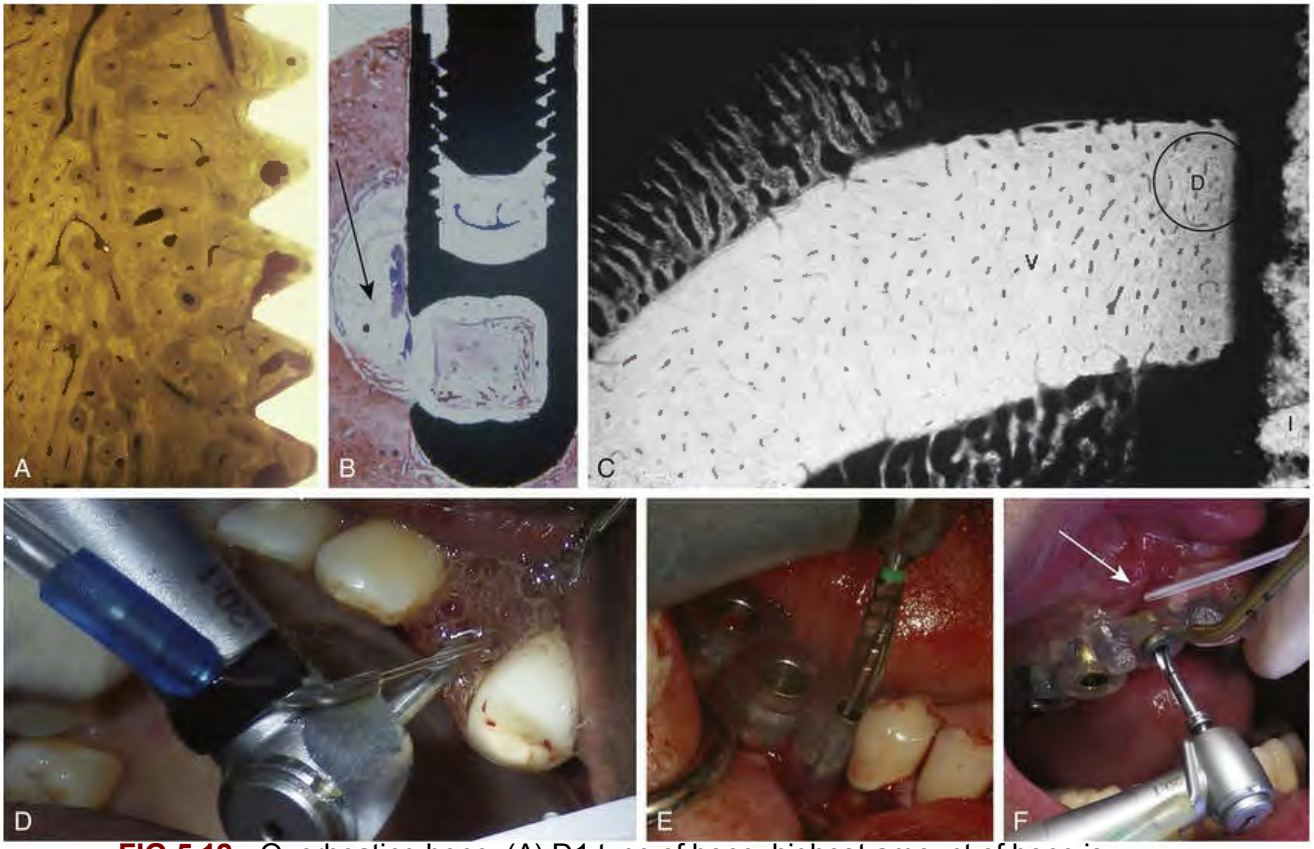

FIG 5.12 Overheating bone. (A) D1 type of bone: highest amount of bone is present at the interface, which predisposes to heat generation. (B) Area of bone necrosis from overheating around implant *(arrow)*. (C) Devitalized bone *(D)* and vitalized bone *(V)*. (D) Use copious amount of irrigation during osteotomy preparation to avoid overheating the bone. (E) Caution should be exercised with the use of surgical templates because minimal irrigation enters the osteotomy site and overheating the bone is a common problem. (F) Modification (removal of buccal flange) of the template to allow for increased irrigation (i.e. external irrigation; *arrow*). (A and C, From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.)

Prevention

Intermediate Drills.

Some manufacturers do not utilize an intermediate drill in their drilling protocol. However, a decrease in the heat and trauma generated is found with the intermediate drill. Gradual increases in drill diameter reduce the amount of pressure and heat transmitted to the bone, especially in the presence of dense and thick cortical bone.

Copious Amounts of Saline.

Along with external irrigation from the surgical drills, increased irrigation may be obtained by using internal irrigation (through the surgical bur) or

with supplemental irrigation via a syringe.

Bone Dance.

The bone-dancing technique was introduced by Misch in 1988 to reduce the amount of heat generation. When preparing the osteotomy, small increments of bone should be removed, and by using the up-and-down motion of the drill, irrigation may enter the osteotomy site easier.

Use of Sharp, New Drills.

Drills that are dull will increase heat generation, causing the possibility of no bone integration. On average, surgical drills should be replaced approximately every 20 to 30 autoclave cycles.

Drill Speed.

Sharawy and Misch have shown that the drill speed in hard, dense bone should be approximately 2000 to 2500 RPM. Osteotomy preparation at higher speeds with sharp drills elicits less risk of osseous damage and a decreased amount of devitalized zone adjacent to the implant.[12] Yeniyol et al have shown that drilling at very slow speeds results in a higher degree of bone fragmentation.[13]

Surgical Templates.

Surgical templates often result in overheating of the bone because of the decreased space between the guide tubes in the template and the drill size. Ideally, the template should be modified to open up the facial aspect of the template so supplemental irrigation may be utilized.

Treatment

If known excess heat generation occurs during implant placement, ideally the implant should be removed, regional acceleratory phenomenon (RAP) initiated, and the site grafted for future implant placement. If bone width is available after sufficient RAP is completed, a wider implant may be placed.

Implant Pressure Necrosis

A possible cause of early implant failure is pressure necrosis. Overcompression of the crestal bone has been shown to be a contributing

factor in implant failure.[14] It is postulated that excessive tightening of the implant creates compression forces within the crestal bone around the implant. This may impair the microcirculation and lead to bone resorption.

Etiology

Pressure necrosis from implant placement may increase the devital zone of bone around the implant or even cause short-term neurosensory impairment when the implant site is in the vicinity of the mandibular canal. This most often occurs where there exists a cortical component of bone in the crestal region (~D1–D2 bone). If a crestal bone drill is not used in higher bone density with a cortical component, excess stress will be generated upon insertion of the implant, which will lead to a devitalized zone (Fig. 5.13).

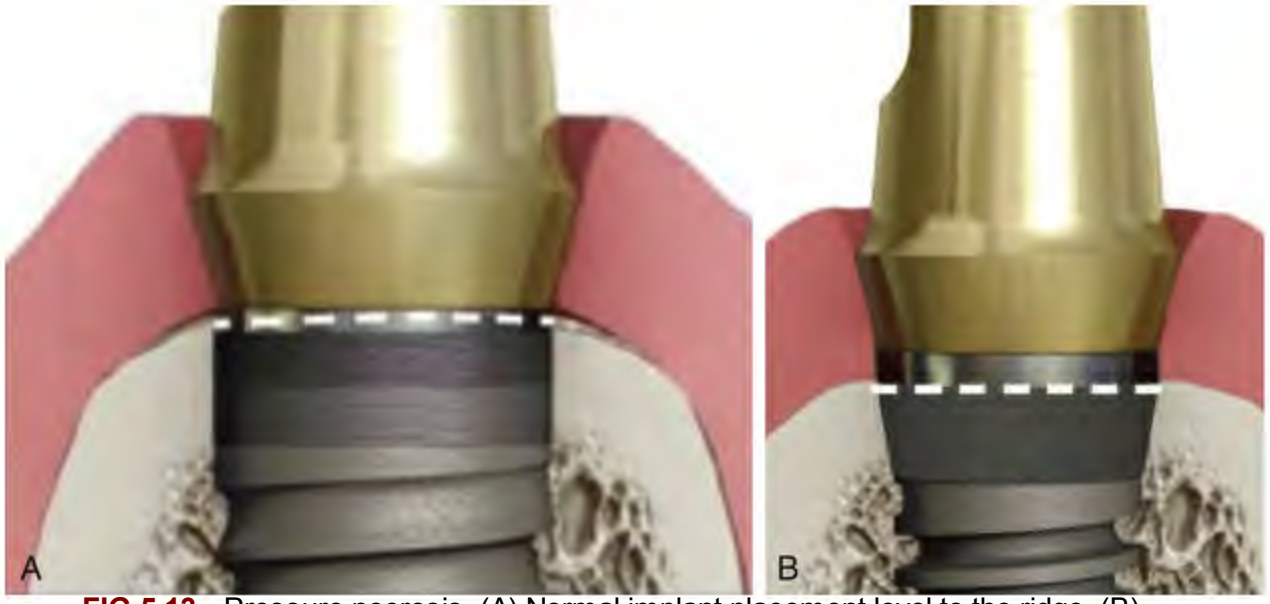

FIG 5.13 Pressure necrosis. (A) Normal implant placement level to the ridge. (B) To decrease pressure necrosis in highly dense bone (~D1), the implant is unthreaded ≈1 mm after insertion.

Prevention

Torque.

The implant should not be tightened into the osteotomy, such as a nut onto a bolt. A torque value up to 35 N/cm is considered safe with most threaded implant designs.

Crestal Bone Bur.

Because most implants have a wider crest module (wider diameter of the neck of implant in comparison to implant body), greater stress can be concentrated upon placement in D1 and D2 types of bone. To decrease crestal pressure, the implant may be placed to ideal position, then backed off approximately 1 mm to avoid pressure necrosis.

Treatment

Ideally, the thickness of crestal bone and bone quality type should be ascertained prior to implant osteotomy preparation. This is easily evaluated on a CBCT radiographic examination. If a large cortical component of bone is present and the implant placed is known to contain excess pressure, the implant should be removed and the crestal bone modified. The implant should be then reinserted.

Bone Spreading Complications

Bone spreading has become a popular surgical technique to expand the available bone width prior to implant placement. Since Tatum developed the bone spreading technique in the early 1970s, the expansion technique has been primarily used in regions of division B bone to increase the bony width. However, the easiest edentulous ridges to expand are division A bone volume with associated D3 or D4 bone densities. The narrower the bone, the greater the risk of fracture of the facial plate. The softer the trabecular bone quality, the lower the elastic modulus and the greater the viscoelastic nature of the ridge. Therefore, the less dense the bone, the easier and more predictable the bone expansion. There exist three main complications that may occur during bone spreading.

Splintering of Facial Plate

Etiology.

The most common complication of bone spreading, especially in division B bone that is D2 quality, is splitting the facial plate during the procedure. Once this occurs the surgeon must decide whether to continue, place the implant, and perform a barrier membrane layered bone graft, or abort the procedure and place only a bone graft (Fig. 5.14).

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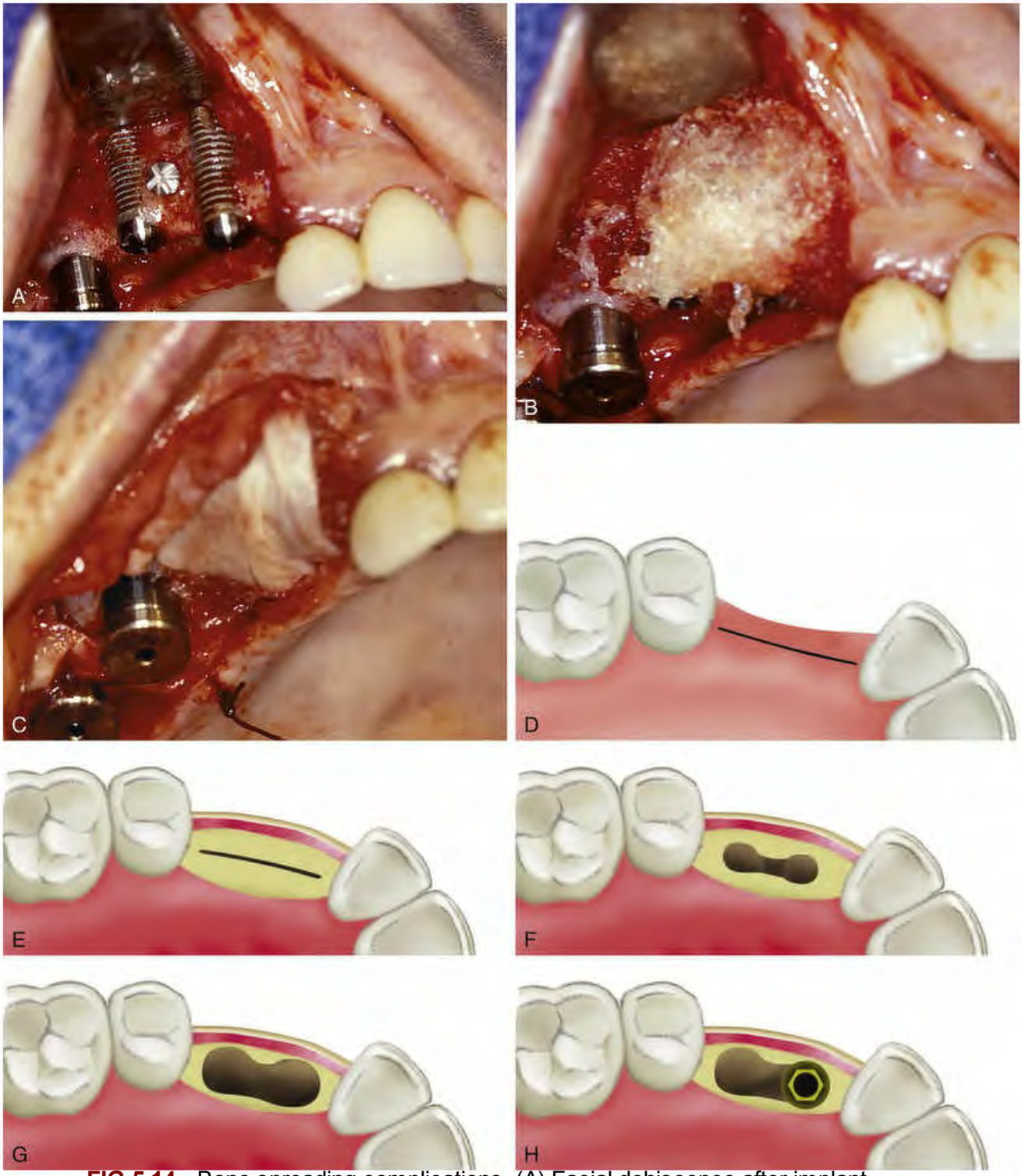

FIG 5.14 Bone spreading complications. (A) Facial dehiscence after implant healing. (B) Autogenous and allograft bone graft with tent screws. (C) Barrier membrane is placed (e.g., accelular dermal matrix). (D) A second complication occurs with the bone grafting being too facial leading to a facial plate fracture, incision is made slightly lingual to center of ridge. (E) Osteotomy is made lingual to center of ridge. (F) Bone spread maintaining buccal plate. (G) Care should be exercised to minimize compromising facial plate thickness. (H) Implant placement with maintaining buccal plate intact.

Prevention.

Make sure there exists sufficient bone for bone spreading and good surgical technique. A common misconception is that division C minus width (C−w) ridges may be spread with simultaneous implant placement. This often results in fracturing the facial plate. Bone spreading should be restricted to division A and B ridges.

Treatment.

The implant may be inserted when the following factors are positive: (1) the implant is rigid at the proper depth, (2) the implant is in a favorable angulation, and (3) the facial plate is farther facial than the implant (it is fractured, but expanded). Under these conditions the barrier membrane layered graft procedure will predictably restore the facial bone, and the implant is not compromised. If one of these three factors is negative, it is more prudent to remove the implant, harvest additional autograft, and perform the bone graft without the implant in situ.

Dehiscence

Etiology.

Another complication of bone spreading is the dehiscence of the labial plate after healing and bone remodeling around the implant. This results from insufficient bone quantity preoperatively. Because of its modulus of elasticity the expansion of the labial plate is not beyond the point of permanent deformation, and the bone does not fracture. It will attempt to rebound to its original size during remodeling. As a result, during bone remodeling the bone does not heal in its expanded position, instead returning to its initial narrow dimension, and the implant fenestrates the labial plate. When bone expansion is performed at implant placement, a stage II uncovery with reflection of the facial soft tissue is advantageous to evaluate the facial plate.

Prevention.

To decrease the possibility of bone dehiscence after bone spreading, the technique should be restricted to division A and B ridges.

Treatment.

When a dehiscence is observed, a barrier membrane with layered graft

approach is indicated to restore the facial plate. Because the implant is integrated to the remaining bone, the implant may be progressively loaded after a 3- to 4-month period, rather than waiting 6 to 9 months, as with augmentation by barrier grafts alone.

Poor Position

Etiology.

The third complication of bone expansion is a poor final implant position, usually more facial than ideal. The thicker palatal cortical plate tends to push the osteotomes to the facial; if the implant surgeon is unaware of this malpositioning, the end result will be an implant that is too facial and will be problematic esthetically and functionally.

Prevention.

Constant attention of angulation and modification of the palatal bone with side-cutting drills (Lindemann drills) is necessary to prevent this problem.

Treatment.

The final prosthesis should not be compromised for the advantage of placing the implant during the surgery. Bone augmentation and reentry 6 months postoperatively often improve the implant position and, as a result, the final restoration.

Inability to Determine True Location of Mental Foramen on CBCT

If the true position of the mental foramen cannot be determined from the CBCT, reflection of the foramen is recommended to determine the exact position.

Etiology

Although rare, sometimes it is difficult to determine the exact location of the mental foramen or if an anterior loop exists from a CBCT. Because of the possible consequences of placing an implant too close to the mental foramen, care must be exercised to prevent impingement.

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Prevention

A CBCT evaluation utilizing the cross-sectional and 3-D images should be used to clearly identify the mental foramen. In some cases, the brightness and contrast will need to be altered to depict the mental foramen.

Treatment

The primary incision is extended anterior and posterior with releases to minimize stretching of the tissue so the foramen may be identified. The location of the foramen is variable, depending on age, ethnic background, amount of resorption, and skeletal relationship. Initially, the periosteum is reflected off the residual crest, and a moist surgical sponge can be used to wipe the periosteum off the dense labial cortical plate to identify the superior aspect of the foramen. After the superior aspect of the foramen is identified, the tissue is reflected anterior and posterior to confirm the exact location of the foramen (Fig. 5.15).

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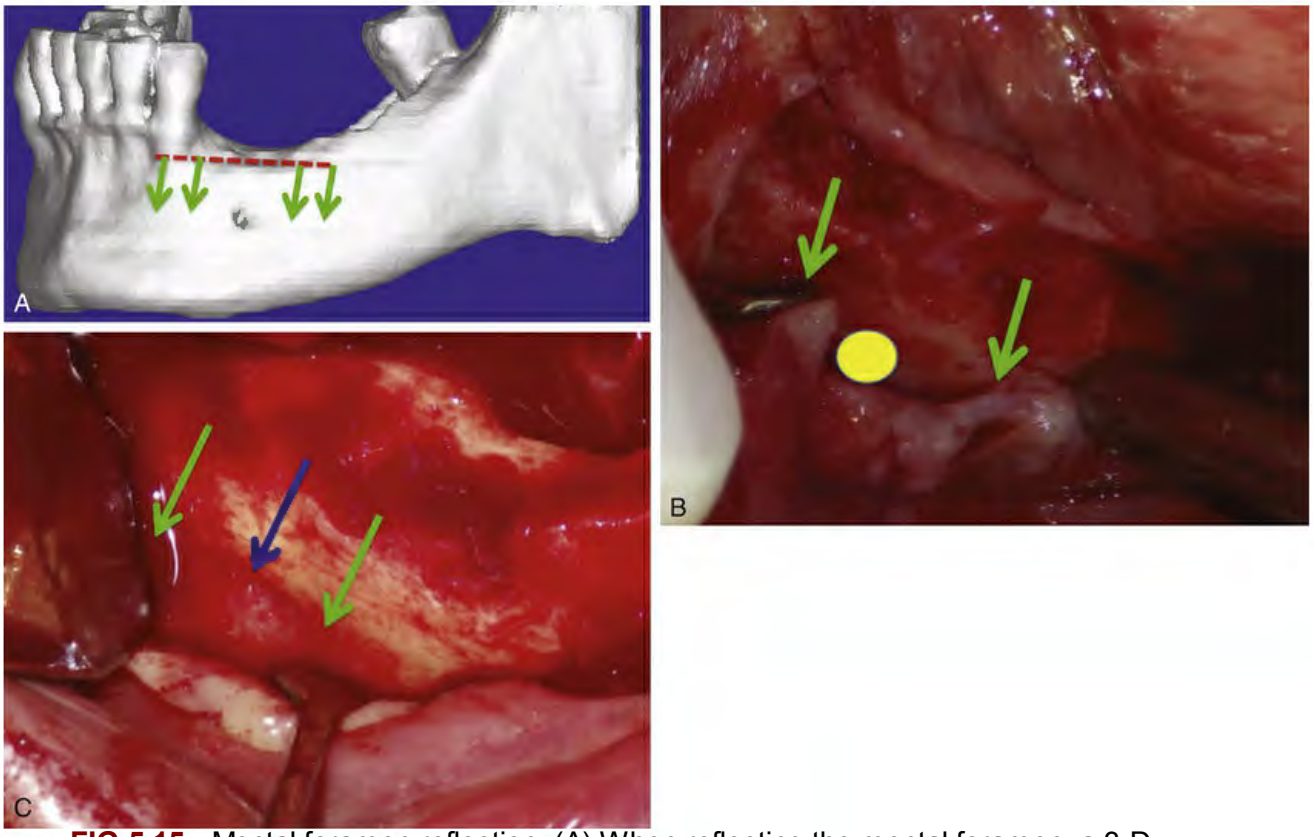

FIG 5.15 Mental foramen reflection. (A) When reflecting the mental foramen, a 3-D CBCT image is used to determine position in reference to an adjacent tooth *(arrows)*. Reflection should be initiated anteriorly and posteriorly *(green arrows)* to allow for access to the foramen. (B) Full-thickness reflection exposing the superior aspect of the mental foramen. (C) Mental foramen exposure *(blue arrow)*.

Incisive Foramen Implant Placement Complications

The incisive foramen region, rather than a central incisor site, may also be used to insert an endosteal implant, especially when an overdenture is the intended final prosthesis.[15] The incisive canal ranges in length from 4 to 26 mm and is directly related to the height of bone in the premaxilla. As alveolus height is resorbed, the canal reduces in length; therefore division A, B, and C–w bone have greater canal length than division C–h and D. The incisive canal has an average axis of 70 degrees with a range of 57.0 to 89.5 degrees from the horizontal plane.[16] This structure contains terminal branches of the nasopalatine nerve, the greater palatine artery, and a short mucosal canal (i.e., Stensen duct). A vertical projection above the incisive canal along the nasal floor is called the *premaxillary wing*. The nasal process of the premaxilla rises 2 to 3 mm above the nasal floor. As a result, when 7 to 11 mm of bone is present below the nasal floor, a large osteotome may create

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a greenstick fracture in this process above the foramen and permit the placement of a 9- to 14-mm implant. The foramen is usually 4 to 6 mm in diameter at the crest and narrows down to 4 mm at the apex. Implants inserted at the same time as the soft tissue is curetted are usually 5 to 6 mm in diameter.

Prevention/Treatment

There exist many possible complications with incisive foramen implants.

The first surgical complication of an incisive foramen implant is the result of an implant that is too small for the foramen and not properly fixated. The implant may be inadvertently pushed through the incisive canal and into the nares proper. Because the patient is lying on their back during the surgery, the implant may fall back into the soft palate, then into the trachea or esophagus. If the implant disappears from the oral site, the patient's head should be turned to the side immediately, then down and forward. A nasal speculum and tissue forceps may then be used to recover the implant.

A second surgical complication may include bleeding from the incisive foramen. Although this complication is very rare, it is possible. When reflection of the palatal tissue off the incisive canal is associated with arterial bleeding, a blunt bone tap (mirror handle) may be placed over the canal and a mallet used to hit the instrument firmly, crushing the bone over the artery. After several minutes the procedure may continue, and the implant insertion will obdurate the site and arrest the bleeding.

The short-term complication of an incisive foramen implant is associated with enucleation of the soft tissue from the foramen. Although the author has not witnessed this complication, neurologic impairment of the soft tissues in the anterior palate may exist. This may lead to paresthesia to the soft tissue or a dysesthesia, with a report of a burning/painful sensation. It is logical to include this risk in an informed consent. If it should occur, removal of the implant for dysesthesia is warranted, whereas paresthesia of the palate most likely is a condition the patient can tolerate without significant issues. In many cases the patient will regain neurosensory feeling from collateral innervation.

A long-term complication that has been observed twice by the author is the regeneration of the soft tissue in the incisive canal, resulting in bone loss around the implant. When the implant is removed and the soft tissue biopsied, nerve fibers can be seen reinvading the site. This most likely occurs because the implant was too small for the size of the foramen, and the soft

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tissue can reform around the implant. Treatment of this complication includes removing the implant and, if necessary for the treatment plan, regrafting and/or reimplantation (Fig. 5.16).

FIG 5.16 Incisive foramen implant failure. (A) Bone loss and probing depths resulting from not removing all soft tissue from the incisive foramen implant. (B) Removal of implant with trephine bur. (C) Implant removed with soft tissue interface. (D) Histologic examination of the soft tissue around the implant reveals the contents of the incisive canal are reforming around the implant. (E) Histologic examination demonstrates nerve fibers in the soft tissue around the implant.

Implant Placement Impinging on the Nasopalatine Canal

There exists a close anatomic relationship between the nasopalatine canal and the maxillary central incisor area. The anterior maxillary area has high esthetic importance, and ideal implant placement is mandatory. The nasopalatine canal is located in the maxillary palatal midline, just posterior to the central incisor area. There is a funnel-shaped opening of the canal into the oral cavity, which is known as the incisive foramen. The canal divides into

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two canaliculi towards the nasal cavity, and terminates at the nasal floor as the foramina of Stensen. The canal contains the nasopalatine (incisive) nerve and the terminal branch of the descending nasopalatine artery.

Etiology

When the maxillary teeth are lost, the buccal plate anterior to the canal will lose up to 60% of its width. Also, the canal diameter of the canal and foramina (nasopalatine foramina and incisive foramen) will increase in size.[17] When implants are placed in this area, they may impinge upon the area and be in contact with soft tissue, which may lead to a soft tissue interface or implant failure. (Fig. 5.17).

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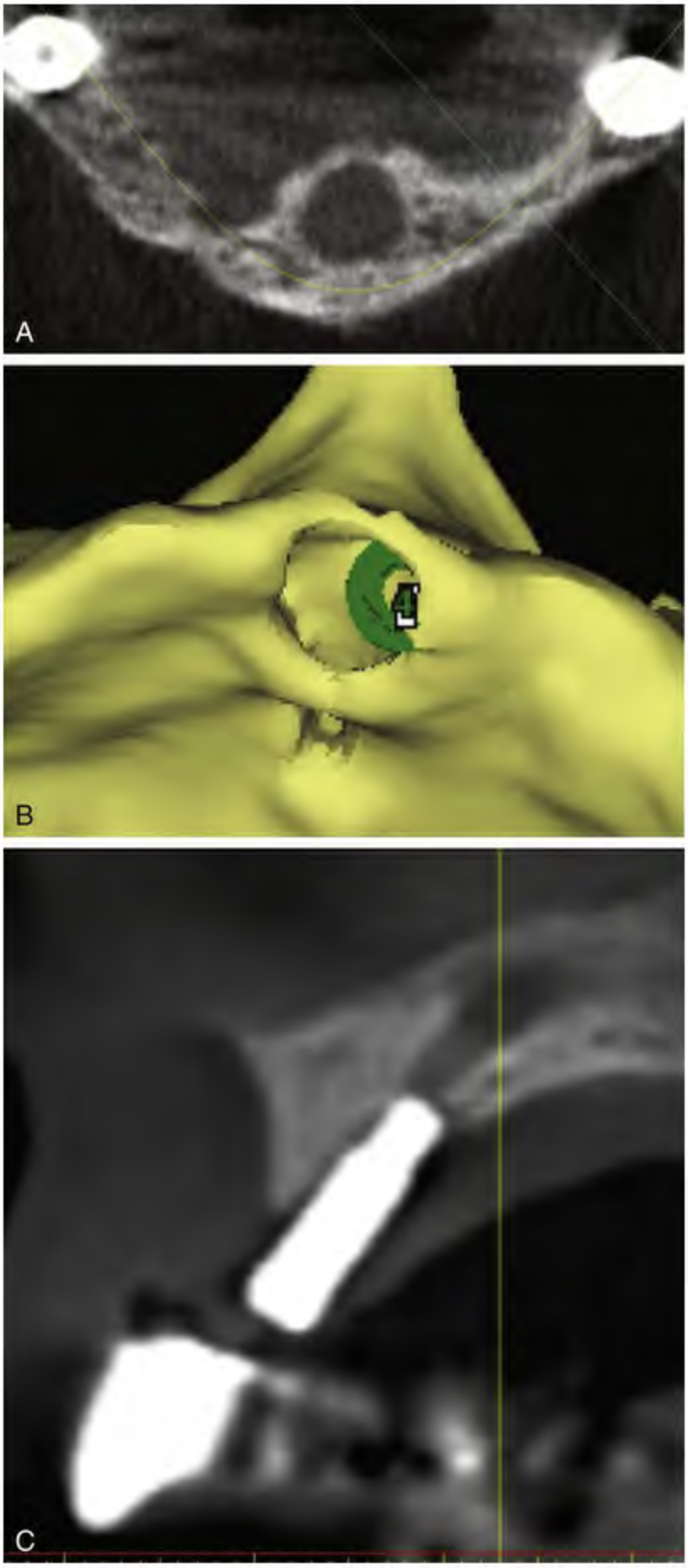

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FIG 5.17 Implant impingement on the nasopalatine canal. (A) Axial image depicting a very large nasopalatine canal. (B) 3-D interactive treatment planning showing implant impingement into the canal. (C) Implant violating the nasopalatine canal resulting in soft tissue interface.

Prevention

To prevent implant placement into the nasopalatine area, CBCT imaging is recommended to determine the dimensions and morphology of the nasopalatine canal. The nasopalatine canal has many variations ranging from one canal to various types of "Y" configurations.

Treatment

When it is determined that an implant will impact upon the nasopalatine canal, alternative procedures must be considered. One such treatment is for enucleation of the canal, then bone grafting, with subsequent implant insertion. Alternatively, implants may be placed directly into the canal, usually for overdenture treatment plans.[18]

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Stage II Uncovery Surgery Complications

Tissue Punch Reducing Amount of Attached Tissue

A common technique to uncover or expose a healed implant (stage II surgery) is the use of a tissue punch that is slightly larger than the implant placed. The tissue punch is preferred by many practitioners because it is quick and easy; however, it may be detrimental to the soft tissue health of the implant.

Etiology

A tissue punch is often used because it is fast and simple and can be used without reflecting the periosteum. However, this may lead to potential prosthetic and long-term complications because it decreases the available amount of attached tissue. The tissue punch is placed directly over the top of the implant and pressure is exerted to remove the tissue, exposing the implant cover screw. However, the disadvantage of this technique is the keratinized tissue that is sacrificed, which is often much larger than the diameter of the implant (Fig. 5.18).

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FIG 5.18 Tissue punch. (A–B) Tissue punch used when inadequate attached tissue will often result in a mucogingival defect. (C) Lack of sufficient attached tissue for the final prosthesis because of excessive tissue removal. (D) Care should be exercised in using high speed handpiece and diamond bur as damage to the implant body can result.

Prevention

If inadequate keratinized tissue is present (<3 mm), a tissue punch should not be used to uncover an implant. A tissue punch that is significantly larger than the implant crest module should not be used because excessive tissue will be removed.

Treatment

In cases of inadequate keratinized tissue, a slightly lingual incision is made to create a soft tissue flap to uncover the implants. Tissue grafting with autograft or AlloDerm may be used to increase attached tissue volume surrounding the implant.

Bony Defects at Uncovery

On occasion, a vertical or horizontal defect may be revealed around the uncovered implant at the second stage surgery. This often presents a very difficult decision for the clinician as to the course of action.

Etiology/Prevention

The etiology for this type of defect are often similar to those of premature implant exposure and include crestal bone trauma during surgery, inadequate bone volume prior to placement, excess torque from implant insertion (especially with wider crest modules), bone flexure or torsion in the posterior mandible, local patient habits that load the implants during healing, incision line opening, postoperative infection, implant surface contamination, idiopathic bone loss, or healing factors related to systemic disease. Proper treatment planning and good surgical technique is recommended to minimize bone loss after implant placement.

Vertical Defects

Treatment.

If a vertical defect filled with soft tissue is identified anywhere around the implant, a curette is used to eliminate the tissue. When soft tissue is removed from around a tooth, the root is scraped because the tissue attaches to the cementum. The fibrous tissue in a vertical defect around an implant is not attached to the implant. Therefore, the bone is scraped, but not the implant. This loosely bound and unorganized tissue is relatively easy to remove at this time. The implant surface should not be scratched or contaminated during this procedure. If soft tissue is present around the threads, a wire brush bur maybe used to remove the tissue. The extent of bone loss is assessed and should be less than 3 mm if the implant is to be uncovered at this appointment. Special brush burs (Salvin) may be used to remove tissue from the implant surface (Fig. 5.19).

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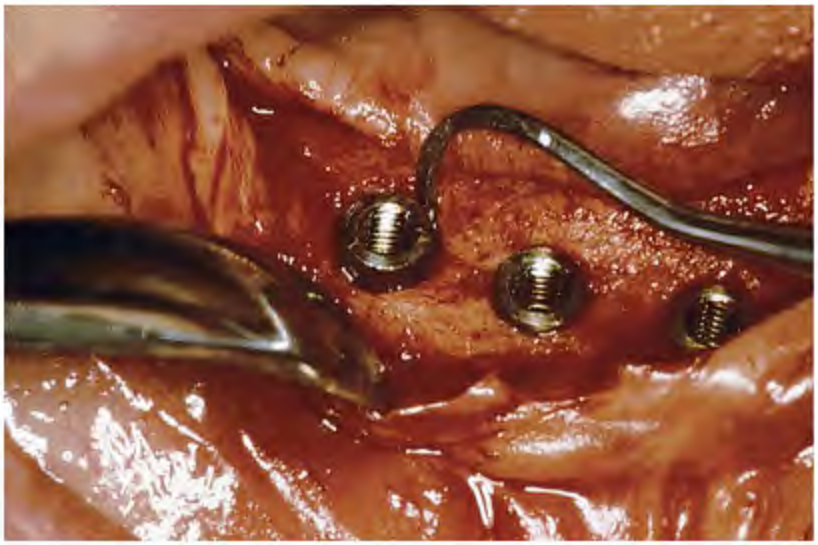

FIG 5.19 Removing tissue from defect. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Defect greater than 3.0 mm.

If the vertical defect around the implant is of moderate depth (greater than 3 mm) for more than 25% of the circumference, a bone graft/barrier membrane is placed over the grafted defect, and the soft tissue is reapproximated. This prevents soft tissue ingrowth into the defect and provides an improved environment for the bone graft healing time against the implant surface. In this scenario the second stage uncovery is delayed for approximately 2 to 4 months, depending on the size of the defect.

When bone loss exposes the threads of the implant body, the ability to reform bone in the defect when the implant is uncovered and loaded is reduced. When the implant has not been exposed before the uncovery procedure, the implant body is usually not contaminated by microorganisms because it has been under soft tissue. The full-thickness reflection of the region has exposed areas of vital bone not involved in the implant support. This bone may be harvested and packed into the vertical defect (after the soft tissue in the defect has been thoroughly removed). The defect and surrounding area are overpacked. When the implant defect is larger than 3 mm, the most predictable method to correct the condition is with a particulate autologous bone graft covered by a resorbable membrane (e.g., AlloDerm, Biomend), and the soft tissue is reapproximated over the membrane, bone graft, and implant for an additional 8 to 12 weeks of healing. A vertical defect greater than 3 mm is usually grafted unless it represents half or more of the total implant height, in which case the implant

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should be removed.

Defect less than 3.0 mm.

When the vertical bone defect around an implant is less than 3 mm, the implant may be uncovered and used in the current condition for the prosthetic abutment. After the soft tissue is removed from a defect, the surrounding bone is again evaluated. In the case of a vertical bone defect of less than 3 mm, there are three surgical options:

First, an osteoplasty may eliminate the vertical defect when the reduced bone-implant interface does not compromise the prosthetic support or esthetics. The permucosal abutment (PME) is placed at the same appointment (Fig. 5.20).

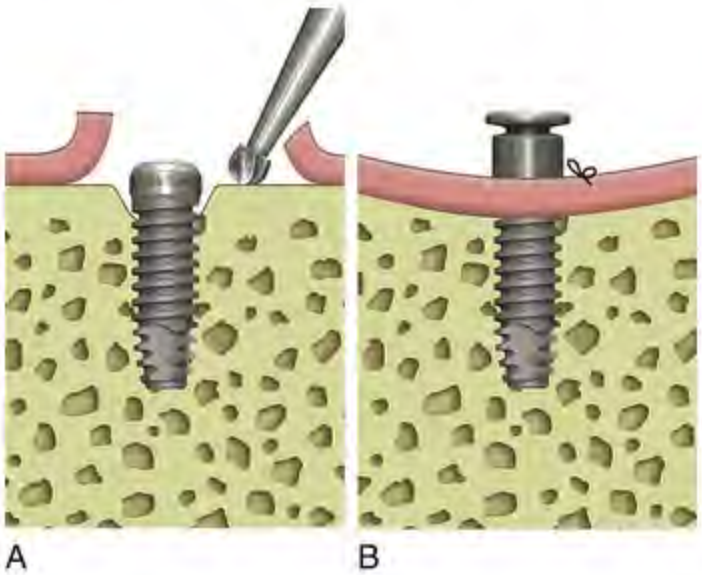

FIG 5.20 Osteoplasty with bur. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

A second method to correct a vertical defect less than 3 mm is to curette the defect and overfill the region with an autograft. The PME may be added at the same appointment and the tissue approximated around the site. When there is a desire to have thicker soft tissue around the site, a barrier membrane (e.g., AlloDerm) may be used over the implant site and covered with soft tissue (Fig. 5.21).

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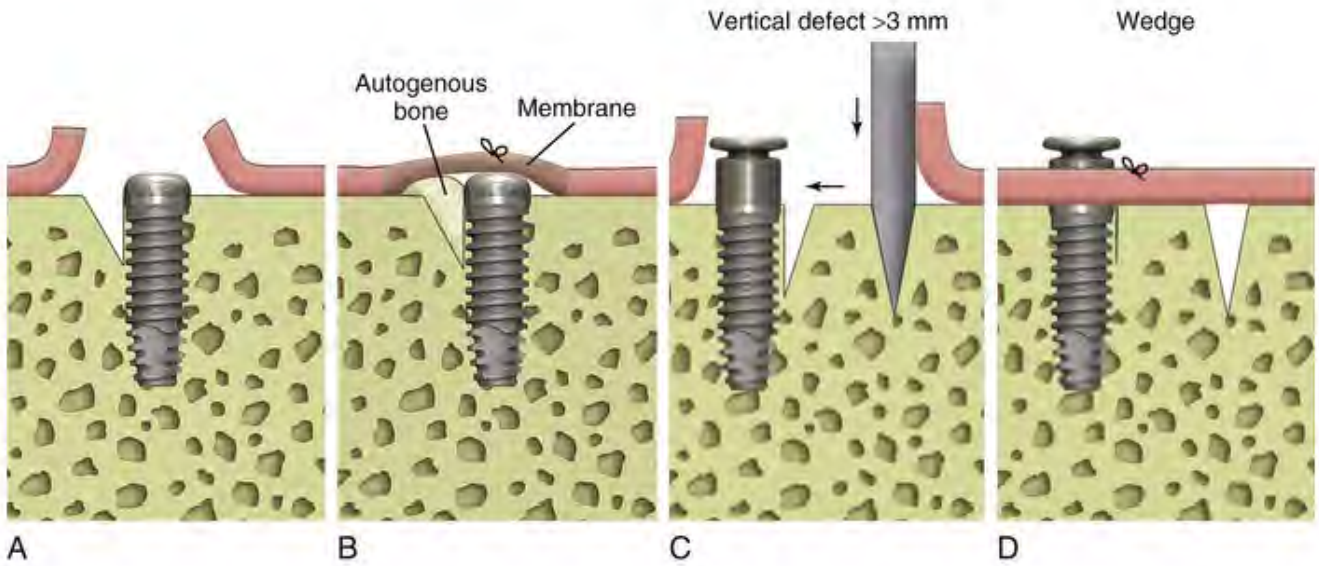

FIG 5.21 A method to correct a vertical defect less than 3 mm (A) is to curette the defect and fill the region with an autograft (B). The implant may be exposed with a permucosal extension or covered by a membrane when additional soft tissue thickness is desired. (C) The implant on the left has a vertical defect less than 3 mm deep. (D) A wedge is driven into the bone in the appropriate side, and vital bone is pushed up against the implant. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

A third alternative to correct a vertical defect on the mesial and distal region is to drive a wedge into the bone several millimeters away from the implant body. Tapping a wedge-shaped osteotome into the distal bone compresses vital bone up against the implant body. The wedge-shaped defect created in the ridge as a result of the osteotome is several millimeters away from the implant and is surrounded by bone; this defect will heal without consequence. A facial or lingual vertical defect may be corrected by taking a blunt instrument with a mallet and compressing the facial or lingual bone against the implant body. This technique also places live, viable bone (autogenous) adjacent to the implant body. The PME is placed at this appointment.

Horizontal Defects

Treatment.

A horizontal bony defect of bone around the implant body may also be treated in several ways.

Greater than one-half length.

When horizontal bone loss around an implant is more than half of the

implant body, the implant should be surgically removed and the site grafted at the uncovery appointment for future implant placement.

Less than one-half length.

The most predictable method to treat horizontal bone loss that is less than 50% of the implant body is to reduce the soft tissue thickness to decrease the probing depth around the implant. The soft tissue may be apically repositioned, exposing a portion of the implant body into the oral cavity. If threads or a rough surface are present above the bone, an aluminum oxide ("white") stone and rubber wheel are used under copious irrigation to smooth the region and limit plaque accumulation. A cement-retained prosthesis on an implant with horizontal bone loss may be placed on the implant body in esthetic regions.

Another option to address horizontal bone loss is to grow bone above the defect, and this method is used when the final prosthesis is a fixed-prosthesis 1 (FP-1) or additional bone-implant interface is required to withstand the forces exerted on the prosthesis. To improve the amount of bone formation, several steps may be taken. The first is to use autogenous bone for the graft. In most cases, bone is harvested and placed on the crest after the region has been curetted to increase blood supply and increase the regional acceleratory phenomenon. A barrier membrane is also placed over the site to prevent fibrous tissue ingrowth into the region. Anaerobic bacteria are often growing on the implant body when bone loss is present and should be mechanically removed. In addition, before grafting the first-stage cover screws are removed, and the internal cavity of the implant body is thoroughly flushed with chlorhexidine 0.12% before replacing the screws into the implant body. The tissues are reapproximated over the bone graft and membrane with primary closure. The second stage uncovery is delayed for approximately 3 to 4 months, depending on the size of the horizontal defect and bone graft.

Excessive Tissue Thickness at Stage II Surgery

The thickness of the overlaying crestal tissue is evaluated once it is reflected. Soft tissue greater than 4 mm in thickness will result in a less-than-ideal pocket depth around the implant.[19,20]

Etiology

It is not uncommon when implants are placed in edentulous ridges to have

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excessive tissue thickness before and after implant surgery. This is most common in the posterior maxilla and patients with a thick biotype (Fig. 5.22).

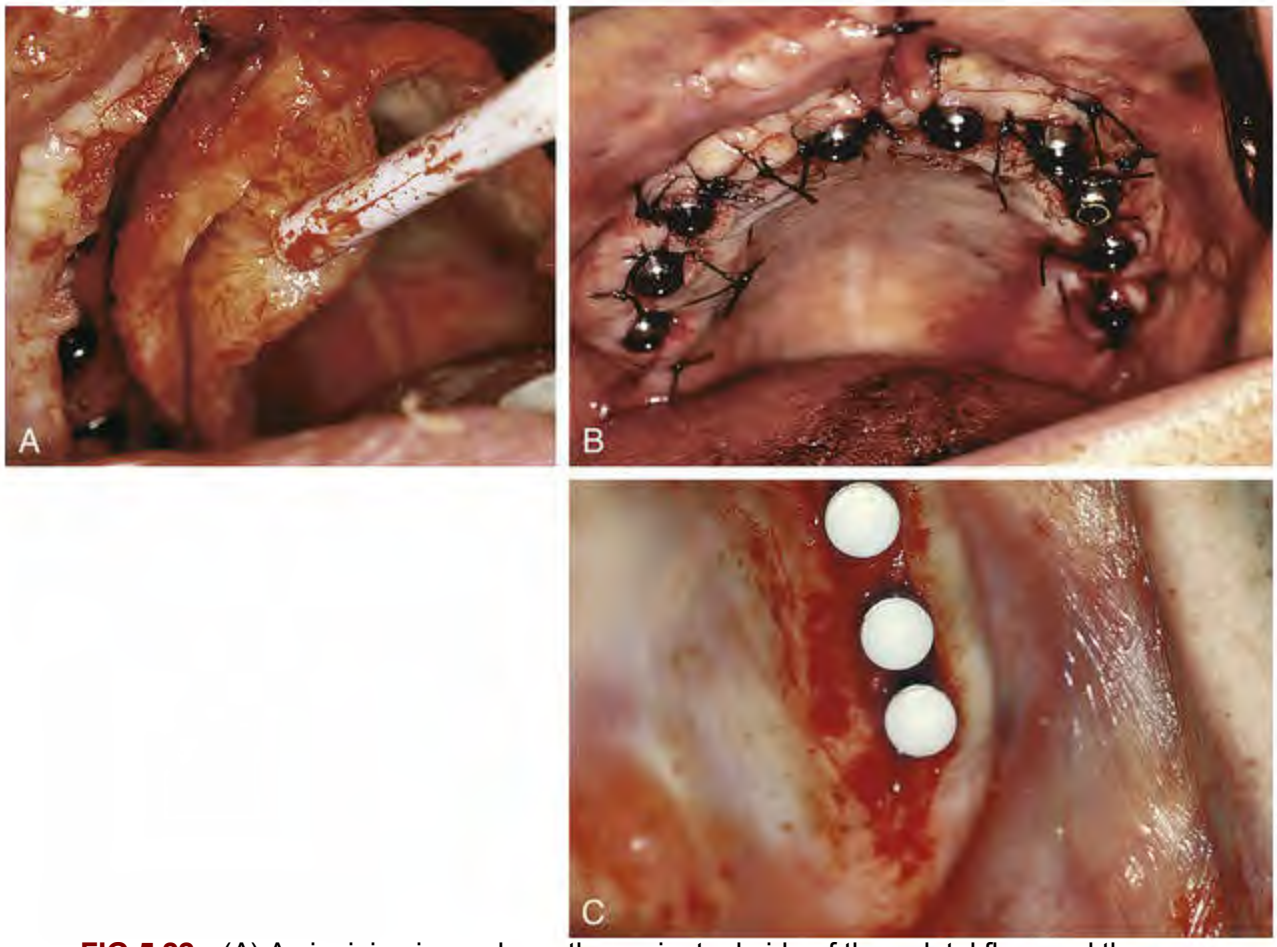

FIG 5.22 (A) An incision is made on the periosteal side of the palatal flap, and the excessive connective tissue is excised to decrease the overall palatal tissue thickness. (B) The tissue with a reduced thickness may then be approximated around permucosal extensions 3 to 5 mm in height. (C) A gingivoplasty is often performed in abundant areas of keratinized, attached tissue, such as on the palate, to reduce sulcus depth around the implant. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Prevention

Preoperative assessment of tissue should be conducted or the tissue maybe thinned out at the implant placement appointment.

Treatment

The tissue is relieved from the periosteal surface, especially in the labial flap,

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until it is less than 3 mm thick. If abundant attached tissue is present in the palatal region of the maxillary implants, a gingivoplasty may be performed.

When the tissue requires apical repositioning or when it is 3 to 4 mm thick and may grow over the healing abutment, the suture groove may be used. A suture is placed next to the healing abutment (PME) and is tied to lower the tissue level. Tissue forceps lift the suture from the incision line, and the suture is then rotated to form a loop. The loop is placed over the enlarged healing abutment and into the suture groove or under the healing cap. The suture may then be tied, securing the tissue at the height of the suture groove. A similar technique is used on the other side of the healing abutment. These two sutures (one on each side) hold the tissue at the level of the suture groove and prevent it from lifting up and over the healing cap during soft tissue healing (Fig. 5.23).

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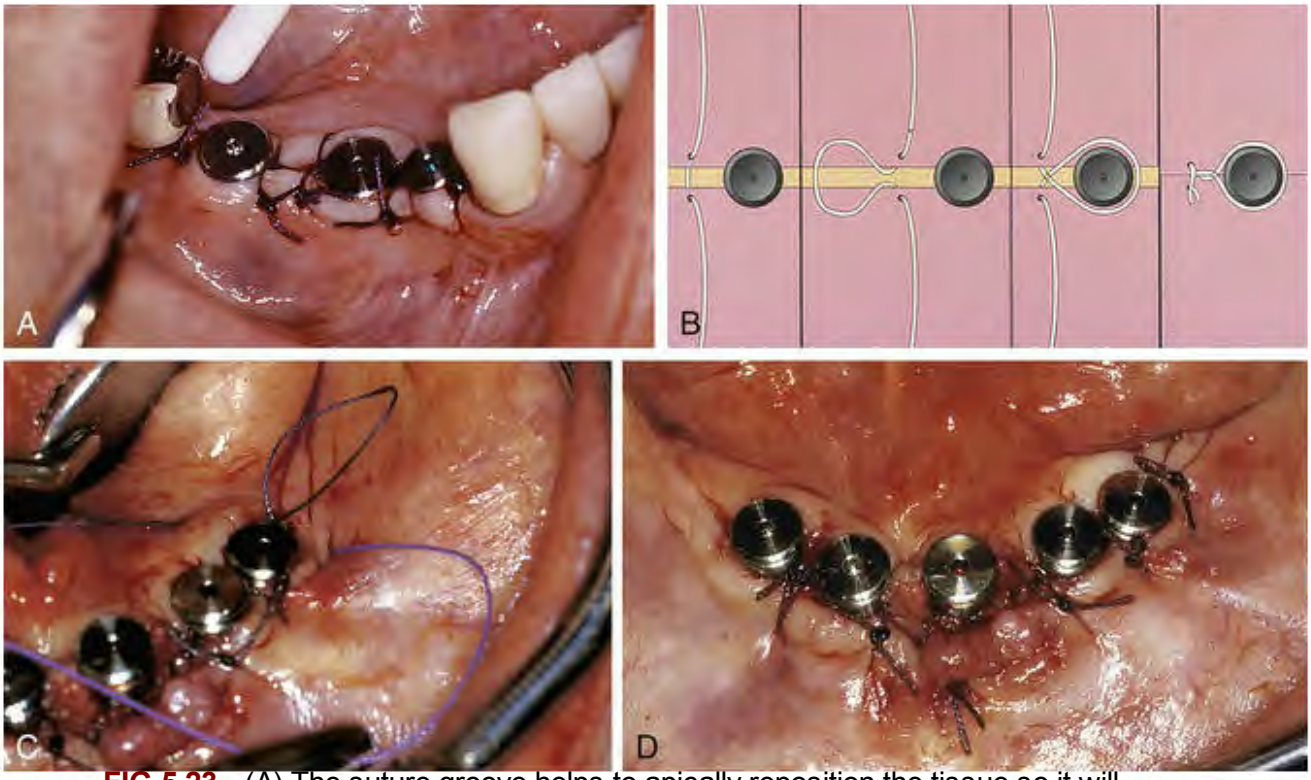

FIG 5.23 (A) The suture groove helps to apically reposition the tissue so it will remain less than 3 to 5 mm thick to reduce the sulcus depth. (B) The suture groove in the permucosal extension may be used to loop the suture around the groove and tie the tissue at a more apical position. (C) The most distal implant to the right has mobile tissue around it, which is difficult to reposition apically. The suture is placed on the distal aspect and looped over the suture groove to act as a soft tissue retainer. (D) When the suture is tied around the permucosal extension, it apically positions the tissue around the implants. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Loss of Papilla After Uncovery (Split-Finger Technique)

When the implant-bone interface is acceptable, the exposure of the implant body should be accomplished with the soft tissue final architecture in mind. To achieve and maintain the proper soft tissue architecture, several options are available, depending on the soft tissue appearance before stage II uncovery. It is imperative, especially in the maxillary anterior region, that exposure of the implant does not lead to gingival recession or loss of papilla.

Prevention

An ideal stage II uncovery procedure developed by Misch is called the *split-finger technique*.[21] This technique is utilized to increase the amount of papilla

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height around the implant body.

Treatment

Maintain Papilla.

An incision is made in the gingival sulci of the adjacent teeth. The incision is started at the distolingual line angle of the adjacent teeth and forms a loop at the facial emergence location of the implant crown. This creates two “fingers” at least 2 mm in width adjacent to each natural tooth. Once elevated, these two facial fingers will become the facial aspects of the interdental papillae. A central palatally supported finger is also created. The tissues are then elevated, and the implant cover screw is exposed and replaced with an abutment. The palatal finger may then be split into two segments (i.e., the split-finger approach). Each segment is rotated to the interproximal region to support the elevated facial fingers. A 4-0 or 5-0 modified mattress suture positions the papillae in the proper location, next to a transitional crown (Fig. 5.24).

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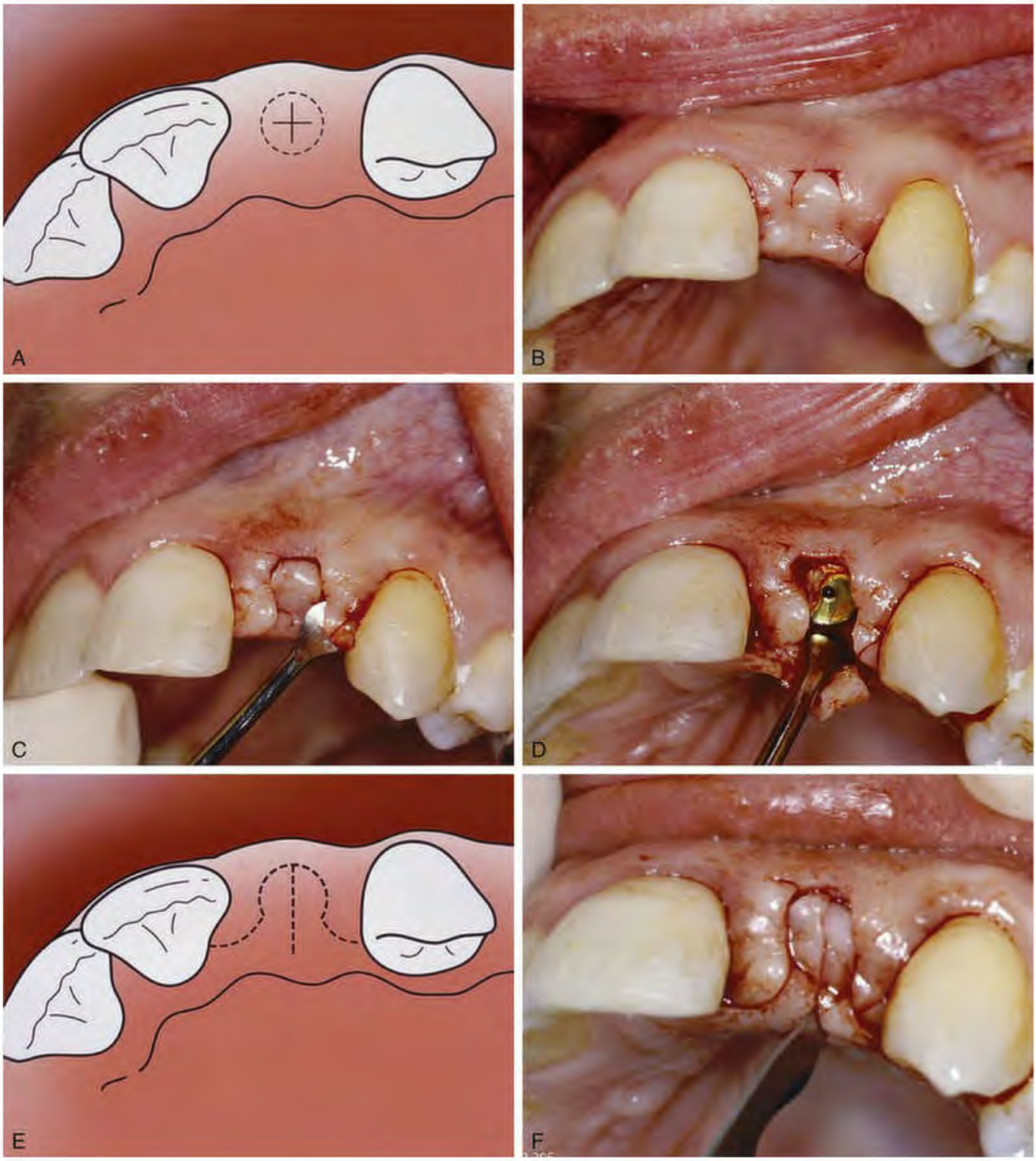

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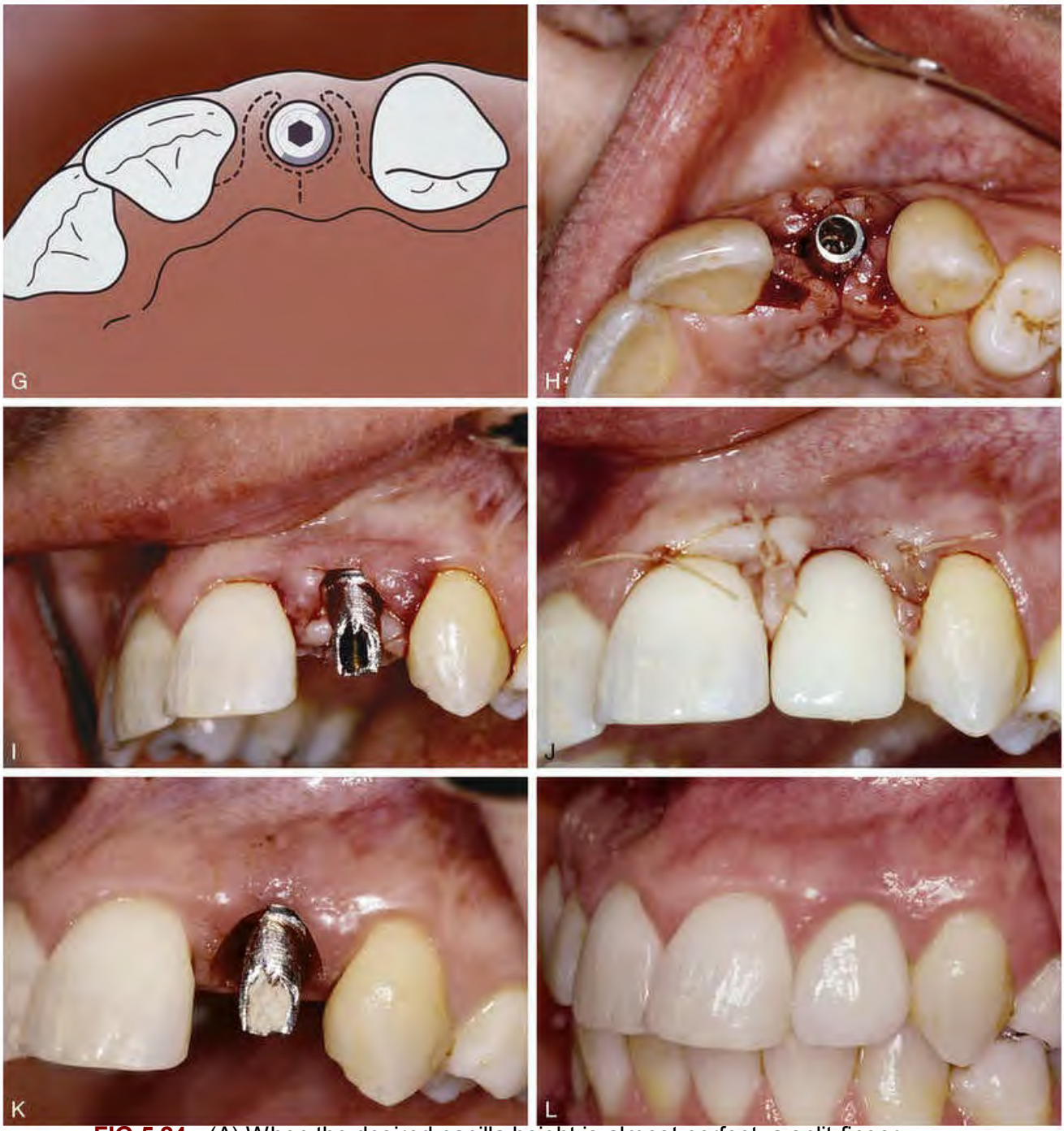

FIG 5.24 (A) When the desired papilla height is almost perfect, a split-finger technique may be used. (B) An incision is made in the sulcus of the adjacent teeth and continues from the palatal aspect of each tooth for 1.5 to 2.0 mm and loops to the facial, parallel to the adjacent interproximal teeth. The incisions then connect on the facial aspect at the desired midfacial emergence of the crown. (C) The facial fingers are elevated facially. (D) The palatal finger is reflected palatally. (E) The palatal finger is split into two sections (mesial and distal). (F) This creates four interfacing fingers (two on the facial and one toward the palate). (G) The implant abutment (or permucosal extension) is added, and each split palatal finger is positioned under the facial corresponding finger. (H) The split palatal fingers are rotated and support the appropriate facial finger. (I) The implant abutment and elevated facial fingers are in position. (J) The temporary crown is cemented, and the fingers are sutured into position. (K) After soft tissue maturation, the final crown is fabricated. (L) The final crown in position with properly developed interdental

papillae. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Increase Papilla Height.

When additional height is required, the split-finger technique may be used in conjunction with a connective tissue graft or AlloDerm to further augment the tissue height. This procedure may also be performed at insertion surgery, when a one-stage approach is desired.

Once the soft tissues are subtracted or added to obtain the desired emergence contour, the surgeon has basically two options to maintain this region. The first option is that a PME abutment may be inserted. Its size and shape should be smaller than the cervical contour of the final crown and extend through the tissue 1 to 2 mm. The emergence of the PME abutment will develop the initial soft tissue form. A wide-profile PME abutment should not be used because it may cause gingival shrinkage and limit the restoring dentist's ability to shape it into its ideal form. A transitional prosthesis is recontoured to fit over the healing cap for the next few weeks, until the patient is seen for the first prosthetic appointment. The soft tissue heals and is allowed to contour to the healing abutment or permucosal device. Usually, 4 to 6 weeks is needed for ideal tissue maturation.

Reverse Torque Testing Complications

Reverse torque testing (RTT), used as verification for rigid fixation, involves placing a defined reverse torque (counterclockwise) to the implant (via mount) at stage II uncovery surgery. The level of applied torque ranges from 10 to 20 N/cm. Implants failing such testing are presumed to be nonintegrated, likely to become early loading failures, and are not recommended for use as prosthetic abutments. Reports in the literature have suggested RTT at stage II surgery or to assess an implant suitability for immediate loading.[22] Two alleged advantages are its use as a biomechanical measure of initial stability and its use as a definitive verification of initial osteointegration.

Etiology

The RTT is suggested to be most beneficial in less dense bone, yet bone of this density is most at risk of failure during the RTT evaluation. In addition, bone is often only 60% mineralized at stage II uncovery after the surgical

trauma from stage I surgery. According to computer densitometry reports, bone may be more dense and the bone interface stronger on the day of surgery, compared with the stage II uncovery date.[23,24] It takes 52 weeks after initial surgery for bone to be completely mineralized. The mineralization of bone is related to its strength. Using RTT at stage II uncovery evaluates the interface when it is weak and more at risk to fracture from overload. In addition, at 4 months the bone is often still histologically woven bone rather than lamellar bone. Woven bone is unorganized and weaker than the load-bearing lamellar bone, which is more desirable at the implant interface. An RTT at uncovery does not permit this improved interface to develop before testing. RTT of implants too early in the healing process (relative to bone density) is more likely to lead to the removal of implants that would otherwise be integrated.

Prevention

In the author's opinion RTT presents too many subjective variables. Misjudgment can damage the bone-implant interface and prolong treatment and increase costs associated with the extra reparative treatment. The desire for objective standards for clinical verification of osteointegration is understandable. The most common methods of clinical verification used today, radiographs and manual mobility testing, have an admittedly subjective component. However, they do not place the implant at risk and have stood the test of time.

Treatment

It is recommended not to utilize a reverse torque test in the evaluation of the dental implant integration.

Anesthesia/Platelet-Rich Fibrin Complications

Inability to Obtain Mandibular Block

With the placement of implants in the mandible, profound anesthesia is a crucial component of surgical success. In edentulous mandibles or patients being treated with sedation, this may be difficult, and alternative anesthesia techniques are warranted. The Misch Implant Institute has recommended for years a rarely used technique in obtaining profound anesthesia in the mandible, the Akinosi technique.

Etiology

With edentulous patients the Akinosi technique is preferred because traditional techniques (Halsted block) require the use of reference points (occlusal plane), which are not present in edentulous patients. Additionally, many dental implant patients are sedated, which results in difficulty for the patient to open fully for the injection.

Prevention

The implant clinician must understand and utilize profound, alternative anesthesia techniques such as the Akinosi technique.

Treatment

The Akinosi block procedure is administered with the mouth in an almost closed position or, because the patients often wear a denture, in an approximate occlusal vertical dimension. In addition, it is a benefit when the patient positions the jaw toward the side of the injection (e.g., slides the jaw to the right for a right mandibular block-teeth edge to edge). A long, 27-gauge needle is used in the syringe. The needle is bent 30 degrees near the base, so the needle direction on a horizontal plane will be away from the midline. This is advantageous because the ramus flares laterally as it proceeds distal. The syringe and needle are placed parallel to the occlusal plane, at the height of the maxillary mucogingival junction. The needle penetrates approximately half its length (25 to 30 mm) before aspiration and injection of anesthetic. For this technique, no bony landmark is used. The Akinosi block is usually less painful for the patient because the anesthetic

fluid is injected into the top of the pterygoid triangular space, which has more room for the solution. In addition, the top of this triangular space has fewer muscle fibers in the pathway of the injection compared to the penetration site of the Halsted block and is associated with less discomfort (Fig. 5.25).

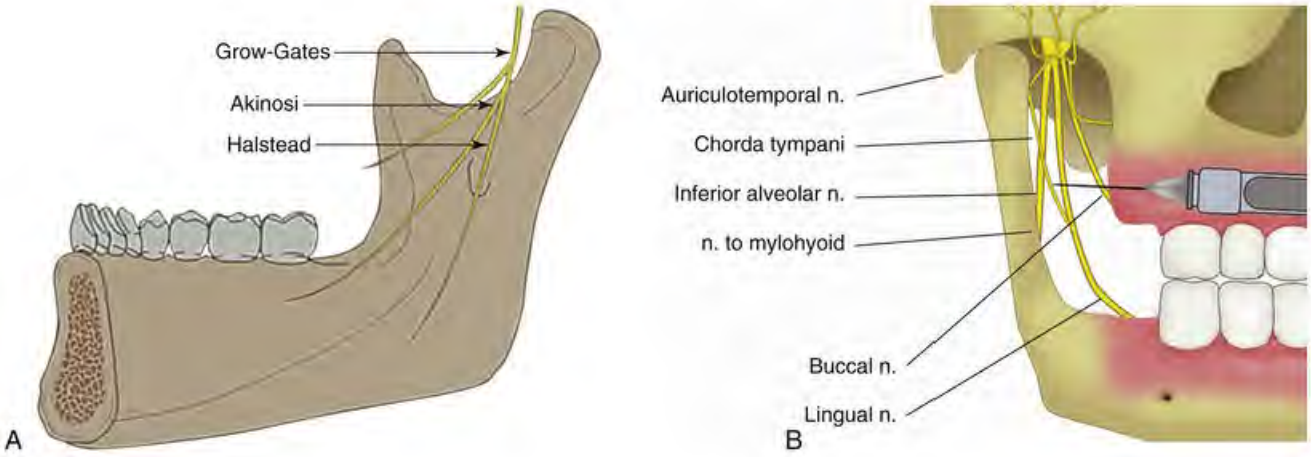

FIG 5.25 (A) The Akinosi block procedure for local anesthesia is more effective than the traditional dental injection in the edentulous patient. (B) Akinosi technique: The patient's mouth is almost completely closed or at the approximate occlusal vertical dimension in a denture wearer. The cheek is retracted with the free hand to expose the posterior teeth. The syringe is aligned parallel to the occlusal plane of the maxillary molars, and the needle is positioned level with the mucogingival junction of the maxillary second and third molars. The needle is inserted into the buccal mucosa as close as possible to the medial surface of the mandibular ramus to a depth of 25 to 30 mm without contacting bone. After careful aspiration, the anesthetic solution is deposited approximately halfway between the mandibular foramen and the neck of the condyle into the middle of the pterygomandibular space. (From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.)

Inadequate Blood Spin for Platelet-Rich Fibrin

Platelet-rich fibrin (PRF), described by Choukran et al, has become very popular in the field of implant dentistry.[25] The obtained fibrin platelet matrix contains numerous growth factors that are responsible for cell mitosis, increasing collagen production, recruiting cells to the injury site, initiating angiogenesis, and inducing cell differentiation. After drawing the patient's blood, a centrifuge process allows the formation of a fibrin mesh that is enriched with platelets and growth factors. This natural fibrin matrix concentrates platelets and growth factors and allows for enhanced hard and

soft tissue healing. Within the tube the fibrin clot is formed in the middle layer. The upper layer contains the acellular plasma, and the bottom part contains red corpuscles.

Etiology

When the centrifuge process does not work properly, a distinct middle layer (PRF) will not be present. This may happen because of numerous possibilities including:

- Delay in centrifuging blood (the longer the delay, the less clot formed)
- Insufficient time in the centrifuge
- Inadequate centrifuge RPM (3000 rpm)
- Test tube contains anticoagulant (e.g., chloral hydrate)

Prevention

The blood sample should be immediately placed in the centrifuge without delay and spun for a minimum of 12 minutes.

Treatment

If the fibrin clot is not present, a new blood sample should be obtained and the process is repeated (Fig. 5.26).

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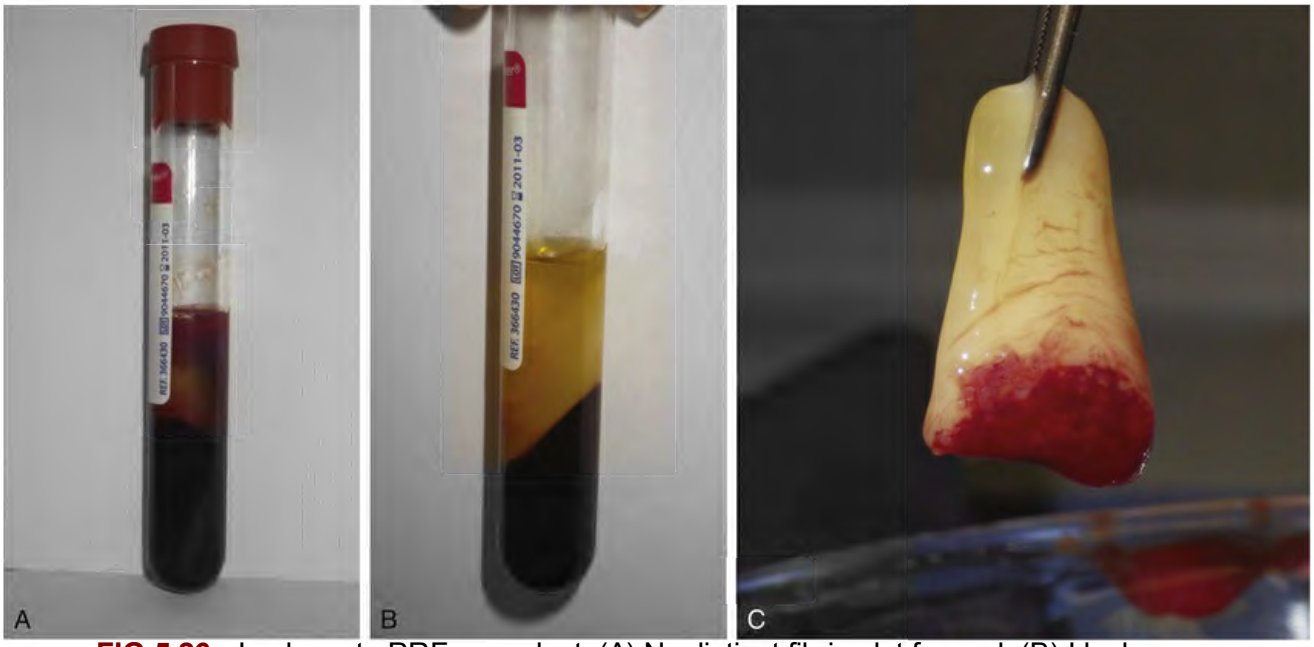

FIG 5.26 Inadequate PRF coagulant. (A) No distinct fibrin clot formed. (B) Ideal spin includes the three distinct layers. (C) PRF clot.

Difficulty in Obtaining Blood Sample for PRF Process

A failed blood draw is most commonly caused by improper needle position. Ideally, with the use of a vacutainer, after penetration into the vein, negative pressure allows for the rapid filling of the sample tube.

Etiology

If free flow of the blood into the tube is not present, it is most commonly due to one of the following improper needle positions: (1) needle insufficiently deep enough to penetrate vessel; (2) needle too deep, resulting in perforation of vessel; (3) needle bevel against the wall of the blood vessel; (4) venospasm resulting in the collapse of the vessel; (5) hematoma formation at the site of needle entry; (6) intraarterial insertion (Figs. 5.27 and 5.28).

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FIG 5.27 Ideal venipuncture technique. (A) Vacutainer armamentarium. (B) Enter vessel with bevel up and at a 30-degree angle. (C) Once the vessel has been entered, decrease angle slightly while advancing. (D) Press collection tube to perforate, negative pressure will allow tube to fill with blood. The tube will fill until pressure decreases (≈10 mL). The vacutainer is removed. (E) Final tube with blood specimen. (F) Pressure is placed over venipuncture site.

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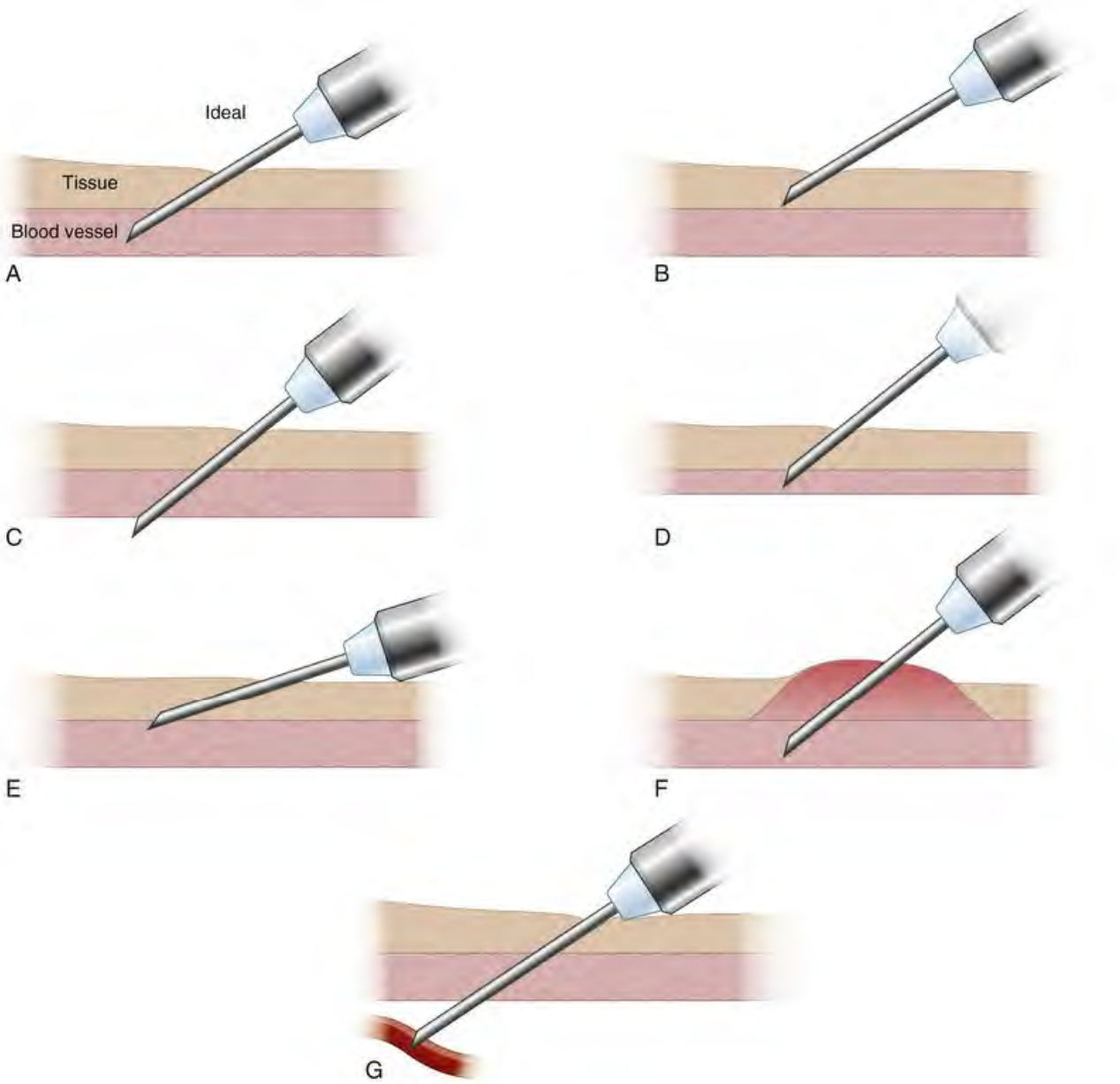

FIG 5.28 Venipuncture troubleshooting. (A) Ideal needle placement. (B) Needle too shallow, needs to be placed deeper into the tissue to perforate vessel. (C) Needle too deep, should be removed and a new venipuncture site selected. (D) Vein collapse, replace tourniquet, if still no flow, remove and select new site. (E) Bevel against vein wall, increase angle and place needle slightly deeper. (F) Hematoma formation, remove needle and select new site, pressure and ice. (G) Intraarterial entry, remove needle and select new site.

Prevention

Follow the ideal protocol for a venipuncture:

1. Place tourniquet approximately 5 inches above proposed entry site.

2. Identify vein and alcohol antiseptic swab.

3. Skin pulled in opposite direction of needle.

4. With bevel up, enter at a 30-degree angle.

5. Perforate vein and decrease angle with slight advancement.

6. Remove tourniquet.

7. Remove needle.

Treatment

If there is an unsuccessful blood draw, the process should be repeated, usually on the opposite arm. If a hematoma results, the following treatment should be rendered:

1. Immediate pressure and ice application.

2. Moist heat to decrease pain after 4 hours of venipuncture.

3. Analgesics for pain.

4. Usually requires 10 to 14 days for subcutaneous blood to resolve.

Severe/Life-Threatening Complications

Swallowing/Aspiration of Implant Components

Unfortunately, any type of dental procedure may result in the aspiration or ingestion of dental parts or materials. Accidental inhalation of dental instruments (drills, burs, direction indicators, root tips, crowns, etc.) can result in many complications, including life-threatening situations. When this complication occurs, the implant dentist must act proactively to avoid complications and medicolegal issues.

Etiology

Because of the small size of abutments, screws, drivers, and other implant components, a significant risk for the implant clinician exists. This may occur during any dental implant procedure, including the surgical and prosthetic phases.

There are two possibilities: the patient may swallow the foreign object into the stomach or aspirate the foreign material into the lungs.

Swallow.

If the object is swallowed, usually the patient will be asymptomatic. However, depending on the shape and size of the object, it may need to be removed because of the complication of blockage or not passing through the gastrointestinal system.

Aspiration.

The object may end up in the lungs, in which case the patient will be symptomatic. The patient will exhibit signs of coughing, wheezing, hoarseness, choking, stridor, or cyanosis.

Prevention

Various techniques are available for the implant clinician to prevent aspiration or swallowing of a foreign object. There is no one technique that will guarantee that this complication will be avoided; however, extreme caution should always be exercised. Techniques to prevent swallowing or aspiration include:

- Floss ligatures to all possible implant components

- Use AS123 prosthetic tool
- Use throat packs (4 × 4 gauze) or pharyngeal screens
- High-vacuum function
- Use curved hemostats

Treatment

If an instrument is lost in the mouth, the patient should first be instructed to not sit straight up because this will ensure the swallowing or aspiration of the instrument. The patient should turn to the side and attempt to “cough” the instrument up. If the instrument is lost, symptoms usually will determine if aspiration into the lungs or swallowing into the stomach has occurred. If the instrument has been swallowed into the stomach, usually the patient will exhibit no symptoms. If the patient has aspirated the instrument, this will most likely be accompanied with coughing, wheezing, pain, and cyanosis. This may be life-threatening and should be treated accordingly as a medical emergency. In all swallowing/aspiration situations, the patient should be referred to their physician or emergency room for an immediate chest x-ray. If the instrument has been aspirated, it is usually located in the right bronchus because the right main bronchus has a more acute angle than the left. Rigid bronchoscopy is usually used for the removal of the instrument under general anesthesia (Fig. 5.29).

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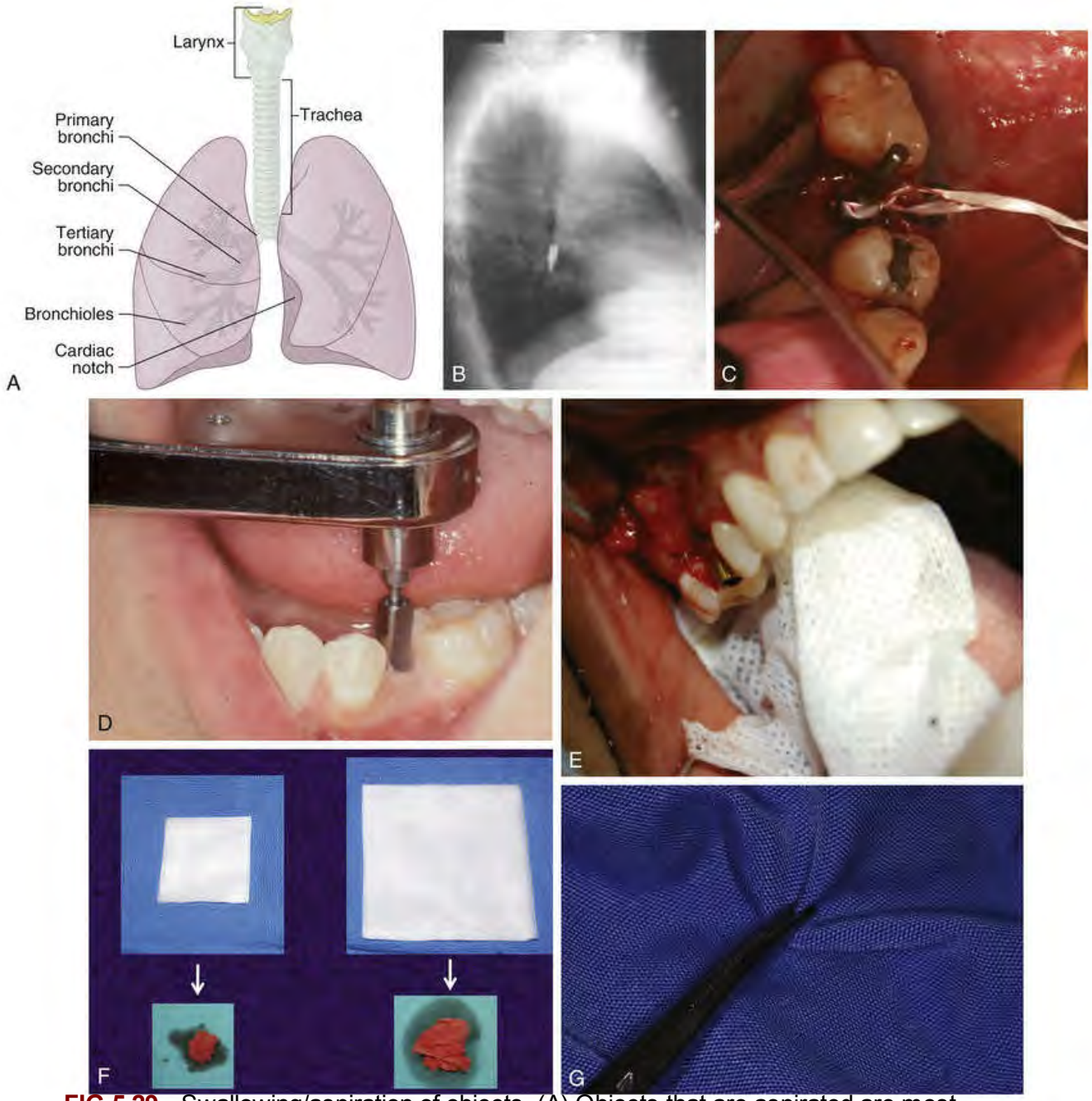

FIG 5.29 Swallowing/aspiration of objects. (A) Objects that are aspirated are most likely to enter the right bronchi because it is more vertical than the left. (B) Chest x-ray of implant hex driver in lungs. (C) Floss ties used to prevent aspiration. (D) Extraoral prosthetic tool allows for safer placement of abutments/screws. (E) 4 × 4 gauze throat pack. (F) 2 × 2 throat packs should never be used during implant surgery because they can be easily aspirated, swallowed, or left under a soft tissue flap. (G) Curved hemostats should always be available to retrieve any implant components in the oral cavity.

Air Emphysema

Subcutaneous air emphysema can lead to many devastating complications during and after dental implant surgery. Early recognition and management of this condition is crucial to preventing progression of the problem. As the air accumulates subcutaneously, dissection occurs along the connective tissue that joins the adjacent muscle planes. Via the fascial spaces, air from the oral cavity may extend into the mediastinum space, where it may communicate with parapharyngeal and retropharyngeal spaces, which lead to airway compromise. From the retropharyngeal space, air may lead into the pleural space and pericardium, which could result in heart and lung failure.

Etiology

Because of the attachment apparatus difference between implants and teeth, air extruded into the sulcular area around implants may lead to air emphysema. The two most common ways for this to occur is the use of an air-driven handpiece or an air-water syringe in which air is forced into the sulcular area. Symptoms will include swelling that increases over time with a "crackling" feeling with pain. Crepitus to palpation will confirm the diagnosis of air emphysema. The patient will usually be apprehensive with a feeling of difficulty in breathing.

Prevention

When placing implants, modifying abutments with the mouth, or removing bone around an implant body, an electric handpiece should always be used (i.e., never use a air-driven handpiece). Additionally, an air-water syringe should never be used to place air into the sulcular area parallel to the long axis of the implant.

Treatment

Usually symptoms arise immediately; however, cases have been described that have occurred minutes to hours after a procedure. Patients with significant emphysema should be monitored closely prior to discharge for respiratory or cardiac distress. Treatment should include supportive therapy with heat and analgesics. Antibiotic therapy should always be given because infection may result from bacteria being induced into the fascial spaces with resultant cellulitis or necrotizing fascitis. Resolution usually occurs in 4 to 7 days with minimal morbidity. In isolated cases, exploratory surgery, emergency tracheotomy, and the placement of chest tubes have been

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reported (Fig. 5.30).[26]

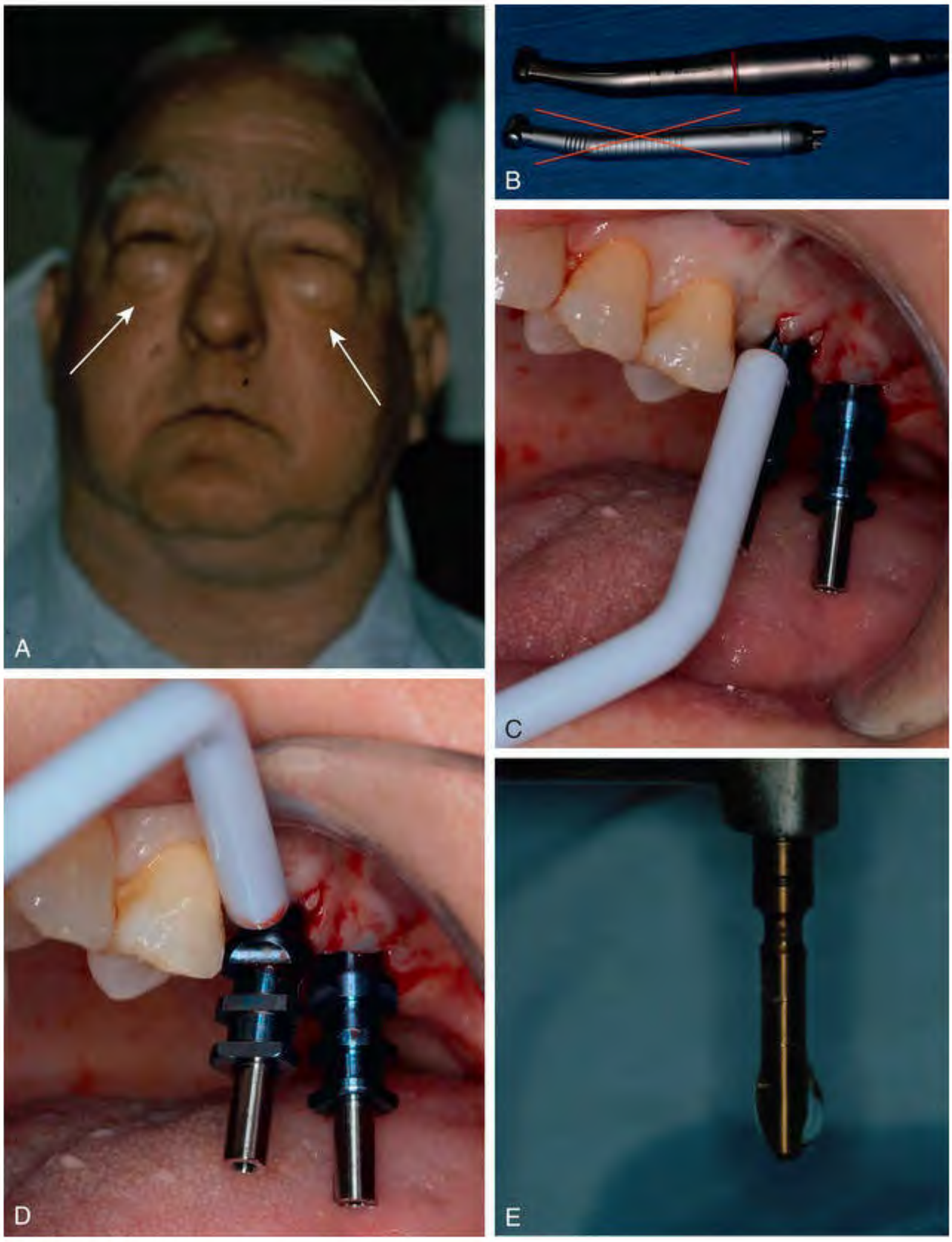

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FIG 5.30 Air emphysema. (A) Patient with air emphysema extending into the orbital region. (B) Air-driven handpieces (air used to turn turbines) should be used with extreme caution around implants. Electric handpieces can be used because there is no chance of expelling air into the fascial spaces. (C) the air-water syringe should never be directed into the sulcular area (i.e. parallel to the long-axis of the implant as an air emphysema may result, (D) air-water syringe can be used with caution perpendicular to the abutment/implant. (E) Internal irrigated burs are a common way to expel air into the marrow spaces and should be used with caution.

Soft/Hard Tissue Complications

Electric Handpieces

Electric handpieces, the most common type of handpieces used in implant dentistry today, have a tendency to overheat, which may result in significant soft tissue complications. In 2007 and 2010, the FDA released warnings to health professionals concerning possible serious burns related to electric dental handpieces. The FDA has requested manufacturers to decrease these issues by design modification, overheating alarms, warning labels, and clinician training to avoid overheating.

Etiology.

Because electric handpieces have insulated housings, the clinician may not be aware of the extent of the heat generated in the handpiece. Compounding the problem is that the patient may be anesthetized and unaware of the thermal injury. Injuries have been reported ranging from first- to third-degree burns and may require reconstructive surgery. Unlike conventional air-driven handpieces that decrease efficiency when overworked, electric handpieces will maintain higher efficiency, thus generating a greater amount of heat.

Prevention.

Awareness is most crucial for avoiding this complication. The clinician should be conscious of the possibility of handpiece overheating, take frequent breaks during treatment, and check continuously for the implant motor becoming hot during treatment. The electric handpieces should have routine maintenance according to manufacturer's recommendations.

Treatment.

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If a burn occurs, treatment will vary depending on the severity usually. Treatments range from OTC ointment to a physician referral. For severe burns, systemic antibiotics are warranted. If the burn does not penetrate the vermillion border, healing will usually result without a defect (Fig. 5.31).

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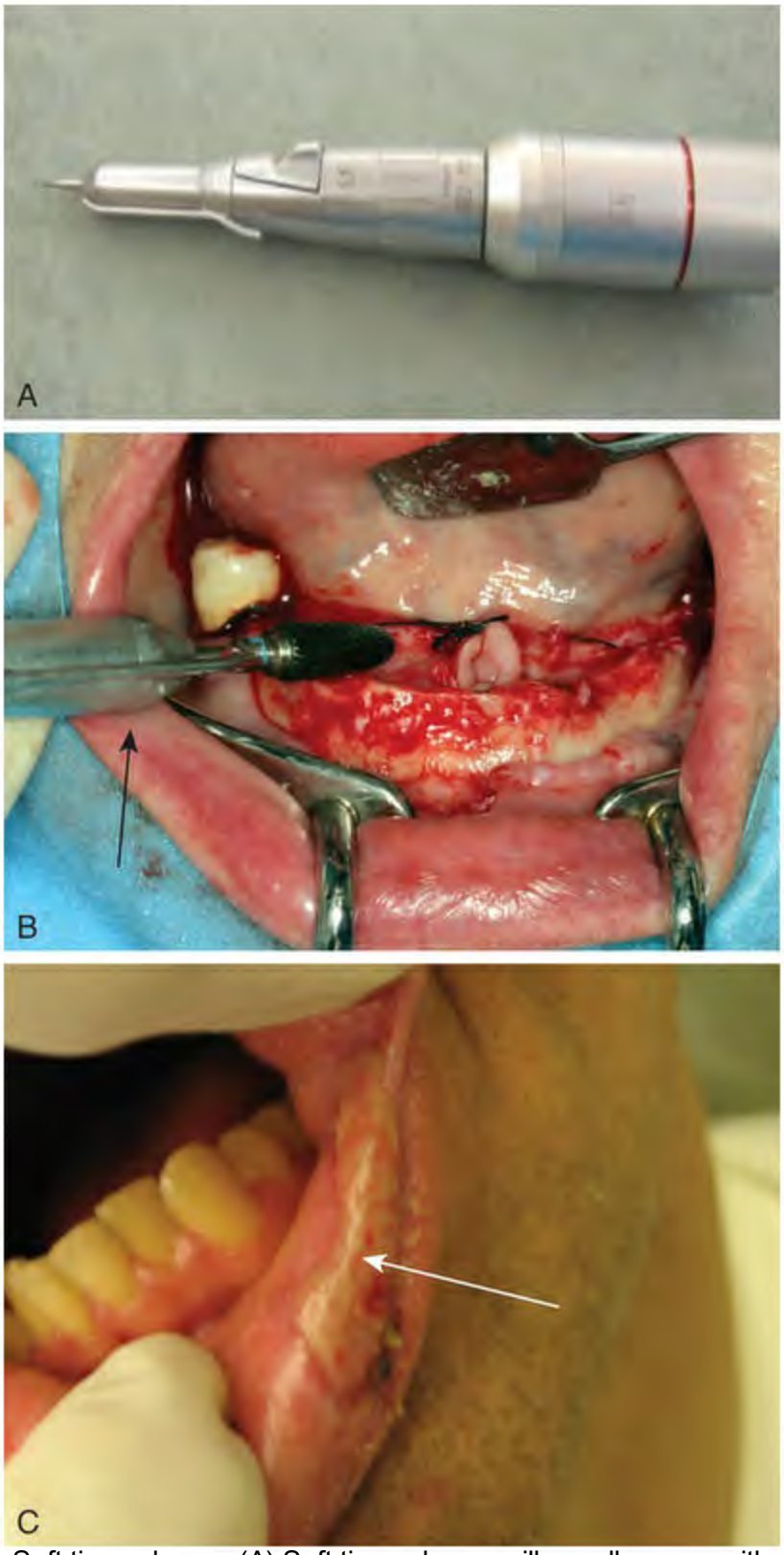

FIG 5.31 Soft tissue burns. (A) Soft tissue burns will usually occur with an electric handpiece (e.g., 1 : 1 straight handpiece). (B) Handpiece in contact with anesthetized tissue *(arrow)*. (C) Soft tissue injury from implant handpiece in contact with anesthetized tissue *(arrow)*.

Monopolar Electrosurgery Units

Monopolar electrosurgical units are a common soft tissue modality used in dentistry today. However, in implant dentistry, when these units are used around dental implants, significant complications may arise. Monopolar electrocautery should never be used in the proximity of a dental implant or implant prosthesis.

Etiology.

Electrosurgery is defined as the controlled passage of high-frequency waveforms, or currents, for the purpose of altering the surrounding soft tissue. The action of monopolar electrocautery is cutting the tissue by means of advancing spark with a grounded patient. This results in sparking, current spread, and thermal damage in the tissues because of the generation of heat.

Prevention.

In implant dentistry, monopolar electrosurgery units are contraindicated. The monopolar electrodes cannot contact an implant or electrical shock osteoradionecrosis and possible implant loss may result (Fig. 5.32). However, bipolar electrosurgical units have been shown to be effective around dental implants. Bipolar electrocautery utilizes molecular resonance with a sine-wave current that prevents sparking and thermal damage. These types of units may be used continuously because they produce progressive coagulation rather than a single high-output discharge, thus creating no spark.[27]

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FIG 5.32 Soft tissue burns. (A) Electrosurgery (monopolar) used around implant with associated thermal damage. (B) Injury one week after electrosurgery. (C) Injury two weeks after surgery. (D) Failure of implant.

Treatment.

Treatment is usually palliative in nature as electrosurgery damage is usually irreversible.

Salivary Gland Injury

The sublingual gland may be injured when an implant is placed in the posterior mandible, which may cause the formation of a ranula. Ranulas are defined as an accumulation of extravasated salivary secretions that form pseudocysts in the submandibular area. When the ranula form above the mylohyoid muscle, they appear as a translucent, bluish swelling in the

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sublingual space. Most ranulas are visible on a clinical examination and are considered “plunging” when they extend inferiorly from the sublingual space into the neck area. Ranulas are usually not fixed, and they are very rarely painful unless they become secondarily infected. In some cases, they develop into larger lesions and may compromise the airway.

Etiology

The proximity of the sublingual gland to the lingual cortical plate of the mandible makes it susceptible to injury. If the gland is traumatized, a ranula may result. Trauma usually occurs from improper angulation during dental implant surgery, which perforates the lingual cortex and causes damage to the sublingual gland. Additionally, the gland may be injured during aggressive reflection and retraction when working in the sublingual area.

Prevention

To prevent damage to salivary glands, ideal preoperative treatment planning, good surgical technique, proper implant angulation, and careful retraction will avoid these complications. Additionally, the anatomy of the sublingual area must be understood. The sublingual gland is positioned adjacent to the lingual cortex and seated below the mylohyoid muscle. The submandibular duct is positioned inferior and medial to the sublingual gland. The lingual nerve will cross the submandibular duct from medial to lateral and then cross back at the first premolar area, where it branches into the tongue musculature.

Treatment

Treatment should include referral to an oral and maxillofacial surgeon, which usually involves the complete removal of the sublingual gland. In some cases, where the ranulas are very small and asymptomatic, no surgery may be indicated or marsupialization to reestablish connection with the oral cavity (Fig. 5.33).[28]

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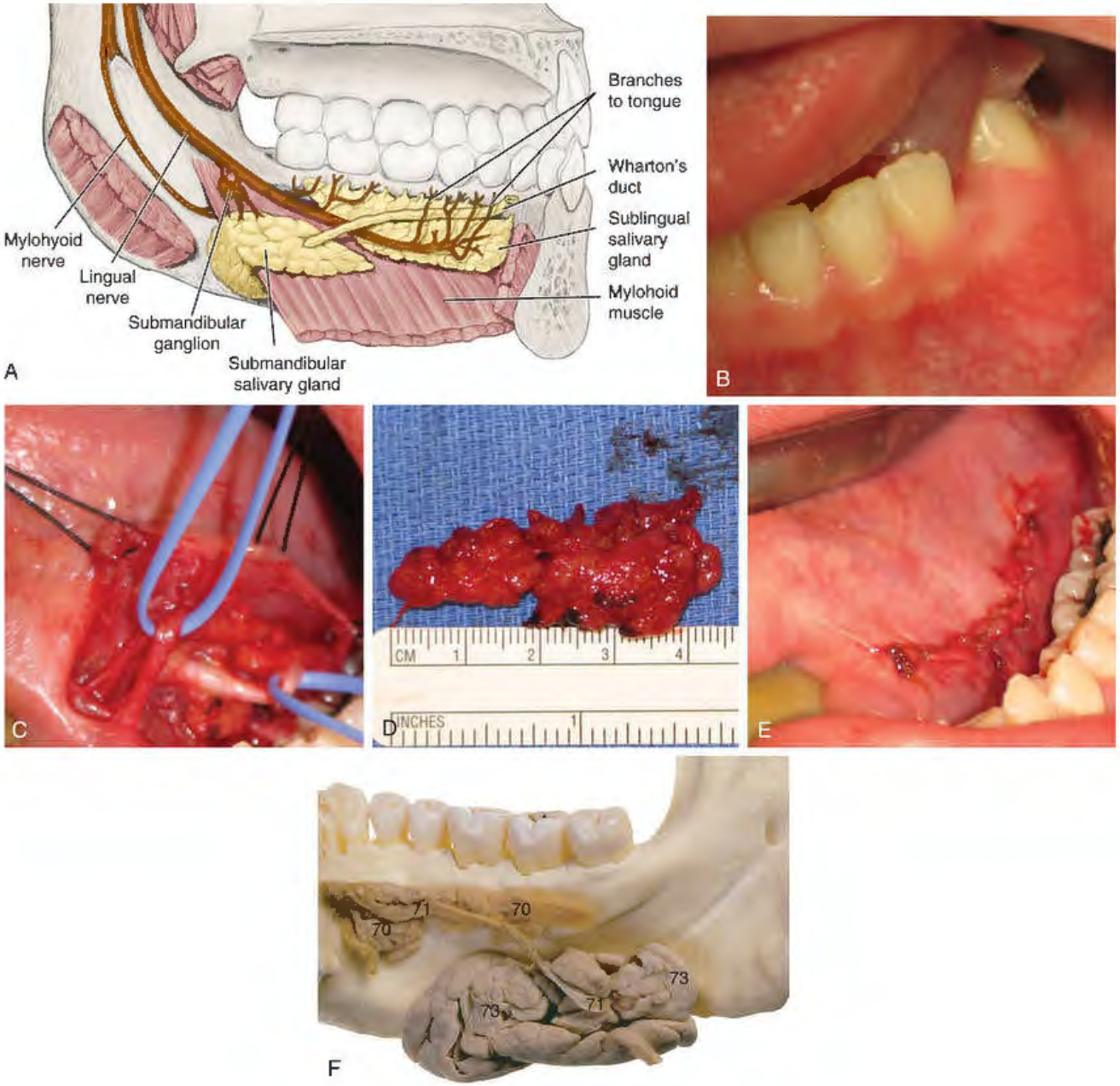

FIG 5.33 Salivary gland damage. (A) Sublingual gland anatomy. The interrelationships between the ductal systems of the submandibular and the sublingual glands and the relationship of the lingual nerve to Wharton's duct are demonstrated. (B) Sublingual ranula after implant placement in premolar area. (C) Dissection including the retraction of the lingual nerve, which transverses the sublingual gland. (D) Treatment included complete removal of sublingual gland. (E) Sublingual closure after removal. (F) Close approximation of sublingual gland (70), submandibular gland (73), and submandibular duct (71). (A, From Fehrenbach MJ, Herring SW: *Illustrated anatomy of the head and neck*, ed 5, St. Louis, 2017, Elsevier; B–D, From David J. Datillo, DDS, Allegheny General Hospital, Pittsburgh, PA; F, From Logan BM, Reynolds P, Hutchings RT: *McMinn's color atlas of head and neck anatomy*, ed 4, Philadelphia, 2010, Mosby.)

Anesthetic Toxicity

A serious complication, local anesthetic overdosage is of great concern in implant dentistry. Because many implant-related surgeries are of longer duration, a greater amount of anesthetic is often administered. Special attention must be taken during implant surgery as to the number of cartridges and type of anesthetic used during a procedure.

Etiology

The maximum number of cartridges that can be administered safely to a patient is time dependent. The elimination half-life is not indicative of anesthetic duration; however, it may be used as a guide for repeated anesthetic administration during a lengthy procedure. After one half-life, as much as 50% of the permissible dose can be administered with reasonable safety if liver function is normal. Special care must be given to the use of combination local anesthetics. In implant dentistry, it is common to use two amide anesthetics together—lidocaine and bupivacaine. Although acceptable, total doses should not exceed combined maximum recommended doses. Calculations should factor in the total dose of the combination and whether sufficient time has elapsed for elimination of the initial dose.[29]

Treatment

Most amide anesthetics (except for articaine) are metabolized by the liver by a microsomal enzyme system. Special attention should be given to patients with decreased liver function (e.g., as a result of chronic alcoholism, hepatitis), especially elderly patients. The half-life of lidocaine has been shown to be greater than 2.5 times the normal values in patients with hepatic disease.[30] Special attention must be given to the amount of anesthetic used, and concern for reinjection (i.e., amount of anesthetic administered after initial block) must be strictly evaluated in these patients. In addition to the liver, the kidneys are the primary organs responsible for excretion of the local anesthetic and its metabolites. Patients with significant renal impairment will also have difficulty in removing the anesthetic from the blood, resulting in an increased chance of toxicity.

Patients with cardiovascular disease should be well evaluated before the use of epinephrine-containing anesthetics, and care should be taken as to the amount of epinephrine administered. Recommendations on the maximum safe dose for a healthy patient are 0.2 mg epinephrine vs. 0.04 mg epinephrine for the cardiac-impaired patient. It should be noted that when

epinephrine is not included in the anesthetic, the systemic uptake of the drug is more rapid and the maximum number of carpules given is significantly less in comparison to anesthetics with vasoconstrictors.

If local anesthetic toxicity reactions occur,[31] central nervous system excitation, convulsions, respiratory depression, and cardiac arrest may occur. Appropriate emergency medical care should be administered immediately (Box 5.1 and Table 5.1).

Box 5.1

Signs and Symptoms of Local Anesthetic Toxicity

Mild Symptoms

- Talkativeness
- Slurred speech
- Apprehension
- Localized muscle twitching
- Lightheadedness/dizziness
- Tinnitus
- Disorientation

Progressive Symptoms

- Lethargy
- Unresponsiveness
- Drowsiness/sedation
- Lack of muscle tone
- Mild drop in blood pressure, heart, and respiratory rate

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From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby; Adapted from Bennett CR: *Monheim's local anesthesia and pain control in dental practice,* ed 7, St Louis, 1984, Mosby.

TABLE 5.1

Maximum Manufacturer-Recommended Number of Anesthetic Capsules

Weight of Patient (lb)	2% Lidocaine 1/100 K Epinephrine	2% Mepivacaine 1/20 K Neocobefrin	4% Articaine 1/100 K Epinephrine	5% Bupivacaine 1/200 K Epinephrine
80	6.5	6.5	3.5	5
100	8	8	4.5	6.5
120	10	10	5.5	8
140	11.5	11	6	9
160	13	11	7	10
180	13.5	11	7	10
200	13.5	11	7	10

From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby; Data from Malamed SF: *Handbook of local anesthesia,* ed 6, St Louis, 2013, Mosby.

Surgical (Anesthesia) Fires

Dental surgical fires are rather rare; however, with the increased use of sedation in implant dentistry, this potentially devastating complication may occur. The FDA receives reports of approximately 500 to 600 surgical fires each year in the United States. Deaths are rare except for fires that occur in the airway. Clinicians need to be aware of the possibility and take steps to prevent this complication.

Etiology

Surgical fires occur in dental surgery when the following three elements of the fire triangle are present:

1. Ignition source (e.g., electrosurgery, lasers, fiberoptic light sources)

2. Fuel source (e.g., surgical drapes, alcohol-based skin preparation agents such as chlorhexidine)

3. Oxidizer (e.g., oxygen, nitrous oxide)

The most significant risk for a dental surgical fire occurs when laser or electrocautery units are use in an oxygen-rich environment such as when supplemental oxygen is administered via a nasal cannula. The spark from the electrocautery unit or laser in the presence of oxygen or highly inflammable

anesthetic gases may cause the explosion or surgical fire.[32]

Prevention

The FDA recommends the following steps to prevent dental surgical fires[33]:

1. Determine which procedures carry high risk, which will include any procedure requiring the use of supplemental oxygen and the operation of an ignition source near the oxygen.

2. Use supplemental oxygen safely. Deliver the minimum concentration of oxygen needed to maintain adequate oxygen saturation for your patient. If any type of ignition source is required, oxygen should be decreased or shut off.

3. Use alcohol-based (flammable) skin preparation agents safely. Prevent alcohol-based antiseptics from pooling in the surgical area (mouth). Remove alcohol-soaked materials from the prep area, such as 4 × 4 gauze that is used for intra or extra oral scrub. Allow adequate time for the alcohol-based antiseptic to dry.

4. Use surgical equipment safely and consider alternatives to using an ignition source for dental implant surgery. If an ignition source must be used, know that it is safer to do so after allowing time for the oxygen concentration to decrease. It may take several minutes for a reduction of oxygen concentration in the area even after stopping the gas or lowering its concentration.

5. Understand that surgical drapes and other fuel sources (e.g., patient napkins, surgical table covers) can ignite easily and burn in an oxygen-enriched environment, even if the products are described as “flame-resistant.”

Treatment

In case of an airway fire, immediately halt the procedure and stop the flow of any gases (e.g., oxygen) and ventilate the operatory. Remove any flammable material such as gauze and patient drapes. Saline may be used to extinguish an airway fire. Assess the patient; medical assistance should be summoned in most cases (Boxes 5.2 and 5.3).

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Box 5.2

Surgical Fire Sources in Oral Implantology

IGNITION (HEAT) SOURCES

- Electrosurgery
- Lasers
- Fiberoptic cables and lights
- Heat and spark from tooth/implant abutment preparation from high-speed handpiece
- Defibrillators

OXYGEN (OXIDIZERS)

- Oxygen – usually via nasal cannula
- Nitrous oxide – via nasal hood, nitrous oxide releases oxygen when heated

FUEL

- Gauze and cotton rolls
- Surgical gowns and blankets
- Petrolatum (petroleum jelly)
- Chlorhexidine
- Alcohol-based skin prep solutions
- Facial hair, epithelium, and so forth
- Vellus hair
- Rubber and plastic goods
- Nasal cannula and nasal hood

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- Latex

From Bosack RC, Bruely ME, VanCleave AM, et al: Patient fire during dental care: a case report and call for safety. *J Am Dent Assoc* 147(8): 661–666, 2016.

Box 5.3

Surgical Fire Treatment Algorithm

PREVENT

- Fire drills with surgical staff
- "Time out" after use of certain fuels (i.e., sufficient drying time for alcohol-based prep solutions)
- Follow all safety practices when using potential ignition sources
- Coat hair around the mouth with water-soluble surgical jelly; keep fuels moist
- Open-face surgical draping
- Stop flow of oxidizers for at least 1 minute before the use of potential ignition sources

RECOGNIZE

- Any unexpected patient movement, odor, unexpected discomfort/pain, discoloration, heat, or smoke

MANAGE

- Immediately remove burning materials that should be extinguished by another team member
- Stop the flow of oxygen or nitrous oxide to the patient
- Smother or pour sterile saline or water on small patient fires
- Care for the patient: airway, ventilation, and immediate emergency medical service

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From Bosack RC, Bruely ME, VanCleave AM, et al: Patient fire during dental care: a case report and call for safety. *J Am Dent Assoc* 147(8):661–666, 2016.

Oral/Conscious Sedation Toxicity

It has been estimated that as many as 75% of adults in the United States have some degree of dental fear, ranging from mild to severe,[34] and that approximately 5% to 10% avoid dental care because of anxiety.[35] In implant dentistry the use of conscious sedation is a valuable adjunct. The American Dental Association defines *conscious sedation* as a minimally depressed level of consciousness that retains the patient's ability to independently and continuously maintain an airway and respond appropriately to physical stimulation or verbal command and that is produced by a pharmacologic or nonpharmacologic method or combination thereof.[36] Several sedative agents are currently available for oral and intravenous sedation. Table 5.2 lists the most commonly used oral and intravenous sedative agents.

TABLE 5.2

Most Commonly Used Oral and Intravenous Sedative Agents

Sedative Agent	Class	Administration	Onset (min)	Duration (hr)	Half-Life (hr)	Active Metabolites	Oral Dose	IV Dose	Amnesia	Analgesia
Triazolam	Benzodiazepine	PO	60	1–2	2–3	No	0.125–0.25 mg	—	Yes	No
Diazepam	Benzodiazepine	PO/IV	PO: 60 IV: 1–2	0.25–0.5	21–37	Yes	0.2–0.5 mg/kg; maximum 15 mg	0.1 mg/kg	Yes	No
Lorazepam	Benzodiazepine	PO/IV	PO: 120–240	IV: 1–2	10–20	No	0.053 mg/kg; maximum 4 mg	0.03–0.04 mg/kg	Yes	No
Brevital	Barbiturate	IV	0.5	0.3	4	No	—	0.2–0.4 mg/kg	Yes	No
Fentanyl	Narcotic	IV	0.5	0.75–1	3–4	No	—	1–2 μg/kg	No	Yes
Propofol	Sedative hypnotic	IV	0.2–0.5	3–8 min	0.5–1.5	No	—	25–100 μg/kg/min	Yes	No
Midazolam	Benzodiazepine	PO/IV	0.5–1	0.25–1.25	1–4	No	0.5 mg/kg	0.01–0.1 mg/kg	Yes	No

IV, intravenous; *PO*, oral.

From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.

Benzodiazepines

Etiology.

Benzodiazepines are the most effective drugs available for dental-related

anxiety used in private practice today. Benzodiazepines mainly produce anxiolysis and anterograde amnesia, which are extremely useful for patients undergoing conscious sedation for dental implant procedures. The exact mechanism is not known; however, benzodiazepines are thought to have an effect on the limbic system and the thalamus, which are involved with emotions and behavior.[37] Unfortunately, in the field of sedation dentistry, the use of oral sedative agents is often misused, which may lead to significant complications.

Triazolam.

One of the most common benzodiazepines used today in implant dentistry is triazolam (Halcion), which is an orally administered and short-term hypnotic drug. In addition to its hypnotic properties, triazolam also has the advantages of anterograde amnesia, anxiolytic, sedative, and anticonvulsant properties. When given orally, this drug is fast acting with short duration and has been shown to be safe and effective for dental procedures. Studies have shown that triazolam given in doses of 0.25 to 0.5 mg does not produce adverse effects in respiration, heart rate, or arterial pressure.[37]

Diazepam.

Diazepam (Valium) is a long-acting drug that for years has been the most commonly used form of benzodiazepine. Basically, in low doses, diazepam reduces anxiety without sedation and in high doses it acts as a sedative and promotes sleep. Diazepam has anxiolytic, anticonvulsant, sedative, hypnotic, skeletal muscle relaxant, and amnestic properties. It is mainly used in dentistry to reduce tension and anxiety and induce retrograde amnesia. When given orally, it is rapidly absorbed and has a fast onset of action within 60 minutes. The bioavailability after oral administration is 100%, and the peak plasma levels occur between 30 minutes and 90 minutes after administration. Diazepam has the disadvantage of pharmacologically active metabolites, which may interact with other medications. Because of the active metabolites, diazepam has a biphasic half-life of about 1 to 2 days and 2 to 7 days for the active metabolite desmethyldiazepam, which results in prolonged action, causing drowsiness and lethargy for up to 48 hours.[38]

Additional Conscious Sedation Medications

Fentanyl is a synthetic opioid agonist narcotic that produces analgesia, drowsiness, sedation, and euphoria, but no amnesia. All opioid agonists

produce dose-dependent depression of ventilation. Respiratory depression is a result of a decreased response of the ventilatory centers to carbon dioxide. For this reason, care should be taken when administering opioid agonists, especially in combination with other sedatives. Nausea and vomiting are another undesirable effect of opioid agonists. Opioid-induced nausea and vomiting are caused by direct stimulation of dopamine receptors in the chemoreceptor trigger zone in the fourth floor of the fourth ventricle.

Propofol (Diprivan) is an intravenous sedative-hypnotic agent commercially introduced in the United States in 1989 by Zeneca Pharmaceuticals. It was the first of a new class of intravenous anesthetic agents: the alkylphenols. Propofol is an ideal sedative anesthetic for dentistry because it is fast-acting and possesses a short half-life. The elimination half-life of propofol has been estimated to be between 2 and 24 hours. However, its duration of clinical effect is much shorter because propofol is rapidly distributed into peripheral tissues. Because of its pronounced respiratory depressant effect and its narrow therapeutic range, propofol should be administered only by individuals trained in airway management. There is no reversal agent at this time for Propofol.

Prevention

The first key to prevention is obtaining adequate training in the use of conscious sedation. The implant dentist must acquire sedation skills from both a theoretical and a practical standpoint. The second key to prevention is preparedness, which first includes an up-to-date emergency kit containing emergency drugs (including reversal agents) and an airway kit that enables them to deliver oxygen under positive pressure. Oxygen is the first line of defense in a sedation emergency, and proper administration must be understood. The office should have an emergency plan in place. The third key of prevention is the use of sedative medications within maximum doses with strict protocol to patient monitoring.[39]

Treatment

Besides maintaining the patient's airway and an emergency protocol, implant dentists must have ideal reversal agents for benzodiazepines. Flumazenil (Anexate, Lanexat, Mazicon, Romazicon) is a benzodiazepine antagonist used as a reversal agent for the treatment of benzodiazepine overdose. It reverses the effects of benzodiazepines by competitive inhibition at the

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benzodiazepine binding site on the $GABA_A$ receptor.

The onset of action is rapid, and effects are usually seen within 1 to 2 minutes. The peak effect is seen at 6 to 10 minutes. The recommended dose for adults is 200 mg every 1 to 2 minutes until the effect is seen, to a maximum of 3 mg per hour. It is available as a clear, colorless solution for intravenous injection, containing 500 mg in 5 mL. It is hepatically metabolized to inactive compounds, which are excreted in the urine.[40] Many benzodiazepines have longer half-lives than flumazenil. Repeated doses of flumazenil may be required to prevent recurrent symptoms of overdosage after the initial dose of flumazenil wears off (Fig. 5.34). Reversal drug of choice is naloxone HCl (Narcan 0.4 mg/ml). The initial naloxone dose is 0.4 mg that can be repeated every 2 to 3 minutes depending on the patient's respiratory status. The duration of action of naloxone is shorter than most opioids, so the patient should be closely monitored for recurrence of opioid toxicity.

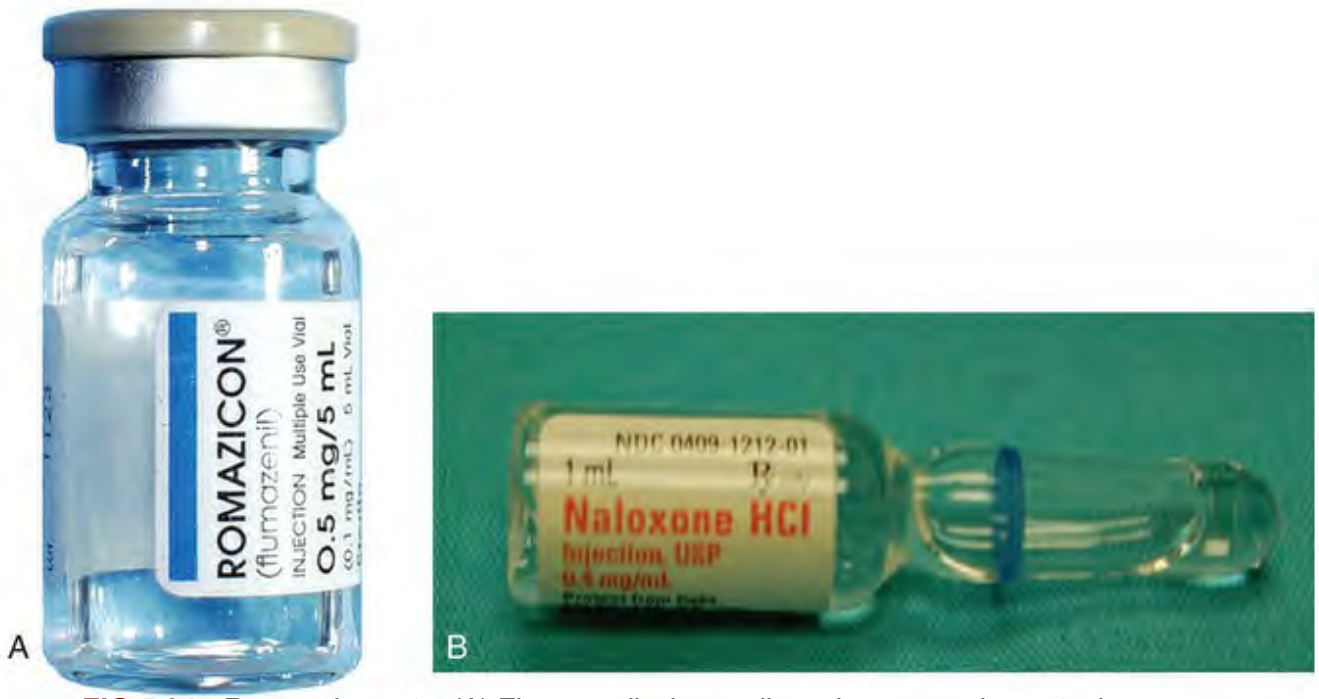

FIG 5.34 Reversal agents. (A) Flumazenil—benzodiazepine reversal agent, given in 2-mL doses (0.2 mg/mL) to a maximum of five doses. (B) Narcan—narcotic reversal agent, given in 0.4 mg/mL doses.

There exists numerous routes of pharmacologic administration for medical emergency episodes. The most ideal site for administration is intravenous (IV) because this method has direct access to the bloodstream. In most

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nonsedation cases, this is route is impractical. Another option for the implant clinician for the administration of an injectable emergency drug is the sublingual approach. This method allows for fast, easy access for the administration below the tongue, which allows for the medication to diffuse into the bloodstream. The insertion point is the sublingual midline to avoid damage to the salivary ducts.

The deltoid approach (intramuscular) utilizes the deltoid muscle site (upper arm), which is recommended for injections of smaller volume. To locate this administration site, the acromian process is palpated as the superior landmark and the axilla is the inferior landmark with the injection site in the middle. The deltoid technique has slower uptake than the sublingual approach.

The last approach utilizes the lateral vastus lateralis muscle (IM injection) corresponds to the lateral thigh. This site has slower uptake than the deltoid; however, faster than the gluteal. The lateral thigh is divided into thirds, from the anterior knee to the posterior gluteal region. The entry point is in the center of the middle third (Fig 5.35).

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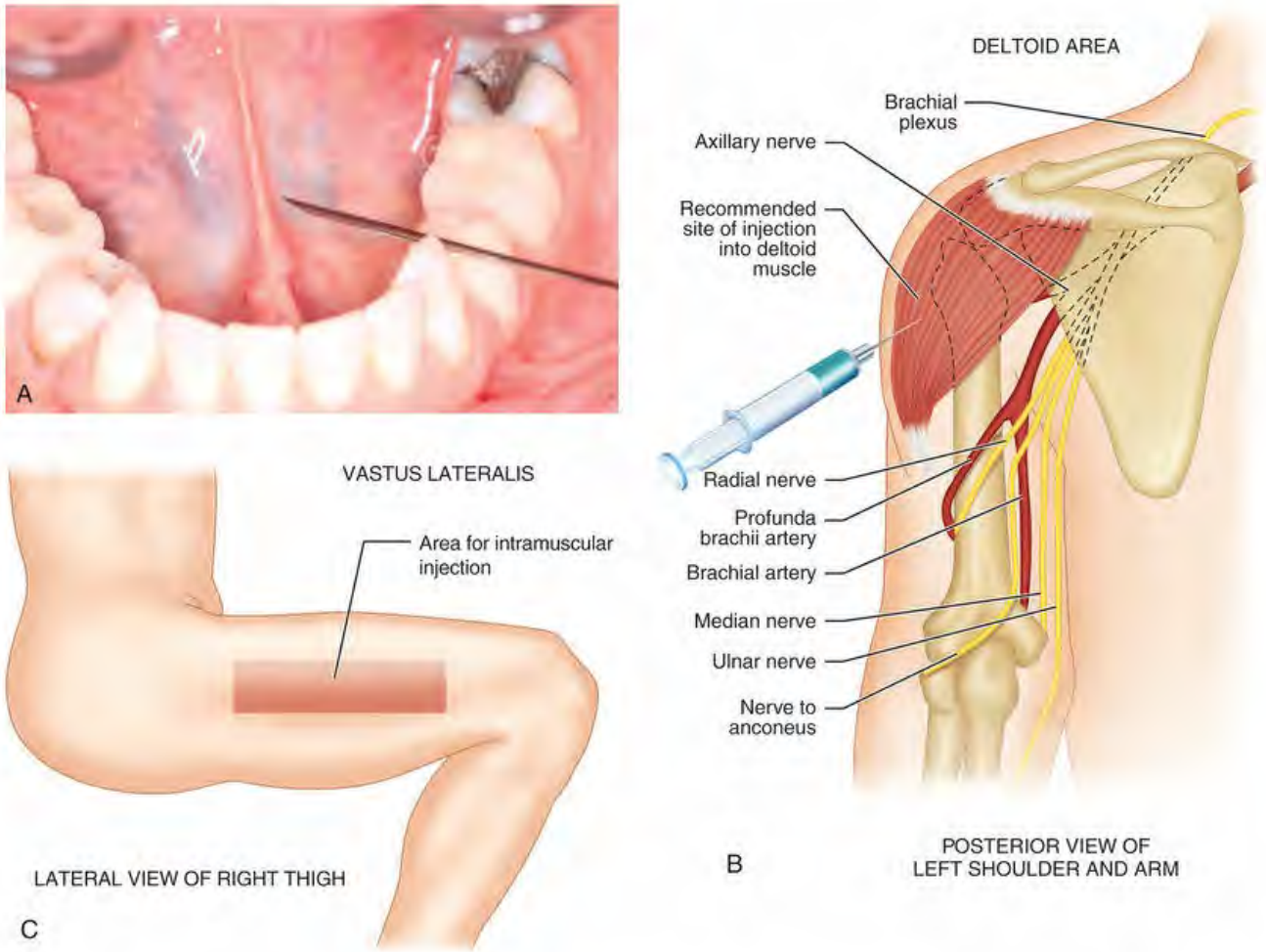

FIG 5.35 Emergency medication administration. (A) Sublingual—fast, easy access. (B) Deltoid—slower uptake, not as convenient as sublingual. (C) Thigh—fast, access more difficult than sublingual.

Summary

Over the course a career as an implant surgeon, regardless of skill level or experience, a clinician will undoubtedly come across some form of complication during the placement of a dental implant. Regardless of the severity of the complication, the proper means of remediation must be called upon at a moment's notice. With a vast, detailed knowledge of the many intraoperative complications reported during implant surgery, a plan to prevent them, and a protocol to treat them should they arise, the surgeon will provide a much safer and predictable surgical outcome for every patient.

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Ideal Implant Positioning

Randolph R. Resnik

To obtain proper esthetics and function of an implant supported prosthesis, the three-dimensional positioning of the dental implant is critical. The malposition of the implant can lead to significant implant complications and morbidity. In order to achieve an ideal result for the patient, a clinician must initially place implants in a correct orientation for the prosthesis design. Nonideal implant positioning may result in undesirable outcomes that may affect the success and longevity of prosthetic rehabilitation.[1] Optimal dental implant positioning should consider the three-dimensional placement of implants with respect to the biomechanical and prosthetic principles related to the final implant prosthesis. Recently, advances in implant dentistry have created a greater appreciation for the esthetic results of the implant restoration. Implant dentistry has experienced a profound shift: from a functional thought process with a surgical approach to esthetics, with a prosthetically and biologically driven approach.[2] The implant should be positioned in ideal relation to existing teeth, vital structures, and other implants as well as in buccolingual, mesiodistal, and apicocoronal dimensions. When implants are malpositioned, any of the following detrimental effects may occur (Fig. 6.1):

- Increased implant morbidity
- Increased prosthetic complications (e.g., esthetics, prosthesis)
- Increased prosthetic costs
- Increased periodontal complications
- Decreased longevity of prosthesis

The ideal three-dimensional positioning of a dental implant needs to be addressed prior to the surgical procedure. Lack of proper planning leads to malpositioning in the three spatial planes (Fig. 6.1). The placement of a dental implant in available bone is comparable to an object in space that is defined by "x," "y," and "z" coordinates. In implant dentistry, the x-axis is defined by the mesiodistal plane, the y-axis is the buccolingual dimension, and the z-axis is known as the apicocoronal (length of implant body in relation to the osseous crest).[3] Placement of dental implants ideally in the

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available bone does not necessarily prevent complications from arising. Not only does the implant need to be placed in the ideal three-dimensional position but also according to the type of final prosthesis. In this chapter the proper positioning of implants will be discussed according to the final prosthetic demands of the patient.

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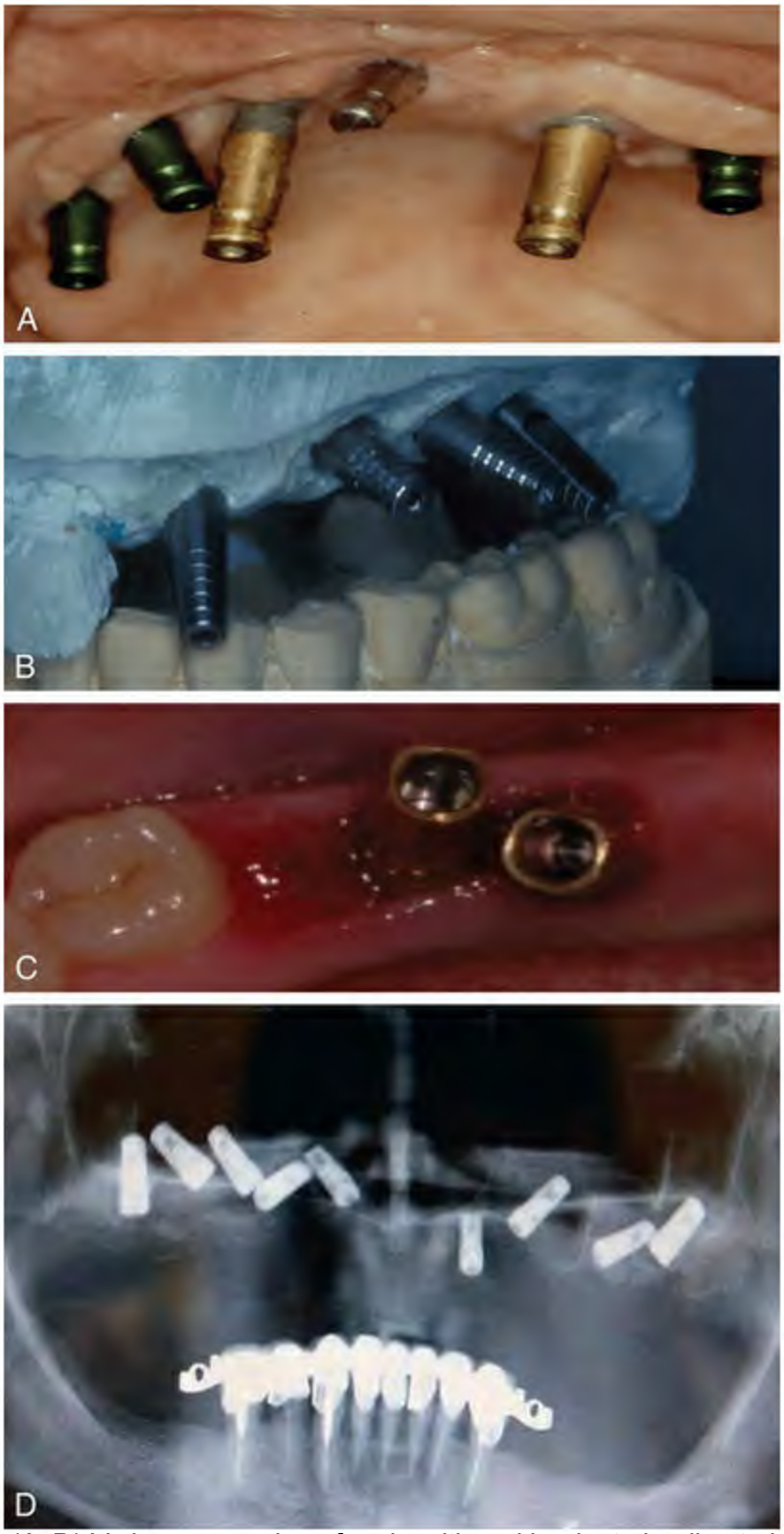

FIG 6.1 (A–D) Various examples of malpositioned implants leading to increased morbidity.

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Mesial-Distal (“X” Axis): Implant–Natural Tooth

Insufficient Implant–Root Apex Distance

Etiology

Implants placed too close to an adjacent tooth root are usually the result of poor treatment planning (inadequate space), poor surgical technique (improper angulation), or placement of too wide of an implant body. This may occur when there are root dilacerations of an adjacent tooth or if a tooth has been orthodontically repositioned to where the tooth root has encroached on the intraroot space (Fig. 6.2A).

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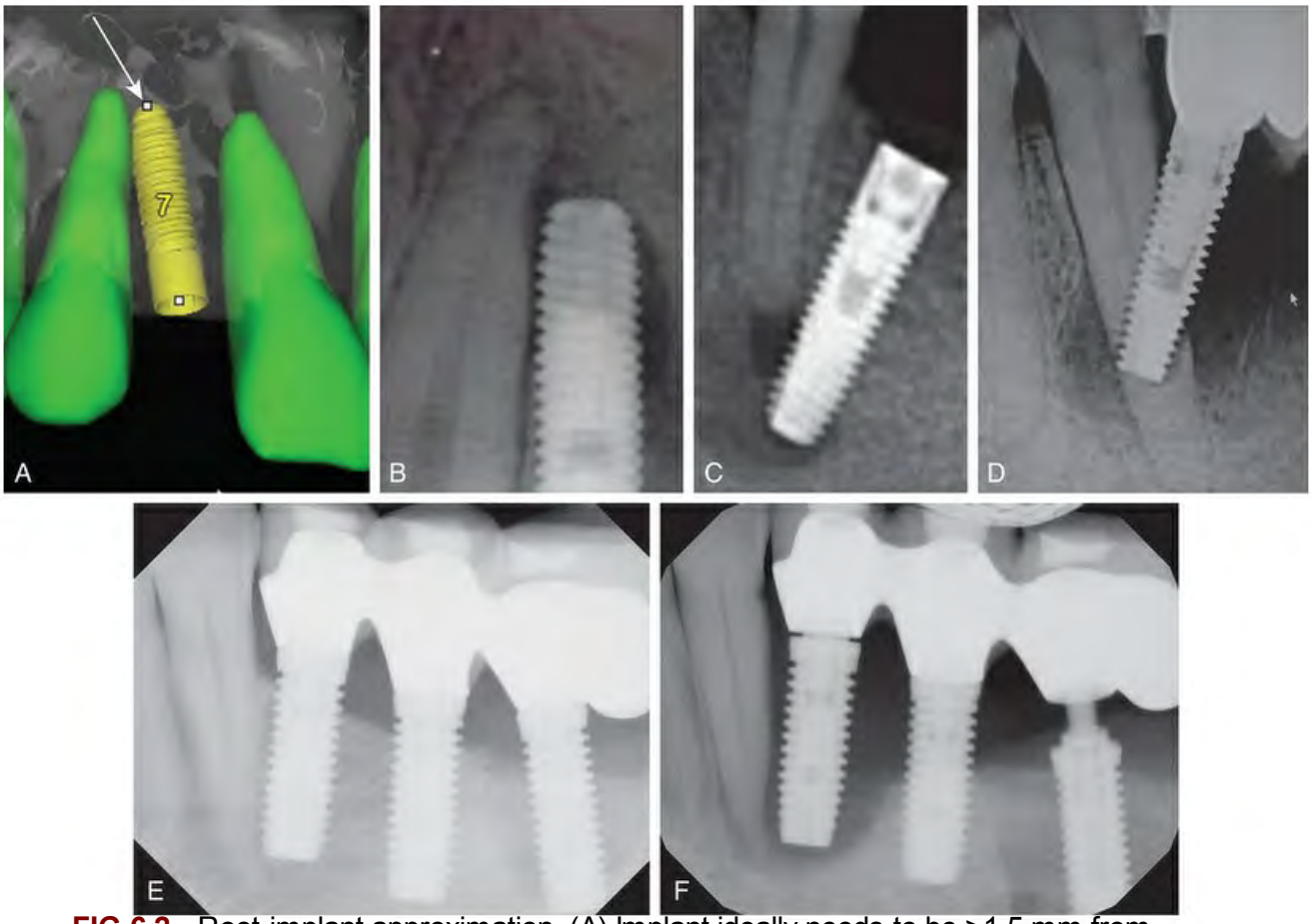

FIG 6.2 Root-implant approximation. (A) Implant ideally needs to be >1.5 mm from root apex. (B) Implant impingement causing apical pathology encompassing the root and implant. (C) Root apex damaged by implant surgical drill. (D) Resultant irreversible root damage. (E) Example of a time-related complication involving an implant placed too close to a tooth root (i.e. immediate post-operative radiograph), (F) Pathology present four years later resulting in the loss of the tooth and implant.

Complications

Damage to Adjacent Periodontal Ligament.

Implants positioned too close to a tooth risk damage to the periodontal ligament and surrounding structures. This may cause displacement of bone into the periodontal ligament (PDL) space and result in altered blood supply to the adjacent tooth, loss of tooth vitality, apical periodontitis, and internal or external resorption.[4]

Loss of Implant.

Implants that are placed too close to an adjacent tooth may fail due to infection or bone resorption. If more than 1.5 mm of space exists between the

implant and the adjacent tooth, any bony defect around an implant will remain a vertical defect and will ususally not cause bone loss on the adjacent natural tooth. If bone loss around an implant is less than 1.5 mm then the bone on the adjacent tooth will maintain the interdental papilla height.

Loss of Tooth.

If adequate space is not maintained between a tooth and an implant, the adjacent tooth may be irreversibly traumatized and may be lost to a fracture or to internal or external resorption (Fig. 6.2B–D).

Prevention

Ideal Position.

The ideal position is to maintain at least 1.5 mm from the adjacent tooth root or tooth structure. Ideal angulation should be strictly adhered to by evaluating initial osteotomy position via a radiograph of a direction indicator after the first pilot drill (Fig. 6.3A).

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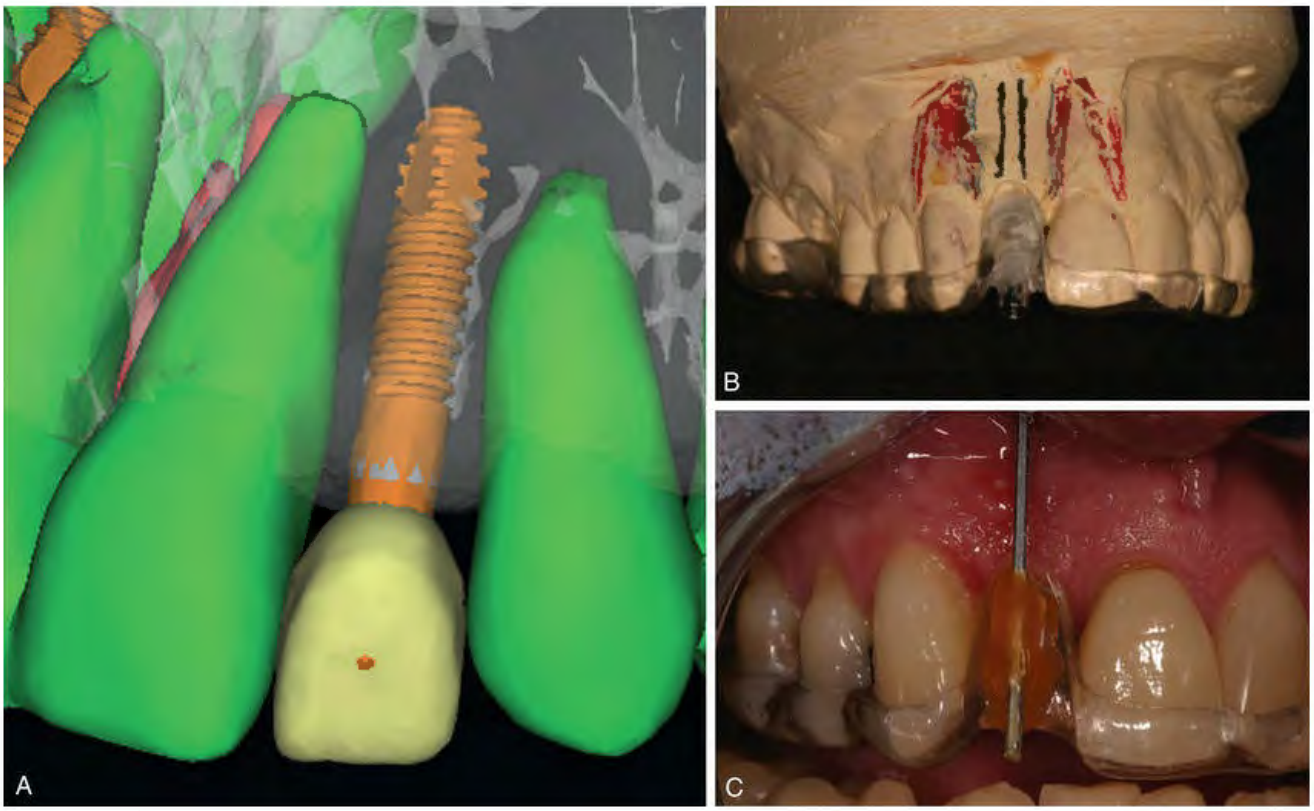

FIG 6.3 Ideal Implant Positioning (A) 3-D image depicting implant >1.5 mm for tooth roots. (A) Ideal positioning. (B–C) Errors in positioning are often a result of using study casts or two-dimensional radiographs (which do not show the true root position) for implant placement planning. Without evaluating the third dimension, it is impossible to determine the exact root position.

Proper Treatment Planning.

The exact measurement of intraroot distance should be determined to prevent implant approximation to the root. Additionally, evaluation for anatomic variants such as dilacerations of adjacent teeth should always be radiographically diagnosed. The use of CBCT images should be utilized to confirm exact space available between the root and intended implant position. The most accurate CBCT image is the axial slice, which can be easily used to verify measurements.

Use of Study Casts.

Study casts should not be used as the sole determinate of implant position. In most cases, root position and angulation cannot be determined from study casts. A common problem is when positional (fully limiting) surgical guides are made from study casts without three-dimensional evaluation (Fig. 6.3B–C).

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Two-Dimensional Radiographs.

In evaluation of intraroot distances, caution must be used in using two-dimensional radiographs as the sole determinants of implant positioning. Both periapical and panoramic radiographs have inherent disadvantages in providing accurate measurements (Fig. 6.4A). Ideally, to verify adequate intraroot distance, a three-dimensional (computed tomography [CT] or cone beam computed tomography [CBCT]) scan should be performed. Accurate measurements may be made in the axial images at three locations: the cementoenamel junction (CEJ), midroot, and root apex (Fig. 6.4B–E).

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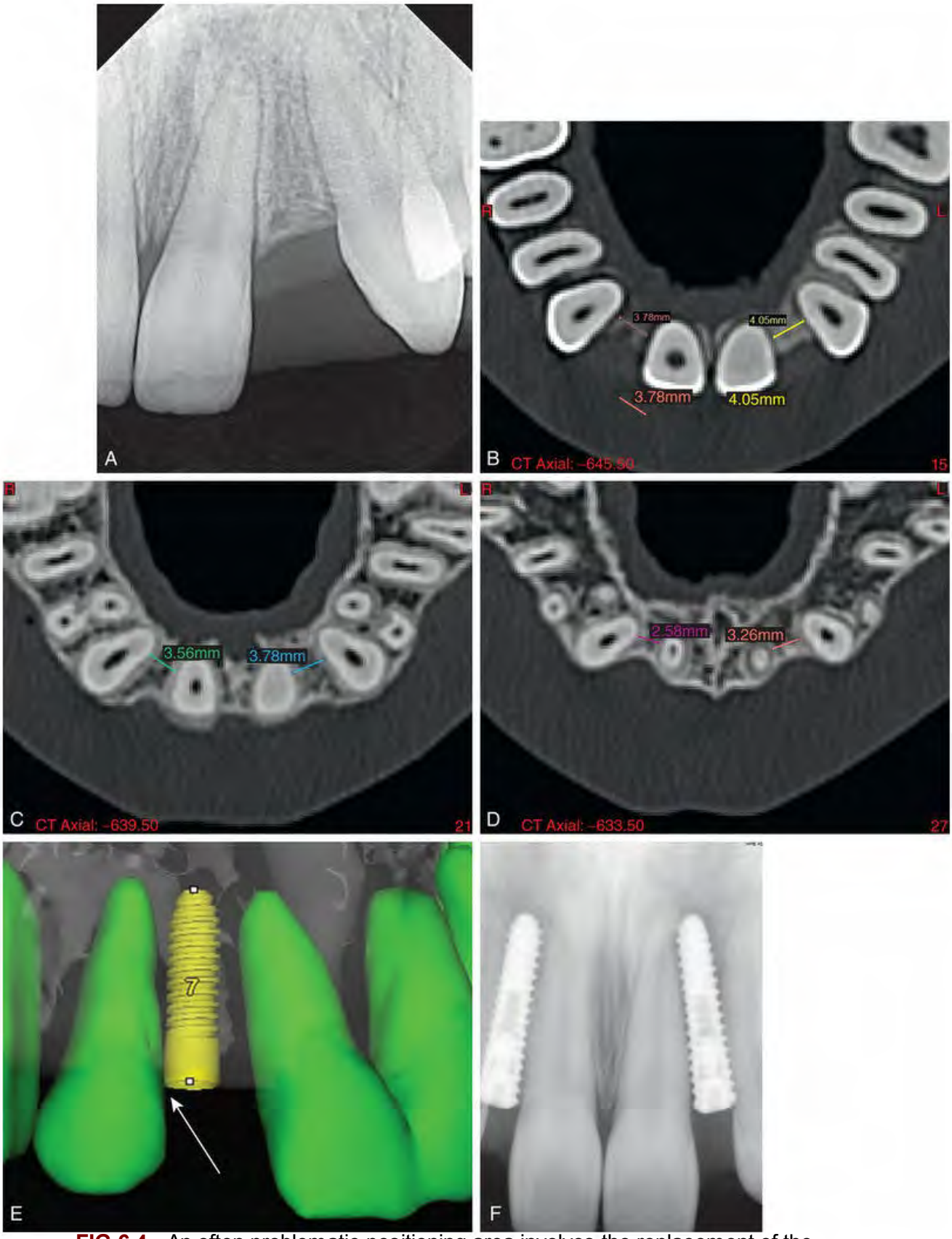

FIG 6.4 An often problematic positioning area involves the replacement of the maxillary lateral incisor. This situation often results after orthodontic treatment (A) when there is close proximity of roots (converging). Ideal computed tomography evaluation should include evaluation of the axial images at the (B) crestal, (C) midroot, and (D) root apex. (E) Illustration depicting ideal apical spacing with

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nonideal crestal positioning. (F) Caution should be exercised in using two-dimensional radiographs because of their inherent positioning complications.

Caution With Orthodontic Implants.

A popular relatively new implant modality is the use of orthodontic implants temporary anchorage devices (TADs) for anchorage. Orthodontic implants utilize the use of smaller diameter implants, which are inserted perpendicular to the long axis of the tooth in the interradicular spaces of the maxilla and mandible. TADs are utilized for tooth movement (e.g., labial segment retraction or mesial movement of teeth) or for intraoral anchorage, in which tooth movement in all three planes may be accomplished. Interradicular orthodontic implant complications include loss of tooth vitality, tooth loss, osteosclerosis, and dentoalveolar ankylosis.[5,6] These implants should be cautiously placed because they often are placed in areas of minimal intraroot distance and above the mucogingival line in attached tissue, which often leads to detrimental effects on adjacent tooth structure (Fig. 6.5A–B).[7]

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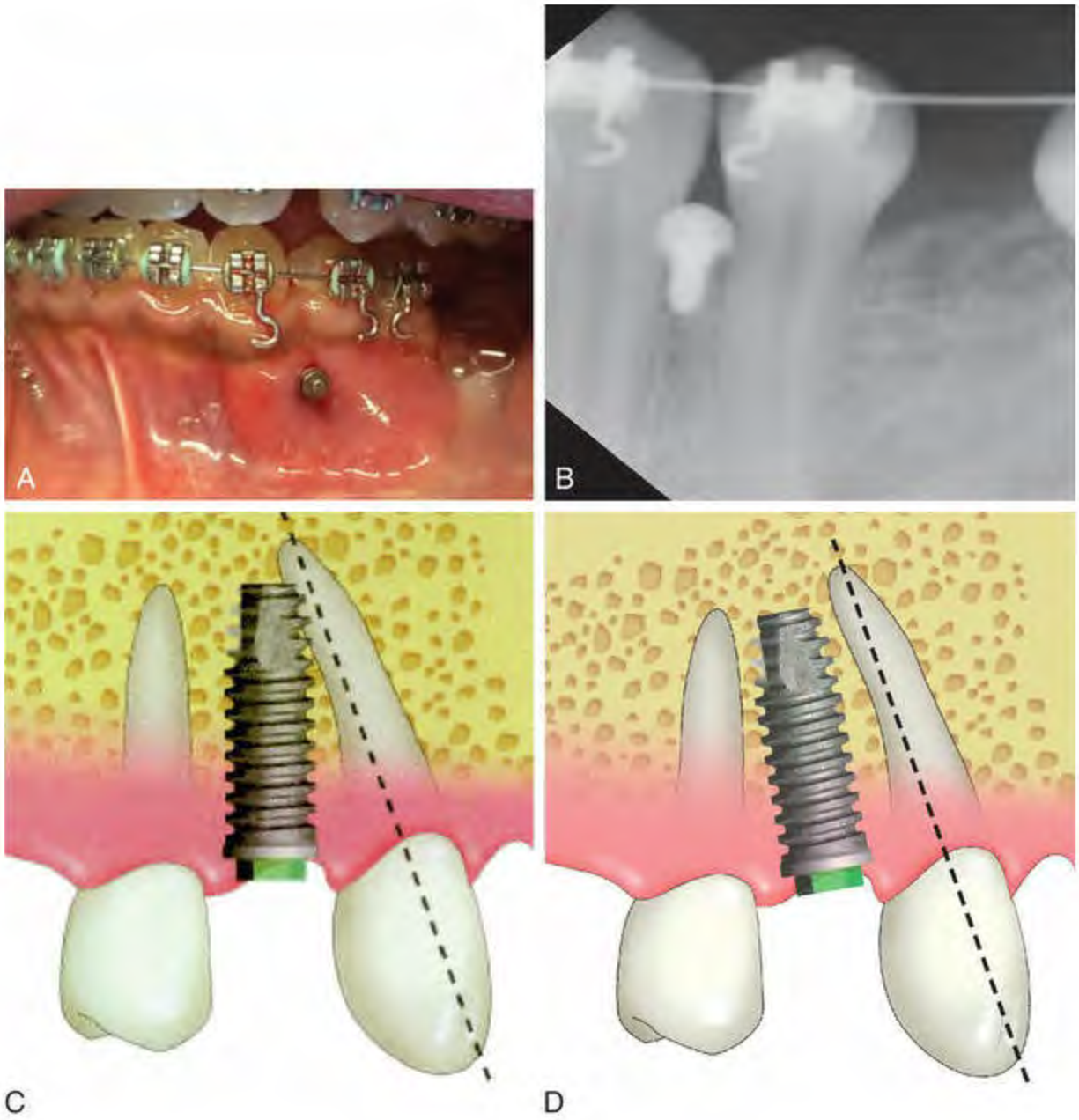

FIG 6.5 Implant-root impingement. (A) Orthodontic implants are often problematic because of their intended position between tooth roots within attached tissue. (B) Temporary anchorage device (TAD) placement in close approximation to an adjacent tooth. (C) A maxillary canine root is often slanted 11 degrees distally and has a distal curvature 32% of the time. When the implant is placed parallel to the first premolar, it may inadvertently encroach upon the canine root. (D) A maxillary first premolar implant may need to be parallel to the canine. (C–D, From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Maxillary Lateral Incisor Region.

In regards to implant position, one of the most common problematic areas is the replacement of congenitally missing lateral incisors. Often after orthodontic treatment, there exists a normal mesiodistal distance of the

clinical crowns; however, compromised intraroot distance will result. This is most likely to occur in the apical area. Lack of space may contraindicate implant placement or require orthodontic treatment for repositioning of the roots (see Fig. 6.4).

Maxillary First Premolar Site.

Another common area for root approximation problems is in the maxillary first premolar edentulous site. Careful consideration for the angulation of a natural canine must be evaluated. The 11-degree average distal inclination and distal curvature of the canine root frequently place the apex of the root into the first premolar implant area. The implant should be angled to follow the root of the canine and prevent contact with or perforation of the natural root. A shorter implant often is indicated, especially when a second premolar is also present (Fig. 6.5C–D).

FP-2, FP-3, RP-4, and RP-5.

More latitude exists with the mesiodistal positioning of implants for FP-2, FP-3, RP-4, and RP-5 prostheses; however, the anteroposterior (A-P) spread should always be maximized. Because the soft tissue is replaced in these types of prostheses (pink acrylic or porcelain), implants need not be placed in specific tooth positions. Implant positioning is usually dictated by 3-mm spacing between implants and maximizing the A-P spread whenever possible.

Treatment

Initial Placement.

If there is insufficient space between an implant and a natural tooth, the implant should be removed and repositioned, especially if the adjacent tooth is symptomatic. If space is compromised (<6.0 mm), the roots should be repositioned via orthodontics or treatment plan changed to a different type of prosthesis.

Past Placement.

If an implant has been restored and root approximation (<1.5 mm) exists, the tooth/implant should be monitored on a regular basis and the patient informed of the possible morbidity. If symptomatic or radiographic

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pathology is present, the implant should be removed and repositioned along with vitality testing of the tooth.

Lack of Implant–Coronal Distance

Etiology

Lack of space between the implant platform and the coronal aspect of the adjacent tooth occurs most likely from poor initial osteotomy positioning, poor treatment planning, or the use of too large of an implant body, leading to a situation where the implant encroaches upon the adjacent tooth. Implant clinicians must be aware that most implant crestal platforms are larger than the implant body, which will result in decreased space between the adjacent tooth (e.g., a 3.8-mm implant may have a 4.1-mm platform) (Fig. 6.6 and Table 6.1).

FIG 6.6 Mesiodistal distance. Implant body diameter vs. implant crest module. The crest module of an implant is often wider than the implant body dimension. (Pictured: External hex implants. Courtesy BioHorizons Implant Systems, Inc.)

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TABLE 6.1

Average Mesiodistal Width of Permanent Teeth

Tooth	Mandibular (mm)	Maxilla (mm)
Central incisor	5.3	8.6
Lateral incisor	5.7	6.6
Cuspid	6.8	7.6
First bicuspid	7.0	7.1
Second bicuspid	7.1	6.6
First molar	11.4	10.4
Second molar	10.8	9.8

From Hebel MKS, Gajjar R: Anatomic basis for implant selection and positioning. In Babbush C, editor: *Dental implants: the art and science,* ed 2, Philadelphia, 2001, Saunders.

Complications

If implants are positioned too close to the coronal portion of the tooth, many complications can result.

Interproximal Bone Loss.

When there is a lack of space between the tooth and implant, bone resorption will occur due to lack of a sufficient blood supply. Esposito has shown a correlation between increased bone loss and decreased distance of the implant from the adjacent tooth.[8]

Compromised Emergence Profile.

Due to a lack of space between the adjacent clinical crown and implant, it may be difficult, if not impossible, to form an ideal emergence profile in the new final prosthesis. Lack of proper emergence profile leads to esthetic, hygienic, and soft tissue complications, which increases implant morbidity (Fig. 6.7A–C).

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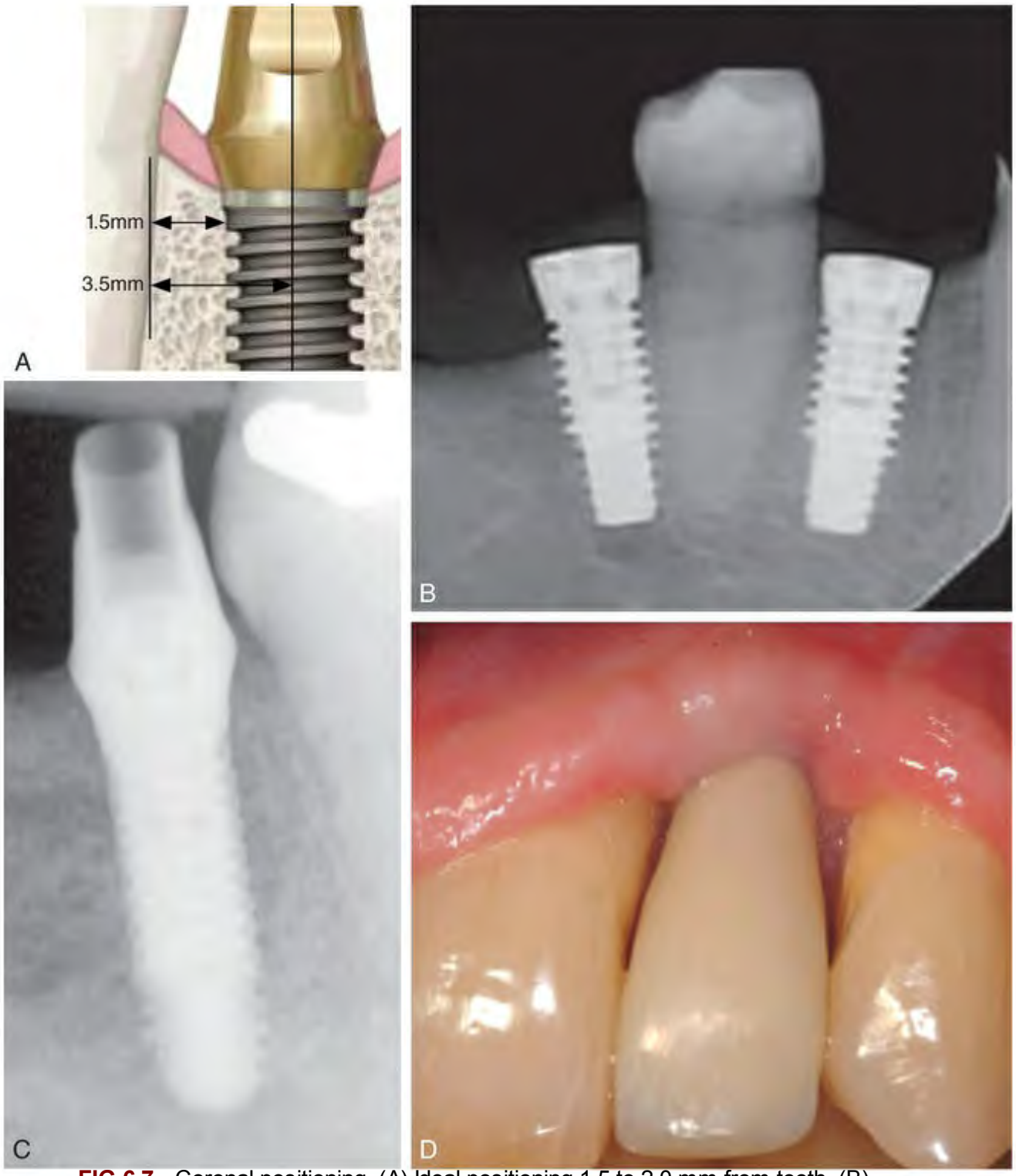

FIG 6.7 Coronal positioning. (A) Ideal positioning 1.5 to 2.0 mm from tooth. (B) Implant/abutment too close to adjacent crown exhibiting bone loss. (C) Abutment in close approximation to adjacent tooth. (D) Lack of papilla height resulting from lack of space from implant to adjacent tooth.

Hygiene Difficulties.

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Because of the unnatural contours of the prosthesis and the lack of space for cleansibility, proper hygiene techniques will be difficult. This will result in plaque buildup and related periodontal complications.

Reduced Papilla Height.

Because of interproximal bone loss due to the proximity of the implant to the coronal portion of the tooth, a lack of or reduction in the size of papilla will be present. This will result in periodontal conditions and esthetic issues (Fig. 6.7D).

Prevention

Treatment Planning.

The use of an accurate radiographic modality (CBCT) is paramount in determining if sufficient space exists for ideal clinical crown size (measurement on axial slices). Additionally, a study cast and diagnostic wax-up may be utilized. Ideally, 1.5 to 2.0 mm should be present from the implant neck to the adjacent tooth (Fig. 6.8).

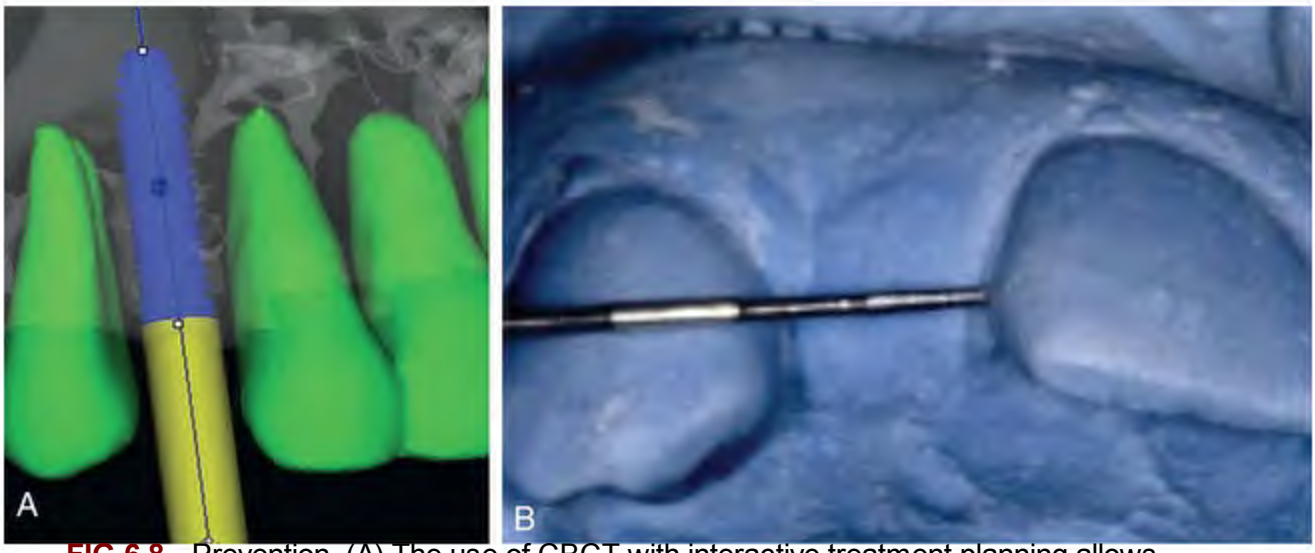

FIG 6.8 Prevention. (A) The use of CBCT with interactive treatment planning allows for the accurate placement and positioning of the implant for ideal prosthetic replacement. (B) Study cast may be used in conjunction with CBCT to evaluate coronal space available.

Preoperative Modification.

Upon preoperative evaluation, if inadequate space exists for implant treatment, the following options may be completed to increase mesiodistal distance:

1. Enameloplasty (modification of the interproximal contact areas) may be completed on the proximal contours of the adjacent teeth to increase mesiodistal dimensions. However, aggressive modification may lead to hypersensitivity and possible endodontic intervention (Fig. 6.9A).

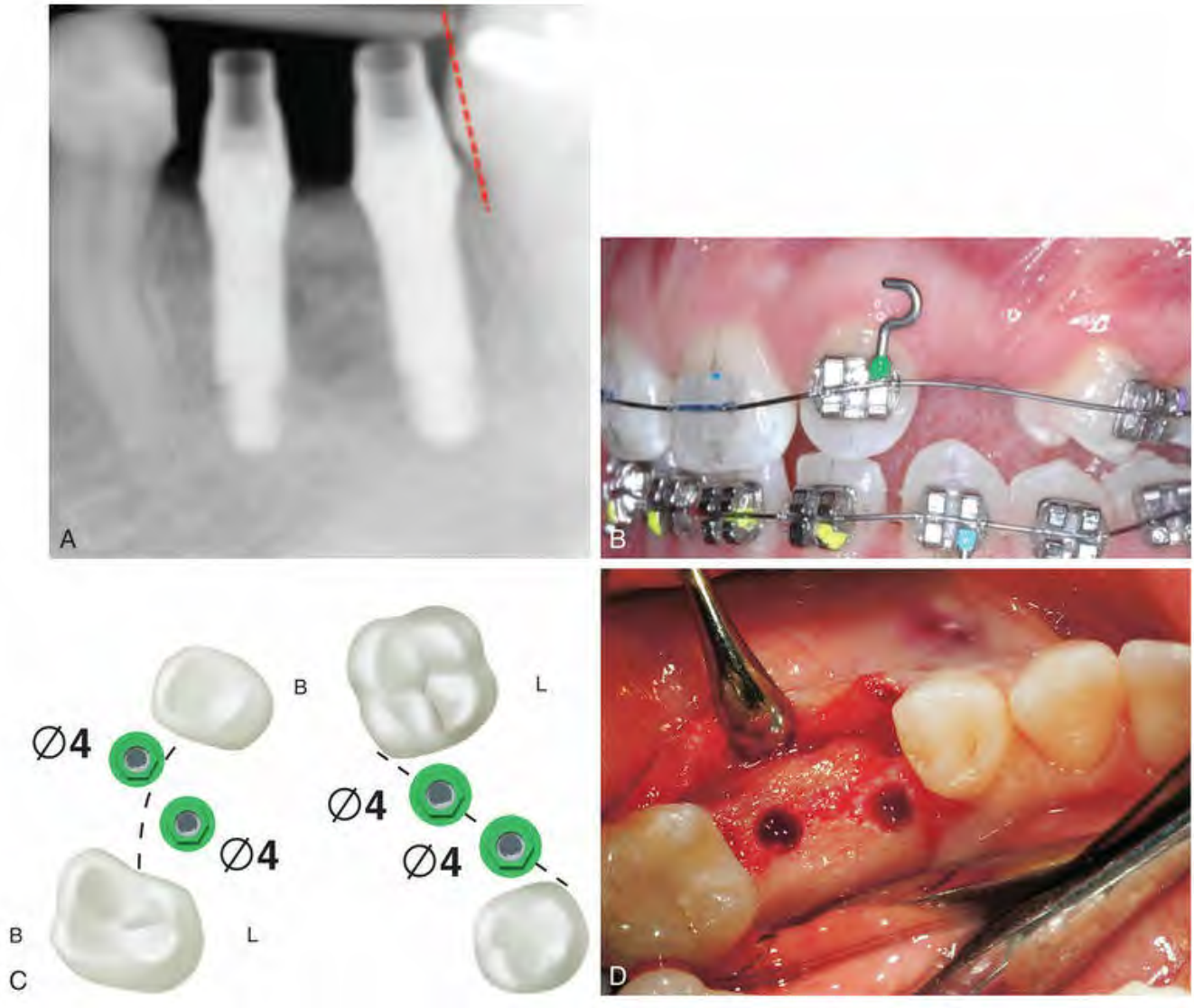

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FIG 6.9 Possible treatment options for inadequate spacing. (A) Enameloplasty of adjacent tooth allows for additional space for prosthesis emergence. (B) Orthodontic repositioning allowing more space additional spacing (when 12 to 14 mm of space is available, the mesial and distal contour of the adjacent teeth is modified to gain addition space). (C) A periapical radiograph of two 3.7-mm implants to replace one molar, in which the proximal contours of adjacent teeth were reduced. (D) An intraoral view of two osteotomy sites for the replacement of a mandibular first molar. (E) When the mesiodistal space is 12 to 14 mm, the implants may be offset to increase space between the implants. (F) In the mandible, the distal implant is positioned more buccal and the mesial implant more lingual. In the maxilla, the mesial implant is more buccal and the distal implant is more lingual. (G) Intraoral view of mandibular molar with offset implants, the distal implant being more lingual to facilitate easier flossing (hygiene). (C–G, From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

2. Orthodontic intervention may be utilized to upright a tilted adjacent tooth

to increase the intratooth space. For larger spaces (multiple spaces), one implant may be placed and an orthodontic spring incorporated in the transitional crown. The spring pushes the distal tooth more distal and, after orthodontic movement, the second implant may be inserted with less risk and improved hygiene between each implant. Another option is to reduce the space orthodontically and place only one implant and crown (Fig. 6.9B).

3. For larger spaces (multiple implants) the implants may be offset with one implant placed buccal and the other implant on a diagonal toward the lingual.[9] The diagonal dimension increases the mesiodistal space by 0.5 to 1 mm. In the mandible, the most anterior implant is placed to the lingual aspect of the midcrest and the more distal implant is placed to the facial aspect to facilitate access of a floss threader from the vestibule into the intraimplant space. The occlusal contacts also are slightly modified on the buccal aspect of the mesial implant to occlude over the central fossa. In the maxilla, the anterior implant is placed facially and the distal implant palatally to improve esthetics. The distal occlusal contact is placed over the lingual cusp, and the mesial occlusal contact is located in the central fossa position. The cervical esthetics of the maxillary molar are compromised on the distal half of the tooth to achieve greater intratooth distance and easier access for home care. This maxillary implant placement requires the intraimplant furcation to be approached from the palate, rather than the buccal approach, as for the mandible (Fig. 6.9C–D).

Surgical Adjuvants.

A large number of implant clinicians are utilizing positioning devices that allow for ideal osteotomy preparation and adherence to an implant placement at least 1.5 to 2.0 mm from the adjacent tooth. A surgical spacer may be used, which enables the initial osteotomy site to be placed at the correct position, allowing for adequate space between the tooth and final implant position (Fig. 6.10A–B). Surgical guidance systems (Salvin) may also be used to ensure ideal implant placement (buccal-lingual and mesial-distal spacing) and may be used with any surgical drill system (Fig. 6.10C–D). The most accurate positioning adjunct is the use of CBCT-generated surgical templates (tooth supported) (Fig. 6.10E).

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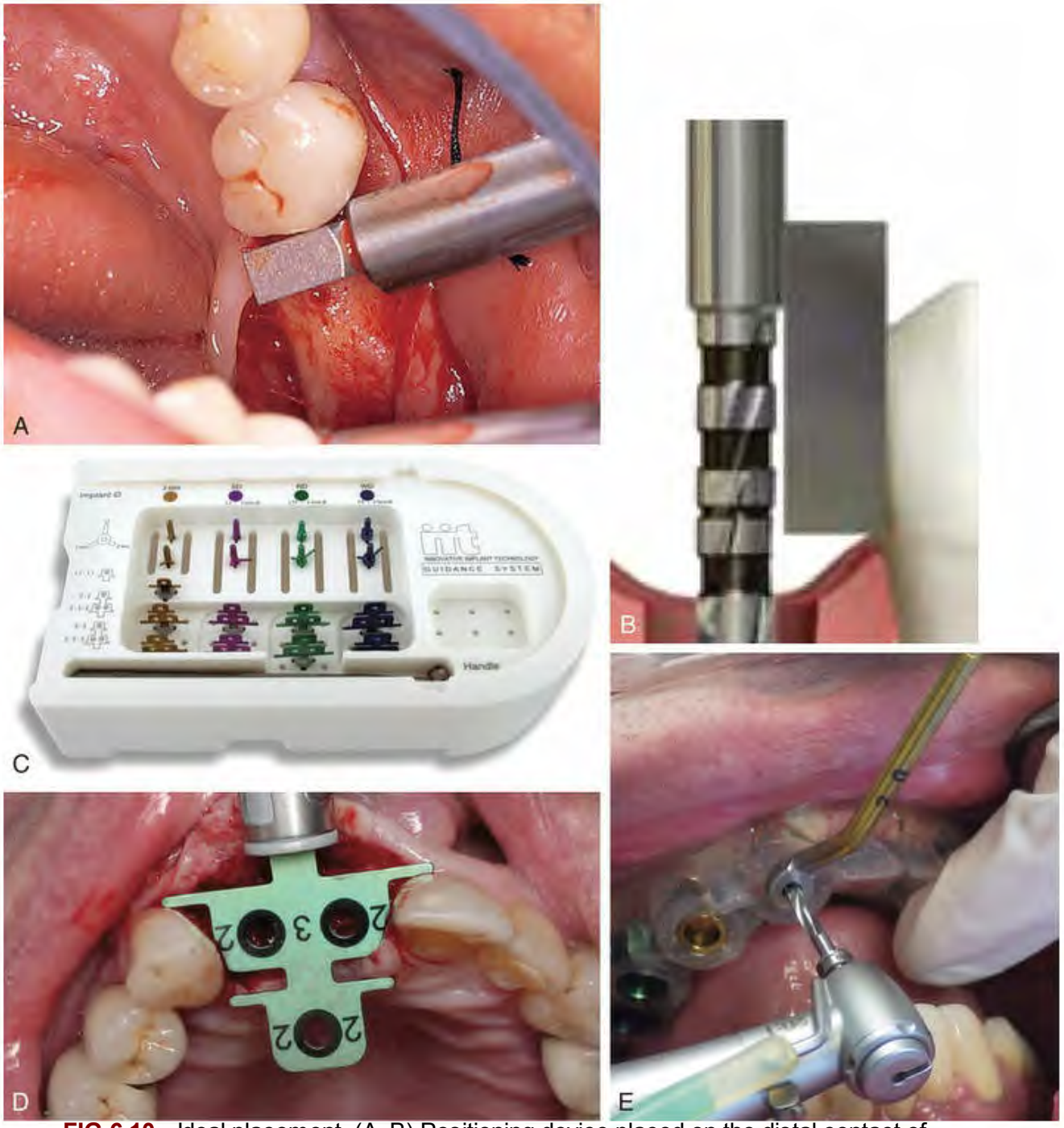

FIG 6.10 Ideal placement. (A–B) Positioning device placed on the distal contact of adjacent tooth allowing for ideal osteotomy site in the edentulous space. (C–D) Surgical guidance systems may be used for various situations and spacing between teeth. (E) Tooth-supported surgical template allowing for accurate implant positioning. (C, Courtesy Salvin Dental Specialties, Inc., Charlotte, NC.)

Treatment

Initial Placement.

If the position of the implant is less than 1.0 mm from the adjacent clinical crown, removal and reposition of the implant should be completed. If the implant is positioned 1.1 to 1.5 mm from adjacent tooth, removal or modification (enameloplasty) of the adjacent tooth may be completed, as long as irreversible damage to the tooth is not done.

Past Placement.

If implant has been restored and root approximation (<1.5 mm) exists, the tooth/implant should be monitored. If symptomatic, the implant should be removed and repositioned along with vitality testing of the tooth.

Too Great a Distance Between Implant and Tooth

Etiology

Too much space between an implant and adjacent tooth is the direct result of poor treatment planning and/or surgical technique (Fig. 6.11). When implants are placed more than 2 mm from an adjacent tooth, a cantilever effect will result on the marginal ridge of the implant crown. In some cases, this may lead to biomechanical overload or esthetic issues with resulting bone loss and increased morbidity.

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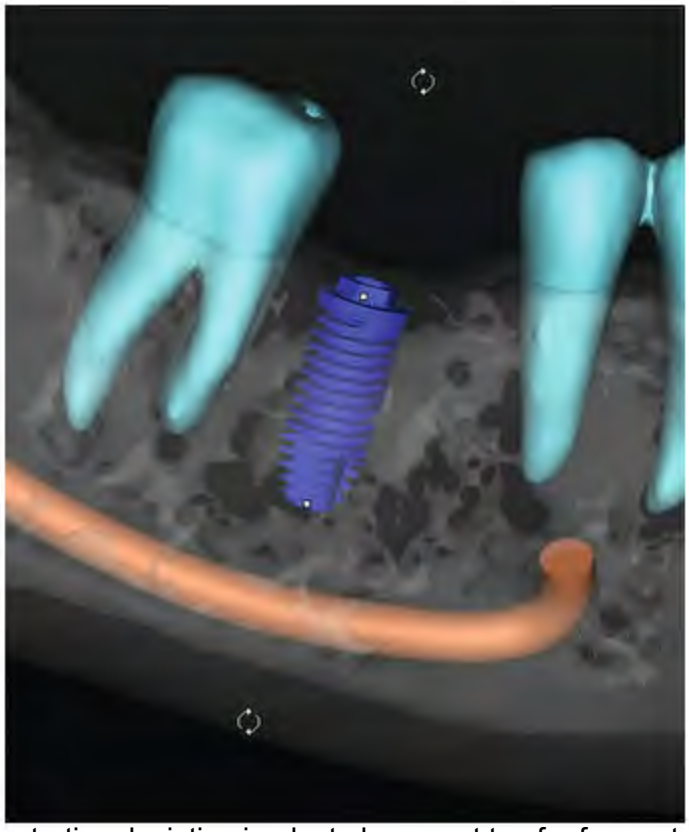

FIG 6.11 Illustration depicting implant placement too far from a tooth (mesial) leading to a cantilever effect and biomechnical issues.

Complications

Overcontoured Crowns.

Because of the excessive space between the implant and tooth, overcontouring of the final prosthesis is required to achieve a contact area with the adjacent tooth. This results in biomechanical issues as well as esthetic complications.

Atypical Prosthesis.

Because of the need to obtain interproximal contact, the final prosthesis will be atypical, which may lead to increased difficulty in prosthetic impression, laboratory, and insertion procedures (Fig. 6.12).

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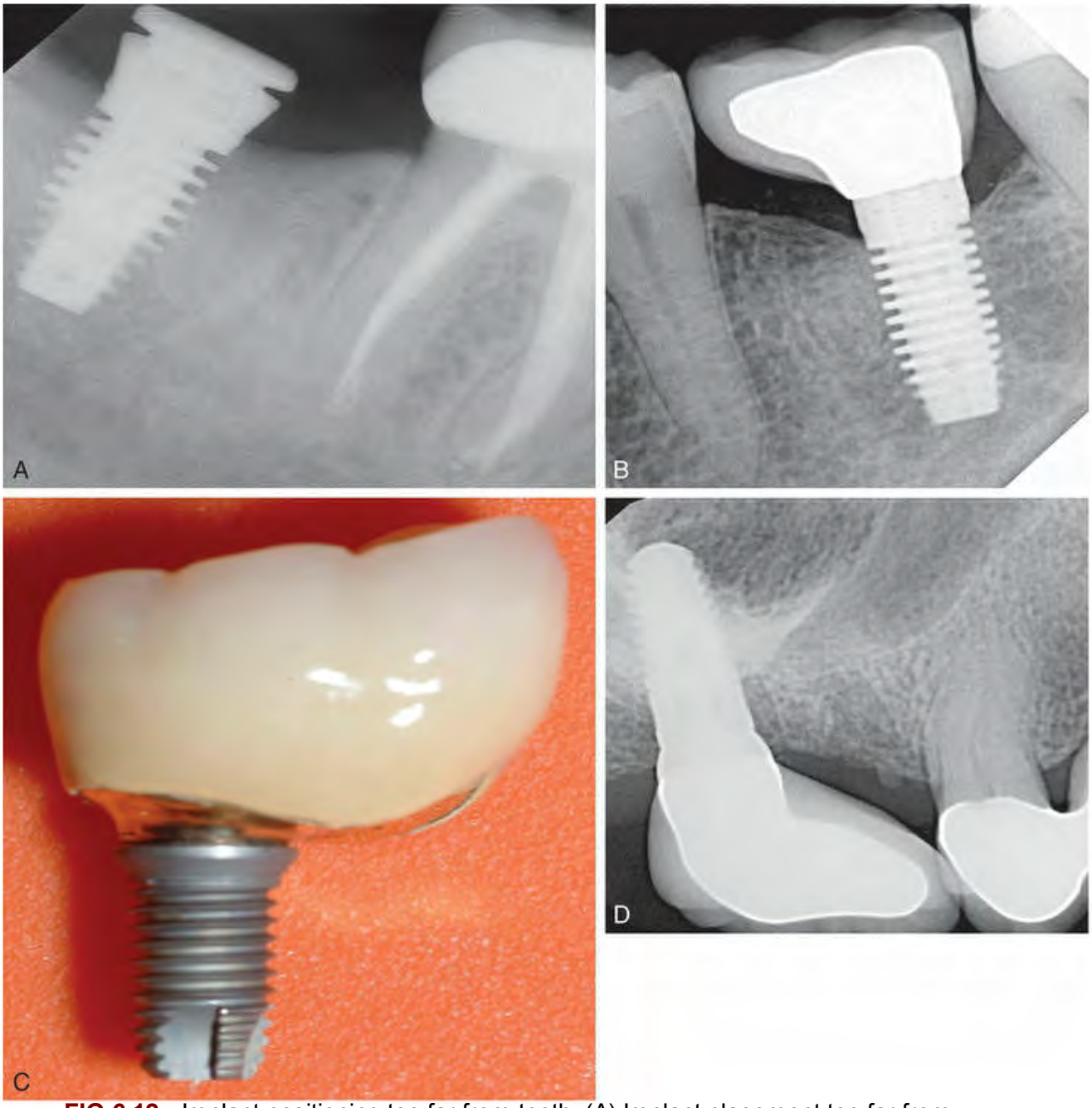

FIG 6.12 Implant positioning too far from tooth. (A) Implant placement too far from adjacent crown resulting in an excessively large, cantilevered crown. (B) Resultant prosthesis gives rise to overcontouring/cantilever effect. (C–D) Atypical prosthesis because of nonideal implant placement and need to obtain contact area, which results in biomechanical complications and food impaction.

Cantilever Effect (Biomechanics).

The resultant cantilever from a malpositioned implant results in a biomechanical disadvantage with damaging moment forces, which may result in bone loss. Cantilevers present on implant prostheses are more problematic than on natural teeth for several reasons. Forces are magnified

to the entire implant system, which may result in implant screw loosening, cement retention failure, or even possibly the mobility and failure of the implant itself. Secondly, because the implant is void of a periodontal ligament, there is no stress release system in place to protect the implant. Weinberg et al have shown a 10-degree increase in cusp inclination leads to a 30% increase in the force applied to the restoration. Additionally, studies have shown that a 10-degree increase in implant inclination can lead to a 5% increase in force-related function.[10] A 1-mm increase in the horizontal offset of an implant restoration may produce a 15% increase in torque during function, and a 1-mm increase in the vertical offset introduces a 5% increase (Fig. 6.13).[11] The overcontoured crown leads to resultant shear forces, which may lead to component failure (i.e., screw loosening, screw fracture, implant fracture).

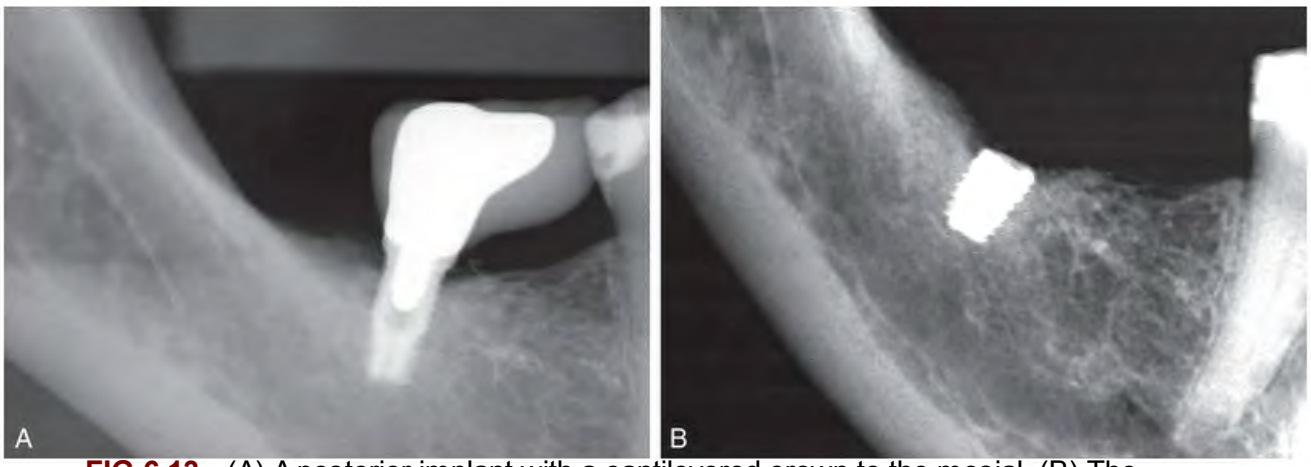

FIG 6.13 (A) A posterior implant with a cantilevered crown to the mesial. (B) The implant fractured within a few years. It is often more predictable to join an implant to a natural tooth than to cantilever from one implant. (From Misch CE: *Dental implant prosthetics*, ed 2, St. Louis, 2015, Mosby.)

Food Impaction.

Food impaction is a common complaint from patients with an increased implant-tooth distance because periodontal maintenance is difficult as a result of related soft tissue complications.

Periodontal Complications.

Because of difficulty in hygiene, chronic tissue problems often result, which may cause perimucositis or peri-implantitis, leading to implant morbidity

(see Figs. 6.11–6.12).

Prevention

Positioning Devices.

Prevention for malpositioning may include the use of special positioning devices that allow for ideal osteotomy placement and adherence to the ideal placement of 1.5 to 2.0 mm from the adjacent tooth. These predetermined distance spacers will minimize the possibility of placing the implant too close or too far from the adjacent tooth (Fig. 6.14).

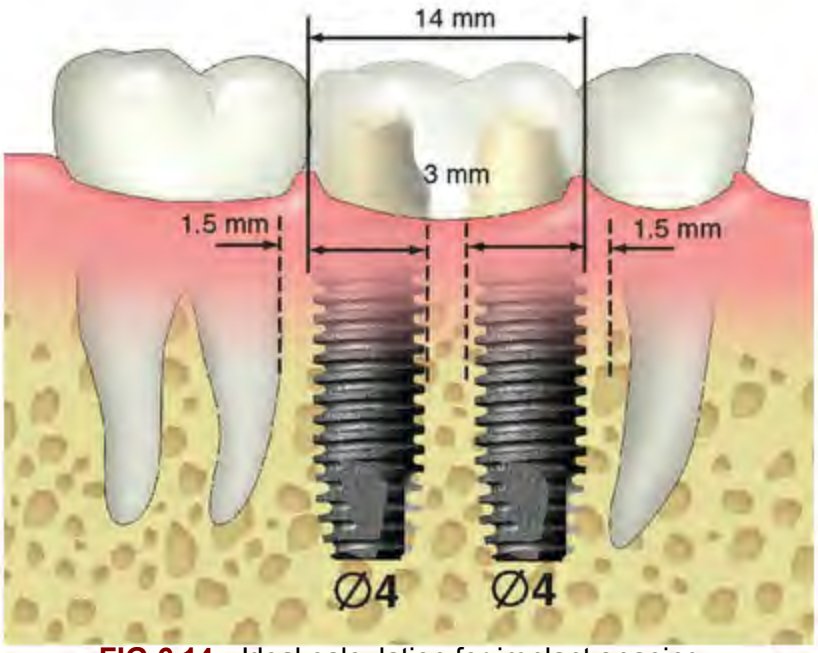

FIG 6.14 Ideal calculation for implant spacing.

Surgical Templates.

A CBCT-generated template may be used to accurately place the implant. When an implant is to be placed adjacent to a tooth, a tooth-supported guide is the most accurate in comparison to bone- or tissue-borne guides (see Fig. 6.10A–B, E).

Treatment

Initial Placement.

If nonideal placement is determined during surgery, the implant should be repositioned in the ideal position (i.e., 2 mm from adjacent tooth). The osteotomy should be initiated with the following formula:

½ diameter of the implant + 2.0 mm from tooth

In other words, a 4.0-mm implant pilot osteotomy would be 2.0 mm + 2.0 mm = 4.0 mm from the adjacent tooth. If the initial osteotomy is not ideal, a Lindemann drill (side cutting) is used to reposition the osteotomy into the correct position.

Past Placement.

If the implant has already been placed and is ready to be restored, the amount of occlusal force should be assessed to determine the ideal treatment:

Minimal Occlusal Forces: If favorable force factors exist, then a cantilever (overcontoured crown) may be fabricated with (Fig. 6.15A):

- Narrow occlusal table
- Minimal cusp height: It has been reported that every 10-degree increase in cusp inclination leads to a 30% increase in the torque applied to the restoration during function[10]
- No lateral contacts

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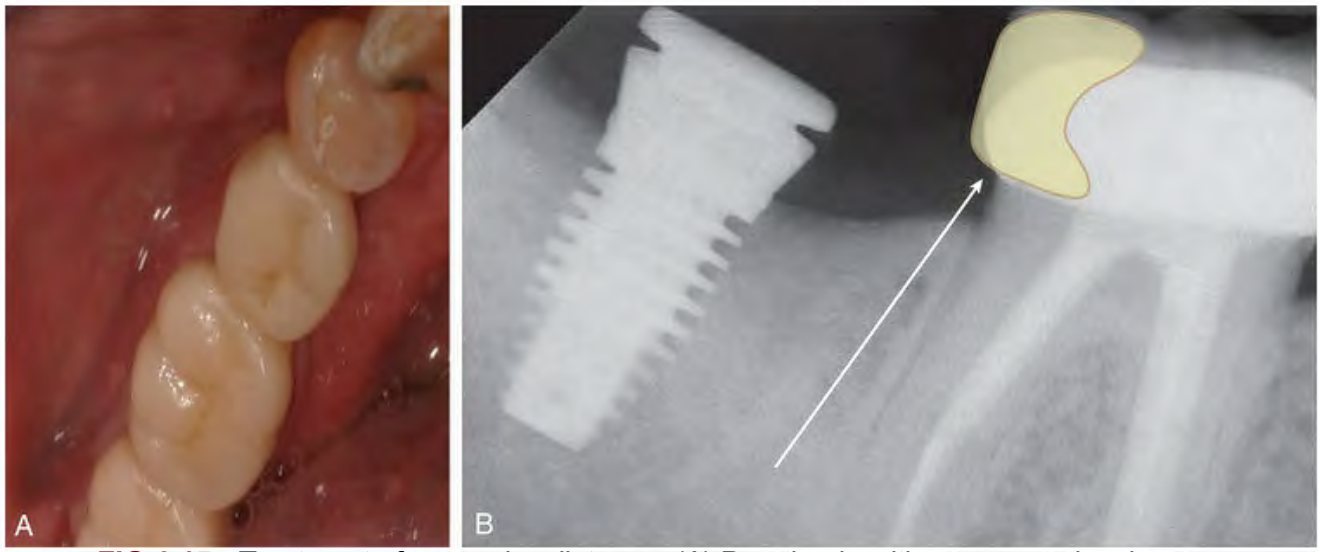

FIG 6.15 Treatment of excessive distance. (A) Prosthesis with narrow occlusal table, minimal cusp height and no lateral contacts. (B) To decrease implant-tooth distance, the natural tooth may be elongated or overcontoured by the use of a crown or bonding *(arrow)*.

High Occlusal Forces: If unfavorable forces are present, a cantilever is contraindicated and the mesiodistal distance is reduced by either:

- Overcontouring adjacent crown (e.g., crown, composite) (Fig. 6.15B)
- Remove implant and reposition

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Mesial-Distal ("X" Axis): Implant–Implant

Lack of Implant-Implant Distance

Etiology

When implants are placed too close together, it is usually the result of poor treatment planning or surgical technique (Fig. 6.16). Treatment planning issues can be prevented by using ideal spacing rules. The guidelines include approximately 3.0 mm between implants, and >1.5 to 2.0 mm from adjacent teeth.

FIG 6.16 Illustration depicting inadequate space between two implants.

Complications

Bone Loss.

Because of the lack of interproximal bone a decreased blood supply will result in bone loss. Tarnow et al have shown that implants placed less than 3.0 mm apart may have adequate stability and function; however, this placement will likely result in crestal bone loss. In this study, implants with greater than 3 mm distance between implants resulted in a 0.45 mm bone

loss, while implants positioned less than 3 mm had over twice the amount of bone loss, or approximately 1.04 mm.[12]

Lack of Interimplant Papilla.

When lack of space exists between the implants, the resultant bone loss will be responsible for the loss of the papilla. As the bone resorbs, the distance between the contact point of the crowns and the bone level increases. As this distance increases (i.e., above 5 mm), the papilla will become smaller in size and contour.

Hygiene Difficulty.

Because of the lack of space, difficulty in hygiene access will result in poor tissue health. The resultant tissue condition will most likely lead to perimucositis or peri-implantitis.

Prosthetic Issues.

Inability or difficulty in obtaining a final impression (placement of impression transfer copings) may result from lack of space between implants. With some implant systems the transfer copings may be adjusted to allow for impression of the implant bodies. Additionally, an unconventional implant prosthesis (irregularly contoured) will most likely need to be fabricated (Fig. 6.17).

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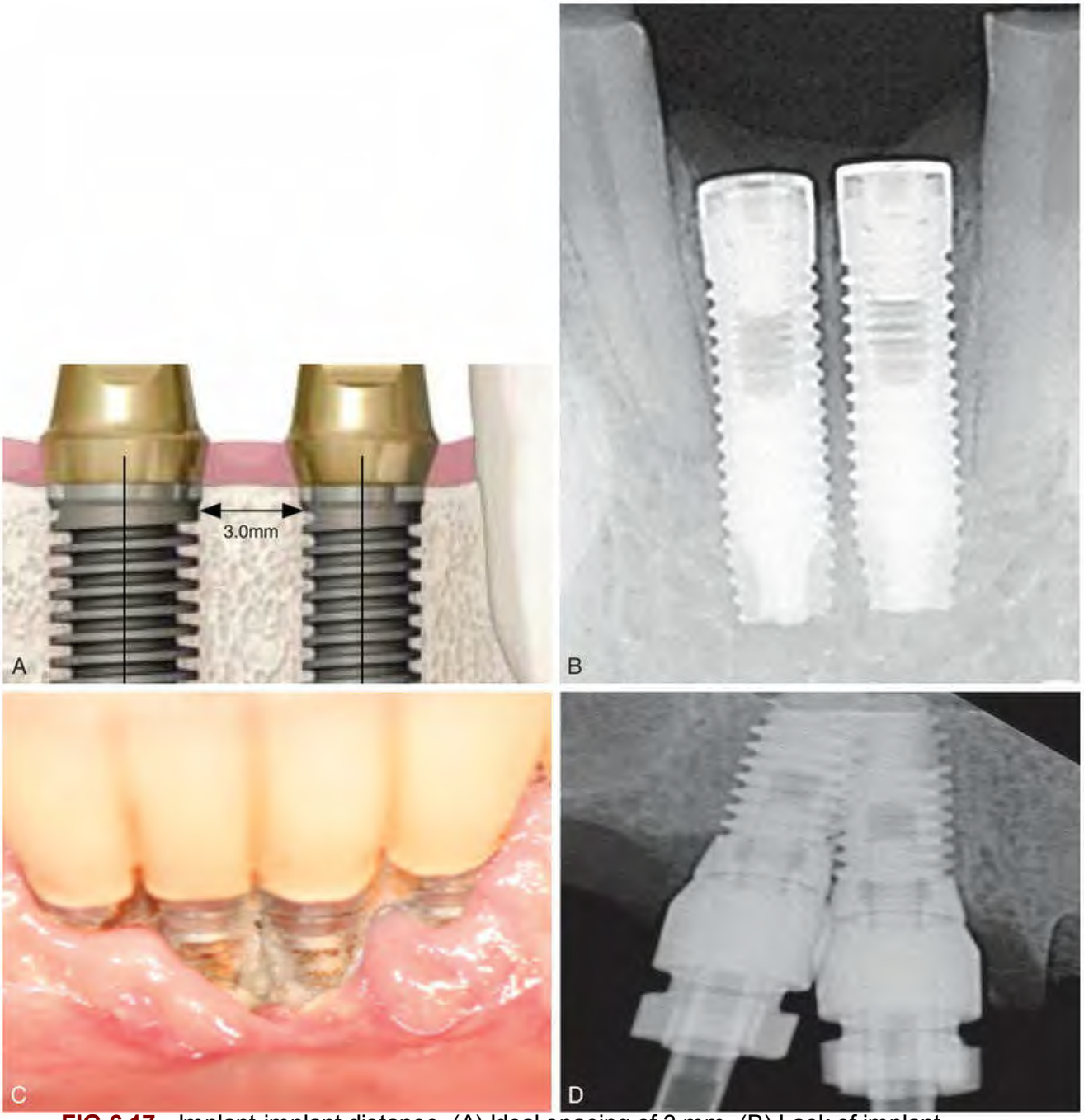

FIG 6.17 Implant-implant distance. (A) Ideal spacing of 3 mm. (B) Lack of implant-implant distance showing minimal space for prosthesis and maintaining bone health. (C) Lack of space results in difficulty in hygiene with resultant soft tissue complications. (D) When implants are placed too close together, difficulty in obtaining accurate transfer impressions results. In some cases, the transfer impression copings may be altered to obtain final seating. A radiograph confirming the complete seating of the transfer copings should be completed prior to the impression.

Prevention

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Ideal Distance.

It is important to maintain 3 mm or more space between final implant positions. This will allow adequate room for interdental papilla and tissue health, cleansibility, transfer copings during prosthetic impressions, and minimizing horizontal bone loss.

Osteotomy Measurement.

A formula exists for ideal placement of initial osteotomies in anticipation of the final implants. For example, when placing 5.0 mm and 4.0 mm implants, add ½ diameter of implant + 3.0 mm between implants and 2.5 mm + 2.0 mm + 3.0 mm = 7.5 mm between osteotomy sites. Additionally, special spacing guides may be used for ideal positioning.

Treatment

Initial Placement.

If implants are not ideally positioned (see Figs. 6.10 and 6.14), the osteotomy should be repositioned to ideal positions (3 mm between implants). The implant positions may be altered with the side-cutting Lindemann drill (Fig. 6.18A–B).

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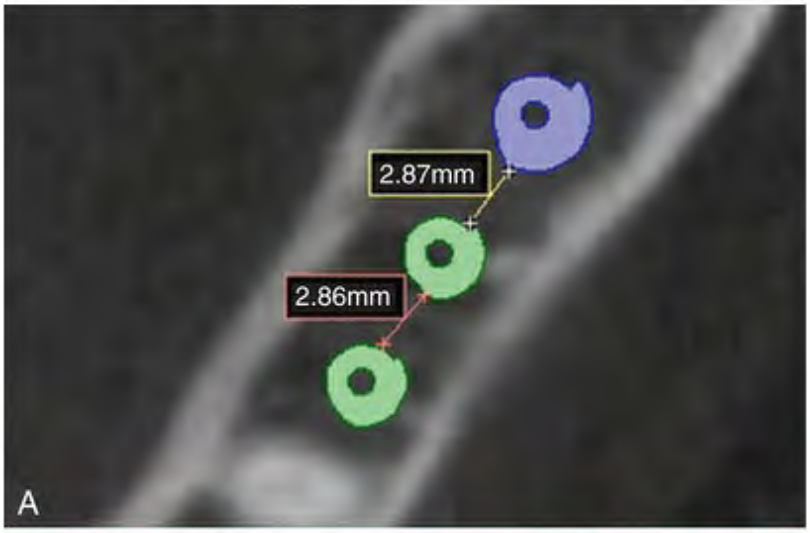

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FIG 6.18 (A) The prevention of multiple implants being placed too close together includes the use of interactive treatment planning to ensure ideal spacing. (B) Inadequate space between implants; ideally one of the implants should be removed and replaced in a more ideal position. (C) When implants are already restored, a strict recall should be adhered to monitor bone loss and related periodontal complications.

Past Placement.

If implants have been restored, removal of implants and repositioning should be completed if the patient cannot adequately clean the prosthesis. In some situations, the abutment/implant body may be minimally modified to gain extra space, usually with a flame-shaped diamond bur. This is best completed with external hex implants because modification of internal hex implants may alter structural integrity of the implant leading to possible fracture (Fig. 6.18C).

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Implant Angulation Positioning (“Y” and “Z” Axis)

Buccolingually (“Y-Axis”)

The buccolingual positioning of the dental implant is crucial to the esthetic and biomechanical effectiveness of the final prosthesis. Frequently, implant positioning is dictated by the resulting available bone, leading to angulation complications. Bone remodeling after tooth extractions is common with resorption occurring from the buccal plate initially, thereby decreasing the width of bone. Ideally, the implant position is in the center of the ridge, with a minimum of 1.5 mm present on the buccal and 0.5 mm on the lingual aspects of the ridges (Fig. 6.18). When present, adequate cortical bone minimizes future hard and soft tissue recession. In this scenario, if bone loss occurs on the implant, the facial plate will remain intact and minimal recession on the facial aspect of the implant will result. Spray et al have shown if the facial bone is more than 1.8 mm in thickness (after implant placement), recession infrequently results. However, if the facial plate is less than 1.8 mm, vertical resorption occurs quickly, mainly because of the lack of blood supply (Fig. 6.19).[13] Improper buccal-lingual positioning has a direct impact on the type prosthesis, and resultant complications are prosthesis-dependent.

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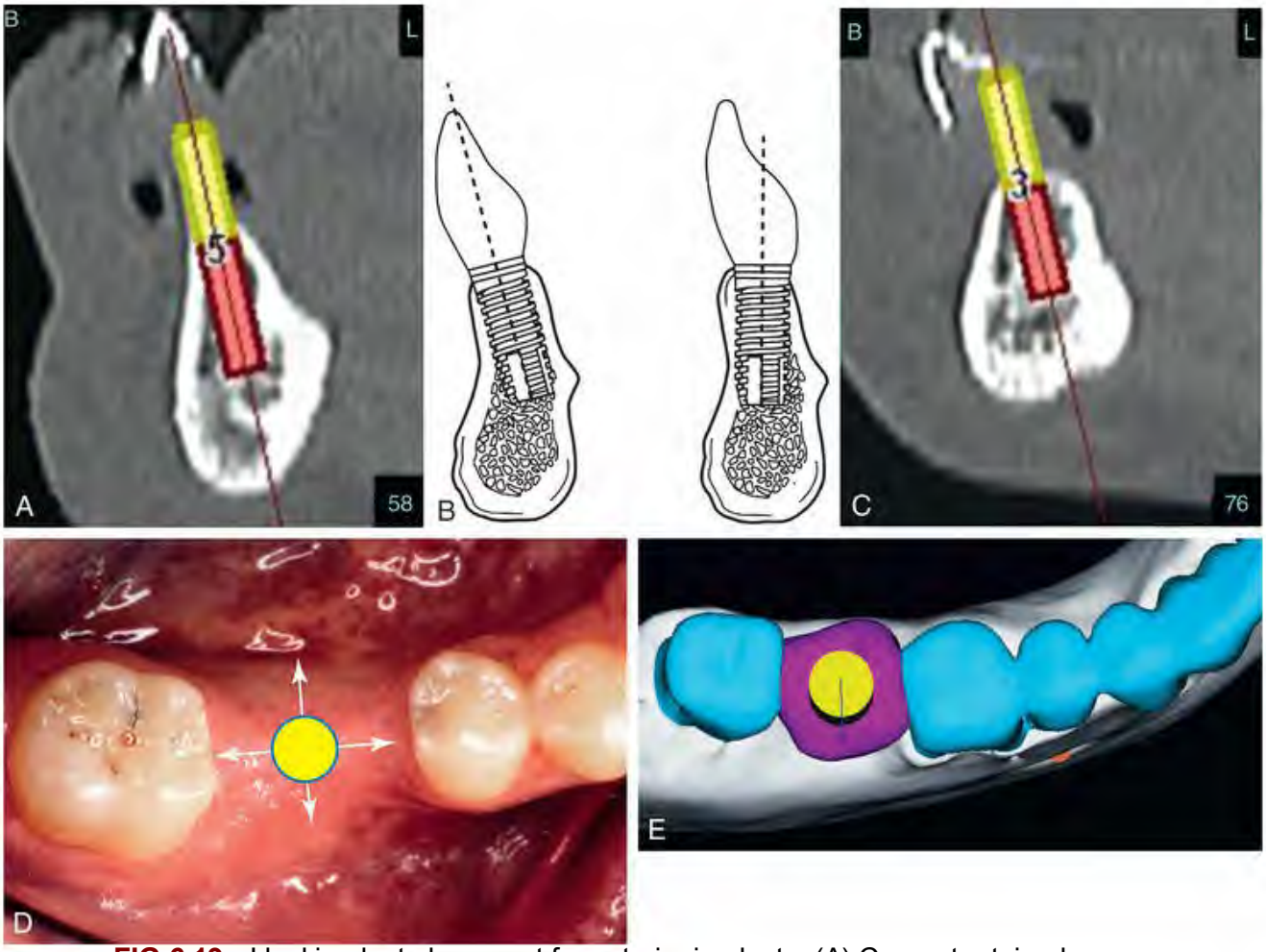

FIG 6.19 Ideal implant placement for anterior implants. (A) Cement retained through the incisal edge. (B) Ideal Positioning. (C) Screw retained through the cingulum area. (D–E) Ideal posterior implant placement with buccal-lingual placement in line with the central fossa of adjacent teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St. Louis, 2015, Mosby.)

Fp-1 and Fp-2 Prosthesis

Prevention

Cement-retained (anterior).

When a FP-1 prosthesis is indicated, precise implant placement is necessary to obtain an ideal result. In the anterior region, the ideal implant position allows the placement of a straight abutment directly under the incisal edge of the final crown for a cemented prosthesis. The resulting forces are concentrated along the long axis of the implant, minimizing damaging shear forces. For example, the natural maxillary anterior teeth are loaded at a 12- to 15-degree angle, mainly because of their natural angulation in comparison

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with the mandibular anterior teeth. This is one reason the maxillary anterior teeth are wider in diameter than mandibular anterior teeth (which are loaded in their long axis). The facial angulation position of the implant body often corresponds to an implant body angulation, with 15-degree off-axial loads. The angled load will result in an approximate 25% increase in force to the implant prosthesis. Many complications may occur from the offset loads, which include abutment screw–implant–bone complex by 25.9% compared with a long-axis load.[14] Abutment screw loosening, crestal bone loss, and cervical soft tissue marginal shrinkage.[15] As a result, implants angled facially may compromise the esthetics and increase the risk of technical complications.

Screw-retained (anterior).

For screw-retained prostheses the implant should emerge toward the cingulum of the anterior tooth so that the access hole does not affect the esthetics of the restoration. If the implant is placed too facially, the access hole will impinge on the esthetics of the restoration (screw hole through the facial of the restoration). If the implant is placed too far lingually, overcontouring of the final crown may result in biomechanical issues and possible occlusal interferences (Fig. 6.19A–C).

Posterior region (cement- or screw-retained).

In the posterior region, the long axis of the implant should emerge within the approximate center (central fossa) of the prosthesis for a screw- or cement-retained FP-1 or FP-2. This allows occlusal forces to be directed ideally along the long axis of the implant (Fig. 6.19D–E).

Complications

Facial.

If the implant is placed too facial for an FP-1 or FP-2 prosthesis, esthetic issues will result due to overcontouring of the prosthesis. Bone dehiscence usually will be accompanied by tissue recession and this complication is more pronounced in thin biotype patients. Facial positioning is often a complication when implants are placed in immediate extraction sites.

To correct the facial position of the implant, an angled abutment must be used. However, because of the access hole, the facial of the abutment is more bulky. This results in overcontouring of the facial aspect, which will lead to

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tissue recession and bone loss (Fig. 6.20).

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FIG 6.20 Facially placed complications. (A) Facial positioning, lack of bone present. (B–C) Resultant prosthetic and periodontal complications. (D) Severely facial-positioned implants predisposing to prosthetic rehabilitation issues. (E–F) An angled abutment has an access hole for the fixation screw, which exits the facial of the abutment. As a result, less metal is on the facial. The manufacturer usually increases the metal thickness to improve the strength (E). As a result of the facial flare of metal on an angled abutment, the abutment is more facial than the implant body (F). (G) The angled abutment is usually wider on the facial than the implant to

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increase the metal thickness on the facial of the abutment. (E–G, From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Lingual.

Implants placed too far to the lingual can result in facial overcontouring of the final prosthesis (ridge lap) for esthetic reasons. The prosthetic impression and placement of the prosthesis is also complicated, which results in difficulty with the seating of the abutments. Because of the overcontouring of the lingual contours, patients often complain of lack of space for the tongue, which may impede speech. In the anterior region, a lingual placed implant may make the implant nonrestorable if the patient has a deep bite occlusion and insufficient interocclusal space (Fig. 6.21).

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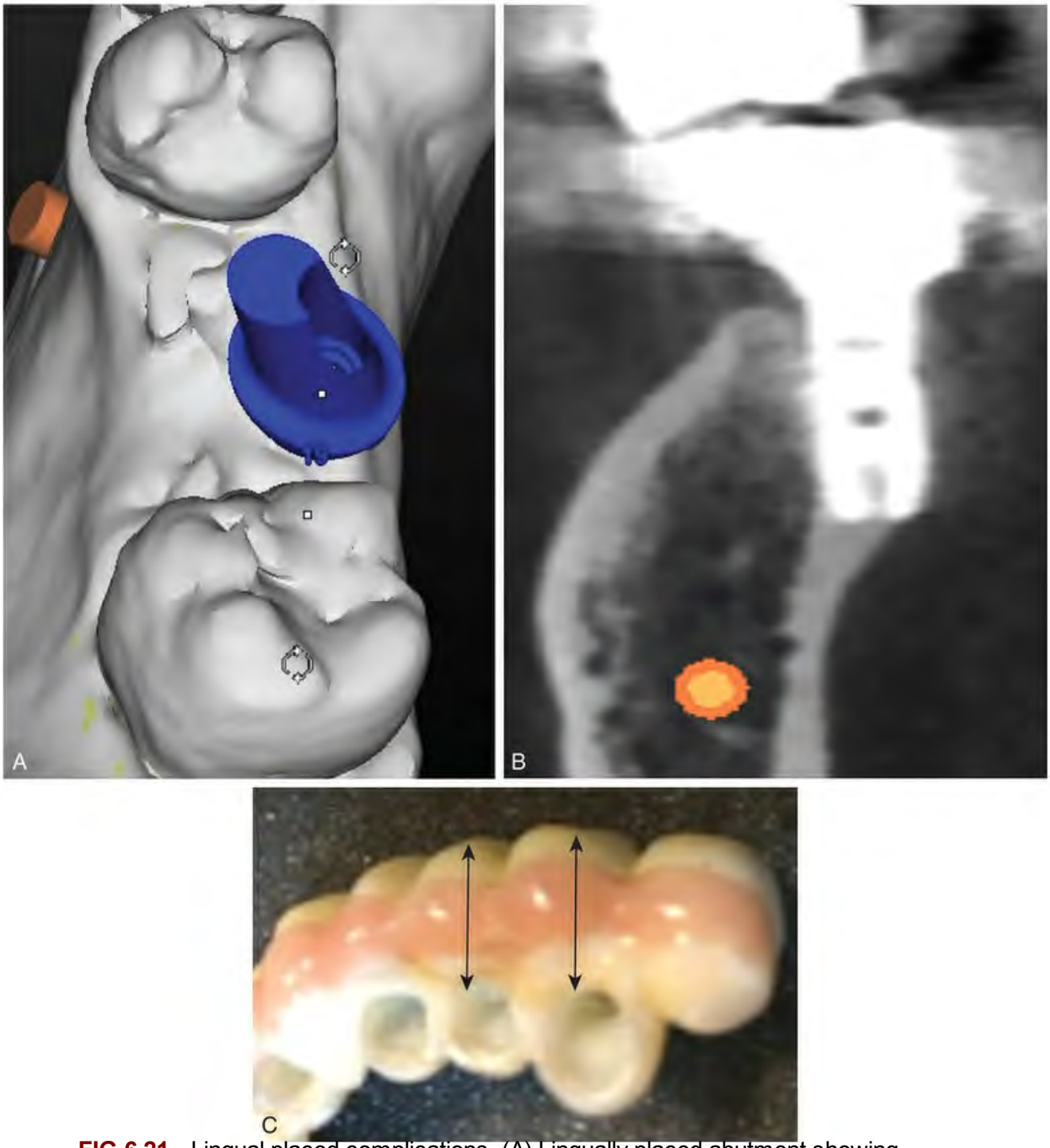

FIG 6.21 Lingual placed complications. (A) Lingually placed abutment showing overcontouring and possible tongue impingement. (B) Lingually placed implant showing biomechanical offset loading (cantilever). (C) FP-3 prosthesis showing ridge lap of prosthesis, complete lingual version.

FP-3 Prosthesis

Prevention

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Screw-retained.

After evaluation of the articulated setup, arch form, available bone, and force factors, the FP-3 prostheses should be determined to be either screw retained or cement retained. For screw-retained prostheses, ideal positioning should be slightly lingual to the denture or porcelain teeth to minimize tooth fractures and delamination.

Cement-retained.

For cement-retained restorations, implant positioning should be located along the incisal edge in the anterior region and in the central fossa area in the posterior. If force factors are a concern, ideal implant placement is crucial to minimize biomechanical overload. However, if force factors are low, nonideal placement is less of a problem with cement-retained prostheses because abutment angulation may be modified (Fig. 6.22).

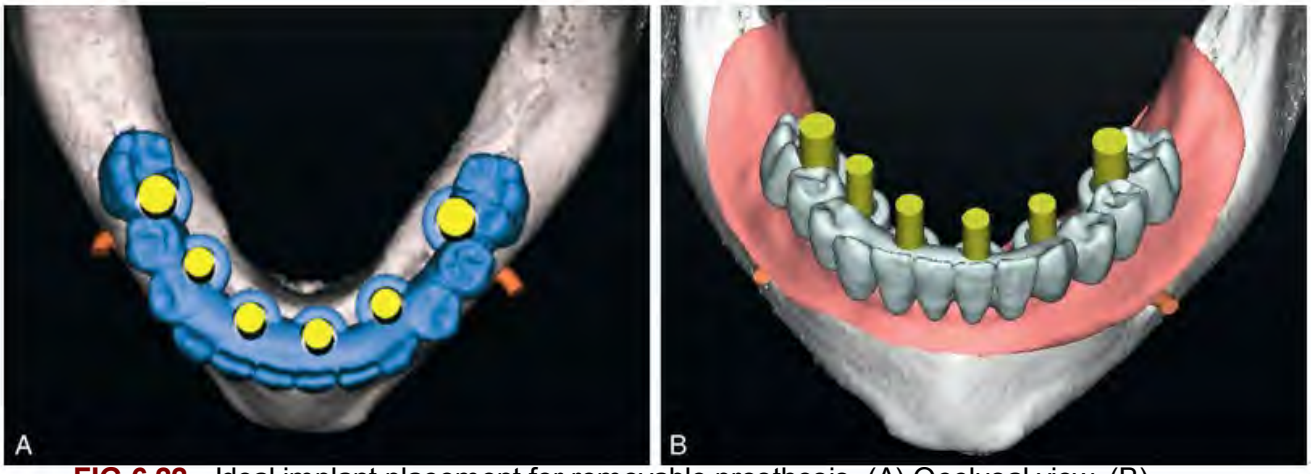

FIG 6.22 Ideal implant placement for removable prosthesis. (A) Occlusal view. (B) Anterior view. (From Misch CE: *Dental implant prosthetics,* ed 2, St. Louis, 2015, Mosby.)

Complications

Facial.

Implants positioned too facially will impinge on the esthetics, complicate screw insertion, and result in increased prosthesis component fractures. Every 10-degree increase in implant inclination may lead to a 5% increase in the torque applied to the restoration during function.[10]

Lingual.

Implants placed too far lingually will result in an overcontoured prosthesis, resulting in possible speech problems in the maxilla and crowding of the tongue in the mandible.

RP-4 and RP-5

Prevention.

Implants placed for removable overdentures should be positioned to emerge within the body of the denture base. This is important so the components that are attached to the implant do not impinge on the ideal setting of the denture teeth. Denture acrylic requires a minimum of 2.0 mm of bulk for strength and resistance form to prevent fractures and delamination.

Complications

Lingual.

Implants that are positioned too far lingually for an overdenture will result in overcontouring the lingual surface of the denture. This may interfere with phonetics, and often patients will complain of lack of space for the tongue. If the lingual aspect of the denture is thinned too much during adjustment, this will result in an area of possible fracture.

Facial.

Implants placed too far facially will interfere with ideal denture tooth placement, leading to possible denture tooth “pop offs.” In addition, facially positioned implants often result in lack of adequate attached tissue and potential periodontal concerns because gingival irritation and recession are more likely to result. This may lead to chronic pain, and remediation is usually unsuccessful (Fig. 6.23).

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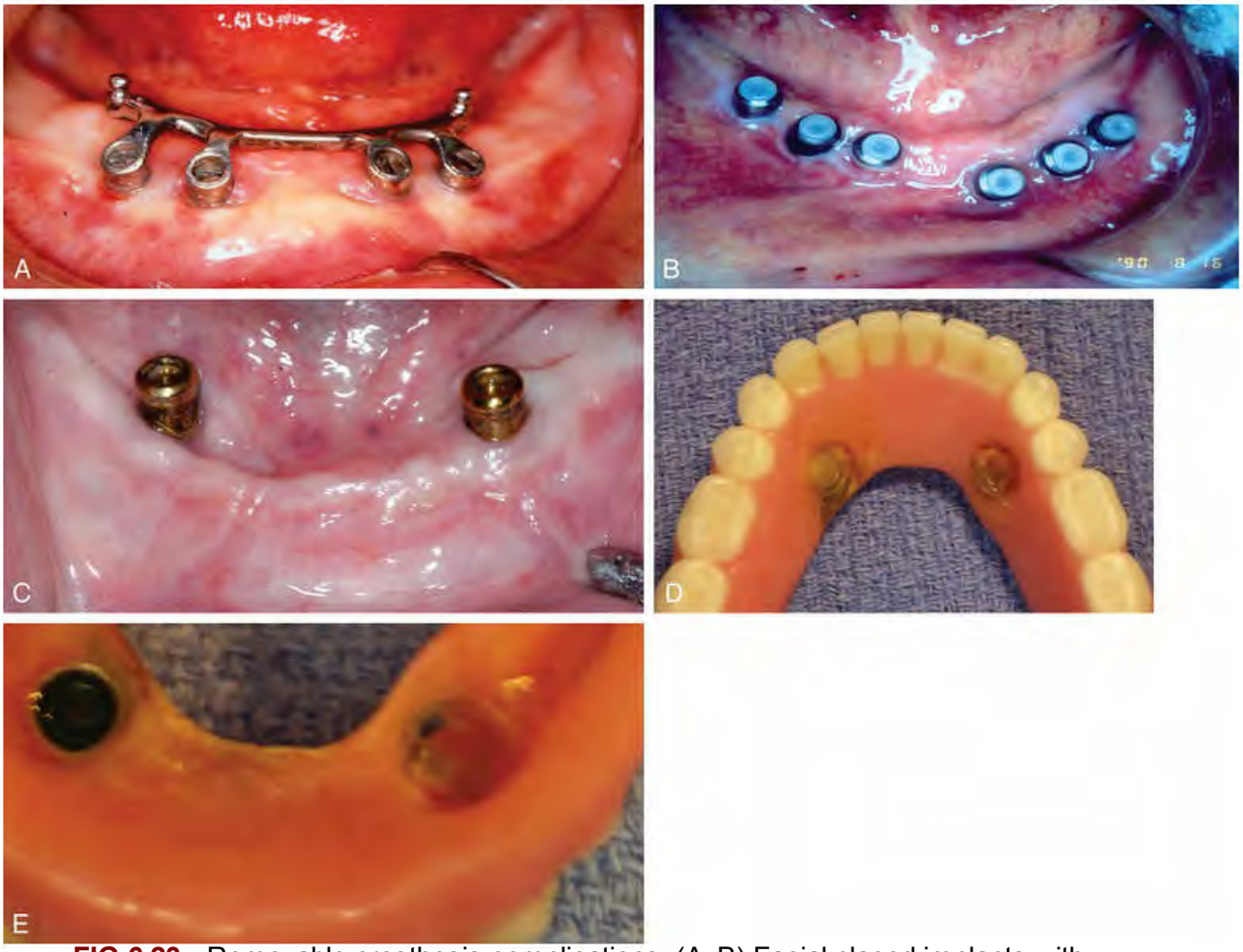

FIG 6.23 Removable prosthesis complications. (A–B) Facial placed implants with resultant soft tissue complications leading to tissue soreness. (C) Lingually placed implants resulting in tongue space impingement. (D–E) Lingually placed implants leading to overdenture attachment complications and fracture of the denture base because of minimal acrylic thickness.

Apicocoronal (Z-Axis)

The depth of implant placement is significant in relation to complications. Whether placed too deep or not apical enough, prosthetic and periodontal complications may increase implant morbidity.

There exists much controversy in implant dentistry regarding the placement level of an implant. Some authors have suggested that the implant be countersunk below the crestal bone more than 4 mm below the facial CEJ of the adjacent teeth to develop a crown emergence profile similar to a natural tooth, to prevent soft tissue recession, and to support the tissue of the adjacent natural teeth.[16,17] In theory, this provides an emergence transition of approximately 5 mm on the facial aspect to obtain the width of

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the natural tooth (the ideal free gingival margin on the facial is 1 mm above the CEJ).

The ideal crown height space (CHS) for a fixed prosthesis is between 8 and 12 mm, accounting for an ideal 3 mm of soft tissue, 2 mm of occlusal material thickness, and a 5 mm or greater abutment height. A CHS greater than 12 mm may be of concern in fixed restorations. The replacement teeth are elongated (FP2 or FP3) and often require the addition of gingival tone materials in esthetic regions. The greater impact force on implants compared with teeth, combined with the increased crown height, creates increased moment forces on implants and carries the risks of uncemented or unretained prostheses as well as component and material fracture. These problems are more problematic when associated with less favorable biomechanics on cantilevered sections of fixed restorations.[18] In case of excessive CHS, bone augmentation may be preferred to prosthetic replacement, especially in type C–h or D bone volumes. Surgical augmentation of the residual ridge height reduces the CHS and improves implant biomechanics by both position and number. Augmentation often permits the placement of wider-body implants with the associated benefit of increased surface area. Prosthetics is the most commonly used option to address excess CHS; however, it should ideally be the last choice. Using gingival-colored prosthetic materials (pink porcelain or acrylic resin) on fixed restorations or changing the prosthetic design to a removable restoration should often be considered when the prosthesis is used to restore excessive CHS with unfavorable conditions.

In regards to the effects of CHS on papilla form, Tarnow et al have shown that if the bone level to the contact area is less than 5 mm, 98 % of the time the embrasure space will be filled in. If the distance increases to 6 and 7 mm, the presence of a papilla reduces to 56% and 27%, respectively (Fig. 6.24).[19]

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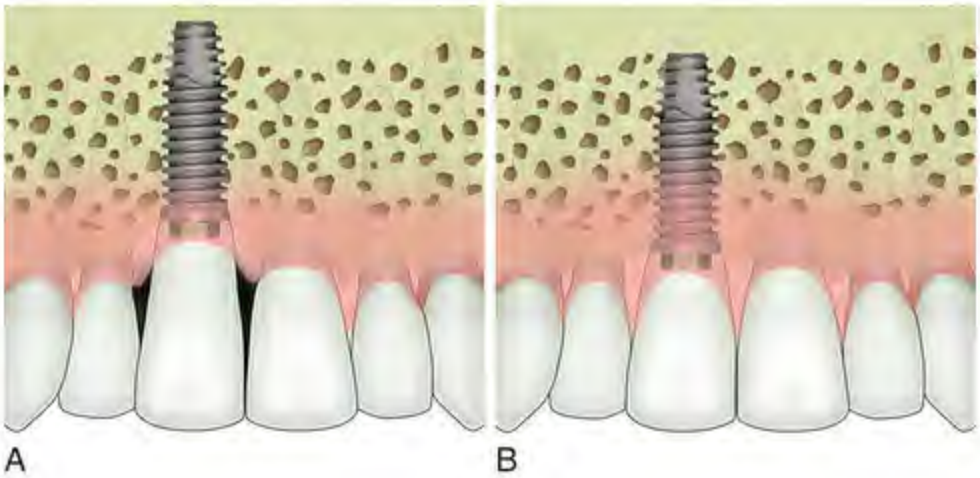

FIG 6.24 Ideal and nonideal apicocoronal positioning. The literature usually reports two positions for the depth of the implant. The facial bone of a healthy natural tooth is about 2 mm below the cement-enamel junction (CEJ), and the soft tissue from the free gingival margin to the bone is 3 mm. An implant inserted 4 mm or more below the facial CEJ often is countersunk below the crestal bone 2 mm or more (A). This gives "running room" for the porcelain on the crown to create a natural-looking emergence profile. However, bone loss is likely to occur beyond the implant abutment connection and often proceeds to the first thread beyond the crest module. As a result, an increase in probing depth and growth of anaerobic bacteria are more likely. (B) An implant placed 2 mm below the adjacent facial CEJ provides 3 mm of soft tissue drape to develop with a natural appearance and is best. An implant placed too shallowly causes severe emergence profile angles and compromises esthetics. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Fp-1, Fp-2, Fp-3

Complications

Placement too deep.

When implant placement results in positioning 2 mm below CEJ or 3 mm below free gingival margin, many complications may result:

- Unfavorable crown height space (crown-implant ratio).
- Periodontal complications because of inability to perform proper hygiene and bone loss on adjacent teeth
- Higher moment forces may cause biomechanical overload with resultant crestal bone loss
- Prosthetics are more complicated with difficulty in impression taking, placing abutments, and seating the prosthesis.
- With deeply placed implants, often the facial plate will resorb, especially if facial inclination is present.

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- Long-term sulcular health is decreased because the trabecular bone around the crest module is weaker against occlusal loads.
- Resultant initial crown height is increased, as are moment forces. A further increased risk of soft tissue shrinkage occurs long term, with additional bone loss at the crest module. The result is longer clinical crowns, which also decrease gradually in width (as the narrowing dimensions approach the implant body), with resultant black triangular spacings in lieu of interdental papillae and compromised long-term esthetics (Figs. 6.25–6.26).

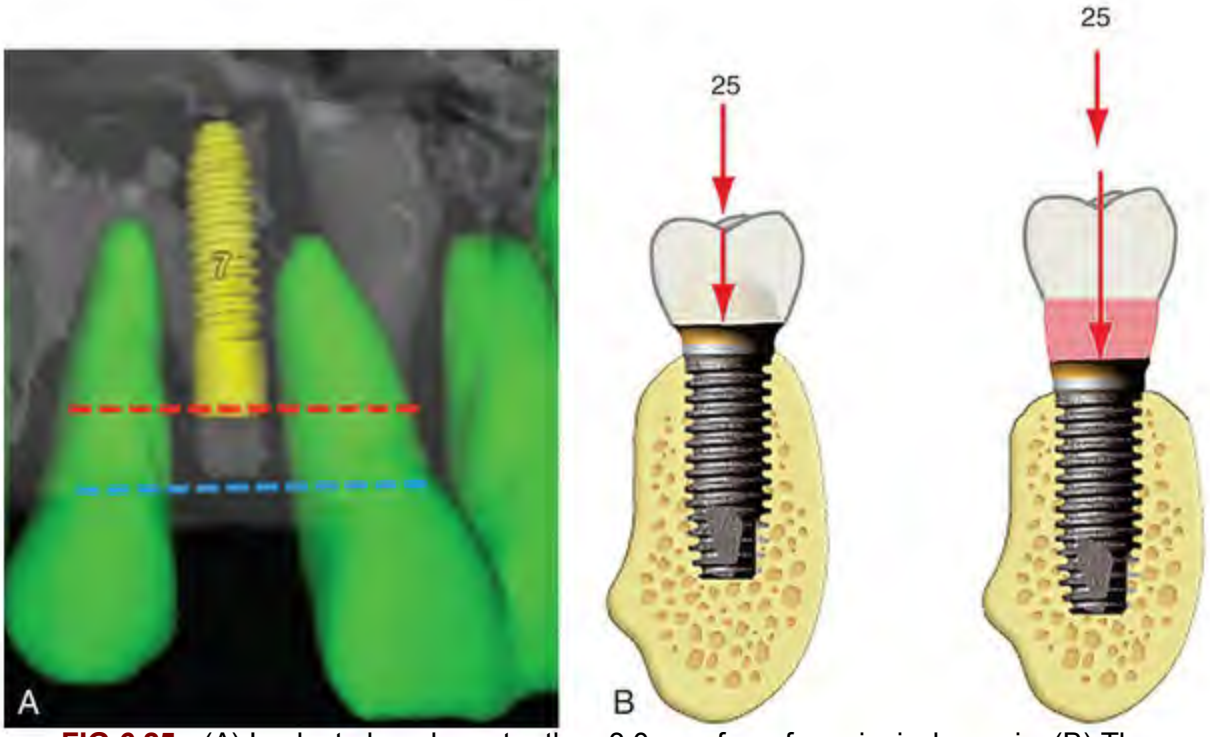

FIG 6.25 (A) Implant placed greater than 3.0 mm from free gingival margin. (B) The crown height is not a multiplier of force when the load is in the long axis of the implant. However, any angled force or cantilever increases the force and the crown height magnifies the effect. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

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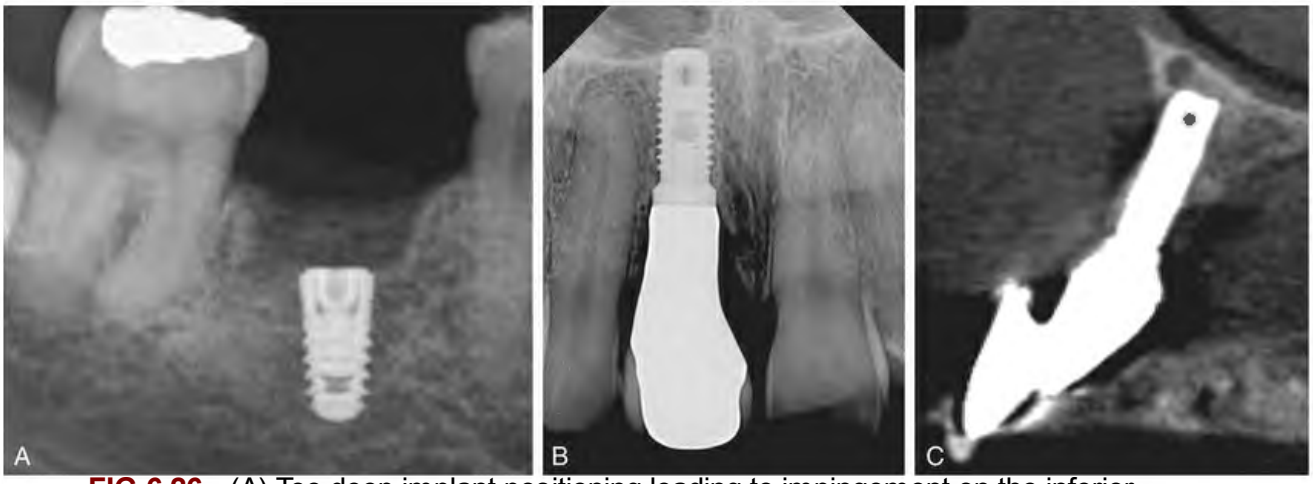

FIG 6.26 (A) Too deep implant positioning leading to impingement on the inferior alveolar canal. (B) Resultant periodontal and increased crown-implant ratio. (C) Unfavorable crown-implant ratio with implant placed too deep and lingually positioned with unfavorable biomechanics.

Treatment

Treatment planning phase.

If during the treatment planning phase it is determined there exist no alternatives to placing the implants at a compromised depth (i.e., bone grafting contraindicated), the following can be completed to decrease the possible of complications:

- Increase the number of implants.
- Increase the diameters of implants.
- Design implants to maximize the surface area.
- Fabricate removable restorations (less retentive) and incorporate soft tissue support.
- Remove the removable restoration during sleeping hours to reduce the noxious effects of nocturnal parafunction.
- Splint implants together, regardless of whether they support a fixed or removable prosthesis (Fig. 6.27).

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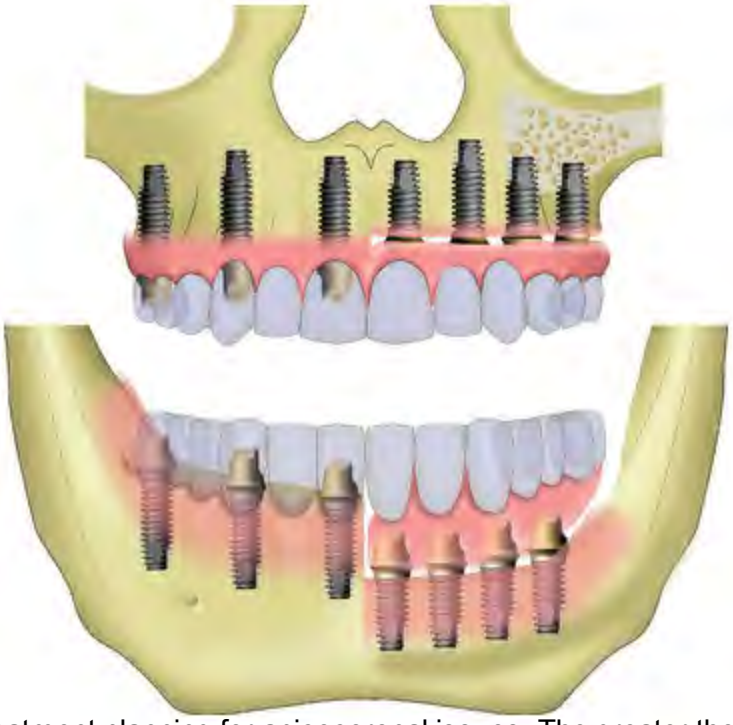

FIG 6.27 Treatment planning for apicocoronal issues. The greater the crown height space (CHS), the more implants are required to restore the patient *(right side of drawing)*. The less the CHS *(left side)*, the fewer the implants to restore the patient. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

At time of surgery.

If an implant is inserted and the position is known to be excessively deep, ideally the implant should be removed, bone graft the site, and then replace the implant at an ideal position after sufficient healing. If rigid fixation cannot be accomplished, the implant should be removed and grafting allowed to heal with future implant placement.

Integrated implant.

If it is determined after integration that the implant position is compromised, then the risk vs. benefit of removing the implant needs to be determined. If the morbidity of removing the implant is too significant, then the implant may be be restored with the following guidelines:

- Shorten cantilever length.
- Minimize buccal and lingual offset loads.
- Ideal emergence profile.
- Occlusal contact load should be reduced on any offset load from the implant support system.

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- Occlusal contacts in centric relation (CR) occlusion may be eliminated on the offset load area. A parafunction load may be reduced because the most cantilevered portion of the prosthesis is loaded only during functional activity while eating food.[20]

Note: Questionable treatments including segmental osteotomies are not recommended due to the invasiveness, length of treatment time, and questionable prognosis.

Complications

Placement with inadequate depth

- When implant positioning is not deep enough (<3 mm from CEJ, <2 mm from free gingival margin).
- Inadequate emergence profile (transition from the narrower diameter of the implant compared with the wider dimension of the crown)
- Decreased retention of the implant, which may lead to uncementable restorations or component fracture
- Poor resultant esthetics because implant abutment or implant body will show through resulting in cervical darkness, and if this occurs in the anterior region, it may be unpleasant for the patient. Normally, the facial margin of the crown will not be able to be placed subgingival enough to mask the titanium color of the abutment below the margin.
- Inadequate running room because the location of the crest module will leave inadequate room for adequate hygiene. An abrupt change from the prosthetic platform to the diameter of the restoration will result. Normally, this will most likely result in hygiene difficulty.

Treatment

Treatment planning phase.

If it is determined during the treatment planning phase that implant positioning would result in an implant being in a nonideal location with respect to the free gingival margin, modifications to the treatment plan or final prosthesis may be indicated. Skeletal discrepancies (deep bite), reduced occlusal vertical dimension (OVD) from attrition or abrasion, minimal bone atrophy after tooth loss, and supraeruption of unopposed teeth may all result in less-than-ideal space for prosthetic replacement of the dentition.

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Traditional prosthetic and restorative procedures are indicated to restore the proper OVD and plane of occlusion and increase the crown height space.

- Modification or adjustment of opposing occlusion should always be explained to the patient at the initiation of treatment to prevent miscommunication issues. This is extremely important, especially if alteration of the opposing tooth would result in the need for endodontic therapy.
- Ideally, 8.0 mm of space is required for a cementable prosthesis. The 8-mm requirement for CHS consists of 2 mm of occlusal material space, 4 mm minimum abutment height for retention, and 2 mm above the bone for the biologic width dimension (which does not include the sulcus because a crown margin may be 1 mm subgingival for retention or esthetics). If this cannot be accomplished, a screw-retained prosthesis or change to a fixed partial denture treatment plan is indicated.

At time of surgery.

If the implant is inserted and the position is known to be excessively shallow, removal of the implant is indicated, the osteotomy should be deepened if available bone is present, and the implant is reinserted at a more favorable depth. The location of vital structures should always be determined prior to deepening of the osteotomy.

Integrated implant.

After implant integration, if the implant is determined to be of inadequate depth, the implant should be ideally removed. However, if the morbidity of removing the implant is too significant, then the following may be evaluated as possible treatment options:

- A screw-retained prosthesis
- Shorten cantilever length
- Minimize buccal and lingual offset loads
- Ideal emergence profile (Fig. 6.28)

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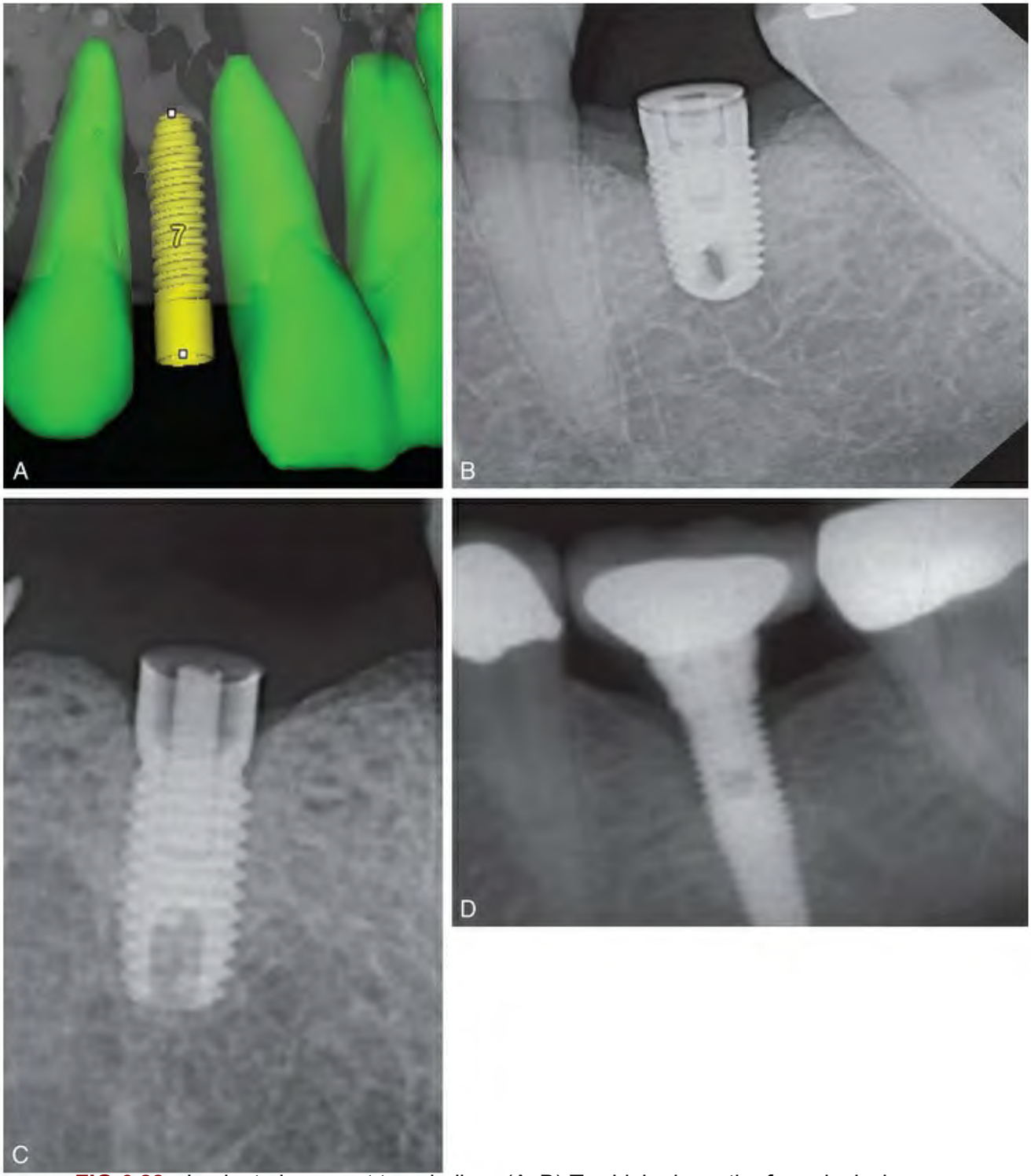

FIG 6.28 Implant placement too shallow. (A–B) Too high above the free gingival margin (FGM) and cemento-enamel junction (CEJ). (C) Resultant fracture screws. (D) Poor emergence profile because of lack of crown height space.

- Increase mechanical and chemical retention of the abutment by roughening the abutment surface.

RP-4 and RP-5

Prevention (RP-4, RP-5).

Caution must be exercised to ensure there is adequate interocclusal space for the overdenture prosthesis, especially if a connecting bar is used. For a bar and overdenture with attachments, at least 15 mm from the crest of the ridge to the incisal edge is suggested. If interocclusal space is needed, an osteoplasty at the time of surgery should be completed to increase space for the final prosthesis. Interactive treatment planning may be used to fabricate a reduction guide, which will allow the implant clinician to remove the ideal amount of bone. A minimum of 2.0 mm of acrylic is required to adequately retain denture teeth and maintain structural integrity of the prosthesis.

Complications

More than 15 mm.

For an RP-5 prosthesis, greater interocclusal space is usually not problematic because of the soft tissue support. However, with an RP-4 (implant supported)prosthesis, greater interocclusal space may pose a problem with increased “rocking” of the prosthesis because of the lack of soft tissue support (i.e., RP-4 is completely implant supported). With removable prostheses, two prosthetic levels of height should be taken into consideration. The first is the height of the attachment system to the crest of the bone. The greater the height distance, the greater the forces applied to the bar, screws, and implant structures. The second CHS to consider is the distance from the attachment to the occlusal plane. This distance represents the increase in prosthetic forces applied to the attachment. For example, in a CHS of 15 mm, a locator attachment may be 7 mm from the crest of bone, resulting in a lever action of 7 mm applied to the implants. The distance from the rotation point of the locator attachment to the occlusal plane may be an additional 8 mm. Under these conditions, a greater lever action is applied to the prosthesis than to the implant interface. This results in increased instability of the restoration under lateral forces.[20]

Treatment.

If more than 15 mm of space is present, a RP-5 prosthesis should have ideal interocclusal space for the final prosthesis. Peripheral extension and the primary stress-bearing area support (maxilla—horizontal palate; mandible—buccal shelf) should be utilized to decrease excessive loading force. The

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occlusion should include bilateral balanced contacts with no occlusal prematurities. If excessive force exists, (i.e., excessive CHS and/or parafunction) an RP-4 (totally implant supported) may be changed to an RP-5 (soft tissue supported) to decrease the force.

Complications

Less than 15 mm.

When sufficient CHS is lacking and the prosthesis is more prone to component fatigue and fracture, an overdenture is more difficult to fabricate than a porcelain-to-metal fixed prosthesis. The 15-mm minimum CHS provides adequate bulk of acrylic to resist fracture, space to set denture teeth without modification, and room for attachments, bars, soft tissue, and hygiene. In the mandible, the soft tissue is often 1 to 3 mm in thickness above the bone, so the occlusal plane to soft tissue should be at least 9 to 11 mm in height. An osteoplasty to increase CHS before implant placement or a fixed restoration is often indicated when abundant bone height and width are present (Fig. 6.29).

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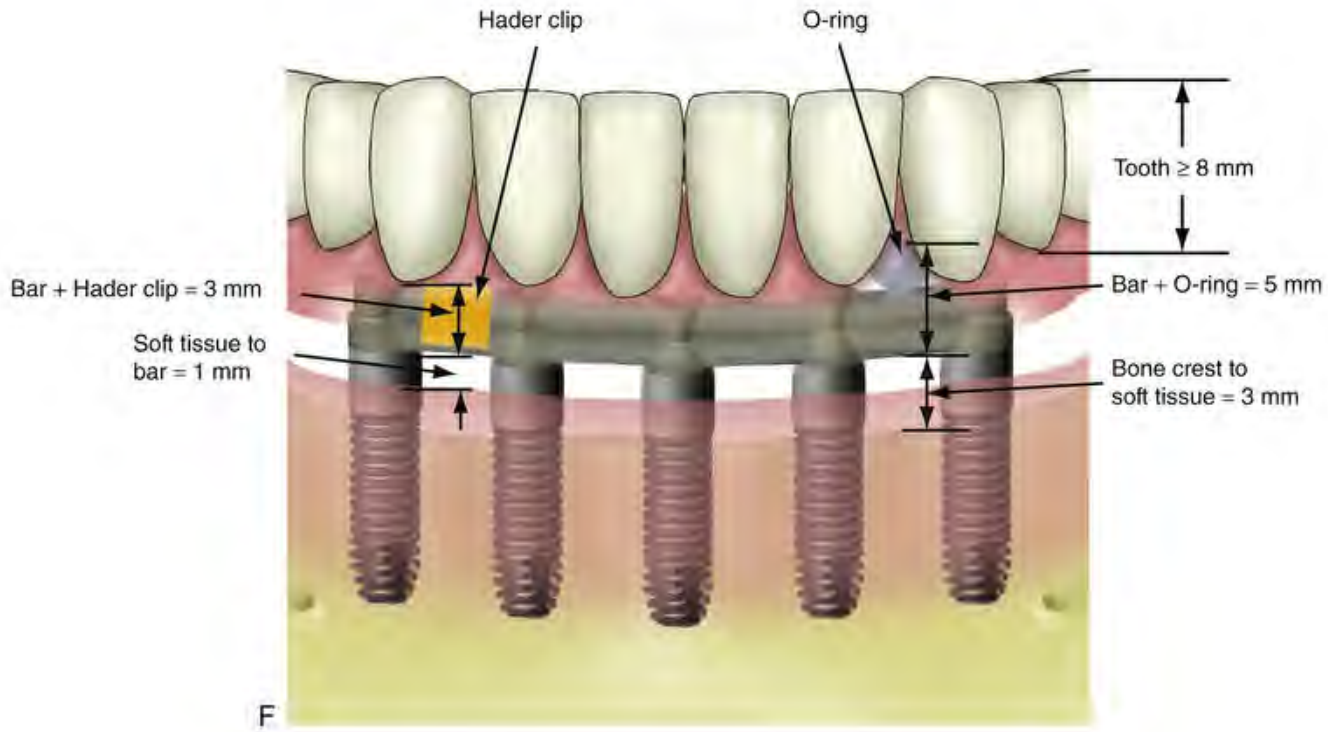

FIG 6.29 Lack of interocclusal space for removable prosthesis. (A) Evaluation in the treatment planning phase. (B) Complication resulting from lack of interocclusal space, patient in rest position showing bar (suprastructure). (C–D) Decreased interocclusal space should be diagnosied preoperatively and treated with aggressive osteoplasty. (E) Lack of acrylic bulk leads to poor retention of denture teeth and possible fracture of denture base (<2 mm); at least 2 mm of acrylic is needed for strength. (F) For a bar-retained overdenture, approximately 15 mm (from alveolar ridge to incisal edge) is required for adequate space of teeth, acrylic, bar, and soft tissue space. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Treatment.

If less than 15 mm of CHS is present, an RP-4 and RP-5 may present issues. Without sufficient space for tissue health, attachment space, bulk of acrylic, and nonmodified denture teeth, the overdenture may undergo fatigue and possible fractures. An RP-4 may be changed to an RP-5 to obtain soft tissue support to minimize forces to the attachments. Additionally, the overdenture prosthesis should be changed to a metal base, metal reinforced, or fiber mesh to increase the strength of the prosthesis to prevent prosthesis fracture.

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Distance From Vital Structures

Implant Position

Inferior Alveolar Nerve Canal or Mental Foramen

Accurate positioning of implants in approximation to the inferior alveolar canal and mental foramen is crucial in preventing neurosensory impairment. The correct location of the nerve and canal should ideally be ascertained via three-dimensional imaging, especially when the implant may be within 2 mm of the nerve. After identification of the vital structures, the implant should be placed greater than 2 mm from the inferior alveolar canal or mental foramen. Implant placement less than 2 mm increases the risk of compression or traumatic injuries to the nerve trunk, which may result in neurosensory deficits (Fig. 6.30).

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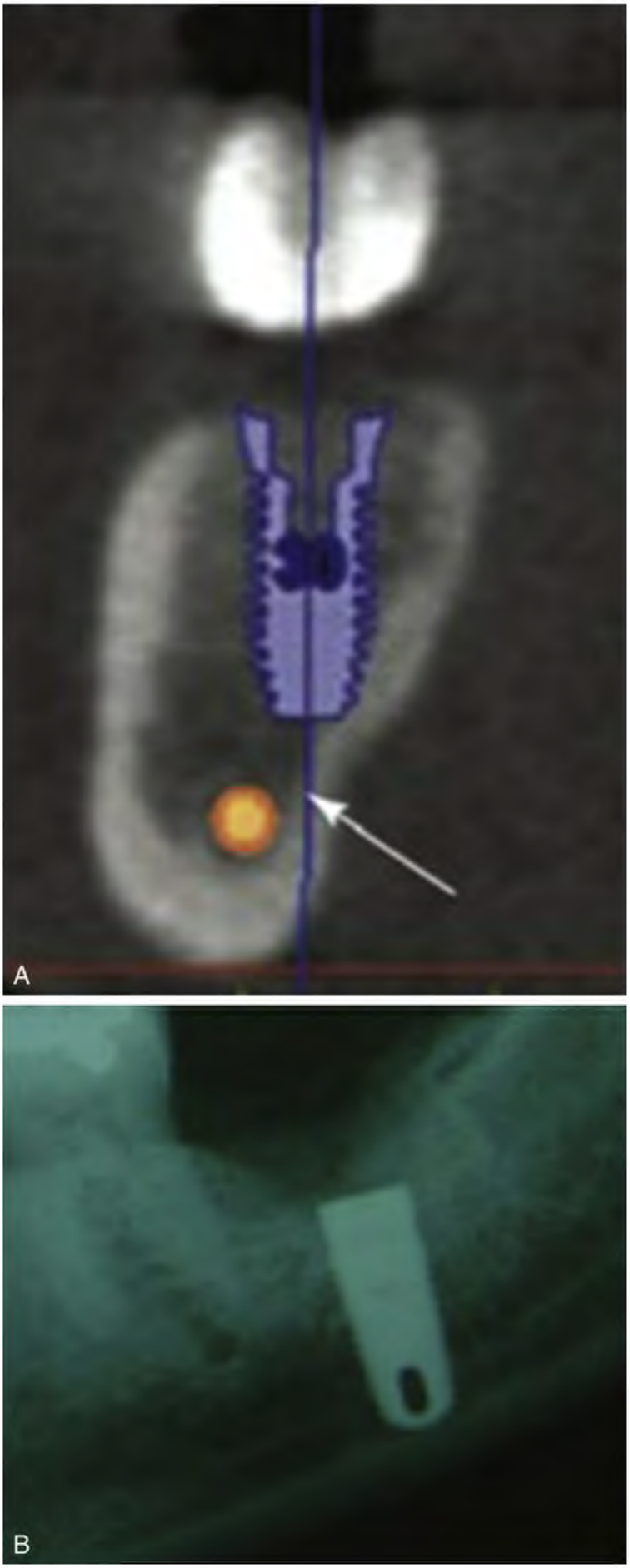

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FIG 6.30 Distance from the (A) inferior alveolar nerve canal or mental foramen. (B) Placement of implant too deep, violating the inferior alveolar canal.

Inferior Border of Mandible

Placement of dental implants in the anterior mandible can lead to significant and even life-threatening complications. Care should be noted to evaluate the angulation and trajectory of the anterior mandible with three-dimensional imaging to minimize the possibility of perforating the lingual cortex. Two-dimensional radiographs (i.e., panoramic) may lead to false representation of the amount of bone available. If the inferior border of the mandible is perforated, bleeding may become evident from the sublingual and submental blood vessels. Because this area is difficult to obtain access to, dangerous sublingual bleeding complications may arise (See Chapter 7) (Fig. 6.31).

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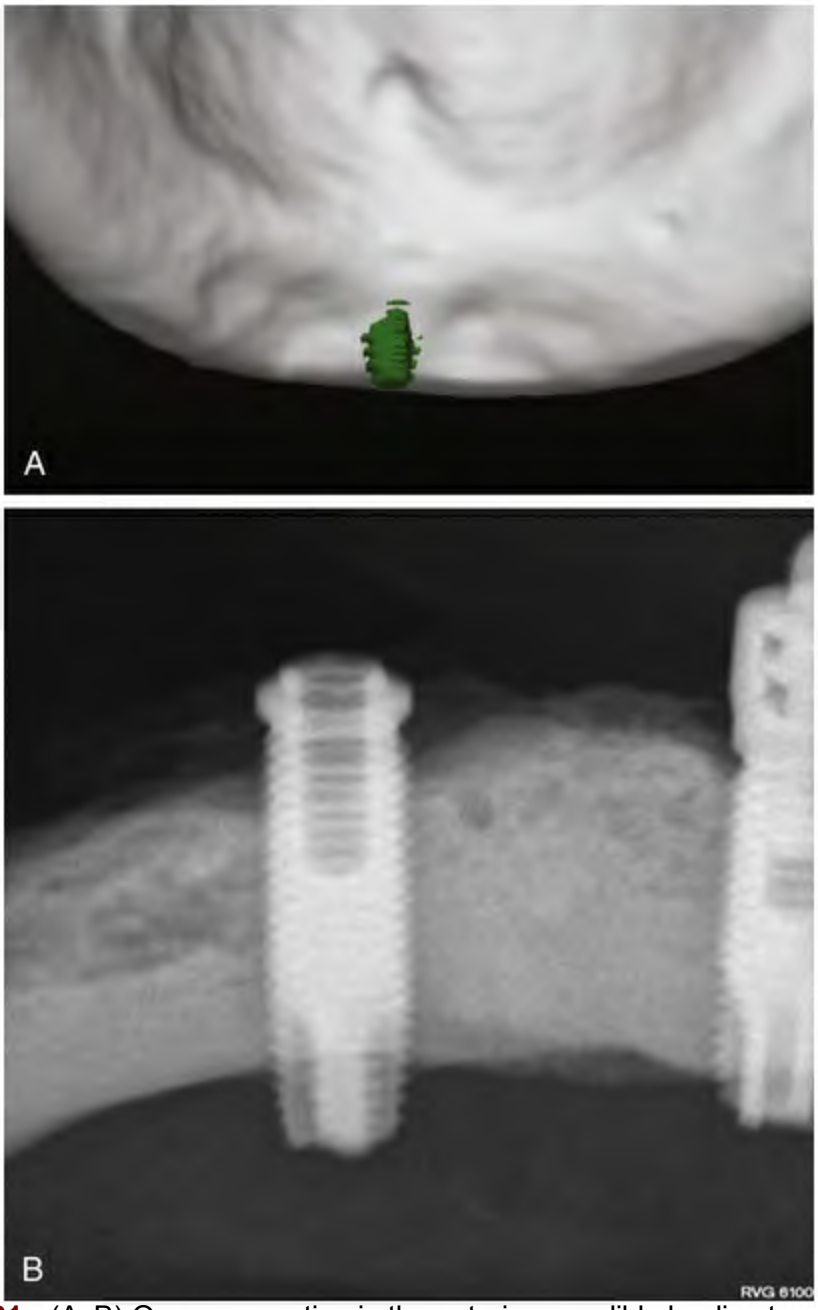

FIG 6.31 (A–B) Over preparation in the anterior mandible leading to possible sublingual bleeding.

Nasal Cavity

The anterior maxilla is often a very challenging area to place implants. Because of the compromised bone in width and height, along with angulation issues, implants are often malpositioned. Placement of implants in the anterior maxilla may be very challenging, especially when minimal height of bone is present. Ideally, implants should be positioned just short of the nasal floor, without engaging the thin inferior floor of the nasal cavity.

There does exist more advanced surgical techniques where the implants may extend into the nasal cavity 2 to 4 mm via a subnasal graft; however, these procedures should only be completed in ideal circumstances (Fig. 6.32).[21]

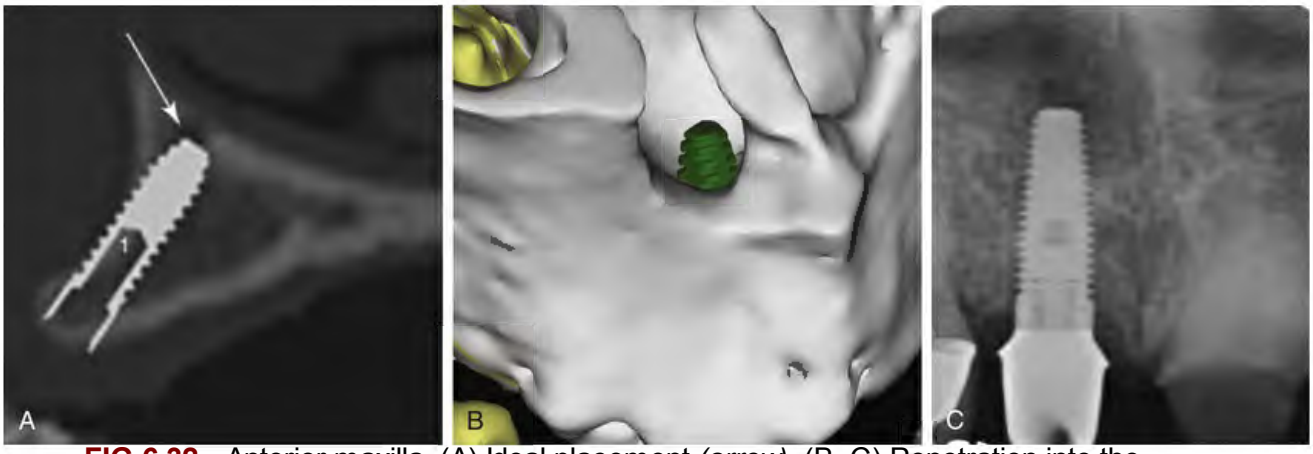

FIG 6.32 Anterior maxilla. (A) Ideal placement *(arrow)*. (B–C) Penetration into the nasal cavity.

Distance From the Maxillary Sinus (Inferior Border)

One of the more challenging areas for implant placement involves the posterior maxilla. The implant dentist often encounters compromised bone height and poor bone quality in this area because of bone loss and pneumatization of the maxillary sinus. There are four treatment options (Misch Classification) for implants placed in this area with respect to the quantity of bone from the crest of the ridge to the inferior border of the sinus (Fig. 6.33)[15]:

1. SA-1: Greater than 12 mm of bone; a standard implant placement protocol is indicated

2. SA-2: When 10 to 12 mm of bone is present and the implant is placed along with antral floor elevation through the osteotomy site 0 to 2 mm

3. SA-3: When 5 to 10 mm of bone is present, sinus grafting is indicated with (SA-3I) or without (SA-3D) simultaneous implant placement.

4. SA-4: Less than 5 mm of bone is present, which necessitates a lateral wall sinus augmentation procedure before implant placement.

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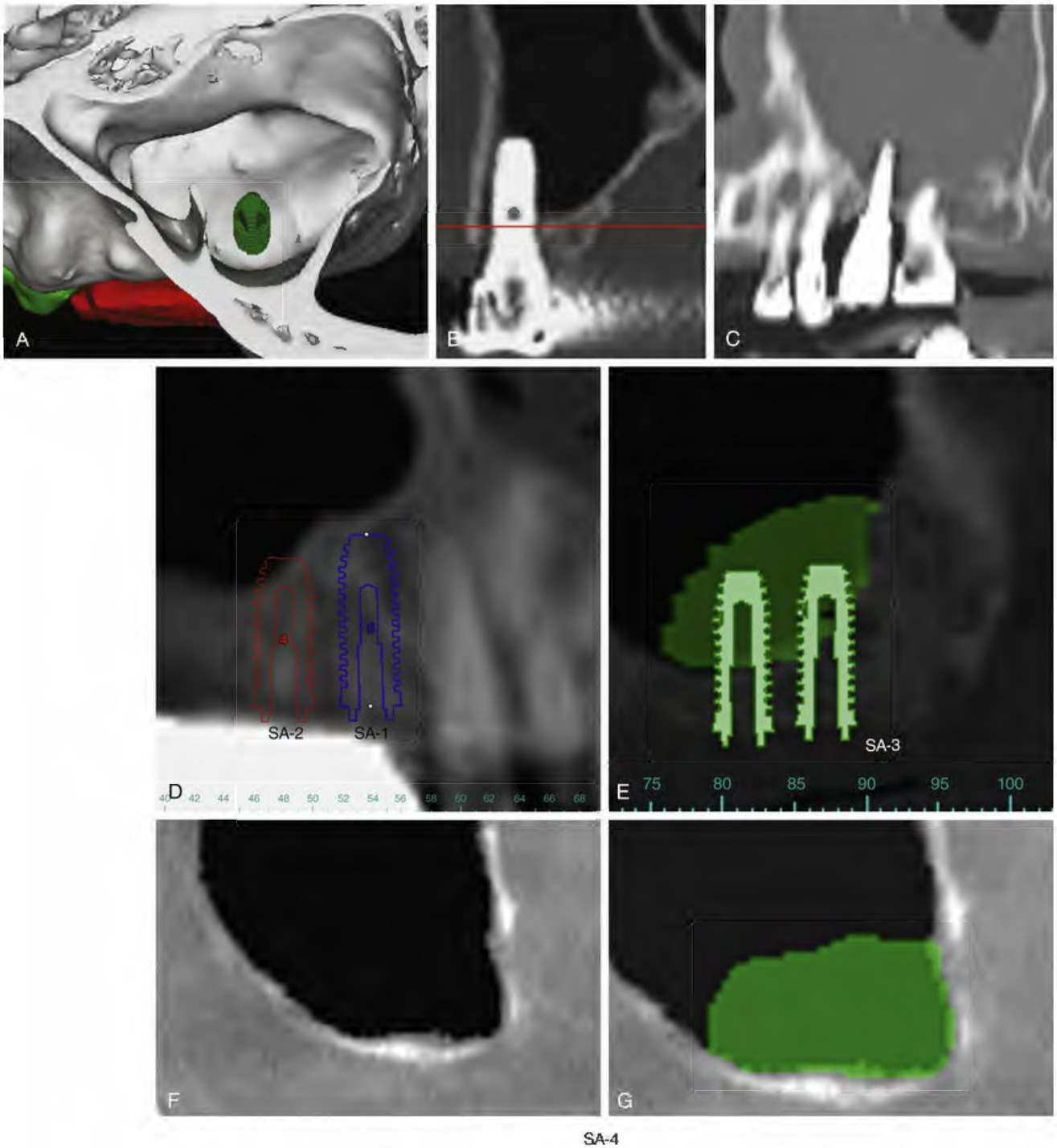

FIG 6.33 (A–B) Implant penetration into the sinus cavity. (C) Implant-induced rhinosinusitis. (D–G) Posterior maxilla treatment planning: SA-1 and SA-2 (D and E), SA-3 (F), and SA-4 (G). (D–G From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Malpositioning Complication Summary

Prevention

Ideal Treatment Planning

The surest way to minimize prevent errors in angulation during implant surgery is to develop a comprehensive strategy during the preoperative assessment phase of treatment. CBCT analysis offers the clinician an excellent evaluation of the patient's anatomy to properly plan implant position, diameter, and length helping prevent positional, spacing, and depth issues.

Ideal Available Bone

The amount of available bone width (faciopalatal) should be at least 2.0 mm greater than the implant diameter at implant insertion. A 3.5-mm implant requires at least 5.5 mm of bone width (minimum). Augmentation has become very predictable and accepted in the profession, therefore the clinician should never compromise when adequate bone is not available. Various bone grating techniques and materials are available that the clinician should implement in treating these compromised cases.

Understanding the Prosthesis Type and Associated Ideal Positioning

When treatment planning, the final prosthesis should always be evaluated first, prior to implant placement. The implant clinician must have a strong understanding of the various prosthesis types (e.g., FP-1, FP-2, FP-3, RP-4, RP-5) along with the positional and prosthesis demands and needs. The prosthesis type (fixed [FP-1, FP-2, FP-3] or removable [RP-4, RP-5]) dictates the ideal placement of implants. The implant clinician must understand that positioning changes as per the type of prosthesis.

Soft Tissue Evaluation

The biotype (thin vs. thick) bone should always be evaluated prior to implant placement. Thin biotypes are at higher risk of gingival recession and esthetic issues, especially in the anterior part of the mouth. Thin biotype patients are more susceptible to malpositioning issues and greater emphasis should be noted on ideal conditions. If needed, soft tissue augmentation should be

completed prior to implant placement.

Condition of the Adjacent Teeth

Prior to implant placement in edentulous sites, the adjacent natural teeth should be evaluated for restorability and existing pathology that may be present. A 5- to 10-year prognostic window should be established for each natural tooth prior to the completion of an implant treatment plan. If a tooth does not possess a favorable 5- to 10-year prognosis, extraction should be discussed or alternative treatment options.

Presence of Pathology

The intended implant site should be carefully evaluated for the presence of pathology at the site or latent adjacent pathology associated with natural teeth, which may lead to increased implant morbidity. It is common to have residual bacteria still present, especially if a recently infected natural tooth extraction was performed. Additionally, the adjacent teeth should be evaluated for periapical pathology, as this may lead to a retrograde peri-implantitis.

Good Surgical Technique

To minimize the possibility of improper angulation, the implant clinician should evaluate the osteotomy angulation after the use of the first pilot drill. Usually, the pilot drill is used to a depth of 6 to 8 mm. A direction indicator is placed, and should be evaluated both radiographically and with a surgical template for proper positioning. The position can also be evaluated by having the patient close lightly to determine the interocclusal positioning with the direction indicator. Any modifications of the angulation should be completed with a Lindemann drill.

Poorly Dense Bone

In poorly dense bone (≈D4), overpreparation of the osteotomy site may lead to redirection of the implant upon placement. Additionally, implants should be inserted with a handpiece instead of by hand ratcheting. When implants are placed in poorly dense bone with a ratchet, the implant may be easily redirectioned by placing in a more elliptical direction.

Understand the True Location of Vital Structures

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Knowing the exact location of the vital structures is paramount in avoiding complications. Impinging on vital structures such as the mandibular canal, maxillary sinus, or nasal cavity may increase morbidity and place the patient at risk for irreversible complications.

Use of Surgical Templates

A surgical template is defined by the prosthodontics glossary as a guide used to assist in ideal surgical placement and angulation of dental implants.[22] The objective of using a surgical template is to provide accurate placement of the implant according to a surgical treatment. There are many different types of surgical templates used today. Stumpel classified surgical templates according to the amount of surgical restriction that is utilized in the template. The categories are: (1) nonlimiting, (2) partial limiting, and (3) complete limiting design.[23]

Nonlimiting Design.

The nonlimiting template allows the implant surgeon dimensional variability in the implant location because the template indicates the ideal space (location) for the final restoration, not the actual mesiodistal angulation. The nonlimiting template has become popular because of the ease in fabrication and the low cost involved.

Complication.

These templates allow the implant surgeon only an initial location of the proposed prosthesis, not the correct angulation (buccal-lingual) and position (mesiodistal). A great deal of flexibility and latitude regarding the final position of the implant is inherent with this type of template (Fig. 6.34).

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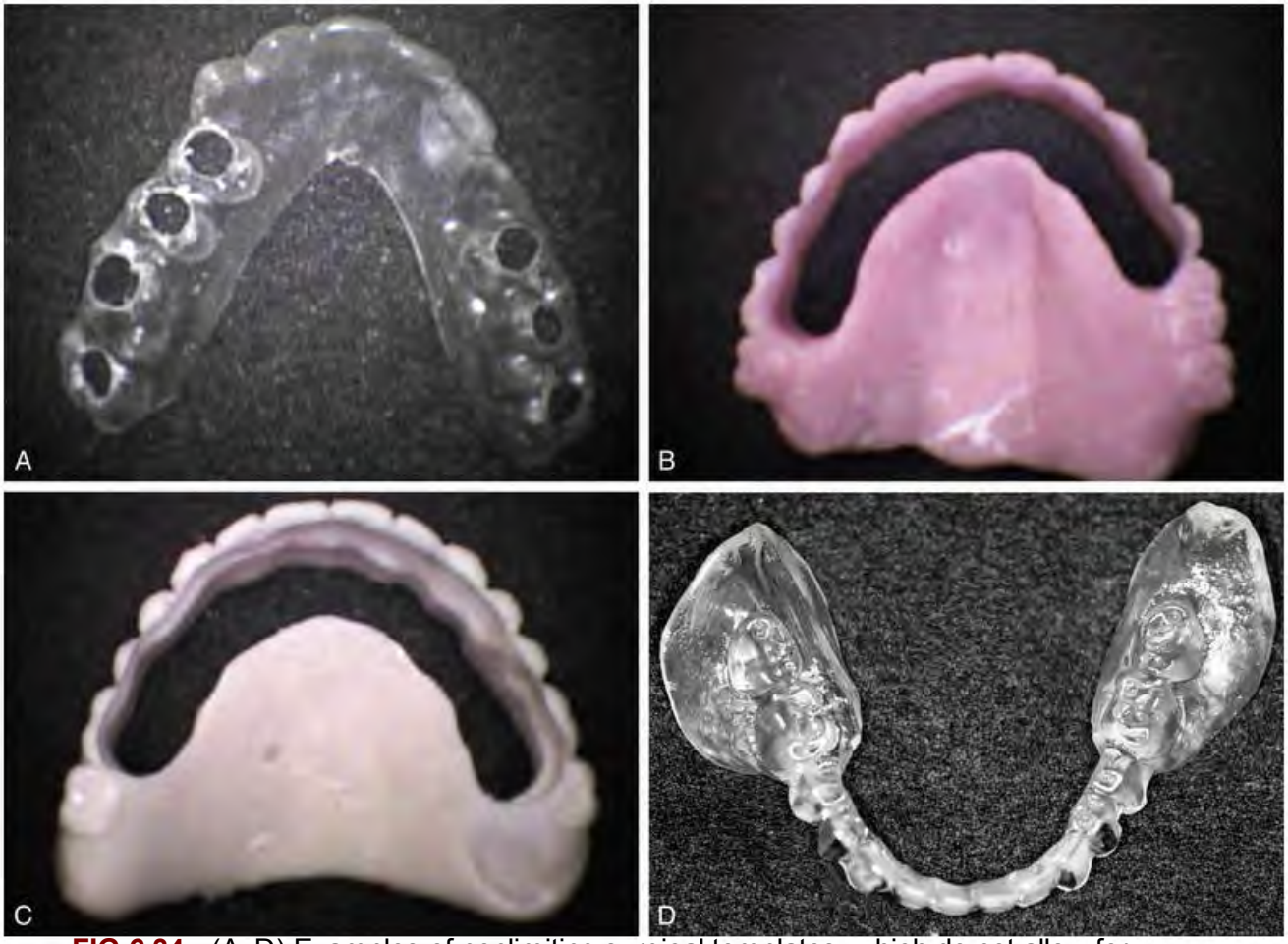

FIG 6.34 (A–D) Examples of nonlimiting surgical templates, which do not allow for accurate mesial-distal or buccal-lingual positioning of the patient. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Partial Limiting Design.

The partial limiting design incorporates a guided sleeve or a slot that allows for angulation of one drill size, usually the pilot drill. After the first drill is used, the rest of the osteotomy sites are completed freehand. Various techniques can be utilized in fabricating a partial limiting template including manual laboratory-fabricated templates or templates fabricated from a radiographic template, which is then converted into a surgical guide template.

Complication.

Although the partial limiting design is more accurate than a nonlimiting design, these templates still do not allow for final, accurate positioning of the implant. Clinical studies have shown these types of templates to have high degree of error in the buccal-lingual orientation (Fig. 6.35).[24]

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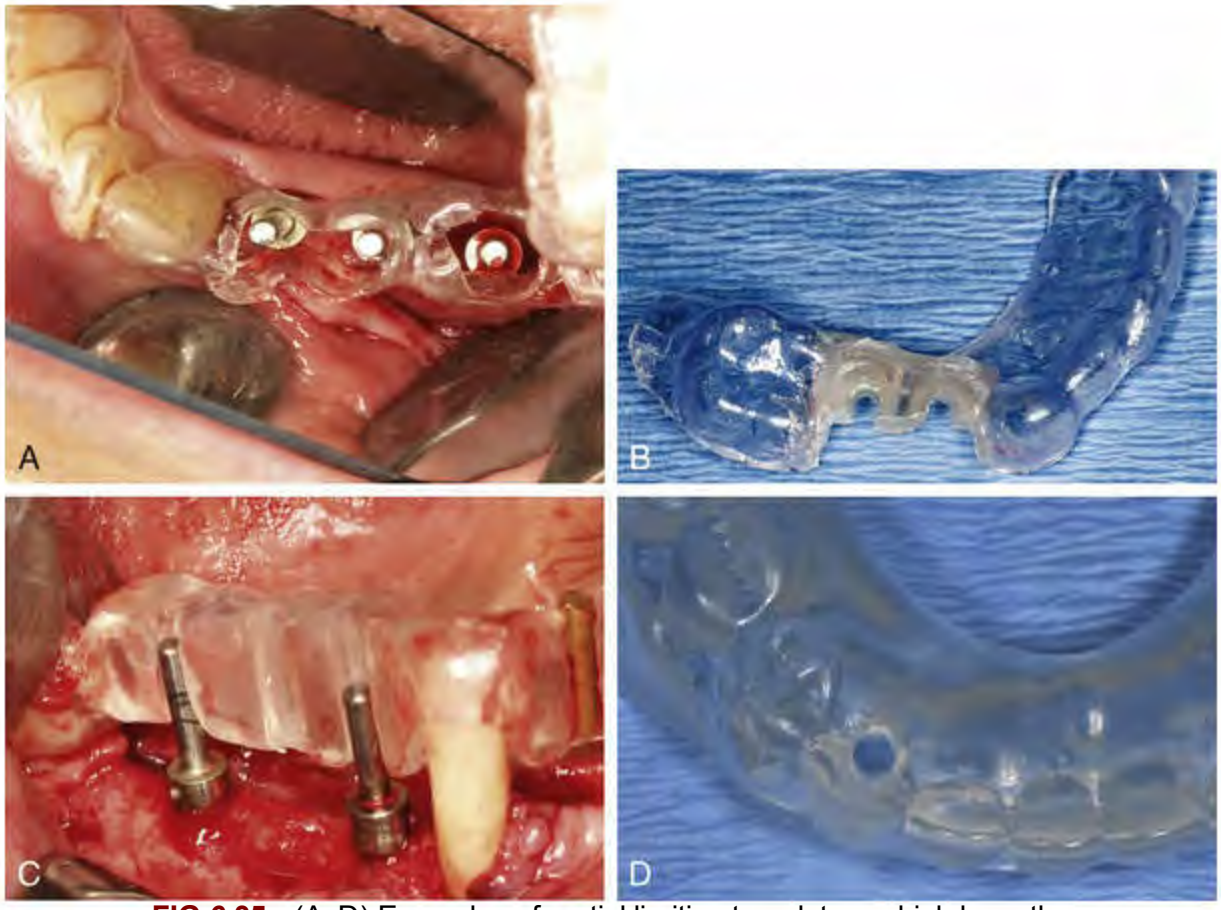

FIG 6.35 (A–D) Examples of partial limiting templates, which have the disadvantage of not allowing for final positioning or placement of the implant. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Complete Limiting Design.

With the complete limiting template design, the position, angulation, and depth of the osteotomy are dictated by the guided tubes or sleeves, thus restricting any variation by the implant surgeon. This type of guide prevents any osteotomy error in the bucco-lingual and mesiodistal planes. Additionally, drill stops can be incorporated to prevent overpreparation of the site. Basically, with the complete limiting design, the final position of the implant is known before the actual surgery. This technique is becoming popular because the prosthetic final abutment or provisional restoration can be prefabricated for immediate provisionalization after implant placement.

Complication.

The use of complete limiting surgical templates that are fabricated from interactive treatment planning with cone beam technology has been shown to be highly accurate. However, caution must be used when employing

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surgical templates that are fabricated conventionally (not from CBCT) on dental study casts, which are rigid, nonfunctional surfaces without information of the soft tissue thickness and bone morphology. These types of surgical templates allow for placement of implants according to an estimate of location of teeth, soft and hard tissue, and vital structures without three-dimensional guidance (Figs. 6.36–6.37).[25]

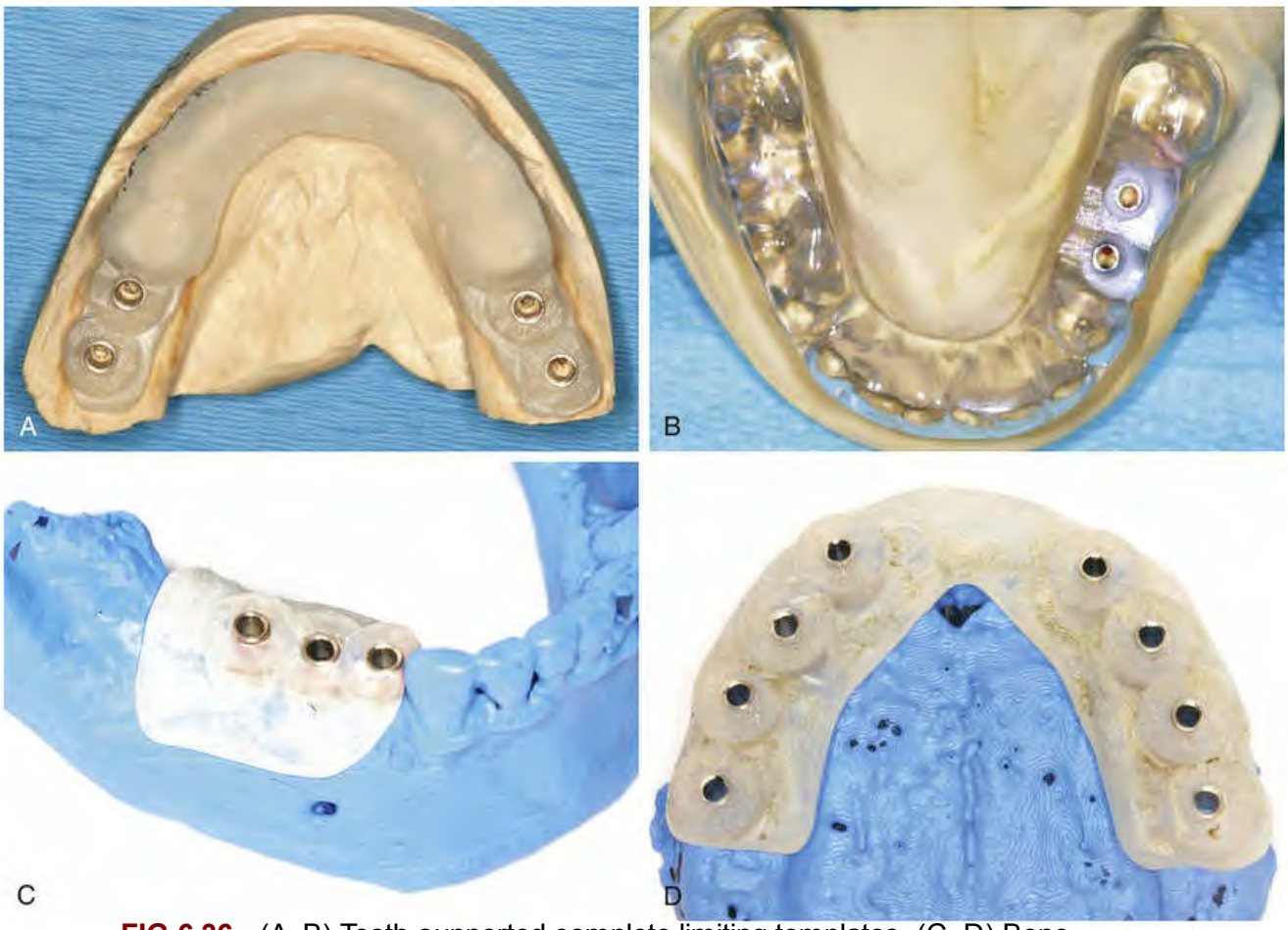

FIG 6.36 (A–B) Tooth-supported complete limiting templates. (C–D) Bone-supported complete limiting templates. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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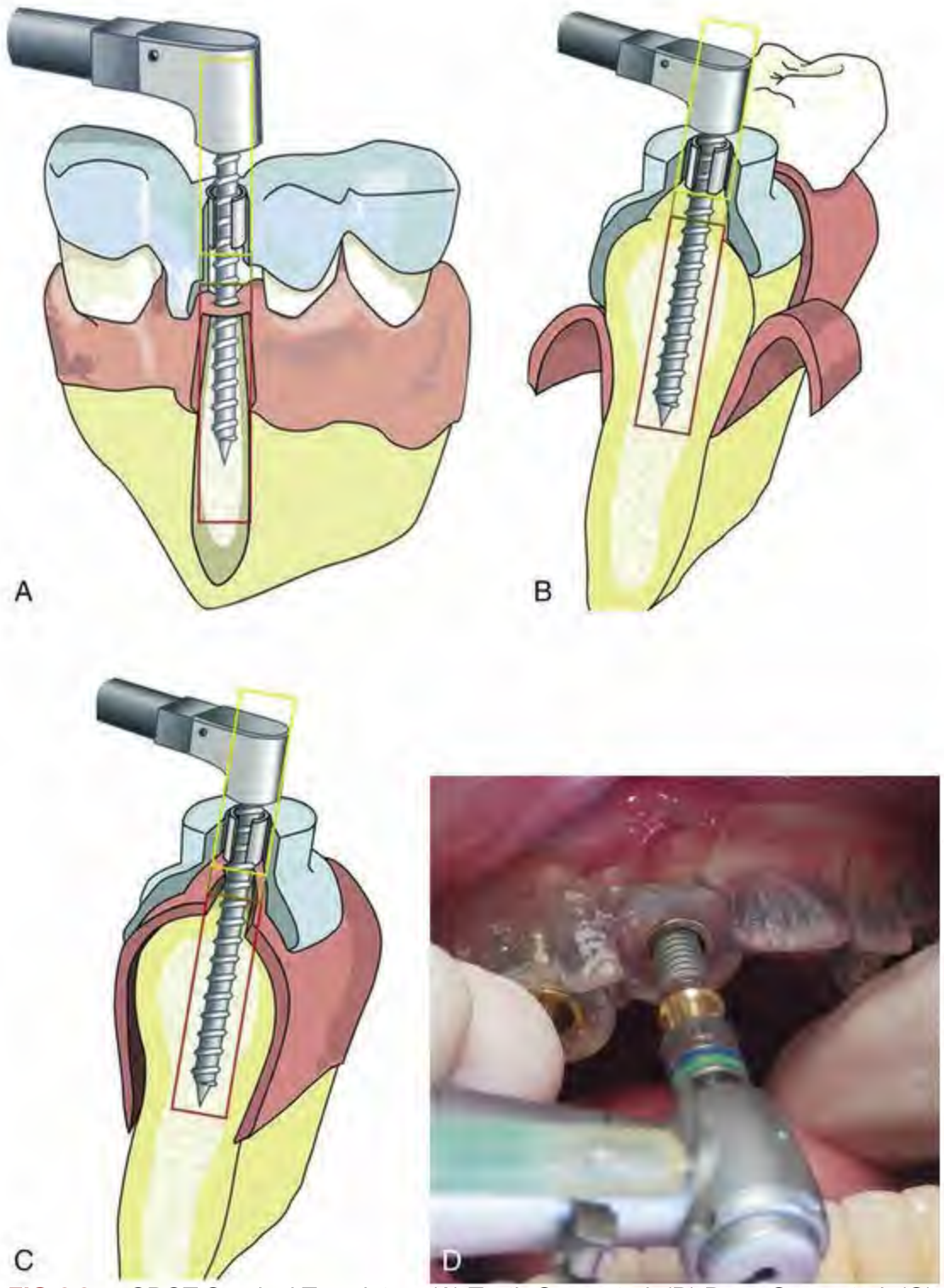

FIG 6.37 CBCT Surgical Templates, (A) Tooth-Supported, (B) Bone-Supported, (C) Tissue-Supported, (D) CBCT surgical templates allow for accurate placement of implants.

Use of CBCT Surgical Guides

To overcome the limitations and complications inherent with conventional

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surgical templates, the use of CBCT-generated templates has evolved in implant dentistry today. A computer-generated surgical guide (partial limiting or complete limiting) provides a link between the CBCT treatment plan and the actual surgery by transferring the interactive plan accurately to the surgical site. The two most common surgical templates are those from Materialise (SimPlant), which are termed *surgiguides,* and those from Nobel Biocare (NobelGuide), which are termed *surgical templates.* Other commercially available software programs include ImplantMaster (I-Dent Imaging, Ltd., Hod Hasharon, Israel), Easy Guide (Keystone Dental, Burlington, MA), and coDiagnostiX (IVS Solutions AG, Chemnitiz, Germany).

With the use of CBCT-generated software programs (e.g., SimPlant), this anatomic relationship can be predictably determined before surgery. After the scan is completed with the radiopaque template, the data must be converted into a format that can be used by the scanning software. Every treatment-planning software program has its own specific protocol, but all software is compatible with DICOM (digital imaging and communication in medicine) files that are generated and downloaded from the scanner. Although third-party vendors have integrated a interactive treatment planning for the placement of the implants, it is highly recommended that the implant dentist be involved in this planning process.

After the files have been converted into the software program, evaluation of potential implant sites in the desired prosthetic locations can be completed. Virtual implants may be placed via comprehensive implant libraries, which include the implant brand, type, diameter, and length. The available bone dimensions may be ascertained along with the density and angulation with respect to the planned prosthesis. After completion of the final implant positions, the treatment plan is saved, and the surgical template is designed.[20]

Complications.

Even though CBCT surgical templates are highly accurate, there are inherent errors that may occur when placing dental implants, which will result in malpositioning of the implants. Studies have shown that tooth-supported guides are the most accurate, followed by bone supported, with the least accurate being soft tissue–supported. This is mainly due to the questionable stability of the template during the CBCT scan and the implant placement with tissue supported templates. Bone-supported templates frequently result

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in malpositioning because of bony interferences and inability to seat the template completely. Soft-tissue templates result in errors because of nonuniform tissue thickness and incorrect positioning because of decreased retention. Studies have shown implant placement after virtual planning of implant position using cone beam CT data and surgical templates is significantly more accurate than free-hand insertion.[26] With all types of guides the implant clinician must show good judgment as to the accuracy of the template and must be able to determine any discrepancies (especially in bone volume) between the intended osteotomy site and the actual current bony architecture of the patient.

Summary

One of the most critical skills in the practice of implant dentistry is the ability to place an implant in the ideal and correct position. The complexity of this skill set is underrated, as the clinician needs to understand the three planes of placement along with maintaining a safe distance from vital structures. Malpositioning may result in a successful integration of the implant, but may place the intended restoration at significant risk for complication and/or failure. Technological advances such as guided surgery and surgical templates have proven to be helpful to implant clinicians, especially those early on their surgical learning curve or in cases where space tolerances are low. However, even these techniques have margins of error and tolerances that need to be fully understood.

With a combination of proper treatment planning and ideal positioning guidelines (Table 6.2), the implant clinician can ensure a predictable surgical and prosthetic outcome.

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TABLE 6.2
Ideal Distances and Positional Measurements

Distances	
Implant–tooth	>1.5–2.0 mm
Implant–implant	3.0 mm
Crown height space	>8 mm (cementable prosthesis)
Interocclusal distance	~15 mm (removable prosthesis)
Mandibular nerve	>2.0 mm
Nasal cavity	< engaging cortical plate
Maxillary sinus	Misch SA Classification
Bone Thickness: (After Implant Placement)	
Buccal	>1.5 mm
Lingual	>0.5 mm
Positioning	
Anterior	
Cement-retained	Slightly lingual to incisal edge
Screw-retained	Cingulum area
Posterior	
Cement/Screw-retained	Central fossa
Apicocoronal	2–3 mm below free gingival margin

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Intraoperative Complications

Bleeding

Randolph R. Resnik

During dental implant and bone graft procedures, persistent minor bleeding is a common sequela. However, on occasion a significant bleeding episode may occur. The most common sources of intraoperative bleeding include incision into highly vascularized areas of the mucosa or periosteum, anatomic vascular variants, areas of infection, and trauma to nutrient arteries in the alveolar bone. The implant clinician must be able to identify and understand the source of the bleeding, which may occur from many different types of bleeding episodes. These include hemorrhage from small vessels, large vessels, oozing, medication-induced bleeding, or coagulopathies.

The management of hemostasis during dental implant surgery has many key factors, the first of which is an accurate preoperative assessment of the patient followed by good surgical technique. If a bleeding episode occurs, the implant clinician must be able to utilize various hemostatic agents if traditional methods fail. These agents may range from absorbable hemostats, such as gelatins and collagens, to biologically active topical hemostats, such as thrombin and combined agents. However, the implant clinician must first have a thorough understanding of all aspects of hemostasis cycle. With this knowledge the clinician will be in a better position to avoid bleeding episodes and more importantly, will also have the ability to act decisively and skillfully during a potential “slippery slope” and scenario with significant medical implications. It is not always possible to avoid bleeding complications, but it is of paramount importance to be able to treat them effectively.

Risk of Bleeding

Bleeding during dental implant surgery poses many potential complications for the patient and the dental implant surgeon. These include an obscured surgical field, prolonged surgical time, increased the risk of physiologic

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complications, and increased procedural morbidity (Fig. 7.1). Surgical bleeding may be classified in various ways according to the source or onset (Box 7.1).

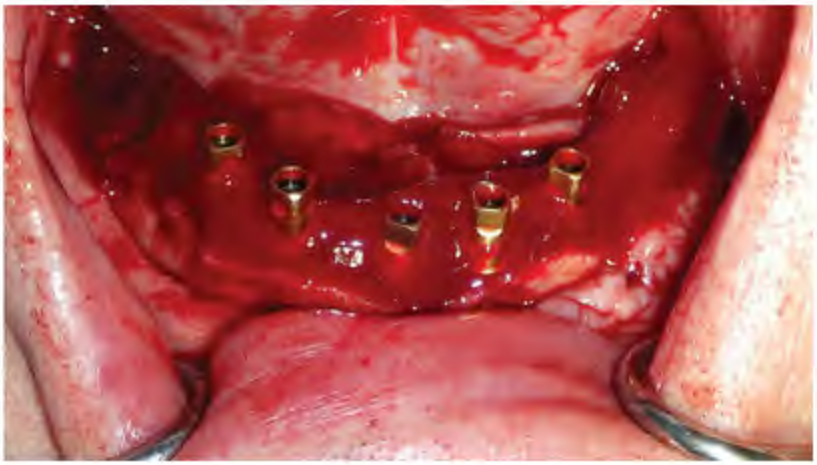

FIG 7.1 Extensive bleeding during dental implant surgery may cause many complications that lead to surgical and implant morbidity.

Box 7.1

Classification of Surgical Hemorrage

Bleeding According to Source

Arterial hemorrhage: bright red, spurting/pulsatile

Venous hemorrhage: dark red, continuous

Capillary hemorrhage: bright red, continuous

Bleeding According to Onset

Primary hemorrhage: This type of bleeding occurs during surgery and is usually the result of the incision, retraction, or preparation of the soft or hard tissue. It is usually controlled with conventional mechanical methods or with local hemostatic agents.

Reactionary hemorrhage: This type of bleeding usually will occur within hours after surgery. Reactionary hemorrhage most likely occurs in patients who

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exhibit systemic bleeding issues, are on anticoagulant therapy, or experience postoperative trauma to the surgical area that disturbs the clot. Additionally, reactionary bleeding may also occur up to 24 hours after surgery, which is most likely the result of complete arterial sectioning causing vasospasm. The vasospasm, coupled with the use of vasoconstrictors, may delay bleeding for hours in the postoperative period.

Secondary hemorrhage: This type of bleeding occurs 7–10 days after surgery and is most likely the result of an infection. Secondary hemorrhage is very rare with dental implant procedures.

Mechanism of Hemostasis

Understanding the mechanism of hemostasis is crucial to the surgical treatment of the dental implant patient. Hemostasis is defined as a highly regulated process that maintains blood flow through the vasculature simultaneously as a thrombotic response to the tissue damage.[2] Biologically, hemostasis requires a complex cascade of interactions involving the vessel wall, platelets, and fibrin coagulation and fibrinolytic systems. For this to occur, there are three reactions—primary, secondary, and tertiary—that act simultaneously (Fig. 7.2).

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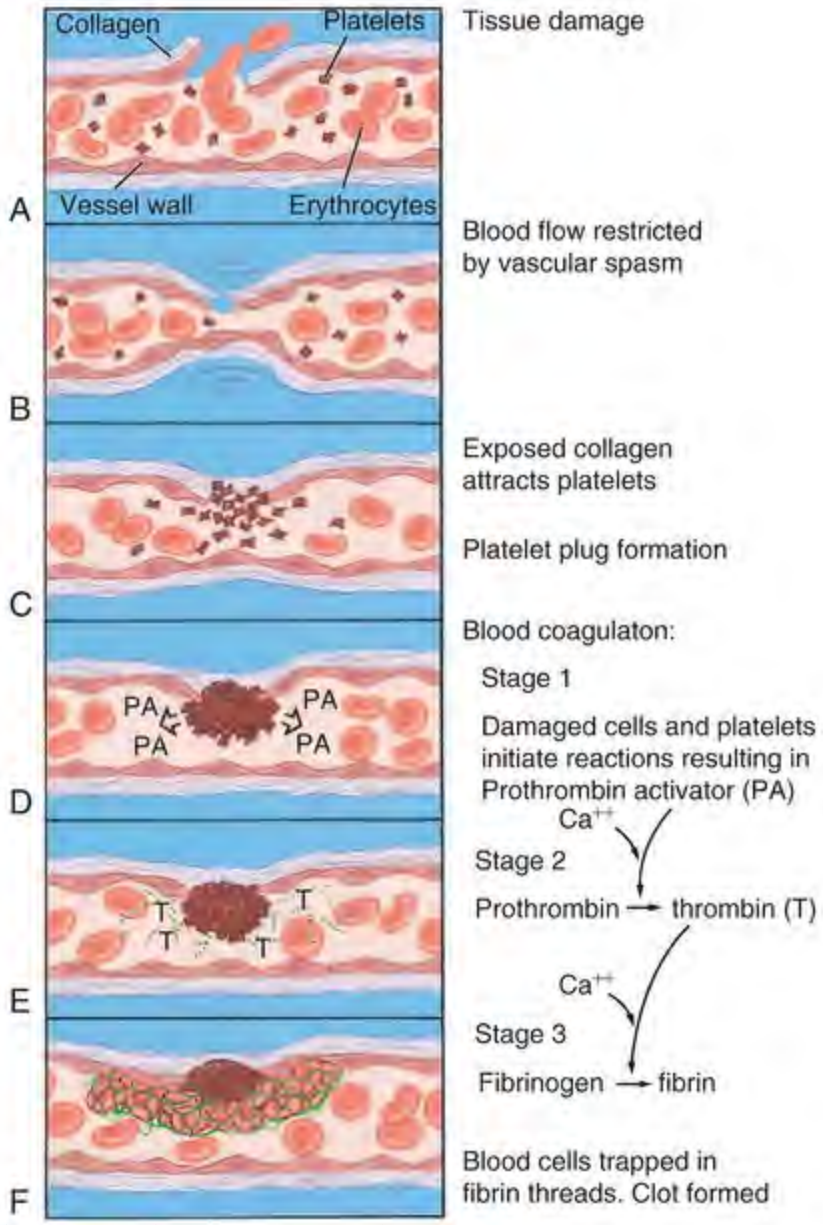

FIG 7.2 Summary of hemostasis. (A-C) Primary hemostasis: vascular and platelet activity. (C-D) Secondary hemostasis: blood coagulation phase. (E) Tertiary hemostasis: fibrinolysis. (From Applegate E: *The anatomy and physiology learning system*, ed 4, St Louis, 2011, Saunders.)

Vascular and Platelet Activity (Primary Hemostasis).

The first phase of hemostasis occurs immediately after blood vessel damage as a result of vasoconstriction. This reduces blood flow, limits the amount of blood loss, enhances platelet adherence, and activates coagulation.[3] Vasoconstriction is triggered by direct injury to vascular smooth muscle, chemicals released by endothelial cells and platelets, and reflexes initiated by pain receptors. This spasm response becomes greater as injury increases and

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is more effective on smaller blood vessels.[4] Mechanical blockage occurs by platelets adhering to exposed collagen (platelet adhesion), which release cytokines (serotonin, thromboxane A2, and endothelin[1]) into the area of tissue injury.[3] This plug formation is activated by von Willebrand factor (vWF), a glycoprotein found in plasma. The platelets forming the plug will release chemical messengers such as adenosine diphosphate (ADP), fibronectin, thrombospondin, fibrinogen and PDGF, which causes more platelets to aggregate and enhance vascular spasms.[5] As more platelets adhere and release their chemicals, a positive feedback loop results, which ends in the formation of a platelet plug. Drugs that affect primary hemostasis include aspirin and clopidogrel, which affect platelet function and prevent thrombosis.

Blood Coagulation (Secondary Hemostasis).

The second step in the process of hemostasis occurs when the clotting factors within the blood plasma form a collagen fiber called *fibrin*. This fibrin forms a mesh, collecting red and white blood cells that strengthen the clot, which is termed the *coagulation cascade*.[6] The coagulation cascade is divided into three pathways, the intrinsic pathway, extrinsic pathway, and coagulation cascade.

The intrinsic pathway (contact activation pathway) requires clotting factors VII, IX, X, XI, and XII as well as proteins and calcium ions and phospholipids secreted by platelets. This pathway has a less significant effect on hemostasis in comparisons to the extrinsic pathway under normal physiologic conditions.

The extrinsic pathway (tissue factor pathway) is the main pathway that generates a “thrombin burst,” which involves a feedback activation role where thrombin is released rapidly. Thrombin activates factors V and VII, which in turn activate other factors to continue the coagulation process.

Common pathway involves factor X generation of thrombin from prothrombin. Thrombin then activates factors XI and VIII, which amplify the coagulation cascade, releasing more thrombin. Thrombin then causes fibrinogen to form, which results in cross-linked fibrin. Drugs that effect secondary hemostasis include warfarin, the direct thrombin inhibitors, and heparin[5,7] (Fig. 7.3).

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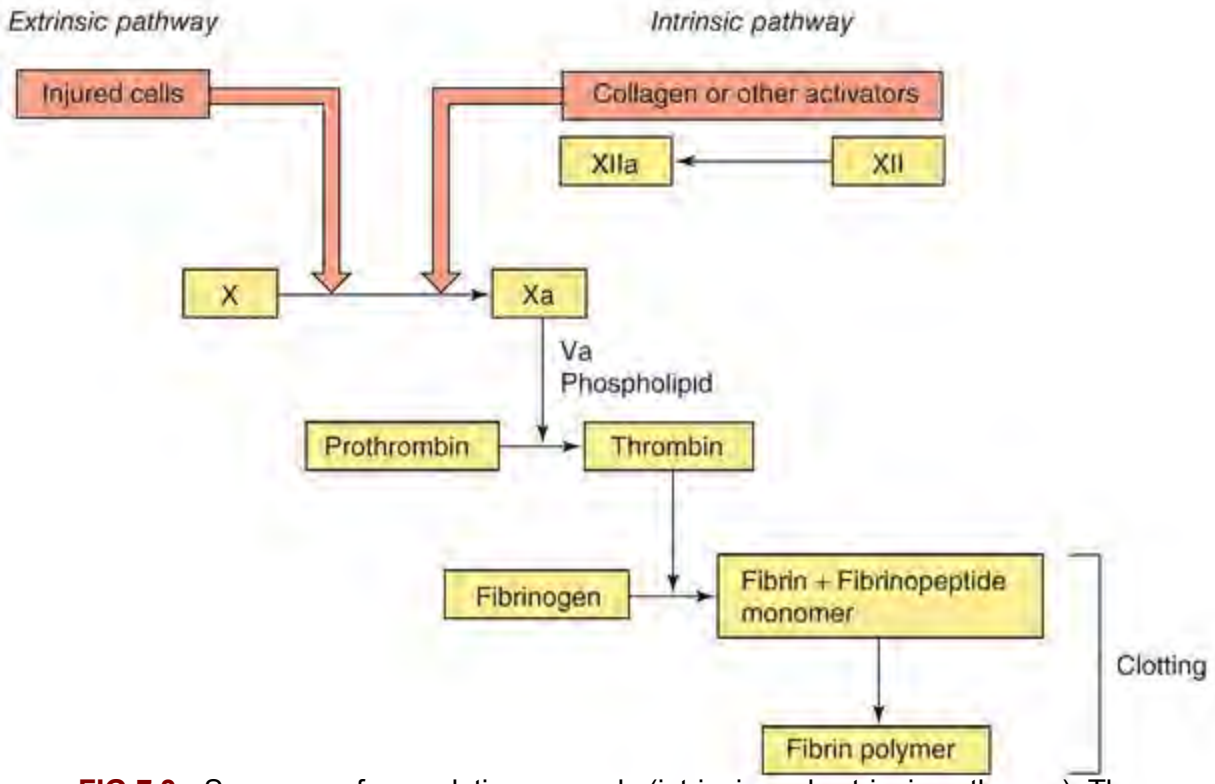

FIG 7.3 Summary of coagulation cascade (intrinsic and extrinsic pathways). The coagulation process results in hemostasis which involves a complex set of reactions. These reactions end by converting fibrinogen into insoluble strands of fibrin which form a stable clot. (From Huether S, McCance K: *Understanding pathophysiology,* ed 5, St Louis, 2012, Mosby.)

Fibrinolysis (Tertiary Hemostasis).

The last phase of hemostasis involves the formation of plasmin from plasminogen. Plasmin lyses fibrinogen and fibrin. This releases fibrin degradation products, which are cleared by the kidney and liver. Thus the fibrin clot, the final product of coagulation, is broken down (fibrinolysis). A drug that inhibits the tertiary hemostasis is tranexamic acid.[8]

Factors Contributing to Intraoperative Bleeding

Many factors may contribute to intraoperative bleeding. The incidence of bleeding episodes during dental surgery has been shown to be up to 4% of patients exhibiting normal hemostasis. In chronically anticoagulated patients, studies have shown bleeding episodes to be in the range of 8.6% to 32.1%.[9] Although rare, bleeding during dental implant surgery may be life threatening. The implant clinician must be conscious of the signs and symptoms of a potential bleeding emergency. If the patient displays any

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signs of shock (tachycardia, hypotension, cold/clammy skin, lethargy), immediate medical assistance is recommended along with immediate intravenous fluid replacement to replenish the intravascular volume and reestablish tissue perfusion.

The first step in preventing bleeding issues is with the medical history (see Chapter 2). A thorough review of the medical history may alert the clinician to many factors that may ultimately potentiate intraoperative bleeding. A detailed medical history screening should evaluate current and past systemic disorders, medication list, and history of past bleeding episodes.

Medications

Anticoagulants.

The most common class of medications that predispose patients to bleeding problems is the anticoagulants. These may include Coumadin derivatives, antiplatelets, direct thrombin inhibitors, and herbal supplements. In most cases of Coumadin-based medications, discontinuation is not recommended for routine dental implant procedures because local hemostatic measures are effective in managing hemorrhage. Stopping these medications may have deleterious effects and have a greater chance of creating complications for the patient. The patient's physician should always be consulted and the implant clinician should NEVER unilaterally cease or modify any medication that was prescribed by a physician (Table 7.1).

TABLE 7.1

Common Anticoagulants[54]

	Coumadin (warfarin)	Pradaxa (dabigatran)	Xarelto (rivaroxaban)	Eliquis (apixapan)
Mode of action	Four vitamin K–dependent factors	Thrombin-fibrin clot	Factor Xa–fibrin clot	Factor Xa–fibrin clot
Testing	Requires regular blood tests (PT/INR)	None	None	None
Diet restrictions	Many diet restrictions	None	None	None
DOSE (daily)	Varies according to PT/INR	75–150 mg twice/day	10–15 mg	2.5–5 mg twice/day
Elimination half-life	20–60 hr	12–17 hr	5–13 hr	6–12 hr
Reversal agent	Vitamin K plasma	None	None	None
Modification for implant surgery	Not recommended	MD consult; usually discontinuation	MD consult; usually discontinuation	MD consult; usually discontinuation

INR, international normalized ratio; *PT,* prothrombin time.

Novel Oral Anticoagulant (NOACs).

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Because of the disadvantages of Coumadin-based medications, new anticoagulant drugs have recently come to the market without the associated disadvantages of warfarin. The direct thrombin inhibitors have a wide therapeutic index, less complex pharmacodynamics, fewer drug and food interactions, and a very predictable response that makes routine blood testing unnecessary.[10] These targeted anticoagulants bind directly to thrombin and block the interaction with its substrates. Unfortunately, there is no reversal agent or antidote for these drugs to counteract the anticoagulant effect at this time, which may lead to serious issues when uncontrolled bleeding occurs (Table 7.2).

TABLE 7.2

Medications That Increase Bleeding[7]

Medication	Effect on Bleeding
Alcohol	Warfarin enhanced by large amounts of alcohol
Analgesics	Bleeding enhanced by aspirin effect on platelets
Antibacterials	Warfarin enhanced by cephalosporins, erythromycin and metronidazole. Ampicillin and amoxicillin may increase bleeding
Antifungals	Warfarin enhanced by azoles, including miconazole topically
Antiinflammatories	Bleeding enhanced by antiplatelet activity of NSAIDs; warfarin may also be enhanced. Corticosteroids may alter warfarin activity

NSAID, nonsteroidal antiinflammatory drug.

Antiplatelet Medications.

Antiplatelet medications affect clotting by inhibiting platelet aggregation; however, this occurs by many different mechanisms. Aspirin irreversibly acetylates cyclooxygenase, thus inhibiting the production of thromboxane A_2, and clopidogrel (Plavix) selectively inhibits ADP. Thus both have the end result of reducing platelet aggregation. Both of these drugs will affect the platelet function for the life of a platelet, which is 7–10 days. The synthesis of new platelets will overcome the platelet dysfunction, and in 50% to 80% of cases, platelet aggregation returns to normal (Table 7.3).[11]

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TABLE 7.3

Medications That Impair Platelet Function[7]

Class	Medication
Alcohol	
Analgesics and other platelet inhibitors	Aspirin and other NSAIDs Clopidogrel
Antibiotics	Amoxicillin Ampicillin and derivatives Azithromycin Benzylpenicillin (penicillin G) Carbenicillin Cephalosporins Gentamicin Methicillin Rifampicin Sulphonamides Trimethoprim
Antidiabetics	Tolbutamide
Cardiovascular drugs	Digitoxin Heparin Methyldopa Oxprenolol Quinine
Cytoxic drugs	Many
Diuretics	Acetazolamide Chlorothiazide Furosemide
General anesthetic agents	Halothane
Psychoactive drugs	Antihistamines (some) Chlorpromazine Diazepam Haloperidol Tricyclic antidepressants Valproate
NSAIDs	Celecoxib (Celebrex) Diclofenac (Voltaren Cataflam) Diflunisal (Dolobid) Etodolac (Lodine) Fenoprofen (Nalfon) Ibuprofen (Motrin, Advil, Nuprin) Indomethacin (Indocin) Ketoprofen (Orudis, Actron) Ketorolac (Toradol) Meloxicam (Mobic) Nabumetone (Relafen) Naproxen (Naprosyn, Aleve) Oxaprozin (Daypro) Piroxicam (Feldene) Sulindac (Clinoril)

NSAID, nonsteroidal antiinflammatory drug.

The combination of aspirin and clopidogrel produces additive and possible synergistic effects because the two medications block complementary pathways in the platelet aggregation cascade. Rarely will physicians allow the complete withdrawal of both of these medications as the cardioprotective benefits outweigh the potential for bleeding episodes in at-risk patients with cardiovascular disease.

Nonsteroidal Anti-Inflammatory Drugs (NSAIDs).

NSAIDs have a reversible effect on platelet aggregation, and platelet function is restored once the drug effects are gone. Minor dental implant surgical procedures can be safely performed without altering the NSAID dose.[12]

Herbal Supplements.

Herbal supplements studies have shown as many as 70% of patients do not reveal they are taking herbal supplements and 40% will take herbal supplements within 2 weeks of surgery.[13] Some herbal remedies are fairly safe and have been supported by sound medical research. Thus many PATIENTS believe that, because a medication is termed “natural,” it is safe. However, the majority of supplements have no research on their safety and efficacy action because of product variability and minimal regulation. This has led to many natural plant products on the market that are addictive and highly toxic and can complicate surgical procedures. Some of these supplements may prolong bleeding and impair the coagulation process, which may lead to intraoperative and postoperative bleeding episodes (Table 7.4). Supplements should be withdrawn for a minimum of 2 weeks prior to surgery.

TABLE 7.4

Herbal Supplements That Inhibit Hemostasis[7]

Herbal	Source
Bilberry	*Vaccinium myrtillus*
Bromelain	*Anas comosus*
Cat's claw	*Uncaria tomentosa*
Devil's claw	*Harpagophytum procumbens*
Dong quai	*Angelica sinensis*
Evening primrose	*Oenothera biennis*
Feverfew	*Tanacetum parthenium*
Garlic	*Allium sativum*
Ginger	*Zingiber officinale*
Ginkgo biloboa	*Ginkgo biloba*
Ginseng	*Panax ginseng*
Grape seed	*Vitis vinifera*
Green tea	*Camellia sinensis*
Horse chestnut	*Aesculus hippocastanum*
Turmeric	*Curcuma longa*

Systemic Bleeding Disorders

Factor Disorders.

Bleeding disorders may directly or indirectly affect the intrinsic or extrinsic pathways of the hemostasis process. The intrinsic pathway affects the activated partial thromboplastin time (aPTT) via factors VII, IX, XI, XII and the extrinsic pathway involves factor VII, which affects the prothrombin time (PT). Any of these intrinsic or extrinsic factors may affect the common pathway, which alters the formation of the fibrin clot. Usually laboratory tests such as partial thromboplastin time (PTT) and PT will reveal the factor deficiency.

Besides factor disorders, there are also congenital disorders that impact hemostasis. Hemophilia is a bleeding disorder that may be very minor or can be a more severe type leading to significant complications. Hemophilia can be classified into type A (Factor VIII) or type B (Factor IX). von Willebrand disease is an inherited disorder that results from the lack of von Willebrand factor, which is a protein within the blood that assists with blood clotting and carrying clotting factors.[11] With any type of systemic bleeding disorder, physician consultation is highly recommended (Box 7.2).

Box 7.2

Recommendations for Anticoagulant Patients

1. **MEDICATIONS (BASED ON PHYSICIAN RECOMMENDATION)**

- In most cases, do not interrupt thrombocyte aggregate inhibitors (e.g., aspirin, clopidogrel).
- Do not interrupt warfarin if INR <3.0.
- Physician consult for direct thrombin inhibitors (e.g., apixaban, dabigatran, and rivaroxaban). Physician consultation should be completed in writing.

2. **PRESURGICAL INTERVENTION**

- Inform patients of the entire procedure and not to interrupt any of their medications unless they receive physician approval.

- Warfarin patients should have their INR checked within 48 hours of the surgical procedure unless they have stable values. INR above 3.0 should be a relative contraindication to the surgical procedure requiring physician consultation.

3. **INTRAOPERATIVE MEASURES**

- Minimize surgical trauma and utilize good surgical technique.

- Reduce surgical time and minimize surgical sites to be treated (schedule into multiple surgeries).

- Good suturing technique to include primary closure with high–tensile strength suture (e.g., Vicryl).

- Minimize trauma on surgical site from prosthesis.

4. **POSTOPERATIVE RECOMMENDATIONS**

- Utilize pressure packs and hemostatic agents if necessary.

- Minimize the use of aspirin, NSAIDs, and COX-2

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inhibitors as analgesics.

- Provide detailed oral and written postoperative instructions.
- More frequent postoperative appointments.

COX-2, cyclooxygenase-2; *INR,* international normalized ratio; *NSAID,* nonsteroidal antiinflammatory drug.

Liver Disorders.

Liver disease (e.g., cirrhosis, acute liver failure) is associated with many significant abnormalities of the coagulation system. The coagulation system and the interrelationship with liver function is very complex. Because most patients exhibiting liver disease have impaired production of coagulation factors and thrombocytopenia, medical consultation before any dental implant procedure is recommended.

Evaluation of the Coagulation Process

Laboratory Tests

There are many tests of the coagulation system that determine the susceptibility of the patient to a bleeding episode during or after dental implant surgery.

Prothrombin Time (PT)

The PT test is performed routinely for many patients prior to surgery or to monitor the effects of the anticoagulant warfarin (Coumadin). Basically, this test of the extrinsic pathway measures the time it takes for the patient's plasma to form fibrin. Usually, the patient's warfarin dose will be altered depending on PT times. The prothrombin time reference range will depend on the analytical method used; however, it is usually 12-13 seconds. The results should always be interpreted using the reference range from the laboratory.

International Normalized Ratio (INR)

Because of the poor standardization of the prothrombin time, a wide variation in values obtained by laboratories resulted in inconsistent test values. It has become a standard in most laboratories to perform a correction of the prothrombin time, or to “normalize” the result. This normalized test is called the INR (international normalized ratio), and it is much more accurate in the assessment of a patient's bleeding time. A normal INR is 1.0 %. However, in anticoagulated patients, the INR will be higher, usually within the therapeutic range of 2.0% to 3.5%. The target anticoagulation level differs for each patient because the anticoagulation will require different therapeutic INR levels. Prolonged INR and PT values are indicative of liver disease, warfarin treatment, or vitamin K deficiency.

Partial Thromboplastin Time (PTT)

The PTT test is usually performed for many patients prior to surgery and to monitor the effect of anticoagulation using heparin. The test measures the intrinsic pathway and factors V, VIII, IX, X, and XI. The formation of the blood clot requires the participation of a series of proteins, and deficiency of any of these will result in abnormal values. The test is expressed in seconds compared to the number of seconds it takes a control normal plasma sample

to clot. The most common causes of an abnormal PTT are a hereditary deficiency of Factor XI and von Willebrand disease. Ideally, the PTT value should be approximately 1.5 to 2.5 times the mean normal value.

Bleeding Time

The bleeding time test is a rather old method of determining platelet function. The Ivy method is the most common technique, which involves a superficial (less than 1 mm deep), small (1 cm long) cut made on the skin of the forearm using a special instrument. The time it takes for the cut to stop bleeding is a test of the function of the platelets. The normal value is usually less than 9½ minutes. A prolonged bleeding time is a result of decreased number of thrombocytes or impaired blood vessels.

Platelet Count

A platelet count is a test that calculates the number of platelets. Normally, the platelet count should be 100,000–400,000 cells/mm^3. Counts less than 100,000 mm^3 (thrombocytopenia) can be associated with significant intra- and postoperative bleeding.

The platelet is synthesized by the bone marrow and broken down by the spleen. Abnormalities that would cause a decreased number of platelets are either inherited or acquired, with acquired being rather rare.

Interuption of Anticoagulant Therapy[13a]

General Approach

With dental implant patients, interruption of anticoagulation temporarily increases thromboembolic risk. However, continuing the anticoagulation medication may increase the risk of bleeding episodes for the patient (depending on the procedure). The PHYSICIAN should be consulted and perioperative management of anticoagulation should be based on their recommendations. Unfortunately, most anticoagulation interruption approaches are based on expert opinion. Thrombotic and bleeding risks may vary depending on patient and procedure as data from randomized trials are not available to generally guide practices. Most physicians will take the following factors in consideration prior to recommendation:

- **Estimate thromboembolic risk.** When a higher thromboembolic risk exists, the importance of minimizing the interval without anticoagulation is

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critical. Most patients being treated for atrial fibrillation, recommendations are based on age and comorbidities. If thromboembolic risk is transiently increased (e.g., recent stroke, recent pulmonary embolism), usually elective surgery is delayed until the risk returns to baseline. The most common issues that increase thromboembolic risk are atrial fibrillation, prosthetic heart valves, and recent venous or arterial thromboembolism (e.g., within the preceding three months).

- **Estimate bleeding risk.** When the procedure is classified as a higher bleeding risk, there is a greater need for perioperative hemostasis measures and a longer period of anticoagulant interruption. The risk of bleeding is usually determined by the type of surgery and invasiveness of the procedure. Patient comorbidities (e.g., older age, decreased renal function) and current medications that affect hemostasis should also be taken into consideration. Usually with dental implant surgery, bleeding risk is most likely to be classified as "low risk."
- **Determine the timing of anticoagulant interruption.** The timing of anticoagulant interruption depends on the specific anticoagulant the patient is receiving. For example, warfarin and aspirin usually requires earlier discontinuation than the shorter-acting direct oral anticoagulants (e.g., dabigatran, rivaroxaban, apixaban, edoxaban).

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Techniques to Decrease and Control Bleeding

The need to control gross bleeding is paramount for successful surgery because insidious and continuous loss of blood from arteries, veins, or capillaries can become significant if bleeding is not controlled. Dental implant clinicians have numerous options for maintaining hemostasis, which include mechanical, thermal, pharmacologic, and topical agents.

Mechanical Methods

The most common primary mechanical method to control bleeding is to apply direct pressure or compression on the bleeding site along with repositioning the patient. Secondary mechanical methods include suturing, clamping the blood vessel with hemostats, and ligating the bleeding vessel with suture material.

Positional Changes

When significant bleeding occurs, maintaining the patient in a supine position is not recommended because of increased bleeding (head below the heart). Hydrostatic pressure occurs within the vascular system because of the weight of the blood vessels and is dependent on gravity. The pressure is decreased in any vessel above the heart and increased in blood vessels below the heart. Studies have shown that in an upright position, the average pressure at the level of the heart is 100 mm Hg. Vessels in the head and neck averaged 49 mm Hg and 186 mm Hg at the foot level.[14] Repositioning the patient to an upright position (head above the heart) will not stop the bleeding; however, it will significantly decrease the hemorrhage (studies have shown a decrease up to 38%) (Fig. 7.4).[15]

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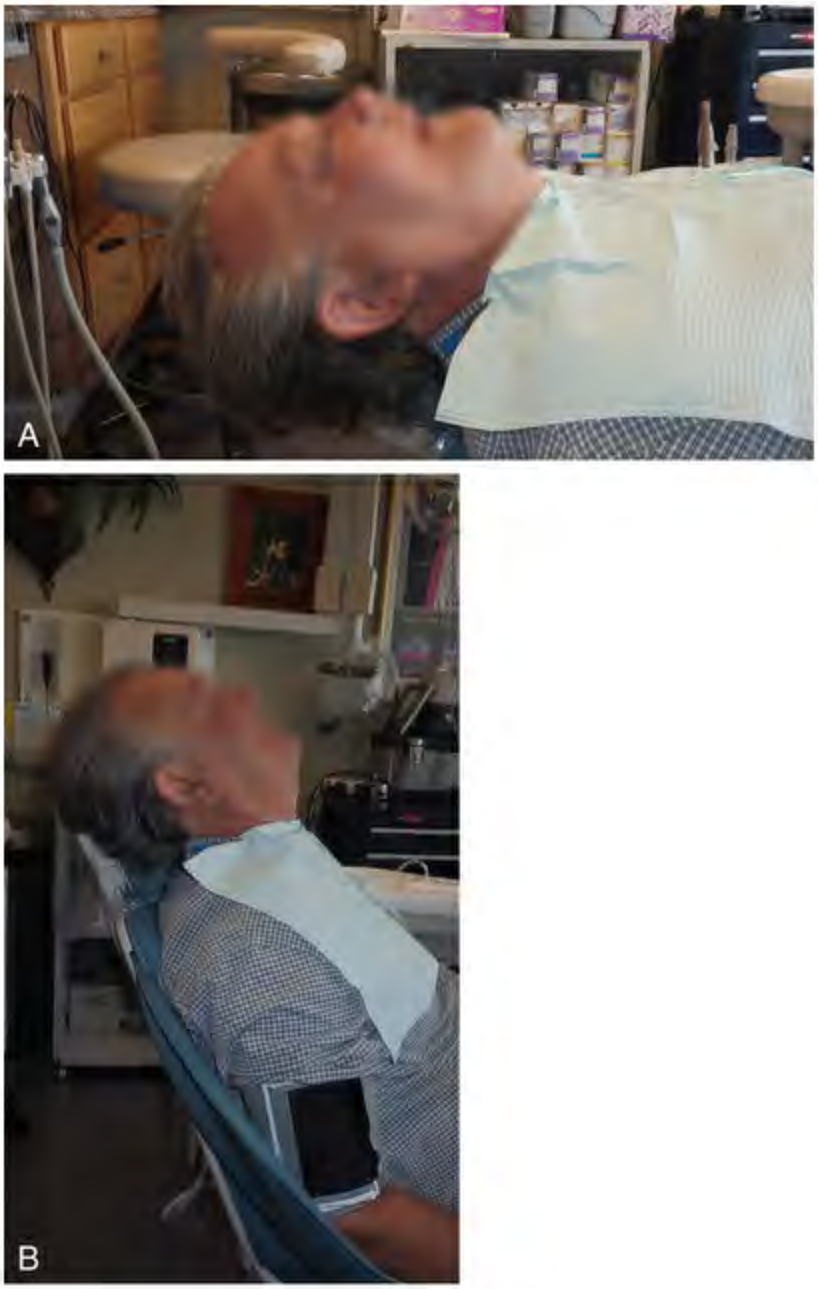

FIG 7.4 Repositioning a patient to decrease bleeding. (A) Supine position results in increased bleeding. (B) Upright position leads to less bleeding and anxiety for the patient.

Direct Pressure

If significant intraoperative bleeding occurs, the ideal treatment should involve immediate application of pressure to the surgical site. Pressure or compression directly on the blood vessel will allow for platelet aggregation and initiation of the coagulation cascade. Pressure may be applied manually or by the patient biting forcefully on a gauze dressing. Pressure should be maintained for at least 3 to 5 minutes to allow the formation of a blood clot.

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Caution should be exercised to not remove the gauze too early because this may dislodge the clot. Ideally, 3 × 3 or 4 × 4 gauze should be utilized because 2 × 2 gauze may be accidentally aspirated. In primary bleeding, pressure is the simplest and fastest method to control bleeding prior to the use of hemostatic measures.

Suturing

Suturing plays a significant role not only in obtaining primary closure for ideal healing but also for maintaining hemostasis (direct vs. indirect). Direct placement of a suture (ligation) is used when there is access to a deep bleeding vessel. The suture is placed by entering the tissue at least 4 mm from the bleeding vessel, 3 mm below the vessel, and 4 mm exiting the tissue. This will ligate or occlude the vessel as long as it is placed proximal to the bleeding area. A figure-eight suture technique is ideally utilized (Fig. 7.5A).

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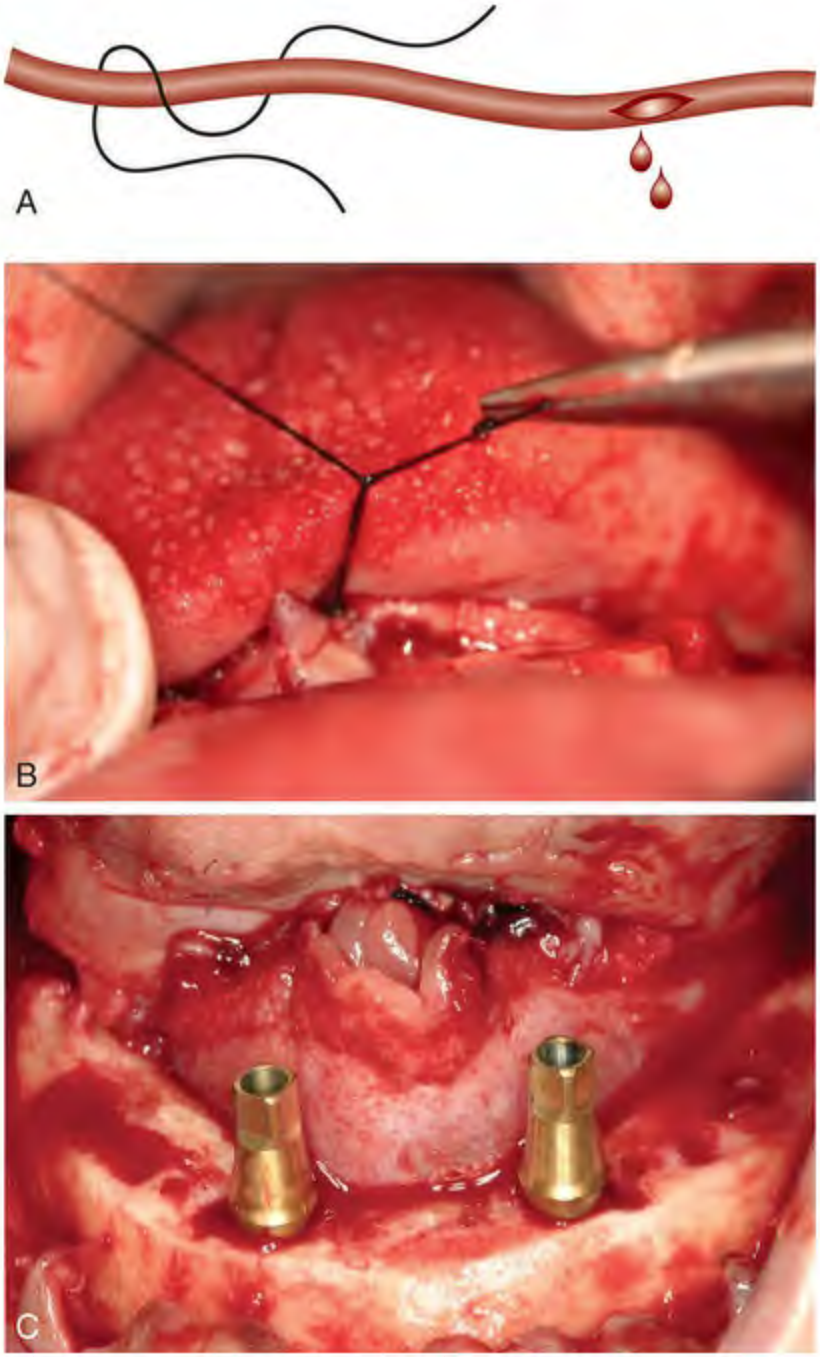

FIG 7.5 Suturing. (A) Direct ligation with figure-eight suturing technique. (B–C) Indirect tie-back of the mandibular lingual tissue from cuspid-molar contralaterally, which decreases bleeding, allows for ease of retraction, and prevents tissue trauma.

Indirect suture placement is utilized to retract the tissue and minimize bleeding via pressure from the accumulated tissue. This is most often used as tie-backs when reflecting an edentulous mandible (cuspid to molar bilaterally). And lastly, good suturing technique is paramount for preventing reactionary bleeding after surgery. Ideally, interrupted or mattress sutures should be placed in conjunction with continuous sutures to maintain closure.

A suture material that exhibits high tensile strength is recommended, such as polyglycolic acid (e.g., Vicryl) (Fig. 7.5B–C). The interim prosthesis should be modified to have no direct pressure on the wound site and this may dislodge the sutures.

Clamped Vessel With Hemostat Forceps

When local measures are not successful in controlling bleeding, a hemostat may be utilized to clamp the blood vessel. Usually a curved Kelly hemostat may be used to clamp the vessel to control the bleeding via two mechanisms:

1. Occluding the vessel and damaging the blood vessels wall to stimulate clotting. This clamping pressure should be maintained for approximately 2–3 minutes, which will usually allow for hemostasis. However, this method may be unreliable because the clot may become dislodged and postoperative bleeding may occur after removal of the hemostat.

2. A more successful technique in controlling bleeding is to use fine-pointed hemostats (Kelly hemostats) and ligate the bleeding vessel with suture material. The vessel should be clamped to obtain immediate hemostasis with the tip of the hemostat extending beyond the vessel. A clamped vessel may be ligated with suture material such as an absorbable suture with high tensile strength (e.g., Vicryl). A tie should be placed around the hemostat, extending to the vessel. The hemostats are then removed, and two additional throws are made with the suture. Usually, bleeding from vessels of 2 mm or greater diameter should be ligated. Direct ligation of the bleeding blood vessel is usually the most effective technique in stopping arterial blood flow. However, exposure and identification may sometimes be extremely difficult (Fig. 7.6).

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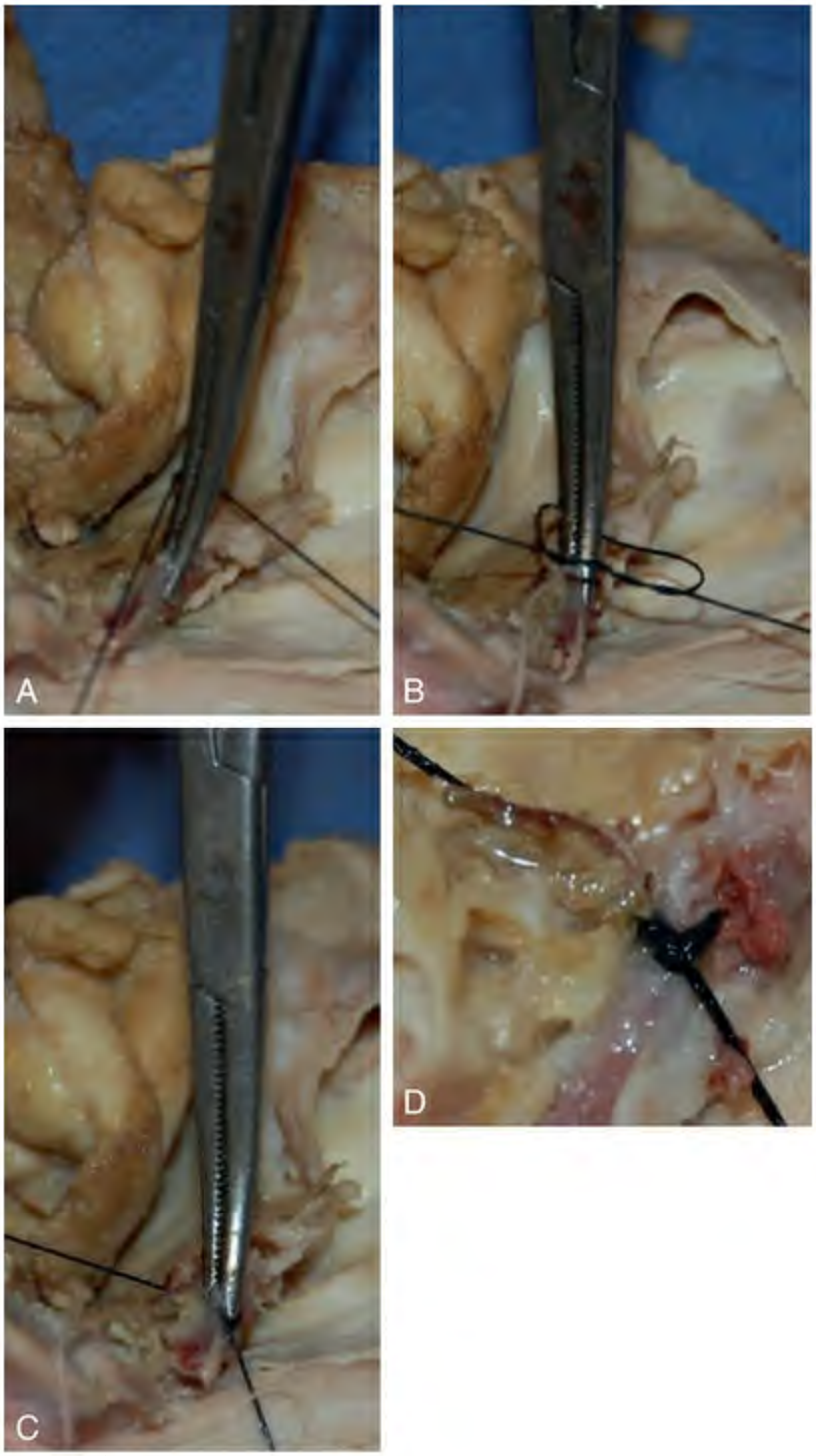

FIG 7.6 Ligation from a clamped vessel. (A) When a bleeding vessel is identified, a Kelly hemostat is used to clamp the vessel. A suture (preferably Vicryl) is placed around the hemostats. (B) A knot is tied around the hemostat and slid to the end of the hemostat tips. (C) The suture is tightened. (D) the hemostats are removed and two more throws may be added to the original knot.

Thermal Techniques

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The use of electrosurgery or lasers to reduce bleeding is a common alternative technique to mechanical methods. However, thermal techniques do have drawbacks, such as episodes where bleeding is present in deeper tissue with limited access or from multiple capillaries, in which maintaining hemostasis may be very difficult.

Electrocautery

Electrocauterization, developed in the 1930s, has been one of the most common hemostatic techniques because of its low cost, accessibility, ease of use, and effectiveness. Electrocautery is the process of destroying tissue using heat conduction with a probe that is heated by an electric current. Different procedures may be completed with the use of high–radio frequency alternating current for cutting, coagulating, and vaporizing tissues. Electrocautery is most effective on small vessels and may be utilized in two modes: monopolar and bipolar (Fig. 7.7).

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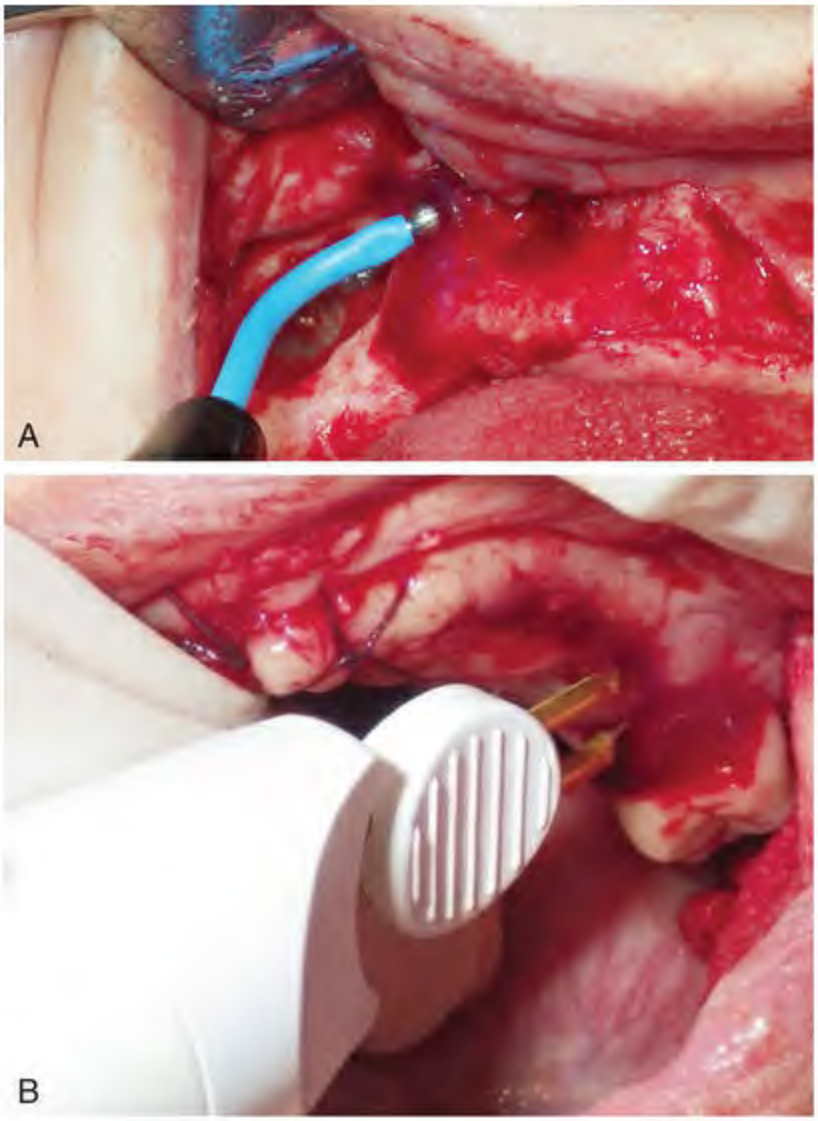

FIG 7.7 Electrocautery. (A) Monopolar electrocautery, which utilizes current to establish hemostasis. A ball electrode is the most common to be used; however, access is sometimes difficult. (B) A battery-operated disposable cautery unit that does not use current, however generates heat to ligate the blood vessel.

Monopolar electrosurgery delivers current using different types of waveforms (i.e., modes). The coagulation mode utilizes an interrupted waveform, which generates heat, thereby coagulating a cell, a phenomenon also termed *fulguration*. The cutting mode is low energy, which produces a cutting effect to vaporize tissue with minimal hemostasis. The blend mode simultaneously cuts tissue and coagulates bleeding. This technique is often difficult to use in implant surgery because access and a relatively dry field is needed to cauterize the vessel. A dry field is needed for the effective electrical current to pass through the tissues. A high-speed plastic, not metal, suction tip should be used to maintain a dry field.

Buzzing the Hemostat: (Electrocautery + Hemostat Ligation)

Usually on larger vessels, the combination of a clamped vessel (with curved hemostat) and electrocautery will allow for the cauterizing of the blood vessel, thus stopping blood flow in the vessel. The protocol is as follows:

1. Use the lowest possible setting to achieve the desired effect.

2. Use the CUT mode, not the COAG mode. COAG has a higher peak-to-peak voltage and is more prone to alternate (small) current pathways.

3. After clamping the vessel, touch the active electrode to the hemostat closer to the patient (below the hand holding the hemostat) and then activate the electrode. This minimizes sparking and the subsequent demodulation of current while encouraging a path of least resistance.

Note: Care should be exercised because the implant clinician may receive burns or be shocked even when wearing protective gloves. When the surgeon clamps a bleeding vessel and the electrode is touched to the hemostat, the tissue between the clamped hemostat is coagulated. The “buzzing” may cause high-voltage breakdown of the surgeon's glove, leading to a burn. To minimize this possibility the surgeon's glove should be changed if wet because hydrated gloves show a lower resistance. Additionally, the electrode should be placed in contact with the hemostat prior to activation of the electrosurgical current to minimize the production of a spark (Fig. 7.8).

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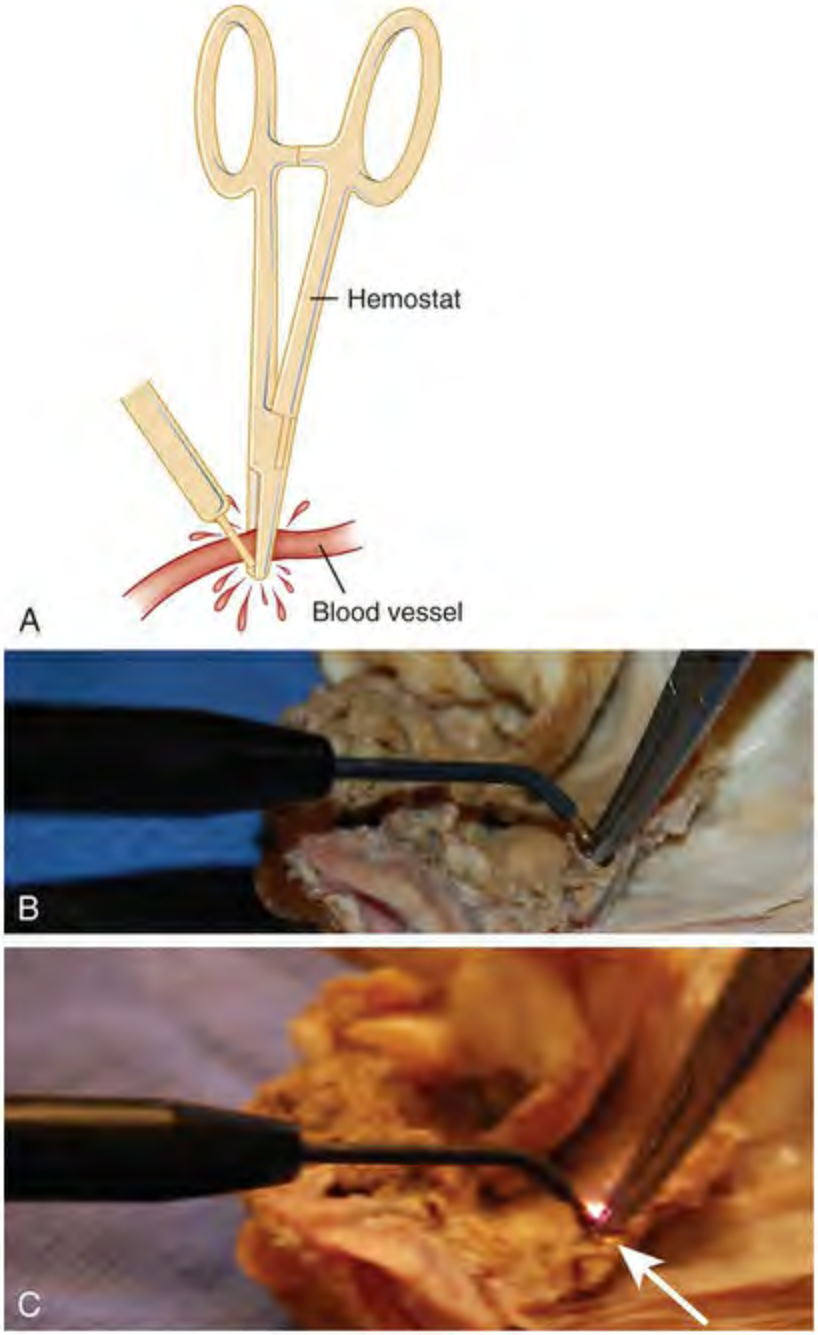

FIG 7.8 (A–C) "Buzzing the hemostat" usually used for larger vessel ligation (arterial). The vessel is clamped with the hemostat and the electrocautery unit is placed on CUT mode and lightly touches the hemostat. A spark will usually result *(arrow)*. Prior to its use, supplemental oxygen (nasal cannula) should be discontinued to prevent a patient fire.

Lasers

Lasers, which are gaining popularity as a tool in dental surgery, may also be used to achieve hemostasis. Laser is an acronym for "light amplification by stimulated emission of radiation," which produces laser light energy. Laser

energy delivered to an area of bleeding may be reflected, scattered, transmitted, or absorbed. The extent of the tissue reaction depends on the laser wavelength, power settings, spot size, and length of contact time with the bleeding area. Lasers have been shown to be a safe or useful modality in treating dental surgery patients with bleeding disorders.[16]

Pharmacologic Techniques

Although pharmacologic techniques may be utilized in implant dentistry to control bleeding, the success of maintaining hemostasis is questionable, with varying results.

Epinephrine

Epinephrine may be used to enhance hemostasis in combination with local anesthesia (e.g., 2% Lidocaine $1/100{,}000$ epi or $1/50{,}000$ epi). When locally placed, epinephrine will reduce bleeding, slow the absorption of the local anesthetic, and prolong the anesthetic and analgesic effect. The hemostatic properties are related to platelet aggregation, which leads to a decrease in the adenoreceptors within the vessel walls, thus producing vasoconstriction. However, rebound hyperemia may result postoperatively, which will increase bleeding. Various studies have shown that topical application of 1/100,000 concentration of epinephrine creates vasoconstriction and controls hemostasis with sinus graft procedures with no appreciable changes in systemic hemodynamics (Fig. 7.9).[17]

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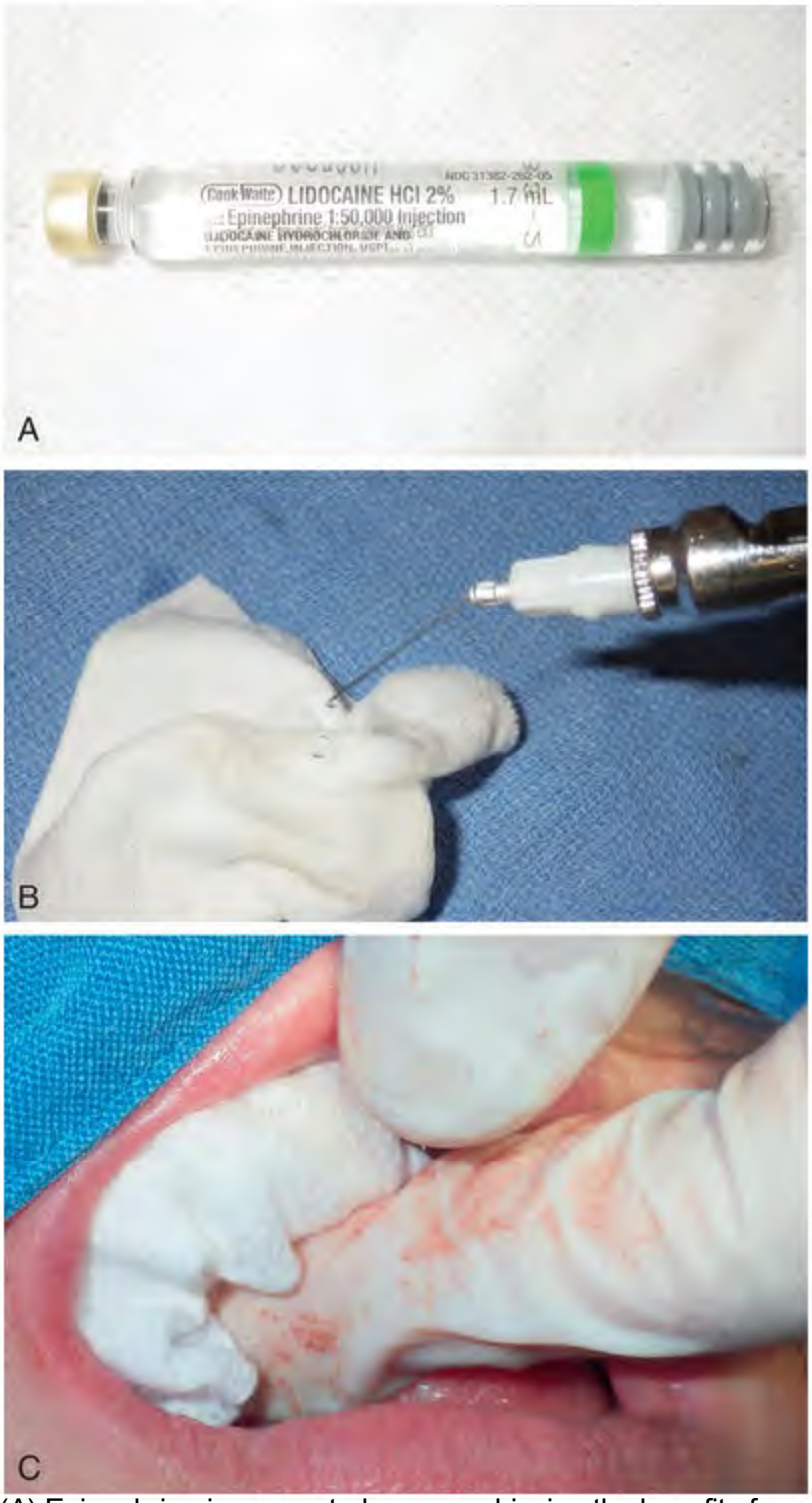

FIG 7.9 (A) Epinephrine-impregnated gauze achieving the benefit of pressure and vasoconstriction. Lidocaine 2% 1/50,000 epinephrine is ideally used because of its greater vasoconstrictive properties. (B) Gauze impregnated with lidocaine, which may be used as a pressure dressing to decrease bleeding. (C) Epinephrine gauze placed over wound site with constant pressure.

Tranexamic Acid Solution

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Tranexamic acid 4.8% is an antifibrinolytic oral rinse that facilitates clot formation by inhibiting the activation of plasminogen to plasmin. Plasmin prevents the clotting process from initiating fibrinolysis. Tranexamic acid solution may be used as a mouthwash postoperatively and has been shown to enhance clotting in patients with coagulopathies or anticoagulant therapy. Ramstrom et al showed a significant reduction in postoperative bleeding with a 10-mL rinse, four times a day for 7 days postoperatively.[18] Choi et al showed a significant decrease in bleeding during maxillary surgery after a bolus of tranexamic acid was given preoperatively (Fig. 7.10).[19]

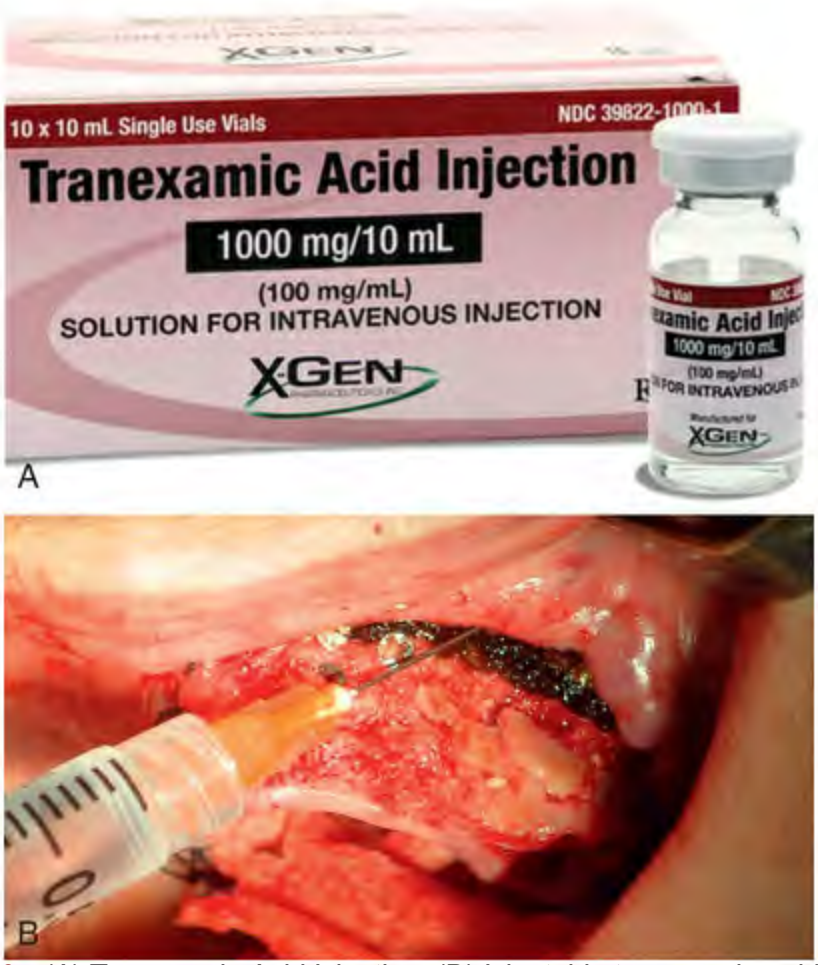

FIG 7.10 (A) Tranexamic Acid Injection. (B) Injectable tranexamic acid placed under bleeding flap. (A, Courtesy X-GEN Pharmaceuticals, Inc., Horseheads, NY.)

Topical Hemostatic Agents

Absorbable topical hemostatic agents are used when conventional methods of hemostasis are ineffective. These agents may be placed directly into the

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bleeding site to decrease bleeding during the procedure or during the postoperative interval. These agents work either mechanically or by augmenting the coagulation cascade. The topical hemostatic agents have the added benefit of minimizing the possibility of systemic blood clots, which are drawbacks of systemic hemostatic agents.[20] There are two types: active and passive (Table 7.5).

TABLE 7.5

Common Hemostatic Agents[55,11]

Type	Product	Advantages	Disadvantages
COLLAGEN Stimulates platelet adherence	OraTape, OraPlug (Salvin) Collatape, Collaplug (Zimmer)	Inexpensive, resorbs in 10–14 days, highly absorbent to many times its own weight	None
MICROCELLULAR COLLAGEN Provides meshwork for platelet adherence	Avitene (Davol) Helitene (Integra) Instat (Ethicon)	Good application for large surfaces, superior hemostasis to gelatin and cellulose	Difficult to handle, expensive
GELATIN Mechanical matrix that increases clotting, absorbs 40 times its weight, resorbs in 4–6 weeks	GelFoam (Baxter) Surgifoam (Ethicon)	Swelling after application results in tamponade effect, neutral pH	May cause tissue/neural damage due to compression from swelling. Possible dislodgement from bleeding site
CELLULOSE Provides a platform for platelet aggregation and activation with a low pH	Surgicel (Ethicon) Blood Stop (Salvin) Oxycel (Becton Dickinson) Actcel (Coreva Health Sciences)	Easy to handle, low pH provides antimicrobial coverage, expands 3–4 times its original size and converts to a gel	Possible foreign body reaction, low pH may lead to possible postoperative irritation, needs to be removed
THROMBIN Converts fibrinogen to fibrin, forming stable clots	Thrombin-JMI bovine (Pfizer) Evithrom-human (Ethicon) Recothrom-recombinant (ZymoGenetics)	Can be added to collagen products, very good for small vessel bleeding	Bovine has been shown to be immunogenic, leads to severe coagulopathy
THROMBIN + GELATIN Converts fibrinogen into fibrin to form clot and gelatin acts as scaffolding for clot formation	FloSeal (Baxter)	Very good for arterial bleeding because it has a tamponade effect	Can result in significant swelling from the compression, can cause neural disturbance
FIBRIN SEALANT Thrombin and fibrinogen are combined with an applicator to form a fibrin clot	Tisseel (Baxter) Evicel (Ethicon)	Good for larger bleeding areas because it acts as an adhesive	Expensive, preparation time
KAOLINITE Naturally occurring mineral; when exposed to human plasma, factors XI and XII activate the intrinsic pathway	QuikClot (Z-Medica)	Kaolin is a naturally occurring mineral	Limited use in dental surgery, needs to be poured into wound, exothermic reaction causes heat
SYNTHETIC BONE HEMOSTATIC AGENTS Tamponades the osseous vascular spaces	Bone wax Ostene (Ceremed)	Ostene is soluble, it dissolves in 48 hours, is not metabolized, with a low bacterial adhesion and infection rate	Bone wax is insoluble, must be removed or will cause inflammation and a foreign body giant cell reaction, should not be used in implant dentistry

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Active Hemostatic Agents

Thrombin

Active topical hemostatic agents have biologic activity that induce clotting at the end of the coagulation cascade. Most active agents used in dental implant surgery contain the coagulant thrombin. Thrombin is a naturally derived enzyme that is formed from prothrombin and acts as the basis for a fibrin clot by converting fibrinogen to fibrin. It is mainly used as a topical hemostatic agent in 5000- to 10,000-unit solutions, which accelerate capillary bleeding. It may be used as a powder or combined with a gelatin sponge during surgical procedures.

Thrombin bypasses the initial enzymatic process, thereby exerting its effect by impairing aspects of the coagulation cascade. For thrombin to maintain hemostasis, circulating fibrinogen is needed because it is necessary for the formulation of a clot. Therefore, when a patient exhibits the absence of fibrinogen, thrombin will not be effective. Fibrinogen is less susceptible to coagulopathies caused by clotting factor deficiencies and platelet dysfunction.[21] However, thrombin does work in the presence of antiplatelet and anticoagulation medications, which are quite prevalent in the population (Fig. 7.11).

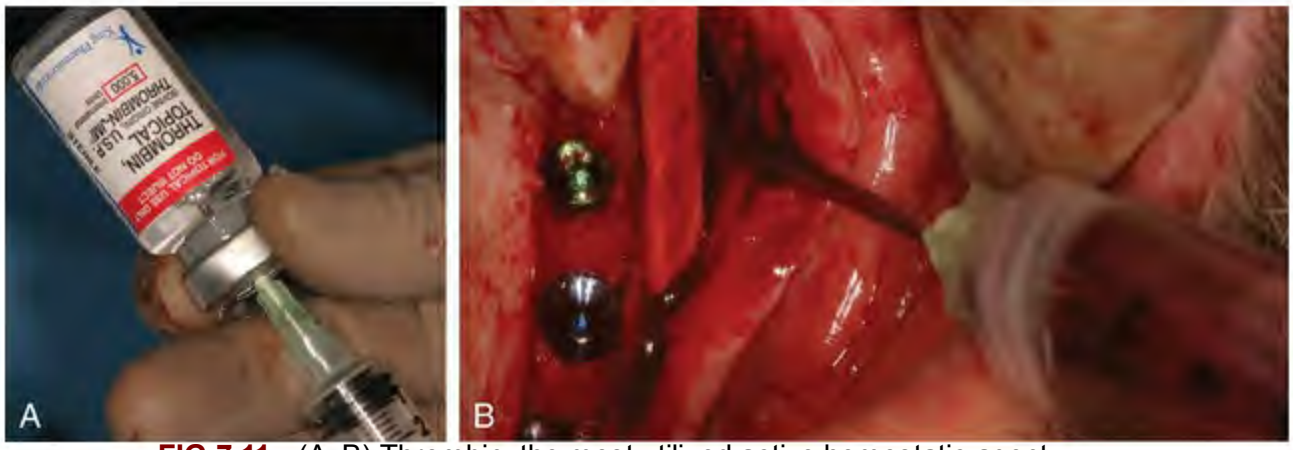

FIG 7.11 (A–B) Thrombin, the most utilized active hemostatic agent.

Types of Thrombin.

Thrombin is available in many forms as a hemostatic agent and has been purified from numerous sources and classified according to the plasma used

to create it.

Bovine thrombin (eg. Thrombin-JMI) is available as a powder that may be used dry, reconstituted with sterile saline, or added to gelatin sponges or collagen. Antibody formation has been associated with bovine thrombin, and this may lead to coagulopathies. [23]

Human plasma thrombin (e.g., Evithrom) is available as a frozen liquid that can be reconstituted via an absorbable gelatin sponge. Human plasma thrombin has been associated with the potential risk of viral or disease transmission.[24]

Recombinant thrombin (e.g., Recothrom) is a genetically engineered thrombin available in a powder form. It may be applied via a spray kit or with an absorbable gelatin sponge. The use of recombinant thrombin eliminates the risk of antibody formation and disease and virus transmission.[25]

Advantages.

Thrombin use is advantageous in patients receiving antiplatelet or anticoagulation medications. Thrombin does not need to be removed from the bleeding site because degeneration and reabsorption of the fibrin clot is achieved during the normal healing process. Usually, thrombin-containing active agents have a rapid onset of action, providing hemostasis within 10 minutes in most patients.[22]

Disadvantages.

Thrombin is ineffective in patients who suffer from afibrinogenemia because fibrinogen will not be present in the patient's blood. Care should be exercised to not use thrombin directly on larger vessels because systemic absorption may lead to intravascular thrombosis.

Passive Hemostatic Agents

Passive hemostatic agents provide hemostasis by accelerating the coagulation process. These agents form a physical, latticelike matrix, which activates the extrinsic clotting pathway and provides a platform for platelets to aggregate and form a clot. Passive hemostatic agents are effective only on patients who have an ideal coagulation process. If the patient suffers from a any type of coagulopathy, other hemostatic techniques should be utilized.

These types of agents are available in many different forms (e.g., bovine collagen, cellulose, gelatins) and application methods (e.g., absorbable

sponge, foam, pads that may absorb several times their own weight). Expansion may lead to complications, specifically pressing on neural tissue (e.g., inferior alveolar nerve). Therefore after hemostasis is obtained, passive hemostats should be removed to minimize postoperative complications. Passive hemostatic agents are readily available and inexpensive.

Collagen

Collagen-based hemostatic agents work by contact activation and promotion of platelet aggregation, which occurs as a result of contact between blood and collagen. Collagen is available in many carrier forms such as a powder, paste, or sponge. Studies have shown that between 2% to 4% of the total population are allergic to bovine collagen.[26]

Bovine Collagen (OraPlug, OraTape [Salvin Dental Specialties, Inc.]).

Products such as OraPlug and OraTape are soft, white, pliable, nonfriable, coherent, spongelike structures that are fabricated from bovine collagen (usually from deep flexor tendons). They are nontoxic, nonpyrogenic, and highly absorbent. Indications include the control of oozing or bleeding from clean oral wounds. They help control bleeding, by stabilizing blood clots, and protect the wound bed to facilitate the healing process. When applied, the products should be held in place for approximately 2 to 5 minutes to achieve ideal hemostasis and then may be removed, replaced, or left in place. Most collagen materials are completely resorbed within 14 to 56 days (Fig. 7.12A–B).[27]

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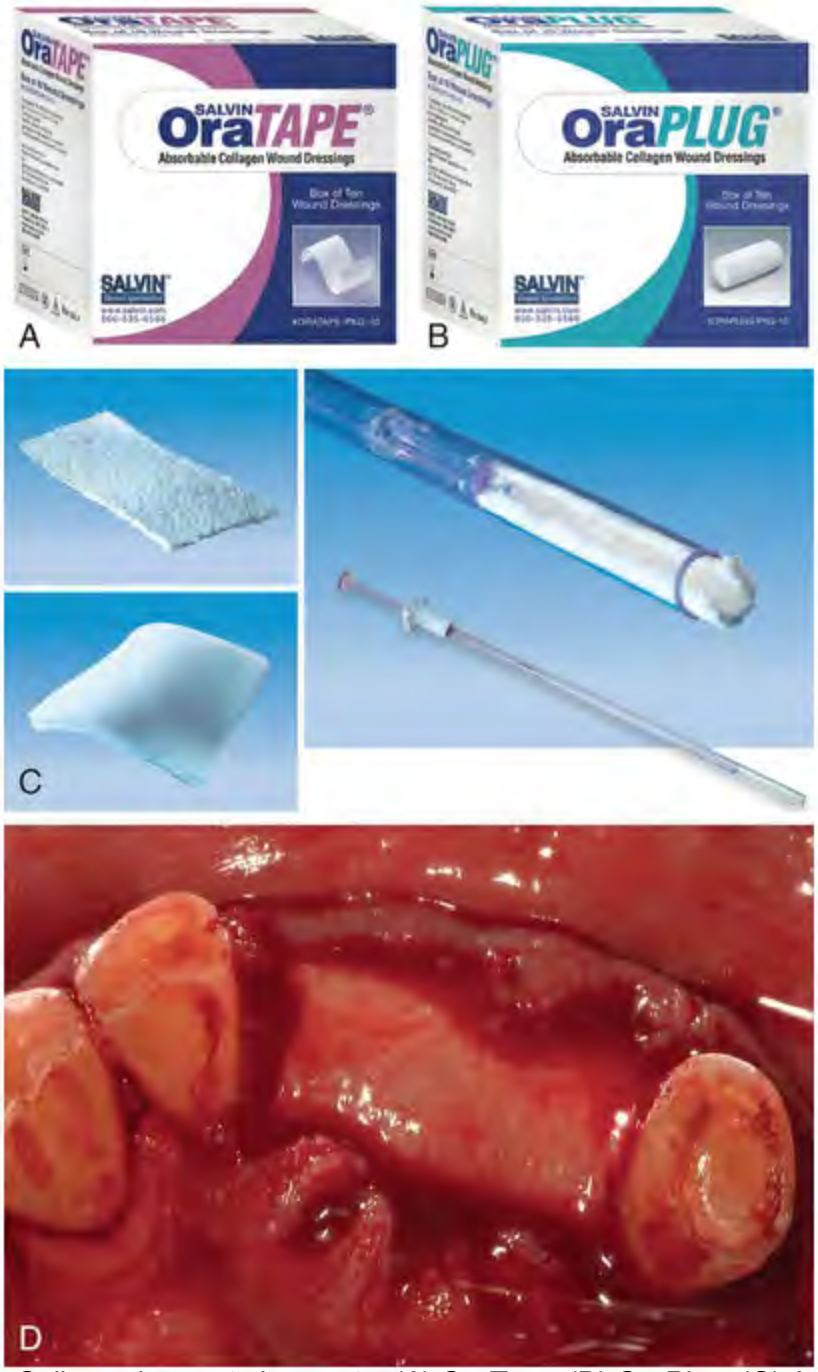

FIG 7.12 Collagen hemostatic agents. (A) OraTape. (B) OraPlug. (C) Avitene. (D) Collagen hemostatic agent placed to control bleeding. (A–B, Courtesy Salvin Dental Specialties, Inc., Charlotte, NC. C, Courtesy C. R. Bard, Murray Hill, NJ.)

Microfibrillar Collagen (Avitene Microfibrillar Collagen Hemostat [Davol Inc.]).

Microfibrillar collagen was first introduced in the 1970s. This hemostatic agent is fabricated by purifying bovine collagen and processing it into microcrystals. Avitene was first launched in a flour form, and it is still

commonly used in the topical powder form. Collagen-based products activate the intrinsic pathway of the coagulation cascade.[28] Avitene produces a large surface area, which acts as a matrix for platelet activation, aggregation, and thrombus formation. Advantages include a rapid onset of hemostasis, minimal tissue reactivity, low infection rate, and ability to be reabsorbed.[29] In vitro studies have shown microfibrillar collagen to be the most effective in maintaining hemostasis, followed by collagen, sponge, and then oxidized cellulose (Fig. 7.12C).[20] The disadvantage of microcellular collagen products is they are extremely expensive with a short shelf life.

Cellulose

The most common cellulose-based hemostatic agent is regenerated oxidized cellulose that initiates clotting via contact activation. Oxidized cellulose has been shown to be poorly absorbed and may cause healing complications postoperatively.

Resorbable Oxidized Cellulose/Fabric Meshwork (Surgicel [Ethicon US]).

Surgicel is a resorbable oxidized cellulose material in a sterile fabric meshwork. When Surgicel is applied to the bleeding area, it swells into a brownish/black gelatinous mass that aids in the clotting process. Because this agent lowers the pH of the surrounding tissue, red cell lysis occurs, accounting for the dark discoloration. This caustic material should ideally be removed because it may delay healing and interfere with osteogenesis (Fig. 7.13A).

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FIG 7.13 (A–B) Oxidized regenerated cellulose (Surgicel). (C) Surgicel placed underneath reflected flap for hemostatis, this should be removed prior to flap closure. (D–E) BloodSTOP Hemostatic Agent. (F) BloodSTOP placed in extraction site. (D–E, Courtesy LifeScience PLUS, Inc., Mountain View, CA.)

Cellulose Fabric Meshwork (ActCel [Coreva Health Science, LLC]).

ActCel is a cellulose fabric meshwork similar to Surgicel. When the meshwork comes into contact with blood, it expands to 3 to 4 times its

original size and is almost immediately converted to a gel. It will undergo complete dissolution within 1 to 2 weeks.[30] This material has the advantage over Surgicel that it degrades rapidly into biocompatible end products (glucose, water) and thus does not adversely affect wound healing or bone formation. The mechanisms of action will enhance the coagulation process biochemically by increasing platelet aggregation and physically by initiating clot stabilization.

Regenerated Cotton Cellulose (BloodSTOP [LifeScience PLUS Inc.]).

BloodSTOP is a biocompatible, nonirritating, water-soluble, regenerated cotton cellulose hemostatic agent that resembles traditional gauze. When applied to a bleeding surgical site, BloodSTOP quickly absorbs blood and transforms into a gel to seal the wound with a protective transparent layer, actively aids in blood coagulation, and creates a positive environment for wound healing. Because BloodSTOP is 100% natural cellulose and is water soluble, it is easliy removed without disruption of the wound surfaces after hemostasis. It is manufactured in a single-use, sterile package with a 0.5- × 2-in size (Fig. 7.13).

Gelatin

Gelatin-based hemostatic agents possess the ability to conform to irregular wound geometries. Gelatin conforms to the wound and will increase in size, providing a tamponade effect in the confined spaces. The gelatin particles restrict blood flow and provide a matrix for clot formation.

Gelatin-Based Hemostatic Agents (Gelfoam [Pfizer Inc.]).

Gelfoam, which was first introduced in the 1940s, is the most common type of gelatin-based hemostatic agents. Gelfoam is a porous, pliable sponge made from dried and sterilized porcine skin gelatin. Gelfoam will liquefy in 7 days and is completely resorbed in 4 to 6 weeks. This material is hygroscopic, absorbing many times its weight in water and allowing the concentration of platelets, clotting factors and the gelatin to swell, which provides additional mechanical hemostatic action through compression (Fig. 7.14).[29]

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FIG 7.14 Gelfoam.

Chitosan

Chitosan is a biocompatible, naturally occurring, positively charged polysaccharide derived from arthropod skeletons. The positive charge attracts the negatively charged red blood cells, forming a viscous coagulum, which seals the bleeding tissue. This material is advantageous due to its ability to maintain hemostasis independent of coagulation factors. Chitosan is useful in patients with coagulopathies or patients on anticoagulants.

Chitosan-Based Hemostatic Agents (HemCon Dressing [Tricol Biomedical, Inc.]).

HemCon dressing is a chitosan-based hemostatic agent that is specifically made for dental use. Studies have shown hemostasis may be achieved with HemCon dressings in less than 60 seconds in comparison to a control of 9½ minutes (Fig. 7.15).[31] HemCon dental dressings mode of action is an adhesive-like action, which provides a physical protective barrier. Because chitosan has a positive charge, it will attract red blood cells, which have a negative charge. The accumulated red blood cells create a physical barrier. This dressing will usually dissolve in 48 hours, so no removal is needed.

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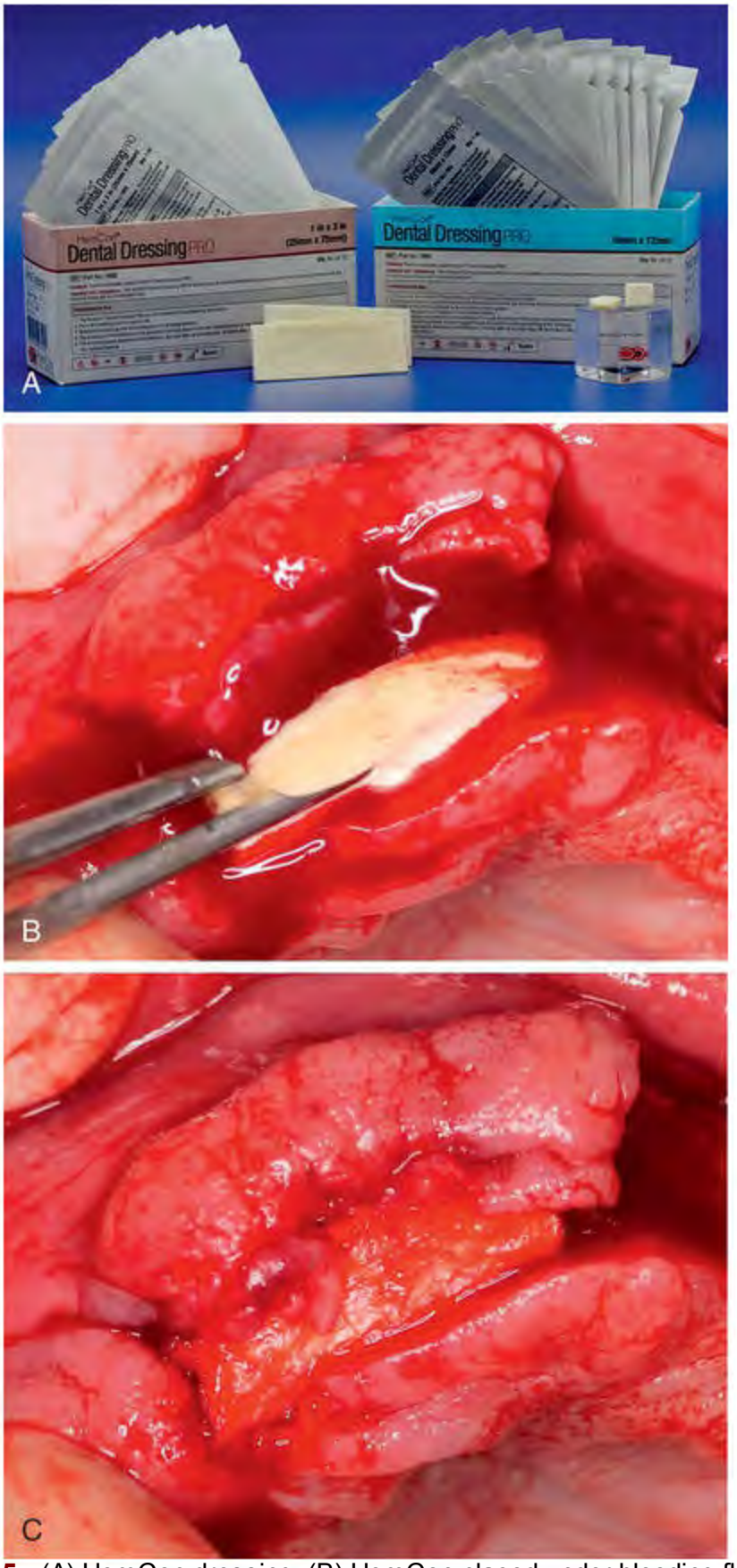

FIG 7.15 (A) HemCon dressing. (B) HemCon placed under bleeding flap. (C) Hemostasis achieved, dressing should be removed prior to flap closure. (A, Courtesy Tricol Biomedical, Inc., Portland, OR.)

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Mechanical

Beeswax.

Bone wax, a soft, malleable, nonbrittle wax, was invented in 1886 by Sir Victor Horsley. The material is a combination of beeswax, salicylic acid, and almond oil.[32] It is most commonly used when the bleeding is visualized as having an origin from within the bone. This type of bleeding most commonly occurs during osteotomy preparation and extractions. Bone wax exhibits no hemostatic quality it obliterates the vascular spaces in cancellous bone. However, caution should be exercised with the use of bone wax because it is water insoluble and will not be absorbed. It may predispose the area to infection or inhibit bone healing. Studies have shown that bone wax, when removed from an osseous defect after 10 minutes, completely inhibited further bone regeneration.[33] Bone wax also increases inflammation, which may cause a foreign body giant cell reaction and infection at the site (Fig. 7.16).[34]

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FIG 7.16 Bone wax.

Synthetic Bone Hemostat Material (Ostene [Ceremed Inc.).

Ostene is a synthetic bone hemostat material approved in 2004 by the FDA for use in cranial and spinal procedures. This material is a mixture of water-soluble alkylene oxide copolymers that elicits minimal postoperative inflammation. It has many advantages over bone wax because it is water soluble and dissolves in 48 hours. It has been associated with a decreased infection rate and positive bone cultures.[35] Ostene is supplied in sterile peel pouches and is applied in a manner similar to bone wax without the associated disadvantages. (Fig. 7.17).

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FIG 7.17 Ostene. OSTENE (Bone Hemostatis Material). OSTENE material is a sterile water-soluble surgical implant material. It can be used for the control of bleeding from bone surfaces by acting as a mechanical barrier. (Courtesy Baxter Healthcare Corporation, Deerfield, IL. Baxter is a registered trademark of Baxter International Inc. OSTENE is a registered trademark of Apatech Limited. Copyright © 2017 Baxter Healthcare Corporation. All rights reserved.)

Combination Agents

Thrombin is used mostly in combination with numerous passive hemostatic agents such as collagen, gelatin, and fibrin sealant sponges. When fibrinogen and thrombin is combined, thrombin modifies the fibrinogen into monomers that polymerize and form a soft plug. The soluble fibrin is then converted into insoluble fibrils, which form a stable clot.

Combination Hemostatic Agents (FloSeal Matrix Hemostatic Sealant [Baxter Healthcare Corporation]).

FloSeal was approved in 1999 and is a fast, effective, and proven hemostatic agent. FloSeal is a combination of two independent hemostatic agents, combining human-derived thrombin with bovine-derived gelatin matrix granules, which are mixed at the time of use.[36] This hemostatic agent is of liquid nature, which encompasses crosslinking of the gelatin matrix granules that minimizes in vivo expansion.[37] The gelatin granules swell approximately 10% to 20% when exposed to blood, which helps to seal off the area of bleeding. This agent works very well on wet, bleeding areas and has been shown to stop 96% of bleeding with 10 minutes. FloSeal is absorbable within 6–8 weeks, well tolerated, and useful for hard and soft tissues (Fig. 7.18).

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FIG 7.18 (A) FLOSEAL Hemostatic Matrix dispensed in a syringe form. (B) FLOSEAL is indicated in surgical procedures (other than in ophthalmic) as an adjunct to hemostasis when control of bleeding by ligature or conventional procedures is ineffective or impractical. (Courtesy Baxter Healthcare Corporation, Deerfield, IL. Baxter and FLOSEAL are registered trademarks of Baxter International Inc. Copyright © 2017 Baxter Healthcare Corporation. All rights reserved.)

Advantages.

FloSeal is a passive topical hemostatic agent that can be used when hemostatic control is needed during dental implant procedures. It has been shown to be effective when more significant and heavier bleeding occurs because of the larger absorption capacity and greater mass. These agents may absorb several times their own weight with bleeding. For example, oxidized cellulose can absorb 7 times its weight, and collagen may absorb 32 times its own weight.[20]

Disadvantages.

The expansion of FloSeal can result in complications if placed in close approximation to a vital structure (e.g., inferior alveolar canal) because neuropraxia type of nerve impairments may result. Additionally, in arterial bleeds, passive hemostatic agents may not be completely effective. If a significant arterial bleed occurs, ligation of the artery is usually the ideal treatment. Caution should be noted on the use of nonabsorbable passive agents, which can potentiate a foreign-body reaction resulting in chronic inflammation, infection, or granuloma formation.

Summary of Techniques to Decrease and Control Bleeding

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Intraoperative bleeding episodes during dental implant surgery are most likely to increase in the future as more medically compromised and elderly patients are being treated, including patients utilizing anticoagulant medications. In rare situations, these bleeding episodes may be life threatening, which necessitates the dental implant surgeon having knowledge of fast and effective techniques to achieve hemostasis. The use of topical agents has been shown to improve blood conservation, avoid potential adverse effects, and decrease surgery time. The dental implant clinician must be familiar with products that help to achieve hemostasis in case of complications that may arise.

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Prevention/Treatment of Bleeding

Anatomic Areas

The ideal management of intraoperative hemorrhage is prevention. Though the clinician should be capable of handling potential bleeding complications, the best course of action is to avoid them as much as possible, which is aided by taking the appropriate preventive measures. A preoperative assessment of the patient is mandatory, including a thorough preoperative patient history, medical consultation when indicated. The clinician should also be familiar with managing patients on anticoagulants and those who have bleeding issues, utilize meticulous intraoperative surgical technique, and provide appropriate postoperative instructions, care, and follow-up. Patients need to be instructed on the importance of compliance with prescribed medication and proper postoperative instructions and care.

Incision/Reflection of Tissue

The dental implant clinician must carefully plan the location of incisions with respect to surgical anatomy to maintain hemostasis and minimize bleeding. Ideally, incisions should always be made over bony support when possible. This will allow for pressure to be applied over bone in the event of uncontrolled bleeding. The flap design should incorporate release incisions so that excessive pressure and stretching is reduced in order to decrease possible tearing of the tissue. Elevation of the mucosa and periosteum should be carefully completed with full-thickness and atraumatic reflection. Split-thickness flaps should be avoided to minimize potential bleeding sites. Anatomic areas containing vital structures, that may be highly vascular, should be carefully evaluated and avoided if possible (Fig. 7.19).

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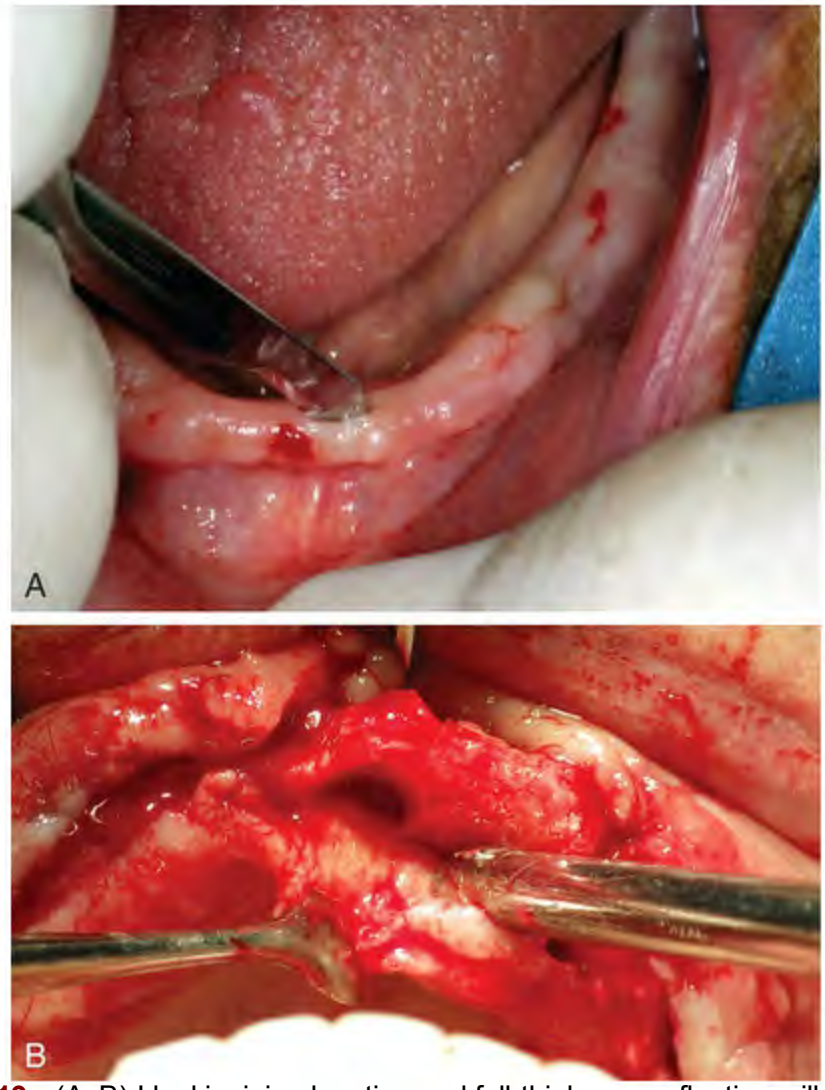

FIG 7.19 (A–B) Ideal incision location and full-thickness reflection will reduce bleeding with atraumatic reflection of the tissue. Incisions should ideally be over bone to minimize trauma to the tissue.

Anatomy/ Anatomic Variants

Strategic planning of potential implant sites is mandatory, with a thorough understanding of anatomic structures and variants with the use of a cone beam computed tomography (CBCT). The lack of distortion of the CT images allows the clinician to better plan surgical sites while maintaining relative safe zones from anatomic structures.

Mandibular Anterior: Intraosseous Vessels

Median Vascular Canal

On occasion, in the mandibular midline, copious bleeding may be present

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(e.g., “C” position, even though no bone perforation has occurred). Bilateral sublingual arteries enter through the lingual foramen within the lingual plate below the genial tubercles within the mandible. As this anastomosis transverses within the anterior mandible, the canal is termed the *median vascular canal*. Bleeding in this area may be significant; however, it is not associated with any type of neurosensory impairment.

Prevention.

The presence and size of the sublingual anastomosis and the median vascular canal is easily seen on a cross-sectional or axial image of a CBCT scan. The position of the planned osteotomy may need to be modified if a significant anastomosis is present.

Management.

If significant bleeding occurs after implant osteotomy, a direction indicator or surgical bur can be placed in the osteotomy site to apply pressure. If the osteotomy is completed, an implant may also be introduced into the site, which will compress the walls of bone, thus slowing the bleeding process (Fig. 7.20). In most cases, intraosseous bleeding is more easily controlled in comparison to soft tissue hemorrhage.

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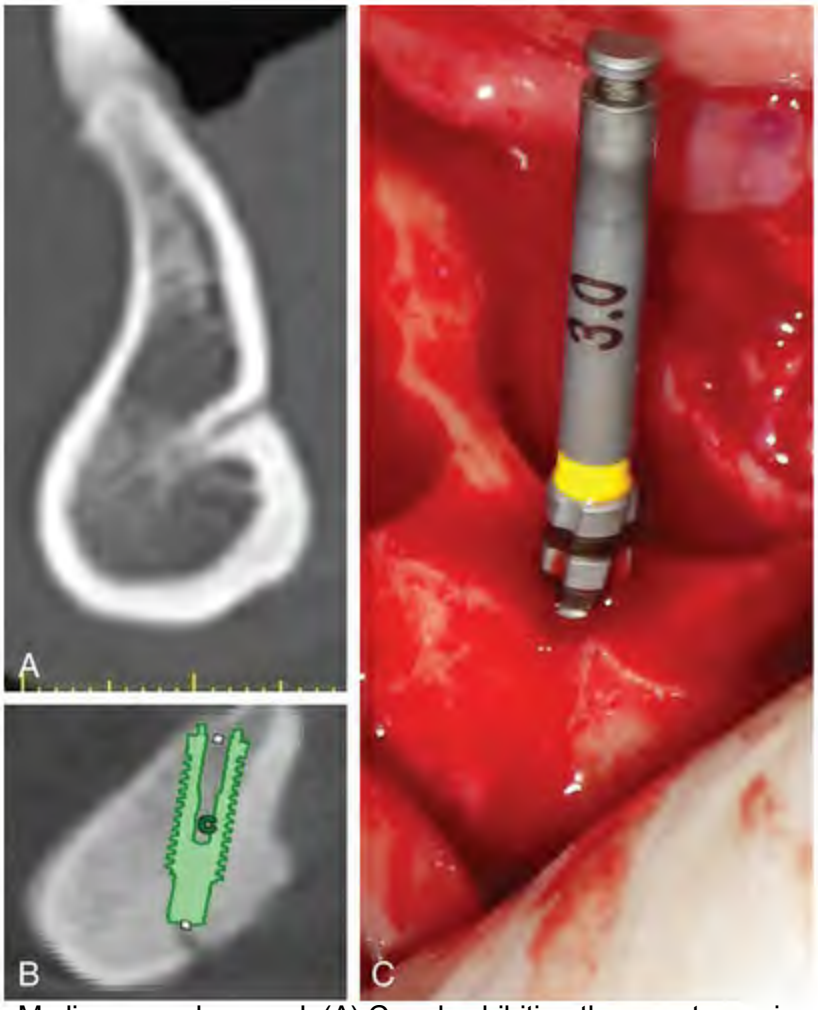

FIG 7.20 Median vascular canal. (A) Canal exhibiting the anastomosis of the right and left sublingual arteries. (B) Implant placed in the midline area may cause significant intraosseous bleeding. (C) Treatment includes placing in the osteotomy site the surgical drill, direction indicator, or implant to stop the bleeding.

Inferior Alveolar Artery

The inferior alveolar artery is a branch of the maxillary artery, one of the two terminal branches of the external carotid. Prior to entering the mandibular foramen, it gives off the mylohyoid artery. In approximately the first molar region, it divides into the mental and incisal branches. The mental branch exits the mental foramen and supplies the chin and lower lip, where it eventually will anastomose with the submental and inferior labial arteries.

Prevention.

The exact location of the inferior alveolar artery is easily determined via a CBCT evaluation in the panoramic or sagittal views.

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Management.

Normally, the inferior alveolar artery is located superiorly to the inferior alveolar nerve within the bony mandibular canal. Drilling or placing an implant into the inferior alveolar canal may predispose to significant bleeding. Hemorrhage may be controlled by placement of an implant or direction indicator short of the canal. A 2.0-mm safety zone should be adhered to. If bleeding does occur, follow-up postoperative care is essential because hematoma formation within the canal may lead to a neurosensory impairment. This condition should be monitored because it may progress to respiratory depression via a dissecting hematoma in the floor of the mouth (Fig. 7.21).

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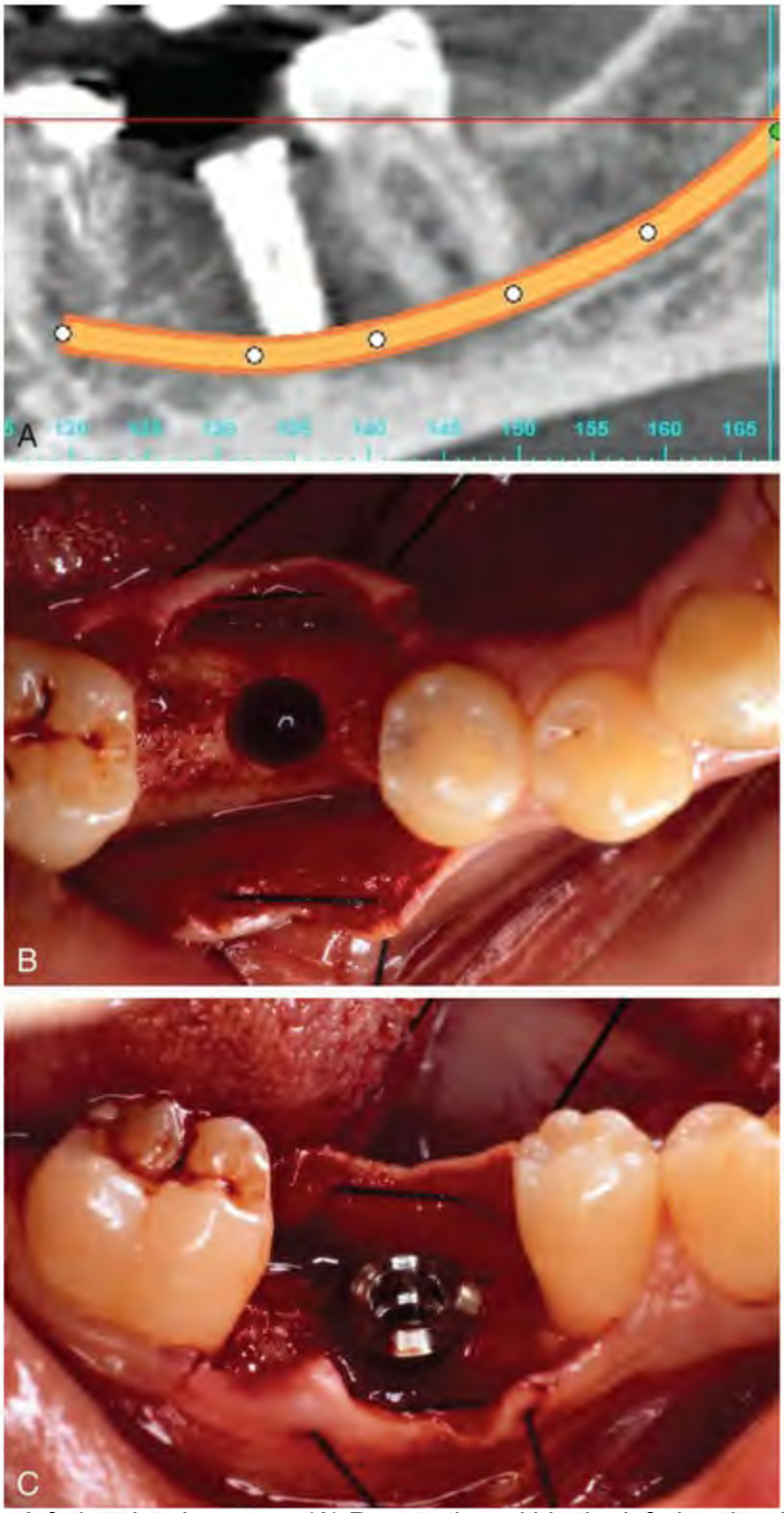

FIG 7.21 Inferior alveolar artery. (A) Penetration within the inferior alveolar canal. (B) May cause profuse bleeding. (C) Treatment includes placing the drill, direction indicator, or implant to stop the bleeding.

Incisive Artery

The incisive artery is the second terminal branch of the inferior alveolar artery, which is a branch of the maxillary artery. The incisal branch continues anteriorly after supplying in the mandibular first molar area, where it innervates the incisor teeth and anastomoses with the contralateral incisal artery. In rare cases, the incisive canal is large, lending to greater bleeding during osteotomy preparation or bone grafting procedures.[1]

Prevention.

The exact location of the incisive canal is easily determined via a CBCT evaluation in the panoramic or sagittal views.

Management.

Bleeding complications can occur when implants are placed into the mandibular incisive canal, which contains the incisive artery. If bleeding does occur during placement of the implant, a direction indicator or surgical bur can be placed into osteotomy to apply pressure (Fig. 7.22).

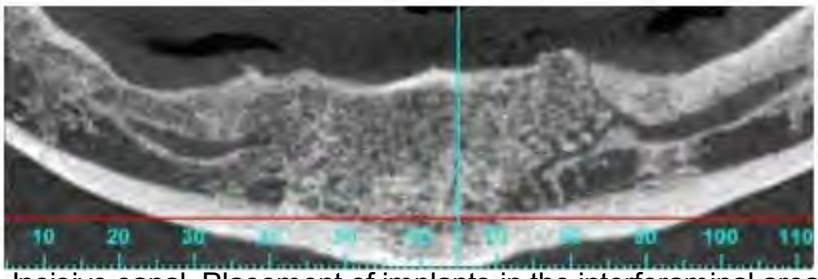

FIG 7.22 Incisive canal. Placement of implants in the interforaminal area may lead to increased bleeding; it is usually self-limited.

Mandibular Anterior: Extraosseous Vessels

The anterior mandible is usually known as a safe area for implant placement, but in certain situations, it may present with a significant undercut on the lingual aspect between the foramina. Life-threatening hemorrhage has been reported when a drill perforates the lingual plate of the sublingual region of the mandible and traumatizes a sublingual or submental artery, especially in the canine region.[38,39] If perforation of the lingual cortical plate is associated with arterial bleeding, it is critical to identify its origin and treat aggressively. The origin of bleeding in the floor of the anterior region of the mouth may be

from the lingual artery, facial artery, or one of its branches. The submental artery originates from the facial artery and courses along the inferior border of the mandible. The sublingual artery, a branch of the lingual artery, runs along the inferior border of the mandible and terminates in the midline. Perforation in this area may lead to bleeding, causing an expanding ecchymosis (sublingual hematoma) and compromising the airway.

Sublingual Artery (Lingual Artery)

The lingual artery is a branch of the external carotid artery between the superior thyroid and facial arteries. The lingual artery courses medially to the greater horn of the hyoid bone and crosses inferiorly and facially around the hypoglossal nerve. It then transverses deep to the digastric and stylohyoid muscles and courses between the hyoglossus and genioglossus muscles. There exist four main branches of the lingual artery: the suprahyoid, dorsal lingual, deep lingual, and sublingual. Of clinical significance to oral implantology is the sublingual artery, which supplies the sublingual salivary gland, mylohyoid and surrounding muscles, and the mucous membranes and gingiva of the mandible. A distal branch runs medially in the anterior lingual mandibular gingiva and anastomoses with the contralateral artery. An additional branch connects with the submental artery under the mylohyoid muscle.[40] The lingual artery will anastomose throughout the tongue area, with more anastomoses occurring anteriorly.[41]

Submental Artery (Facial Artery)

The most important branch of the facial artery associated with oral implantology is the submental branch, which is the largest of the branches of the facial artery. The submental branch exits the submandibular gland and proceeds anteriorly on the surface of the mylohyoid muscle, just inferior to the body of the mandible. The submental branch terminates as an anastomosis with the sublingual branch of the lingual artery and the mylohyoid branch of the inferior alveolar artery.[40]

Studies have shown that the floor of the mouth and lingual gingiva is supplied approximately 53% by the submental artery and the remaining by the sublingual artery.[42] Perforation of the lingual cortical plate may result in trauma to the submental artery. Treatment should include immediate repositioning of the patient in an upright position followed by the application of bimanual pressure. This should be immediately applied,

followed by airway management and emergency protocol. Bleeding from the submental artery may be decreased by applying finger pressure over the lower border of the mandible. Doppler ultrasonography studies have shown this to reduce the arterial blood by 25% to 50% at the oral commissure level and 33% to 50 % at the inferior border of the nares.[43]

Katsumi et al described four types of sublingual and submental arteries:

Type 1: Sublingual artery, no submental artery (63%)

Type 2: Sublingual and submental present (5.6%)

Type 3: Submental, no sublingual (29.6%)

Type 4: Submental with no deep lingual artery (1.8%)

In Types 2, 3, and 4 vessel anatomy are associated with sublingual bleeding issues.[44] There also exists a relationship of the submental and sublingual arteries in dentate vs. edentulous patients. Usually the sublingual arteries course above the mylohyoid line and the submental arteries run below or within the muscle.[45,46] In dentate patients hemorrhage risk is high with vessels above the mylohyoid. In edentulous patients the mylohyoid line approaches the alveolar crest, thus lending to high risk of hemorrhage, which may result in arterial damage in the submandibular space.

Prevention.

Clinical and radiographic evaluation should be completed to ascertain the amount of available bone and osseous angulation in the anterior mandible. The length of implants should be carefully evaluated because bicortical stabilization (which may lead to perforation of the lingual plate) is no longer advocated for implant success. This is most important in the mandibular canine position. Additionally, care should be exercised in elevation of the lingual flap and manipulation of the lingual tissue.

Clinical Significance.

Bleeding into the sublingual and submaxillary spaces will cause elevation of the tongue and floor of the mouth. Bleeding in these spaces will proceed to airway obstruction because the anterior extension of the hematoma is limited by the superficial layers of the cervical fascia.[47] The signs and symptoms of

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sublingual swelling include immediate or delayed (up to 4–8 hours after surgery) elevation of the floor of the mouth, protrusion of the tongue, profuse intraoral bleeding, difficulty in swallowing, and respiratory depression. The submandibular swelling may dislocate the trachea to the contralateral side and compromise the airway.[48] Additionally, pulsatile hematomas (pseudoaneurysms) of the lingual artery may result from the injury (Fig. 7.23).[49]

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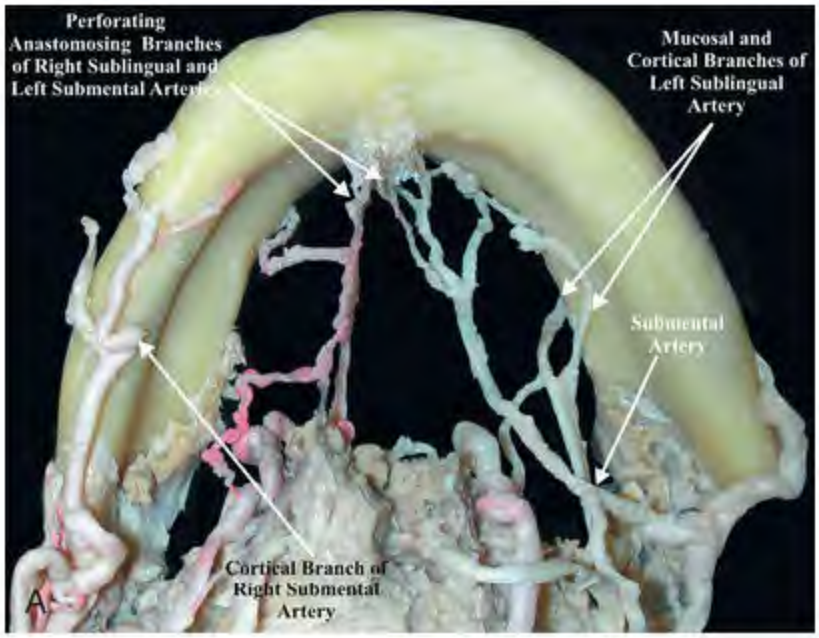

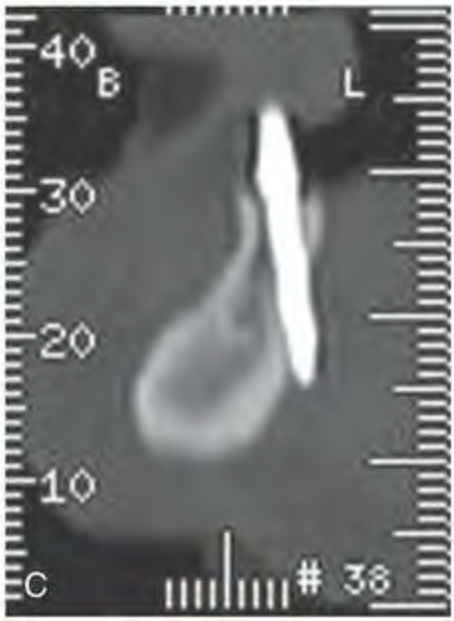

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FIG 7.23 (A) Sublingual and submental arteries showing proximity to inferior border of mandible. (B) Perforation of the lingual cortical plate. (C) Perforation into sublingual space may traumatize the sublingual and submental vessels leading to significant bleeding. (D) To slow sublingual bleeding, apply bimanual pressure with 4 × 4 gauze on lingual surface of mandible and superior pressure extraorally. (A, From Loukas M, Kinsella CR Jr, Kapos T, et al: Anatomical variation in arterial supply of the mandible with special regard to implant placement. *Int J Oral Maxillofac Surg* 37(4):367–371, 2008.)

Management.

Immediate bimanual pressure should be applied to the bleeding area if location can be determined. A 4 × 4 gauze may be used to apply the bimanual compression downward from floor of the mouth (lingual surface of the mandible) and in an upward direction from the submental skin area. The patient should be repositioned from a supine to an upright position. A Young forceps may be used to pull the tongue outward, which will slow the bleeding. Airway obstruction should be of vital concern because this may lead to a life-threatening situation. If any clinical signs of airway obstruction exist (e.g., dyspnea, dysphagia, wheezing, stridor, cyanosis), emergency intervention should be summoned immediately. Ligation of the bleeding vessel is the ideal treatment to control the hemorrhage. This may be very difficult in an office setting due to the location and surgical access of the bleeding vessel. To obtain definitive control of sublingual artery bleeding, surgical intervention with selective ligation of the branches along with arterial embolization via interventional angiography is indicated (Fig. 7.24).[50]

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FIG 7.24 Sublingual hematoma. (A) Four implants placed flapless in the anterior mandible. (B) Resultant sublingual hematoma with airway compromise. (C) Axial CT images showing extent of hematoma *(blue arrows)* with airway compromise. Note perforation of lingual cortical plate *(red arrow)*. (D) Young forceps may be used to pull tongue out to decrease the bleeding and helps maintain airway until medical assistance arrives. (From Limongelli L, Tempesta A, Crincoli V, et al: Massive lingual and sublingual haematoma following post extractive flapless implant placement in the anterior mandible. *Case Rep Dent*, vol. 2015, Article ID 839098, 4 pages, 2015.)

Mandibular Posterior: Extraosseous Vessels

Lingual Undercut

In the mandibular posterior area a lingual undercut may be problematic and difficult to manage. In this area, perforation of the lingual plate can occur very easily, thereby causing bleeding episodes, with an origin that may be

difficult to locate. Life-threatening situations may result from sublingual bleeding. Violation of this area may cause infection or constant irritation from the extruded implant in the soft tissue. If the perforation were to occur above the mylohyoid muscle, damage to the lingual nerve could result in a neurosensory impairment.

Prevention.

A clinical exam should always be carried out to determine if an osseous undercut exists. This may be confirmed with a CBCT examination because cross-sectional images are a very effective way of observing lingual undercuts. Additionally, angulation and positioning must be continuously verified to prevent inadvertent perforation. Studies have shown that lingual undercuts occur in approximately 66% of the population with a mean undercut of 2.4 mm.[51] Accurate measurements must be made to prevent overpreparation of the osteotomy site in the anterior mandible. This is most easily completed with a CBCT examination. Osteotomy angulation should always be carefully evaluated because improper drilling angulation may lead to perforations. Additionally, hourglass mandibles, which have been shown to have an incidence of approximately 4%, should always be concerning because perforation will occur.[52] Palpation of the ridge during osteotomy preparation will minimize perforations and decrease complications.

Management.

If sublingual posterior bleeding (submental or sublingual arteries) occurs, the patient should be repositioned in an upright position and bimanual pressure should be applied to the area of bleeding. If the airway is compromised, immediate emergency assistance should be summoned (Fig. 7.25).

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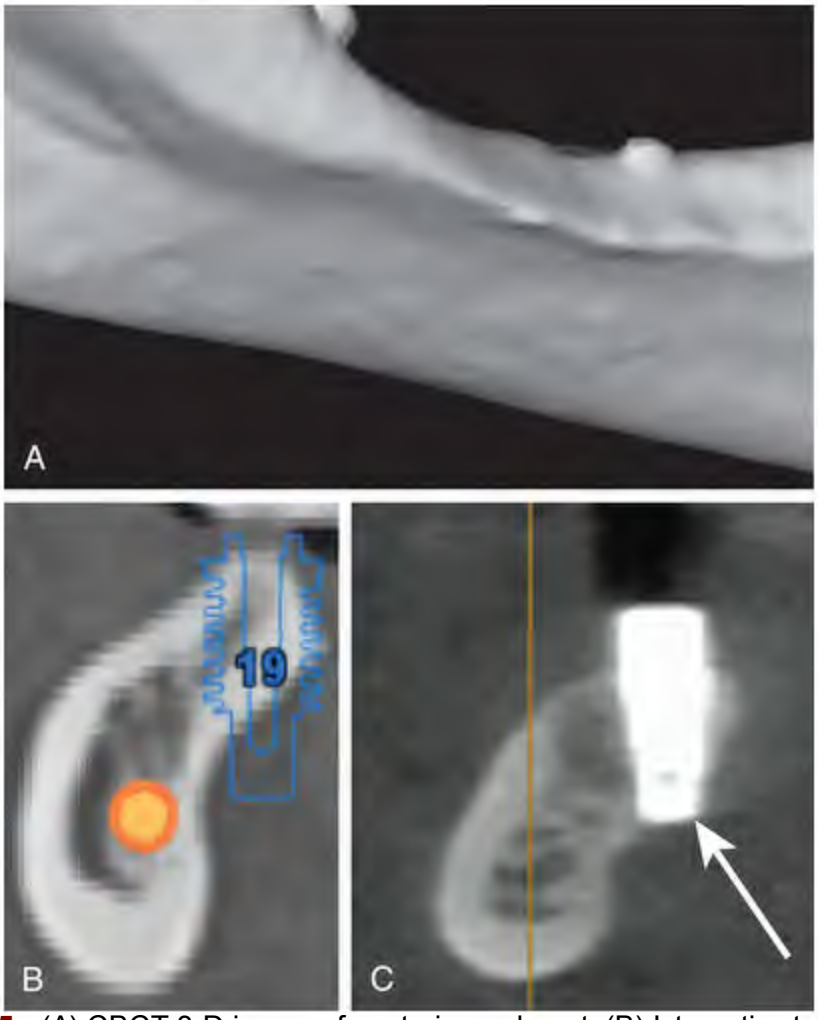

FIG 7.25 (A) CBCT 3-D image of posterior undercut. (B) Interactive treatment planning showing implant placement into sublingual undercut, in this case an implant would most likely be contraindicated. (C) Cross-section of implant perforation that may lead to pain, bleeding, and implant morbidity.

Mylohyoid Artery

The mylohyoid artery branches from the inferior alveolar artery and courses along the medial surface of the mandible in the mylohyoid groove, which supplies the mylohyoid muscle.

Prevention.

This artery is very rarely involved in bleeding episodes with oral implantology procedures, but an episode may occur from lingual cortical perforation in the molar region or aggressive reflection of the lingual tissue.

Management.

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Bleeding may be controlled locally by applying finger pressure along the medial side of the mandible (Fig. 7.26).

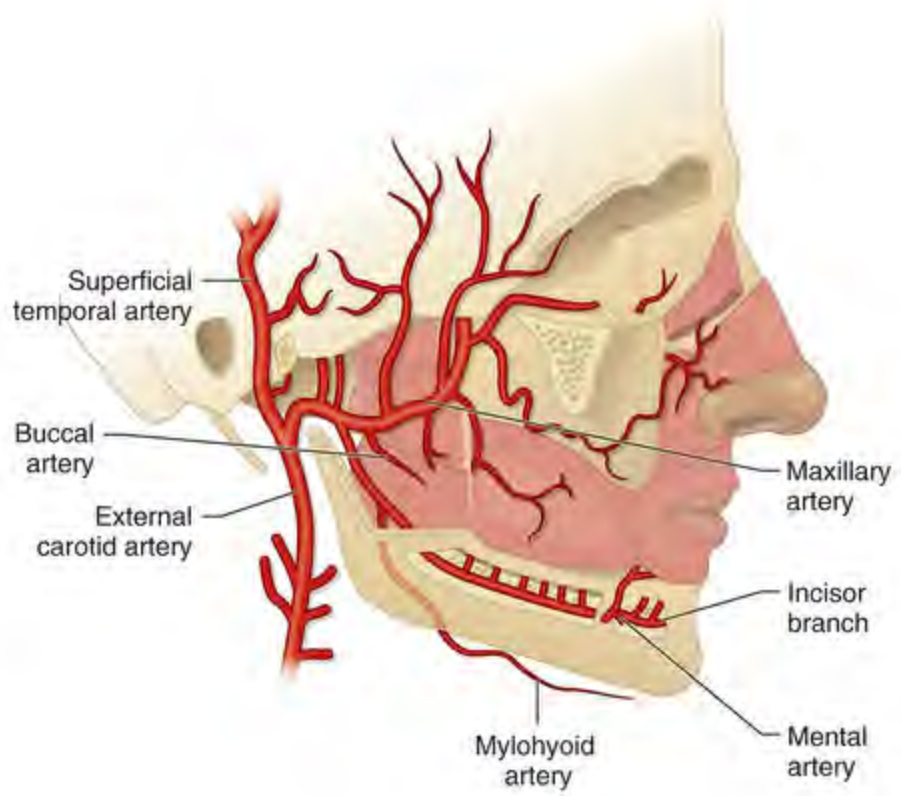

FIG 7.26 Most common arteries of the head and neck region.

Buccal Artery

A common donor site for autogenous grafting is the lateral ramus area in the posterior mandible. When making the incision lateral to the retromolar pad, a common blood vessel to damage is the buccal artery. The buccal artery is a branch of the maxillary artery and will most likely cause a significant bleeding episode. This artery runs obliquely between the internal pterygoid and the insertion of the temporalis on the outer surface of the buccinator.

Prevention.

In most cases, damage to the buccal artery is impossible to avoid. Incision and reflection will usually encompass the area of buccal artery location. When performing surgery in this area, a hemostat should always be available for immediate access in order to clamp the vessel.

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Management.

A curved hemostat should be utilized to control the bleeding. It should be left in place for 3–5 minutes. If bleeding persists, a ligature may be placed with Vicryl suture material (see Fig. 7.26).

Facial Artery

The facial artery is a branch of the external carotid, lying superior to the lingual artery and medial to the ramus of the mandible (Fig. 7.27). It courses below the digastric and stylohyoid muscles and passes through a groove in the submandibular gland before it becomes superficial around the inferior border of the mandible. There are two main branches of the facial artery: the facial and cervical. The facial branch encompasses five branches, which supply the eye, nose, and lips. There are four branches of the cervical region supplying the pharynx, soft palate, auditory tube, and submandibular gland.

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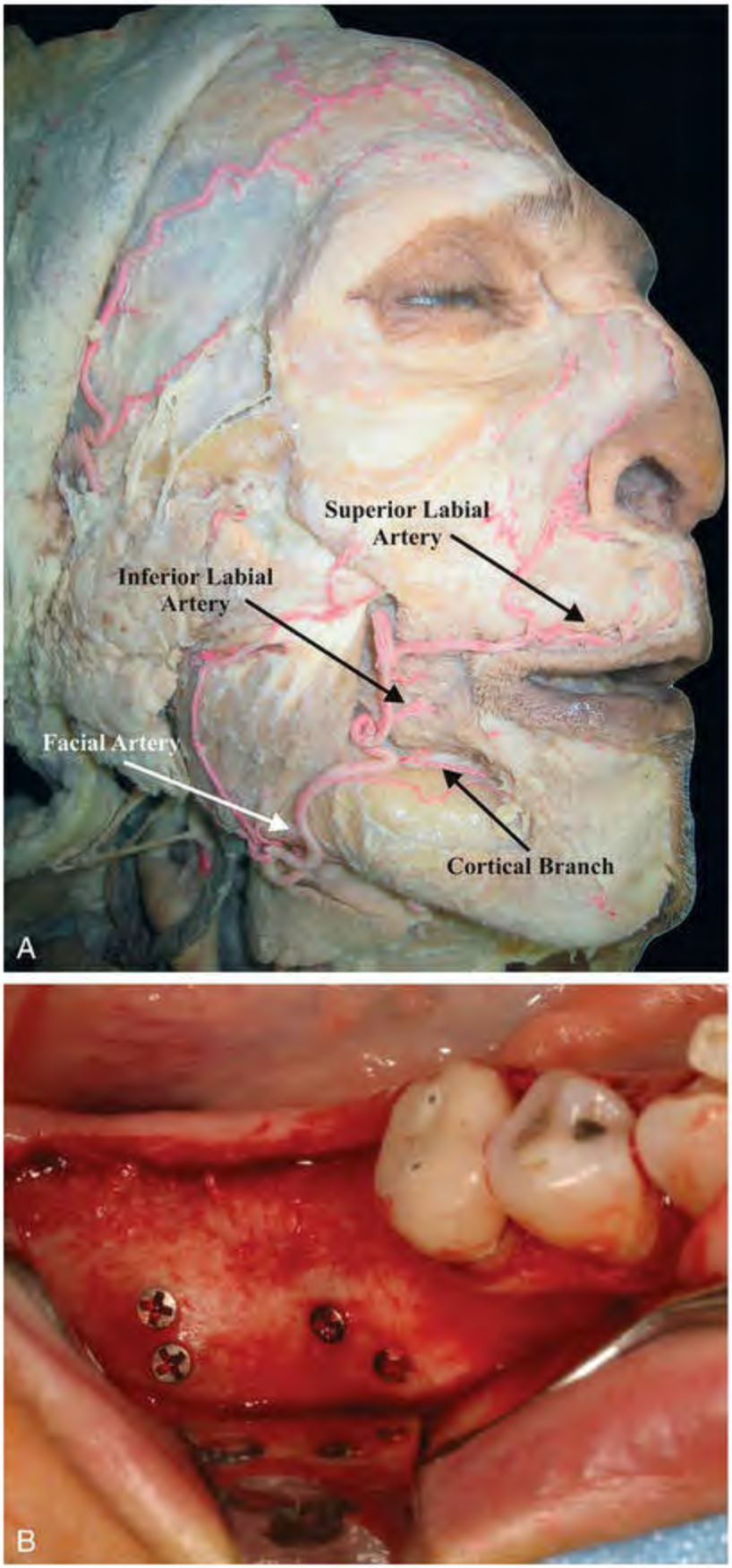

FIG 7.27 Facial artery. (A) Location in the facial notch in the angle of mandible. (B) Care should be exercised when using retraction in this area because damage to the facial artery could occur. (A, From Loukas M, Kinsella CR Jr, Kapos T, et al: Anatomical variation

in arterial supply of the mandible with special regard to implant placement. *Int J Oral Maxillofac Surg* 37(4):367–371, 2008.)

Prevention.

Trauma to the facial should always be avoided as the clinician should refrain from excessive retraction in this area.

Management.

If bleeding from the facial artery exists, pressure should immediately be applied to the angle of the mandible over the vessel. Usually, medical assistance will need to be summoned.

Maxilla: Lateral Wall/Nasal Bleeding

Significant bleeding from the lateral-approach sinus elevation surgery is rather rare; however, it has the potential to be troublesome. Three main arterial vessels should be of concern with the lateral-approach sinus augmentation. Because of the intra- and extraosseous anastomoses that are formed by the infraorbital and posterior superior alveolar arteries, intraoperative bleeding complications of the lateral wall may occur. In some cases, this bleeding may be significant.

Extraosseous Anastomosis

The soft tissue vertical-release incisions of the facial flap in a resorbed maxilla may sever the extraosseous anastomoses during lateral wall osteotomy preparation for sinus graft surgery. The extraosseous anastomosis on average is located 23 mm from the crest of the dentate ridge; however, in the resorbed maxilla, it may be within 10 mm of the crest. When this artery is severed, significant bleeding has been observed. These vessels originate from the maxillary artery and have no bony landmark to compress the vessel. Vertical release incisions in the soft tissue should be kept to a minimum height with delicate reflection of the periosteum. Hemostats are usually difficult to place on the facial flap to arrest the bleeding. Significant pressure at the posterior border of the maxilla and elevation of the head to reduce the blood pressure to the vessels usually slows the bleeding. The elevation of the head may reduce nasal mucosal blood flow by 38%.[15]

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Intraosseous Anastomosis

The vertical component of the lateral-access wall for the sinus graft often severs the intraosseous anastomoses of the posterior alveolar artery and infraorbital artery, which is on average approximately 15 to 20 mm from the crest of a dentate ridge. Methods to limit this bleeding, which is far less of a risk, include cauterization with the use of a hand piece and diamond bur without water, electrocautery, or pressure on a surgical sponge while the head is elevated. In some cases, a second window is made distal to the bleeding area source for access to ligate (Fig. 7.28).

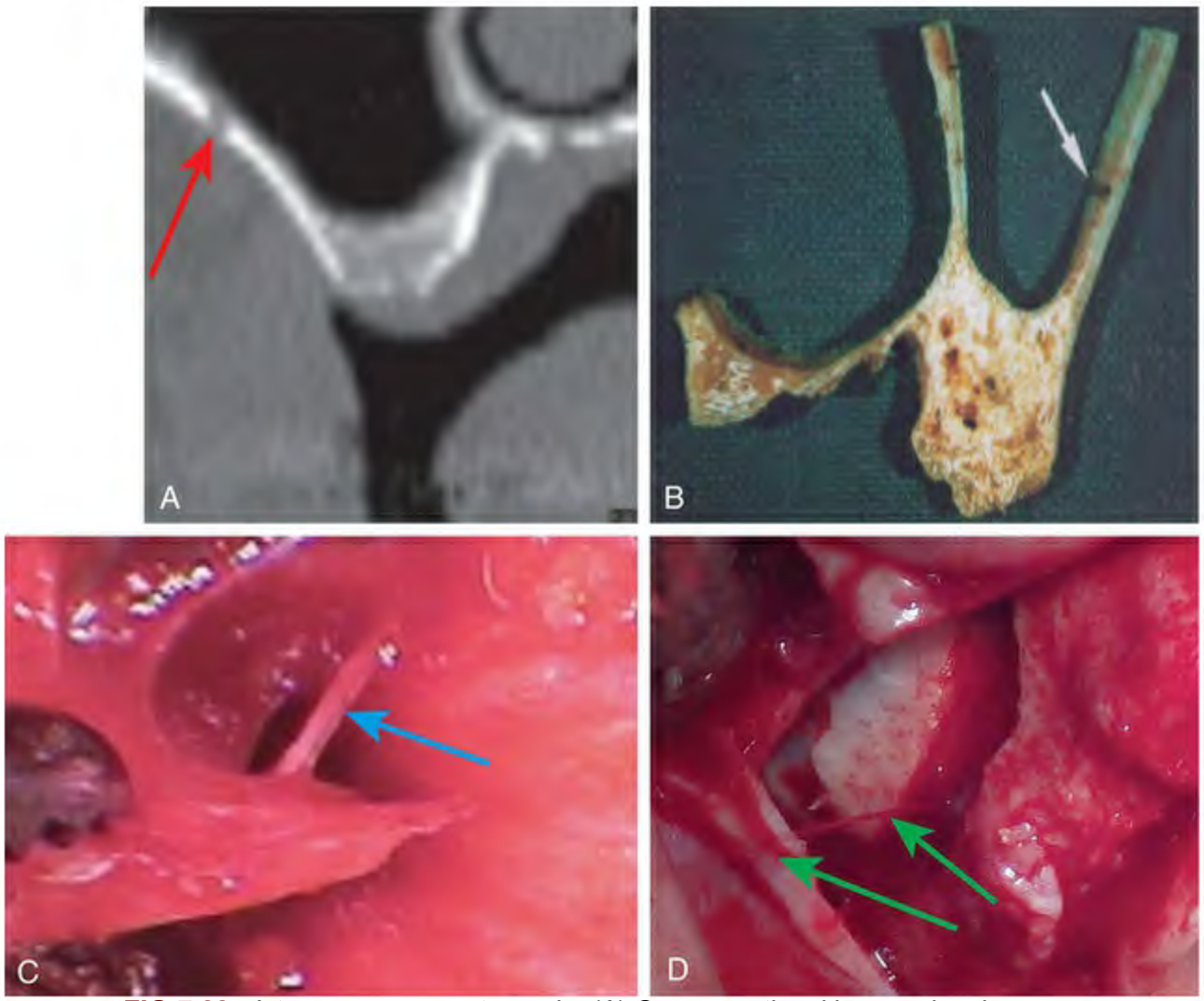

FIG 7.28 Intraosseous anastomosis. (A) Cross-sectional image showing radiolucent notch on the lateral wall of the sinus *(red arrow)*. (B) Intraosseous notch *(white arrow)*. (C) Clinical view of lateral wall removed showing size of intraosseous anastomosis *(blue arrow)*. (D) Intraosseous anastamosis pulsating bleed.

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Posterior Lateral Nasal Artery

The third artery implant surgeons should be cautious of is the posterior lateral nasal artery (Fig. 7.29). This artery is a branch of the sphenopalatine artery, which is located within the medial wall of the antrum. As it courses anteriorly, it anastomoses with terminal branches of the facial artery and ethmoidal arteries. A significant bleeding complication may arise if this vessel is severed during elevation of the membrane off the thin medial wall.

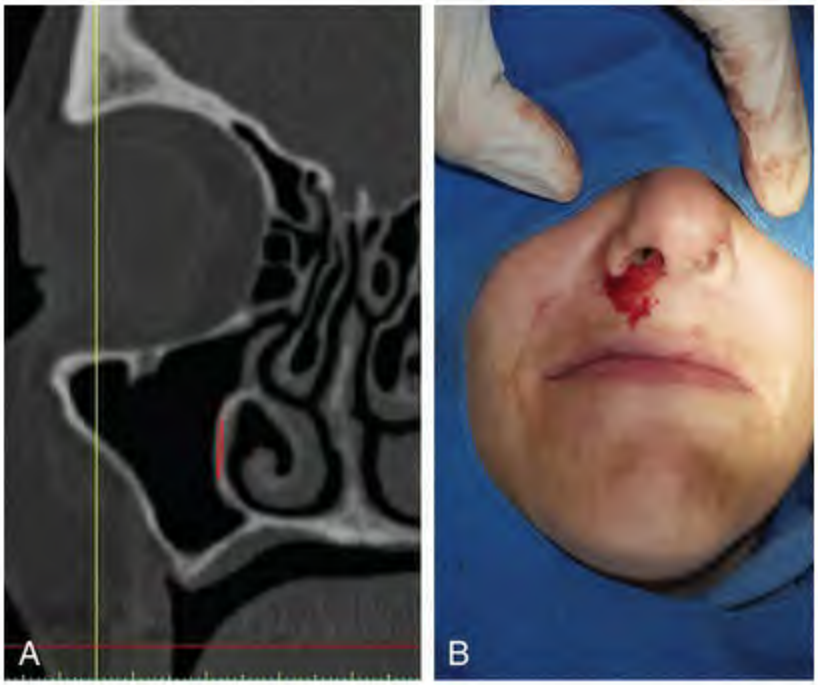

FIG 7.29 (A) Posterior lateral nasal artery *(red line)* in close approximation to the lateral wall of the nasal cavity (medial wall of maxillary sinus). (B) Nasal bleed during sinus augmentation procedure.

If the excessive bleeding occurs while the medial wall is elevated, the sinus may be packed with hemostatic agents, followed by packing with large 4 × 4-inch surgical sponges, and elevation of the head. Once the bleeding is arrested, the sponges are removed, the layered graft materials may be inserted, and the procedure completed.

Epistaxis (active bleeding from the nose) following sinus graft surgery is rather common. This may occur with or without a membrane perforation. Usually epistaxis is limited to the first 24 hours after surgery, and the patient should always be warned of this potential complication.

If bleeding should occur through the nose, there exist numerous techniques to obtain hemostasis. Placing a cotton roll, coated with petroleum

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jelly with dental floss tied to one end, within the nares may obtund nose bleeding after the surgery. After 5 minutes the dental floss is gently pulled and the cotton roll removed. The head is also elevated, and ice is applied to the bridge of the nose. If bleeding cannot be controlled, reentry into the graft site and endoscopic ligation by an ENT surgeon may be required.

If the orbital wall of the sinus is perforated or if an opening into the nares is already present from a previous event (i.e., previous sinus surgery), the sinus curette may enter the nares and initiate bleeding. The arteries involved in this site are composed of branches of the sphenopalatine and descending palliative arteries, which are branches of the internal maxillary artery. The posterior half of the inferior turbinate has a venous network, the Woodruff plexus, which is highly vascular. A cotton roll with silver nitrate or lidocaine with 1 : 50,000 epinephrine is also effective in obtaining hemostatis.

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Postoperative Bleeding Control

Patient Education

It is imperative that patients understand that minor oozing may persist for up to 24 hours after dental implant surgery. If the patient is on anticoagulants, this may persist for up to 48 hours. The patient should be instructed on the use of pressure dressings, and special care should be taken to minimize any trauma to the surgical site (e.g., eating, pulling on lip to see surgical site). The patient should avoid rinsing the mouth vigorously. All postoperative instructions should be reviewed with the patient and given in writing prior to surgery.

Patients should be instructed to limit their activities for a minimum of 24 hours depending on the extent of the surgery. The head should be elevated as much as possible during the daytime hours and the use of two pillows (i.e., elevate head) during sleeping will reduce secondary bleeding episodes.

Postoperative hemorrhage in the anticoagulated patients may lead to significant issues. Studies have shown bleeding episodes in anticoagulant patients will most likely occur within 6 days of the surgery.[53] In patients who have exhibited significant bleeding during surgery, hemorrhagic shock, although rare, should be evaluated. If the patient displays any signs or symptoms of shock (e.g., tachycardia, hypotension, lethargy, disorientation, cold/clammy skin), immediate medical assistance should be summoned. Treatment would include intravenous fluid replacement to replenish the intravascular volume and restore tissue perfusion.

Finally, caution should be exercised on the postoperative use of medications that may increase bleeding. A comprehensive review of the patient's medications should be completed to determine if any drug interactions may exist that would increase bleeding. Agents that interfere with platelet function should be avoided for routine analgesia (e.g., nonsteroidal antiinflammatory drugs [NSAIDs], aspirin) unless the benefit outweighs the increased risk of bleeding. The routine perioperative use of aspirin should usually be avoided due to an increased risk of bleeding and lack of benefit. However, if these medications are administered for a separate indication under the recommendation of a physician (e.g., recent stroke, acute coronary syndromes, implanted coronary stent) they should be continued.

Summary

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During the course of any dental implant surgery, the opportunity for a bleeding episode exists. The network of vascular structures coursing through the maxillofacial region is extensive, and many of these structures lie extremely close to the surgical site, regardless of procedure. Damaging these vessels may cause bleeding episodes that range from very benign to life-threatening events, and the ability to achieve hemostasis is of paramount importance. Maintaining hemostasis during the surgical procedure is crucial to preserving the physiologic functions of the patient, providing the implant clinician with a clear operating field, and allowing for successful postoperative wound healing. Understanding factors that predispose the patient to bleeding issues should be evaluated for each patient. The arterial vs. venous bleeding is much different and should be able to be differentiated to determine the origin of the bleeding and treated accordingly. The clinician must be able to eliminate potential risks that increase bleeding and to utilize various techniques to maintain hemostasis throughout the intra- and postoperative time periods.

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Intraoperative Complications

Infection

Randolph R. Resnik, Joseph E. Cillo

Among the numerous potential complications that clinicians face during implant or bone grafting surgery, the possibility of infection by microorganisms carries some of the most significant ramifications. Infection can lead to a multitude of problems, including pain, swelling, loss of bone, possible failure of the implant, and patient morbidity issues. Studies have shown that infection after implant surgery occurs approximately 4% to 10% of the time with over 66% of implants failing.[1] It is crucial for the implant clinician to prevent, diagnose, and treat infections associated with implant procedures.

There is a large contingent of factors that may promote the occurrence of infection during the surgical implant process. Given that dental implants and bone graft materials are placed in an entirely nonsterile environment, the clinician must pay attention to every aspect that may hinder the healing process and promote infection at the surgical site. In this regard, the clinician must obtain a detailed history of the patient's past and current medical histories and any medications/supplements. This will allow the clinician to obtain the best possible environment to achieve surgical implant success.

Some of the systemic conditions that clinicians placing implants may encounter, such as diabetes, may contribute to an increased chance of infection in the implant and bone graft patient. Uncontrolled diabetes has long been known as a potential source of infection in dental implant surgery.[2] Additionally, two often overlooked medical conditions that have recently been shown to increase the occurrence of infection and failure in implant and bone graft surgery are the high levels of low-density lipoprotein (LDL) cholesterol and low levels of serum vitamin D. These and other biologic conditions highlight the importance of a comprehensive medical history to ascertain the risk of infection in the dental implant patient (Box 8.1).[3]

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Box 8.1

Factors Associated With Increased Risk of Infection for Dental Implant Procedures

Systemic Factors

- Diabetes
- Long-term corticosteroid use
- Smoking
- Immunocompromised systemic disorders
- Malnutrition, obesity
- Elderly population
- ASA 3 or ASA 4

Local Factors

- Use/type of grafting material (autogenous, allograft, alloplast)
- Periodontal disease
- Tissue inflammation
- Odontogenic infections
- Ill-fitting provisional prosthesis
- Incision line opening
- Inadequate hygiene

Surgical Factors

- Poor aseptic technique

- Skill/experience of the surgeon
- Increased duration of surgery
- Wound contamination during surgery
- Foreign body (implant)

ASA, American Society of Anesthesiologists, physical status classification.

(From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Patients with one or more of the above diseases need to be evaluated as high risk for postoperative infection and delayed healing. A medical clearance from the patient's physician along with antibiotic prophylaxis is highly recommended.

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Risk of Infection

Even under ideal conditions a dental implant or bone graft is basically placed into a contaminated field due to the natural flora of the oral environment. The amount of bacteria required to cause an infection is far less than that required in a clean surgical wound. For example, when a suture is placed through the tissue, the amount of bacteria that is needed to cause an infection is reduced by a factor of 1000. Thus not only are these procedures complicated by the initial bacterial load but also by an inoculation of the implant or bone graft area by oral bacteria.[4]

To evaluate the risk for postoperative wound infection, a classification of operative wounds and risk of infection was developed by the American College of Surgeons Committee on Control of Surgical Wound Infections. All surgical procedures were classified according to four levels of contamination and infection rates. Within these classifications, it is generally accepted that all class 2, class 3, and class 4 procedures warrant the use of prophylactic antibiotics (Box 8.2).[5]

Box 8.2

Surgical Wound Classifications With Associated Infection Rates

Class 1: Clean (<2%)

- Elective, nontraumatic surgery; no acute inflammation, respiratory, gastrointestinal, and biliary tracts not entered

Class 2: Clean-Contaminated (10% to 15%)

- Elective opening of the respiratory, gastrointestinal, and biliary tracts entered
- **Elective dental implant and bone procedures**

Class 3: Contaminated (20% to 30%)

- Inflammation; gross spillage from gastrointestinal and biliary tracts along with fresh traumatic injuries

Class 4: Dirty/Infected (50%)

- Established clinical infection; perforation of respiratory, gastrointestinal, and biliary tracts

(Adapted from American College of Surgeons Committee on Control of Surgical Infections. *Manual on control of infection in surgical patients*, ed 2, Philadelphia, 1984, JB Lippincott.)

By definition, elective dental implant surgery falls within the class 2 (clean-contaminated) category. Class 2 medical and dental surgical procedures have been shown to have an infection rate of 10% to 15%. However, with proper surgical technique and prophylactic antibiotics, the incidence of infection may be reduced to less than 1%. In a healthy patient, risk of infection after dental implant surgery is influenced by numerous factors such as type and location of surgery, skill of the surgeon, methods of intraoperative management, patient factors, and aseptic technique.[6,7] Moreover, additional patient-related (systemic and local) risk factors that are not addressed in these classifications and mentioned above have also been correlated with increased susceptibility to infection.

One of the most significant surgical factors that may contribute to infection is poor aseptic technique. Various routes of transmission of virulent bacteria include (1) direct contact with the patient's blood or other body fluids; (2) indirect contact with contaminated objects; (3) contact of infected nasal, sinus, or oral mucosa; and (4) inhalation of airborne microorganisms. To prevent these conditions a controlled, well-monitored aseptic setting should be achieved for the surgical procedure. The aseptic surgical site includes proper disinfection and draping procedures of the patient, hand scrubbing, sterile gowns worn by all surgical members, and maintenance of complete sterility of the instrumentation.

Another important surgical factor related to postoperative infection is the duration of the surgical procedure. This factor has been shown to be the second most critical risk factor (after wound contamination) affecting postoperative infection rates. In general, surgical operations lasting less than 1 hour have an infection rate of 1.3%, whereas those lasting 3 hours have a rate of more than 4%.[8] It is postulated that the rate of infection doubles with every hour of the procedure.[9]

The skill and the experience of the surgeon with the placement of implants have been shown to be significant in postoperative infections and implant

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failures. A recent study has shown that less experienced surgeons (<50 implants placed) have 7.3% more failure rates than do experienced surgeons.[10] Clinicians early on their learning curve must adhere to strict aseptic protocol and good surgical technique to reduce the possibility of infections.

In the medical literature, it is well documented that the insertion of any prosthetic implant or device increases the chance of infection at the surgical site. A dental implant can act as a foreign body, and the host's defenses may be compromised. The surface of the implant has been shown to facilitate bacterial adherence, and the presence of an implant can compromise the host's defenses. This may result in normal flora with low virulence potential causing infections at the implant-host interface, which has been shown to be very difficult to treat.[11]

The probability of risk for infection for a given procedure is related to local, systemic, and surgical factors. The patient's American Society of Anesthesiologists (ASA) score may be used as the systemic baseline and then can be correlated with various local and surgical factors. A risk index may then be modified from the literature to correlate these factors to dental implant surgeries. The probability of wound infection may then be correlated with the type of wound contamination (class 1 to 4) and the risk index. A class 2 wound and a risk index 2 has a greater risk of complications, and a class 1 wound and risk index 0 has the least risk of postoperative infection (Table 8.1).[12]

TABLE 8.1

Probability of Wound Infection by Type of Wound, Risk Index, and ASA Status

	RISK INDEX		
Operation Classification	**0**	**1**	**2**
Clean	1.0%	2.3%	5.4%
Clean-contaminated	2.1%	4.0%	9.5%

ASA, American Society of Anesthesiologists, physical status classification; 0; ASA 1 or ASA 2: As the number of local and surgical risk factors increase, the probability of wound infection increases significantly.

(From Misch CE: *Contemporary implant dentistry*, ed 3, St. Louis, 2008, Mosby; data from Cruse PJ Foord R: A five year prospective study of 23,649 surgical wounds, *Arch Surg* 107:206–210, 1973.)

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Diagnosis of an Infection

Etiology of the Infectious Process

In order to determine if an infection is present the clinician must evaluate various factors, which include the host, environment, and the organism. In health, there exists a balance between the three. In a diseased state, there is an imbalance between the three, with the host usually being the most important factor in determining the outcome of the infection. There exists an adversarial relationship between infectious microbes and the host (Box 8.3).

Box 8.3

Microorganisms Most Commonly Associated With Periimplant Complications

Staphylococcus spp

Actinomyces spp

Surface translocating bacteria

Wolinella spp

Capnocytophaga spp

Fusobacterium spp

Entamoeba gingivalis

Motile rods

Fusiforms

Spirochetes

Enteric gram-negative bacteria

Candida albicans

(From Misch CE: *Contemporary implant dentistry*, ed 3, St. Louis, 2008, Mosby.)

The pathologic potential of microbes depends on three factors[4]:

1. **Virulence:** the degree of pathogenicity of a microorganism, which includes the pathogen's genetic, biochemical, and structural features.

2. **Pathogenicity:** the potential or capacity of a pathogen to cause disease.

3. **Infectivity:** the ability or level at which a pathogen may infect the host and cause an infection.

In normal conditions the host factors will predominate, and a greater number of host factors present will increase the ability to fight infection. If the microbial load increases, an imbalance occurs until the microbial factors predominate, which results in infection. During a dental implant procedure, usually there is a breakdown in the local natural barrier, which may lead to microbes obtaining an advantage over the host defenses. This will result in the host mobilizing humoral and cellular factors.

Humoral immunity is mediated by macromolecules, which are found in extracellular fluids such as antibodies, proteins, and antimicrobial peptides. Humoral immunity substances are found mainly in bodily fluids. Antibodies or immunoglobulins are glycoproteins that are found in the blood and tissue fluids. An antibody identifies and neutralizes the bacteria by binding to the antigens and causing agglutination, which allows for phagocytosis to break down the bacteria.

Cellular immunity is the body's immune response that does not involve antibodies, but utilizes phagocytes, T lymphocytes, and cytokines in response to an antigen. Cellular immunity protects the body from infection via three mechanisms:

1. activating T lymphocytes that are antigen specific to induce apoptosis within the body's cells;

2. activate macrophages that destroy pathogens and debris;

3. stimulate cells to secrete a variety of cytokines that influence the functional aspects of cells in adaptive immune responses.

In most hosts, these humoral and cellular defenses are sufficient to prevent dissemination of the pathogens and allow for normal healing, free of infections. However, in some instances, the presence of foreign bodies (implants, bone grafts) and a breakdown in local defenses will result in an infectious process.[13,14]

Host Response to Infection

When the infectious pathogens overcome the host defenses and result in an infection, the host will trigger a series of reactions in response to the infectious insult. The first initial reaction is the inflammatory reaction, which consists of a release of mediators, vascular changes (vasodilation or hyperemia and increased vascular permeability), and mobilization and activation of leukocytes. This is the body's physiologic response to the antigenic stimulation to rid itself of the infectious stimulus, which is localized to the site of the infectious pathogen. Normally, the initial inflammatory response to infection is rapid, usually within minutes of the pathologic stimulus.

The inflammatory response is designed to eliminate the infectious pathogens and allow for tissue healing. In a healthy individual, there are six phases of the inflammatory response:

1. hyperemia, which is caused by vasodilation of the arterioles and capillaries, and increased permeability of venules with the slowing of the venous blood flow;

2. exudate that is rich in plasma proteins, antibodies, nutrients, and leukocytes enters into the surrounding tissue;

3. leukotaxin, a permeability factor, is released, which is essential for the migration of polymorphonuclear leukocytes toward the infected area;

4. fibrin synthesis from the exudate, which walls off the area of infection;

5. phagocytosis of the bacterial and dead cells;

6. macrophages dispose of the necrotic debris.

In addition to the inflammatory reaction they cause, pathogens may attack the host by direct injury to the host cells, enhancement of the pathogen's

invasiveness, and neutralization of the host defenses. Systemic effects may result such as fever, shock, hypersensitivity reactions, and autoimmune responses and may be life threatening.[4]

Impaired Host Defenses

As stated previously, the host defenses are the most important aspect in the resolution of the infection. With the inflammatory response a migration of the white blood cells and the production of antibodies results, which may resolve the infection allowing for normal tissue healing. However, if the host defenses are impaired in any way, the host will not be able to overcome the infectious process. Peterson has shown that depressed defenses are divided into four categories: physiologic, disease-related, impaired immune system, and drug suppression–related.[4]

Physiologic.

The patient has the inability to deliver white blood cells, antibodies, and complements to act against the bacterial insult. This may be related to increased age, obesity, lifestyle issues, and fluid imbalances. Also, stress and many psychologic disorders have been associated with this immune suppression.

Disease Related.

Several diseases may affect the defense system, such as malnutrition, cancers (e.g., leukemia, lymphoma, multiple myeloma), uncontrolled diabetes, pulmonary diseases, and human immunodeficiency virus (HIV).

Impaired Immune System.

The immune system may be suppressed in congenital defects (e.g., agammaglobulinemia) in combination with health issues such as multiple myeloma and radiation therapy.

Drug Related.

There are numerous drug-related groups that may affect the defense systems.

Cytoxic drug group.

These drugs (e.g., alkylatine, antimetabolite drugs) exert their cytotoxic effect

on the DNA or RNA, which results in protein synthesis and cell division. The end result will be the impaired proliferation of fibroblasts and collagen formation, which predisposes implant patients to poor wound healing and increased infection rate.

Glucocorticosteroids.

The use of glucocorticoids (e.g., prednisone, dexamethasone) suppresses the inflammatory response, which may result in wound healing complications and possible infection. The exogenous corticosteroids decrease collagen formation, vascularity, and fibroplasia. The fibroblasts are decreased by approximately 30%, thus delaying epithelialization and wound contraction.[15]

Antibodies (e.g., mono- and polyclonal).

Mono- and polyclonal antibodies are lab-produced molecules that are specifically engineered to attach to specific defects in cancer cells. They mimic the antibodies your body naturally produces in response to bacterial infections.

Drugs acting on immunophilins.

Cyclosporine, which is used in organ transplantation, depresses the T cells while allowing the B cells to continue their antibacterial activity. Additional drugs, which affect immunophilins, are interferons, opioids, and tumor necrosis factor (TNF)–binding proteins.

Signs of Infection

To ascertain if an infection is present, it is crucial to evaluate the patient for local signs that may include pain, swelling, erythema, presence of exudate, and limitation in motion. Systemically, the patient may present with fever, lymphadenopathy, malaise, and an elevated white count.

Vital Signs

The patient's vital signs should be obtained, including blood pressure, pulse rate, respiratory rate, and temperature.

With infection, the following will be noted:

- Temperature: >101°F (38°C) (normal: 98.6°F [37 °C])
- Pulse Rate: >100 beats/min (normal: 60–100 beats/min)

- Blood Pressure: Systolic will be elevated if there is pain/anxiety
- Respirations: >18 breaths/min (normal: 14–16 breaths/min)

Objective Signs

There are five cardinal signs of inflammation:

1. *Rubor:* tissue redness, which is caused by arterial vasodilation.

2. *Tumor:* swelling, which is the accumulation of pus or fluid exudate.

3. *Calor:* heat, which is the result of inflow of warm blood from deeper tissues, increased quantity of blood from the vasodilation, and increased rate of metabolism.

4. *Dolor:* pain, which results from pressure on sensory nerve endings caused by the distention of the tissue.

5. *Functio laesa:* loss of function, which is difficulty in chewing, swallowing, and breathing.

A common acronym used to describe inflammation is PRISH: Pain, Redness, Immobility (loss of function), Swelling, and Heat.

Mild vs. Severe Infection

Mild Infection.

Normal vital signs with slight elevation of temperature. Usually associated with one of the following:

- Fatigue: extreme tiredness
- Malaise: a general feeling of discomfort, illness, or uneasiness
- Lethargy: lack of energy or enthusiasm

Severe Infection.

Elevated pulse, blood pressure, and respirations along with temperature and any of the following.[4]

Trismus.

Limited or reduced opening of the jaws caused by spasm of the muscles of mastication. This is usually painful and distressing to the patient, often interfering with eating, speech, and oral hygiene and causing an altered facial appearance. When the etiologic factor is infection, it is usually from a masticatory space or lateral pharyngeal space complication. Untreated, this may lead to spread of infection to various facial spaces that may lead to cervical cellulitis and mediastinitis. Trismus is classified as per the interincisal opening[16]:

- Normal (vertical): 35–45 mm
- Normal (lateral): 8–12 mm
- Mild: 20–30 mm
- Moderate: 10–20 mm
- Severe: <10 mm

Lymphadenopathy.

In general, palpable lymph nodes greater than 1 cm in diameter are considered to be abnormal and should be subject to further evaluation. Lymphadenopathy is referred to nodes that are abnormal in either size, consistency, or number. The lymphadenopathy is classified as *generalized* if lymph nodes are enlarged in two or more noncontiguous areas or *localized* if only one area is involved.[17] In acute infection the lymph nodes are enlarged, soft, and tender, and the skin is red. With chronic infection the enlarged nodes are less firm, not tender, and edema of the surrounding area exists.

Dysphagia.

Symptoms of dysphagia include difficulty in chewing, initiating swallowing, difficulty in moving food or liquids from the mouth to the throat, and pain during swallowing. Dysphagia requires immediate medical care.

Dyspnea.

Dyspnea is difficult or labored breathing, requiring immediate medical care. Additional symptoms may include respiratory impairment, difficulty in swallowing, impaired vision, severe headache, stiff neck, vomiting, and decreased level of consciousness, which all would necessitate immediate medical care.

Definitions of Terms Related to Postoperative Infection

The definitions of specific terms that describe infections of the head and neck provide keys to the methodology of treatment and improved communications (Box 8.4 and Table 8.2).

Box 8.4

Common Terms Related to Postoperative Infection

Abscess: most commonly has distinct and well-defined borders, usually very soft and doughy. Will be fluctuant to palpation because of fluid involvement. The presence of pus will most likely indicate the body has walled off the infection and the body's host defenses are controlling the infection.

Cellulitis: is typically larger and more widespread than an abscess or edema. Its borders are more diffuse; thus the clinician cannot determine borders. Is usually indurated or hard to palpation and contains no pus. The severity of the infection is proportional to the firmness.

Chronic skin fistula: is a sign of retained focus of infection and, in some cases, a more serious condition of bone and bone marrow inflammation called osteomyelitis. This is most likely observed in the mandible and is associated with infection of both endosteal and subperiosteal implants in patients who have poor dental hygiene awareness and lack of implant maintenance.

Edema: is characteristic of the inoculation stage and is the easiest stage to treat. Is more diffuse and jelly-like with minimal tenderness to palpation

Lymphadenitis: is a condition in which the regional lymph nodes become inflamed, enlarged, and tender. The node may become suppurated, break through the capsule, and involve the surrounding tissues.

Noma: starts as a gangrenous stomatitis and spreads to adjacent bone and muscles, causing lysis and necrosis of tissue. This rare condition perforates the cheek, floor of the mouth, or both, and is usually seen in debilitated individuals.

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Phlegmon: is any cellulitis that does not go on to suppuration. In this condition the inflammatory infiltration of the subcutaneous tissue leads to accumulation of foul-smelling brownish exudate. Hemolytic streptococci are usually present.

Sepsis: is a whole body inflammatory reaction to infection. The signs and symptoms include fever, increased heart rate, increased respiration, and confusion. Sepsis is usually caused by an immune response triggered by a bacterial infection and is treated with intravenous antibiotics and fluids. If the patient does not respond to intravenous fluid treatment, the patient may go into septic shock, which is characterized by severe hypotension. These patients are usually treated in an intensive care unit in a hospital.

TABLE 8.2

Edema vs. Cellulitis vs. Abscess

Characteristic	Edema (Inoculation)	Cellulitis	Abscess
Duration	0-3 days (acute)	1-5 days (acute)	4-10 days (chronic)
Pain, borders	Mild-moderate	Severe, localized	Moderate, localized
Size	Small	Large	Smaller
Color	Normal	Reddened	Shiny center, peripheral reddened
Consistency	Jelly-like	Doughy, indurated	Fluctuant
Progression	Increasing	Increasing	Decreasing
Exudate	None	None	Present
Bacteria	Aerobic	Mainly aerobic	Anaerobic
Surface temperature	Slightly heated	Hot	Moderately heated
Levels of malaise	Mild	Severe	Moderately severe
Seriousness	Minimal	Greater	Less

Stages of Infection

There are two main stages of clinical infection, a cellulitis stage and an abscess stage.

Cellulitis Stage

The initial stage of clinical infection is the cellulitis stage, which exhibits classic signs of inflammation: heat, pain, redness (erythema), and swelling (edema) (Fig. 8.1). These are sometimes referred to in the Latin as *calor, dolor, rubor,* and *tumor,* respectively. Heat *(calor)* is the result of the inflow of blood and an increased local metabolic rate in attempts by the body to both fight and localize the infection. Pain *(dolor)* results from the increasing pressure on local sensory nerve endings caused by the release of endogenous

inflammatory mediators, such as histamine, and the resulting edema. Edema *(tumor)* is this associated swelling as well as the influx of blood and fluid exudate into the local area. Redness *(rubor)* is the result of vasodilation close to the mucosa/skin surface as a combined result of the other signs. Once the body begins to successfully wall off and fight the developing infection or the use of medications, such as antibiotics, is initiated, the clinical stage of the infection may progress to the abscess stage.

FIG 8.1 Cellulitis Stage of Infection: the initial stage of infection characterized by edema (tumor) that is associated with swelling caused by an influx of blood and fluid exudate *(arrow)*.

Abscess Stage

The abscess stage is the last stage of an infection. An abscess is an enclosed collection of liquefied tissue, or pus, that is the result of the body's defensive reaction to foreign materials or organisms (Fig. 8.2). The abscess will form once the cellulitis stage begins to consolidate through the body's immune system response through the use of appropriate antibiotics. Once an abscess is formed, the purulence that produced it will migrate by the path of least resistance. This may be either through the mucosa or skin or through the fascial pathways of the head and neck. An abscess that migrates through the deeper layers of the head and neck, through the lingual mandibular plate to the sublingual space for example, may block respiration (as in Ludwig's angina) or enter the brain (as in cavernous sinus thrombosis or meningitis). This may be life threatening and require immediate surgical and medical attention. When an abscess spontaneously drains to an area outside the body, an orocutaneous fistula for example, it will continue until the source of the

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infection is treated.

FIG 8.2 Abscess Stage of Infection. The infection has resulted in the formation of an orocutaneous fistula *(arrow)*, in which purulence drains via the path of least resistance.

Determination of infection stage.

One of the primary ways to distinguish among the various stages of infection is to palpate the area in question. The following should be noted:

Temperature: evaluate warmth or heat, which is sign of infection

Consistency of the swelling:

Soft to firm (doughy): usually inoculation stage

Hard (indurated): cellulitis stage

Fluctuance fluid (pus): abscess stage

Routes of Infection

The principal routes for the spread of infection are through the following four mechanisms:

1. *Vascular System:* The vascular system of the head and neck allows for the

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spread of infection because pathogens may travel via the venous system, which drains into other tissues or organs (Fig. 8.3).

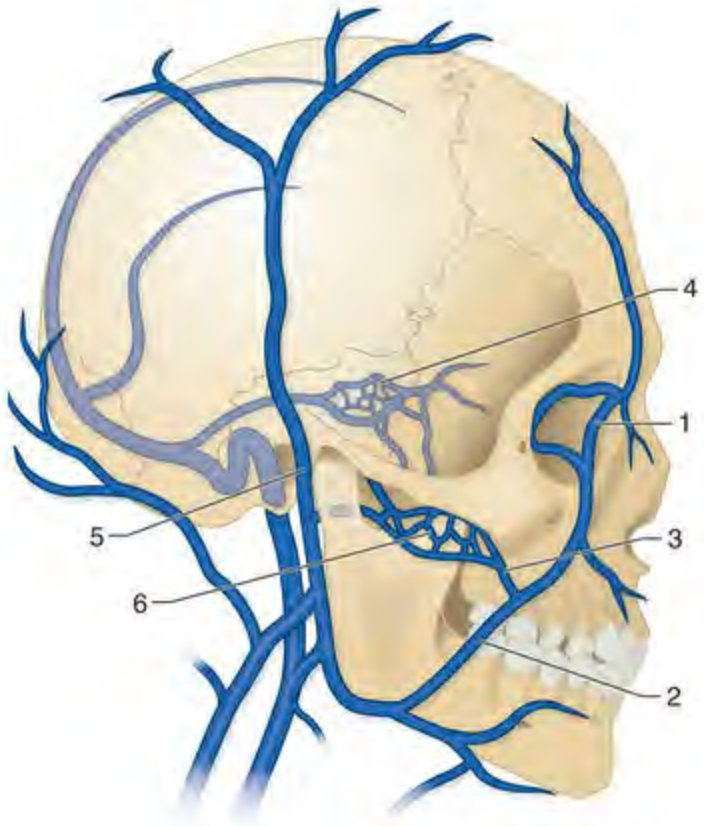

FIG 8.3 Veins implicated in the spread of infection. 1, angular vein connecting to ophthalmic vein and then to cavernous sinus; 2, facial vein to deep facial vein (3) connecting to pterygoid plexus of veins; 4, emissary veins; 5, maxillary vein; 6, pterygoid plexus of veins.

2. *Thrombophlebitis:* Infection may spread to the walls of the veins, which may also thrombose and create a condition referred to as *thrombophlebitis*. A lack of valves in the head and neck's venous system allows retrograde flow of blood and may involve the cavernous sinus, pterygoid, and pharyngeal plexuses with infected thrombi.

3. *Lymph Vessels:* The lymph vessels are very prevalent in the head and neck (Fig. 8.4). They commonly drain the infected site and carry the infection to regional lymph nodes. The nodes become tender, enlarged, soft, and mobile on palpation. This is termed *lymphadenitis*.

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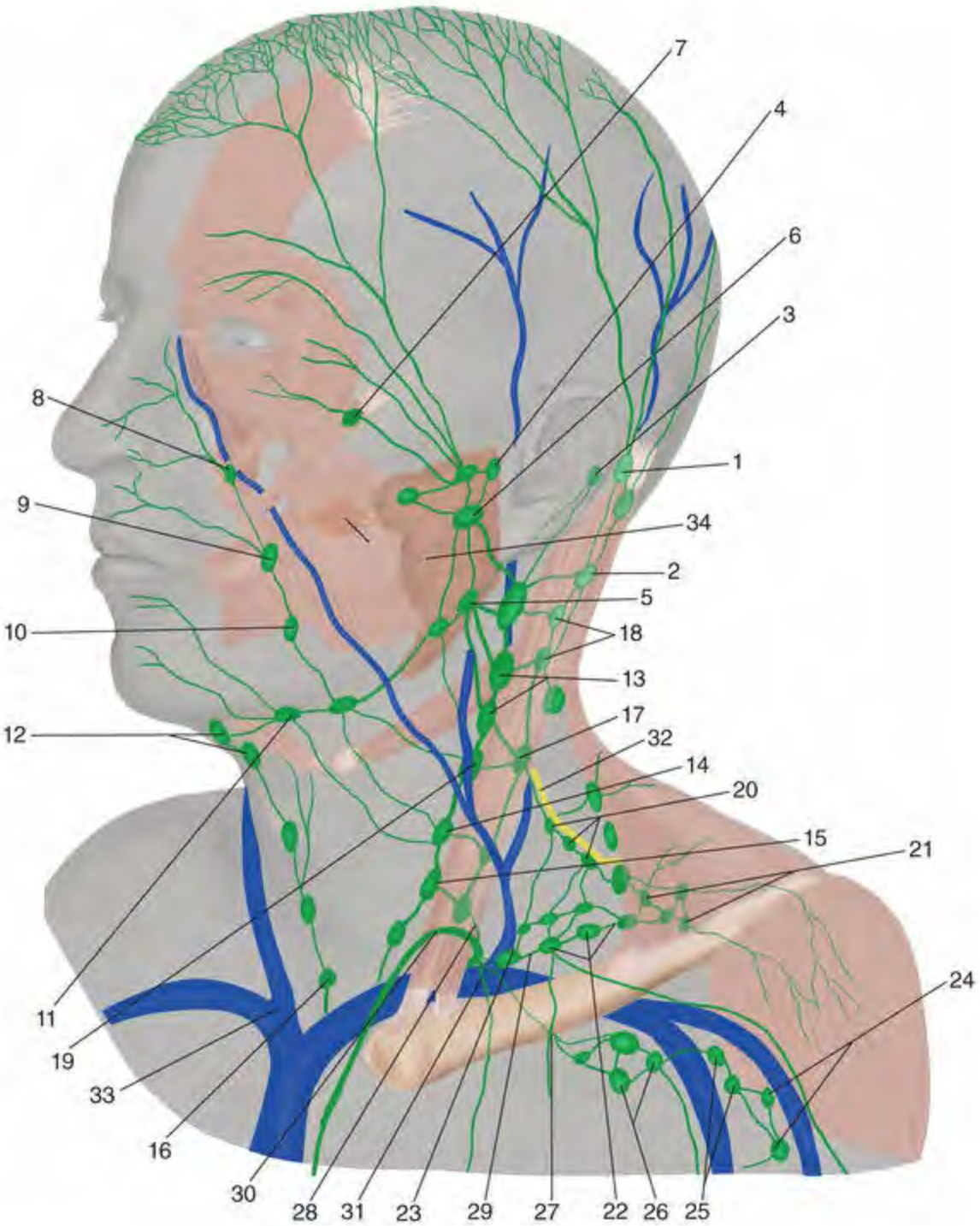

FIG 8.4 Lymph Nodes: Parotid - 6, Submental - 12, Submandibular - 11, Posterior Auricular - 3, Occipital - 1, Deep Cervical - 2, 18.

4. *Fascial Spaces:* Once the infection is outside the bone, the loose areolar connective tissue produces a path of least resistance into the various surgical spaces of the head and neck, including the thoracic mediastinum (Fig. 8.5). The muscle attachments to the maxilla, mandible, and fascial compartments limit or direct the path of infection. Infections that may occur after surgeries

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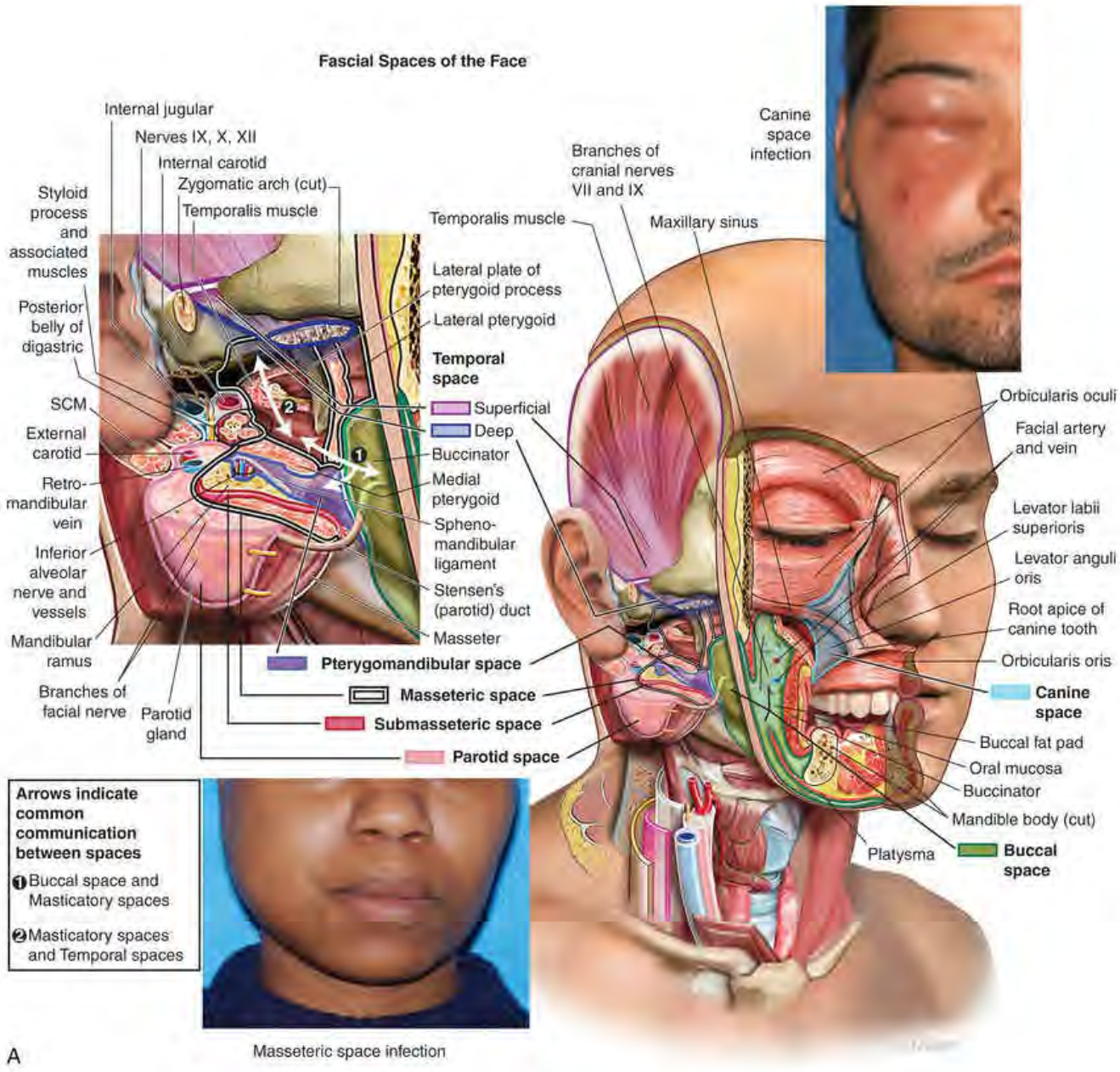
involving reflection of muscle attachments may permit the infection to spread more easily into these surgical spaces. It is prudent to prophylactically cover patients with antibiotics when larger regions of soft tissues are reflected beyond the facial vestibule or mucobuccal fold, which violate the muscle attachments and invade the subcutaneous tissues.



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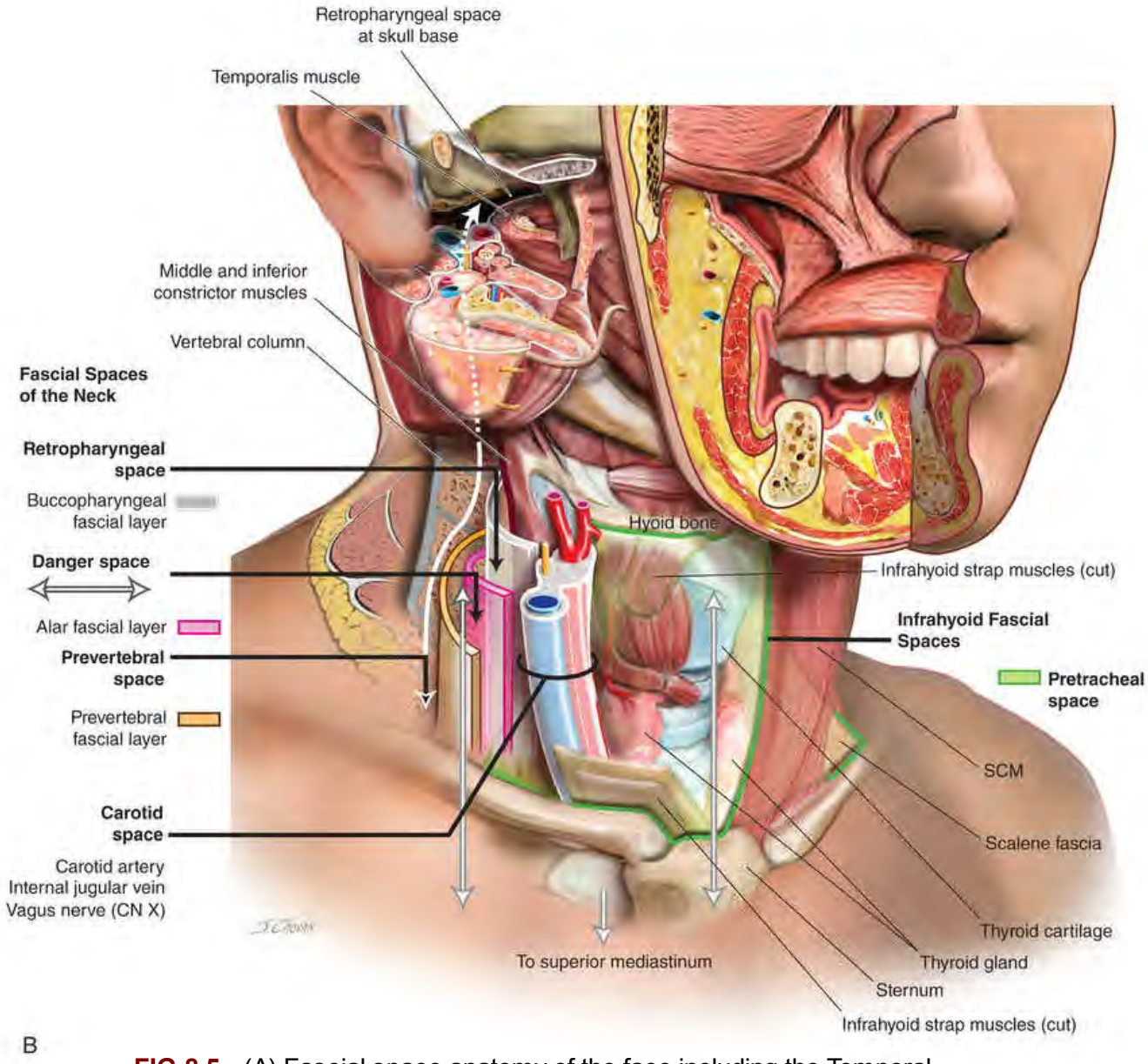

FIG 8.5 (A) Fascial space anatomy of the face including the Temporal, Pterygomandibular, Masseteric, Parotid, Canine, and Buccal spaces. (B) Fascial spaces of the neck. (From Kademani D, Tiwana P: *Atlas of oral and maxillofacial surgery*, St. Louis, 2016, Saunders.)

Lymphatic Spread of Infection

The lymphatic system is a part of the greater lymphoid system and is a part of the body's immune system. It is an accumulation of small vessels connected by lymph nodes that function as a fluid return system for the body. A filtrate of the blood plasma flows out of the capillaries into the surrounding tissues, where it becomes extracellular fluid and is eventually gathered by the lymphatic vessels. Through a continuous circulation process, the lymph nodes filter the extracellular fluids, while lymphocytes, produced

within the lymph nodes, fight infectious organisms that are acquired throughout the system.

The head and neck region has a vast network of lymphatic drainage that aids in the fight of foreign microorganisms. There are approximately 600 lymph nodes in the body, but only the submandibular, axillary, or inguinal regions are palpable in the healthy patient. In the head and neck area the retropharyngeal, submental, submandibular and cervical lymph nodes are the most important to be evaluated in the diagnosis of infections. The retropharyngeal nodes are located behind the pharyngeal wall and drain to the upper deep cervical lymph nodes. The submental nodes are located under the chin, are small in number, and drain the anterior mandible and associated structures (mandibular incisors, the tip of the tongue, and the midline of the lower lip and chin), which then drain into the submandibular nodes or directly to the cervical nodes. The submandibular nodes are located around the submandibular gland, the areas of the maxillary teeth, maxillary sinus (except the maxillary third molars area), the mandibular canines, all mandibular posterior teeth, floor of the mouth, most of the tongue, the cheeks, the hard palate, and the anterior nasal cavity all drain to these nodes. As the submandibular lymph nodes drain a large and extensive area, they are usually the first to be noticed in the occurrence of oral infections. The cervical lymph nodes are divided into upper and lower divisions and are located deep in the neck. The upper deep cervical nodes are located on the lateral surface of the internal jugular vein and lie just beneath the anterior border of the sternomastoid muscle. They receive drainage from the submandibular and retropharyngeal nodes. The lower deep cervical nodes are also found on the lateral surface of the internal jugular vein and beneath the anterior border of the sternomastoid muscle (but lower, approximately 2 inches above the clavicle) and drain the upper deep cervical nodes and many of the nodes at the back of the neck. Both the upper and lower cervical lymph nodes are impractical to palpate.

Lymph Node Examination.

Ideally, in a lymph node examination, always examine both sides of the head simultaneously with the pads of the fingertips (most sensitive part of the hands) (Fig. 8.6). Use steady, gentle pressure to determine enlargement, inflammation, or pain with respect to the contralateral side. Evaluate for:

- Mobility (mobile vs. fixed)

- Consistency (soft vs. firm)
- Tenderness (tender vs. nontender)
- Shape (regular vs. irregular)

FIG 8.6 Palpating the deep cervical lymph nodes by having the patient's head turned. (From Fehrenbach MJ, Herring SW: *Illustrated anatomy of the head and neck*, ed 5, St. Louis, 2017, Elsevier.)

Fascial Spaces of the Face (see Fig. 8.5)

The fascial spaces of the face are subdivided into five spaces: the canine space, the buccal space, the masticatory space (further divided into the masseteric, pterygomandibular, and temporal spaces).

Canine Space.

The canine space is located between the levator anguli oris and the levator labii superioris muscles. Infection spreads to this space through the root apices of the maxillary teeth, usually the canine. Direct surgical access is achieved via incision through the maxillary vestibular mucosa above the mucogingival junction.

Buccal Space.

The buccal space is bounded anterior to the masticator space and lateral to

the buccinator muscle with no true superior or inferior boundary and consists of adipose tissue (the buccal fat pad that fills the greater part of the space), the Stensen duct, the facial artery and vein, lymphatic vessels, minor salivary glands, and branches of cranial nerves VII and IX. When infection is involved in the buccal space, the space can serve as a conduit for spreading disease between the mouth and the parotid gland. Surgical access to the buccal space infections may be easily accomplished through the intraoral approach. More complicated infections, directed by location within the buccal space, may require a preauricular and/or submandibular approach.

Masticatory Spaces

Masseteric space (and submasseteric space).

The fascia that forms the borders of the masticator space is a well-defined fibrous tissue that surrounds the muscles of mastication and contains the internal maxillary artery and the inferior alveolar nerve. It is bounded anteriorly by the mandible, posteriorly by the parotid, medially by the lateral pharyngeal space, and superiorly by the temporal space. Infections in this space may be misdiagnosed as a parotid abscess or parotitis.[18]

The most pronounced clinical feature of infection in this space is trismus. Computed tomography (CT) scan or magnetic resonance imaging (MRI) may be an invaluable resource to distinguish abscess from cellulitis and the surgical course required for treatment.[19]

Intraoral surgical access to this space for simple, isolated abscesses is generally adequate to allow for drainage but with extension into adjacent spaces, an external approach may be required.

Pterygoidmandibular space.

The pterygoidmandibular space is bounded by the mandible laterally and by the medial pterygoid muscle medially and inferiorly. The posterior border is formed by parotid glandular tissue, which curves medially around the posterior mandibular ramus and anteriorly by the pterygomandibular raphe, the fibrous junction of the buccinator and superior constrictor muscles. Surgical access to this space may be achieved intraoral in the case of simple infections, but may require extraoral access when multiple adjacent spaces are involved.[20]

Temporal space.

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The temporal fascia surrounds the temporalis muscle in a strong fibrous sheet that is divided into clearly distinguishable superficial and deep layers that originate from the same region with the muscle fibers of the two layers intermingled in the superior part of the muscle. Infections of odontogenic or implant treatment origin are rare in this space but may occur. If an abscess does develop in this space, intraoral incision and drainage is difficult and usually requires an extra oral approach. Communicating facial-zygomaticotemporal nerve branches piercing through the fascial and muscular planes of the temporal fascia in the superior part of the muscle are important landmarks to prevent temporal hollowing that may occur due to surgical access procedures.[21]

Sublingual Space.

The sublingual space is bounded between the mylohyoid muscle and the geniohyoid and genioglossus muscles. This space contains the lingual artery and nerve, the hypoglossal nerve, the glossopharyngeal nerve, Wharton's duct, and the sublingual salivary gland, which drains into the oral cavity through several small excretory ducts in the floor of the mouth and a major duct known as Bartholin's duct. Infectious spread to this space is through perforation of the lingual mandibular cortical plate (Fig. 8.7). Incision and drainage of abscesses in this area are generally adequately treated through a simple intraoral approach.

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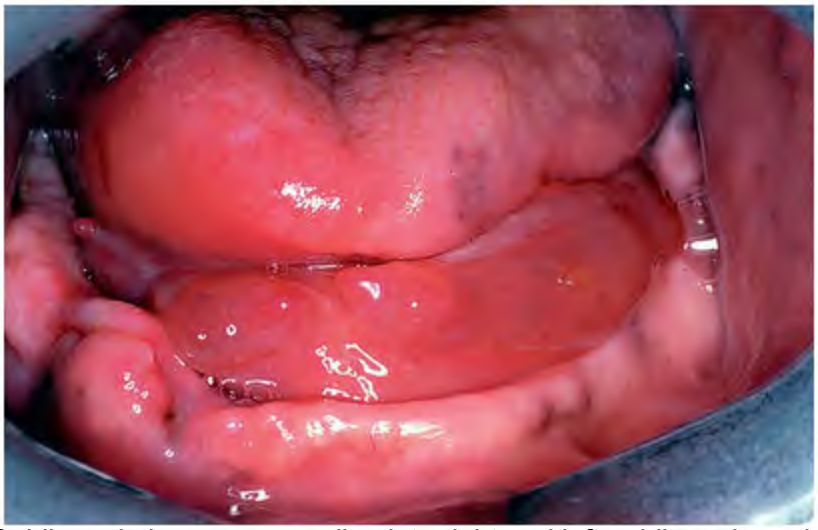

FIG 8.7 Sublingual abscess spreading into right and left sublingual surgical spaces and into the tongue. (From Hupp JR, Tucker MR, Ellis E: *Contemporary oral and maxillofacial surgery*, ed 5, St. Louis, 2009, Mosby.)

Submental Space.

The submental space is bounded anteriorly by the symphysis of the mandible, laterally by the anterior bellies of digastric muscles, superiorly by the mylohyoid muscle, and inferiorly by the superficial fascia of the platysma muscle. There are no vital structures that traverse the submental space. This space is usually involved in odontogenic infections from the anterior mandibular teeth as benign or malignant lesions in this area are rare. Surgical access for drainage of infection is generally through an extraoral incision below the chin (Fig. 8.8).

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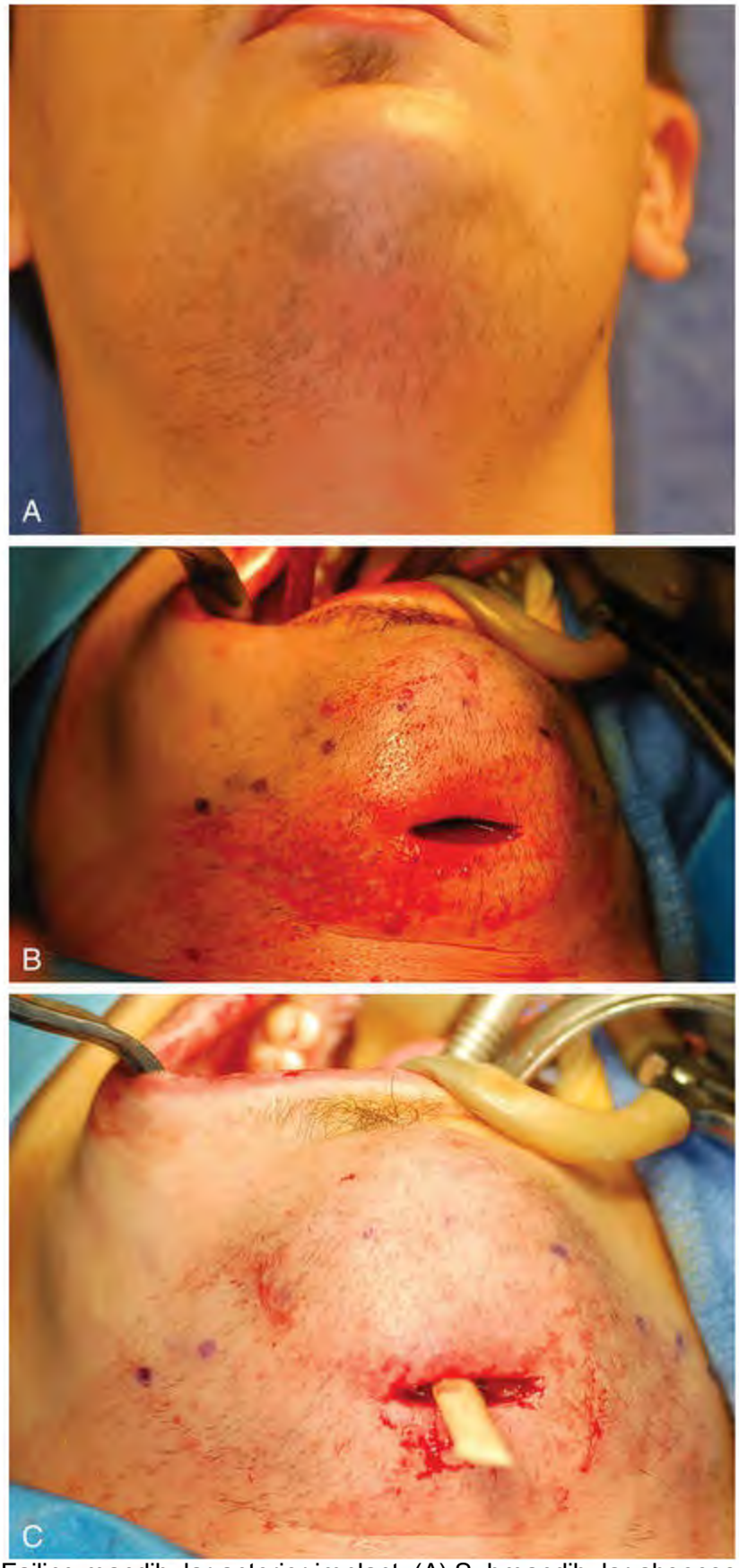

FIG 8.8 Failing mandibular anterior implant. (A) Submandibular abscess formation depicted as a submandibular swelling. (B) Incision and drainage. (C) Penrose drain placed.

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Submandibular Space.

The submandibular space extends from the hyoid bone to the mucosa of the floor of the mouth, and is bound anteriorly and laterally by the mandible and inferiorly by the superficial layer of the deep cervical fascia. The mylohyoid muscle separates it superiorly from the sublingual space, which communicates with it freely around the posterior border of the mylohyoid. The mylohyoid muscle also plays a key role in determining the direction of spread of oral infections. As it attaches to the mandible at an angle, infections that perforate the mandible on the lingual side above the mylohyoid line will involve the sublingual space below.

Surgical access for abscess drainage may be either intraoral or extraoral, but is generally more suited for the extraoral approach. When infection has spread to the bilateral submandibular spaces, it represents one of the components (along with submental and bilateral sublingual space involvement) of Ludwig's angina (Fig. 8.9). Surgical drainage in these situations is almost always through multiple extraoral incisions.

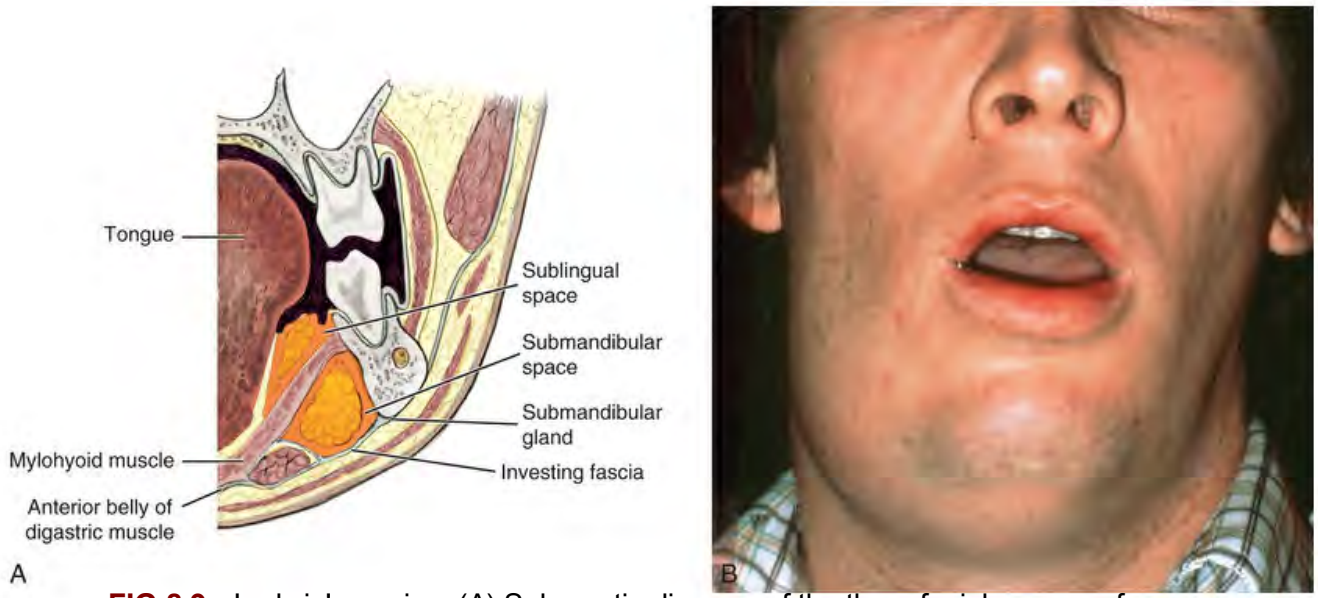

FIG 8.9 Ludwig's angina. (A) Schematic diagram of the three facial spaces of involvement. (B) Fascial space infection with bilateral involvement of the submandibular, sublingual and submental spaces. (A, From Fehrenbach MJ, Herring SW: *Illustrated anatomy of the head and neck*, ed 5, St. Louis, 2017, Elsevier. B, Auerbach FP: *Wilderness Medicine*, ed 6, Philadelphia, 2012, Mosby.)

Lateral Pharyngeal Space.

The lateral pharyngeal space is an inverted cone with its base at the base of skull and apex at the hyoid bone and is bounded posteriorly by the prevertebral fascia, anteriorly by the raphe of the buccinator and superior constrictors muscles, and laterally by the mandible and parotid fascia. Infections present with pain, fever, neck swelling below the angle of the mandible and trismus (Fig. 8.10). Rotation of the neck away from the side of swelling causes severe pain from tension on the ipsilateral sternocleidomastoid muscle.

FIG 8.10 The patient had trismus and pain on swallowing following the development of submandibular abscess. The infection spread to the pterygomandibular, parapharyngeal spaces. The patient needs to be hospitalized for multiple incisions and drainage. (From Hupp JR, Tucker MR, Ellis E: *Contemporary oral and maxillofacial surgery*, ed 5, St. Louis, 2009, Mosby.)

Spread of oral infection to this space may produce an ominous sign. Airway impingement due to medial bulging of the pharyngeal wall and supraglottic edema may occasionally occur, which may require the procurement of a stable airway by either tracheotomy or intubation. The treatment of lateral pharyngeal space infections requires surgical drainage through either a transoral or extraoral approach.[22] While an intraoral approach may reach the anterior compartment, extraoral access through a

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submandibular approach will allow for adequate access.

Significant Complications of Infections

Head And Neck

Osteomyelitis

Osteomyelitis is an inflammatory condition of the bone that originates as an infection of the medullary space and eventually extends into the cortical bone and periosteum. The bone infection becomes active in the calcified portion of the bone and will produce pus in the medullary cavity and beneath the periosteum, which compromises the blood supply. This initiates ischemia of the bone, which results in necrosis. Osteomyelitis of the jaws has two main classifications, acute and chronic, based on the duration of the disease. Chronic osteomyelitis has classically been defined as a condition that has lasted over 1 month.[23] While there are many subclassifications, acute and chronic osteomyelitis are generally subclassified as suppurative or nonsuppurative and usually is different in the etiology, microbiology, pathogenesis, and treatment in comparison to long bone osteomyelitis.[24]

Osteomyelitis has been associated with dental implants, usually starting as a periimplant radiolucency with eventual osteolytic changes. Case reports have also shown that implants placed in association with retained tooth roots have caused osteomyelitis infections.[25]Left untreated, osteomyelitis may become refractory with bacteria induced peri-implantitis that may lead to deep bone invasion of bacteria, and the spread of infection into deeper tissues. [26]

Accurate diagnosis of mandibular osteomyelitis is based on clinical, radiographic, histologic, and microbiologic findings followed by surgical debridement of the infected area and a long-term antibiotic regimen (Figs. 8.11 to 8.13). Radiographic changes show a poorly defined, radiolucent bone loss with intermixed radiopaque areas, which show the classic signs of sequestrum. Conventional radiography of mandibular osteomyelitis has a higher specificity than its sensitivity, which makes early detection difficult. Radiographic signs of mandibular osteomyelitis are generally not apparent until they extend at least 1 cm in bone and compromise 30% to 50% of bone mineral content and may not be radiographically apparent in adults for up to two weeks.[27] Typical early bony changes seen on conventional radiography may include: periosteal thickening, lytic lesions, endosteal scalloping, loss of trabecular architecture, and new bone apposition.[28] This gives the classic “moth-eaten” appearance that is diagnostic for osteomyelitis.

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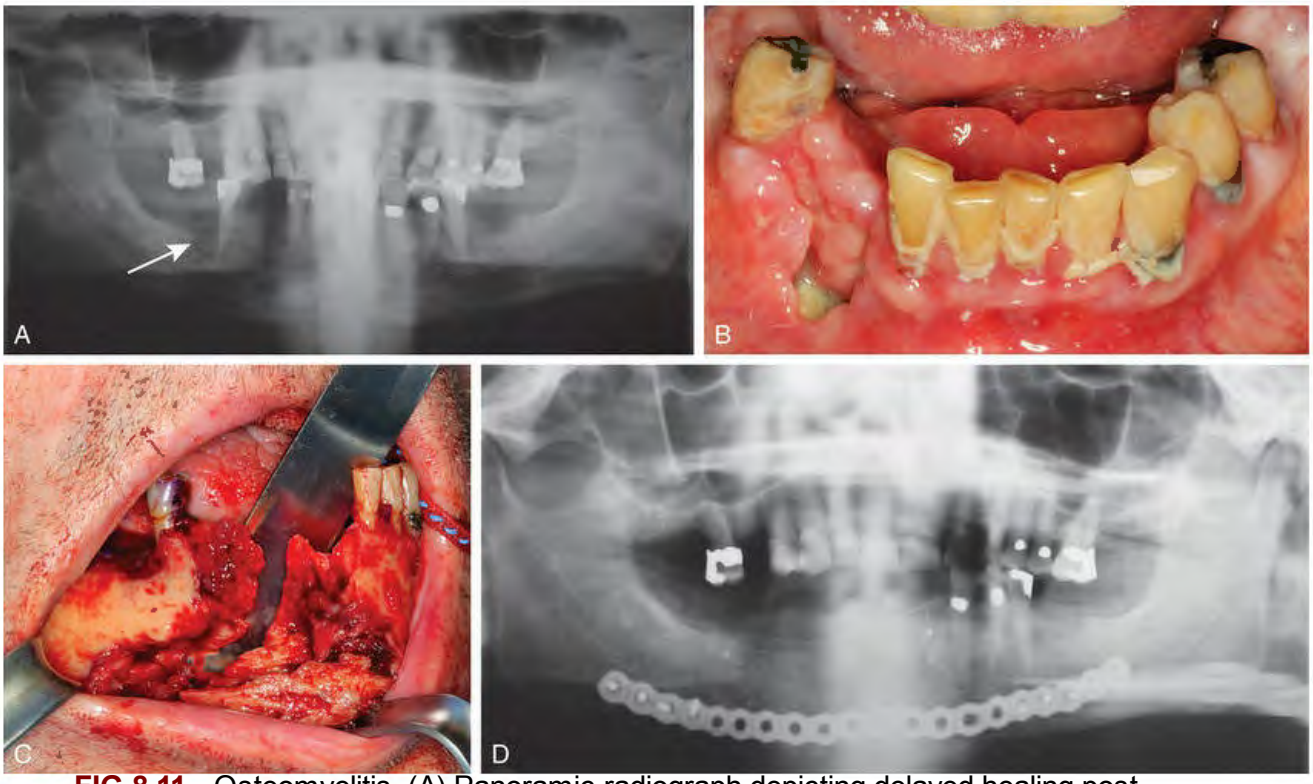

FIG 8.11 Osteomyelitis. (A) Panoramic radiograph depicting delayed healing post-implant removal. (B) Intraoral photo showing nonhealing, postimplant removal. (C) Surgical resection. (D) Postoperative bone graft.

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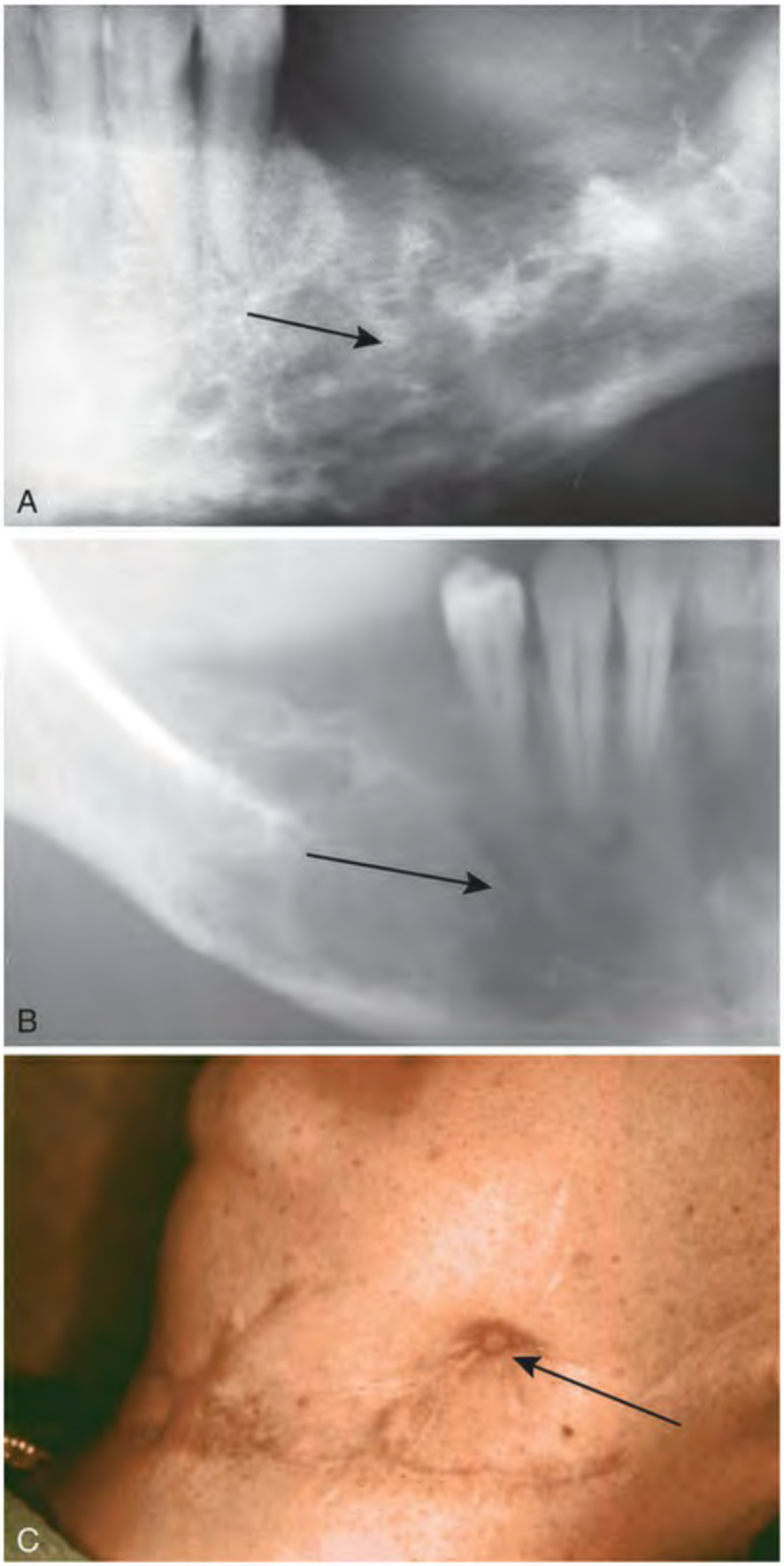

FIG 8.12 Osteomyelitis. (A–B) Radiographic images of bone destruction. (C) Multiple sinus tracts from osteomyelitis of the mandible from a subperiosteal implant.

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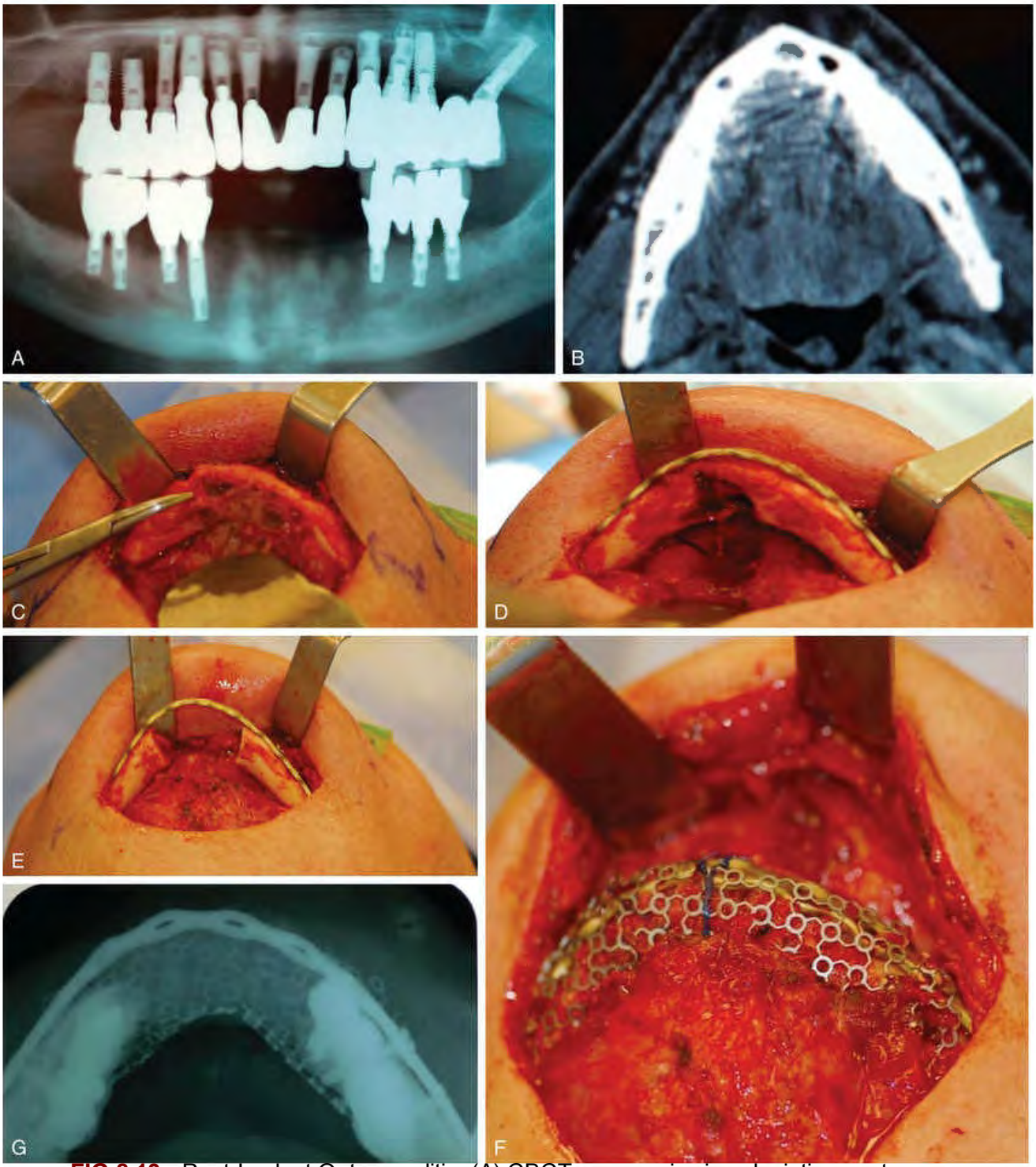

FIG 8.13 Post-Implant Osteomyelitis: (A) CBCT panoramic view depicting post-implant removal in the anterior mandible, (B) Axial image, depicting postimplant failure and associated osteomyelitis. (C–D) Defect from infection. (E–F) Surgical reconstruction. (G) Postoperative radiograph showing bone graft. (Courtesy David Datillo, DDS, Chairman OMFS, Allegheny General Hospital, Pittsburgh, PA.)

Given the difficulty of detecting early stage osteomyelitis with conventional radiography, CT scanning and MRI are considered standard of care in the diagnosis of osteomyelitis because they are sensitive and specific.

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CT provides excellent delineation of even the most subtle osseous changes such as abnormal thickening of the affected cortical bone with sclerotic changes, encroachment of the medullary cavity, and chronic draining fistulas. Although CT may show these changes earlier than do conventional radiographs, CT is less desirable than MRI because of decreased soft tissue contrast as well as exposure to ionizing radiation. A T1-weighted short inversion time recovery (STIR) MRI has been shown to be able to detect bony changes indicating osteomyelitis as early as the subacute phase.[29]

Histologically, suppurative osteomyelitis is characterized by intense microorganism-provoked marrow inflammation and marrow vessel thrombosis with retention of viable osteoclasts and periosteum, which creates an environment conducive to continual bacterial proliferation.[30] In the past, *Staphylococcus aureus* was thought to be the main causative organism of osteomyelitis. However, given the unique environment of the oral cavity, there tends to be a mixed infection with hemolytic streptococci and a predominance of oral anaerobes (e.g., *Peptostreptococcus*, *Fusobacterium,* and *Bacteroides*). Additionally, various other organisms, such as *Actinomyces* spp and *Treponema pallidum,* cause other types of osteomyelitis.[31]

Treatment of osteomyelitis usually involves removal of the suspected source, antibiotic therapy, medical treatment, and surgical intervention. Topazian has established the principles of treatment for osteomyelitis to include: (1) evaluation and correction of host defense deficiencies; (2) Gram staining, culture, and sensitivity; (3) radiographic imaging; (4) administration of stain-guided empirical antibiotics; (5) removal of mobile teeth/implants and sequestra; (6) administration of stain-guided antibiotics; (7) possible placement of irrigating drains; (8) and sequestrectomy, debridement, decortication, resection, and reconstruction.[1] The complete resolution of the infection should be the main focus of management in patients with chronic osteomyelitis of the mandible, and aggressive surgical management is more likely to result in an ideal outcome.

Medication-Related Osteonecrosis of the Jaws (MRONJ)

In 2003 simultaneous and independent reports were published by Marx[32] and Ruggiero[33]describing nonhealing exposed bone cases in the oral-facial region in patients treated with oral and intravenous bisphosphonate drugs. Shortly thereafter the manufacturers of intravenous bisphosphonates pamidronate (Aredia) and zoledronic acid (Zometa) notified health care professionals concerning the risk of developing osteonecrosis of the jaws in patients using

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these medications.[34]

Most recently, the American Association of Oral and Maxillofacial Surgeons (AAOMS) recommended changing the terminology of this condition. Previously termed *bisphosphonate-related osteonecrosis of the jaw (BRONJ),* the condition is now referred to as *medication-related osteonecrosis of the jaws (MRONJ).* This was related to the fact there is a growing number of osteonecrosis cases involving the maxilla and mandible associated with other intravenous antiresorptive, antiangiogenic, and monoclonal antibody medications, such as Denosumab (Prolia, Xgeva), which is a fully human monoclonal antibody used for the treatment of osteoporosis, treatment-induced bone loss, bone metastases, and giant cell tumor of bone.

AAOMS has recently initiated guidelines on the signs and symptoms of MRONJ in comparison with other nonhealing issues.[35] Treatment guidelines have also been established which relate to various stages of the condition (Table 8.3). (The preoperative management of patients on bisphosphonates and antiresorptive medications is discussed in Chapter 2). Current or previous treatment with antiresorptive or antiangiogenic agents:

- Exposed bone or bone that can be probed through an intraoral or extraoral fistula(e) in the maxillofacial region that has persisted for more than 8 weeks; and
- No history of radiation therapy to the jaws or obvious metastatic disease to the jaws.

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TABLE 8.3
Staging and Treatment Strategies for MRONJ

MRONJ Staging[a]	Treatment Strategies[b]
At risk category: No apparent necrotic bone in patients who have been treated with either oral or IV bisphosphonates	• No treatment indicated • Patient education
Stage 0: No clinical evidence of necrotic bone, but nonspecific clinical findings, radiographic changes, and symptoms	• Systemic management, including the use of pain medication and antibiotics
Stage 1: Exposed and necrotic bone, or fistulae that probes to bone, in patients who are asymptomatic and have no evidence of infection	• Antibacterial mouth rinse • Clinical follow-up on a quarterly basis • Patient education and review of indications for continued bisphosphonate therapy
Stage 2: Exposed and necrotic bone, or fistulae that probes to bone, associated with infection as evidenced by pain and erythema in the region of the exposed bone with or without purulent drainage	• Symptomatic treatment with oral antibiotics • Oral antibacterial mouth rinse • Pain control • Debridement to relieve soft tissue irritation and infection control
Stage 3: Exposed and necrotic bone or a fistula that probes to bone in patients with pain, infection, and one or more of the following—exposed and necrotic bone extending beyond the region of the alveolar bone (i.e., inferior bone and ramus in the mandible, maxillary sinus and zygoma in the maxilla) resulting in pathologic fracture, extraoral fistula, oral antral/oral nasal communication, or osteolysis extending to the inferior border of the mandible of sinus floor	• Antibacterial mouth rinse • Antibiotic therapy and pain control • Surgical debridement/resection for longer term palliation of infection and pain

[a]Exposed or probably bone in the maxillofacial region without resolution for more than 8 weeks in patients treated with an antiresorptive and/or an antiangiogenic agent who have not received radiation therapy to the jaws.

[b]Regardless of the disease stage, mobile segments of bone sequestrum should be removed without exposing uninvolved bone. The extraction of symptomatic teeth within exposed, necrotic bone should be considered because it is unlikely that the extraction will exacerbate the established necrotic process.

(From Ruggiero SL, Dodson TB, Fantasia J, et al: American Association of Oral and Maxillofacial Surgeons position paper on medication-related osteonecrosis of the jaw—2014 update, *J Oral Maxillofac Surg* 72(10):1938–1956, 2014.)

Although the true pathophysiology of MRONJ is not yet fully understood, decreased bone turnover (altered bone remodeling or over suppression of bone resorption) and infection are thought to be central to the pathogenesis of MRONJ.[36]

Histologically, MRONJ is characterized by marrow spaces with empty Howship lacunae and an absence of osteoclasts and viable periosteum. This

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suggests a noninflammatory drug toxicity to bone by osteoclastic death leading to oversuppression of bone renewal. Many additional hypotheses have been proposed such as angiogenesis inhibition, constant microtrauma, suppression of innate or acquired immunity, vitamin D deficiency, soft tissue toxicity to bisphosphonates, and inflammation (Fig. 8.14).[37-40]

FIG 8.14 Medication related osteonecrosis of the jaws (MRONJ). (A) Implant related MRONJ. (B) Multiple areas of nonhealing exposed bone. (B, From Marx RE: Bone and bone graft healing. *Oral Maxillofac Surg Clin North Am* 19(4):455–466, 2007.)

Bisphosphonates prevent the renewal of old and injured bone because they make it brittle and prone to fracture, have a half-life in bone of 11 years due to irreversible binding to bone, and (when administered intravenously) accumulate in bone 142.8 times faster than oral bisphosphates.[41]

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Additionally, osteoclastic resorption of bisphosphonate-loaded bone results in osteoclast death in which the cell bursts and releases retained bisphosphonate molecules inside the cell that redistribute in the local bone or bone marrow in a redosing effect.

Recently, the presence of biofilm has emerged to explain the etiology of many chronic infections, and this may be a contributing factor in the development and proliferation of MRONJ. Biofilm is an aggregation of bacterial colonies and other microorganisms such as yeast, fungi, and protozoa that have established a microenvironment from the secretion a mucilaginous protective coating in which they are encased that may be extremely difficult to treat with medications alone.

Sedghizadeh et al looked at biofilm composition on specimens from individuals who had sequestrectomy of bone for MRONJ.[42] They found that bone specimens from affected sites in all patients revealed large areas occluded with biofilms comprising mainly bacteria and occasionally yeast (*Candida* spp). The specimens included a large number of bacterial morphotypes and included species from the genus *Fusobacterium*, *Bacillus*, *Actinomyces*, *Staphylococcus*, and *Streptococcus*. Bacterial colonization of the denuded bone in MRONJ has suggested that bisphosphonates may increase bacterial adhesion and biofilm formation. Kos et al discovered an up to a seven-fold increase in bacterial colonization on pamidronate-coated hydroxyapatite disc compared to controls.[43] They postulated that the nitrogen group on pamidronate may act as a steric factor that facilitates anchoring of bacteria to the hydroxyapatite surface or may attract bacteria by direct electrostatic interaction. These studies lay credence to the high probability that increased bacterial adhesion in the presence of bisphosphonates may promote MRONJ and osteomyelitis development.

Individuals taking oral bisphosphonate therapy for short durations of time, less than 3 years, do not appear to have significantly higher rates of implant failure or infection.[44] However, for patients taking long-term oral bisphosphonate therapy (exceeding 3 years) with concomitant prednisone treatment, there may be a significant increase in the incidence of both implant failure and infection. This phenomenon may be location specific because implants placed in the posterior mandible or maxilla in patients with a history of long-term oral bisphosphonate have a greatly increased risk of MRONJ development.[45] Individuals who have received at least three or more doses of any intravenous antiresorptive medication (e.g., Reclast) may be considered an absolute contraindication to dental implant therapy with an

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almost guaranteed development of MRONJ.[46]

Cavernous Sinus Thrombosis

Cavernous sinus thrombosis is a very rare but extremely dangerous major complication of head and neck infections. Although the advent of antibiotics has decreased the incidence of the condition, a clinician should be able to recognize its signs and immediately refer the patient to the proper specialists.

The cavernous sinuses are trabeculated sinuses located at the base of the skull that drain venous blood from valveless facial veins. Infections may be delivered to this location from sources of infection in the vicinity of this vein, most likely those located in the midface. Initial symptoms are progressively severe headache or facial pain, usually unilateral and localized to retroorbital and frontal regions with high fever. Eventually, paralysis of the ocular movements in the eye on lateral gaze is a classic sign of this condition. This is termed *ophthalmoplegia* because it is due to compression of the sixth cranial nerve (lateral ocular gaze) from the pressure of purulence in the confined space of the sinus. Proptosis (anterior bulging of the eye) and eyelid edema also develop and may occur bilaterally. As the condition progresses, facial sensation may diminish confusion, and seizures, and a decreased level of consciousness may develop. Treatment involves removal of the infection source as well as administration for weeks of intravenous antibiotics and fluids because surgery is considered difficult and problematic (Fig. 8.15).

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FIG 8.15 Cavernous sinus thrombosis. (A) Seventy-two hours post dental treatment, patient presented with severe headache, high fever (104°F), chills, parasthesia of upper and lower eyelids, inability to move her right eye around and little hemorrhagic spots (petechea) on edematous skin of nose and eyelids. She was diagnosed with having cavernous sinus thrombosis. (B) Chemosis, proptosis, and ophthalmoplegia from cavernous sinus thrombosis infection. (B, From Del Brutto OH: Infections and stroke. *Semin Cerebrovasc Dis Stroke* 5(1):28–39, 2005.)

Brain Abscess

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Transmission of oral infection and the development of brain abscess are a rare but extremely dangerous and life-threatening situation. Oral microorganisms may enter the cranium by several pathways including by direct extension, by hematogenous spread, by local lymphatics, and, indirectly, by extraoral odontogenic infections.[47] Similar to the treatment of cavernous sinus thrombosis, several weeks of intravenous antibiotics and fluids are recommended (Fig. 8.16).

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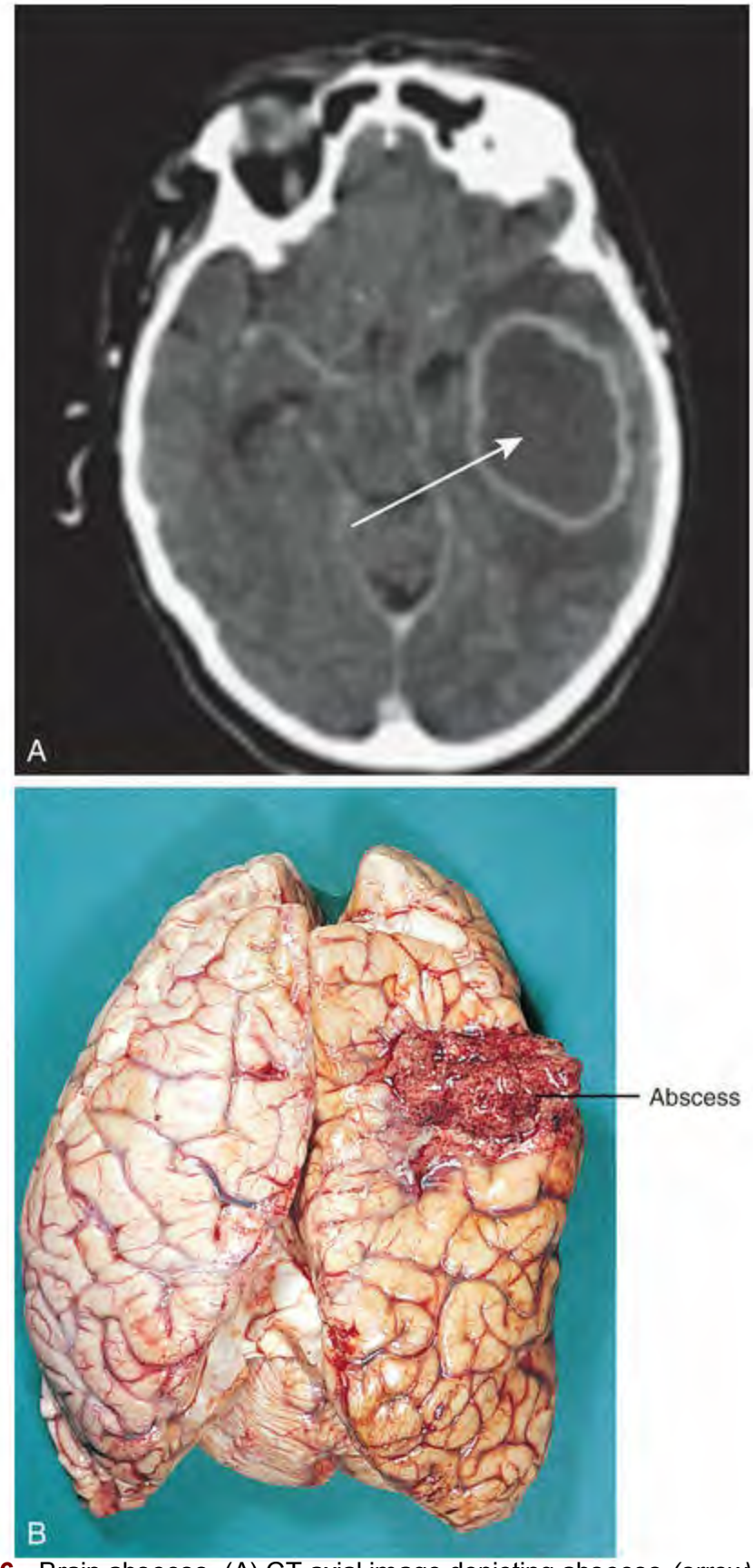

FIG 8.16 Brain abscess. (A) CT axial image depicting abscess *(arrow)*. (B) Dry specimen. (A, From Laban JT, O'Neill K: CNS infection. *Surgery* (Oxford) 25(12):517–521, 2007. B, From Damjanov I: *Pathology for the health professions*, ed 4, St. Louis, 2012, Saunders.)

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Neoplasms

Although rare, the development of neoplasms in association with dental implants has been reported (Figs. 8.17 and 8.18). To date, squamous cell carcinoma is the most common cancer that has been reported to involve dental implants.[48,49] Other reports have reported dental implant failure related to the development of a plasmacytoma[50] and in association with breast and lung metastasis.[51,52]

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FIG 8.17 (A) CT scan showing a mixed radiopaque/radiolucent lesion of the right maxilla associated with the dental implant. The tumor has infiltrated the periodontal ligament space of the second premolar. (B) CT scan showing the osteosarcoma eroding the buccal cortex of the maxilla with extension into adjacent soft tissue *(arrow)*. (From McGuff HS, Heim-Hall J, Holsinger FC, et al: Maxillary osteosarcoma associated with a dental implant: report of a case and review of the literature regarding implant-related sarcomas. *JADA* 139(8):1052–1059, 2008.)

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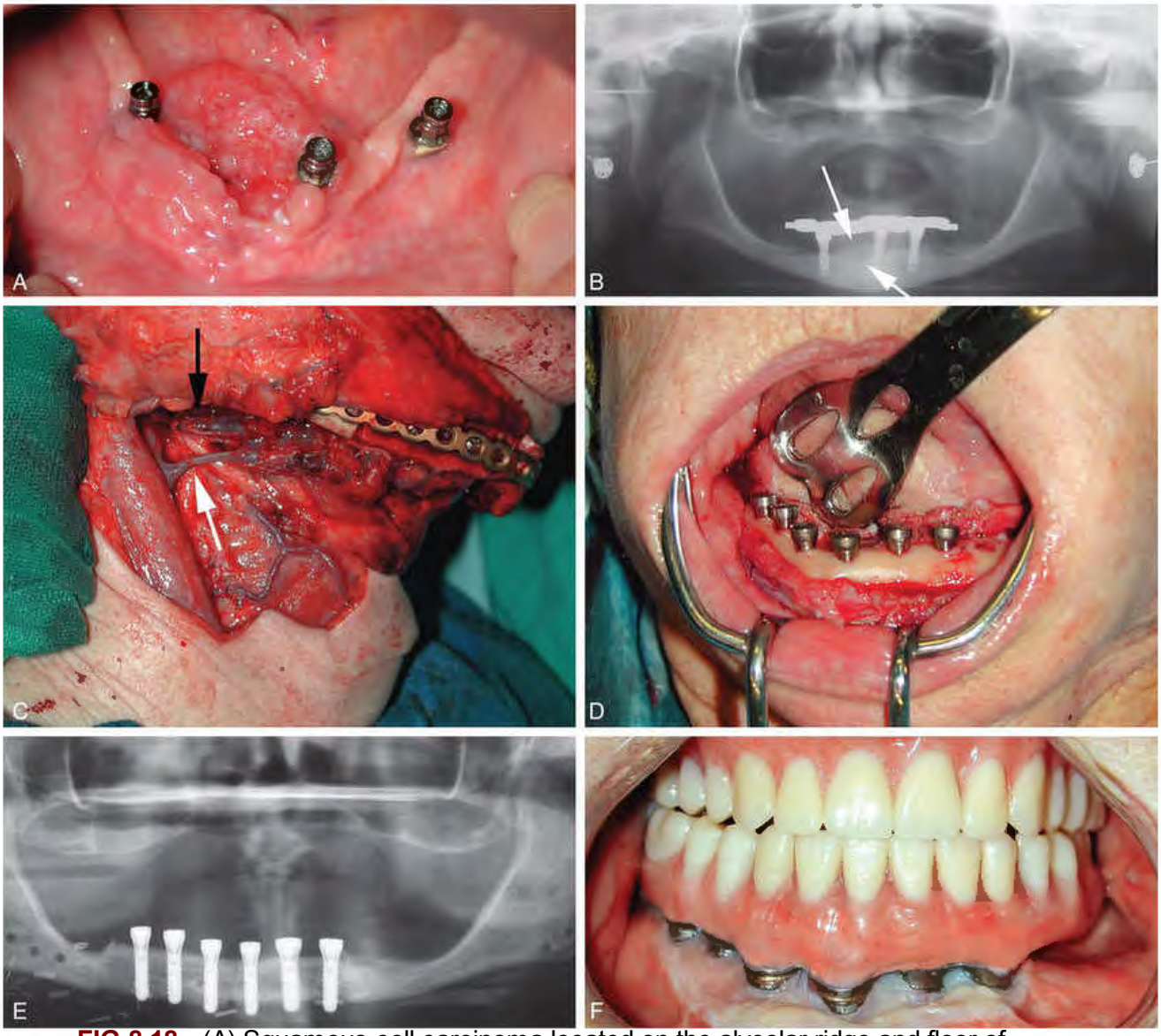

FIG 8.18 (A) Squamous cell carcinoma located on the alveolar ridge and floor of mouth. (B) Panoramic radiograph showing erosion of lesion into bone *(arrows)*. (C) Intraoperative photograph after mandible and surrounding soft tissues were resected, and a free fibular bone flap and reconstruction bone plate have been used to reconstruct the mandible. Note the venous anastomosis *(white arrow)*. The arterial supply to the flap is also shown *(black arrow)*, but the actual anastomosis is located more proximally, under the tissue, and is not visible. (D) After the bone graft has healed, dental implants are inserted. (E) Panoramic radiograph showing the reconstructed mandible after implants have been inserted. (F) Intraoral view of prosthetic reconstruction of dental implants. The white tissue surrounding the implants is skin that was transferred with the bone flap. (Courtesy Dr. Remy Blanchaert, Jr. In Hupp JR, Tucker MR, Ellis E: *Contemporary oral and maxillofacial surgery*, ed 6, St. Louis, 2014, Mosby.)

In most cases, the clinical signs and symptoms are consistent with peri-implantitis, which leads to a delay in diagnosis. The pathophysiology of the carcinogenesis has not been determined, but implant biomaterials, persistent inflammation, and chronic osteomyelitis have been theorized as

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contributing factors.[53]

The implant biomaterial, along with tumor induction, has been shown to be related to the development of sarcoma in association with dental implants. This is thought to be mediated by the toxic and mutagenic properties of titanium alloy.[54] Although more commonly associated with orthopedic appliances, it has been shown that metallic corrosion occurs with dissolution into periimplant tissues. Titanium levels have been shown to reach up to 300 parts per million in tissues around implants, which produces discoloration.[55]

Although there are many case reports of neoplasms and dental implants, this is a relatively rare occurrence. It is difficult to determine a direct cause-and-effect relationship with the use of titanium and cancer. The most likely scenario is when an implant exhibits chronic inflammation and peri-implantitis does not respond to any treatment.

Treatment of Infections

The management of infections can be associated with a high degree of morbidity and should be related to the comfort level and the training of the implant clinician. If the implant clinician is unfamiliar or early on their learning curve with treatment of infections, the patient should be referred to a specialist.

Normally, the first goal of treatment is to treat or remove the cause of the infection. This could be an implant, bone graft, or tooth. The secondary goal is to allow drainage of accumulated pus and bacteria.

Incision and Drainage

This procedure includes the incision of the abscess or cellulitis, which results in the removal of the accumulated pus and bacteria from the underlying tissue. The opening of the abscess cavity will decrease the load of bacteria, reduce the hydrostatic pressure in the region by decompressing tissues, and allow for the introduction of a local blood supply that increases the delivery of host defenses and antibiotics to the infected area.

Incision and drainage of a cellulitis serves to prevent the spread of the infection into deeper anatomic spaces. This usually includes the insertion of a drain to prevent the closure of the incision line, which prevents the infection from reforming.

Procedure

An incision with a #15 scalpel blade is made through the mucosa into the infected cavity. The incision is usually less than 1 cm in length but should be sufficiently long to allow for adequate access into a gravity-dependent area of the abscess to allow for drainage. A closed curved hemostat is inserted into the incision and opened in several directions. The hemostat should be removed in the open position and never in the closed position to avoid inadvertent clamping of possible vital structures in the area. This is completed to break open any small loculations or cavities of purulence. The area should then be copiously irrigated with sterile saline solution until the fluid runs clear, an indication that all gross evidence of infection has been removed. After all visible purulence has been removed, a small drain may be placed into the opening. The most common drain is a quarter-inch Penrose drain, which is a soft rubber tube placed in a wound area to prevent the fluid

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or purulence accumulation (see Fig. 8.8). Incision and drainage of surgical spaces such as the sublingual, submandibular, pterygomandibular, and parapharyngeal spaces that require an extraoral approach and careful dissection are commonly done under general anesthesia in a hospital setting with the appropriate preoperative, operative, and postoperative care by a surgical specialist.

Culture and Sensitivity

In some cases a culture and sensitivity (C&S) test is administered before the drainage of an abscess. This should ideally be completed at the beginning of the procedure (Box 8.5).

Box 8.5

Indications for Culture and Antibiotic Sensitivity Testing

- Infection spreading beyond the alveolar process into fascial spaces
- Symptomatic, rapidly progressive infection
- Nonresponsive infection (after more than 48 hours) with the use of antibiotics
- Multiple doses of antibiotic therapy
- Chronic, recurrent infection
- Patients who have compromised immune system and comorbidities

(From Hupp JR, Tucker MR, Ellis E: *Contemporary oral and maxillofacial surgery,* ed 6, St. Louis, 2014, Mosby.)

Procedure

After adequate anesthesia, the surgical area is disinfected and dried with sterile gauze. With the use of an 18-gauge needle or the cotton applicator, a specimen is collected. The needle or cotton-tipped applicator is inserted into the abscess or cellulitis, and 1–2 mL of pus or tissue fluid is aspirated. The

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specimen should include pus, blood, tissue fluid, or necrotic tissue. The specimen is placed (inoculated) directly into aerobic and anaerobic culturettes, which are sterile tubes containing a swab and bacterial transport medium (Fig. 8.19). Culturettes usually have a short shelf life, so the expiration date should be checked before use. The clinician should request in writing a Gram stain, aerobic and anaerobic cultures, and antibiotic sensitivity testing.

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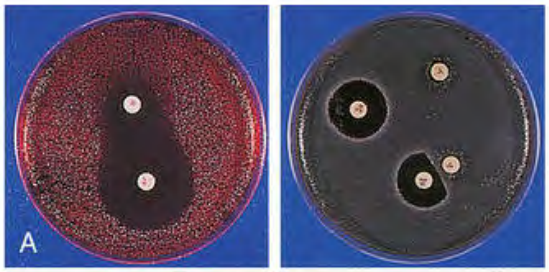

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FIG 8.19 Culture and sensitivity test. (A) Method to determine which antibiotics are effective against the specific bacteria. Various antibiotic agents are impregnated and inoculated with the microorganism. Note the areas of no colonization around the antibiotic spheres. (B) Anaerobic specimen collector, (C) Remove Handle and cotton applicators, (D) Inoculate the area of infection, (E) Place cotton tip specimen collector into agar, (F) Sample sent to lab for culture and sensitivity tests. Culturette used for C&S test. (A, From Goering R, Dockrell H, Wakelin D et al: *Mim's medical microbiology*, ed 4, St Louis, 2008, Mosby. B, Courtesy GettyImages.com.)

After the C&S is completed, an incision with a #15 scalpel blade is made through the mucosa into the infected cavity. The incision is usually less than 1 cm in length. A closed curved hemostat is inserted into the incision and opened in several directions. This is completed to break open any small lobulations or cavities of pus. After all pus has been removed, a small drain may be placed into the opening. The most common drain is a Penrose drain. Incision and drainage of surgical spaces such as the buccal, sublingual, submandibular, pterygomandibular, and parapharyngeal spaces require skin incision and careful dissection commonly done under general anesthesia in a hospital setting with the appropriate preoperative, operative, and postoperative care by a specialist (Fig. 8.20).

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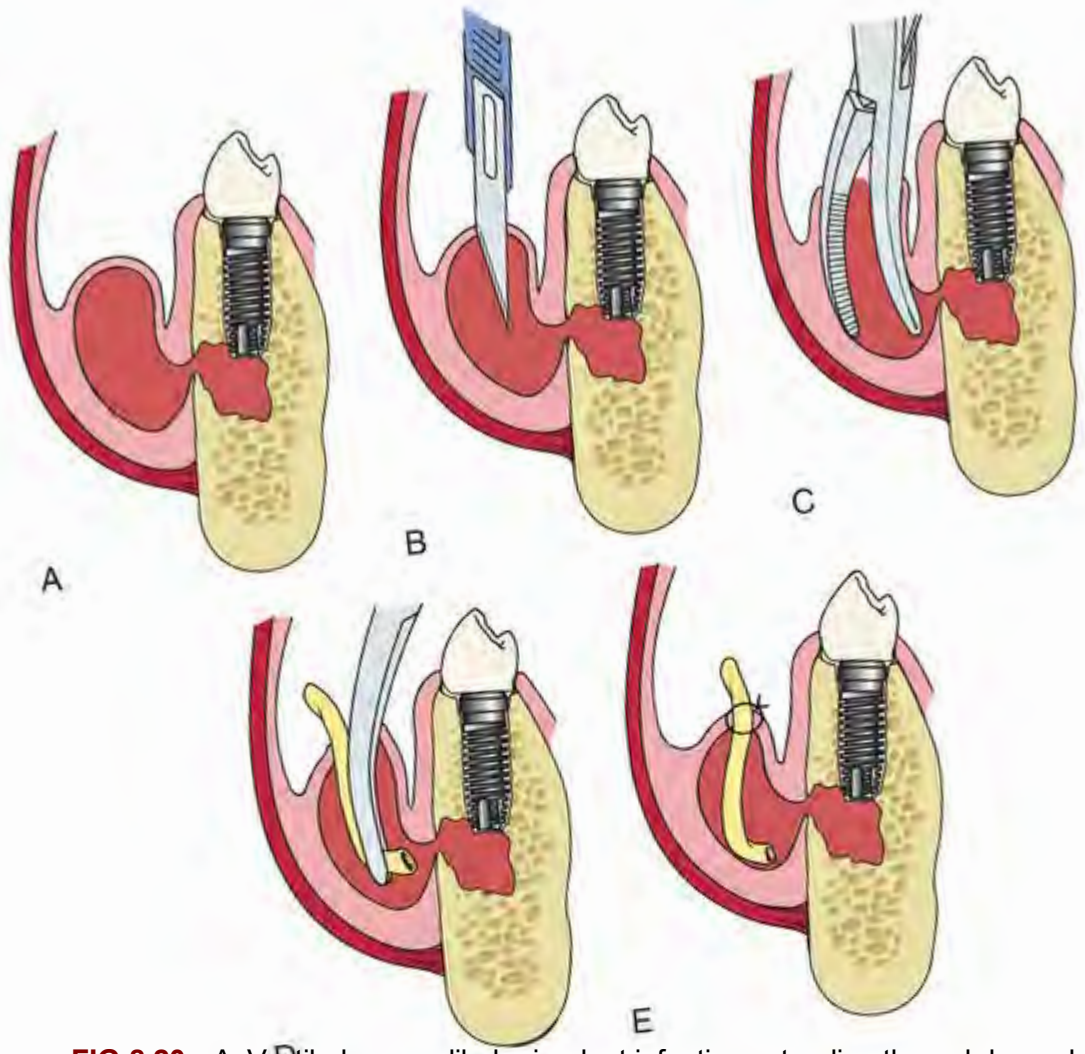

FIG 8.20 A, Vestibular mandibular implant infection extending through buccal plate and creates sizable vestibular abscess. B, Abscess is incised with #11 blade. C, Beaks of hemostat are inserted through incision and opened so that beaks spread to break up any loculations of pus that may exist in abscessed tissue. D, A small drain is inserted to depths of abscess cavity with a hemostat. E, The drain is sutured into place with a single black silk suture. Note that pus usually flows out along, rather than through, a tubular drain. (Adapted from Hupp JR, Tucker MR, Ellis E: *Contemporary oral and maxillofacial surgery*, ed 6, St. Louis, 2014, Mosby.)

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Antibiotics Used in Implant Dentistry (Table 8.4)

Beta-Lactam Antibiotics

The most common beta-lactam antibiotics used in dentistry are the penicillins and cephalosporins. These antibiotics have similar chemical structures, and the mechanism of action is the inhibition of bacterial cell wall synthesis (bactericidal) via the interruption of the cross linking between peptidoglycan molecules.

TABLE 8.4

Commonly Used Antibiotics in Oral Implantology

			THERAPEUTIC		
Generic Name	**Brand Name**	**Bactericidal/Bacteriostatic**	**Usual Adult Dose**	**Maximum Adult Dose**	**Prophylactic Doses**
Amoxicillin	Amoxil Polymax Trimax	Bactericidal	250–500 mg TID	4 g/day	SBE: 2 g 1 hr before Surgical: 1 g 1 hr before
Amoxicillin/clavulanic acid	Augmentin	Bactericidal	250–500 mg TID or 825 mg BID	4 g/day	Surgical: 825 mg
Cephalexin	Biocef Cefanex Keftab Keflex	Bactericidal	250 mg QID or 500 mg BID	4 g/day	SBE: 2 g 1 hr before Surgical: 1 g 1 hr before
Cefadroxil	Duricef Ultracef	Bactericidal	500 mg BID	4 g/day	SBE: 2 g 1 hr before Surgical: 1 g 1 hr before
Azithromycin	Zithromax	Bacteriostatic	500 mg immediately, 1000 mg/day	—	SBE: 500 mg 1 hr before
Clarithromycin	Biaxin	Bacteriostatic	250 mg	—	SBE: 500 mg 1 hr before
Erythromycin	E-mycin E-tab	Bacteriostatic	250 mg QID	4 g/day	—
Tetracycline	Achromycin Sumycin	Bacteriostatic	250 mg QID	4 g/day	—
Clindamycin hydrochloride	Cleocin HCl	Bacteriostatic	150–300 mg TID or QID	1.8 mg/day	SBE: 600 mg 1 hr before Surgical: 600 mg 1 hr before
Metronidazole	Flagyl	Bactericidal	250 mg TID or QID	4 g/day	—
Levofloxacin	Levaquin	Bactericidal	500 mg/day	500 mg/day	Surgical: 500 mg
Moxifloxacin	Avelox	Bactericidal	400 mg/day	400 mg/day	—
Trimethoprim/sulfamethoxazole	Bactrim Septra	Bacteriostatic	160 mg (DS) BID 80 mg BID	—	—

SBE, Subacute bacterial endocarditis; *DS,* double strength.

(From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Penicillins

Penicillin V.

Penicillin V is the oral form of penicillin (penicillin G being the intravenous form) that is one of the more common antibiotics used in dentistry today. It is bactericidal, well absorbed, and will achieve peak serum levels within 30 minutes of administration with detectable blood levels for 4 hours. Penicillin and all its derivatives produce bactericidal effects by inhibition of bacterial cell wall synthesis. Penicillin V is effective against most *Streptococcus* species and oral anaerobes. The main disadvantages of penicillin are four times per day dosing due its very short half-life and susceptibility to resistant bacteria (β-lactamase–producing bacteria).

Amoxicillin.

Amoxicillin, an ampicillin analog, is a penicillin-derived, broad spectrum, bactericidal, semisynthetic beta-lactam antibiotic, with superior absorption, high bioavailability, and very low toxicity. It acts through the inhibition of cell wall biosynthesis during bacterial multiplication that leads to the bacterial death and has excellent diffusion in infected tissues where high tissue concentrations are easily achieved. Schüssl et al showed that a single dose of oral amoxicillin (2 grams) leads to concentrations in teeth that exceed the minimal inhibition concentration of some oral bacteria within 1 hour of administration.[56] It is effective against gram-negative cocci and gram-negative bacilli, having a greater activity than penicillin V against streptococci and oral anaerobes.

Amoxicillin/Clavulanic Acid (Augmentin).

This antibiotic is a combination of amoxicillin, a β-lactam antibiotic, and clavulanic acid, a β-lactamase inhibitor. Certain bacteria, such as *Streptococcus aureus*, may produce the enzyme beta-lactamase, which acts to hydrolyze, or disrupt, the beta-lactam ring that permits penicillin-derivative antibiotics to function. This may lead to decreased efficacy of the antibiotic and development of antibiotic resistance. Penicillinase is a specific type of beta-lactamase that has a specificity for penicillin and penicillin-derived antibiotics. To counteract the activity of beta-lactamase destruction, clavulanic acid was added to amoxicillin to form Augmentin (trade name), which has an affinity for penicillinase-producing bacteria. Clavulanic acid functions as a “suicide molecule” that inactivates the resistant bacteria through disruption of penicillinase function, which makes the bacteria more

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susceptible to the effects of the accompanying amoxicillin. An increase in the prevalence of penicillinase-producing bacteria (especially in the sinus), has made this antibiotic combination popular in oral implantology. This antibiotic is used mainly in cases in which penicillinase bacteria is suspected (or known by culture) and is very practical as a perioperative antibiotic for sinus augmentation (Fig. 8.21).

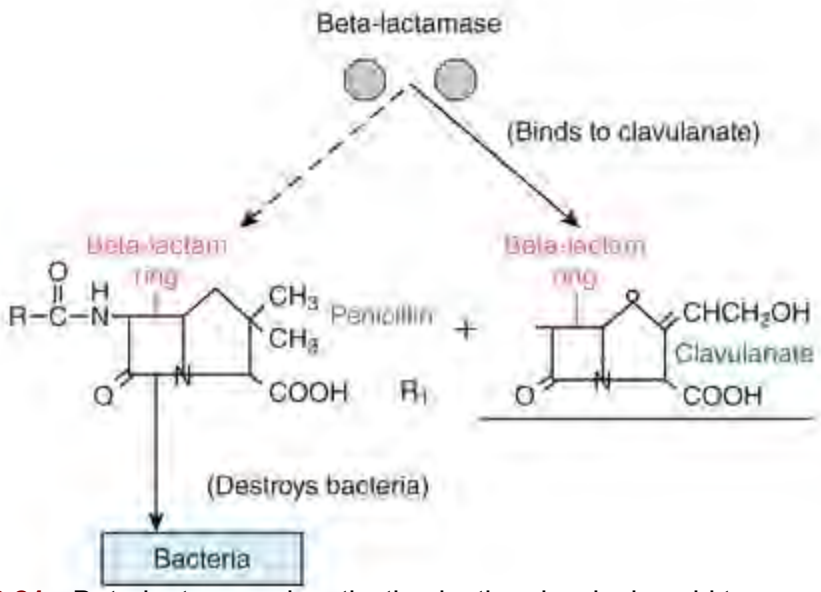

FIG 8.21 Beta-lactamase inactivation by the clavulanic acid to amoxicillin (Augmentin). Because of the high binding affinity of clavulanic acid, beta-lactamase will be inactivated, allowing penicillin to destroy the bacteria. (From Misch CE: *Contemporary implant dentistry*, ed 3, St. Louis, 2008, Mosby.)

Cephalosporins

Cephalexin/Cefadroxil.

The first-generation cephalexin/cefadroxil antibiotics have an antibacterial spectrum similar to amoxicillin. However, they have the advantage of not being susceptible to beta-lactamase destruction by *S. aureus*. They are often used in dentistry as an alternative for the penicillin-allergic patient, although cross-reactivity between these two drugs may occur. The cross-reactivity rate to first-generation cephalosporins with penicillin-allergic patients has been found to be approximately 1%.[57]

Caution must be exercised because Food and Drug Administration (FDA) guidelines report a 10% cross-reactivity. The most recent studies have shown

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only patients who have had type I (immunoglobulin E: immediate hypersensitivity reactions) should not be administered a cephalosporin. If the patient has a previous history of a reaction that was not immunoglobulin E–mediated (types II, III, IV, or idiopathic reactions), a first-generation cephalosporin may be administered. Newer second- and third-generation cephalosporins exhibit a broader spectrum, less cross-reactivity, and a greater resistance to beta-lactamase destruction.[58]

Macrolides

The most common macrolide used in dentistry is erythromycin. It is active against most streptococci, staphylococci, and some anaerobes, and it is an alternative for patients who are allergic to penicillin. Erythromycin has the advantage of excellent absorption and, unlike many drugs, is affected by the presence of food. It is administered primarily by the oral route and has a relatively low toxicity. This antibiotic has a high incidence of nausea and is bacteriostatic rather than bactericidal. It is therefore not an ideal first-line choice for infections in the oral cavity.

These characteristics are also unattractive when either high doses are required, severe infection exists, or the patient is immunocompromised and requires bactericidal activity. Even more disturbing is its implication in numerous drug interactions, including its proclivity for elevating serum levels of digoxin, theophylline, and carbamazepine. Erythromycin has also been found to prevent conversion of terfenadine (Seldane), a nonsedating antihistamine, to its active metabolite. As a result, elevated serum concentrations of the predrug may result and lead to cardiotoxicity, presenting a particular form of ventricular tachycardia called *torsades de pointes* that may lead to sudden cardiac death.

During the past several years, three novel macrolides have been introduced that offer advantages over erythromycin (i.e., clarithromycin [Biaxin], azithromycin [Zithromax]). Unlike other macrolides, they do not appear to inhibit hepatic cytochrome P450 isozymes, which account for most drug interactions of erythromycin. Biaxin produces less nausea and has better Gram activity; Zithromax appears to be more effective against *Haemophilus influenza*. A detailed medical and medication history should be obtained prior to the administration of either clarithromycin or azithromycin as potentially lethal cardiac rhythms such as QT prolongation, torsades de pointes, arrhythmia, and even cardiovascular death have been reported,

particularly in individuals with a family history of these conditions or who are already at a higher risk of cardiovascular events.

Clindamycin

Clindamycin (Cleocin Phosphate), a semisynthetic bacteriostatic derivative of lincomycin, is a bacterial protein synthesis inhibitor through inhibition of ribosomal translocation at the 50s RNA subunit. The use of clindamycin has increased for the treatment of dental infections primarily because of its activity against anaerobic bacteria. It is most effective against aerobic gram-positive cocci, such as *Staphylococcus* and *Streptococcus* species, and anaerobic gram-negative rod-shaped bacteria, such as some *Bacteroides*, *Fusobacterium*, and *Prevotella*.

Clindamycin is also supplied in an aqueous 300-mg/2-mL solution that is sometimes used in the incorporation of graft material for sinus augmentation procedures. It is bacteriostatic in normal concentrations and has a rather high toxicity in larger concentrations. The main disadvantage of clindamycin is the occurrence of diarrhea in 20% to 30% of patients treated. This antibiotic also has a higher incidence of antibiotic-associated pseudomembranous colitis (PMC) caused by *C. difficile* when administrated for extended periods. PMC has been reported to occur with most long-term antibiotics.

The toxicity of antibiotics related to PMC is elevated with ampicillin, amoxicillin, cephalosporin, and clindamycin. Penicillin, erythromycin, and quinolones are moderate risk, and the lowest risk is with tetracycline, metronidazole, and vancomycin. The latter group is often used to treat PMC conditions.

The patient should be informed that if either diarrhea or abdominal cramping occurs during or shortly after antibiotic therapy, the drug should be discontinued and the doctor should be notified.

Antidiarrheal medications should be avoided in these cases because they hinder the fecal elimination of the pathogen. If it is necessary to continue management of the dental infection, imidazole or vancomycin is most logical (if not the original cause of the complications). Metronidazole is not only effective against anaerobes contributing to the dental infection but also against *C. difficile*, the causative agent. If the condition persists after 3 days, the patient should be assessed by an internist for fluid and electrolyte imbalance.

Tetracyclines

Tetracyclines have been available since the 1950s and have a wide spectrum of activity against streptococci, staphylococci, oral anaerobes, and gram-negative aerobic rods. Because this antibiotic has been so extensively used in the past, there is a high degree of bacterial resistance. Tetracycline is an attractive adjunct for the treatment of gingival and periodontal disease with a high bioavailability in the gingival sulcus. For these reasons, tetracyclines are used by some practitioners as primary agents for treating implant disease and infections around implant posts. Their efficacy for managing infrabony infections is questionable, considering their inactivity when chelated with calcium complexes. The disadvantages of this antibiotic include a high incidence of promoting *Candida* spp infections and the fact that it may be associated with photosensitivity reactions.

Fluoroquinolones

A recent classification of antibiotics has had a definite impact on the treatment of infections in dentistry and medicine. Fluoroquinolones are bactericidal antibiotics and have a broad antibacterial spectrum, which may be used either orally or parenterally. Ciprofloxacin was one of the first-generation quinolones and is the prototype for this antibiotic classification. Newer third- and fourth-generation quinolones have been developed with great activity against resistant bacteria and anaerobic bacteria. In implant dentistry, fluoroquinolones are used mainly in the prophylactic and therapeutic treatment of sinus augmentation procedures. Care should be exercised with the use of Levaquin and Avelox as they have been associated with tendon damage.

Metronidazole

Metronidazole is a bactericidal antibiotic that is most often used for anaerobic infections. Because metronidazole has no activity against aerobic bacteria, it is seldom used for mixed infections unless it is combined with another antibiotic. It may be combined with penicillin when managing severe infections. Patients should be cautioned against drinking alcoholic beverages while taking this medication because disulfiram-like reactions have been reported. These consist of severe nausea and abdominal cramping caused by the formation of a toxic compound resembling formaldehyde.

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Metronidazole should not be prescribed for patients taking the oral anticoagulant warfarin (Coumadin).

Prevention and Treatment of Infection

Because of the risk of morbidity from infections, antimicrobial therapy is an essential component of the surgical protocol. Although adverse effects are associated with antibiotic therapy, these are usually mild and infrequent. The antimicrobials most commonly used in implant dentistry are antibiotics (local and systemic) and antimicrobial rinses (0.12% chlorhexidine gluconate).

The use and understanding of the various antibiotic regimens available in implant dentistry are beneficial for the initial success and long-term maintenance of implant therapy. Antibiotic therapy utilized in implant dentistry may be classified as either prophylactic (to prevent infection) or therapeutic (to treat infection).

Prophylactic Antibiotics

A landmark study by Burke defined the scientific basis for the perioperative use of antibiotics to prevent surgical wound infection.[59] From this work, Peterson established principles on the perioperative use of prophylactic antibiotics.[60]

In general surgery (including its subspecialties), the principles of antibiotic prophylaxis are well established. Guidelines are specifically related to the procedure, the type of antibiotic, and the dosage regimen. The use of prophylactic antibiotics in dentistry has also been documented in the prevention of complications for patients at risk of developing infectious endocarditis and immunocompromised patients. In oral implantology, there is no consensus on the use and indications for prophylactic antibiotics. Disadvantages of the use of antibiotics include the development of resistant bacteria, adverse reactions, and possible resultant lax surgical technique. As a result, the need for prophylactic antibiotics in healthy patients, type of antibiotic, dosage, and duration of coverage is controversial. On the other hand, postoperative surgical wound infections can have a significant impact on the well-being of the patient and the survival of the implant. Documented cases of potential consequences of infection range from increased pain and edema to patient death. According to Esposito and Hirsch, one of the main causes of dental implant failure is bacterial contamination at implant insertion.[61]

A local inoculum must be present for a surgical wound infection to occur,

to overcome the host's defenses, and allow growth of the bacteria. This process has many variables including various host, local tissue, systemic, and microbial virulence factors. Antibiotic prophylaxis is only one component of this complex cascade, but the efficacy and impact of antimicrobial prophylaxis has been proven to be significant.[62]

Several studies have concluded there is benefit from using preoperative antibiotics for dental implantology.[63,64] In the most comprehensive and controlled study to date, over 30 VA hospitals and dental schools formed the Dental Implant Clinical Research Group and concluded the use of preoperative antibiotics significantly improved dental implant survival, both in early and later stages. In the evaluation of 2973 implants a significant difference was found with the use of preoperative antibiotics (4.6% failure) compared with no antibiotics (10% failure).[63]

The main goal of the use of prophylactic antibiotics is to prevent infection during the initial healing period from the surgical wound site, thus decreasing the risk of infectious complications of the soft and hard tissues. Although there is no conclusive evidence on the mechanism of preoperative antibiotics, most likely a greater aseptic local environment is achieved.

The Appropriate Antibiotic for the Surgical Procedure Must Be Selected[60]

The prophylactic antibiotic should be effective against the bacteria that are most likely to cause an infection. In the majority of cases, infections after surgery are from organisms that originate from the site of surgery. Most postoperative infections are caused by endogenous bacteria including aerobic gram-positive cocci (streptococci), anaerobic gram-positive cocci (peptococci), and anaerobic gram-negative rods (bacteroides).[6]

Although oral infections are mixed infections in which anaerobes outnumber aerobes 2:1, it has been shown that anaerobes need the aerobes to provide an environment to proliferate.[65] Subsequent studies have shown that the early phase of intraoral infections involves streptococci that prepare the environment for subsequent anaerobic invasion.[66] The ideal antibiotic must be effective against these pathogens.

Least Toxic Antibiotic Should Be Selected

The second factor in selecting the correct antibiotic is to use the antibiotic with the least amount of adverse effects. These effects may vary from mild

nausea to an extreme allergic reaction.

The final selection factor is that the antibiotic should ideally be bactericidal. The goal of antibiotic prophylaxis is to kill and destroy the bacteria. Bacteriostatic antibiotics work by inhibiting growth and reproduction of bacteria, thus allowing the host defenses to eliminate the resultant bacteria. However, if the host's defenses are compromised in any way, the bacteria and infection may flourish. Bactericidal antibiotics are advantageous over bacteriostatic antibiotics in that (1) there is less reliance on host resistance, (2) the bacteria may be destroyed by the antibiotic alone, (3) results are faster than with bacteriostatic medications, and (4) there is greater flexibility with dosage intervals.

An Appropriate Tissue Concentration of the Antibiotic Must Be Present at the Time of Surgery[60]

For an antibiotic to be effective a sufficient tissue concentration must be present at the time of bacterial invasion. To accomplish this goal, the antibiotic should be given in a dose that will reach plasma levels that are three to four times the minimum inhibitory concentration (MIC) of the expected bacteria.[67] The MIC is the lowest antibiotic concentration sufficient to destroy the specific bacteria. Usually, to achieve this cellular level the antibiotic must be given at twice the therapeutic dose and at least 1 hour before surgery.[68] It has been shown that normal therapeutic blood levels are ineffective to counteract bacterial invasion. If antibiotic administration occurs after bacterial contamination, no preventive influence has been seen as compared with taking no preoperative antibiotic.

Use of the Shortest Effective Antibiotic[60]

In a healthy patient, continuing antibiotics after surgery often does not decrease the incidence of surgical wound infections.[69] A single dose of antibiotics is usually sufficient. However, for patients or procedures with increased risk factors, a longer dose of antibiotics is warranted.[60] With the high degree of morbidity associated with dental implant infections, one must weigh the benefits vs. risk involved for the extended use of antibiotics.

Complications of Antibiotic Prophylaxis.

It is estimated that approximately 6% to 7% of patients taking antibiotics will have some type of adverse event.[70] Incidence of significant complications

with the use of prophylactic antibiotics is minimal; however, a small percentage can be life threatening. The risks associated with antibiotics include gastrointestinal tract complications, colonization of resistant or fungal strains, cross-reactions with other medications, and allergic reactions.

Allergic reactions have a wide range of complications, ranging from mild urticaria to anaphylaxis and death. Studies have shown that 1% to 3% of the population receiving penicillin will exhibit urticaria type of reactions, with 0.04% to 0.011% having true anaphylactic episodes. Of this small percentage of anaphylactic reactions, 10% will be fatal.[71]

An unusual but increasing complication in the general population after antibiotic use is pseudomembranous colitis. This condition is caused by the intestinal flora being altered and colonized by *Clostridium difficile*. Penicillin and clindamycin use has been significantly associated with pseudomembranous colitis. All antibiotics have been shown as potential causative agents. The most common treatment for antibiotic-induced colitis is vancomycin or metronidazole.

The most recent concern with respect to antibiotic use is the development of resistant bacteria. It has been observed that the overgrowth of resistant bacteria begins only after the host's susceptible bacteria are killed, which usually takes at least 3 days of antibiotic use. Short-term (1-day) use of antibiotics has been shown to have little influence on the growth of resistant bacteria.

Use of Prophylactic Antibiotics in Oral Implantology.

Postoperative wound infections can have a significant effect on the success of dental implants and bone grafting procedures. The occurrence of surgical host defenses allows an environment conducive to bacterial growth. This process is complex, with interactions of host, local tissues, and systemic and microbial virulence factors. Various measures attempt to minimize infection by modifying the host and local tissue factors. The use of antimicrobials has been shown to be significant in reducing postoperative infections.

The antibiotic chosen for prophylaxis should encompass the bacteria most known to be responsible for the type of infection found with the surgical procedure. The following antibiotics are suggested against pathogens known to cause postoperative surgical wound infections in bone grafting or implant surgery:

- *Amoxicillin* is the drug of choice. If the patient is allergic, alternative drugs are:

Cephalexin (nonanaphylactic allergy to penicillin)

Clindamycin (anaphylactic allergy to penicillin)

- Sinus involvement procedures (e.g., sinus grafts)

Augmentin

Levaquin (if history of recent use of Augmentin [within 4 weeks])

Treatment.

When surgical wound infections arise, a specific diagnosis is advantageous to treat the complication. When evaluating the various antibiotics possible that are effective against the bacteria in question, a broad-spectrum beta-lactam antibiotic is most often the first-line medication. The duration of treatment should include antibiotic administration for 3 days beyond the occurrence of significant clinical improvement, (usually at the fourth day) for a minimum of 7 days.[72]

Therapeutic Antibiotics in Implant Dentistry

The recommended treatment for intraoral infections associated with grafting or implant therapy include the following:

1. Surgical drainage

2. Systemic antibiotics

- Amoxicillin (500 mg)/two immediately, then one tablet three times daily for 1 week; *or if penicillin allergy exists* Clindamycin (300 mg)/two immediately, then one tablet three times daily for 1 week.

- *Note:* If no improvement is seen after 4 days, a culture and sensitivity test can be administered to select the antibiotic most effective against the responsible organisms.

- Until culture and sensitivity test results are obtained, change antibiotic to Levaquin (500 mg)/one tablet daily for 1 week and 0.12% chlorhexidine gluconate rinse (½ oz twice daily for 2 weeks).

Chlorhexidine

Another modality for antimicrobial prophylaxis for implant surgery is the use of an oral rinse, 0.12% chlorhexidine digluconate (Peridex; Procter & Gamble). Chlorhexidine gluconate is a potent antibacterial that causes lysis by binding to bacterial cell membranes. It has high substantivity that allows it, at high concentrations, to exhibit bactericidal qualities by causing bacterial cytoplasm precipitation and cell death.[73] In the oral cavity, chlorhexidine has been shown to have a slow release from tissue surfaces over a 12-hour period.[74]

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In vitro studies have shown an inhibitory effect of chlorhexidine on cultured epithelium and cell growth; however, clinical studies have not shown this effect.[75] To the contrary, the use of chlorhexidine has been shown to be an effective adjuvant in reducing plaque accumulation, enhancing mucosal health,[76] improving soft tissue healing,[77] treating periodontal disease, preventing alveolar osteitis,[78] improving tissue healing after extractions,[79] reversing peri-implantitis,[80] and it has been shown to have no adverse effect on implant surfaces.[81]

When evaluating the effect of preoperative chlorhexidine before dental implant surgery, a significant reduction in the number of infectious complications (2 to 1) and a sixfold difference in implant failures compared to no use of chlorhexidine has been shown.[82]

Use of Chlorhexidine in Oral Implantology

As a consequence of many reported benefits of chlorhexidine, the use of this antiseptic is suggested in many ways in oral implantology as follows:

- **Patient presurgical rinse.** It can be used in the aseptic protocol before surgery for reduction of bacterial load
- **Surface antiseptic.** It can be used in the intra- and extraoral scrub of patient, scrubbing of hands before gowns and gloves
- **Postsurgical rinse.** Patient should rinse twice a day until incision line closure
- **Periimplant maintenance** on daily basis. Treatment of postoperative infections.

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Sterile Technique

Ideally, any surgical procedure where there may be an increased bacterial insult should utilize a sterile technique. There is much misunderstanding though, when it comes to the terms *clean*, *aseptic*, and *sterile*.

- **Clean technique:** The clean technique includes the routine hand washing, hand drying, and use of nonsterile gloves.
- **Aseptic technique:** The aseptic technique is used for short invasive procedures. It includes antiseptic hand wash, sterile gloves, antiseptic rinse, and use of a clean, dedicated area.
- **Sterile technique:** The sterile technique includes measures to prevent the spread of bacteria from the environment to the patient by eliminating all microorganisms in that environment. This is mainly used for any procedure in which the bacterial count needs to be lowered and an increase in infection rate will lead to significant morbidity. This will include surgical hand scrub, hands dried with sterile towels, complete sterile field, sterile gown, mask, and gloves (Table 8.5, Boxes 8.6 and 8.7).

TABLE 8.5

Clean vs. Aseptic vs. Sterile

	Clean	Aseptic	Sterile
Procedure space	Dental operatory	Surgical suite	Surgical suite
Gloves	Nonsterile	Sterile	Sterile surgical
Hand hygiene before the procedures	Routine	Aseptic (e.g., alcohol)	Surgical scrub Iodophors, chlorheximide
Skin antisepsis	No	Alcohol	Chlorhexidine
Sterile field	No	No	Yes
Sterile gown, mask, head covering	No	No	Yes

Box 8.6

General Considerations of a Sterile Technique

- Only sterile materials and instruments are placed within the sterile field.
- Check for chemical indicators to verify sterility of items placed onto the sterile field along with package integrity and package expiration (if appropriate).

- Above and below the sterile field table is considered "nonsterile."

- Materials that display a manufacturer's expiration date should be considered unsafe for use after that date. (Rationale: Expiration dates do not guarantee either sterility or lack of sterility.)

- If any sterile item (material, instrument, gown, glove) has been compromised, the package contents, gown, or the sterile field is considered contaminated. This may happen when:

- nonsterile items contact sterile items;

- liquids or moisture soak through a drape, gown, or package (strikethrough).

- Single-use materials should only be used on an individual patient for a single procedure and then discarded.

- Reusable medical devices shall be reprocessed and sterilized according to the manufacturer's directions.

- Any item that falls below table level is considered unsterile (see Fig. 8.22).

Box 8.7

Sterile Technique

Step 1: Prescrub Wash (see Fig. 8.23)

A short prescrub wash is completed including the hands up to the elbow. This is to remove superficial microorganisms and gross debris. (Duration = 1 minute)

- Prior to the scrub, make sure surgical attire is worn

and remove all jewelry. Glasses (loops, lights, etc.) should be placed in the ideal position.

- Perform a rinse from the finger tips to the elbows so the water flows from the cleanest area (finger tips) to the less clean area (elbows). Utilize a sink that is wide and deep so that both arms are contained within the borders so that water is not splashed out of the sink.

- The next part of the prescrub is to clean the subungal area of each cuticle. With the disposable nail cleaning device, remove any debris from under each cuticle.

Step 2: Primary Scrub (see **Fig. 8.24**)

Depending on the hospital or surgical center, scrubbing methods and protocol will vary. The counted stroke method seems to be the most efficient to guarantee sterility. This involves 10 strokes for each side of each finger (four sides), 10 strokes for each side of the hand, and 10 strokes for each forearm side. Rinse hands and arms under running water in only one direction, from finger tips to elbows. Care must be exercised to ensure fingers, hands, and arms do not touch any nonsterile surface (e.g., faucet). The hands should remain above the waist and below the axilla. If the water is controlled by hand-control levers, a nonsterile surgical assistant should turn the water off.

Step 3: Gowning (see **Fig. 8.25A–D**)

The hands should be dried with a sterile towel. Care should be exercised to prevent the sterile gown or gloves from water contamination. When moving from the scrub sink to the sterile area, keep hands in front of the body, above the waist, and below the axilla. The neckline, shoulders, underarms, and sleeve cuffs are considered nonsterile.

The sterile gown should be immediately donned after complete drying of the hands and forearms, before gloving. Even though the complete gown is sterile when placed on the sterile table, once the gown is donned, only the front from the waist to the axilla is sterile. The gown should be lifted upward and away from the table and allowed to open by locating the neckline and armholes. Hold the inside front of the gown at the level of the armholes to allow the gown to unfold. Do not touch the outside of the gown with bare hands. Extend both arms into the armholes, and the gown and sleeves will unfold. The gown is pulled onto the body with the cuffs of the sleeves extended over the hands. Do not push the hands completely through the cuffs.

Surgical gowns establish a barrier that minimizes the possibility of contamination from nonsterile to sterile areas, which is commonly referred to as a "strikethrough" barrier. They are made of a material that is resistant to blood and fluid penetration.

Step 4: Sterile Gloves (see Fig. 8.25E–I)

Sterile gloves are packaged in a sterile package. The closed-gloving technique is most widely used. It ensures the hands only touch the inside of the gown and gloves. With the dominant hand, pick up the nondominant glove by the inner wrap straight up, placing it on the nondominant hand. Guide and wiggle the fingers into the glove. Using the gloved hand, pick up the remaining glove and guide it on the nondominant hand, making sure the gown cuff is covered. The nondominant glove will then pull the dominant glove cuff over the gown.

Step 5: Tying of the Gown (see Fig. 8.26)

After the gown and gloves are in place, the front tie of the gown must be secured. The surgeon holds the left string with the left hand and holds the right large string and tag with the right hand. The tag is separated from the small string and handed to an assistant. The surgeon rotates 360 degrees and the assistant tears off the tag, leaving the right and left for the surgeon to tie.

Achieving surgical asepsis requires multiple steps including surgical gloving and gowning along with maintaining a sterile field. Each member of

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the team involved in a sterile procedure is responsible for maintaining the aseptic environment.

Sterile Field

Sterile drapes are most often used within the sterile field to cover any surgical area utilized during the surgery (Fig. 8.22). Drapes come in various sizes and are most easily purchased in a kit. The inner surface of the sterile field, except for a 1-inch border, is considered the sterile field that may be used to add sterile items. This 1-inch border may also be used to position the drape within the surgical field. When placing sterile items onto the surgical field, items may be "dropped" from approximately 6 inches above the sterile field.

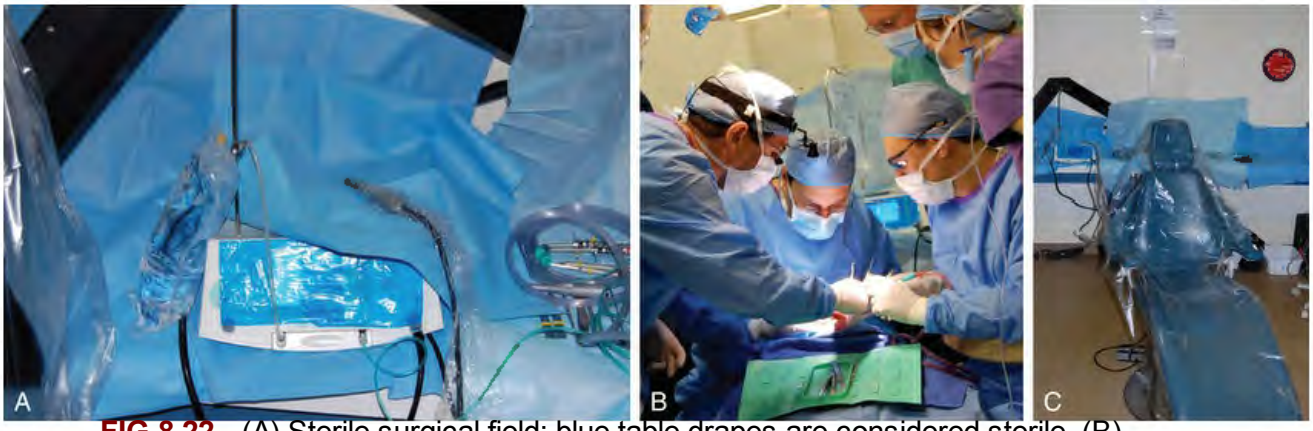

FIG 8.22 (A) Sterile surgical field; blue table drapes are considered sterile. (B) Sterile technique includes all doctors and staff to be wearing a surgical hat, mask, glasses, and gown as well as the sterile patient drape. (C) The chair should be covered, but it is considered nonsterile.

Surgical Scrub

The surgical scrub is the process that removes as many microorganisms from the nail beds, hands, and forearms by mechanical washing and chemical antisepsis for a surgical procedure. This will result in a decrease in microbial count and inhibits the regrowth of bacteria. There are two different types of scrubbing techniques, a sterile sponge/brush with antimicrobial agent or a brushless technique with alcohol/chlorhexidine gluconate (Figs. 8.23 and 8.24).

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FIG 8.23 Prescrub. (A) Make sure hat, mask, glasses are worn and in place prior to the initiation of scrubbing. (B) A prescrub brush. (C) Prerinse from finger tips to elbows. (D) Open prescrub brush. (E) Clean under all fingernails.

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FIG 8.24 Primary scrub. (A) With the scrub brush, do a preliminary wash from finger tips to elbow and then rinse. Brush each side of finger (B), each side of the hand (C), and each side of both forearms with 10 strokes (D–E). (F–G) Rinse from

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the finger tips to the elbows.

All rings, watches, bracelets, and jewelry should be removed prior to starting the hand scrub. Surgical hats, protective eyewear, headlights, and surgical mask must be donned prior to surgical hand asepsis. Drying of the hands and arms is a priority because moist surfaces allow bacteria to multiply. Gowning, gloving, and tying the front tie of the gown occur after the handscrub (Figs. 8.25 and 8.26).

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FIG 8.25 (A) Sterile gown and gloves. (B) Dry hands thoroughly, moist hands will impair glove positioning. (C) Pick up the gown from the sterile field from the inside surface of the gown, step back from the sterile field allowing the gown to unfold from the body, place arms into the sleeves of the gown. (D) When gown is in the ideal position, hands are at the seam of the inside cuff. Keep hands between waist and neck level. (E) With the hands covered by the sleeve of the gown, use the dominant hand to grasp the folded cuff of the glove for the non-dominant hand. (F) The dominant hand pulls the glove completely on the hand from the cuff. (G) Place the second glove on via the same method. (H) Place glove completely over gown. (I) Use the nondominant glove, under the cuff, to fold over the cuff of the gown.

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FIG 8.26 Gown tying. (A) The surgeon holds left string (short) with left hand, holds tag and right string (long) with right hand, then pulls off tag with right hand. (B) The surgeon hands the tag to the assistant. (C) The surgeon spins around 360 degrees and the assistant hands the long string to the surgeon who ties the front of the gown. (D) The assistant or circulator ties the velcro back. (E) The surgeon is gowned and the hands are below the sterile area. (F) The sterile area is below the axilla and above the waist.

Summary

During the course of a career placing dental implants or performing bone grafting procedures, a clinician will most likely encounter situations where a patient presents with infection. As illustrated in this chapter, a seemingly

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small infection of an implant or graft has the potential to involve the surgical spaces of the head and neck, causing life-threatening episodes. The early signs of infection need to be recognized and considered urgently, especially when the patient's swallowing or breathing is compromised. Also, early signs of cavernous sinus thrombosis need to be recognized and the patient referred immediately to a specialist.

Endosteal implants are usually inserted beyond the apex position of natural teeth. Subperiosteal implants traverse natural barriers of infection when extended beyond muscle attachments (Fig. 8.27). Intraoral infections may extend to the base of implants, which may cause more concern than infections of natural teeth. Placement of medical devices into a patient allows for the possibility of infection and places the procedure, patient, and doctor at risk.

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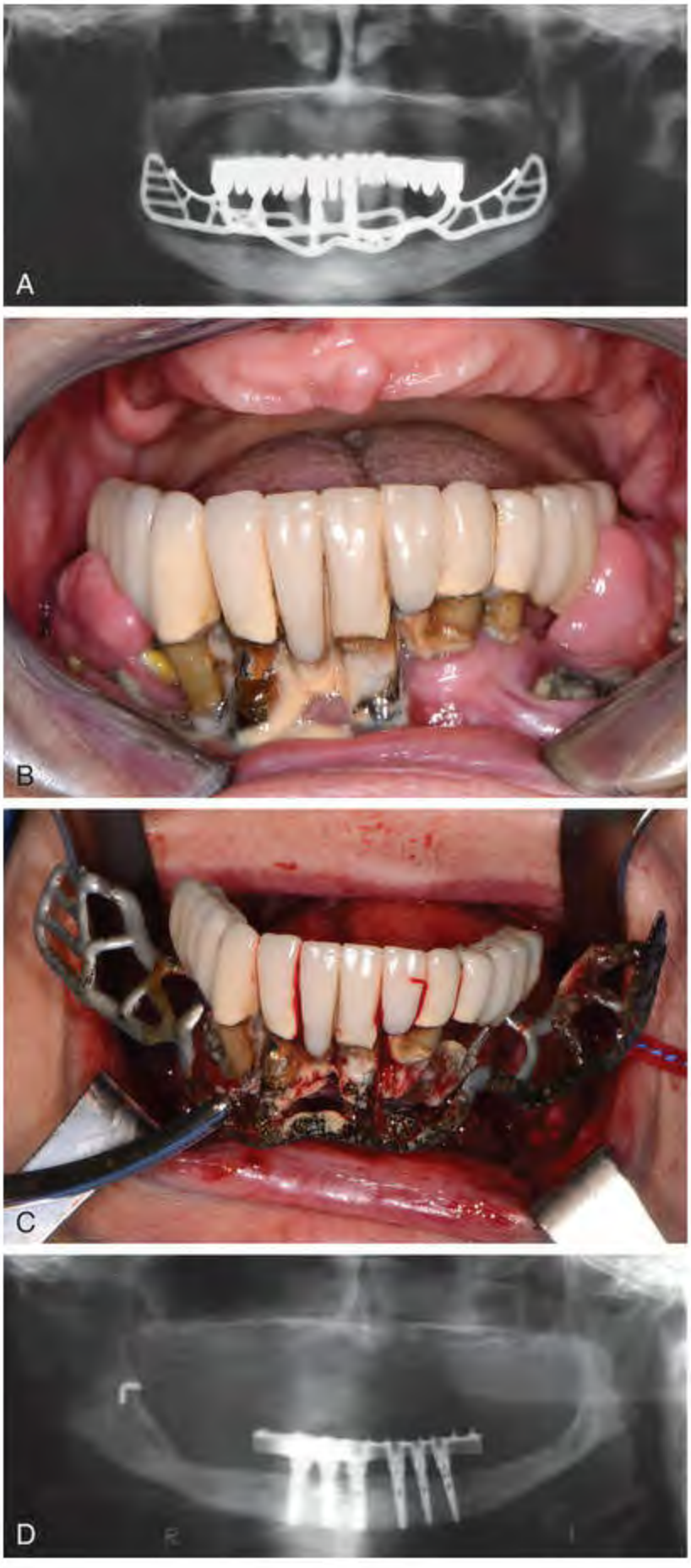

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FIG 8.27 Subperiosteal failure and infection. (A) Panoramic image depicting bone resorption and related infection. (B) Preoperative intraoral view showing anterior teeth and failing circumferential subperiosteal implant. (C) Surgical removal of subperiosteal. (D) Postoperative treatment involved placement of six implants and a fixed prosthesis.

The implant dentist must be aware of the changes in the patient's symptoms as infection progresses and, when indicated, refer the patient immediately to a specialist for treatment. As discussed in this chapter, the infection may start as a painful swelling in the face region with little or no change in the ability of the patient to open the mouth, swallow, or breathe, and with only mild signs of toxemia. The dentist has to be extremely alert to the possibility of a progression of the infection to involve the masticatory, parapharyngeal, perivertebral, and perivisceral spaces and similar areas, with accompanying signs and symptoms, such as the inability to open the mouth and the compromise of vital signs, such as breathing. When this occurs, the patient should be hospitalized without hesitation. It is important that extraoral incisions and management of infection of the head and neck be handled by the appropriate specialists.

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Neurosensory Deficit Complications in Implant Dentistry

Randolph R. Resnik

Iatrogenic injury with resultant sensory impairment of the skin and mucosa innervated by branches of the trigeminal nerve is a major concern in association with dental implant surgery. With the increase in the number of implants being placed and more practitioners becoming involved with dental implant surgery, nerve damage will most likely be a continued problem in implant dentistry. The reported incidence of such nerve injuries following dental implant procedures is highly variable (0% to 44%) in the literature.[1] Studies have shown that approximately 73% of doctors who perform implant surgery have experienced postoperative nerve complications.[2] Libersa et al evaluated transient vs. permanent nerve injuries after implant placement and determined a 75% incidence of permanent injury (Fig. 9.1).[3]

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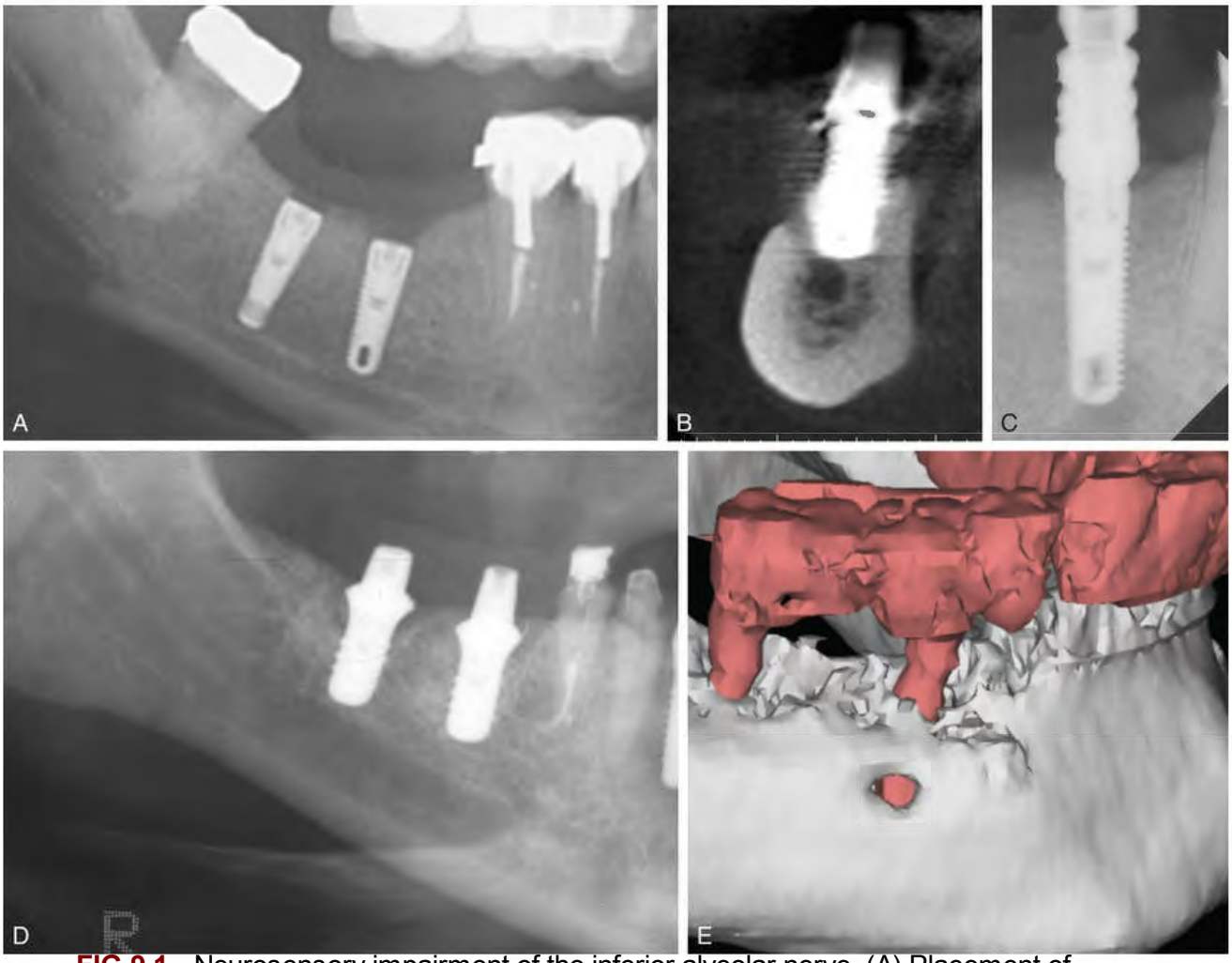

FIG 9.1 Neurosensory impairment of the inferior alveolar nerve. (A) Placement of two implants, completely transecting the mandibular canal. (B–C) Implant placement impinging on the mental foramen. (D) Immediate placement implant after premolar extraction causing nerve impairment. (E) CBCT image depicting implant placement through mandibular canal.

When a nerve injury occurs, it is paramount the dental implant surgeon be able to recognize the type and extent of injury and provide the most appropriate postoperative care. Traumatic and iatrogenic nerve complications may involve total or partial nerve resection, crushing, thermal, stretching, or entrapment injuries. The resulting sensory deficits may range from a nonpainful, minor loss of sensation (hypoesthesia), to a more permanent and severe debilitating pain dysfunction (dysesthesia). Patients with neurosensory deficits often complain of symptoms that include interference with function, speaking, eating, kissing, facial soft tissue dysfunction, and inability to complete everyday tasks such as shaving and placing make-up. The sensory problems often result in an overall decreased quality of life and long-standing psychological problems.[4] Most patients find accepting and

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coping with even minimal nerve injuries difficult to live with. The clinician is usually affected by increased complaints from the patients, embarrassment, with significant medicolegal implications.

In the field of oral implantology today, the clinician must have a thorough understanding of the etiology, prevention, and treatment of neurosensory impairments. The authors have developed postoperative guidelines for diagnosis and possible management of neurosensory deficits following dental implant surgery that are dependent on the history, type, and nature of the injury.

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Anatomy

Peripheral Nerve Fiber Anatomy

The individual nerve fibers of peripheral nerves are situated in fascicles, which are bundles or groups of nerve fibers. For example, the inferior alveolar nerve is classified as polyfascicular, meaning that it contains more than 10 fascicles surrounded by an abundance of interfascicular connective tissue. Within the fascicles, there are approximately 7000–12,000 axons in various fascicular arrangements.[5] The number of fascicles varies along the intramandibular course of the inferior alveolar nerve because there are approximately 18–21 fascicles in the third molar region, decreasing to 12 fascicles in the mental foramen area.[6] Because of the polyfascicular nature of the inferior alveolar nerve, it is better able to regain sensation after injury via compensatory innervation from the uninjured fascicles. Surrounding the polyfascicular makeup of this nerve is the perineurium, which consists of dense, multilayered connective tissue. The perineurium functions to maintain intrafascicular pressure and acts as a diffusion barrier in the protection of the individual nerve fibers. Two types of connective tissue, the inner and outer epineurium, surround the fascicles. The inner epineurium is composed of loose connective tissue with longitudinal collagen bundles. This tissue protects the nerve fibers against compressive and stretching forces, thus maintaining the structural continuity of the nerve. The outer epineurium is continuous with the mesoneurium, which is the outer loose areolar tissue that suspends the nerve trunk within the soft tissue and contains the blood supply to the nerve. The mesoneurium allows the nerve to have longitudinal movement within the surrounding tissue.

If any of these extraneural tissues (epineurium, perineurium, endoneurium, or mesoneurium) is injured, impaired neural transmission by the individual nerve fibers may result in a sensory disturbance. The neurosensory impairment is dependent on the individual fiber type that is involved. The A-alpha fibers are the largest fibers; mediate position and fine touch through muscle spindle afferents and skeletal muscle efferents. The A-beta fibers are solely for proprioception, and the A-delta carries the initial pain impulses along with temperature information. Unmyelinated C-fibers are slow conducting and function for the perception of “second” or slow pain with an additional temperature component. For dental implant surgeons the primary concern is loss of sensory functions such as touch, pressure, pain,

and temperature following trauma (Fig. 9.2).

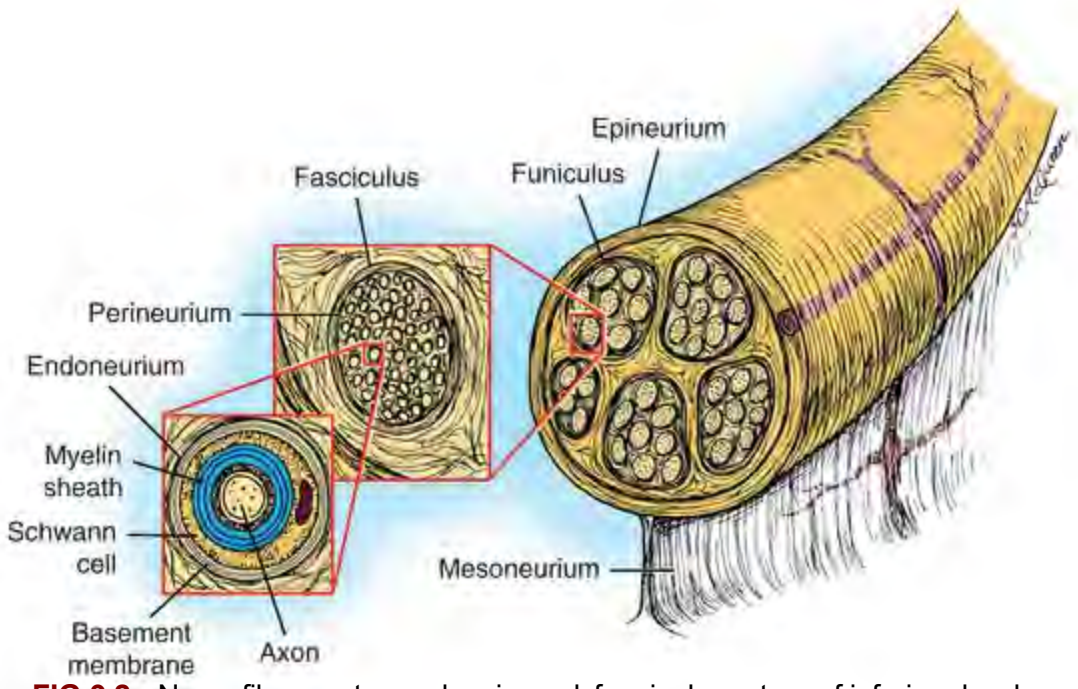

FIG 9.2 Nerve fiber anatomy showing polyfascicular nature of inferior alveolar nerve. (From Canale ST, Beaty JH editors: *Campbell's operative orthopaedics*, ed 11, Philadelphia, 2008, Mosby.)

Trigeminal Nerve

The trigeminal nerve is the fifth cranial nerve and largest of the 12 cranial nerves. This nerve originates from the brainstem at the midlateral surface of the pons with its afferent fibers transmitting innervation from the face, oral and nasal cavity, as well as the scalp. The trigeminal nerve also has visceral efferent fibers for lacrimal, salivary, and nasal mucosa glands. Somatic efferent fibers are present that innervate the masticatory muscles. The trigeminal nerve has three main branches: V_1 (ophthalmic); V_2 (maxillary); and V_3 (mandibular).

V_1: Ophthalmic

The uppermost branch is the ophthalmic nerve, V_1, which is the smallest of the three divisions of the trigeminal nerve. It supplies sensory branches to the ciliary body, cornea, conjunctiva, lacrimal glands, and nasal mucosa as

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well as to the skin of the nose, eyelid, and forehead. The ophthalmic division structures are rarely involved in neurosensory disturbances associated with dental implant procedures.

V_2: Maxillary

The middle branch of the maxillary nerve (V_2) exits the middle cranial fossa through foramen rotundum and enters the pterygopalatine fossa, where it gives off branches to the maxillary teeth and gingiva, maxillary sinus, upper lip, lateral surface of the nose, the lower eyelid, the skin of the cheek and side of the forehead, nasal cavity, and mucosa of the hard and soft palate (Fig. 9.3).

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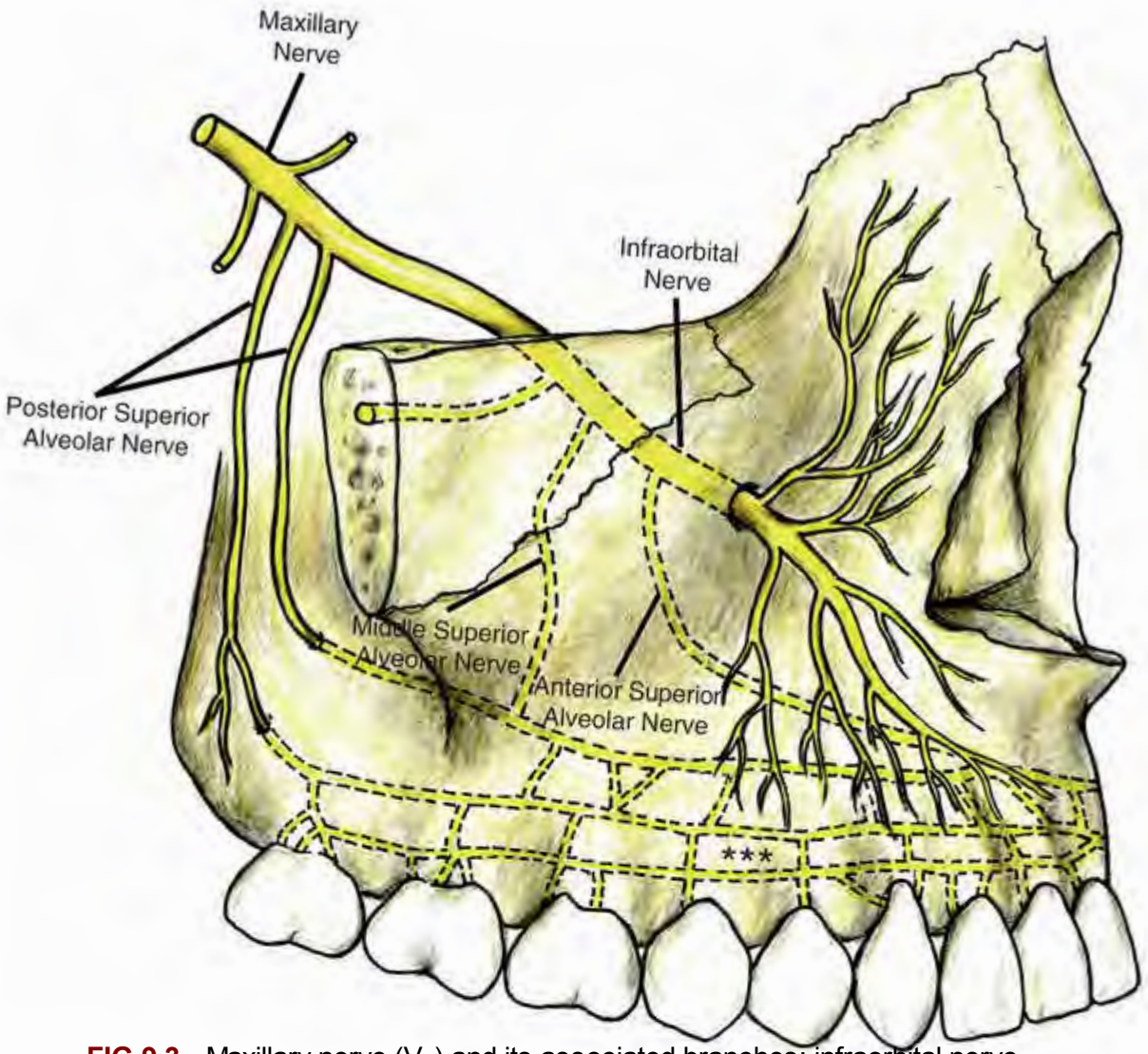

FIG 9.3 Maxillary nerve (V_2) and its associated branches: infraorbital nerve, posterior, middle, and anterior superior alveolar nerves. (From Rodella LF, Buffoli B, Labanca M, et al: Areview of the mandibular and maxillary nerve supplies and their clinical relevance. *Arch Oral Biol* 57:323–334, 2012.)

Nasopalatine Nerve.

The incisive canals fuse and form a common Y-shaped canal that exits lingual to the central incisor teeth (incisive foramen or incisive fossa). The nasopalatine nerve passes through these canals and provides sensation to the anterior palate. These nerves (also termed *incisive nerves*) terminate at the nasal floor and enter the oral cavity via the incisive canal, which is underneath the incisive papilla. To prevent trauma to these nerves, ideal presurgical planning of implant placement in the maxillary incisor region should be carefully evaluated (Fig. 9.4).

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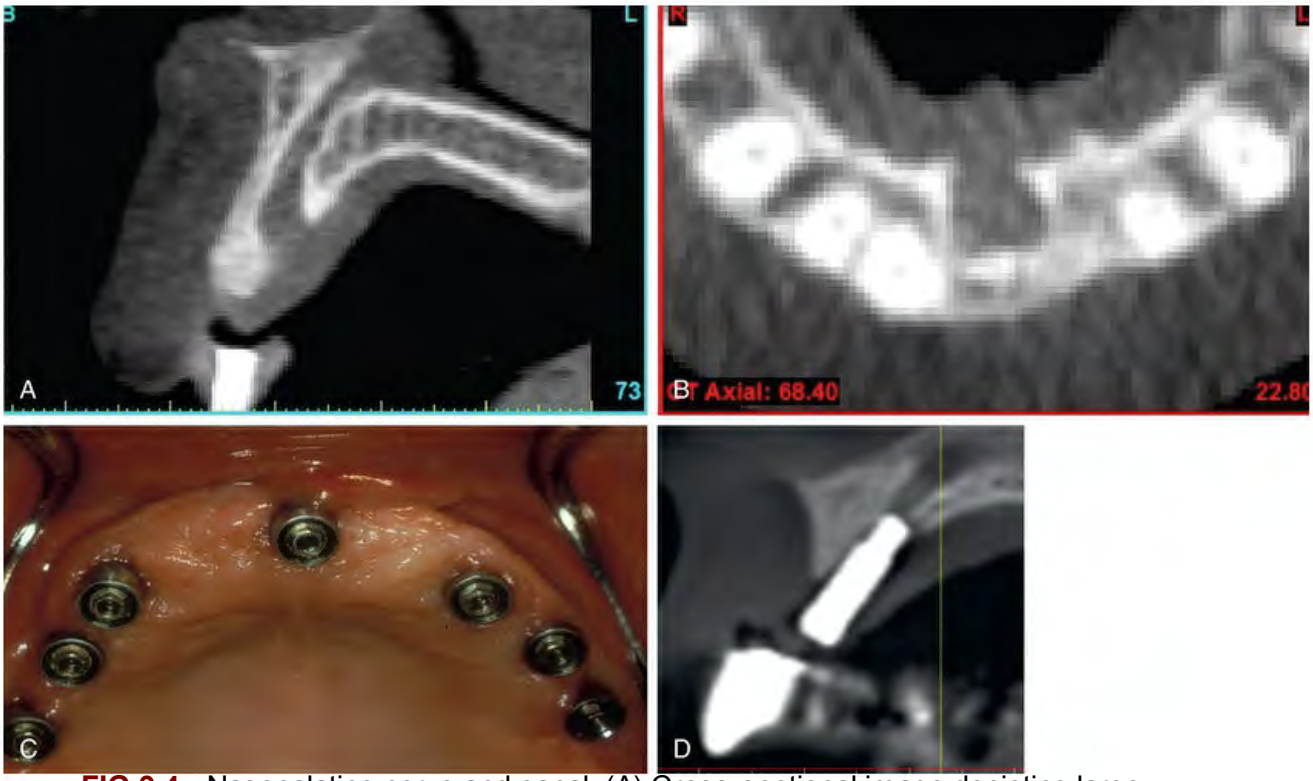

FIG 9.4 Nasopalatine nerve and canal. (A) Cross-sectional image depicting large nasopalatine canal. (B) Axial CBCT image. (C–D) Placement of implant into the nasopalatine canal after removal of soft tissue contents.

Clinical significance.

Removing the contents of the nasopalatine canal and grafting has been reported to have a high success rate.[7,8] Although this nerve is often affected by the placement of implants or bone grafting in the incisor region, sensory disturbances are rare. Nerve damage reported in the literature caused by complete removal[9] or flap surgery[10] is of short duration. This is most likely due to cross innervation of the greater palatine nerve on the anterior palatal area.

Infraorbital Nerve.

The infraorbital nerve emerges from the infraorbital foramen and gives off four branches: the inferior palpebral, external nasal, internal nasal, and the superior labial branches, which are sensory to the lower eyelid, cheek, and upper lip. The inferior palpebral branches supply the skin and conjunctiva of the lower eyelid. The nasal branches supply the lateral nose soft tissue and the movable part of the nasal septum, and the superior labial branches supply the skin of the cheek and upper lip. Normally, the average distance of

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the inferior border of the orbital rim to the infraorbital foramen is 4.6 mm to 10.4 mm (Fig. 9.5).

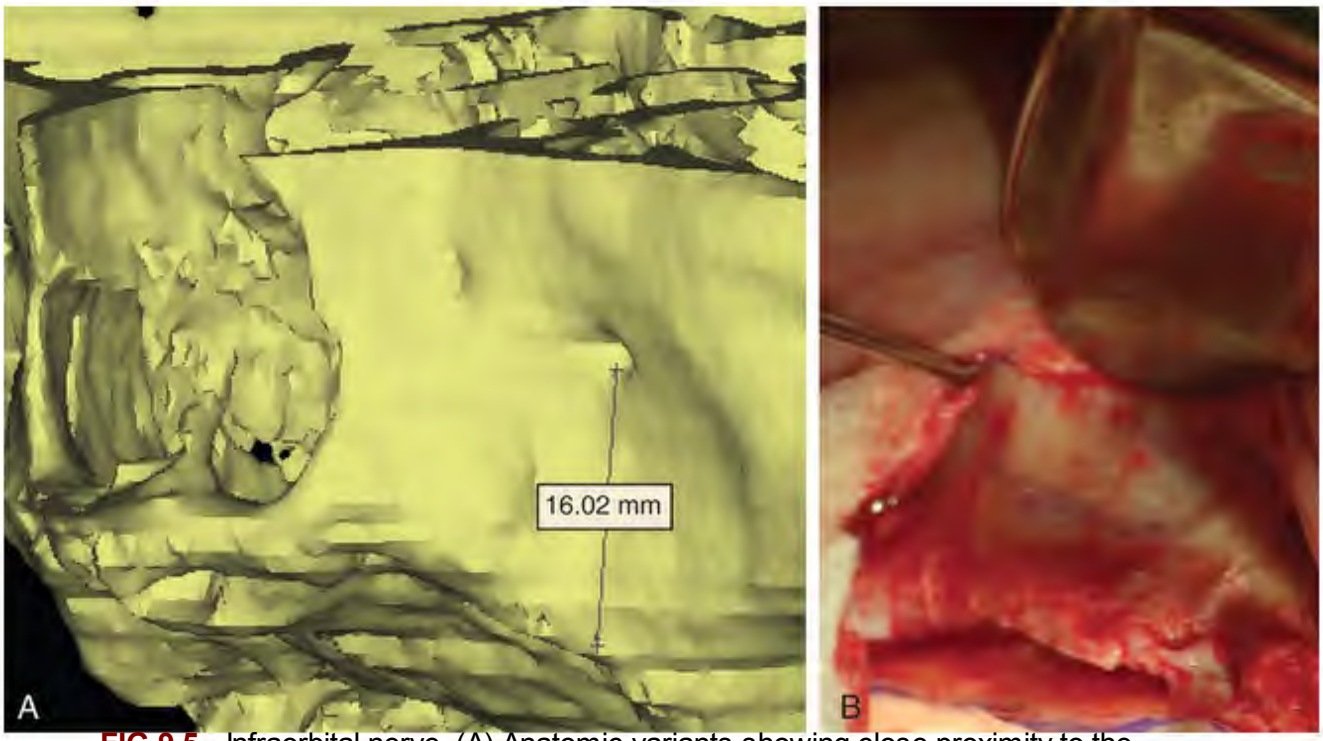

FIG 9.5 Infraorbital nerve. (A) Anatomic variants showing close proximity to the residual ridge. (B) Minnesota retractor in close proximity to the infraorbital nerve.

Clinical significance.

Impairment of the infraorbital nerve may be very traumatic to patients. Damage to branches of the infraorbital nerve usually will result from retraction-related trauma (neuropraxia). Procedures involving the maxillary cuspid-bicuspid area are most susceptible to injuries. Anatomic variants of the infraorbital foramen have been shown to be up to 14 mm from the orbital rim. This is most likely seen in elderly female patients with extensive alveolar atrophy.

Anterior Superior Alveolar Nerve.

The anterior superior alveolar nerve branches from the infraorbital canal on the lateral face. This small canal may be seen lingual to the cuspid and is denoted as the *canalis sinuosus*. The canal runs forward and downward to the inferior wall of the orbit and, after reaching the edge of the anterior nasal aperture in the inferior turbinate, it follows the lower margin of the nasal

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aperture and opens to the side of the nasal septum.[11] Studies have shown that in approximately 15% of the population, this area is described as foramina that are 1–2 mm in diameter. The canals present as a direct extension of the canalis sinuosus and may be clinically relevant when greater than 2.0 mm[12] (Fig. 9.6).

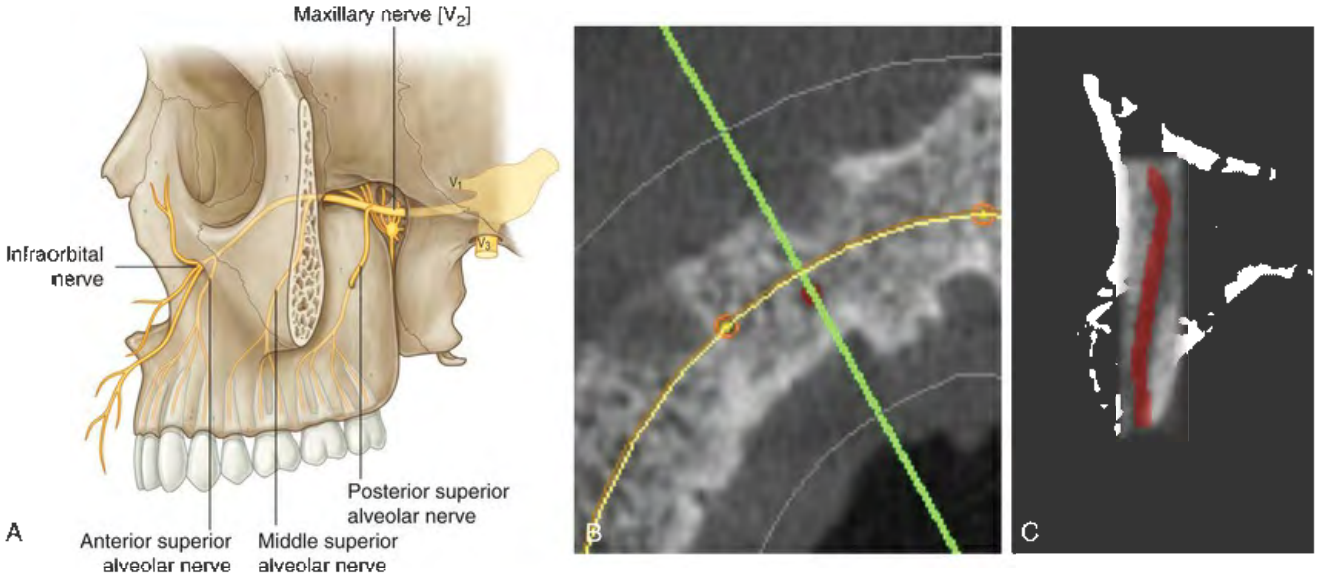

FIG 9.6 (A) Anterior superior alveolar nerve. (B) Canalia sinuosus is an anatomic variant leading to placement of implants into the canal leading to a soft tissue interface. Axial CBCT image showing location in center of residual ridge. (C) Cross-sectional CBCT image depicting the canalia sinuosus. (A, From Wells M: *Local and regional anaesthesia in the emergency department made easy*, Edinburgh, 2010, Churchill Livingstone.)

Clinical relevance.

Because the canine pillar region is a common area for dental implants, care should be taken to check for the presence of neurovascular bundles of the infraorbital canal. Insertion of implants in approximation to the canal may be problematic. Impingement into the canal may lead to a soft tissue interface and failure of the implant and temporary or permanent sensory dysfunction and possible bleeding issues.[13] However, significant sensory impairments are rare because of cross innervation. Many clinicians are unaware of the canalia sinuosus and may misdiagnose this radiolucency as apical pathology of the maxillary cuspid.

V_3: Mandible

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The mandibular nerve is the largest of the trigeminal branches and is the most common branch involved with neurosensory disturbances following dental implant surgery. The mandibular nerve is the lowest branch of the trigeminal nerve, which runs along the floor of the cranium, exiting through the foramen ovale into the infratemporal fossa. It has two branches, the first being a smaller anterior branch containing the buccal and masseteric nerve. A larger posterior component divides the mandibular nerve into three main branches, the auriculotemporal, inferior alveolar (IAN), and lingual nerves (LN).

This nerve innervates the temporomandibular joint, skin above the ears, auricle, tongue and its adjacent gingiva, floor of the mouth, mandibular teeth and associated gingiva, mucosa and skin of the cheek, lower lip and the chin and the muscles of mastication.

Inferior Alveolar Nerve.

The inferior alveolar nerve is the largest branch of the mandibular nerve. Before entering the mandibular foramen on the lingual surface of the mandible, the mylohyoid nerve branches, giving innervation to the mylohyoid and anterior belly of digastric muscles. In the mandibular canal it runs downward and forward before dividing, in approximately the first molar region, into two terminal branches; the incisive and mental nerves.[14] The mental nerve courses anteriorly until it exits through the mental foramen, which is sensory to the soft tissues of the chin, lip, and anterior gingiva. The incisive nerve continues anterior and innervates the mandibular anterior teeth. Accurately determining the exact location of the inferior alveolar nerve as it courses through the body of the mandible is imperative to avoid neurosensory disturbances secondary to implant placement (Fig. 9.7).

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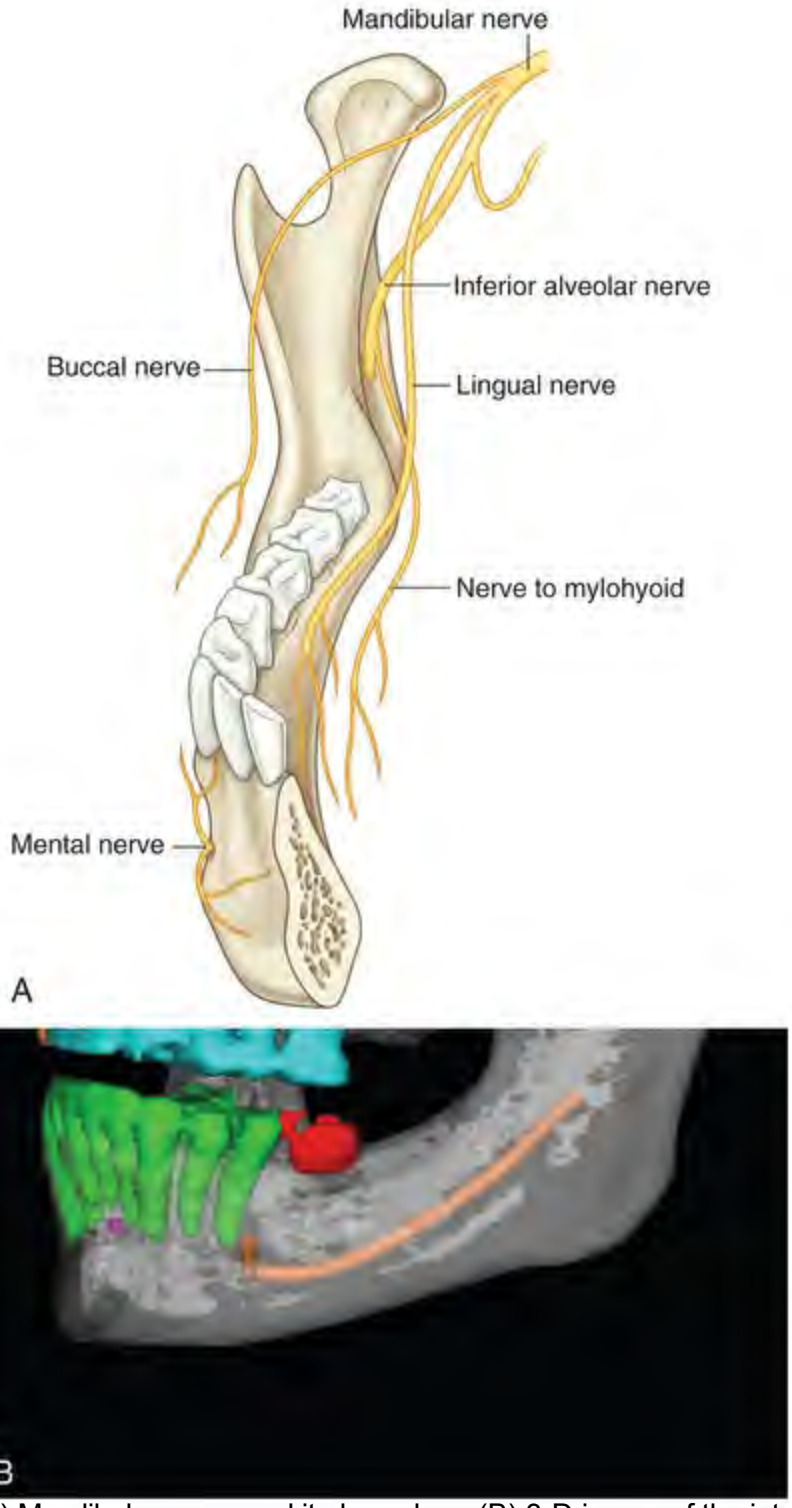

FIG 9.7 (A) Mandibular nerve and its branches. (B) 3-D image of the intraosseous course of the mandibular nerve. (A, From Wells M: *Local and regional anaesthesia in the emergency department made easy*, Edinburgh, 2010, Churchill Livingstone.)

Histologically, this IAN consists of connective tissue and neural components in which the smallest functional unit is the individual nerve fiber. The IAN fibers may be either myelinated or unmyelinated. The myelinated nerve fibers are the most abundant; they consist of a single axon

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encased individually by a single Schwann cell. The individual nerve fibers and Schwann cells are surrounded by the endoneurium, which acts as a protective cushion made up of a basal lamina, collagen fibers, and endoneurial capillaries.

Clinical relevance.

Nerve impairment to the inferior alveolar nerve (mental nerve) is a common clinical complication with major medicolegal implications. Because of its anatomic location, the mental nerve is the most common nerve to be damaged via implants or bone graft procedures. Trauma usually occurs from placement of implants directly into the foramen or into the inferior alveolar canal in the posterior mandible. Sensory nerve injury may result in altered sensation, complete numbness, and/or pain, which may interfere with speech, eating, drinking, shaving, or make-up application and lead to social embarrassment.

Lingual Nerve.

Within the infratemporal fossa, the lingual nerve divides from the posterior division of the mandibular nerve (V_3) as a terminal branch. As the lingual nerve proceeds anteriorly, it lies against the medial pterygoid muscle and medial to the mandibular ramus. It then passes inferiorly to the superior constrictor attachment and courses anteroinferiorly to the lateral surface of the tongue. As it runs forward deep to the submandibular gland, it terminates as the sublingual nerve.

The lingual nerve is sensory to the anterior two thirds of the tongue, floor of the mouth, and lingual gingiva. It also contains visceral afferent and efferent fibers from cranial nerve seven (facial nerve) and from the chorda tympani, which relays taste information. With the prevalence of second molar implants, care should be taken to note the possible position of the lingual nerve on the medial ridge of the retromolar triangle, where it courses anteriorly along the superior lingual alveolar crest, which is slightly lingual to the teeth (Fig. 9.8).[15]

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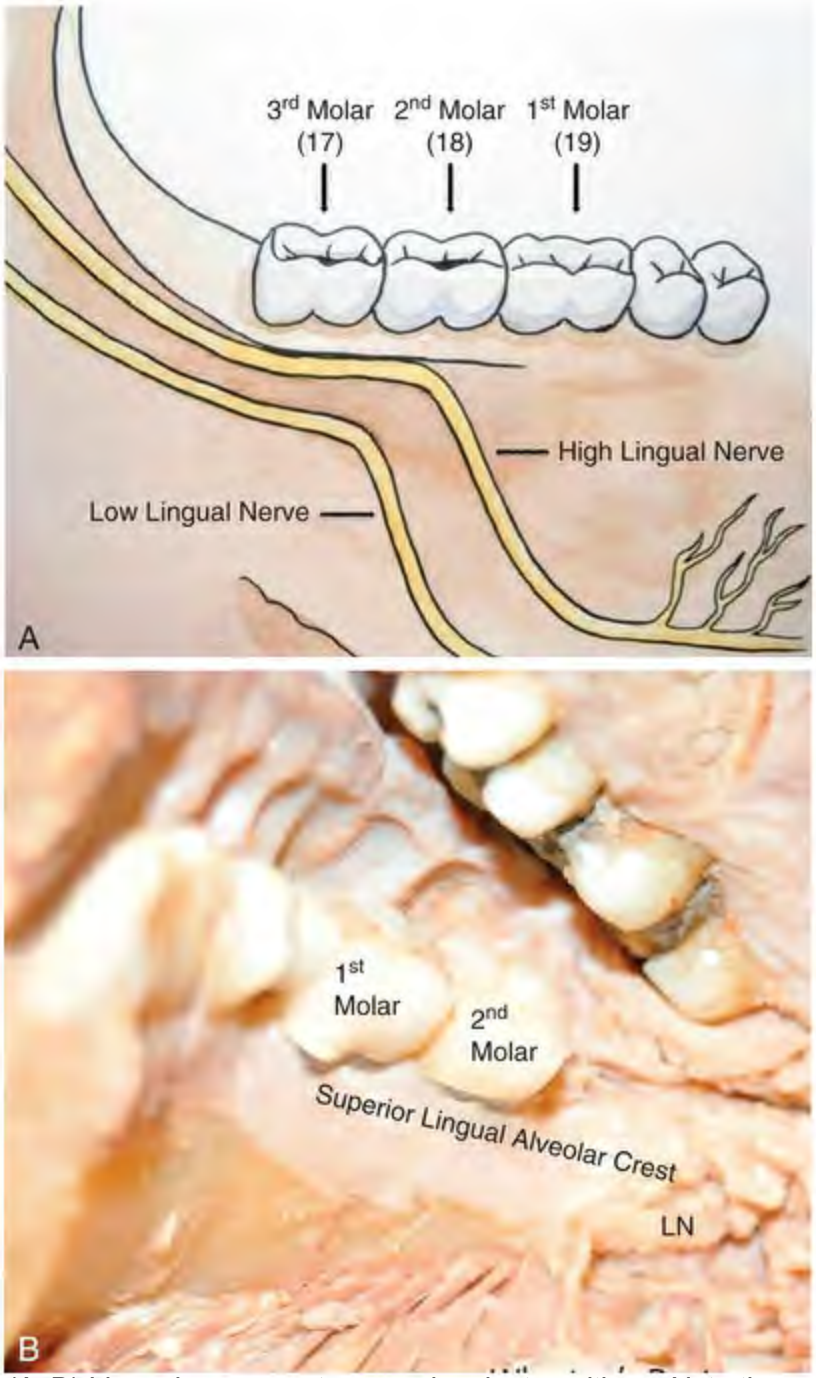

FIG 9.8 (A–B) Lingual nerve anatomy and variant positions. Note the proximity to the crest of the ridge in the "high" variant position. A lingually placed incision or excessive retraction may cause damage to the lingual nerve. (From Benninger B, Kloenne J, Horn JL: Clinical anatomy of the lingual nerve and identification with ultrasonography, *Brit J Oral Maxillofac Surg* 51:541–544, 2013.)

Clinical relevance.

Due to the lingual nerve's variable anatomic location, it may be iatrogenically traumatized during various implant surgical procedures. Usually the lingual nerve is not damaged from the actual osteotomy preparation of implants

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unless the lingual plate is perforated. This sensory nerve is most likely traumatized during soft tissue reflection during implant placement in the second molar area or incision/reflection over the retromolar pad for bone graft procedures. Additionally, the lingual nerve can suffer damage from lingual flap retraction and inferior alveolar nerve blocks. Studies have shown that lingual nerve impairment after nerve blocks occurs twice as often as inferior alveolar nerve damage.[16] This is most likely due to the fact the lingual nerve is most commonly unifascular at the site of the injection. Sensory damage to the lingual nerve may cause a wide spectrum of complications ranging from complete anesthesia to paraesthesia, dysesthesia, drooling, tongue biting, change in taste perception, and change in speech pattern.

Nerve Injuries

Etiology

Most implant-related nerve impairments are the direct result of poor treatment planning and inadequate radiographic evaluation. Nerve trauma occurs when the implant clinician is not aware of the amount of bone or does not know the location of nerve canals or foramens. Preoperative planning is crucial to determine the amount of available bone in approximation to a nerve structure, location of vital structures, bone density, and location for proper placement of implants. A cone beam computed tomography (CBCT) examination is most commonly used for the three-dimensional planning in these areas.

Nerve injuries may result from various intraoperative and postoperative complications. Nerves may be mechanically injured by indirect or direct trauma via retraction, laceration, pressure, stretching, and transection. Thermal trauma may cause inflammation and secondary ischemia injuries with associated degeneration. And lastly, peripheral nerves have been shown to be susceptible to chemical injuries, where the nerve is directly traumatized by chemical solutions.

Administration of Local Anesthesia

Adequate local anesthesia is paramount for successful dental implant surgery and stress reduction protocol. However, although rare, the use of nerve blocks may result in trauma to various branches of the trigeminal nerve. The exact etiology of local anesthesia nerve damage is unclear, and various theories such as injection needle trauma, hematoma formation, and local anesthetic toxicity have been discussed. Although the true incidence is difficult to quantify, studies have shown permanent injury occurs in approximately 1 in 25,000 inferior nerve blocks. Most patients do recover fully without deficits, with full recovery in 85% of patients with complete remission in 8–10 weeks.[17]

Needle.

Complications resulting from needle trauma are likely the most common theory on why nerve injury results after administering nerve blocks. First, it is not uncommon for the tip of the needle to become barbed (damaged) when contacting bone. Stace et al showed that 78% of needles became barbed

after initial injection, increasing the possibility of damaging the nerve. Two-thirds of the needles developed outward-facing barbs, which have been shown to rupture the perineurium, damage the endoneurium, and cause transection of nerve fibers.[18] The lingual nerve has been associated with the highest percentage of nerve impairment cases as a result of an anesthetic injection (~70%)[19]. Because of the lingual nerve's anatomic location, it is predisposed to nerve injuries because it is commonly contacted when using the pterygomandibular raphe as an injection landmark due to the nerve being positioned shallow in the tissue (~3–5 mm from the mucosa).[20]

Hematoma.

The anesthetic needle may also cause damage to the epineurial blood vessels, which may result in hemorrhage-related compression on the nerve fibers. The accumulation of blood may lead to fibrosis and scar formation, which may cause pressure-related trauma.[21] The extent of impairment to the nerve is directly related to the amount of pressure exerted by the hematoma and recovery time of the axonal and connective tissue damage.

Anesthetic Toxicity.

If the anesthetic is injected within the fascicular space, chemical irritation and damage may occur. Studies have shown articaine to comprise 54% of mandibular nerve block injuries,[22] and it is 21 times more likely to cause injury in comparison to other nerve injuries.[23] Theories concerning articaine toxicity include the high concentration of articaine solution[24] and the increased resultant inflammatory reaction.[25] Lidocaine has been shown to be the least toxic anesthetic followed by articaine, mepivacaine, and bupivacaine.[26] Chemical trauma from local anesthetics has been shown to cause demyelination and axon degeneration of nerve fibers.[27]

Soft Tissue Reflection

Injury to nerves and nerve fibers may occur during the reflection, retraction, or suturing of the soft tissue. This is most noted when the mental nerve is dehiscenced or exposed on the mandibular ridge. Special caution should be exercised when making incisions over these areas because complete transection injuries may occur from incisions through the nerve or foramen. Stretching injuries (neuropraxia) may occur from excessive retraction, so care should be noted as to the proximity of neural vital structures within the

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retracted tissue. Complete transection of the nerve results from stretching the tissue to reduce tension over the flap without regard to the anatomic location of the nerve (Fig. 9.9).

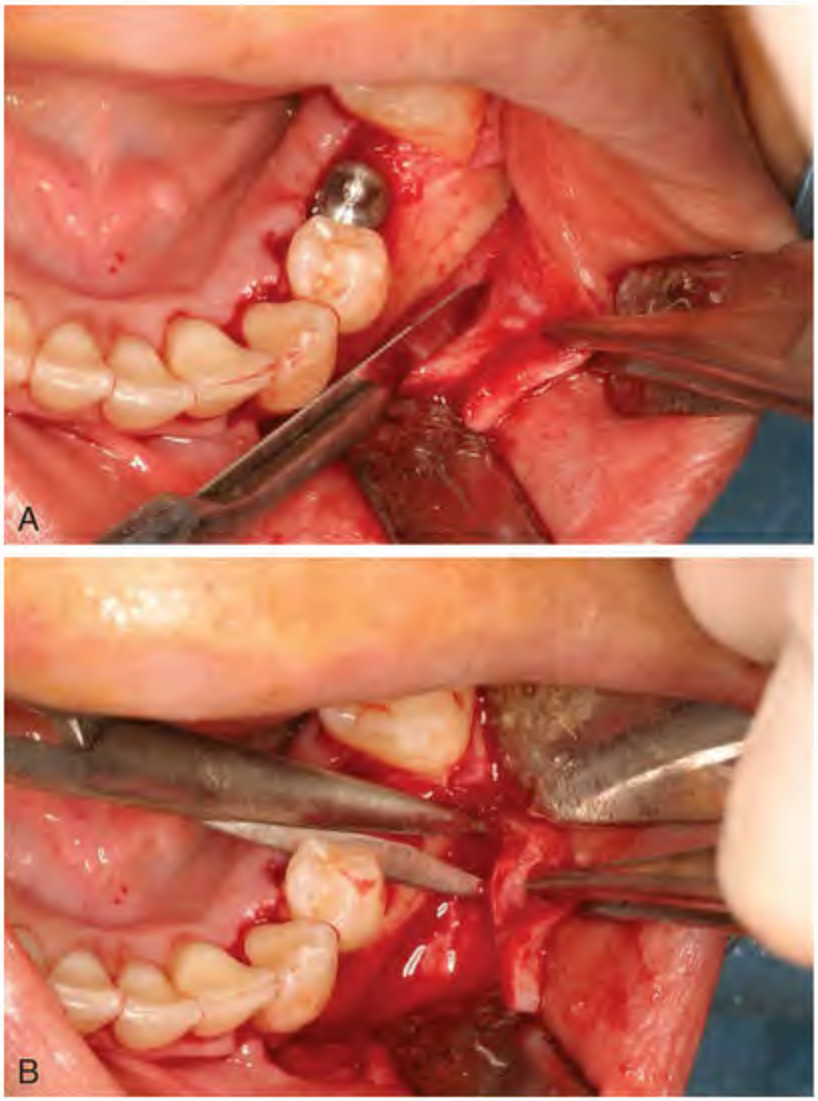

FIG 9.9 Periosteal release of the tissue to obtain tension-free closure. (A) The use of a #15 blade to release the periosteal fibers. (B) Blunt dissection to release tissue with Metzenbaum scissors.

Implant Drill Trauma

Neurosensory impairment may result from direct or indirect trauma from the osteotomy sites. Direct trauma may occur from overpreparation of the osteotomy site or lack of knowledge of the true bur length. The implant clinician must know and understand the true length of the surgical burs used

in the osteotomy site preparation. The marked millimeter gauge lines inscribed on the shank of the drills most often do not include the cutting edge of the drill and do not correspond to the actual depth of the drill. Most drills have a sharp, V-shaped apical portion to improve their cutting efficiency. The V-shaped apical portion of the drill (termed the "Y" dimension in engineering) is often not included in the depth measurements of the commercial drills and may measure as much as 1.5 mm longer than the intended depth.

When the bone is less dense, slippage of the handpiece may occur, leading to overpenetration. The implant clinician should use the initial implant osteotomy twist drill as a gauge for bone density type and for an evaluation of the position of the surgical drill relative to the mandibular canal. In implant dentistry today the overzealous use of immediate implants has been associated with an increase of drilling-related trauma. To gain primary stability, most immediate implant osteotomy sites require drill preparation and implant placement apical to the extraction site. When placing implants in the mandibular premolar area, violation of the canal may occur, causing nerve damage. Therefore in this anatomic area, immediate implant placement is not recommended unless adequate bone is available below the root apex.

The following are the types of surgical drill trauma that may lead to a neurosensory impairment:

Drill Encroachment.

The surgical drill may cause a nerve impairment from thermal damage even though the surgical drill does not violate the mandibular canal. Most commonly, this is the result of insufficient irrigation, which leads to overheating the bone. Thermal trauma may lead to nerve impairment via bone necrosis from overheating the bone during preparation. Nerve tissue has been shown to be more sensitive to thermal trauma than bone (osseous) tissue. Excessive temperatures have been shown to produce necrosis, fibrosis, degeneration, and increased osteoclastic involvement.[28] To minimize this complication the bone density should be evaluated preoperatively via CBCT examination, tactile evaluation, and by location.

Partial Penetration.

The surgical drill may also cause direct trauma to the neurovascular bundle

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by penetrating the mandibular canal or mental foramen. The neurosensory impairment will be directly proportional to the specific nerve fascicles that are damaged. Normally, the vein and artery, which are positioned more superiorly than the nerve, will be damaged when penetration of the canal results. Indirect trauma may also cause nerve damage from the excessive bleeding (hematoma), as well as thermal and chemical injuries from the penetration into the canal.

Transection.

The most severe type of nerve injury, with the lowest probability of regeneration, is when the implant drill transects the canal. Because the nerve is usually completely severed, repair and regeneration is highly variable. This type of injury will usually result in anesthesia-type symptoms and neuroma formation with possible dysesthesia symptoms (Fig. 9.10).

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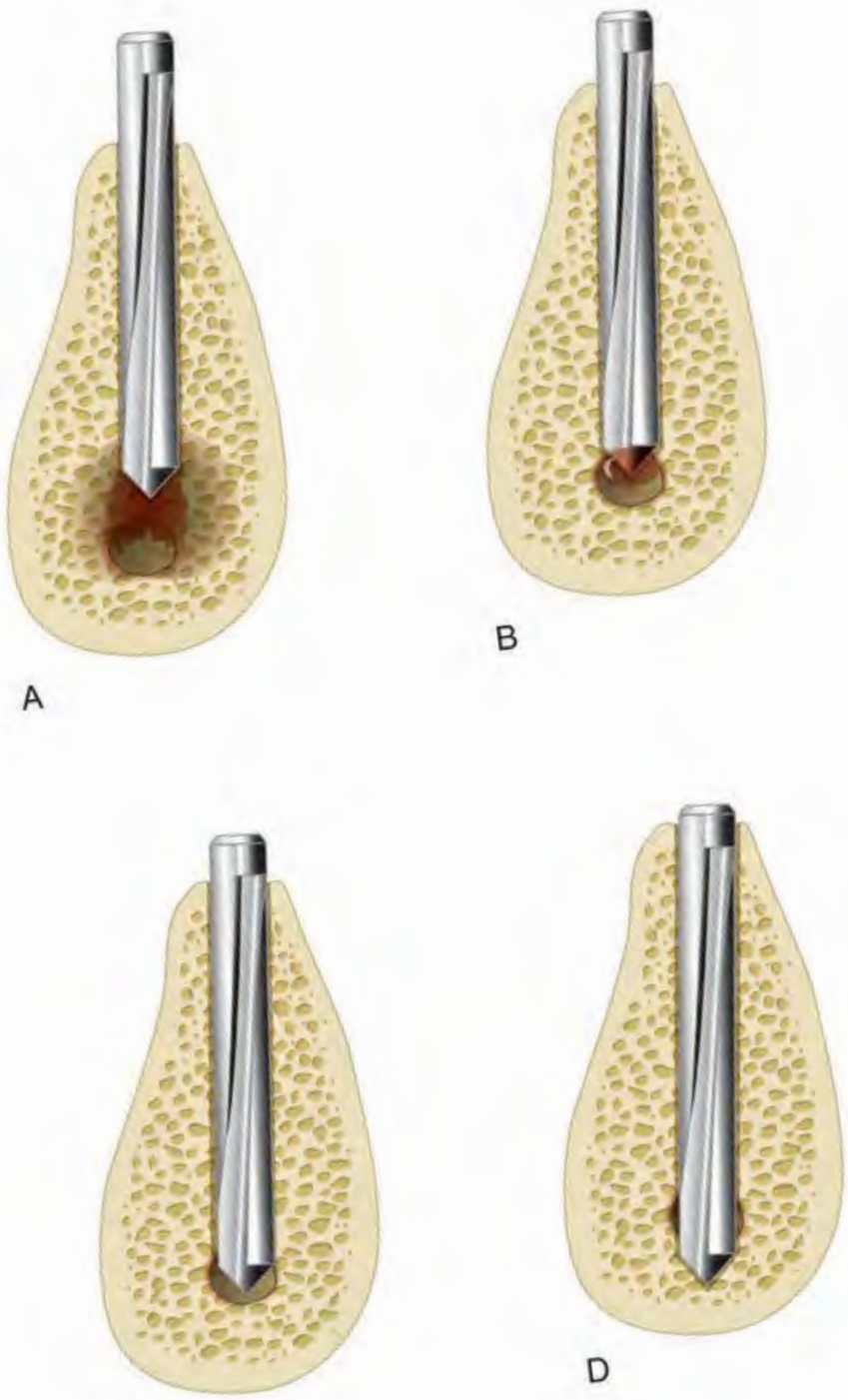

FIG 9.10 Drill impingement trauma. (A) Encroachment: even though surgical drill is short of canal, thermal damage and bone necrosis (brown/green) result in nerve damage. (B) Partial penetration (hematoma): the surgical drill partially penetrates the superior aspect of the canal resulting in bleeding and hematoma formation. (C) Partial penetration (laceration): the surgical drill penetrates deeper into the canal, which results in laceration of nerve fibers. (D) Transection: the surgical drill may penetrate the entire canal leading to complete transection of the nerve fibers.

Implant Encroachment on the Mandibular Canal.

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Injuries to vital nerve structures due to implant positioning are most common in the posterior mandible. These may be caused by direct trauma (mechanical) and indirect trauma or infection (pressure). Placement of an implant into or near the mandibular canal is associated with many types of neurosensory impairments (Fig. 9.11).

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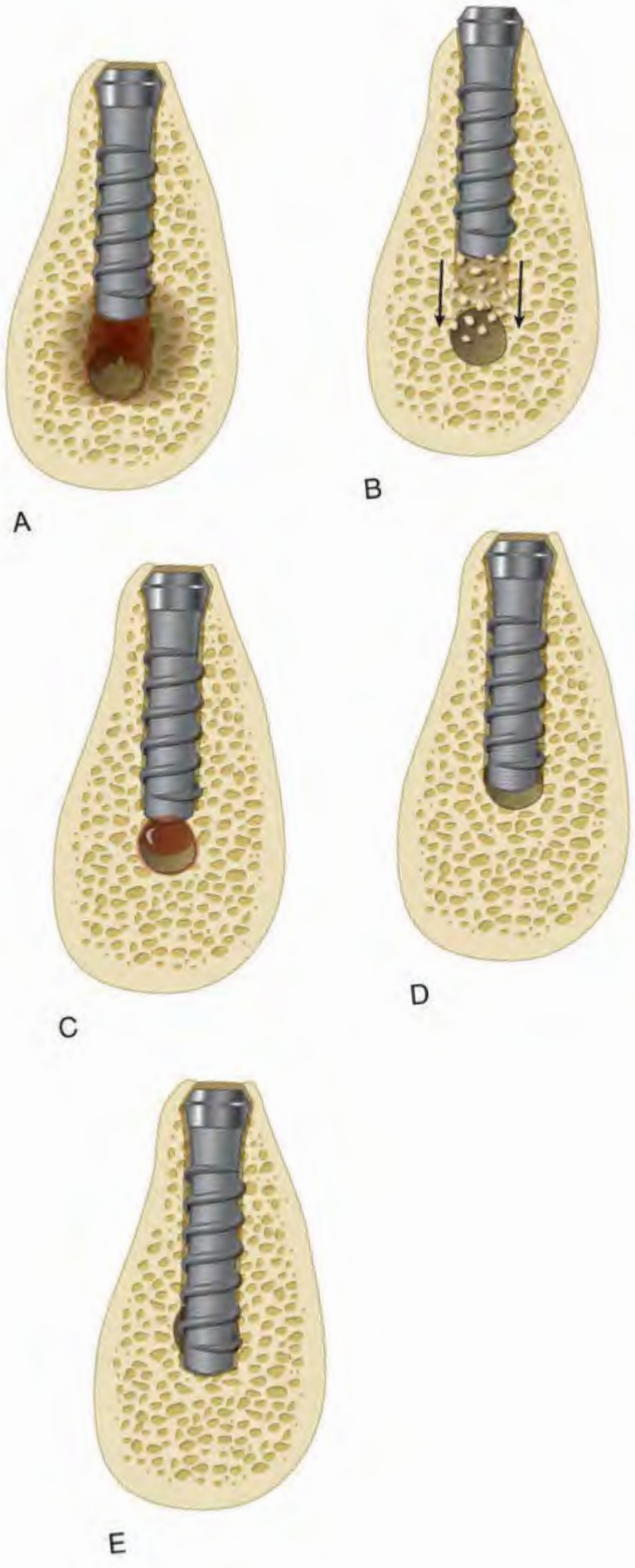

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FIG 9.11 Implant impingement trauma. (A) Encroachment: even though the implant body is short of the canal, thermal damage may occur from overheating the bone. (B) Bone fragments (trabeculae) may be pushed apically resulting in a pressure necrosis nerve injury. (C) Partial penetration (hematoma): the implant body may partially penetrate the superior aspect of the canal resulting in bleeding and hematoma formation. (D) Partial penetration (laceration): the implant body may penetrate deeper into the canal, which results in laceration of nerve fibers. (E) Transection: the implant body may penetrate the entire canal leading to complete transection of the nerve fibers.

Placement of an implant close to the mandibular canal may cause trauma due to compression or secondary ischemia. A 2.0-mm safety zone of the implant in proximity to the canal should always be adhered to. Studies have shown that implant pressure on the canal occurs with increasing stress as the bone density decreases.[29] Khaja and Renton showed that placement of an implant too close to the canal may cause hemorrhage or deposition of debris into the canal, causing ischemia of the nerve. Even removing the implant or repositioning may not alleviate and decrease pressure-related symptoms. Additional studies have shown the presence of postoperative severe pain after implant placement in close approximation to the canal resulting in chronic stimulation and debilitating chronic neuropathy.[30]

Partial Penetration Into Mandibular Canal.

Placement of the implant body into the mandibular canal is associated with a high degree of morbidity. The sensory nerve fascicles are usually inferior to blood vessels within the canal, and the type and extent of injury is proportional to the fibers that are damaged. This is why in some cases the implant is directly within the canal; however, no neurosensory symptoms exist. Additionally, implant placement into the canal may cause hematoma formation (severing of the inferior alveolar artery or vein), leading to a nerve impairment.

Perforation Through the Entire Canal.

Complete transection of the nerve occurs when surgical error involves the preparation of an osteotomy too deep due to inaccurate measurements or slippage of the handpiece. This type of injury results in the most severe of response, a total nerve impairment (anesthesia) and neuroma formation. Usually this type of nerve injury results in a complete anesthesia and retrograde degeneration resulting in future dysesthesia.[27] The extent of neurosensory impairment is proportional to the extent of fascicle injury and

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is dependent upon the time the implant is left to irritate the nerve fibers.

Infection.

Placement of implants in approximation to the canal may cause neurosensory impairments via periimplant infections. Infectious processes after implant placement may result from heat generation, contamination, or prior existence of bone pathology. This may lead to spread of infection that may extend into the neural anatomy. Case reports have shown nerve impairment issues resulting from an implant infected by chronic peri-implantitis.[31]

Mandibular Socket Grafting.

After mandibular tooth extractions, grafting into the socket may effectively expose the inferior alveolar nerve to socket medicaments. This may lead to chemical neuritis and, if the irritation persists, an irreversible neuropathy may occur (Fig. 9.12). Additionally, care should be exercised when removing pathology and granulation tissue from extraction sockets in close proximity to the nerve canal (type 1 nerve).[32] Overzealous curretting of the socket apex may lead to direct traumatic injury of the canal.

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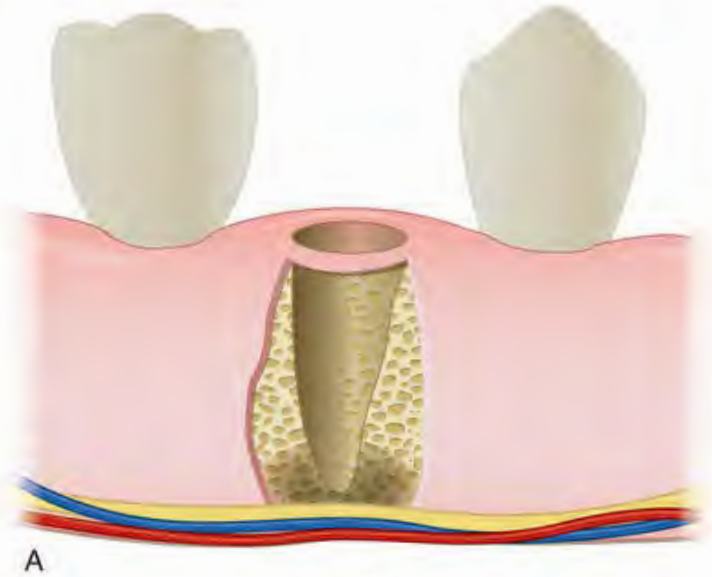

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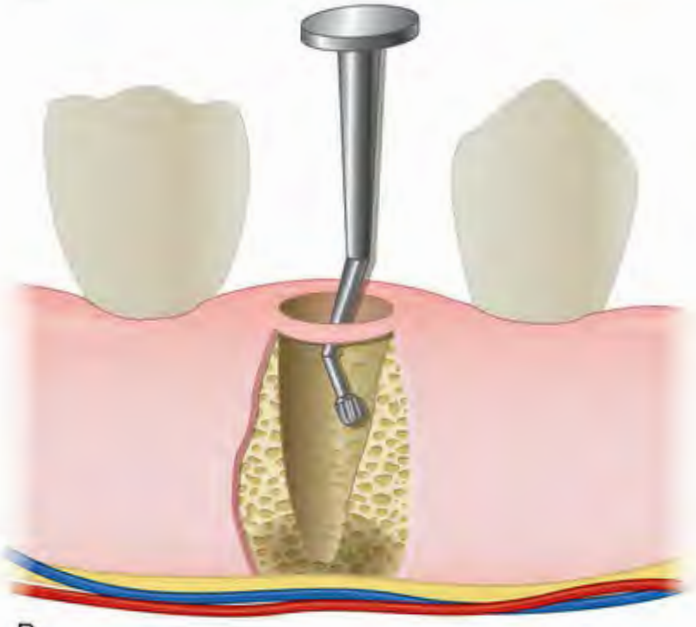

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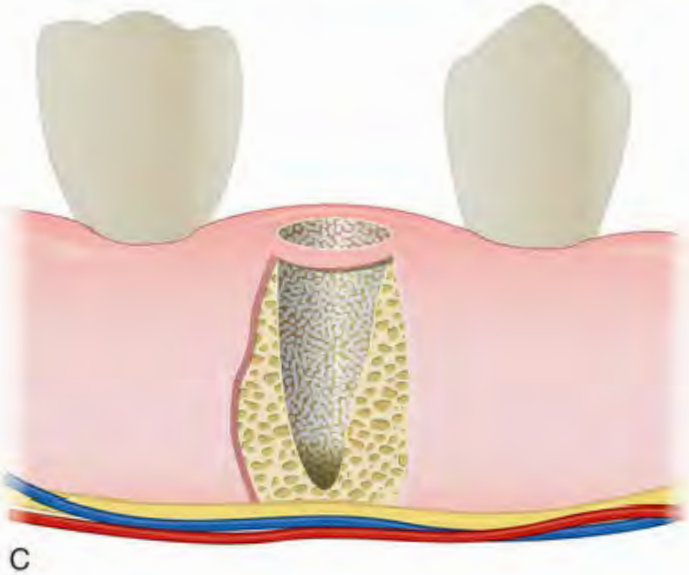

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FIG 9.12 Postextraction site. (A) Care should be taken when grafting an extraction site in close approximation to the inferior alveolar nerve. (B) A curette should be used with caution because direct damage to the nerve may occur. (C) Grafting in close approximation to the canal may lead to nerve trauma.

Delayed Nerve Damage (Canal Narrowing).

Nerve damage may result even when ideal implant placement is performed (>2.0 mm from the nerve canal). Shamloo et al reported an implant placement case in which the implant body caused compression and bone to be forced into the superior aspect of the mandibular canal (canal narrowing). This led to delayed healing and remodeling within the canal and resulted in excessive narrowing of the canal with compression of the nerve fibers. The narrowed aspect of the canal was shown to be approximately 0.2 mm, with an average diameter in the nonaffected sites being approximately 3.2 mm.[33] The nerve impairment (paresthesia and anesthesia) occurred 2 years after implant placement surgery.

Physiologic Response

The incidence of nerve impairment has been shown to be patient specific. Studies have shown that females and older patients are at greater risk of nerve deficits. As patients age, neural cell body regeneration has been shown to be much slower.[34] Women have been shown to have greater associated pain and nerve impairment in comparison to men because of lower pain thresholds, greater chance of seeking treatment in comparison to men, and an increased tendency to communicate their problems.[35]

There are many local and host-related factors that determine the neurologic response to a nerve injury. Older individuals exhibit slower and less dramatic cell body regeneration in comparison to younger individuals. The type of injury is the most significant local factor relating to the neurologic response after trauma. Injuries that occur at the proximal site of the peripheral nerve are usually more significant in comparison to those that occur at distal sites.[9] In the event any of the extraneural tissues (epineurium, perineurium, endoneurium, or mesoneurium) are injured or traumatized, impaired neural transmission may result in a sensory disturbance. The resultant neurosensory impairment is dependent on the varying functional units of the individual fiber type involved. A-alpha fibers are the largest fibers and mediate position and fine touch by way of muscle spindle

afferents and skeletal muscle efferents. The A-beta fibers are mainly proprioceptive in nature, and A-delta fibers mediate initial pain impulses along with temperature information. The C-fibers are unmyelinated and slow conducting, which allow the perception of pain and temperature.[4]

When complete transection of a nerve occurs, within 96 hours the proximal end of the nerve fiber shrinks approximately 20% to 50% in diameter and usually will not recover more than 80% of its original size.[10] Shortly thereafter, axonal nerve sprouts will seek and extend out to the degenerating distal branch. Each axon may contain up to 50 collateral sprouts and advance approximately 1–3 mm per day and eventually attempt to reinnervate the target tissue. If the nerve sprouts are unable to reconnect, forward progress is stopped and Wallerian degeneration will occur. Wallerian degeneration is the process resulting from a damaged nerve fiber in which part of the axon is separated from the neurons cell body. This may also be known as anterograde or orthograde degeneration.[35a] Wallerian degeneration usually results in neuroma (benign growth) formation, which is associated with increased mechanical and chemical sensitivity, resulting in chronic neurosensory deficits.[11]

Quick, immediate treatment is highly recommended in neurosensory impairment cases. Nerve fiber atrophy has been shown to occur with trauma over 6 hours.[36] After 3 months, permanent central and peripheral changes occur that make it unlikely the nerve will respond to surgical treatment intervention.[37] Injuries older than 6 months rarely respond to any treatment and are usually permanent.[38]

Nerve Healing

After nerve injury, there exist two phases of healing, degeneration and regeneration.

Degeneration.

There are two types of nerve degeneration: segmental degeneration and Wallerian degeneration. Segmental demyelination occurs when the myelin sheath is damaged and causes a slowing of the conduction velocity, which may prevent the transmission of nerve impulses. The resulting effects will clinically be paresthesia, dysesthesia, or hyperesthesia. The second type of degeneration is termed *Wallerian degeneration,* in which the axons and myelin sheath distal (away from central nervous system [CNS]) to the injury

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undergo complete disintegration (Fig. 9.13). The axons proximal to the site of injury (towards the CNS) undergo less degeneration, but many nodes of Ranvier (periodic gaps in the myelin sheaths of axons that facilitate the rapid conduction of nerve impulses) are affected. Wallerian degeneration usually occurs after complete transection of the nerve and results in dysesthesia type of symptoms.

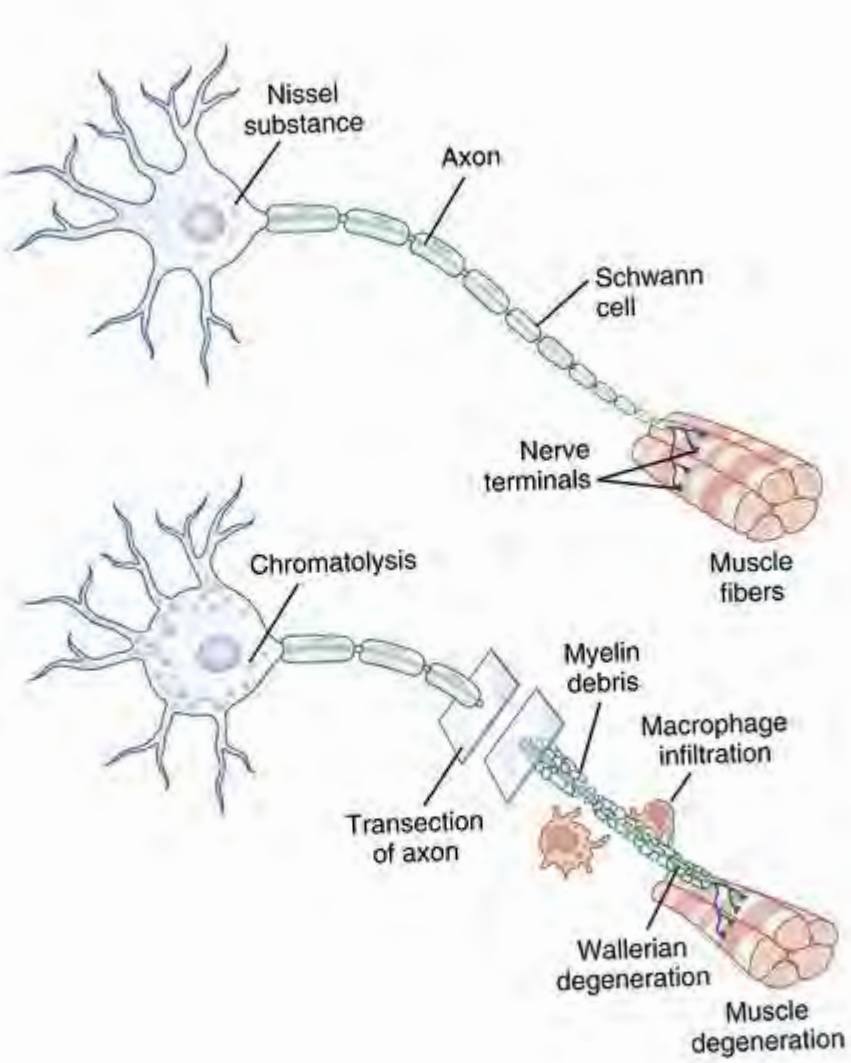

FIG 9.13 Wallerian degeneration resulting with inadequate nerve repair. (From Daroff RB, Jankovic J, Mazziotta JC, et al editors: *Bradley's neurology in clinical practice*, ed 7, London, 2016, Elsevier.)

Regeneration.

Usually, regeneration occurs immediately after nerve injury. The proximal nerve area sprouts out new fibers that grow at a rate of 1.0–1.5 mm per day. This will continue until the site innervated by the nerve is reached or blocked

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by fibrous connective tissue, bone, or object (e.g., dental implant). During the regeneration process, new myelin sheaths form as axons increase in size. In some situations the continuity of the Schwann cells is disrupted, and connective tissue may enter the area. The growth may find an alternative path, or it may form a traumatic neuroma, which is usually characterized by significant pain. Studies have shown that the administration of steroids may minimize the formation of neuromas, especially the administration of high doses within the first week of nerve injury (Fig. 9.14).[2]

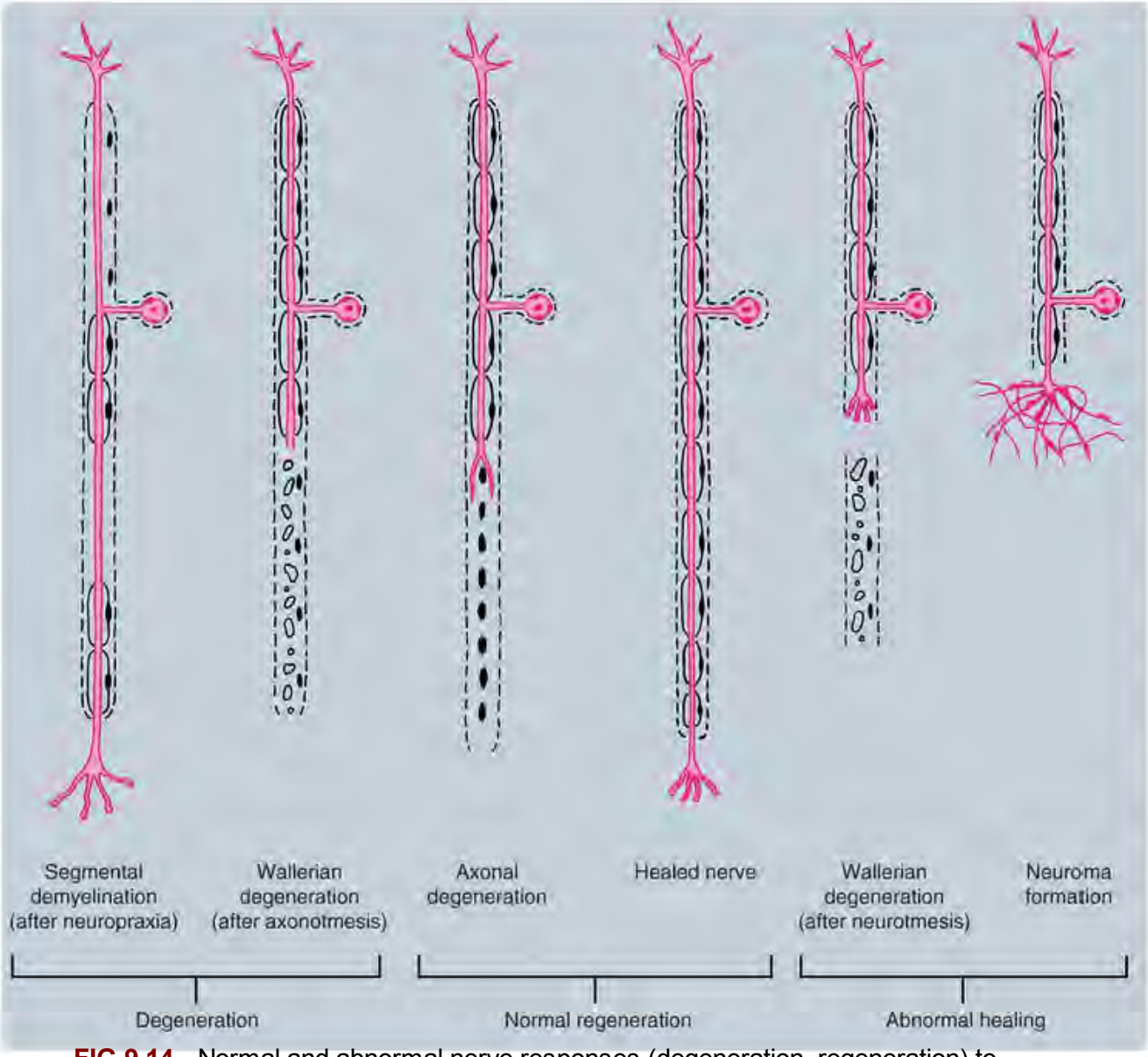

FIG 9.14 Normal and abnormal nerve responses (degeneration, regeneration) to nerve injury. (From Hupp JR, Tucker MR, Ellis E: *Contemporary oral and maxillofacial surgery*, ed 6, St. Louis, 2014, Mosby.)

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Neurosensory Deficit Classification

There are two widely accepted classifications of nerve injuries. In 1943 Seddon postulated a three-stage classification, which was later reclassified by Sunderland in 1951 into five different subclassifications. These nerve injury classifications are described by the resultant morphophysiologic type of injury, which is based on the time course and amount of sensory recovery (Fig. 9.15).

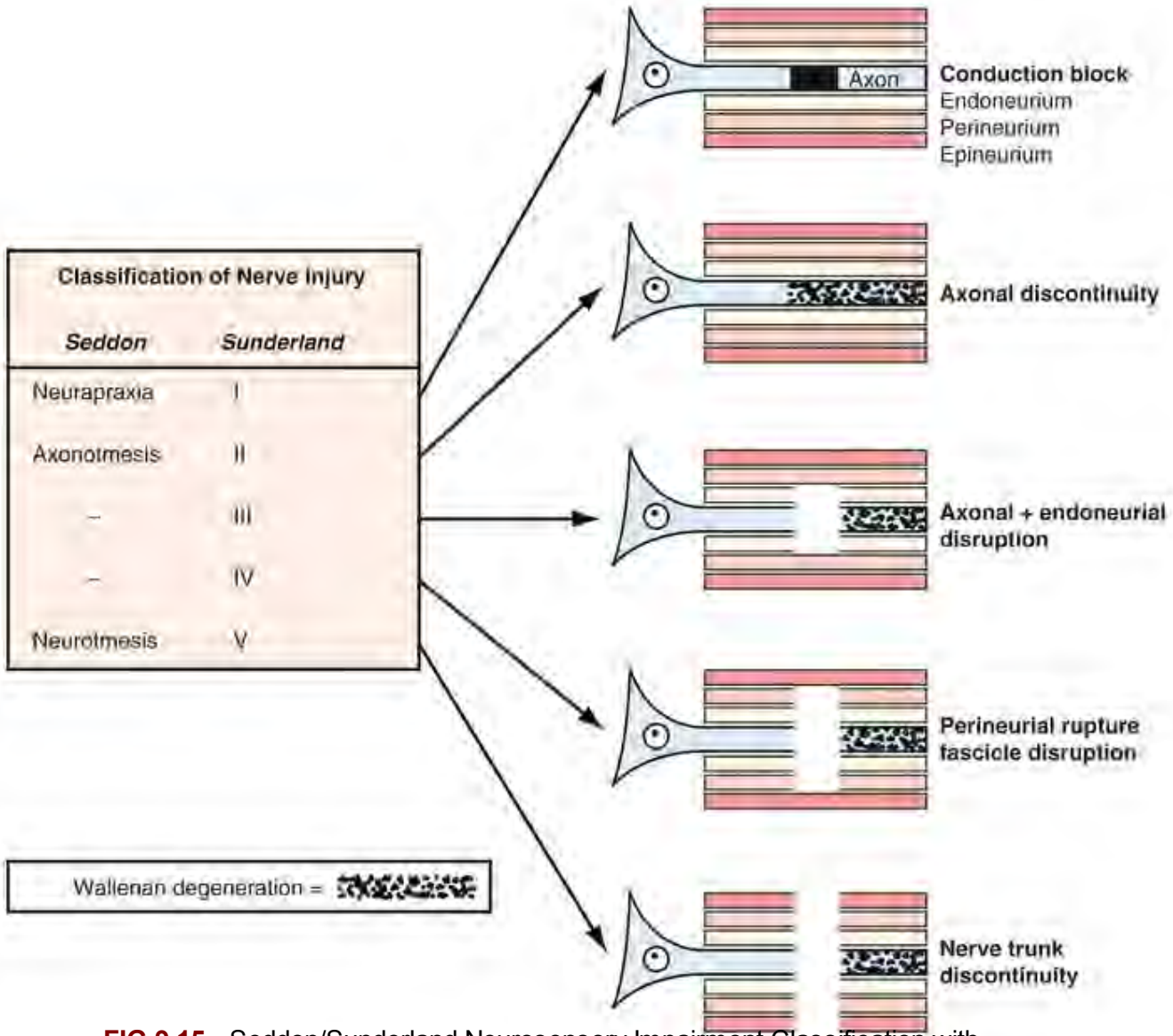

FIG 9.15 Seddon/Sunderland Neurosensory Impairment Classification with description of nerve damage. (From Ellenbogen RG, Sekhar LN, editors: *Principles of neurological surgery*, ed 3, Philadelphia, 2012, Saunders.)

Neuropraxia, or first-degree injury, is characterized by a conduction block

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with no degeneration of the axon or visible damage of the epineurium. Usually, this type of injury is consistent with stretching or manipulation (reflection of tissue) of the nerve fibers, which results in injury to the endoneurial capillaries. The degree of trauma to the endoneurial capillaries will determine the magnitude of intrafascicular edema, which results in various degrees of conduction block. Usually, resolution of sensation and function will occur within hours to weeks.

Axonotmesis (second-, third-, or fourth-degree injury) consists of degeneration or regeneration axonal injuries. The injury classification depends on the severity of axonal damage. This type of injury involves the endoneurium, with minimum disruption to the perineurium and epineurium. The most common type of injuries are traction, stretching, and compression, which can lead to severe ischemia, intrafascicular edema, or demyelination of the nerve fibers. Initially, complete anesthesia is most common, which is followed by paresthesia as recovery begins. Improvement of the related sensory deficits occurs within approximately 2–4 months with complete recovery usually within 12 months. In some cases, painful dysesthesias are possible with resulting neuroma formation.

Neurotmesis (fifth-degree injury) is the most severe type of injury, resulting from severe traction, compression, or complete transection injuries. Initially, patients exhibit anesthesia, followed by paresthesia with possible dysesthesia. A very low probability of neurosensory recovery exists, with immediate referral for a neurosurgical evaluation recommended.[39,40] The axon and encapsulating connective tissue will lose their continuity. There is usually complete loss of motor, sensory and autonomic function. Neuroma formation is common if transection has occurred.

Classification of Sensory Symptoms

The literature involving peripheral nerve injuries is vast, with a significant variation in the nomenclature used to describe the associated clinical signs and symptoms. Neurosensory impairments are classified from complete numbness to severe pain of the facial soft tissues to the intraoral anatomy. Because of these deficits, severe complications result for the patient and the clinician. A thorough understanding of the associated classifications and definitions is necessary (Tables 9.1 and 9.2).

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TABLE 9.1

Neurosensory Impairment Classification and Injury Response[5,6]

Sunderland	Seddon	Description	Causes	Responses	Recovery Rate
I	Neurapraxia	Temporary interruption of nerve transmission (Conduction Block)	Nerve Compression Edema Hematoma Minor Stretching Thermal	• Neuritis • Paresthesia	Complete (Fast—days to weeks)
II	Axonotmesis	Endoneurium, perineurium, and epineurium remain intact. Some axon degeneration may occur	Nerve Compression Traction Hematoma Partial Crush Edema Stretching	• Paresthesia • Episodic • Dysesthesia	Complete (Slow—weeks)
III		Disruption of axon and connective tissue (endoneurium) causing disorganized regeneration. Wallerian degeneration occurs	Crush Puncture Severe Hematoma Stretching	• Paresthesia • Dysesthesia	Variable (Slow—weeks to months)
IV		Damage involves entire fascicle. Axonal, endoneurium, and perineurium changes occur. The epineurium is intact. Scar tissue formation.	Full Crush Extreme Strecthing High Thermal Direct Chemical Trauma	• Hypoesthesia • Dysesthesia • Neuroma formation	Unlikely
V	Neurotmesis	Complete transaction or tear of the nerve with amputation neuroma forming at injury site	Complete Transection (overpreparation with implant drill)	• Anesthesia • Intractable Pain • Neuroma Formation	None

TABLE 9.2

Description of Neurosensory Impairment Deficits[7]

Anesthesia	Total Loss of Feeling or Sensation
Dysesthesia	Abnormal sensation that is unpleasant
Allodynia	Pain due to a stimulus that does not normally provoke pain
Hyperpathia	Abnormally painful reaction to a stimulus
Causalgia	Persistent burning pain
Anesthetic Dolorosa	Pain in an area that is anesthetic
Hyperesthesia	Increased sensitivity to stimulation
Hyperalgesia	Increased response to a stimulus that is normally painful
Paresthesia	Abnormal sensation that is not unpleasant
Hypoesthesia	Decreased sensitivity to stimulation
Hypoalgesia	Decreased response to a stimulus that is normally painful
Synesthesia	Sensation felt in an area when another area is stimulated

To standardize the nomenclature concerning nerve injuries, the International Association for the Study of Pain reduced sensory impairment into three categories: anesthesia, paresthesia, and dysesthesia.[40a] *Anesthesia* is characterized by the complete lack of "feeling," which is usually consistent with complete transection of the nerve. This type of altered sensation is most severe because anesthesias are the most difficult and unpredictable to treat with a high incidence of neuroma formation. *Paresthesia* is defined as an

altered sensation that is not unpleasant. It is usually characterized as a "pins and needles" feeling. Within the paraesthesia category, many subcategories exist including hypoesthesia (decreased sensitivity to stimulation), hypoalgesia (decreased response to a stimulus that is normally painful), and synesthesia (sensation in an area when another is stimulated). *Dysesthesias* are classified as an altered sensation that is unpleasant. Usually pain is associated with this type of impairment, which may be spontaneous or mechanically evoked. Subcategories include hyperalgesia (painful response to nonpainful stimuli), hyperpathia (delayed or prolonged painful response), anesthetic dolorosa (pain in an area that is anesthetized), causalgia (persistent burning pain), and allodynia (pain in response to a stimulus that usually does not provoke pain).

Treatment

Nerve Impairment at Time of Surgery

During surgery, if known traction or compression of the nerve trunk has occurred, the topical application of Dexamethasone may be used to minimize deficits. Upon removal of an encroaching implant on the mandibular canal, 1–2 mL of the intravenous form of Dexamethasone (4 mg/mL) is topically applied (Fig. 9.16). This direct steroid application will reduce neural inflammation and may enhance recovery from neurosensory deficits. Studies have shown no morbidity associated with the topical application of glucocorticoids at the injury site and postsurgical recovery has also been shown to improve significantly.[12] No bone grafting or implant should be placed that may lead to irritation of the traumatized nerve fibers.

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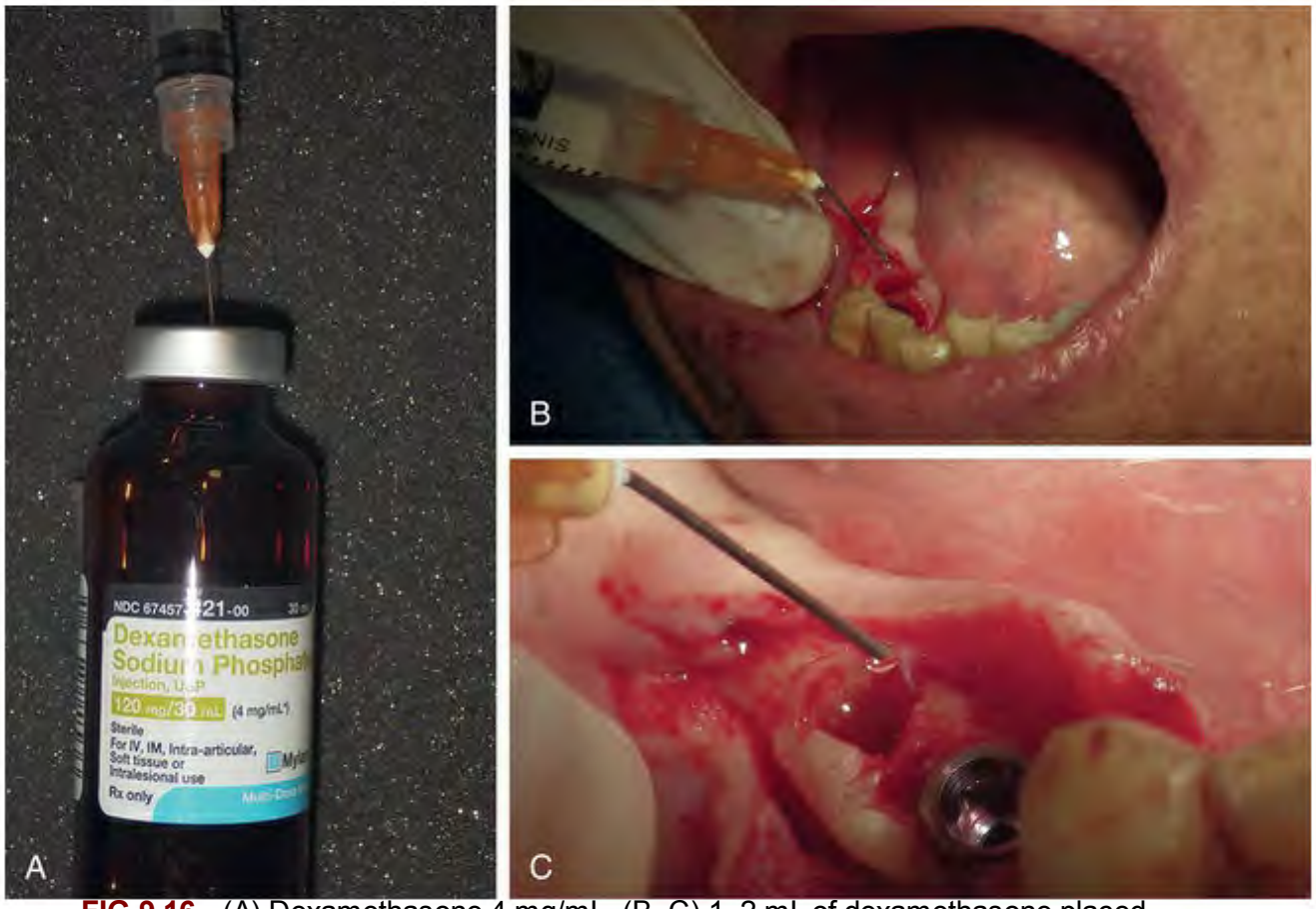

FIG 9.16 (A) Dexamethasone 4 mg/mL. (B–C) 1–2 mL of dexamethasone placed into osteotomy site.

Nerve Impairment Postoperatively

When a neurosensory deficit occurs postoperatively, a comprehensive sensory evaluation must be completed. This initial examination is used to determine whether a sensory deficit exists, to quantify the extent of injury, document a baseline for recovery, and to determine if referral for microneurosurgery is indicated.

Step 1: Clinical Assessment.

The implant clinician must first determine if a neurosensory deficit exists by mapping the area of deficit. This diagnostic examination consists of objective and subjective findings to determine the extent of impairment, to use as a baseline for future evaluation, and to determine when referral for surgical intervention is required.

The subjective clinical sensory tests involve nociceptive and mechanoceptive examinations. Nociceptive tests trigger a variety of

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autonomic responses that result in the subjective experience of pain. Mechanoceptive tests utilize mechanical stimuli to trigger sensory neurons that elicit various responses such as touch, position and motion (Table 9.3 and Fig. 9.17).

TABLE 9.3
Nociceptive and Mechanoceptive Diagnostic Tests

Diagnostic Test	Description
Nociceptive	
Pin pressure (A-Delta, C-Fiber)	Determination of feeling from pin pressure using a blunted explorer. A normal response (distinct sharp pain) is a positive sign of feeling (in relation to an unaffected area) with no pain. If no feeling is present in comparison to an unaffected side, the area is termed *hypoalgesia*. If an exaggerated response is noted in relation to an unaffected side, the area is termed *hyperalgesia*.
Thermal discrimination (warm: A-Delta: cold: C-Fibers)	Ice chips or ethyl chloride spray and a heated mirror handle (warmed to 43°C) are used to determine the patient's ability to feel cold and hot.
Mechanoceptive	
Static light touch	Cotton tip applicator with the patient's eyes closed to test tactile stimulation by gently touching the skin and determining the threshold of the patient. (A-beta afferent axons.)
Directional movement	Soft brush is used to determine the patient's ability to detect both sensation (A-beta and A-alpha axons) and direction of movement. The soft brush is swiped from left to right, as well as in the reverse direction.
Two-point discrimination	With the patient's eyes closed, the patient's ability to discriminate varying (myelinated A-alpha fibers) distances between two points is determined using a caliper. The normal values vary significantly, with the average being approximately 5 mm.[71]

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FIG 9.17 Sensory testing. (A) Mapping out deficit with eyeliner. (B) Light touch with cotton applicator. (C) Directional test with brush. (D) Two-point discrimination utilizing calipers. (E) Thermal test with mirror handle. (F) Pin-point tests with explorer or dull needle.

Clinical examination complications.

There exist many inherent problems with relying on the credibility of the patient's subjective responses. Because there may exist a high degree of false-positive and false-negative results, clinicians should utilize clear and concise instructions when administering these tests. For instance, when administering the “directional movement” test, the clinician should

complete this test on the contralateral side first so the patient understands the technique and response. The results of the subjective clinical examination will depend on good communication between the implant clinician and the patient, with the outcome of the results related to the patient's perceived interpretation and how to relate their perceptions. Additionally, the tests should be administered with the patient's eyes closed, so as to minimize the possibility of incorrect responses.

Step 2: Radiographic Evaluation/Removal or Repositioning of the Implant.

A thorough and comprehensive radiographic examination should be completed including (ideally) a CBCT radiograph. If the implant (or bone screw) is in close approximation of the nerve bundle, removal or repositioning should be completed. Care should be exercised in "backing" the implant out (repositioning farther from the nerve) because trauma to the nerve may still be present from hematoma formation or pressure from cancellous bone crushed into the neural space. Additionally, backing the implant out may lead to the implant being positioned undesirably because of lack of interocclusal space for the restoration (i.e., too coronally positioned). In these cases, the implant should be removed and the osteotomy site irrigated with 4% Dexamethasone (1–2 mL). No graft materials should be added to the osteotomy site because they may interfere with the reinnervation and repair of the nerve trunk.[41]

Step 3: Pharmacologic Intervention.

Immediately after the nerve is traumatized, the inflammatory process begins with the activation of cytokines and inflammatory mediators. These inflammatory mediators will contribute to the development of nerve trauma by activating the neurons and their nociceptors.[42]

With any type of nerve impairment, corticosteroids or nonsteroidal antiinflammatory agents should be used immediately. Studies have shown that the use of systemic adrenocorticosteroids (e.g., Dexamethasone) minimizes neuropathic symptoms following nerve trauma if administered in high doses within 1 week of injury.[43] It has been advocated that a tapering dose of a corticosteroid for 5–7 days following trigeminal nerve injury is beneficial.[44] Dexamethasone (~8 mg) is specifically recommended because of its greater antiinflammatory effects in comparison to other corticosteroids

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such as methylprednisolone or prednisone. Additional pharmacologic agents include antidepressants, neurologic drugs, antisympathetic agents, and topical agents.

Additionally, cryotherapy (ice packs) should be applied to the paraneural tissues intensely for the first 24 hours and then episodically for the first week. Cryotherapy has been shown to be beneficial in minimizing secondary nerve injury from edema-induced compression, decreasing the metabolic degeneration rate of trigeminal ganglion cells and slowing potential neuroma formation.[45] Additional physiologic agents include transcutaneous electric nerve stimulation, acupuncture, and low-level laser therapy.

Step 4: Possible Referral.

In certain situations, patients may need to be referred in a timely manner to a practitioner experienced in nerve injury assessment and repair. The decision and timing to refer should be based on the patient's symptoms and the type of injury, along with the experience of the implant dentist in treating nerve injuries. Usually, sufficient time is given for neurosensory recovery. In cases of dysesthesia, anesthesia, or known nerve transection, prompt surgical intervention may allow for the best chance of neurosensory recovery. Early, aggressive treatment has been shown to minimize possible transition to chronic refractory neuropathies (Table 9.4).[16]

TABLE 9.4
Neurosensory Deficit Treatment Algorithms

Postsurgery	Documentation	Pharmacologic Intervention	Treatment	Referral
≈48 hr	3-D radiographic examination (CBCT); neurosensory examination	Corticosteriods (Dexamethasone 4 mg) 2 tabs AM for 3 days 1 tab AM for 3 days	Implant evaluation: Removal or reposition if impingement within the mandibular canal No bone grafting Cryotherapy (1 week)	None, unless unfamiliar with neurosensory testing
1 week postoperative	Neurosensory examination (Testing should be continued every 2 weeks thereafter)	High-dose NSAIDs (600–800 mg ibuprofen TID)	Palliative	Refer to Oral Surgeon or Neurosurgeon if: • Known nerve transection • Dysesthesia • Complete anesthesia
8 weeks postoperative	Neurosensory examination	NSAIDs (PRN)	Palliative	IF NO SIGN OF IMPROVEMENT Refer to OMFS or microneurosurgeon

Step 5: Follow-Up Care.

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Follow-up care should always be a component of the treatment of a nerve impairment patient. The interval between appointments is determined by the extent and type of nerve injury (see Table 9.4). Usually, after the one week postoperative, patients are seen every 2 weeks with mapping and documentation of the deficits noted.

Surgical Intervention

In some cases of neurosensory impairment, surgical repair is indicated. In general, early treatment is crucial to success and decreased morbidity. Microneurosurgical procedures include direct nerve repair via primary anastomoses of the two severed ends for transection injuries. For nerve splits, reestablishment and proper alignment of nerve stumps will allow for the best chance to correct regeneration of the damaged nerves (Fig. 9.18).

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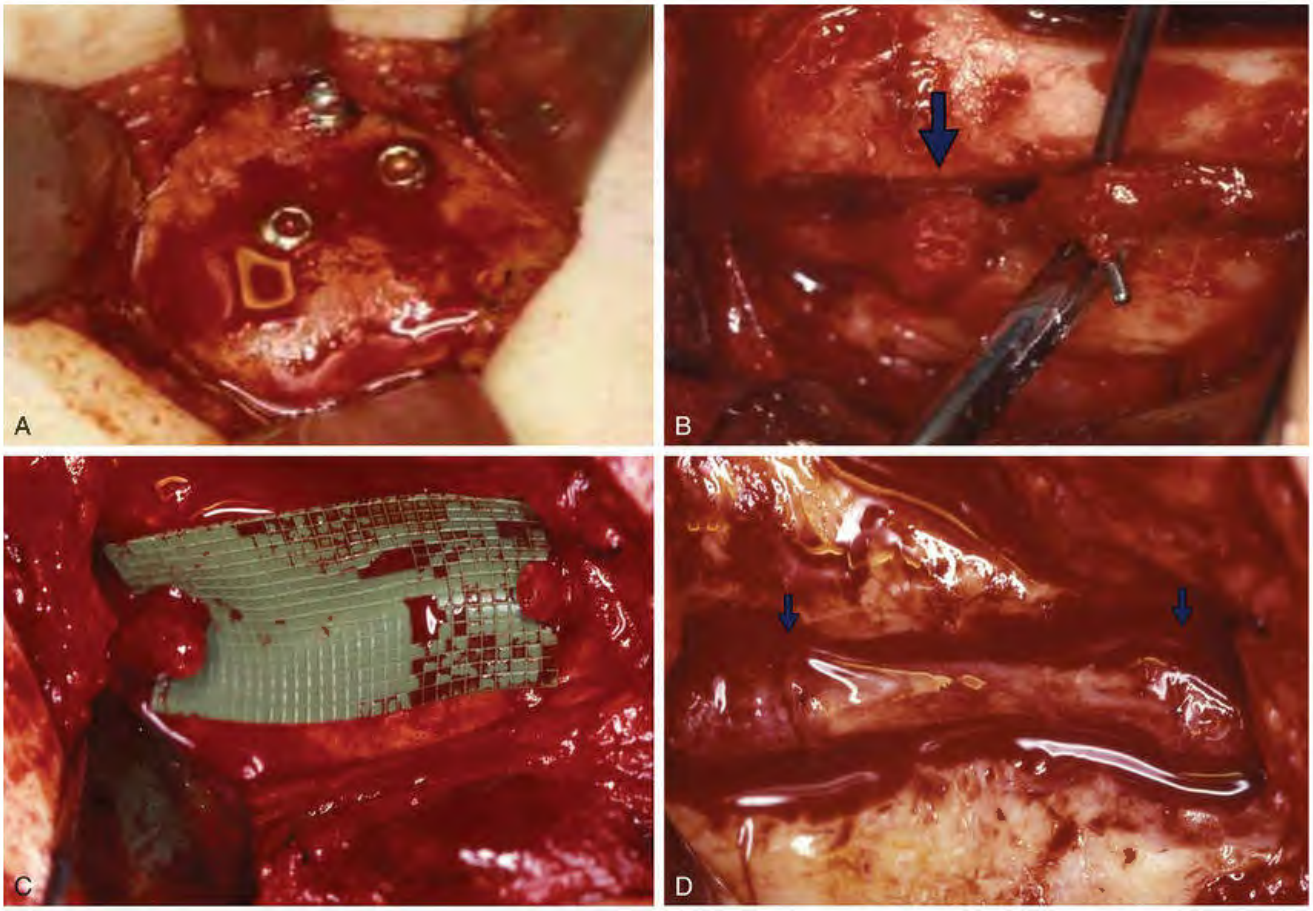

FIG 9.18 Nerve repair. (A) Mandibular internal fixation screws in a 29-year-old patient with right inferior alveolar nerve (IAN) sensory dysfunction after sagittal split ramus osteotomy. (B) The IAN was not directly contacted by any of the screws, but there is a proximal stump neuroma *(arrow)* and a thin stalk of scar tissue, containing no viable nerve tissue, which extends between the proximal and distal nerve (supported by nerve hook) stumps. (C) The proximal stump neuroma has been excised and the two nerve stumps have been prepared for microsurgical repair. (D) The right IAN has been reconstructed with an autogenous right great auricular nerve graft (*arrows* at sutured areas). (From Bagheri SC, Meyer RA, Khan HA, et al: Microsurgical repair of the peripheral trigeminal nerve after mandibular sagittal split ramus osteotomy, *J Oral Maxillofac Surg* 68:2770–2782, 2010.)

Prevention

Iatrogenic injuries to the third division of the trigeminal nerve pose a common and complex problem in implant dentistry today. Neurosensory impairment in the head and neck region may affect the patient's quality of life and can present potentially significant medicolegal problems for the clinician. To prevent damage to vital nerve structures, it is imperative for the implant dentist to have a comprehensive radiographic survey of the region, a thorough knowledge of the normal vs. variant anatomy, and awareness of

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intraoperative surgical techniques to minimize the possibility of nerve impairment.

Radiographic Considerations

Understand Disadvantages and Limitations of Two-Dimensional Radiography.

Today, the sole use of two-dimensional radiography is becoming less common for treatment planning of dental implant patients. Two-dimensional radiographs, mainly panoramic, have many inherent disadvantages in evaluating potential implant sites. All panoramic (2-D) radiographs exhibit some degree of distortion, nonuniform magnification, and image superimposition, which can potentially lead to incorrect measurement and assessment of neural structures. Studies have shown periapical and panoramic radiography to be unreliable in assessing the true location of the inferior alveolar canal and the mental foramen.[46] Extreme caution should be exercised when using two-dimensional radiography as the only modality for implant site evaluation (Fig. 9.19A–B).

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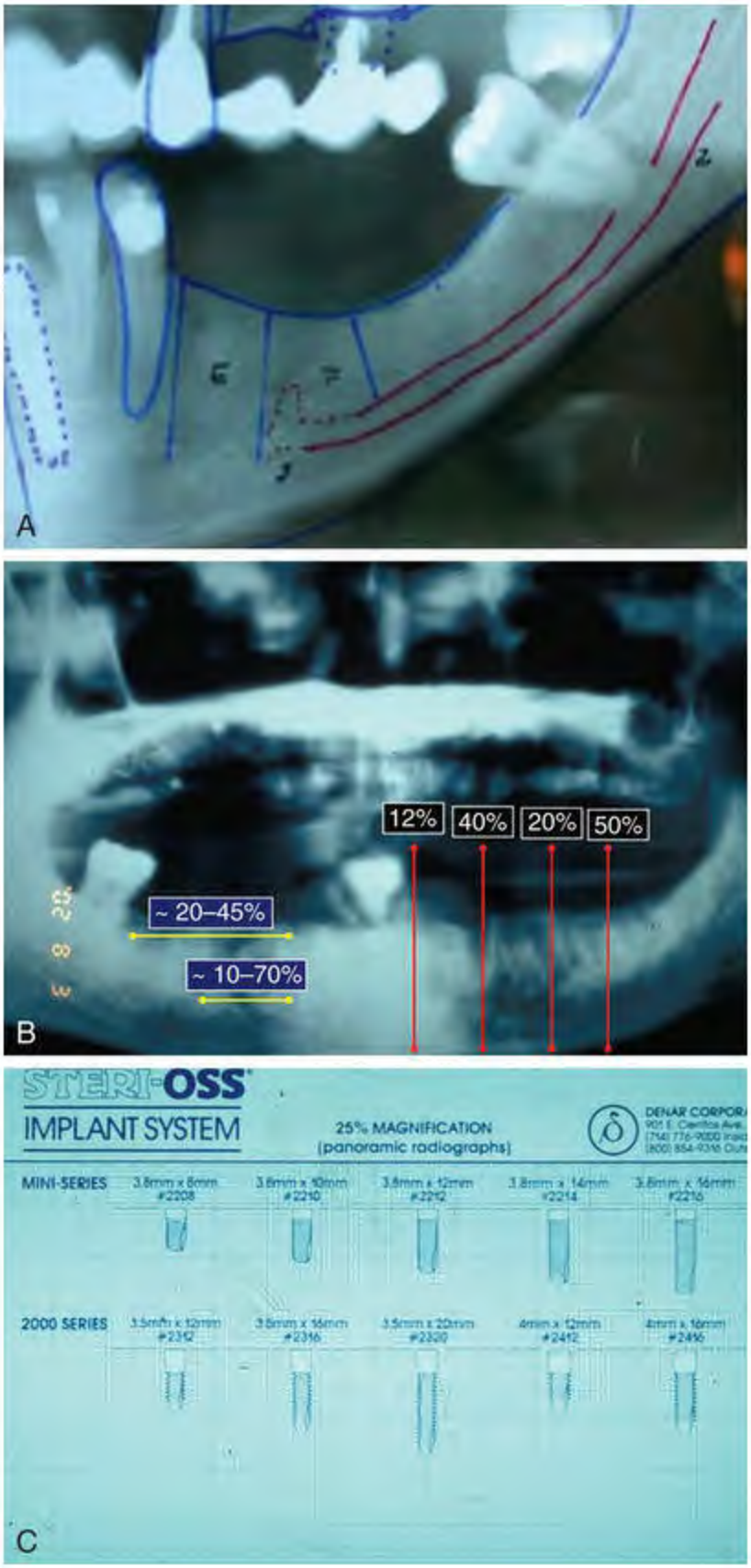

FIG 9.19 (A) 2-D panoramic radiographs exhibit many inherent inaccuracies and should never be solely relied upon in making measurements because they provide nonuniform magnification. (B) Magnification may be determined in the vertical plane. Horizontal magnification is completely unreliable and inaccurate. (C) Magnification

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(25%) guides are superimposed over two-dimensional radiographs, but they often lead to misrepresentation of available bone.

Do Not Use Two-Dimensional Magnification Guides.

Manufacturers have made available to implant dentists magnification guides and digital software programs for intraoral radiographs to assist in the placement of implants over vital structures. Caution should be noted that panoramic radiographs have variable magnification (i.e., not 25% as related by many implant and panoramic companies), and even calibrated intraoral software programs cannot accurately assess true distances because of their two-dimensional origin. Both periapical and panoramic radiography are associated with magnification that is inconsistent and difficult to determine. Schropp et al have shown that over 70% of cases in which implant size was initially determined via panoramic radiographs the size had to be altered after CBCT evaluation.[47] Magnification guides should never be used as the sole criteria for implant site evaluation because they may lead to overestimation of available bone dimensions (Fig. 9.19C).

Three-Dimensional Radiography Is the Most Accurate Type of Radiographic Modality.

In most cases, a three-dimensional radiographic modality is recommended for evaluation of the mandibular arch and related nerve anatomy. To determine the ideal location and measurement parameters associated with the dental implant placement, the clinician must be able to accurately measure the distance between the alveolar crest and the superior border of the mandibular canal, as well as the width of bone in the proposed implant site. Medical slice computed tomography (MSCT) and CBCT images have been shown to be the most accurate radiographic modalities in the assessment of available bone and identification of the inferior alveolar nerve.[1,48] A thorough knowledge of the relative three-dimensional (3-D) position of the inferior alveolar nerve is crucial in preventing mandibular nerve impairment prior to implant placement (Fig. 9.20A).

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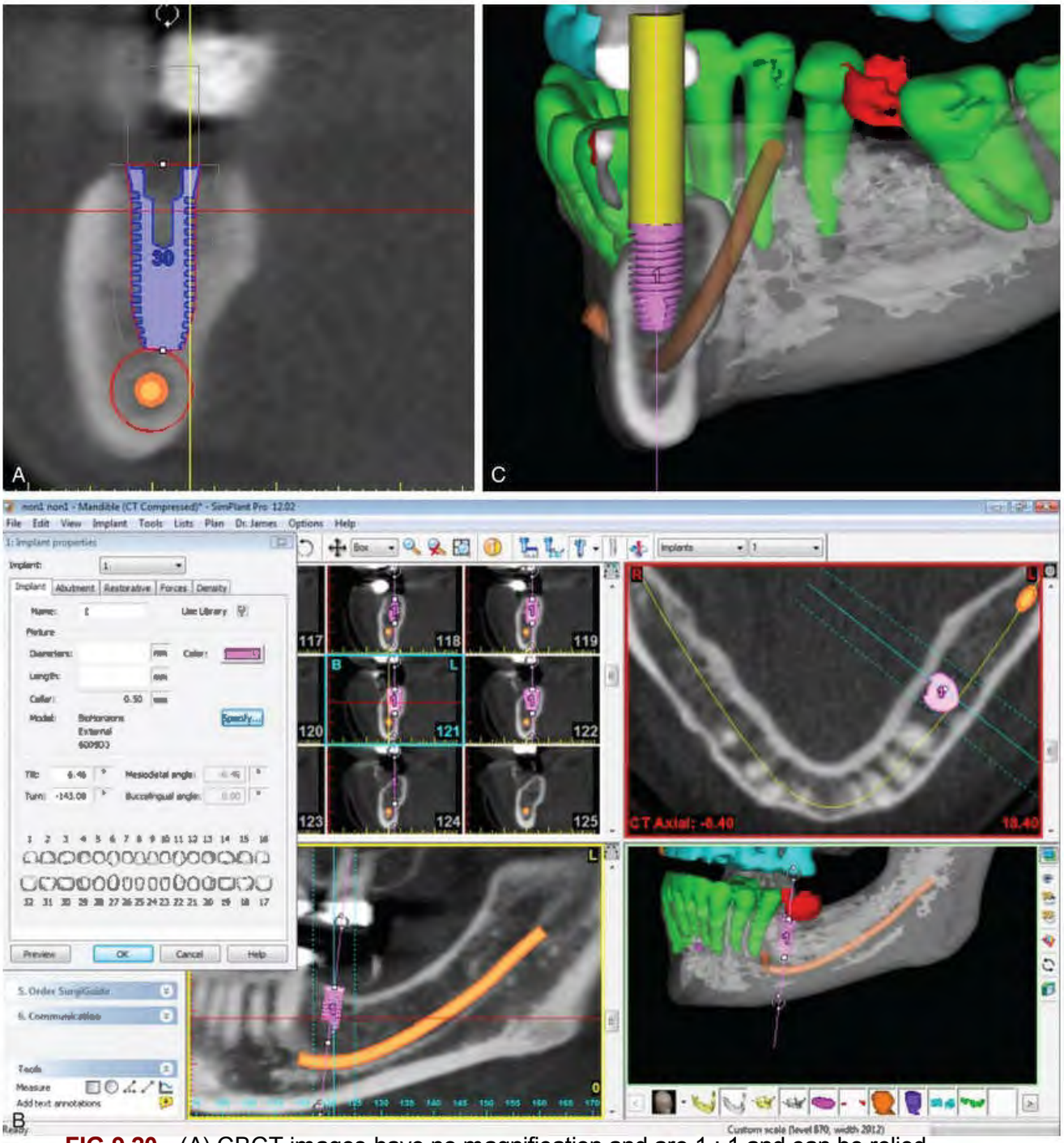

FIG 9.20 (A) CBCT images have no magnification and are 1 : 1 and can be relied upon for measurements that approximate vital structures. (B–C) Third-party interactive software programs showing implant placement via integrated software program.

Use Interactive Treatment Planning Software for Evaluation of the Posterior Mandible.

Because MSCT and CBCT have been proven to be 1 : 1 (no magnification), the implant dentist has the ability to place implants, measure available bone,

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evaluate bone density, and order surgical templates directly from their computerized treatment plan. Interactive treatment planning software programs available today contain libraries of most implants systems, which allow the clinician to accurately access the size, type, and ideal placement of the implant in relation to anatomic structures. This virtual treatment plan may then be transferred to the patient's surgery by means of a surgical template or computer-assisted navigation system (Fig. 9.20B–C).

Use of Bone Models.

For implant dentists early on their learning curve, the fabrication of a bone model can be an invaluable preoperative diagnostic tool. Bone models are made directly from the CT Dicom data, which involves a third-party vendor fabrication through some type of 3-D printer, such as stereolithography. The clinician is able to evaluate the exact osseous morphology (width of bone, undercuts, bony landmarks) and location of vital structures (color coded within the model) prior to the actual surgery. Implant osteotomies may be performed in a laboratory setting to allow the implant dentist to complete the procedure prior to surgery.

Use of Surgical Templates.

Neurosensory impairment issues are most frequently an inadvertent sequela of improper diagnosis, treatment planning, or surgical technique. Many of these complications can be overcome by using three-dimensional surgical guides for the ideal positioning and placement of implants. Basically, the surgical guide is the conduit for transferring the interactive treatment plan from the computer to the patient's actual surgical procedure. This allows the implant dentist to be able to place the implants in the exact location as per the treatment plan. Surgical guides are categorized based on method of retainment: tooth, bone, or mucosa supported. SIMPLANT Safe Guide (DENTSPLY Implants) gives the practitioner the ability to place the implant via an interactive treatment plan in the mesiodistal, buccal-lingual, and apicocoronal dimensions via three types of guides. Guided surgery with surgical templates has been reported to improve the accuracy of implant placement in clinical situations in comparison to conventional surgical methods (Fig. 9.21).[49] Nickenig et al showed that implants placed with surgical templates were within 0.9 mm of the planned positions, whereas free-hand placement resulted in deviations of approximately 2–3 mm.[49a]

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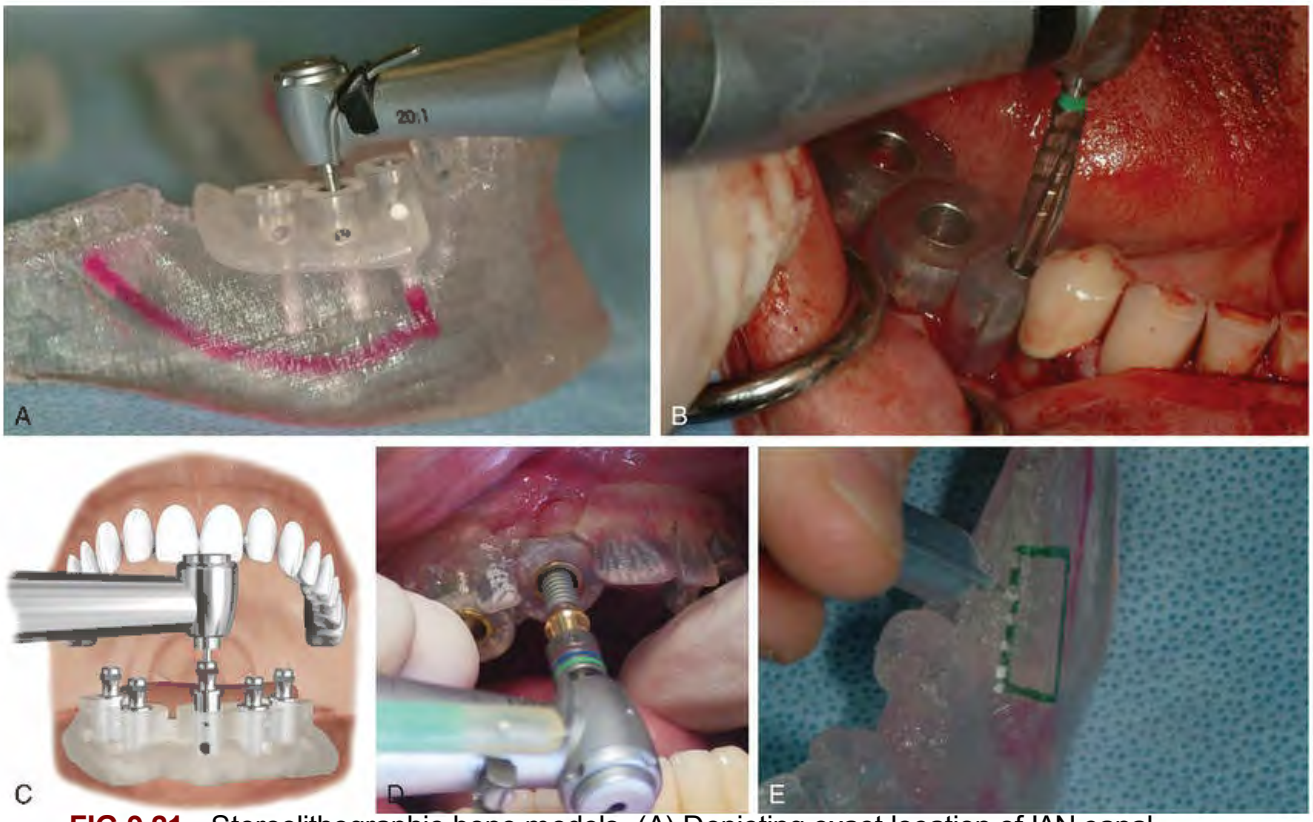

FIG 9.21 Stereolithographic bone models. (A) Depicting exact location of IAN canal and mental foramen for implant placement. (B) Bone-supported SurgiGuide (Materialise Dental) placing posterior mandibular implant. (C–D) Simplant Safe Guide; implant being placed through guide. (E) Bone model showing ramus bone graft with the IAN depicted in red. (C, Courtesy Dentsply Sirona Implants, Waltham, MA.)

Anatomic Considerations: Mandible

The Position of the IAN is Variable and Not Consistent in the Vertical (Inferior-Superior) Plane.

There is a common belief that the vertical position of the inferior alveolar nerve is relatively constant within the mandible. Normally, the IAN runs a concave path from posterior to anterior, with anterior segments exiting the mental foramen and a branch that ascends to the midline of the mandible. However, studies have confirmed the inferior-superior (vertical) positions of the inferior alveolar nerve are not consistent.[50,51] An early classification of the vertical positions of the course of the alveolar nerve was reported by Carter and Keen.[52] They described three distinct types: (1) in close approximation to the apices of the teeth, (2) a large nerve approximately in the middle of the mandible with individual nerves supplying the mandibular teeth, and (3) a nerve trunk close to the inferior cortical plate with large plexuses to the

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mandibular teeth. In type 1 nerves, impairment is very common because of the close proximity to the nerve bundle. Three percent of patients can have the IAN directly contacting one or both of the roots of the mandibular first molar.[53] It is highly recommended that a comprehensive radiographic survey be completed to evaluate the IAN in a vertical plane, especially with type 1 and 2 nerves (Fig. 9.22).

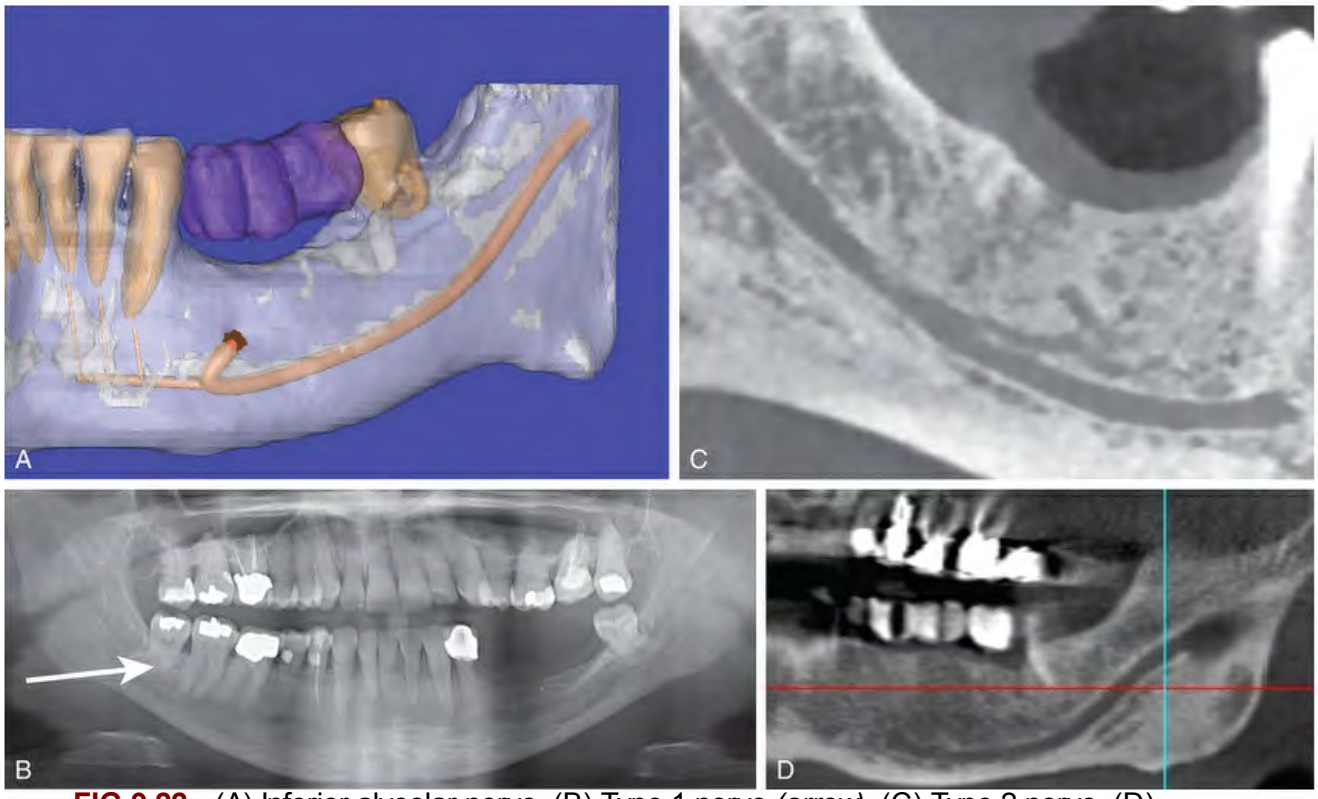

FIG 9.22 (A) Inferior alveolar nerve. (B) Type 1 nerve *(arrow)*. (C) Type 2 nerve. (D) Type 3 nerve.

The Position of the IAN is Variable and Not Consistent in the Buccal-Lingual Plane.

Studies have shown the buccal-lingual location of the IAN as it progresses anteriorly is not constant. The nerve paths have been described in a buccal-lingual direction with a high degree of variability and are dependent on the amount of bone resorption as well as age and race variables.[54] Additionally, older and Caucasian patient groups have shown less distance between the buccal aspect of the nerve and the inferior border of the mandible.[55] Other studies have shown the most common area for the IAN to be in the middle

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of the buccal and lingual cortical plates is the first molar region.[56] Thus, in the buccal-lingual plane, three-dimensional cross-sectional images should be utilized to determine the true position of the nerve (Fig. 9.23).

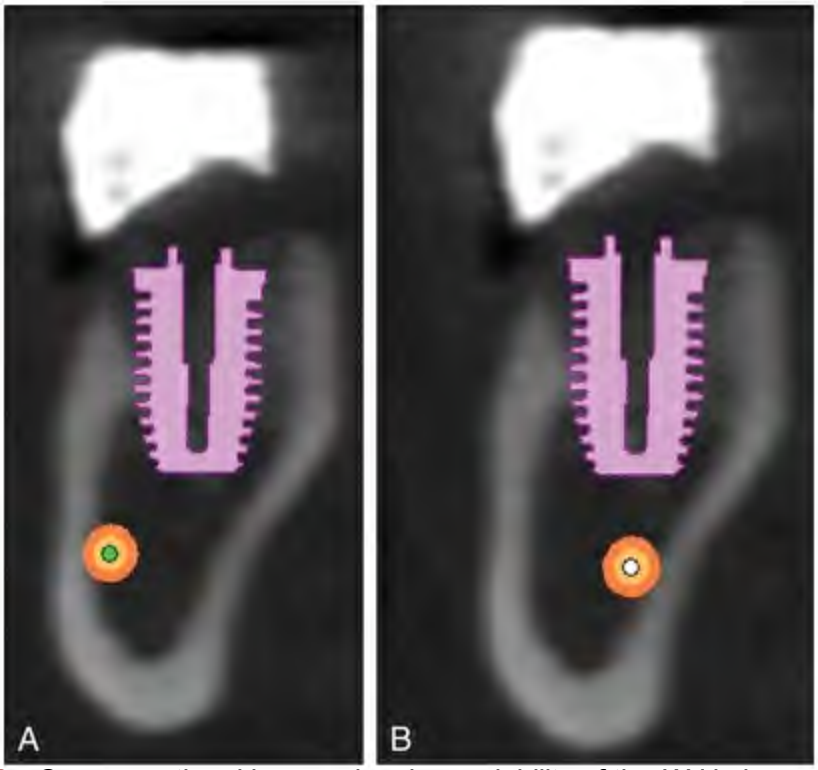

FIG 9.23 Cross-sectional image showing variability of the IAN in buccal-lingual position. (A) Buccal orientation. (B) Lingual orientation.

Understand the Variations of the Mental Foramen Location.

Determining the exact location of the mental foramen is crucial when placing implants in the posterior mandible. Although the foramen has been shown to be symmetrical to the contralateral side in most patients, the location has been shown to be highly variable.[57] The mental nerve passes through the mental foramen with three nerve branches. One innervates the skin of the mental area, and the other two proceed to innervate the skin of the lower lip, mucous membranes, and the gingiva as far posteriorly as the second premolar. Any trauma to this nerve will result in neurosensory impairment in this area. Clinically, there are many different techniques in identifying the foramen with a wide variation of predictability.

Palpation.

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In rare cases, the implant dentist may be able to palpate the location of the mental foramen. Most notably, when bone resorption has caused the nerve to be exposed on the residual ridge, the concavity formed by the exposure of the nerve can be determined. In these cases, the location of the mental foramen may be marked with a surgical pen. When the nerve is located on the buccal surface of the mandible, the palpation method of identification has very low utility (Fig. 9.24A).

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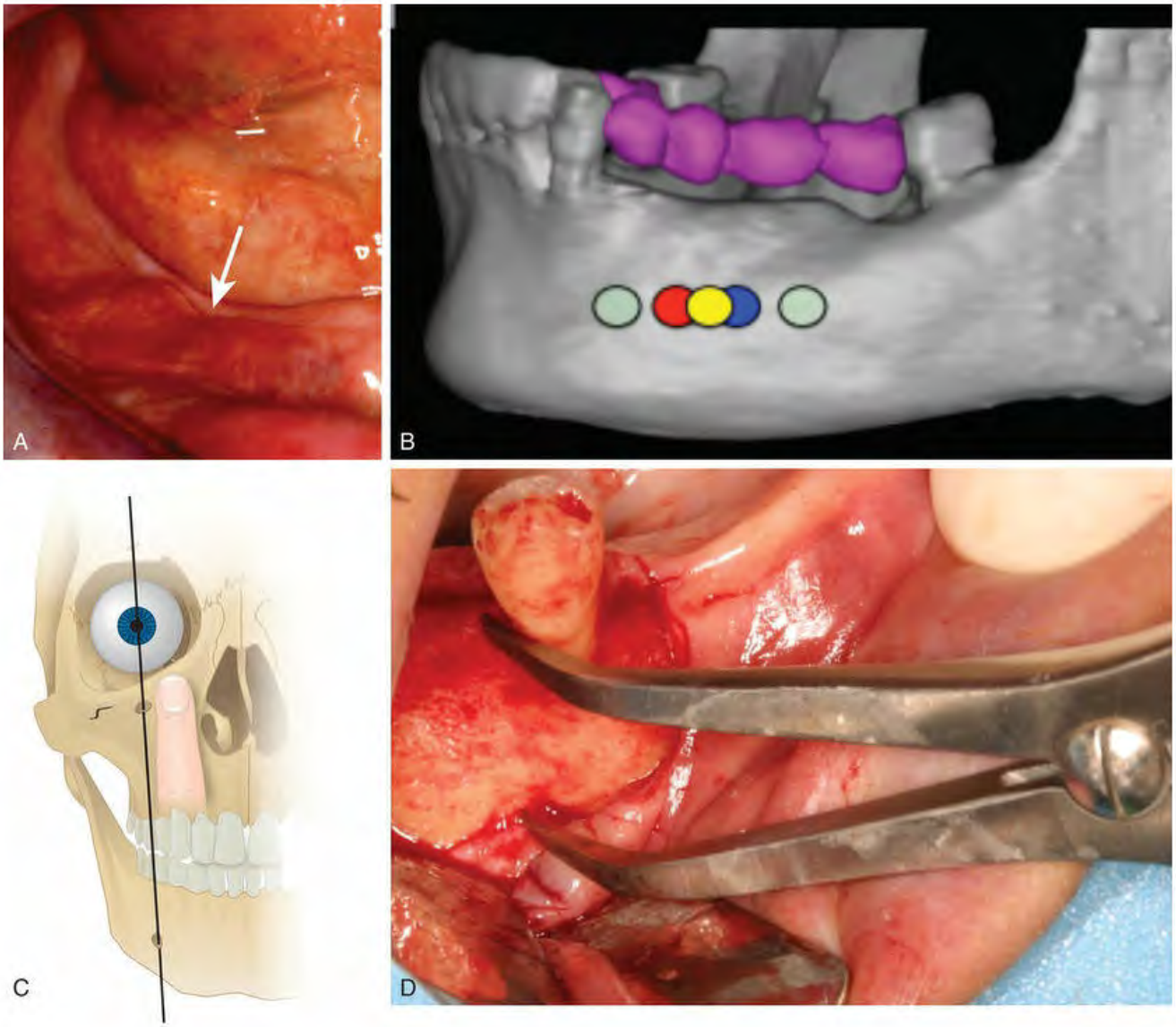

FIG 9.24 Location of the mental foramen. (A) Palpation can be misleading and should not be used as the sole technique of mental foramen identification. (B) Anatomic location with respect to the teeth apices is highly variable—cuspid/molar position *(green circles)*; first premolar *(red circle)*; first/second premolar *(yellow circle)*; second premolar *(blue circle)*—and is dependent on gender, age, and race. (C) Anatomic location: a vertical line through pupils of eyes and infraorbital foramen or a finger width lateral to ala of the nose. (D) Direct exposure of the foramen with the use of calipers to measure distance.

Anatomic landmarks.

In the literature, many authors have postulated that landmarks such as teeth and mandibular bony areas may help identify the location of the mental foramen. With respect to teeth, the location cannot conclusively be associated with a particular tooth (e.g., first premolar, second premolar, between apices of the premolars) because studies have shown the location to be dependent

on gender, age, and race.[58] Certain bony landmarks (e.g., alveolar ridge, mandibular symphysis, infraorbital foramen) have been associated with a general location of the foramen, although these measurements are extremely variable and dependent on the extent of bone resorption, skeletal relationships, and anatomic variants (Fig. 9.24B–C).

Two-dimensional radiographs.

Studies have shown that in over 50% of periapical and panoramic radiographs, the mental foramen is not in the location depicted on the two-dimensional image.[46] Conventional two-dimensional radiography should never be used as the sole diagnostic modality in evaluating the foramen position.

Three-dimensional radiography.

The literature has shown that 3-D imaging is the most accurate tool to ascertain the exact location of the mental foramen. CBCT panoramic images and 3-D images are the easiest and most accurate technique in determining the exact foramen location.

Direct evaluation.

The most precise technique available today to find the exact location of the mental foramen is by direct evaluation. Exposing the mental foramen may be intimidating to some clinicians, especially early on their learning curve. This can be accomplished with very low morbidity; however, the technique's success depends on the implant dentist's training and experience (Fig. 9.24D).

3-D ultrasound.

The most promising imaging technique for the future is ultrasound. Ultrasound has the advantage of no ionizing radiation and the ability to reconstruct 3D images of bone surfaces to within an accuracy level of 24 μm. At this time, ultrasound units are not available specifically for dental use.

Always Evaluate for an Accessory (Double) Foramen.

Studies have shown that in approximately 10% of patients, an accessory (double) foramen is present.[58] In the majority of cases, small accessory foramina usually contain a small branch of the mental nerve and are not problematic because of cross innervation or actually contain nutrient

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branches. However, in a small percentage of cases, a larger branch of the mental nerve (equal or larger size foramen) may exit the second mental foramen. Special care should be extended in this situations because it may contain components of one of the three branches of the mental nerve. Accessory foramina are believed to be the result of early branching of the inferior alveolar nerve, prior to exiting the mental foramen during the 12th week of gestation.[59] Double foramens are easily seen in the 3-D or the coronal CBCT images (Fig. 9.25).

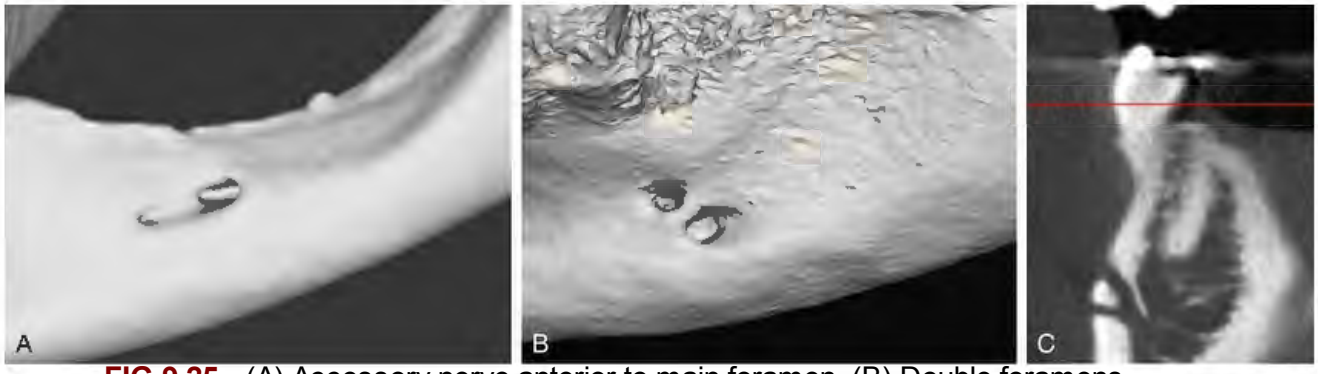

FIG 9.25 (A) Accessory nerve anterior to main foramen. (B) Double foramens showing two large foramens. (C) Coronal image showing two nerve foramina.

Evaluate for Anterior Loops of the Mental Nerve.

As the mental nerve proceeds anteriorly in the mandible, it sometimes runs below the lower border and the anterior wall of the mental foramen. This anterior and caudal component of the mental nerve will curve cranially back to the mental foramen. This anterior and caudal part of the mental nerve is termed the *anterior loop*.[59] Recently, studies have shown a higher percentage (70%) prevalence of anterior loops with a mean of 1.16 mm distance anteriorly. The anterior loop may be depicted most predictably on axial CBCT images, with 2-D radiographs being totally unreliable.

Determining the presence of an anterior loop is critical when placing implants anterior to the mental foramen. Inability to ascertain the presence of an anterior loop may result in damage to the mental nerve (Fig. 9.26). The anterior loop measurement should be added to the safe zone to avoid damaging the mental nerve.

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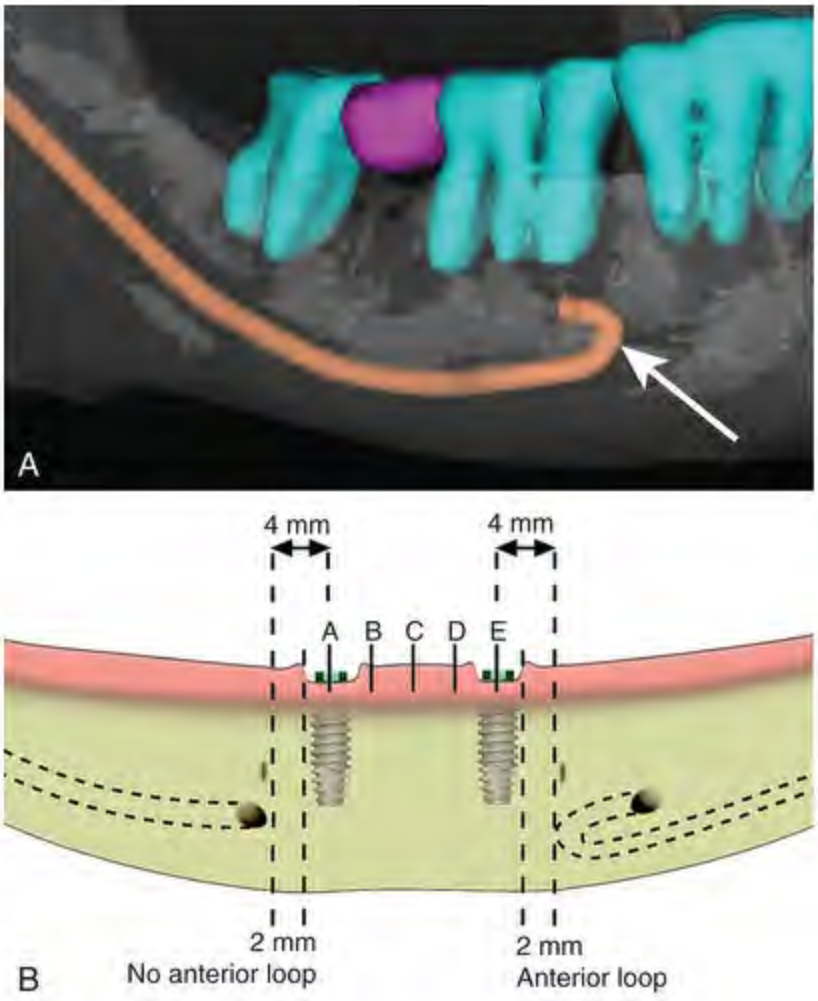

FIG 9.26 (A) An anterior loop showing nerve anterior to foramen. (B) Modification of safe zone with consideration of anterior loop. The anterior loop measurement is added to the 2-mm safe zone.

Do Not Confuse the Incisive Nerve Branch as an Anterior Loop.

The incisive nerve branch, a continuation and terminal branch of the IAN, supplies the mandibular canine and incisor teeth. Because there is no sensory innervation with this nerve, implants may be placed in proximity to it without nerve impairment. Studies have shown incisive canals have a mean diameter of 1.8 mm and location 9.7 mm from the lower cortical border.[60] The incisive nerve has been recognized as an important anatomic structure that must be taken into consideration when performing surgery in this area. It is frequently mistaken as an anterior loop in the mandible. Excessive bleeding has been reported as a significant intraoperative complication in this area when it is perforated during osteotomy preparation (Fig. 9.27).

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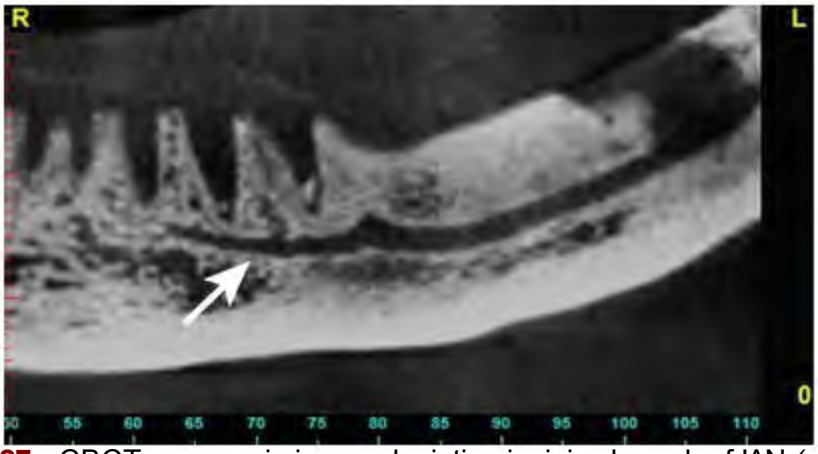

FIG 9.27 CBCT panoramic image depicting incisive branch of IAN *(arrow)*.

Intraoperative Considerations

Utilize the Misch "Zone of Safety" Principle.

To determine the ideal position of implants with respect to the inferior alveolar or mental nerve, Misch, in 1990, identified the "zone of safety" concept. With this technique the mental foramen is directly identified and a measurement from the superior aspect of the foramen to the residual ridge is determined. Research has shown that implants can be placed at this height measurement 100% of the time posterior to the middle half of mandibular first molar and 97.5% of the time to the distal of the first molar. The corresponding safety height measurement extends posterior to the mesial half of the second molar 43% of the time.[61]

Maintain a Safety Zone of 2 mm Upon Osteotomy Preparation and Final Implant Positioning.

A 2-mm safety zone with osteotomy preparation and final implant placement is paramount in preventing neurosensory impairments.[41] Compression-related injuries (neuropraxia) can occur by encroaching on the IA nerve without actual contact. Nerve impairments have been reported when implants are placed less than 2 mm from the canal without invasion of the canal. Bleeding and resultant hematomas have been shown to cause nerve damage because of final positioning too close to the neurovascular canal.[62] Additionally, the IAN superior to cortical bone can be compressed, causing pressure necrosis with resultant nerve impairment.[63] Interactive treatment-planning software programs allow the implant clinician to accurately assess

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the ideal placement with respect to this vital structure (Fig. 9.28).

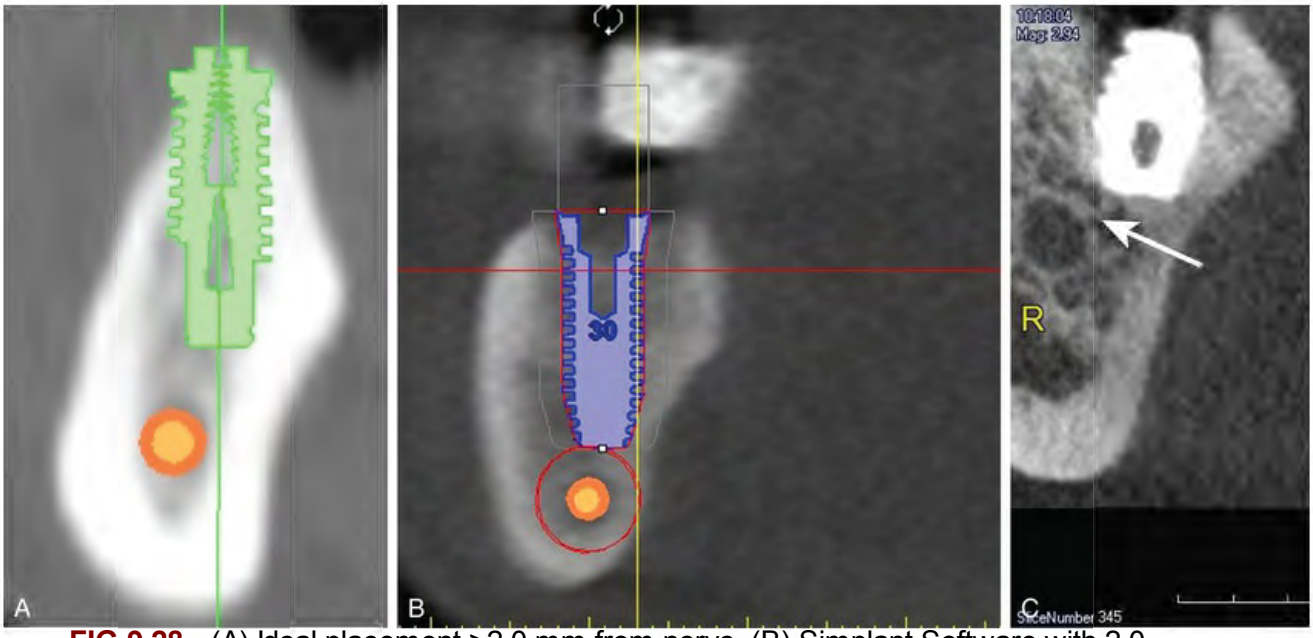

FIG 9.28 (A) Ideal placement >2.0 mm from nerve. (B) Simplant Software with 2.0-mm safety zone for interactive planning. (C) Nerve impairment can be caused from compression necrosis *(arrow)*.

Understand the "True" Implant Bur Drilling Depths.

Care should always be exercised when performing osteotomies over vital structures, especially in the posterior mandible. The implant clinician should double-check the marking depth on the burs prior to initiating the osteotomy. The principle of "MEASURE TWICE, DRILL ONCE" should be followed to prevent iatrogenic overpreparation of the implant site. Additionally, the "Y" dimension of the implant system being used must be known. As noted earlier, the depth of the millimeter lines inscribed on surgical drills do not always coincide with the actual depth of the drill. Most drills contain a V-shaped apical portion designed for cutting efficiency ("Y" dimension). Usually, the wider the drill, the greater the "Y" dimension. The implant clinician should always evaluate the manufacturer's drill length with respect to the length of the implant prior to performing the osteotomy. If this concept is not adhered to, overpreparation of the site may occur, resulting in nerve damage (Fig. 9.29).

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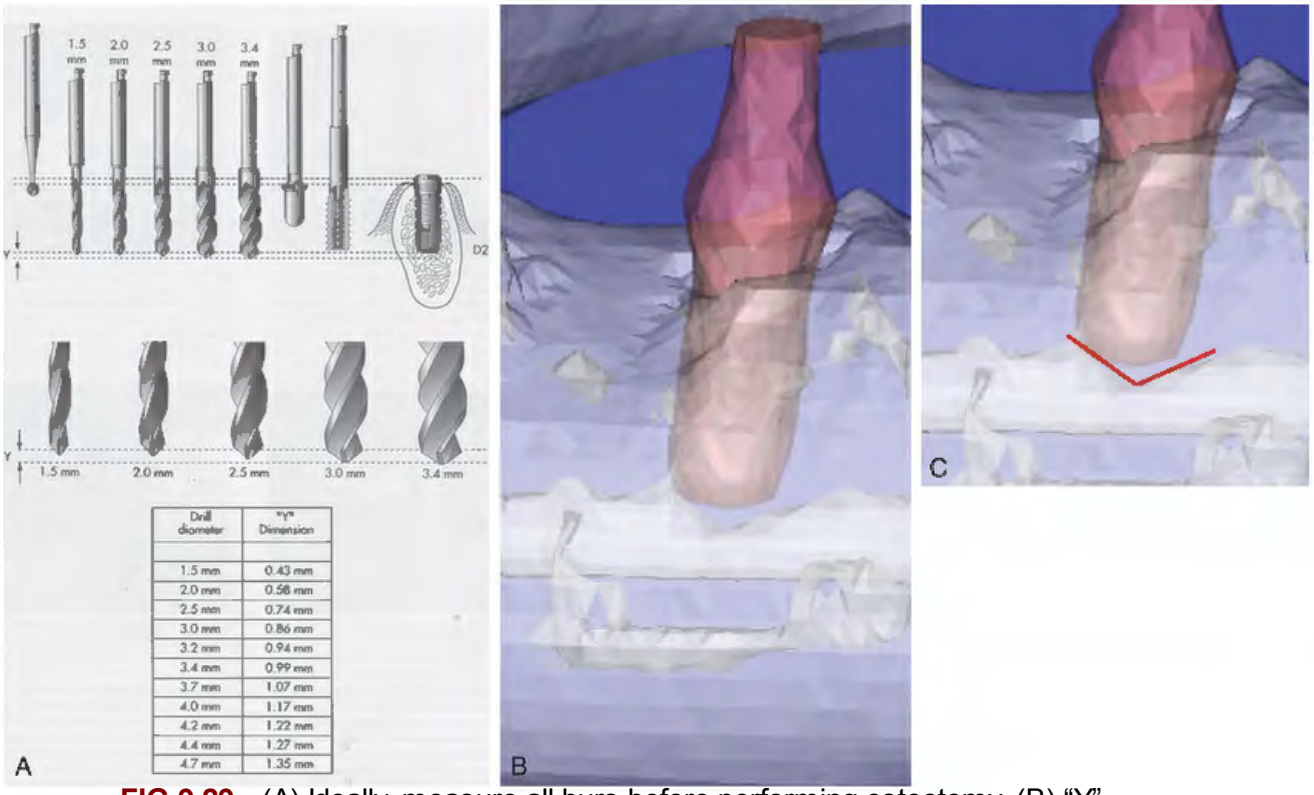

Drill diameter	"Y" Dimension
1.5 mm	0.43 mm
2.0 mm	0.58 mm
2.5 mm	0.74 mm
3.0 mm	0.86 mm
3.2 mm	0.94 mm
3.4 mm	0.99 mm
3.7 mm	1.07 mm
4.0 mm	1.17 mm
4.2 mm	1.22 mm
4.4 mm	1.27 mm
4.7 mm	1.35 mm

FIG 9.29 (A) Ideally, measure all burs before performing osteotomy. (B) "Y" diameter of surgical burs. (C) CBCT image showing penetration from "Y" dimension into mandibular canal. (A, From Misch CE, editor: *Contemporary implant dentistry*, St. Louis, 2008, Mosby.)

Use Drill Stop Burs to Prevent Overpreparation.

An additional technique to prevent overpreparation of the osteotomy site is the use of stop drills. These drills have a predetermined depth marking that prevents overpreparation. Stop drills are very beneficial in the mandibular posterior area, especially when visibility and access is compromised. Generic drill stop kits are also available that may be used with most implant surgical systems (Salvin Dental Corp.). These autoclaveable, reusable kits may be used for any size length implant and corresponding drill (Fig. 9.30). Additionally, some surgical implant systems have specific depth burs that coincide with the actual implant depth (e.g., Hahn Implants, Glidewell Corp.).

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A

B

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FIG 9.30 (A) Drill Stop Kit. (B) Sequential surgical drills with stops that prevent overpreparation. (A, Courtesy Salvin Dental Specialties, Inc., Charlotte, NC. B, Courtesy Dentsply Sirona Implants, Waltham, MA.)

Understand Bony Crest Anatomy.

Due to resultant bone resorption after extraction, the alveolar ridge becomes compromised in width (Division B bone) at the expense of the buccal plate. When measuring available bone height, special consideration should be given to the final location of the superior aspect of the implant platform, not the crest of the ridge. It will often appear that there is adequate vertical height for implant placement; however, when the osteotomy is initiated, the thin crest will be lost and the implant will be placed inferior to where it was originally intended. This can lead to unexpected depth drilling and an implant that is placed too close to the vital structure. The clinician should either augment the ridge to maintain vertical height or reduce the height calculation by the amount of osteotomy induced osteoplasty (Fig. 9.31).

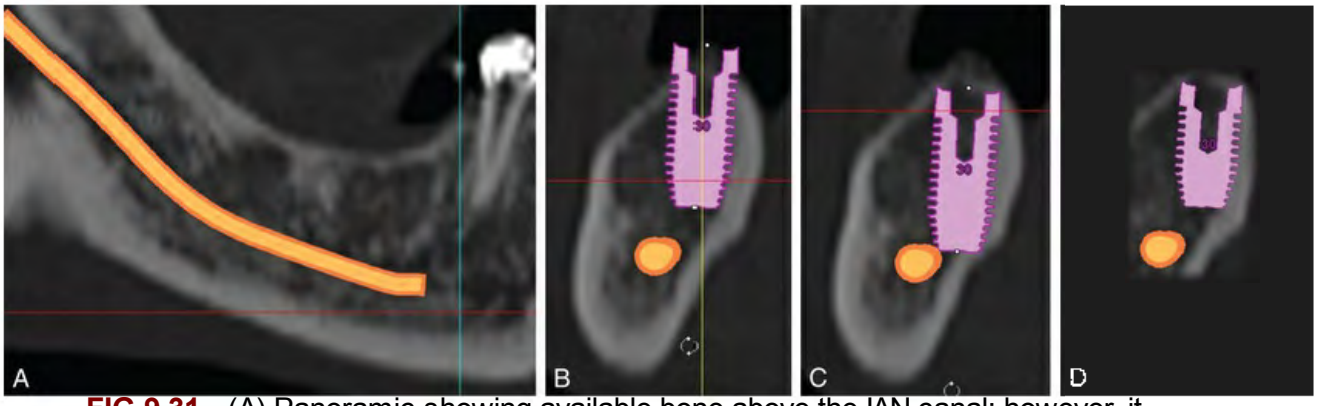

FIG 9.31 (A) Panoramic showing available bone above the IAN canal; however, it does not depict the width of bone. (B) If ridge is Division B (compromised in width) after osteotomy the crestal bone will be removed. (C) Implant placed at position that has adequate width; however, it will impinge on the vital structure. (D) Ideal selection of implant (decreased length) to maintain 2-mm safety zone.

Maintain Total Control of the Handpiece.

When performing osteotomies in the posterior mandible, special care should be noted to maintain complete control of the surgical handpiece. Large marrow spaces (i.e., where there is a lack of or thin trabecular bone) are often present, which may allow the osteotomy site to become deeper than

intended. This will result in the implant being placed more apically, leading to neurosensory impairment. A MSCT or CBCT comprehensive evaluation allows the implant dentist to view the bone quality prior to surgery. Many third-party implant-planning programs allow the clinician to ascertain the density in the intended site. The implant clinician may also determine the bone density by tactile sensation when drilling. Additionally, when drilling the osteotomy near the mental foramen, care should be exercised not to bend the wrist. This can potentially redirect the drill or implant placement in an unwanted direction (e.g., near the mental foramen, into a tooth root). Surgical templates and guides are beneficial in preventing this malpositioning complication (Fig. 9.32).

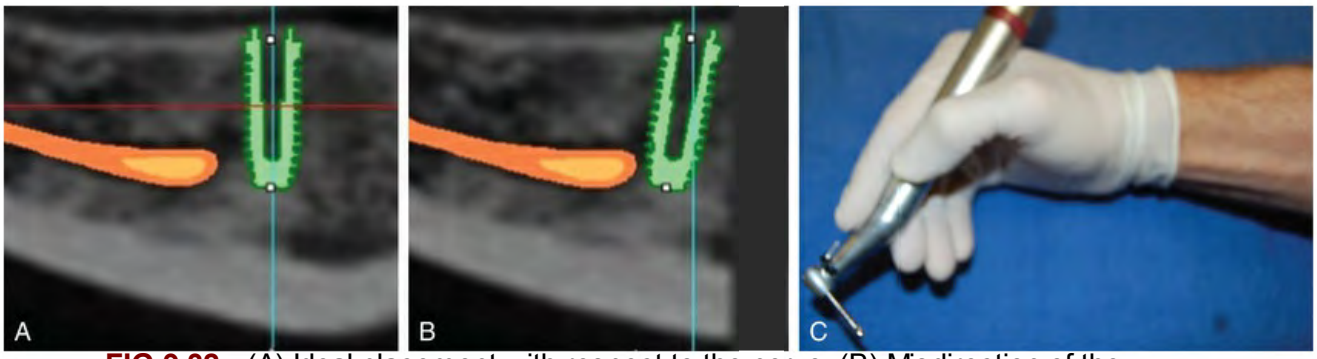

FIG 9.32 (A) Ideal placement with respect to the nerve. (B) Misdirection of the implant from improper drilling technique. (C) When drilling osteotomy, wrist should never be bent.

Do Not Place Bone Graft Material in Close Approximation to Nerve.

After tooth extractions, especially in the mandibular premolar areas, care should be exercised in placing bone graft material (autologous, allogenic, xenogenic) in direct contact with an exposed IAN. Whether socket grafting or in conjunction with implant placement, case studies have shown resultant neurosensory impairment from bone graft material causing compression, crushing, or chemical burn injuries.[64] When socket grafting in this area, excessive pressure should be avoided.

Use Copious Amounts of Irrigation.

Overheating the bone during osteotomy preparation may produce thermal

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stimuli that may lead to periimplant necrosis and secondary postoperative nerve damage. Neural tissue is extremely sensitive and damaged by heat stimuli. The thickness of the necrotic area is proportional to the amount of heat generated during preparation.[65] The implant dentist must be cautious to not overheat the bone. This can be minimized by "bone dancing," which involves drilling in short intervals and allowing irrigation to enter the osteotomy, preventing heat generation. Additionally, new (sharp) and intermediate-sized drill burs may be used to reduce heat generation. This is more crucial with harder bone density (e.g., D1 or D2) or bone with compromised vascularity (Fig. 9.33).

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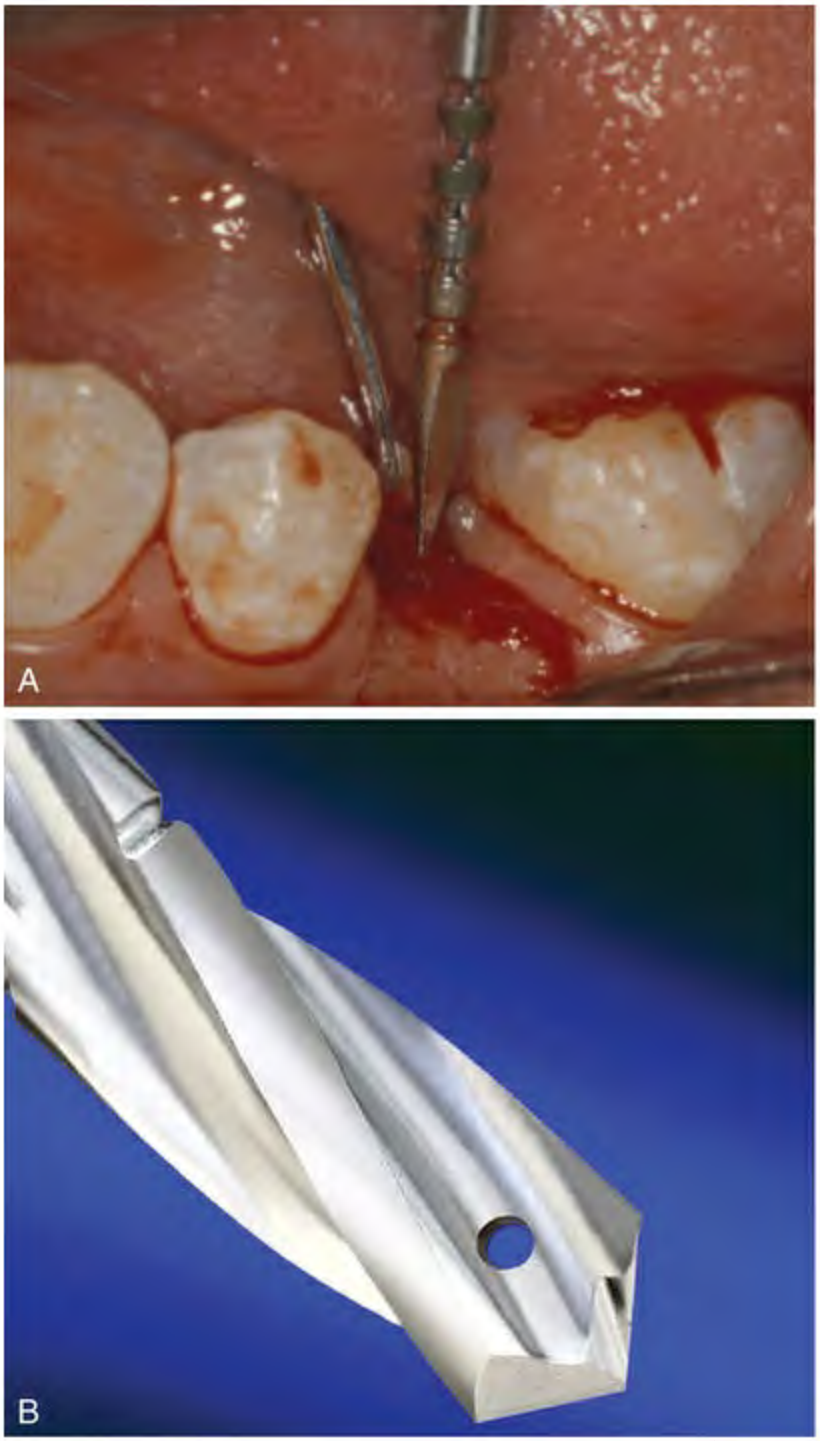

FIG 9.33 (A) During osteotomy preparation, copious amounts of irrigation must be used to decrease heat most commonly with the use of a SurgiGuide. (B) Internally cooled drill. (B, Courtesy FFDM PNEUMAT—Département Dentaire THOMAS, Bourges Cedex, France.)

Avoid Incision-Related Injuries.

There should be an awareness when making incisions near the location of the mental foramen and associated nerve structures in the posterior mandible.

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In cases of severe bone atrophy, the presence of nerve dehiscence may inadvertently result in a transected nerve during the initial incision (i.e., making incision on the crest of the ridge). Anatomic landmarks, 3-D models, accurate measurements from CBCT scan, or palpation of the nerves are ways to avoid this complication. Additionally, incisions in the posterior of the oral cavity should never be made over the retromolar pad. This can result in possible injury to the lingual nerve, which in 10% of cases transects this area (Fig. 9.34).

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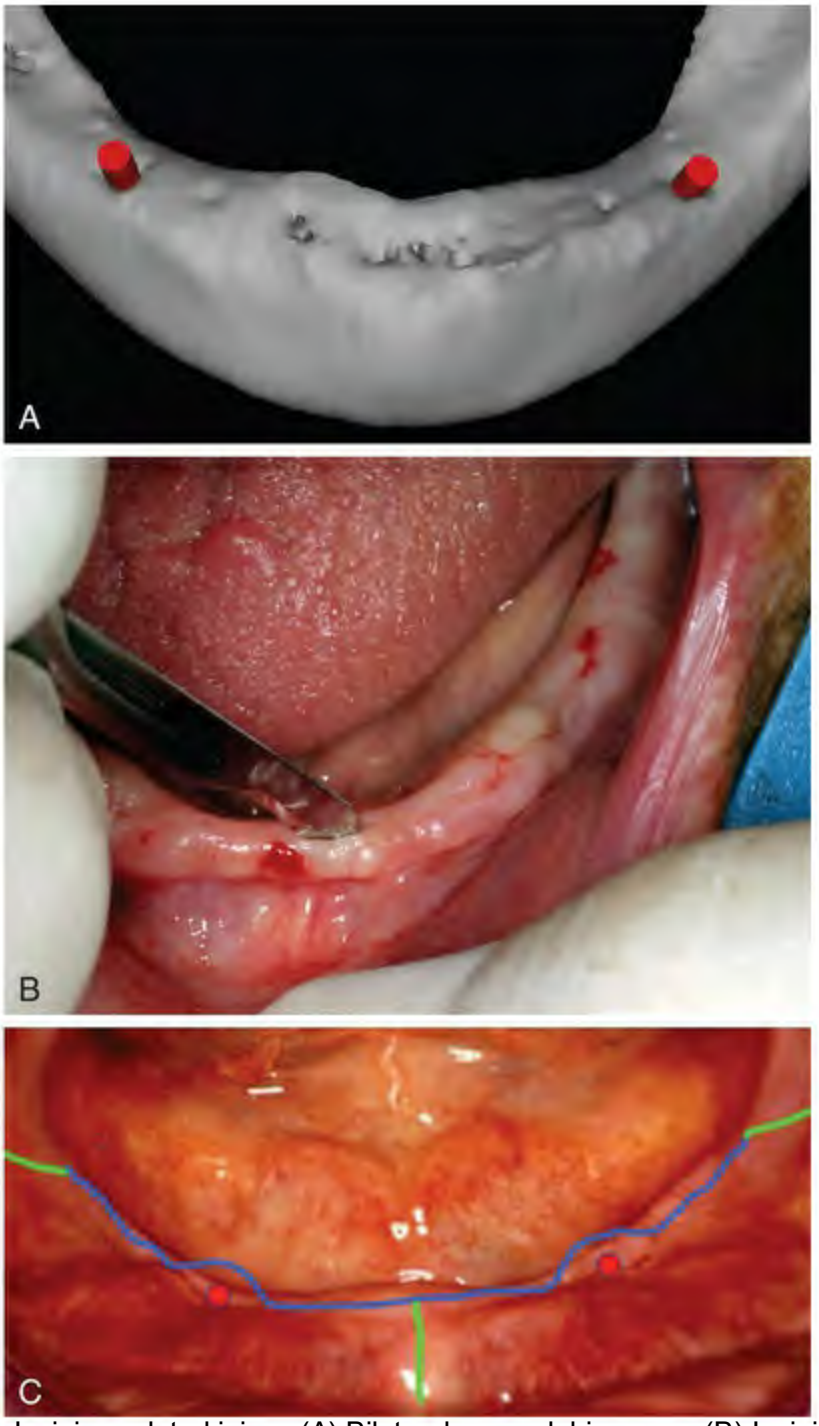

FIG 9.34 Incision-related injury. (A) Bilateral nerve dehiscence. (B) Incision needs to be modified to decrease chance of nerve damage as crestal incision will transect nerve. (C) Incision should be made lingual when nerve dehiscence is present.

Avoid Flap/Retraction-Related Injuries.

Neurosensory impairments may also occur from overzealous use or incorrect placement of retractors. Broad base (not sharp) retractors should be used to retract tissue that is not directly over the mental foramen because excessive

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stretching of the nerve trunk may cause irreversible damage. It is imperative that the mental foramen and associated branches of the mental nerve be identified in this area when placing retractors. Retractors should always be placed and held on the bone to prevent slippage or excessive soft tissue pressure, which can lead to a neuropraxia type of nerve damage (Fig. 9.35). Excessive stretching of the tissue may also lead to neurosensory impairments. It has been shown the perineurium protects the fascicles; however, if greater than 30% elongation of the nerve occurs, structural damage will occur to the nerve fibers.[65a]

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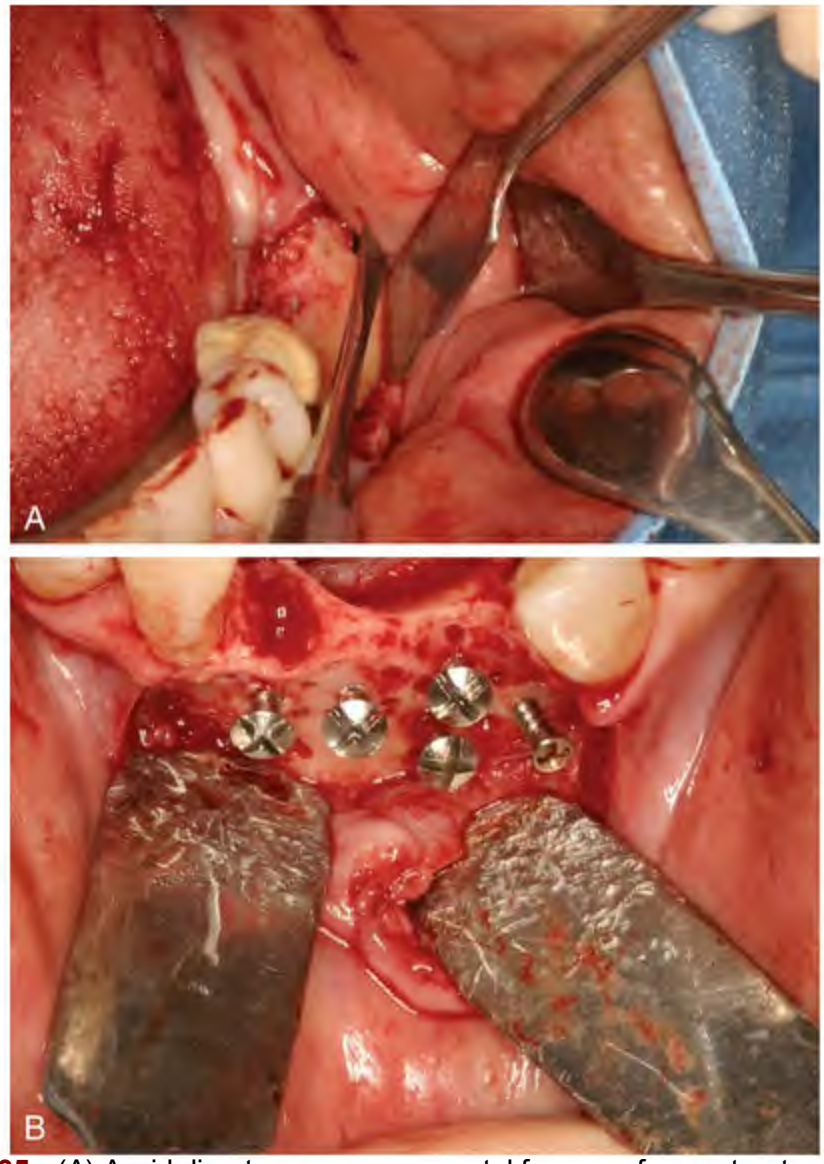

FIG 9.35 (A) Avoid direct pressure on mental foramen from retractor. (B) Be cautious when stretching tissue near the branches of the mental nerve. Note the sharp damaged retractors that may cause tissue damage.

Use Special Care When Releasing Periosteum Over Mental Foramen.

It is a common procedure during closure after implant placement or bone grafting to stretch the periosteal tissue to allow primary and "tension-free" closure. Various techniques are used to "release" the tissue to improve vascularization of the incision line and adhesion of the margins to prevent incision line opening. The submucosal technique developed by Misch in 1988 is an effective method to expand the tissue. This procedure involves the use of a #15 scalpel blade and soft tissue scissors (i.e., Metzenbaum) to create a

blunt dissection. Knowledge of the location of the three mental nerve branches is necessary because inadvertent incisions over the mental nerve branches may result in neurotmesis (transection) type of nerve injuries.

Careful Suturing.

When the mental nerve is exposed, care should be exercised to prevent nerve tissue from being entrapped within the sutures. The mental nerve emerges from the mental foramen and divides into three branches below the depressor anguli oris muscle. Caution must be exercised to prevent any of the mental nerve branches from becoming entrapped within in the suture material, potentially causing a neuropraxia (compression) type of nerve injury. Additionally, nerve fibers may be damaged from the passage of the extremely sharp suture needle through the tissue (Fig. 9.36).

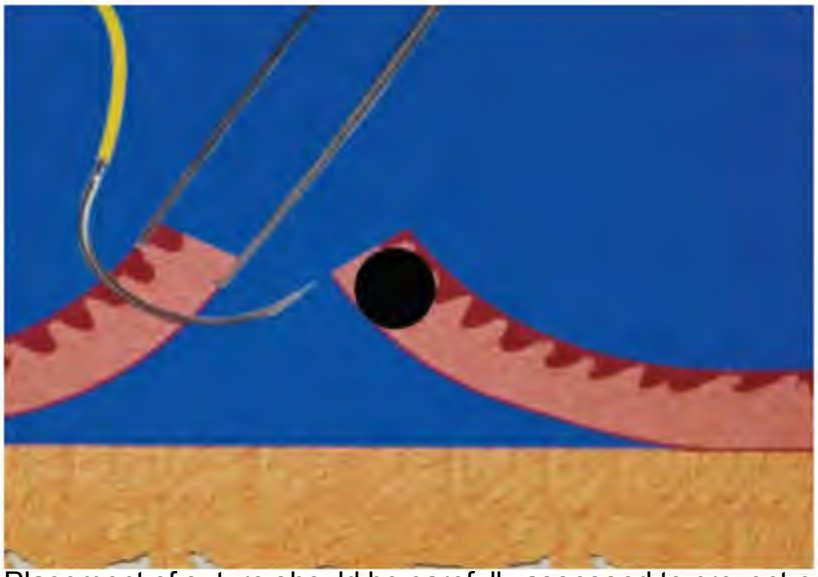

FIG 9.36 Placement of suture should be carefully assessed to prevent nerve tissue from becoming entrapped within suture line.

Verify Correct Positioning of CBCT SurgiGuides.

Studies have shown that the most precise and accurate surgical templates are tooth supported. When using bone- or tissue-supported surgical guides, care must be exercised to correctly position the guide because an error in placement may result in direct damage to the IA nerve. Tooth-supported guides should always be the first choice if possible because they are clinically proven to give rise to the fewest positioning errors. The least accurate is the

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mucosa supported, which are most utilized for flapless surgery.[66] Studies have shown that flapless surgical guides consistently show deviations of implant positions from ideal locations. Perforations of the buccal plate can be found in over 50% of the flapless cases.[67] A very minor discrepancy (anterioposterior) in the placement of the guide can lead to impingement on vital structures (Fig. 9.37). Therefore, surgical templates should always be fixated and ideal position verified.

FIG 9.37 Tissue-borne surgical template fixated with palatal screw to prevent movement of the template.

Miscellaneous Alternative Surgical Techniques

Avoid Immediate Implants in the Mandibular Premolar Area.

Immediate implants have gained overwhelming popularity in implant dentistry today. Extreme caution must be exhibited when extracting and immediately placing implants in the mandibular premolar area. As noted, there are many variables that dictate the position of the mental foramen, with the foramen being highly variable. Studies have shown that 25% to 38% of the time the mental foramen is superior to the premolars apex.[58] Because most immediate implant osteotomy sites involve drilling the osteotomy site deeper for stability, chances of nerve trauma are greatly increased. Because of this the implant clinician must be very selective in cases involving extraction and immediate implant placement in this anatomic area (Fig. 9.38).

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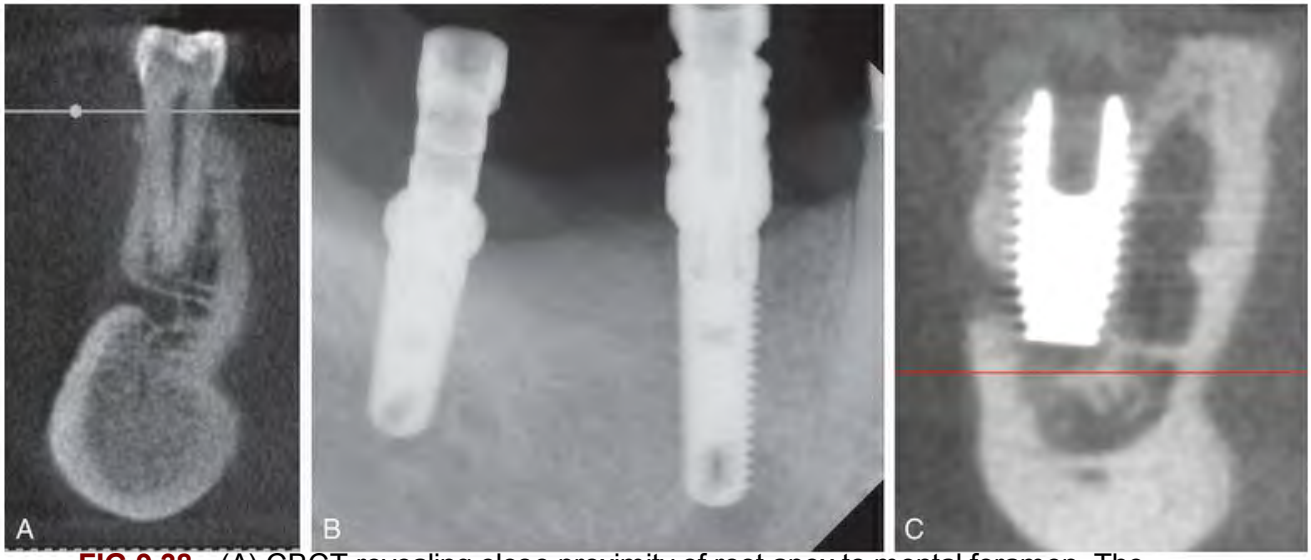

FIG 9.38 (A) CBCT revealing close proximity of root apex to mental foramen. The root apex is inferior to the mental foramen. (B) Complications arising from simultaneous extraction and implant placement in premolar area. (C) Implant placed into mental foramen location.

"Drill Until the Superior Cortical Plate Is Felt."

It has been advocated in the literature that the osteotomy depth maybe determined by "feeling" the superior cortical plate of the inferior alveolar canal. A 2-mm safety zone should always be adhered to because research has shown in approximately 28% of posterior mandibles, there is no superior cortical plate over the inferior alveolar canal.[68] Additionally, studies have shown it to be impossible to use tactile sense to ascertain the presence of superior cortical bone surrounding the mandibular canal.[58] Clinical reports have revealed hemorrhage into the canal or bone fragments may cause compression or ischemia of the nerve from engaging the superior cortical plate. Dependence on the ability to "feel" the superior cortical plate through tactile sense increases the likelihood of nerve complications (Fig. 9.39).

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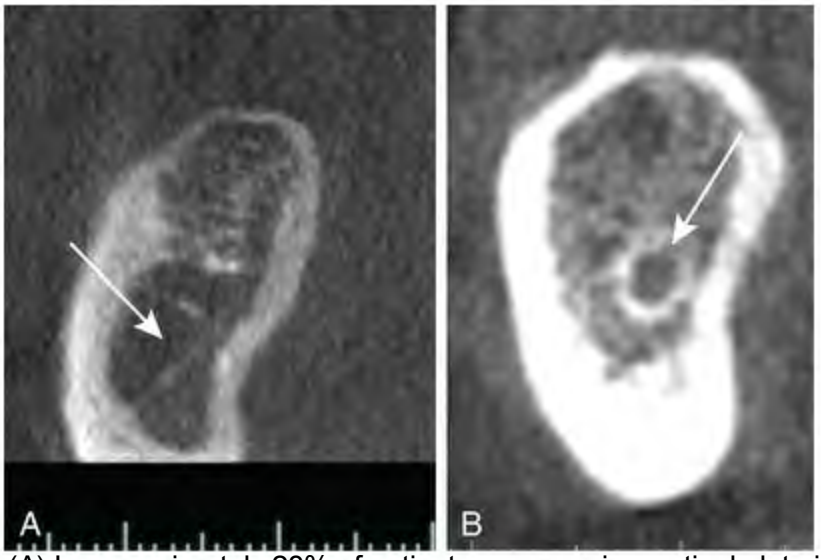

FIG 9.39 (A) In approximately 28% of patients, no superior cortical plate is present. (B) Even when present, cortical plate is very thin, which makes tactile sensitivity extremely difficult.

Infiltration Technique.

An alternative technique in placing implants in the posterior mandible is not utilizing mandibular nerve block anesthesia. Instead, infiltration is accomplished in the soft tissue surrounding the osteotomy site, and the patient is asked to alert the implant clinician on the proximity of the drill to the nerve bundle.[69]

This alternative technique results in a very high degree of subjectivity concerning patient's responses due to varying degrees of pain thresholds. Additionally, disadvantages of this surgical method include inconsistent mandibular nerve anatomy with varying locations of dental-alveolar nerve branches. With the success of CBCT radiography in implant dentistry today in determining the exact location of the inferior alveolar nerve, this technique should be avoided because of the high degree of false-negative and false-positive results from patients. Etoz et al showed this supraperiosteal infiltartion technique to be safe in 91% of cases. However, this results in approximately one patient in ten ending up with a neurosensory deficit.[70]

"Place Implants Buccal or Lingual to the IAN Canal or Foramen."

Many authors have advocated placing implants buccal or lingual to the neurovascular bundle. (Kumar; Stellar) As stated previously, the buccal-lingual nerve position within the mandible is extremely variable along with

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the incidence and trajectory of lingual osseous concavities. Attempting to place implants buccal or lingual to the inferior alveolar canal or mental foramen is associated with a high degree of morbidity, even with the use of CBCT-guided surgery. Additionally, perforation of the cortical plate can occur, which may lead to sublingual bleeding or formation of a sublingual hematoma (Fig. 9.40).

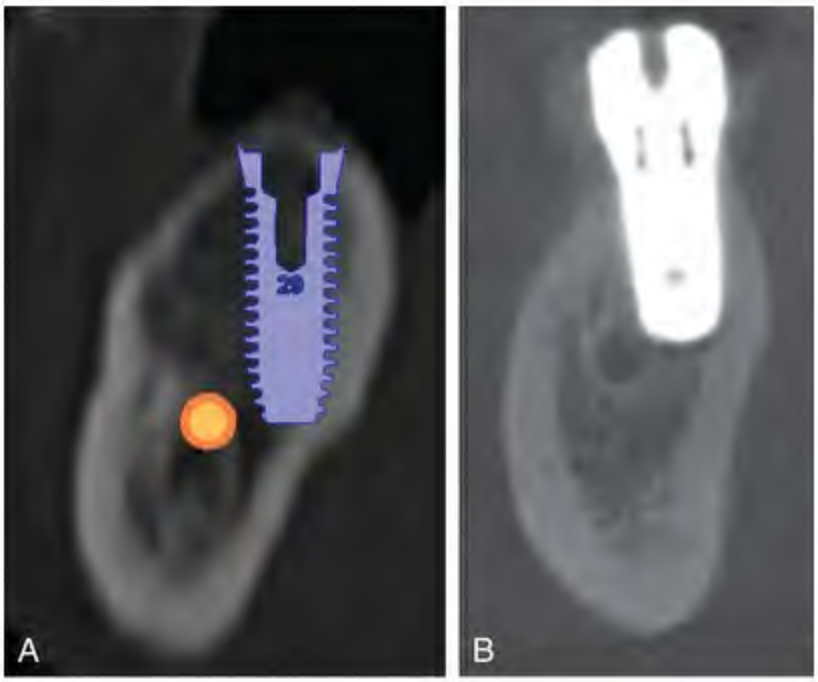

FIG 9.40 (A–B) Placing implants lingual increases chances of nerve impairment or perforation of the lingual cortical plate.

"Place Implants at the Depth of the Adjacent Root Apexes."

Many implant clinicians use the location and length of the adjacent teeth as a guide in determining the size (length) implant to be placed. Usually a panorex or periapical radiograph is utilized in determination of this length. When this technique is used in anatomic type 2 or 3 (i.e., more apically positioned in the vertical dimension) nerve courses, incidence of nerve impairment is low. However, in mandibles that exhibit a type 1 nerve course (close to root apex), close approximation of the implant to the canal is likely leading to a higher probability of neurosensory impairment. Ideally, the implant clinician should ascertain the available bone above the mandibular canal via three-dimensional radiographic analysis (Fig. 9.41).

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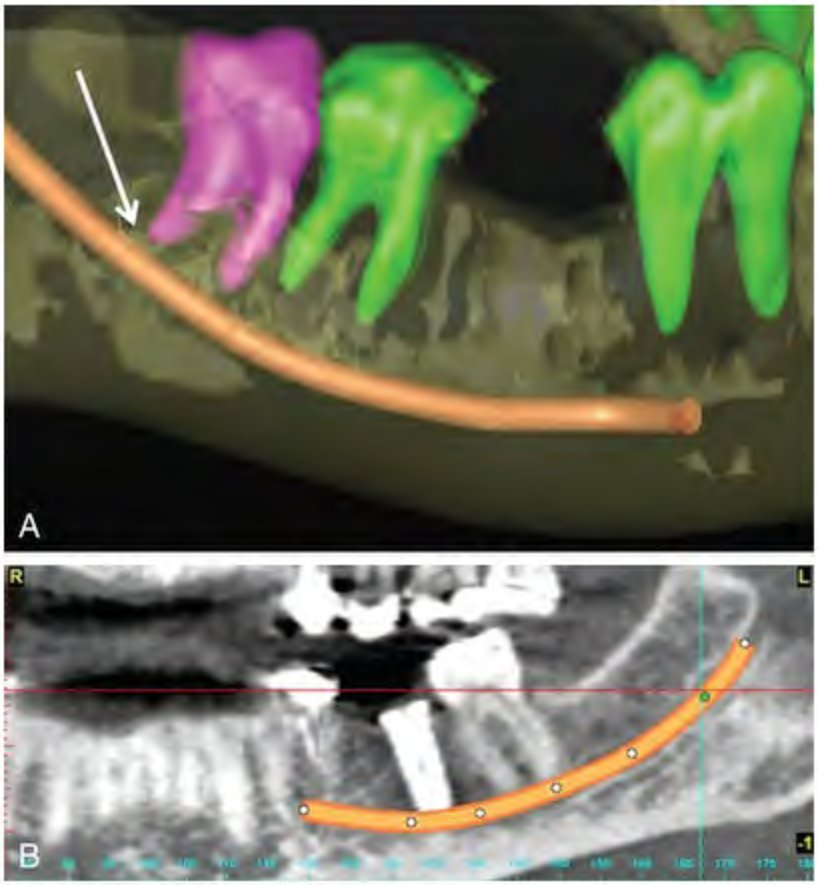

FIG 9.41 (A) Placement of implants at the level of the adjacent roots is ideal when an anatomic type 2 or 3 nerve is present *(arrow)*. (B) However, in type 1 nerve courses, this principle will lead to a greater chance of nerve impairment because of approximation of the implant and mandibular canal.

"As Long as There Is Not Excessive Bleeding, the Mandibular Canal Has Not Been Violated."

Another unconventional technique in avoiding nerve impairment is the evaluation of the amount of bleeding from the osteotomy site. Many practitioners correlate the amount of hemorrhage with the proximity of the neurovascular bundle (inferior alveolar nerve, artery, vein, and lymphatic vessels). Anatomic studies have shown the inferior alveolar artery may lie parallel to the nerve and lingual as it traverses anteriorly. Its position varies with respect to the inferior alveolar nerve within the mandibular canal. Other studies show the inferior alveolar artery appears to be solitary and lies superior and lingual to the inferior alveolar nerve, slightly above the horizontal position.[12] Additionally, there exists multiple inferior alveolar veins positioned superior to the nerve, which may cause venous oozing if directly traumatized.[11] A false positive may occur if this area is damaged as

large marrow spaces, which can cause excessive bleeding, are common in the posterior mandible (D4 bone). The degree of bleeding should not be used as an indication of nerve proximity or violation of the mandibular canal (Fig. 9.42).

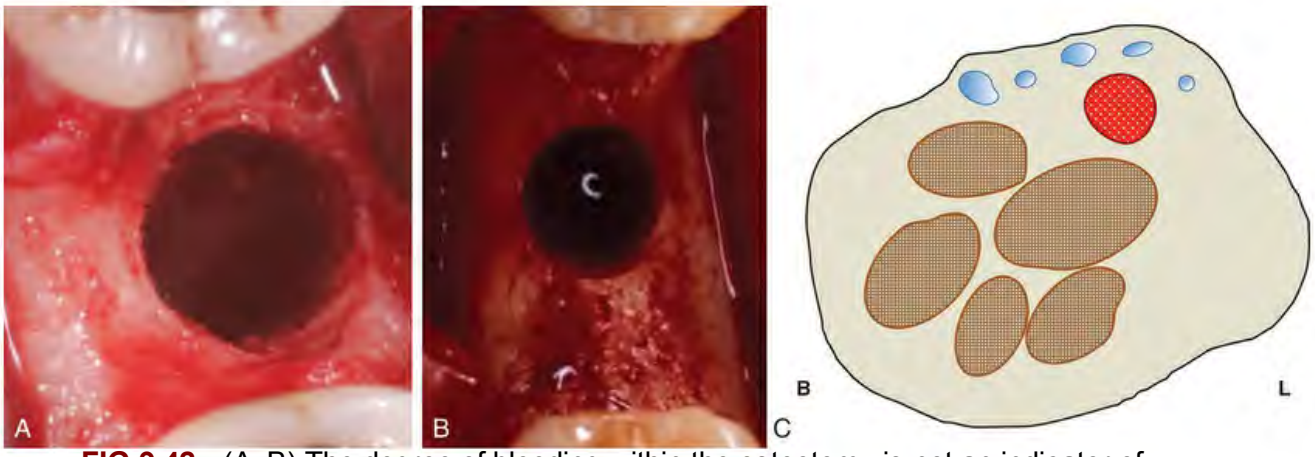

FIG 9.42 (A–B) The degree of bleeding within the osteotomy is not an indicator of proximity or violation of the neurovascular canal. (C) Although variations exist, multiple smaller veins *(blue)* are usually present superior to the polyfascicular inferior alveolar nerve *(brown)* with the inferior alveolar artery *(red)* superiorly and lingually positioned.

"Replacing Second Molars."

There are many prosthetic and surgical disadvantages when evaluating edentulous second mandibular molar sites for implant placement. Disadvantages include high incidence of sublingual bony undercuts, which can result in perforation of the lingual plate or angulation issues, decreased interocclusal space (especially with supraeruption of the adjacent tooth), difficult access for surgery and prosthetic component insertion, and the fact there is 10% greater occlusal force on the second molar vs. the first molar. Function is not a primary reason for replacement because 90% of masticatory efficiency is generated anterior to the mesial half of the mandibular first molar, and cheek biting is more common in this area because of the proximity of the buccinators muscle. One of the most important disadvantages is the close approximation of the mandibular canal in the second molar area, which leads to difficulty in placement of implants in this area. When implants are placed, usually the available bone present is compromised in height. As a result, the second molar is often not replaced when the only posterior teeth missing are the second and third molars. The

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primary disadvantage of not replacing the second molar is extrusion of the opposing maxillary second molar. If extrusion is a significant concern, a full-coverage crown on the mandibular first molar may include an occlusal contact on with the mesial marginal ridge of the maxillary second molar (Fig. 9.43).

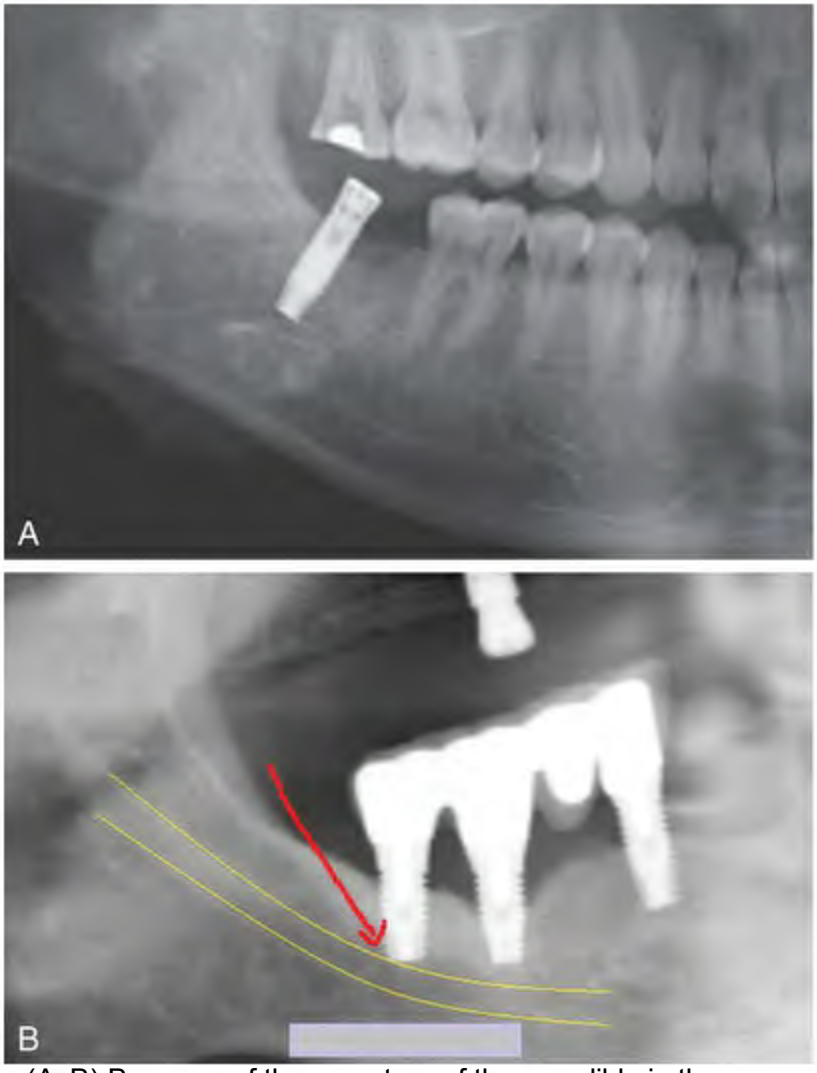

FIG 9.43 (A–B) Because of the curvature of the mandible in the ramus area, the mandibular canal is in close approximation to the second molar tooth roots in all types of nerve courses.

"Nerve Repositioning".

Patients who exhibit compromised alveolar crest height in the posterior mandibular area can be very challenging. Techniques include the use of shorter implants, which become biomechanically compromised, or the use of

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bone grafting to increase available bone for future implant placement. An alternative technique is to reposition the inferior alveolar nerve laterally, either by nerve lateralization or nerve transposition. In nerve lateralization, the inferior alveolar nerve is exposed and retracted laterally while the dental implants are placed. The transposition technique, first published in 1987 by Jenson and Nock, includes the mental foramen in the osteotomy resulting in the inferior alveolar nerve being positioned more posterior.[71] The inherent risk with these complex procedures is neurosensory impairment (anesthesia, paresthesia, or dysesthesia) to the mental nerve branch. Although this is a valid treatment option in significantly atrophied cases, this technique should be reserved for practitioners with advanced training and experience with these procedures (Fig. 9.44).

FIG 9.44 Nerve repositioning in which the IAN is positioned facially and implants placed in the prior position of the nerve bundle.

Summary

In implant dentistry today, one of the most serious complications is neurosensory impairment associated with implant placement or bone grafting. To avoid nerve damage a thorough understanding of the radiographic anatomy is paramount. If nerve impairment does occur, quick recognition and treatment is crucial to decreasing long-term morbidity. The nerves associated with the maxilla and mandible are associated with

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inconsistent anatomic locations. The implant clinician should understand the limitations of two-dimensional radiology and the importance of a comprehensive radiographic evaluation of the neural anatomy of the maxilla and mandible. Additionally, the clinician must understand the complications that may arise from unconventional surgical techniques that may increase the morbidity of the procedure.

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Postoperative Complications

Randolph R. Resnik

Dental implant surgery comprises many diverse procedures that are considered in dentistry to be relatively safe with a high success rate. However, implant clinicians must be aware and take into consideration numerous postoperative complications that may follow dental implant surgery. Most postoperative complications resolve with minimal intervention, but some situations may predispose implants to failure or even subject the patient to life-threatening situations. Understanding the possibility and magnitude of postoperative complications is crucial for today's clinicians practicing implant dentistry. In this chapter a wide range of postoperative complications will be discussed according to the etiology, prevention, and management to decrease implant and patient morbidity.

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Medical Issues

Edema (Postoperative) Surgical Swelling

Postoperative edema is a direct result of tissue injury and is defined as an accumulation of fluid in the interstitial tissue. Two variables determine the extent of edema: (1) the amount of tissue injury is proportional to the amount of edema; (2) the more loose the connective tissue at the surgery site, the more edema is most likely to be present.[1] Because postoperative swelling can adversely affect the incision line (i.e., result in incision line opening), measures should be taken to minimize this condition. Usually, edema will peak at approximately 48–72 hours, therefore patients should always be informed. Increased swelling after the fourth day may be an indication of infection, rather than postsurgical edema.

Etiology

The mediators of the inflammatory process include cyclooxygenase and prostaglandins, which play a significant role in the development of postoperative inflammation and pain. When tissue manipulation or damage occurs, phospholipids are converted into arachidonic acid by way of phospholipase A_2. Arachidonic acid, which is an amino acid, is released into the tissue, which produces prostaglandins via enzymatic breakdown via cyclooxygenases. The end result is the formation of leukotrienes, prostacyclins, prostaglandins, and thromboxane A_2, which are the mediators for inflammation and pain.

Prevention

To minimize postoperative swelling, good surgical technique must be used with minimal tissue trauma. Additional factors include patient systemic disorders, excessive retraction, and long surgical duration, which will all contribute to increased inflammation after surgery. Postoperative prophylactic medications such as ibuprofen (nonsteroidal antiinflammatory drugs [NSAIDs]) and glucocorticosteroids (steroids) are utilized as prophylactic medications, which counteract the negative effects of the edema cascade (Fig. 10.1).

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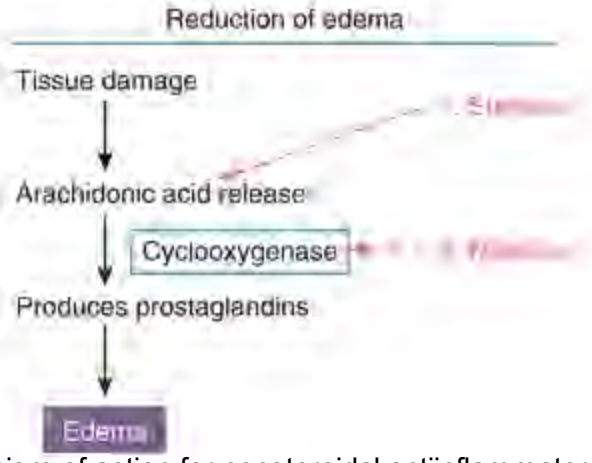

FIG 10.1 Mechanism of action for nonsteroidal antiinflammatory drugs (NSAIDs) and steroids in the reduction of inflammation. Steroids block arachidonic acid and NSAIDs interfere with cyclooxygenase in the reduction of edema. (From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.)

Nonsteroidal Antiinflammatory Drugs.

NSAIDs have an analgesic effect as well as an antiinflammatory effect. This drug class reduces inflammation by inhibiting the synthesis of prostaglandins from arachidonic acid. Therefore the use of the popular analgesic drug ibuprofen has a secondary beneficial antiinflammatory effect. NSAIDs do not have a ceiling effect for inflammation (i.e., ceiling effect for analgesia is 400 mg); however, higher doses to achieve antiinflammatory qualities are accompanied by serious side effects.

Recommendation: Ibuprofen 400 mg for Type 1–4 procedures (see Misch Prophylactic Medication Protocol, Table 10.1).

TABLE 10.1

Procedure-Specific Pharmacologic Protocol for Oral Implantology

Category	Patient Selection	Procedures	Antibiotic	Glucocorticoid	Antimicrobial	Analgesic
Category 1	ASA1/ASA2 >ASA2 = Category 2	• Single implants with minimal reflection	***Amoxicillin 1 gm*** One hour before surgery	None	***Chlorhexidine:*** ½ oz. BID for two weeks	Pain control protocol[a] **PCP 1–2**
Category 2	ASA1/ASA2 >ASA2 = Category 4	• Traumatic extractions with pathology • Socket grafting • Single tooth implants with extensive reflection • Multiple implants with minimal tissue reflection • SA1 sinus procedures	***Amoxicillin 1 gm*** One hour before surgery, then 500 mg 6 hours after	***Decadron 4 mg*** • 1 tab AM day of surgery	***Chlorhexidine:*** ½ oz. BID for two weeks	Pain control protocol **PCP 1–2**
		• Immediate implants without pathology				

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Category 3	ASA1/ASA2 >ASA2 = Category 4	• Single implants with bone grafting and excessive tissue reflection • Multiple implants with extensive reflection • Bone grafting (Allograft/Autograft) • SA2 sinus procedures	***Amoxicillin 1 gm*** One hour before surgery, then 500 mg TID for 3 days	***Decadron 4 mg*** • 1 tab AM day of surgery • 1 tab AM day after surgery • 1 tab AM two days after surgery	***Chlorhexidine:*** ½ oz. BID for two weeks	Pain control protocol **PCP 2–3**
Category 4	**Any of the following:** • >ASA2 • Long duration surgery • Less experienced surgeon • Immunocompromised • Active periodontal disease	• Any Category 3 procedures with surgical or patient factors • Immediate implants with pathology • Autogenous onlay grafting	***Amoxicillin 1 gm*** One hour before surgery, then 500 mg TID for 5 days	***Decadron 4 mg*** • 2 tab AM day of surgery • 2 tabs AM day after surgery • 1 tab AM two days after surgery	***Chlorhexidine:*** ½ oz. BID for two weeks	Pain control protocol **PCP 3–4**
Category 5	All SA3/SA4 Sinus patients	All SA3/SA4 Sinus procedures	***Augmentin*** (875 mg/125 mg): 1 tab BID starting one day before, then 1 tab BID for 5 days	***Decadron 4 mg*** • 2 tab AM day before surgery • 2 tabs AM day of surgery • 1 tab AM day after surgery • 1 tab AM two days after surgery	***Chlorhexidine:*** ½ oz. BID for two weeks	Pain control protocol **PCP 2–3**

[a]See Table 10.5 for pain control protocols.

ASA, American Society of Anesthesiologists; *NSAID,* nonsteroidal antiinflammatory drug; *SA,* subantral.

Alternative Medications:

Amoxicillin (1 gm) = Cephalexin (1 gm), Clindamycin (600 mg)

Augmentin (875/125) = Ceftin (500 mg) = Doxycycline (100 mg)

(*Note:* SBE Prophylaxis : change preoperative antibiotic dose to Amoxicillin [2 gm], Cephalexin [2 gm], or Clindamycin [600 mg])

Ibuprofen (400 mg) > Acetaminophen (500 mg) or Naproxen Sodium (375 mg)

Hydrocodone (5 mg/500 mg) > Tylenol # 2/Tramadol (50 mg)

Hydrocodone (7.5 mg/750 mg) > Tylenol # 3/Tramadol (100 mg)/Nucynta (50, 75, 100 mg)

Hydrocodone (10 mg/660 mg) > Oxycodone (Percocet) 7.5/500 mg

(*Note:* If patient cannot take medication by mouth, [1] Ibuprofen Oral Suspension (OTC); [2] Lortab Elixar [7.5 mg hydrocodone/500 mg APAP/15 ml])

Glucocorticosteroids.

The adrenal cortex, which uses cholesterol as a substrate, synthesizes and

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secretes two types of steroid hormones—the androgens and corticosteroids. The corticosteroids are classified additionally by their major actions: (1) glucocorticoids, which have effects on carbohydrate metabolism and have potent antiinflammatory actions, and (2) mineralocorticoids, which have sodium-retaining qualities. The use of synthetic glucocorticosteroids has become very popular in the postoperative management of inflammation after oral surgical procedures. These synthetic glucocorticoids have greater antiinflammatory potency in comparison to natural steroids with very little sodium and water retention. Most steroids have similar chemical structures; however, they differ in their milligram potency.[2] The antiinflammatory effects are achieved by altering the connective tissue response to injury, causing a decrease in hyperemia, which results in less exudation and cellular migration along with infiltration at the site of injury.[3]

Glucocorticoids bind to glucocorticoid receptors within cells and form a glucocorticoid-GR complex. This complex alters the synthesis of mRNA from the DNA molecule, affecting the production of different proteins. By suppressing the production of proteins that are involved in inflammation, glucocorticoids also activate lipocortins, which have been shown to inhibit the action of phospholipase A2 (PLA2). PLA2 is a key enzyme involved in the release of arachidonic acid from cell membranes.

Arachidonic acid is an omega-6 fatty acid that is incorporated into cell membranes. When a cell is damaged, arachidonic acid is released from cell membranes and is converted into inflammatory and pain prostaglandins by cyclooxygenase (COX)-2 enzymes. The release of arachidonic acid requires the activation of enzyme PLA2. However, lipocortins, which cause the inhibition of PLA2, prevent the release of arachidonic acid, thereby reducing the amounts of inflammatory prostaglandins.

There is a wide range of glucocorticoid preparations available for local, oral, and parenteral administration. In relation to the naturally occurring cortisol (hydrocortisone), synthetic glucocorticoids are longer acting and more potent. The main differences are based on the classification as short acting (<12 hours), intermediate acting (12–36 hours), and long acting (>36 hours). A summary of the most common glucocorticosteroids is shown in Table 10.2.

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TABLE 10.2
Synthetic Glucocorticoids

Glucocorticoids	Antiinflammatory Potency	Equivalent Dose (mg)	Duration (h)
Short Acting			
Hydrocortisone	1.0	20	<12
Cortisone	0.8	25	<12
Intermediate Acting			
Prednisone	4.0	5	24 to 36
Prednisolone	4.0	5	24 to 36
Long Acting			
Dexamethasone	25	0.75	>48

From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.

The ideal synthetic glucocorticoid for dental implant surgery should maintain high antiinflammatory potency with minimal mineralocorticoid effects. The glucocorticoid that best suits the requirements is the long-acting glucocorticoid dexamethasone (Decadron). It is imperative this drug be administered before surgery so that adequate blood levels are obtained. Also, it should be given in the morning in conjunction with the natural release of cortisol (~8:00 am). This timing will interfere the least with the adrenocortical system. Because inflammation usually peaks between 48 and 72 hours, the postoperative regimen of dexamethasone should not exceed 3 days after surgery. This high-dose, short-term glucocorticoid therapy has been shown not to significantly affect the hypothalamic–pituitary–adrenal axis (HPA axis), which controls many of the bodies processes, including reactions to stress.[4]

A significant additional benefit of the administration of dexamethasone is the potent antiemetic effects for the prophylactic treatment of postoperative nausea and vomiting. This is now an accepted medication for hospital-based outpatient surgery, usually given in doses of 8–10 mg intravenously.[5]

Contraindications to the use of corticosteroids include active infections (viral, bacterial, fungal), tuberculosis, ocular herpes simplex, primary glaucoma, acute psychosis, and diabetes mellitus. Special attention must be given to diabetic patients because glucocorticoids have an antiinsulin action that results in increased serum glucose and glycosuria.[6] Usually, corticosteroids are contraindicated with insulin dependent diabetics. For oral and diet controlled diabetics, a medical consult should be completed prior to any treatment.

Recommendation: Decadron 4 mg for Type 1–4 procedures (see Table 10.1, Misch Prophylactic Medication Protocol).

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Cryotherapy.

Cryotherapy (application of ice) is one of the simplest and most economical modalities in the management of postoperative soft tissue inflammation. The use of ice to reduce pain and swelling dates back to the ancient Egyptians, over 4000 years ago.[7]

The use of cryotherapy is highly advised in any dental implant procedure in which excessive inflammation is expected. The mechanism of action involves a reduction in fluid accumulation within the body tissues, slowing of metabolism, control of hemorrhage, and a decrease in the excitability of peripheral nerve fibers leading to an increase in pain threshold.[8]

Caution must be taken to limit the application of ice to no longer than 2 days because prolonged use may cause rebound swelling and cell destruction. Improper and prolonged use of ice may result in cell death due to prolonged vasoconstriction, ischemia, and capillary thrombosis.[9]

After 2 to 3 days, moist heat may be applied to the region to increase blood and lymph flow to help clear the area of the inflammatory consequences. This also helps reduce any ecchymosis that may have occurred from the tissue reflection. Although usually safe, the application of ice is cautioned in patients suffering from cold hypersensitivities and intolerances and peripheral vascular diseases. Additionally, ice application may be problematic in patients who are elderly or very young because they may have impaired thermal regulation and limited ability to communicate. Care should be exercised in using facial bandages because prolonged ice administration may result in soft tissue injury.

Recommendation: Cold dressings (ice packs) should be applied extraorally (not directly on skin: place a layer of dry cloth between ice and skin) over the surgical site for 20 minutes on/20 minutes off for the first 24–36 hours (Fig. 10.2).

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FIG 10.2 Postoperative edema. (A) Postoperative edema after dental implant surgery, which peaks at 48–72 hours. (B) Cryotherapy to decrease swelling with the use of ice packs. (C) Facial wrap bandages should be used with caution because they may cause prolonged exposure and trauma to the skin area. (A, From Torabinejad M, Fouad A: *Endodontics: principles and practice,* ed 4, St Louis, 2009, Saunders; B and C, courtesy of Salvin Dental Specialties, Inc., Charlotte, NC.)

Decrease Activities.

Patients should be instructed to decrease activities after surgery because this will minimize swelling postoperatively. The more active the patient and the more strenuous activity the patient engages in, the greater the extraoral swelling.

Recommendation: Activities should be limited for the first 3 days. Elevation of the head (sitting upright) and sleeping on multiple pillows will minimize the postoperative swelling.

Treatment

Swelling is self-limiting and, once it occurs, it is usually difficult to treat (time-dependent). The above mentioned medications/therapy (Decadron, NSAIDs, cryotherapy) will help to reduce postoperative inflammation.

Ecchymosis (Bruising)

Ecchymosis is subcutaneous extravasation of blood within the tissues, which results in discoloration of the skin from the seepage of blood in the tissues. The location of the ecchymosis may be distant to the surgical site because of gravity (i.e., always inform patients preoperatively). Ecchymosis that presents in the inferior mandibular area or neck may be from bleeding under the flap and traveling via fascial spaces due to gravity (Fig. 10.3).

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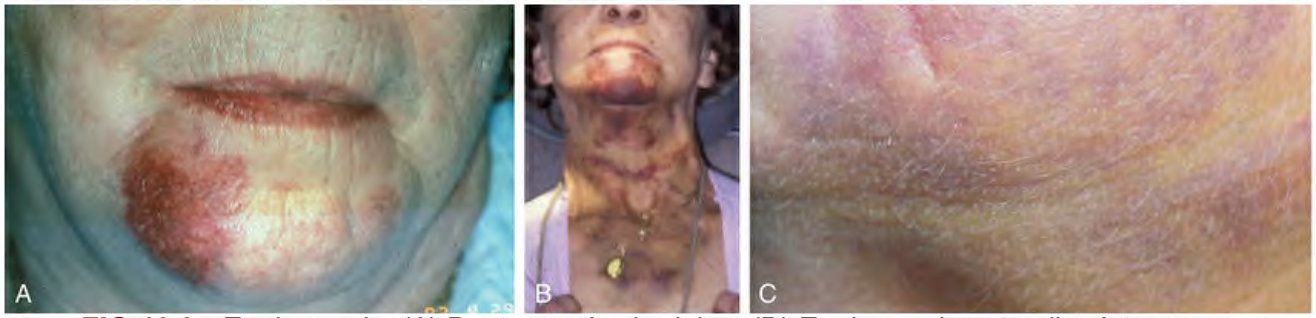

FIG 10.3 Ecchymosis. (A) Postoperative bruising. (B) Ecchymosis extending into the neck area. (C) Resolution of the ecchymosis will result in varying degrees of yellow to golden-brown.

Etiology

The cause of ecchymosis (bruising) is not confined to an existing hematologic disease or to medication induced bleeding. Moderate bruising should be expected after dental implant surgery, especially after longer, more invasive surgeries. Female and elderly patients are more susceptible to bruising. The ecchymosis cascade includes:

1. Blood vessels rupture

2. Red blood cells die and release hemoglobin

3. Macrophages (white blood cells, [WBCs]) degrade hemoglobin via phagocytosis

4. Hemo > bilirubin = bluish-red color

5. Bilirubin > hemosiderin = golden-brown color

Ecchymosis may appear as bright red, black, blue, purple, or a combination of the above colors. It usually consists of nonelevated, rounded, and irregular areas that increase in intensity over 3–4 days postoperation and will diminish and become yellow as they disappear. It may take 2–3 weeks for complete resolution.

Prevention

Unfortunately, even with gentle handling of tissues and good surgical technique, ecchymosis may be unavoidable. To minimize ecchymosis, avoid postoperative aspirin, herbal remedies, and food supplements that may

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increase bleeding. Always inform the patient preoperatively (preferably in written postoperation instructions) that bruising may occur. Elderly patients are more susceptible to ecchymosis because of decreased tissue tone and weaker intracellular attachment.

Treatment

Ecchymosis is self-limiting and usually resolves without treatment. However, the patient may treat the ecchymosis in the following ways:

Rest/avoid strenuous activity: promotes tissue healing and decreases inflammation.

Elevation: helps decrease inflammation, facilitates proper venous return, and improves circulation to the site.

Analgesics: helps reduce pain associated with the onset of ecchymosis.

Sun exposure: inform patient to avoid sun exposure to the area of bruising as excessive sunlight may cause permanent discoloration.

Trismus

Trismus refers to reduced opening of the jaws, which is caused by trauma or spasm to the muscles of mastication. The limited opening may result in an interference with eating, speech, and hygiene and may cause pain.

Etiology

Trismus after implant surgery can be due to multiple factors. The most likely etiologic factor is local anesthetic, secondary to an inferior alveolar nerve block that penetrates the medial pterygoid muscle. Also, complicated or prolonged surgical procedures that require full-thickness mucoperiosteal flaps with resultant edema can lead to trismus. Normal interincisal opening is approximately 35–45 mm, with mild trismus being classified as 20–30 mm and severe trismus less than 10 mm (Fig. 10.4).[1]

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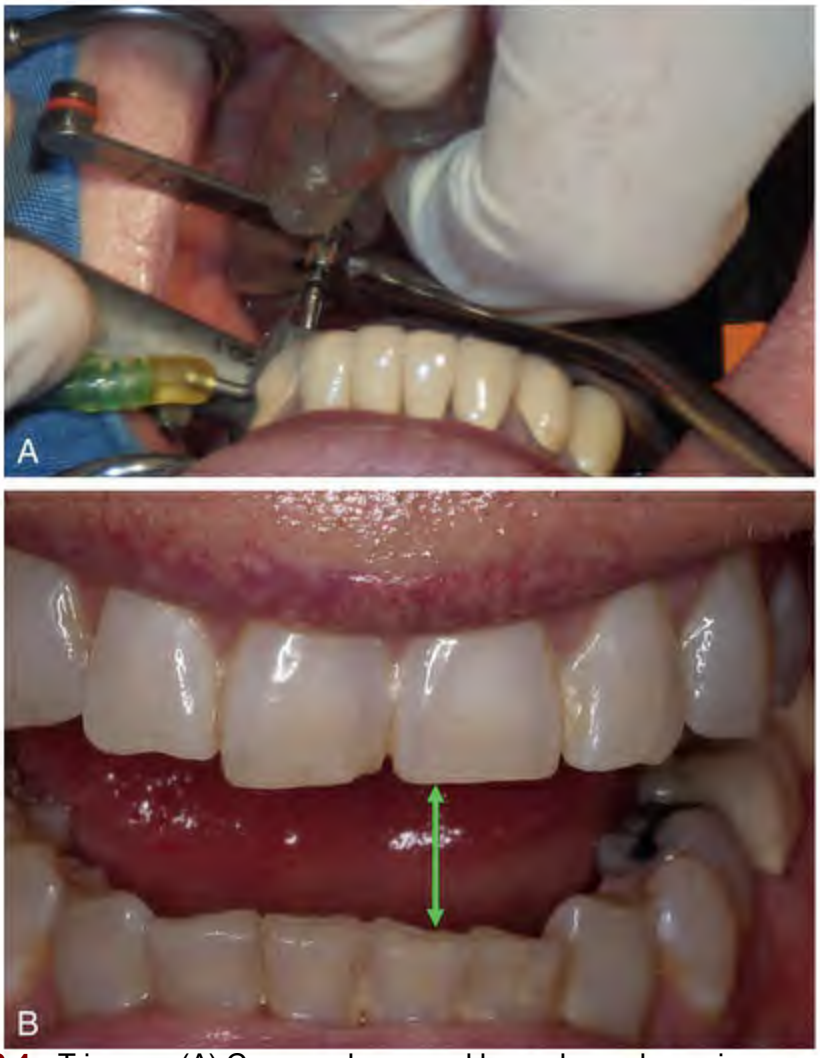

FIG 10.4 Trismus. (A) Commonly caused by prolonged opening resulting in spasms of the muscles of mastication. Care should be exercised in using surgical templates for the placement of implants in the posterior region as access is often compromised. (B) Measurement of maximum opening, which is normally 35–45 mm.

Prevention

When placing implants, especially in the posterior region, care should be taken to minimize excessive opening of the patient to where spasm of the muscles of mastication would result. Bite blocks, short duration treatment, and sedation may decrease the possibility of trismus complications. When using CBCT surgiguides, lateral access openings should be utilized in the guide to prevent extensive opening to accommodate the guide and surgical bur. This mainly occurs in the posterior region of the oral cavity.

Treatment

Usually trismus will resolve with time; however, patients should maintain a soft diet and minimize overactivity. Additional treatment includes the use of physical therapy, passive range of motion exercises, splint therapy, and medications such as NSAIDs, muscle relaxants, and steroids (Medrol Dosepak, Decadron).

Postsurgical Pain

Pain has been documented to be inadequately treated in 50% of all surgical procedures.[10] Oral surgical studies have shown pain in the oral cavity to reach its maximum intensity within the first 12 hours after surgery, and 97% of patients reporting postoperative pain being the greatest during the first day of surgery.[11]

Postsurgical painful experiences predispose the patient to amplification of noxious stimuli (hyperalgesia) and cause typically painless sensations to be experienced as pain (allodynia). Patients who have had painful experiences (surgery) may have increased pain and the need for additional analgesic use in future surgeries. The goal for pain control in oral implantology is to have adequate analgesic levels before the cessation of local anesthesia and a well-administrated postoperative analgesic regimen for patient comfort.

Etiology

The mechanism of painful stimuli is modulated by the peripheral and central nervous systems. Noxious stimuli (e.g., tissue damage or bone preparation) cause peripheral nociceptors to transmit signals along nerve fibers lying in the dorsal root ganglion. Their axons synapse in the dorsal horn of the spinal cord and then travel along the spinothalamic tract of the spinal cord to the thalamus and the cortex. Within the cortex and thalamus, signals originating from tissue damage form the subjective interpretation of pain.

With repeated noxious stimuli, peripheral nociceptors become more responsive. The sensitivity to these receptors is further enhanced by tissue factors and inflammatory mediators released in the course of tissue damage. Numerous inflammatory mediators are present, including prostaglandins, kinins, leukotrienes, substance P, and histamine. These mediators initiate and magnify the nociceptive impulses that are transmitted to the central nervous system for the perception of pain.

The most important mediators, prostaglandins, are extremely important in sensitizing peripheral neurons to the local stimuli. Prostaglandins are also

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synthesized in the spinal cord and brain and enhance pain sensitivity by recruiting secondary neurons to respond to the primary stimulus.[12]

One of most commonly used analgesics, NSAIDs, work at the site of tissue damage, preventing prostaglandin formation by inhibiting cyclooxygenase (COX). COX is an enzyme that breaks down arachidonic acid for prostaglandin synthesis. In the tissue there are two well-identified cyclooxygenases, COX-1 and COX-2. COX-1 enzymes support hemostasis (platelet degranulation and adhesion), stomach mucosal integrity, and regulation of kidney function. COX-2 enzymes are an inducible form whose synthesis is activated in damaged tissue, which leads to the formation of proinflammatory prostaglandins that play a major role in inflammation, pain, and fever. A relatively new COX has been described (COX-3) that is found in the brain and is thought to be the site of action of acetaminophen.[13]

In contrast to NSAIDs, opioids have a different mechanism of action to reduce pain. Opioids act on the central nervous system by binding to specific receptors (m-opioid), thus preventing transmission of nociceptive pathways while also activating inhibitory pathways that descend to the spinal cord. By binding to these m-opioid receptors, substance P is prevented from being released, thus preventing painful stimuli (Fig. 10.5).[14]

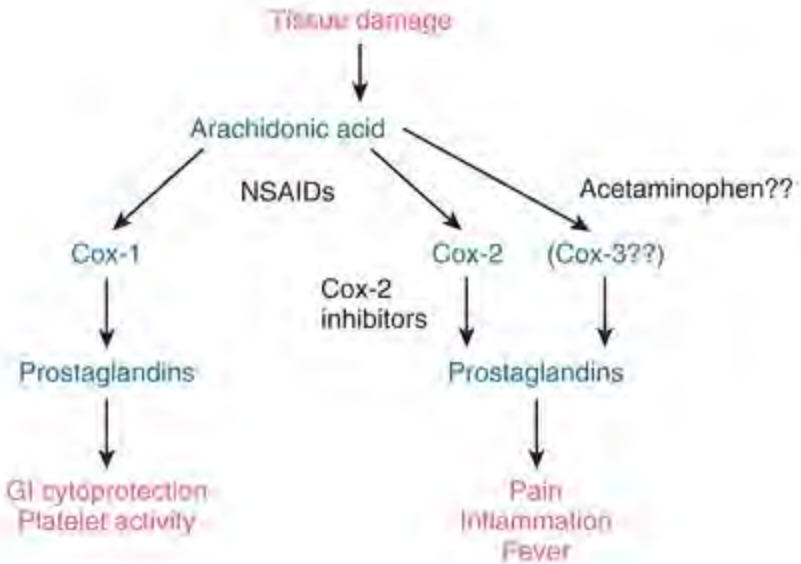

FIG 10.5 Pain cascade depicting the breakdown of arachidonic acid into the various forms of prostaglandins.

Prevention

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The following may be used to prevent postoperative pain:

1. Good surgical technique

2. Surgery duration not to exceed patient's tolerance

3. Postoperative long-acting anesthetics

4. Adequate postoperative pain control and instructions

5. Limitation of patient activities post-operatively.

Treatment

The implant clinician must understand the various aspects of pain control after dental implant surgery. In most cases: (1) pain is not severe and mild OTC analgesics can manage the discomfort, (2) peak pain occurs approximately 12 hours after surgery and diminishes over time, and (3) pain will persist no longer than 2 days. However, this is patient specific.[1]

The most important principle with pain management after implant surgery is the timing of the medication. Ideally, analgesic medications should be taken before the effects of the local anesthetic subside. With this approach postoperative pain is easier to control, and the patient is less likely to experience the acute, severe pain. If the patient takes medication after pain is present, the patient will inevitably have to take more medication to control the pain, increasing the likelihood of analgesic side effects.

In implant dentistry, different classifications and mechanisms of pain suppression may be used. A pain control protocol has been established that simplifies and standardizes the various aspects of pain relief (Table 10.3):

1. Nonopioid analgesics (nonnarcotics)

2. Opioid analgesics (narcotics)

3. Adjuvants

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TABLE 10.3

Analgesic Agents Used to Control Postoperative Surgical Pain

Analgesic	Brand Name	Onset (hr)	Peak (hr)	Duration (hr)	Recommended Dose	Dosing Interval (h)	Maximum Dose/Day
Nonopioid							
Acetaminophen	Tylenol	0.5	0.5–2	4–6	650–1000 mg	4–6	4000 mg
Ibuprofen	Motrin Advil	0.5	1–2	4–6	400 mg	4–6	2400 mg
Naproxen	Anaprox	1	2–4	5–7	275–550 mg	6–8	1375 mg
Tramadol	Ultram	0.5	1–2	4–6	50–100 mg	4–6	400 mg
Opioid							
Codeine	Tylenol with codeine	0.1–0.3	0.5–1	4–6	60 mg	3–4	
Hydrocodone	Dicodid	0.25–0.5	0.5	4–8	5–10 mg	4–6	
Oxycodone	Percocet	0.25–0.5	1	4–6	5–10 mg	4–6	
Meperidine	Demerol	0.1–0.45	0.5–1	2–4	50–100 mg	6	
Propoxyphene	Darvon	0.5–1	2–2.5	4–6	65–130 mg	4–6	

From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.

Nonopioid Medications.

The nonopioid analgesics used in implant dentistry include acetaminophen, NSAIDs, COX-2 inhibitors, and tramadol.

Acetaminophen.

The mode of action of acetaminophen is not known; however, it is believed to involve the prostaglandin pathways within the central nervous system with little influence on peripheral prostaglandin synthesis. COX-3 enzymes have been described as being fully expressed in the brain, spinal cord, and heart. The primary function is to regulate pain responses and fever, and COX-3 has been postulated to be the site of action of acetaminophen.[15]

Acetaminophen is indicated for mild to moderate pain and as a safe alternative to NSAIDs. It has excellent analgesic and antipyretic properties and is void of side effects that are associated with NSAIDs. Like NSAIDs, acetaminophen also has a ceiling dose (4 g/day) for analgesic effects. However, unlike NSAIDs, acetaminophen has the drawback of having minimal antiinflammatory qualities. The main side effect of acetaminophen is liver damage, which is associated with excessive and long-term use of this drug.

Nonsteroidal antiinflammatory drugs.

The NSAIDs are one of the most commonly used analgesic families in implant dentistry today. Clinical trials have shown that NSAIDs are effective in all levels of pain (mild, moderate, severe).[16] The mechanism of action of

NSAIDs is thought to arise from the inhibition of the synthesis of prostaglandins from arachidonic acid. With the inhibition of COX, conversion of arachidonic acid to the immediate precursors of prostaglandins is prevented. Thus, with the lack of prostaglandins in the tissue, the hyperanalgesia and edema associated with acute inflammation is minimized.[17]

The main reasons that NSAIDs are so widely used is the fact that they work very well as analgesics and have variable effects on inflammation (drug and dose dependent). Inflammation and pain are two separate entities, with analgesic doses having a ceiling effect[18] and antiinflammatory doses not having a ceiling effect. In regards to the analgesic effect, there is no reason to exceed the analgesic ceiling for the treatment of acute pain because higher doses give no additional pain relief while increasing the likelihood of side effects.

The side effects of NSAIDs are numerous, including gastrointestinal (GI) disturbances (dyspepsia, erosions, ulcerations) and liver, renal, and cardiac effects.[19] This group of medications is responsible for the largest number of serious drug-related complications, surpassing all other drugs by a wide margin.[20] In 2005 GI-related deaths from NSAIDs were the 14th leading cause of death in the United States, ranked after homicides (13th) and before atherosclerosis (15th).[21]

NSAIDs have very little effect on platelet aggregation because bleeding times are not prolonged. With prolonged use of NSAIDs, interference with most classes of antihypertensives has been noted. If patients take NSAIDs for more than 5 days postoperatively, blood pressure should be monitored.

Ibuprofen.

Ibuprofen was first introduced in 1969 as a new NSAID and has since been the most popular prescribed NSAID. Ibuprofen is used to treat mild to moderate pain and has been proven to significantly reduce postoperative dental pain in clinical studies. The analgesic ceiling dose is 400 mg/dose and 1200 mg/day.[22] At these doses it has been shown to be as safe as acetaminophen, while achieving better analgesia with less nausea and cramping.

Aspirin.

Acetylsalicylic acid (ASA) was the first prototypical NSAID. It has analgesic, antiinflammatory, and antipyretic properties. However, at analgesic doses its

relative risk for GI complications is high. Acetylsalicylic acid is not a drug of choice in the management of dental implant surgical patients because of its very significant antiplatelet effects.

Tramadol.

Tramadol represents a unique classification of analgesic because it is a centrally acting analgesic with two complementary characteristics: opioid and antidepressant. It works by inhibition of norepinephrine and serotonin reuptake within pain pathways of the central nervous system and also by its relatively weak affinity for the m-opioid receptor. Tramadol is a nonscheduled drug and is associated with fewer opioid-like side effects, such as dependence, sedation, respiratory depression, and constipation. Tramadol's analgesic efficacy is similar to that of codeine (60 mg) and is indicated for moderate to moderately severe pain management. This drug is an appropriate analgesic alternative for the treatment of postoperative pain in patients who have NSAID-related GI and opioid intolerance. Tramadol has been shown to be effective in the reduction of pain when used in combination with acetaminophen. Ultracet (tramadol/acetaminophen) has demonstrated excellent efficacy in pain studies and is supplied as a combination analgesic containing 37.5 mg tramadol and 325 mg acetaminophen.[23]

Narcotics (Opioids).

Narcotics (opioids) are the primary medications for analgesia of moderate to severe pain from dental origin. They are centrally acting analgesics that act as agonists at μ- and κ-opioid receptors. Morphine, which is a naturally occurring opioid, is generally accepted as the prototypical narcotic. All other narcotics on the market today are compared in potency to morphine.

Unlike nonopioids, opioids do not have a ceiling effect for analgesia. As the dose increases, the analgesic effect increases. However, in addition to relieving pain by m-receptor binding, euphoria, nausea, vomiting, and constipation may occur. With high doses, sedation and respiratory depression are possible. With chronic use, physical and psychologic dependence are common.

The following section discusses the most commonly used narcotics in oral implantology. Structurally, these narcotics are similar to morphine and provide the same degree of pain relief and unlimited efficacy at equipotent doses.

Codeine.

Codeine is a naturally occurring alkaloid that is classified as a mild analgesic. Codeine has excellent antitussive properties; however, it is associated with high degrees of nausea and constipation. Orally administered codeine is only 60% bioavailable, which results in only 10% being demethylated to morphine. This 10% is the only part responsible for analgesic properties, thus 90% or the drug has no analgesic efficacy. Because of the side effects and low potency compared with other opioids, codeine is usually not the first choice of narcotics used in oral implantology.

Hydrocodone.

Hydrocodone bitartrate is a semisynthetic narcotic analgesic and antitussive with multiple actions qualitatively similar to codeine. It is usually used as a combination analgesic, being combined with either acetaminophen or ibuprofen. For several years, this narcotic has been the most frequently dispensed prescription medication in the United States. Hydrocodone is habit forming, and the most frequent adverse reactions are dizziness, sedation, nausea, and vomiting.

Oxycodone.

Oxycodone is a semisynthetic opioid with analgesic action similar to morphine. It is recommended for moderate to severe pain with its principal actions being analgesia and sedation. It has excellent oral bioavailability because it retains half of its analgesic activity when administered orally. Oxycodone has the same adverse effects as most other opioids, with an increased potential for abuse and drug dependence. Oxycodone is marketed as a combination narcotic, combined with either acetaminophen (Percocet) or aspirin (Percodan). A slow-release oxycodone (OxyContin) has been shown to have a high abuse potential.

Combination Analgesic Therapy for Postoperative Pain.

A pain management strategy using multiple analgesics with different mechanisms of action is termed *combination analgesic therapy*. The goal of combining different types of analgesics is to increase the analgesic effect while decreasing possible side effects. When multiple drugs are used in combination, synergistic and additive effects allow for the use of lower doses of each individual drug (Table 10.4).

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TABLE 10.4
Combination Analgesics

Generic Name	Brand Name	Average Adult Dose	Schedule
5 mg codeine/300 mg acetaminophen	Tylenol #1	1–2 tablets every 4 h	III
15 mg codeine/300 mg acetaminophen	Tylenol #2	1–2 tablets every 4 h	III
30 mg codeine/300 mg acetaminophen	Tylenol #3	1–2 tablets every 4 h	III
60 mg codeine/300 mg acetaminophen	Tylenol #4	1 tablet every 4 h	III
5 mg hydrocodone/500 mg acetaminophen	Vicodin/Lortab 5/500	1–2 tablets every 4–6 h (maximum 8 tablets/24 h)	III
7.5 mg hydrocodone/750 mg acetaminophen	Vicodin ES	1 tablet every 4–6 h	III
7.5 mg hydrocodone/650 mg acetaminophen	Lorcet	1 tablet every 4–6 h	III
10 mg hydrocodone/660 mg acetaminophen	Vicodin	1 tablet every 4–6 h	III
10 mg hydrocodone/650 mg acetaminophen	Lorcet 10/650	1 tablet every 4–6 h	III
7.5 mg hydrocodone/200 mg ibuprofen	Vicoprofen	1–2 tablets every 6 h	III
5 mg oxycodone/325 mg acetaminophen	Percocet 5/325	1 tablet every 4–6 h	II
7.5 mg oxycodone/500 mg acetaminophen	Percocet 7.5/500	1 tablet every 4–6 h/maximum 8/day	II
10 mg oxycodone/650 mg acetaminophen	Percocet 10/650	1 tablet every 4–6 h	II
5 mg oxycodone/400 mg ibuprofen	Combunox	1 tablet every 6 h/maximum 4/day	II

From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.

With combination therapy, acetaminophen or NSAIDs are used with an opioid. Because of the ceiling effects of acetaminophen and NSAIDs, further increases in dosage will not provide any additional analgesia; however, they will increase side effects.

Analgesic Agents in Oral Implantology.

The selection of an analgesic or analgesic regimen for management of postsurgical pain is ideally based on the expected pain intensity. This may be based on the patient's medical history, past pain threshold, type of procedure, extent of tissue reflection, and duration of procedure. Because of the various agents and numerous options for the treatment of postsurgical pain after dental implant surgery, a pain control protocol was formulated to aid in the proper administration of these agents. According to the World Health Organization guidelines, the procedure and patient must be evaluated and classified as mild, moderate, or severe (Table 10.5).

TABLE 10.5

Recommended Pain Control Protocol (PCP)

Drug	Dose
PCP 1: Mild Pain Expected	
Ibuprofen	400 mg 1 h before
PCP 2: Mild to Moderate Pain Expected	
Ibuprofen + hydrocodone (Vicodin)	400 mg 1 h before surgery + continue 4 times daily for 2 days 5 mg/300 mg as needed
PCP 3: Moderate Pain Expected	
Ibuprofen + hydrocodone (Vicodin ES)	400 mg 1 h before surgery + continue 4 times daily for 2 days, then as needed 7.5 mg/300 mg 4 times daily for 2 days, then as needed
PCP 4: Severe Pain Expected	
Ibuprofen + hydrocodone (Vicodin HP)	400 mg 1 h before surgery + continue 4 times daily for 4 days, then as needed 10 mg/300 mg 4 times daily for 2 days, then as needed

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Mild pain.

Mild pain is self-limiting and usually will be resolved with normal recommended doses of NSAIDs.

Moderate pain.

Moderate pain is more intense pain than mild and usually will not be resolved totally by NSAIDs. It will interfere with function and disrupt the activities of daily living.

Severe pain.

Severe pain is defined as pain that interferes with some or all of the activities of daily living. The patient may be confined to bed, and strong opioid treatment will need to be continued for days. Adjuvant drug therapies may be needed for supplementation (Table 10.5).

Control of Postoperative Surgical Pain.

The goal of postsurgical pain management is to optimize patient comfort through pharmacologic and behavioral strategies. The World Health Organization formulated an analgesic "ladder" for the treatment of pain management. The following protocol describes three steps in the treatment of acute pain.[24]

1. The first step is to maximize the use of NSAIDs (acetaminophen, ibuprofen) for mild to moderate pain. Adjuvant medications such as glucocorticoids and cryotherapy are often suggested.

2. When moderate pain is expected or persists, an opioid (hydrocodone, codeine) should be added to the NSAID. The fixed dose of opioids with the NSAIDs provides additive analgesia. Glucocorticoids and cryotherapy are encouraged.

3. Moderate to severe pain that is expected or persists should be treated by increasing the dosage of the opioid. Glucocorticoids and cryotherapy are of particular benefit when not contraindicated.

With the guidelines from the World Health Organization, a pain control protocol was formulated for treatment of procedures based on the expected postoperative pain (Box 10.1).

Box 10.1

World Health Organization Pain Relief Ladder

Three-Step Conceptual Model

1. Nonopioid + adjuvant

2. Nonopioid + adjuvant + opioid (moderate)

3. Nonopioid + adjuvant + opioid (severe)

Adjuvants: long-acting anesthetics, glucocorticoids, tricyclic antidepressants. © Copyright World Health Organization (WHO), 2016. All Rights Reserved.

Treating Each Patient/Procedure the Same Pharmacologically

Complication

Many clinicians treat all dental implant patients with the same prophylactic protocol, irrespective of the patient's ASA classification and type of procedure. For example, a sinus bone graft has much higher morbidity than a single tooth implant, therefore, a different pharmacologic protocol is indicated. The complications and morbidity of the surgical procedure are proportional and directly related to the medical status of the patient, surgical

procedure, length of surgery, and the extent of tissue reflection. The authors have developed a pharmacologic approach that recommends different protocols based the factors mentioned (see Table 10.2).

Prevention

Clinicians should have a clear understanding of all prophylactic medications (antibiotics, antiinflammatories, analgesics) that are indicated to minimize postoperative complications and decrease morbidity. Additionally, the implant clinician must be aware of all drug interactions and contraindications to the use of these agents.

Treatment

Because of the many variables (e.g., local, systemic, surgical) that need to be considered with the use of pharmacologic agents in implant dentistry, a protocol has been developed to standardize the prophylactic use of these agents. A four-category pharmacologic classification is proposed based on the patient's ASA status, type of surgical procedure, and invasiveness of the surgery (see Table 10.2).

Not Giving Adequate Postoperative Instructions

Patients should always receive postoperative instructions both verbally and in writing. Failure to do so may increase the possibility of postoperative complications and loss of confidence in the doctor and place the doctor at risk for medicolegal issues.

Etiology

Unfortunately, many doctors do not have a consistent protocol for the administration of pre- and postoperative instructions. This leads to patient misunderstanding about expectations after surgery, after-hours phone calls, and increased stress for the patient. Additionally, many clinicians have one generic or generalized instruction protocol. Ideally, there should exist an instruction protocol that is specific for the type and invasiveness of the procedure.

Prevention

Detailed postoperative instructions should be given orally and in writing to

the patient before and after surgery. The instructions should also be available for the patient on the office website if possible.

Treatment

Comprehensive review of all postoperative instructions is an important part of treatment. Some of the more common topics for which instructions should be presented to patients include the following:

Bruising.

The possibility of bruising or ecchymosis should always be explained to the patient, even for shorter-duration and less invasive surgeries. It is crucial the patient understand the possibility of bruising because this may lead to embarrassment and esthetic issues for the patient. The patient should be made aware that bruising can appear 3–4 days postoperatively and may take up to 10–14 days for complete resolution. Additionally, patients should be informed about the possibility of bruising extending into the submandibular and neck area (because of fascial planes and gravity) because this will minimize the possibility of patients questioning either an aggressive or poor surgical technique by the doctor.

Bleeding.

The incidence of bleeding postoperatively is extremely high after dental implant surgery. Patients should be cautioned on the potential for bleeding during the first 24 hours and instructed on techniques to decrease the bleeding. Patients should always be given gauze (3 × 3 or 4 × 4 gauze is recommended because 2 × 2 pads may result in inadvertent aspiration by the patient) for use as pressure dressings. Recommendations should be given to minimize wearing an interim prosthesis because this may result in increased bleeding. For significant or prolonged bleeding, the patient should be instructed to contact the doctor (see Chapter 7). The patient should also be instructed not to use a straw when drinking fluids because this may create a negative pressure and increase bleeding. Also, spitting and vigorous rinsing may open the surgical wound and cause bleeding.

Swelling.

The patient should be informed that swelling is most likely to occur after implant surgery and will peak at 48–72 hours. Often, patients will exhibit

minimal swelling the day of surgery; however, it will most likely increase 2–3 days postoperatively. This will prevent the patient from misinterpreting the swelling as a postoperative infection. The patient should be instructed to use multiple pillows because sleeping with the head elevated decreases head and neck swelling.

Hygiene.

Patients may gently brush their teeth during the first day; however, they should avoid the surgical site. Gentle rinsing with chlorhexidine may be initiated the day after surgery. Potent antiseptics (e.g., Listerine) should be avoided until incision line closure.

Diet.

The patient should be counseled that following dental implant surgery, the body requires adequate fluids and nourishment. Ideally, at least 2 liters of fluids (milk, water, nonacidic juice) should be consumed within the first 24 hours. The patient should gradually progress to more solid foods. A high-calorie diet with increased volume of liquid and soft foods for the first 24 hours is recommended. Soft foods are usually tolerated well. These include milkshakes (use a spoon: NO straw), ice cream, applesauce, pudding, jello, yogurt, mashed potatoes, scrambled eggs, pasta (no tomato sauce). Hot liquids (coffee, tea, soup, etc.) should be avoided until local anesthesia has worn off (~4–8 hours).

If the patient was administered intravenous sedation, the patient should be instructed to have some food intake after surgery because they have been NPO for a minimum of 6 hours prior to surgery. This should be in the form of a soft food such as yogurt, jello, soup, or ice cream.

No Smoking or Alcohol Use.

Patients should have a thorough understanding of the effects of smoking and alcohol use postoperatively on incision line opening and implant/bone grafting morbidity. Smoking cessation should be initiated a minimum of 2 weeks prior to surgery and 6 weeks (ideally) postsurgery. The use of alcohol prior to complete incision line healing should be discussed because this may lead to an increased possibility of incision line opening and possible infection.

Nerve Impairment.

Patients should have an understanding of the possible consequences of nerve damage, which may include paresthesia, dysesthesia, and anesthesia. If this occurs and is present after 24 hours, the patient should be instructed to inform the doctor to be seen immediately for evaluation and treatment (see Chapter 9).

Infection.

Although postoperative infections are rare, the patient should be informed of the signs of infection, which may include sudden increase of swelling, pain, elevated temperature, and lethargy. If any of these should occur, the patient should inform the office of their symptoms.

Interim Prosthesis.

If the patient has an interim prosthesis, they should be instructed on its use after surgery. Ideally, the prosthesis should not be worn until incision line closure and inflammation is not present. If the patient is to wear the prosthesis for social esthetic concerns, the doctor should adjust the prosthesis to preserve the primary stress-bearing areas so the surgical area has no pressure areas.

Postoperative Follow-Up.

Patients should have an understanding of the importance of postoperative follow care. Usually, the patient is seen within 2 weeks of the surgery for evaluation and suture removal.

Discontinuation of Current Medications.

Patients should fully understand that they should never discontinue or modify any medication prescribed by their physician. This may result in a serious complication if the patient fails to take medication such as antihypertensives, hypoglycemics, or anticoagulants.

Nausea After Surgery

Nausea is not uncommon after dental implant surgery. Postoperative nausea is usually brief and resolves within several hours. It may be very distressing to the patient, though, especially if they have been NPO (nothing by mouth)

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prior to the procedure.

Etiology

The etiology of nausea after surgery may be a direct result from prophylactic medications or the swallowing of excessive amounts of blood, especially after longer procedures. The most common prophylactic medications to cause nausea are antibiotics. When patients are NPO for IV sedation, many antibiotics have a high incidence of causing nausea (e.g., Augmentin, clindamycin).

Prevention

Narcotic pain medications are the most frequent cause of nausea and should be avoided until the nausea subsides. Nausea can be reduced by preceding each pain pill with a small amount of soft food, and taking the medication with a large volume of water. The prophylactic steroid recommended for most implant surgeries, Decadron, has been shown to be an excellent medication for prevention of postoperative nausea and vomiting (PONV). Additionally, minimizing the swallowing of excessive amounts of blood will reduce the possibility that the blood will irritate the stomach mucosa. The meticulous removal of blood from the surgery site via suctioning and the use of gauze throat packs will minimize the swallowing of blood. Yankauer suctions are especially efficient with removing blood from the oropharynx area (Fig. 10.6).

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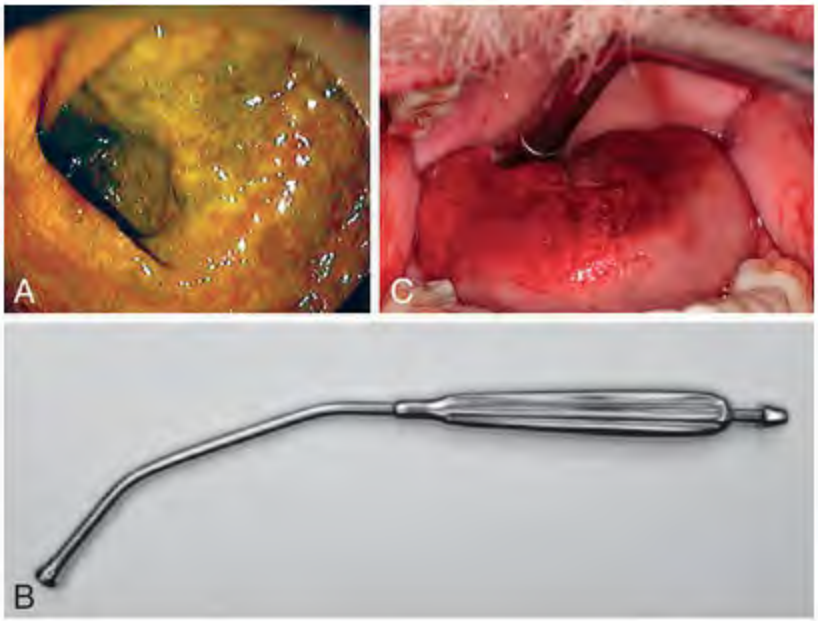

FIG 10.6 (A) Clostridium difficile (C. diff), normal bacteria present in the gut, may cause infection resulting from antibiotic use. (B) Yankauer suction allows for efficient and easy removal of blood from the surgical site and oropharynx. (C) Clinical image depicting the use of the Yankauer suction. (A, Courtesy Dr. Clarence Wong. In Walsh TC, Caraceni AT, Fainsinger R, et al, editors: Palliative medicine, Philadelphia, 2009, Saunders.)

Treatment

If nausea is extensive after surgery, OTC antiemetics may be used or prescription medications (e.g., ondansetron [Zofran] 4-mg sublingual tablets) may be prescribed.

Antibiotic-Associated Diarrhea

Antibiotic-associated diarrhea (AAD) is usually a benign, self-limiting disorder. The frequency of this complication varies among antibiotics. In most cases, no pathogens are identified and the diarrhea is caused by alterations in the composition and function of the intestinal flora. AAD has been defined as a minimum of three watery stools per day. This diarrhea may occur from a few hours to up to 2 months after antibiotic intake. Studies have shown the incidence of AAD after antibiotics is between 5% to 25%.[25]

Etiology

AAD results from an imbalance in the colonic bacteria. The alteration in the microbiota will change carbohydrate metabolism and fatty acid absorption resulting is osmotic diarrhea. Almost all groups of antibiotics may cause

AAD, but those with broad-spectrum coverage—in particular, cephalosporins, fluoroquinolones, extended-coverage penicillins, and clindamycin—are known to have the highest frequency.[26]

Prevention

Taking antibiotics with food helps to minimize AAD. Also, many studies have shown that the use of probiotics decreases the incidence of AAD.[27] These techniques are extremely helpful if the dental implant patient presents with a past history of AAD.

Treatment

Patients with mild diarrhea not caused by *C. difficile* usually will not require any treatment other than antibiotic cessation. Lost fluids and electrolytes should be substituted and poorly absorbable carbohydrates avoided. If a substitute antibiotic is required, consultation with the patient's physician is recommended. If the patient exhibits any signs of dehydration they should be referred to their physician or emergency room.

Pseudomembranous Colitis

In some cases of AAD, colitis (inflammation of the colon) will result. This may lead to a condition called pseudomembranous colitis. Symptoms usually include profuse diarrhea associated with cramps, abdominal pain, nausea, vomiting, and fever. In severe cases, pseudomembranous colitis may be fatal if not treated aggresively.

Etiology

An additional consequence of antibiotic therapy that causes diarrhea is the overgrowth of the pathogen *Clostridium difficile*.[28] More commonly known as C. diff, it may account for up to 10% to 20% of AAD cases. This occurs when inflammatory colitis results in the destruction of a significant amount of the normal gut flora. With the decreased amount of “healthy” bacteria, C. diff will flourish, causing signs of pseudomembranous colitis (see Fig. 10.6).

Prevention

Dental implant patients who present with a past history of AAD or C. diff infection should not be administered any antibiotics until medical

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consultation with the patient's physician. Additionally, patients who are predisposed to C. diff infection include the elderly population. Patients older than 65 have a 10 times greater chance of a C. diff infection than younger age groups. Patients with a past history of a C. diff infection are at a 20% greater risk of contracting C. diff after antibiotic administration.[29]

Treatment

Discontinuation of the antibiotic regimen is highly recommended along with referral to the patient's physician for treatment. Severe cases of *C. difficile*–positive diarrhea require oral antibiotic treatment of Vancomycin (125 mg four times daily), metronidazole (250 mg three times daily), or bacitracin (25,000 units four times daily).[30] These medications should always be prescribed by the patient’s physician.

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Implant-Related Complications

Injury to Adjacent Teeth

Damaging adjacent natural teeth during dental implant placement may lead to adverse effects on adjacent tooth structures and can result in dental implant failure. The injury to the root structure of adjacent teeth may be direct (damage to tooth by the drill or implant) or indirect (thermal damage from the osteotomy process). Damage may result in bone loss, natural tooth or implant loss, infection, internal or external resorption, loss of tooth vitality, or prosthetic failure.

Etiology

Trauma to adjacent teeth may occur upon the placement of dental implants because of improper angulation, implant sites with insufficient available space or bone quantity, or by placement of implants with an incorrect diameter. Dilacerated roots and excessive tilting in the mesiodistal direction may impinge on the implant space and prevent ideal placement. Additionally, available space discrepancies often exist between the coronal space and the apical space. Studies of orthodontic mini-implants placed in contact with teeth (<1.0 mm) have been shown to cause root resorption. However, if the implant is removed in a timely fashion, cementum repair will result.[31]

Prevention

The location of adjacent teeth to the implant site should be evaluated prior to implant placement. The angulation should always be evaluated after the initial osteotomy with a direction indicator (i.e., radiograph with known diameter and length guide pin in osteotomy) to assess proper positioning. Cone beam computed tomography (CBCT) surgical templates may be used to avoid damaging adjacent root surfaces. Ideally, a minimum of 1.5 mm of space between the implant and root surface is recommended (Figs. 10.7 and 10.8).

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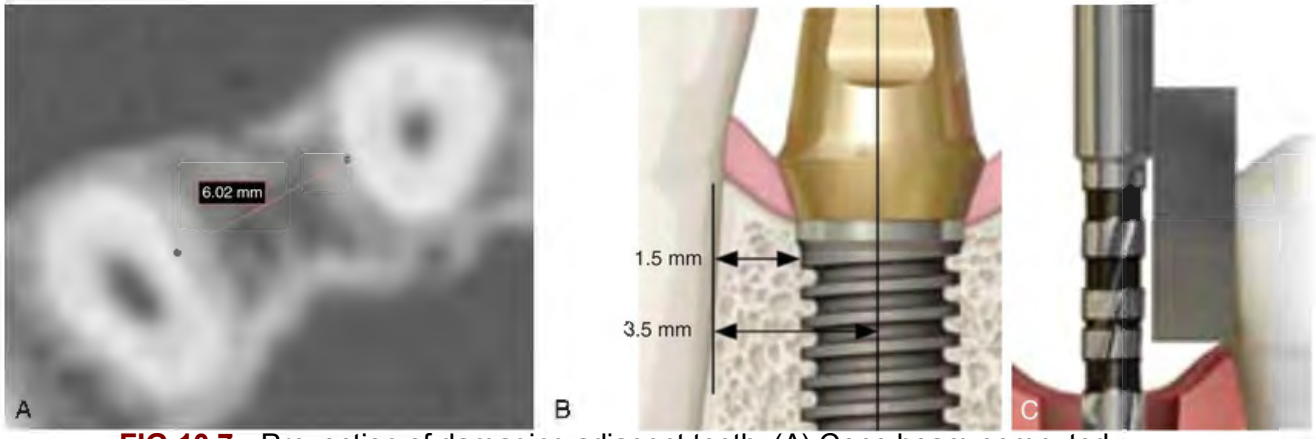

FIG 10.7 Prevention of damaging adjacent teeth. (A) Cone beam computed tomography (CBCT) used to identify the actual space available between adjacent tooth roots. (B) Ideally, a minimum of 1.5 mm space should exist between the implant and tooth structure. (C) Positioning device to prevent improper placement and ideal osteotomy location.

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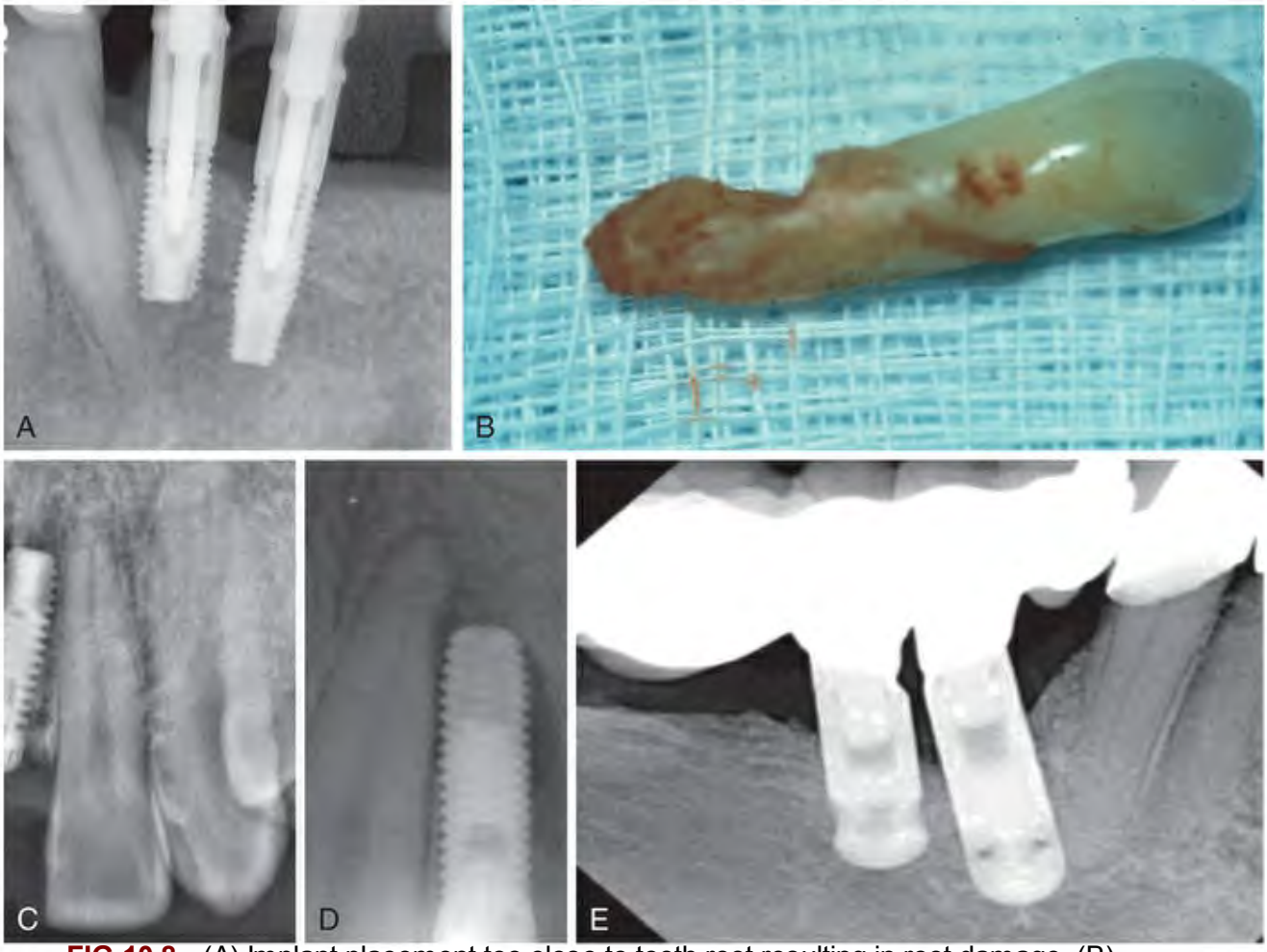

FIG 10.8 (A) Implant placement too close to tooth root resulting in root damage. (B) Resultant loss of tooth. (C–D) Tooth and implant pathology from implant placement too close to tooth. (E) A strict postoperative recall should be adhered to when implant is in close approximation to root. Dilacerated root decreasing intraroot distance for dental implant.

Treatment

Perioperative.

If the implant is encroaching on the periodontal ligament (PDL) or tooth structure, ideally it should be removed and repositioned.

Postoperative/Posthealing.

If the implant has been previously placed and is not encroaching on the PDL/tooth (asymptomatic) structure, strict monitoring should be done with regular vitality testing. If the tooth is sensitive to thermal stimulation of percussion, the implant should be removed immediately.

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Implant Periapical Lesion

Following implant placement and recall examinations, case reports have shown the genesis of periapical lesions (radiolucency), which may suggest a possible precursor to failure of the endosseus implant.[32] These periapical lesions have been termed *apical peri-implantitis* and *retrograde peri-implantitis*.[33] The lesions have been defined as a symptomatic or asymptomatic periapical radiolucency developing after implant placement with a normal coronal bone to implant interface.

Etiology

Asymptomatic.

A clinically asymptomatic periapical radiolucency is considered to be inactive when radiographically there exists evidence of bone destruction with no clinical symptoms. This may result from placing an implant into a site in which the osteotomy was prepared deeper than the implant length, resulting in an apical space. Also, when implants are placed adjacent to a tooth with an apical scar, this may result in a radiolucency. Inactive lesions may be caused by thermal bone necrosis, which is a direct result of overheating the bone. The thermal injury may result in a fibrous tissue interface, which may compromise the prognosis of the implant.[34]

Symptomatic.

A clinically symptomatic lesion is most commonly caused by bacterial contamination during implant placement. This may occur when an implant is placed into a preexisting area with bacteria (existing infection, cyst, granuloma, or abscess). When lesions are initiated at the apex, they may spread coronally or facially. Clinical symptoms with active lesions include intense pain, inflammation, percussion, mobility, or possible fistulas tract formation (Fig. 10.9).[34]

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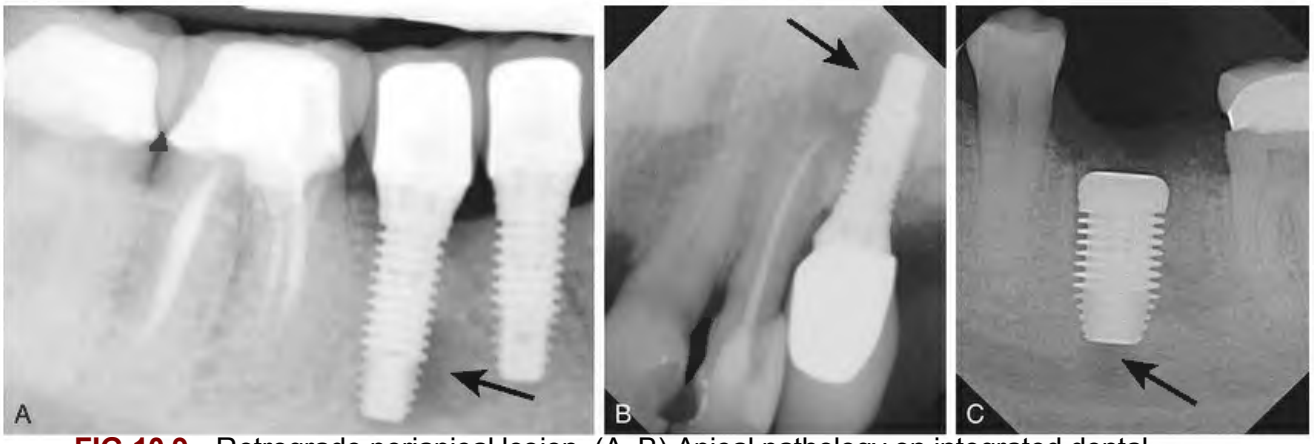

FIG 10.9 Retrograde periapical lesion. (A–B) Apical pathology on integrated dental implants. (C) Apical radiolucency from osteotomy preparation exceeding implant length.

Prevention

Prevention includes the following:

1. Clear evaluation of adjacent tooth structure to rule out preexisting infection or pathology

2. Pulp testing of adjacent teeth

3. Caution when placing immediate implants into sites with possible pathology

4. Extensive debridement of pathologic tissue and decortication of immediate extraction sites

Treatment

Because of the multifactorial etiology of periapical lesions around dental implants, there is no accepted general consensus on the treatment. Nonsurgical antibiotic treatment of periapical lesions has been shown to be unsuccessful.[35] The following has been shown to be effective treatments of periapical lesions:

Exposure: Tissue reflection is completed to expose the apical implant area (buccal or lingual access).

Debridement: The granulation tissue is completely removed to expose the

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bony walls of the apical area.

Removal of implant apex (elective): The apical portion of the implant may be removed to gain better access to the bony walls. This should be completed only if there is no biomechanical compromise for the implant.

Surface decontamination: The implant surface may be detoxified with various chemicals such as tetracycline (250 mg) grafting,[36] citric acid (40%),[37] chlorhexidine, and hydrogen peroxide.[38,39]

Allograft: The defect area is grafted with allograft material along with a resorbable membrane. A local antibiotic (e.g., Ancef, Cleocin) should be added to the graft for additional antimicrobial coverage.

Systemic antibiotics: Systemic prophylactic antibiotics (e.g., amoxicillin) should be used along with 0.012% chlorhexidine oral rinse.

Titanium Allergy/Hypersensitivity

Hypersensitivity to titanium is an ever-increasing reportable complication in medicine today that has been associated with a wide range of situations.

In orthopedic medicine, there are many case reports of titanium alloy hypersensitivity. Witt and Swann reported 13 cases of failed total hip prostheses and concluded the tissue reaction in response to metal-wear debris may have been the etiology of the failed implants. This process has been termed *repassivation* and may produce an oxide that surrounds and turns the periimplant tissues black.[40]

Yamauchi et al reported a titanium-implanted pacemaker developing an allergic reaction. The patient developed a distinct erythema over the implantation site, which resulted in a generalized eczema. Titanium sensitivity was confirmed by intracutaneous and lymphocyte stimulation testing.[41]

In the dental literature, allergic reactions to pure titanium are rare. However, many authors have suggested there is a higher incidence of titanium alloy allergy with respect to dental implants; and is most likely underreported because of a poor understanding of failure or allergy.[42] Preez et al have reported a case of implant failure due to a suspected titanium hypersensitivity reaction around a dental implant. Histologic results showed a chronic inflammatory reaction with concomitant fibrosis.[43] Egusa et al

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reported a titanium implant overdenture case that resulted in generalized eczema that fully resolved after implant removal.[44] Sicilia et al, in a clinical study of 1500 consecutive implant patients, reported approximately nine implants with a positive reaction to titanium allergy.[45]

Etiology

Sensitivity to titanium has been shown to be a result of presence of macrophages and T lymphocytes with the presence of B lymphocytes, which result in a type IV hypersensitivity reaction.[46] All metals, when in a biologic environment, undergo corrosion, which may lead to the formation of metallic ions and trigger the immune system complex with endogenous proteins.[47] Titanium alloy dental implants have been shown to contain many "impurities" that may trigger type IV hypersensitivity reactions. Harloff used spectral analysis to investigate various Ti alloy implants. The results showed that all the Ti alloy samples contained small amounts of other elements such as beryllium (Be), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), and palladium. These impurity elements have been shown to be the etiology of the hypersensitivity reactions.[48]

Prevention

Thorough medical history involving any past history of titanium hypersensitivity.

Treatment

When titanium hypersensitivity is suspected, the implants should be removed and the patient should be referred to their physician for appropriate testing. Case reports have shown that, after complete removal of the implants, complete resolution results.[44] Metal sensitivity is usually diagnosed using a "patch-test," which involves placement of titanium (allergen) to the skin for approximately 3–4 days. A positive test would include the appearance of an erythematous reaction. However, there is a possibility of false negatives because the sealing qualities of the skin against direct contact may make the test unreliable (Fig. 10.10).

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FIG 10.10 Titanium dental implant allergy. (A) Facial eczema after implant placement. (B) Intraoral view of type IV hypersensitivity reaction. (C) Complete resolution after implant removal. (From Egusa H, Ko N, Shimazu T, et al: Suspected association of an allergic reaction with titanium dental implants: a clinical report. *J Prosthet Dent* 100(5):344–347, 2008.)

Fractured Mandible After Implant Placement

Mandibular jaw fractures after implant placement, although rare, may lead to devastating complications for the patient. The fracture may be early (at the time of surgery) or late (during the postoperative period). Most likely, patients will appear postoperatively with severe pain, inflammation, and limited opening. The incidence of mandibular fractures after implant placement is approximately 0.2%.[49] The most common location for fractures to occur after implant placement (late fracture) is near the location of the most distal implant.[50]

Etiology

Fractured mandibles most likely occur from attempting to place implants in patients with severely resorbed ridges, especially when monocortical grafts and ridge-splitting surgeries are completed. Patients who are predisposed to fractures include those with highly excessive occlusal forces, or with division C–w and D mandibles. Studies have shown a higher incidence of fractures in patients who present with osteomalacia or osteoporosis. This is due to the brittle bone being subject to loading forces with insufficient support. Additional causes of mandibular fractures include placing implants that are too wide or too long, which compromises the host bone and requires excessive tightening of implants.[50] Late (after surgery) mandibular fractures most likely are caused by an increased stress at the implant site. The implant generates a concentration of tensile stress that weakens the bone. Repeated functional forces placed on the implant eventually lead to the fracture of the

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bone.[51]

Prevention

The prevention of mandibular fractures includes proper treatment planning and diagnosis, which involves the contraindication of implants placed in division D mandibles. Division D patients should be referred for possible iliac crest grafting. When drilling osteotomy sites in severely resorbed mandibles, care should be exercised to not overheat the bone. This is most easily completed by using intermediate drills, removing less bone with each drill size. Additional techniques include bone plates and simultaneous implant placement.

Treatment

The treatment of a fractured mandible after implant placement is referral to an oral and maxillofacial surgeon for definitive care and possible removal of the offending implants, along with reduction and stabilization of the mandible. Treatment of mandibular fractures is usually based on the type and location of the fracture as well as the extent of atrophy. Treatment options include lag screws, wires, and plates (Fig. 10.11).

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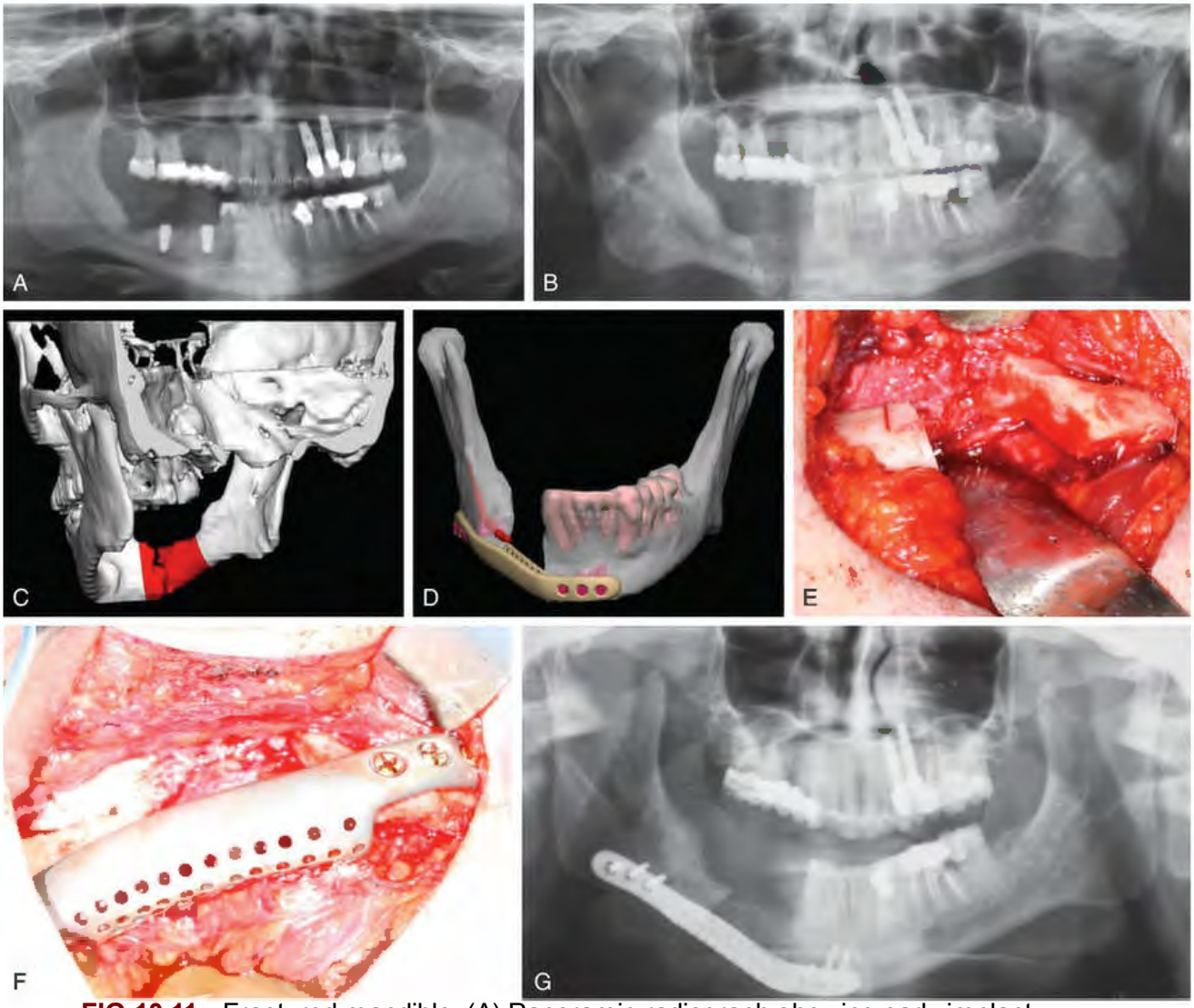

FIG 10.11 Fractured mandible. (A) Panoramic radiograph showing early implant failure. (B) Panoramic radiograph depicting pathologic graft and osteomyelitis. (C) Cone beam computed tomography (CBCT) 3-D image depicting fracture. (D) CBCT 3-D showing bone plate. (E) Resection of fracture and necrotic bone. (F) Bone graft basket encompassing bone graft. (G) Final panoramic image depicting final bone graft. (Courtesy David J. Dattilo, DDS, Chief OMFS Allegheny General Hospital, Pittsburgh, PA.)

Benign Paroxysmal Positional Vertigo

Benign paroxysmal positional vertigo (BPPV) is a disorder arising in the inner ear that presents with symptoms of repeated episodes of positional vertigo. Vertigo is most often characterized by the feeling of a spinning or swaying movement when the patient is stationary. Often BPPV is associated with nausea, vomiting, sweating, and difficulties in walking. BPPV is an unexpected complication that has been reported after dental implant and bone grafting surgery.

Etiology

The etiology of BPPV has been related to the use of specific surgical techniques, prolonged patient positioning (supine), and hyperextension of the neck. BPPV occurs by dislodgement calcium carbonate crystals that are normally embedded in the utricle. The crystals migrate into the semicircular canal. The crystals are not only sensitive to dislodgement but also to prolonged static head positioning. They strike against sensitive nerve endings (cupula) within the balance apparatus in the semicircular canal (ampulla), which results in position- or motion-induced vertigo and disequilibrium.[52]

Prevention

Do not allow patients to maintain hyperextension of the neck for an extended amount of time. During maxillary posterior surgery, be conscious of the possibility of dislodgement of the crystals with the use of osteotomes and a mallet.

Treatment

The only successful treatment for BPPV is referral to an otolaryngologist (ENT) physician or health care provider with knowledge of the Epley procedure (canalith repositioning). This treatment consists of several slow head position maneuvers (Box 10.2 and Fig. 10.12). The goal is to move the dislodged particles from the semicircular canals of the inner ear to the vestibule.

Box 10.2

The Epley Maneuver Procedure (See Fig. 10.12)

1. The patient is positioned in an upright sitting posture, legs fully extended and the head rotated 45 degrees towards the side.

2. The patient is then quickly and passively forced down backwards by the clinician performing the treatment into a supine position with the head held approximately in a 30-degree neck extension for 1–2 minutes.

3. The patient's head is then rotated 90 degrees to the opposite direction,

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while maintaining a 30-degree neck extension for 1–2 minutes.

4. With the head and neck in a fixed position relative to the body, the patient rolls onto the shoulder, rotating the head another 90 degrees in the direction that they are facing. The patient is now looking downwards at a 45-degree angle for 1–2 minutes.

5. The patient is slowly brought up to an upright sitting posture while maintaining the 45-degree rotation of the head, and the patient holds the position for 30 seconds.

6. The entire procedure may be repeated two more times, for a total of three times.[53]

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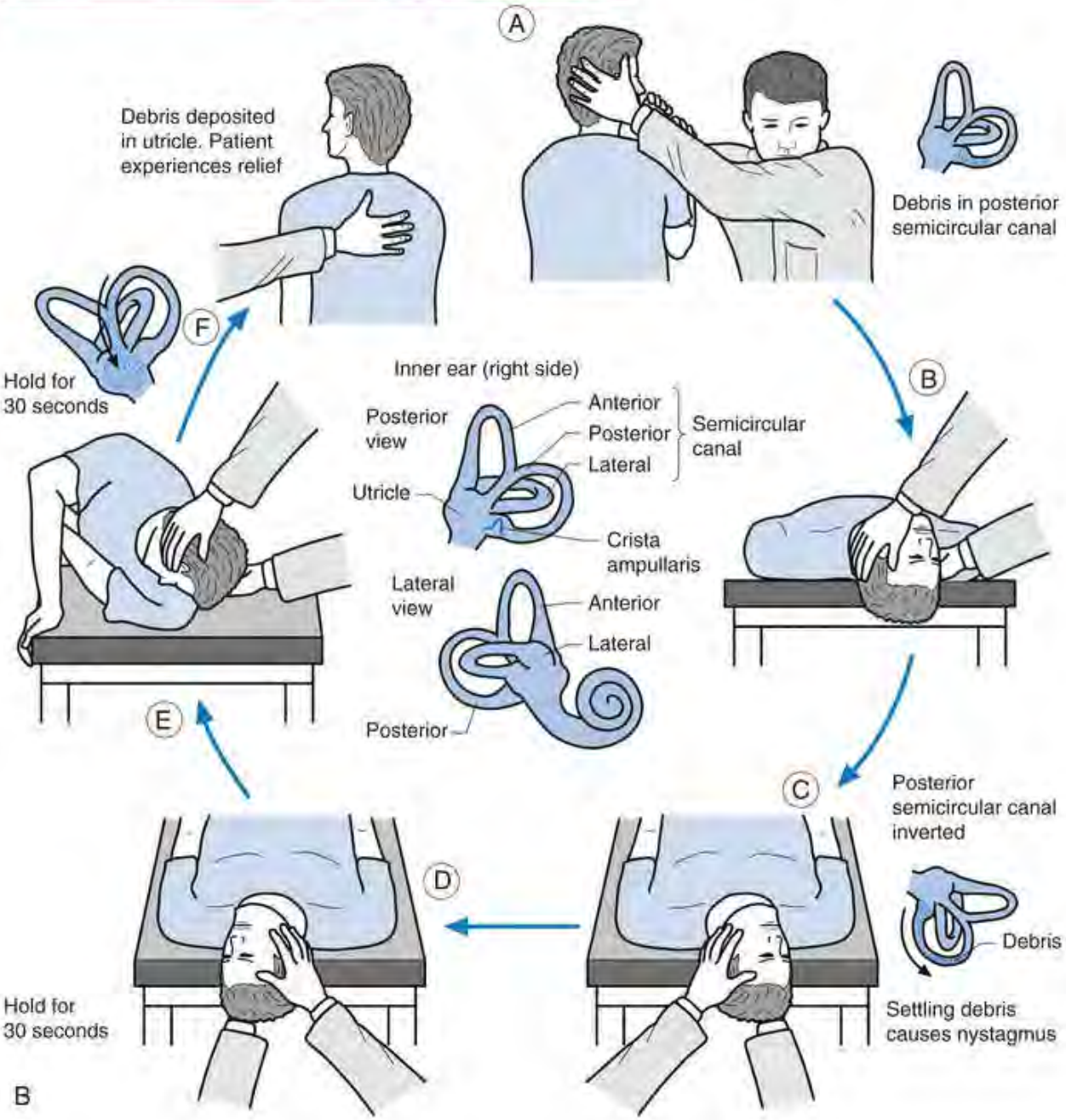

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FIG 10.12 Vertigo after dental implant surgery. (A) Most common cause is the use of osteotomes. (B) Epley maneuver. (B, From Beck RW: *Functional neurology for practitioners of manual medicine*, ed 2, Edinburgh, 2011, Churchill Livingstone.)

Cover Screw Not Fully Seated

With two-stage dental implant surgery, localized superficial infections including a fistulas tract may occur postoperatively. After implant placement, if the cover screw is not adequately tightened, postoperative infections may result, leading to possible implant morbidity.

Etiology

Because of the micro gap between the implant and cover screw, trapped bacteria will colonize, which results in a possible irritation and infection. This may occur from improper placement of the cover screw or excessive force over the submerged implant.

Prevention

Tighten the cover screw at the time of placement so no micro gap exists. Care should be noted to remove any tissue or bone that may impinge on the proper seating of the cover screw. Caution should be exercised to not overtighten the cover screw in D4 bone (Misch classification) because this will result in the possibility of reducing the initial fixation of the implant. Additionally, relieve the prosthesis over the surgical site so no force may be transmitted to the top of the implant (Fig. 10.13).

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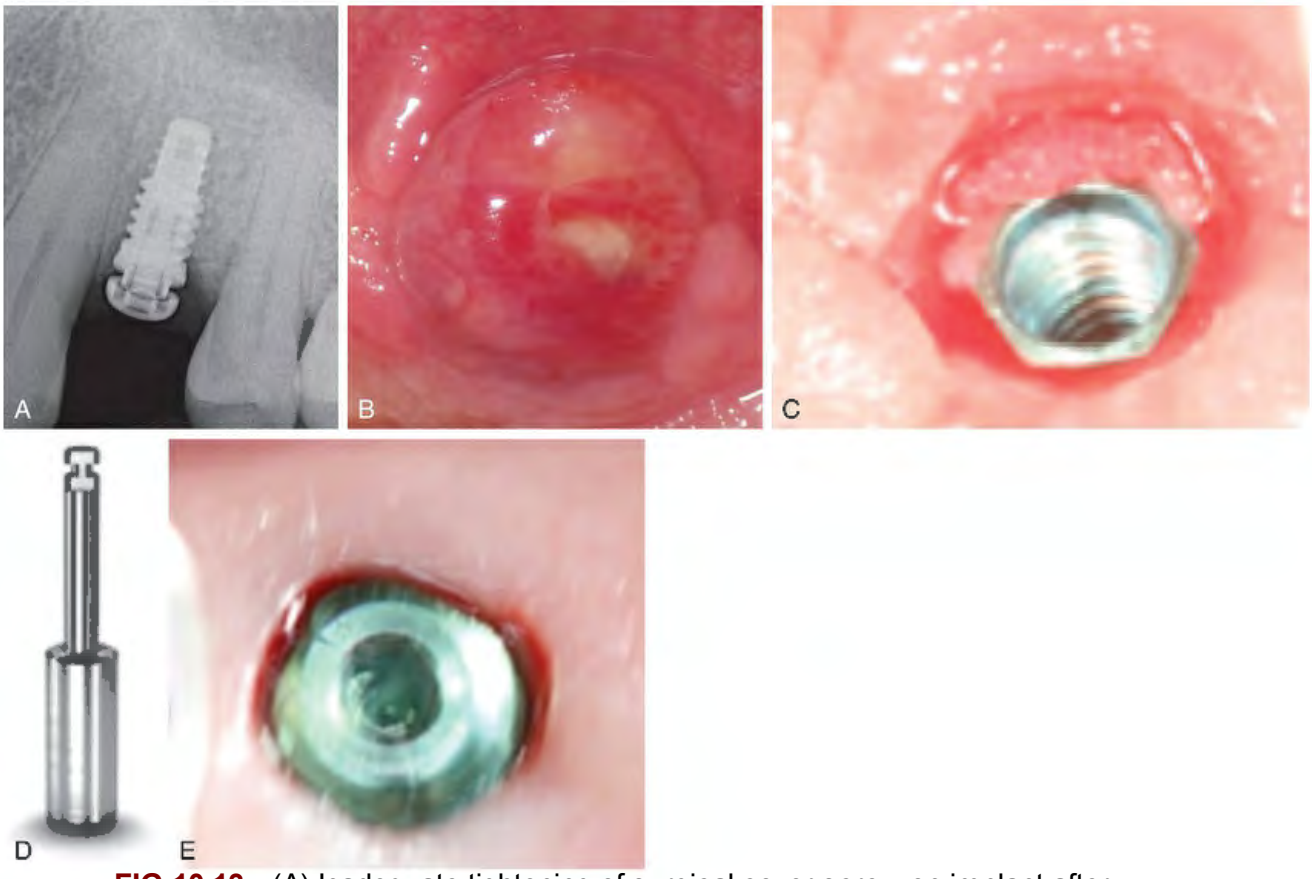

FIG 10.13 (A) Inadequate tightening of surgical cover screw on implant after surgical placement. (B) Resulting swelling with exudate over the cover screw. (C) Tissue overgrowth of implant body. (D) Latch type tissue punch removal bur. (E) Treatment includes complete uncovery of the implant and placement of a healing abutment.

Treatment

Remove the cover screw and, if tissue impingement is the etiologic factor, remove with a hand tissue punch, tissue punch bur, or laser. If bone is present, use a profiling bur (end cutting) to remove the bone. A high-speed handpiece should not be used because implant damage may result. A healing abutment should be placed to allow for ideal healing of the tissue.

Partial Cover Screw Exposure (Two-Stage)

When the cover screw becomes partially exposed during the healing period (two-stage technique), the implant is susceptible to premature loading, increased bone loss, and infection.

Etiology

With two-stage implant surgery, the cover screw may become exposed because of:

- Incision line opening
- Excess tension on the incision line
- Thin tissue (thin biotype)
- Interim prosthesis pressure
- Immediate implant placement
- Implant design—high surgical cover screw

Prevention

To prevent premature opening, tension should be released from the incision line. This will allow for tension-free closure and minimal pressure on the incision line. The interim prosthesis should be adjusted to have no direct contact on the surgical site.

Treatment

A partially exposed cover screw will retain more bacteria and predispose the implant to increased bone loss and morbidity. The implant should be uncovered (tissue punch bur) and the smallest permucosal extension (in height) should be used. Ideally, the permucosal extension should be 1 mm above the tissue height. No attempt should be made to resuture and obtain primary closure. The patient should be instructed on proper hygiene to include gentle brushing of the abutment along with the use of chlorhexidine (Fig. 10.14).

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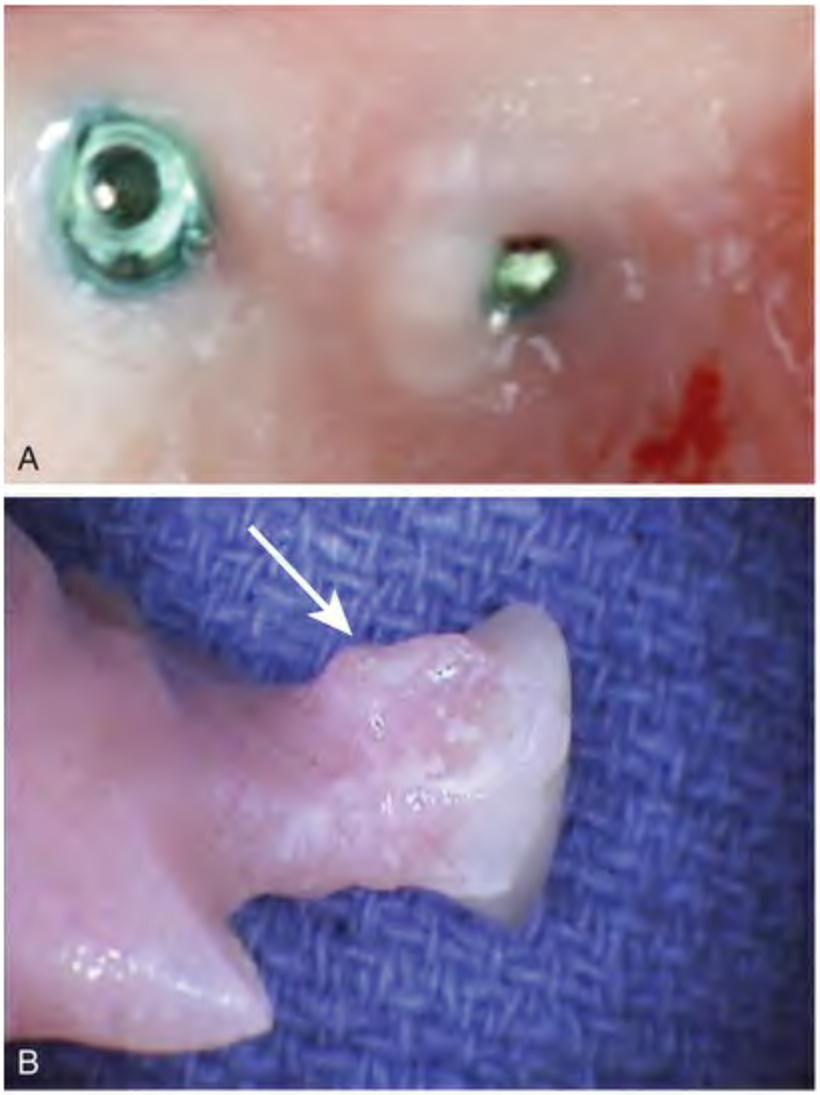

FIG 10.14 Partial cover screw exposure. (A) Incomplete tissue covering of implant is commonly caused by excessive pressure from prosthesis. (B) Prosthesis not adjusted, note protrusion that most likely will result in excess pressure on implant *(arrow)*.

Tissue Impingement Between Abutment and Implant

In some cases, if the final abutment becomes loose during the healing period or prosthetic rehabilitation, tissue impingement may result. The excess tissue can prevent the proper seating of a cover screw, healing abutment, impression transfer, or final prosthetic abutment (Fig. 10.15).

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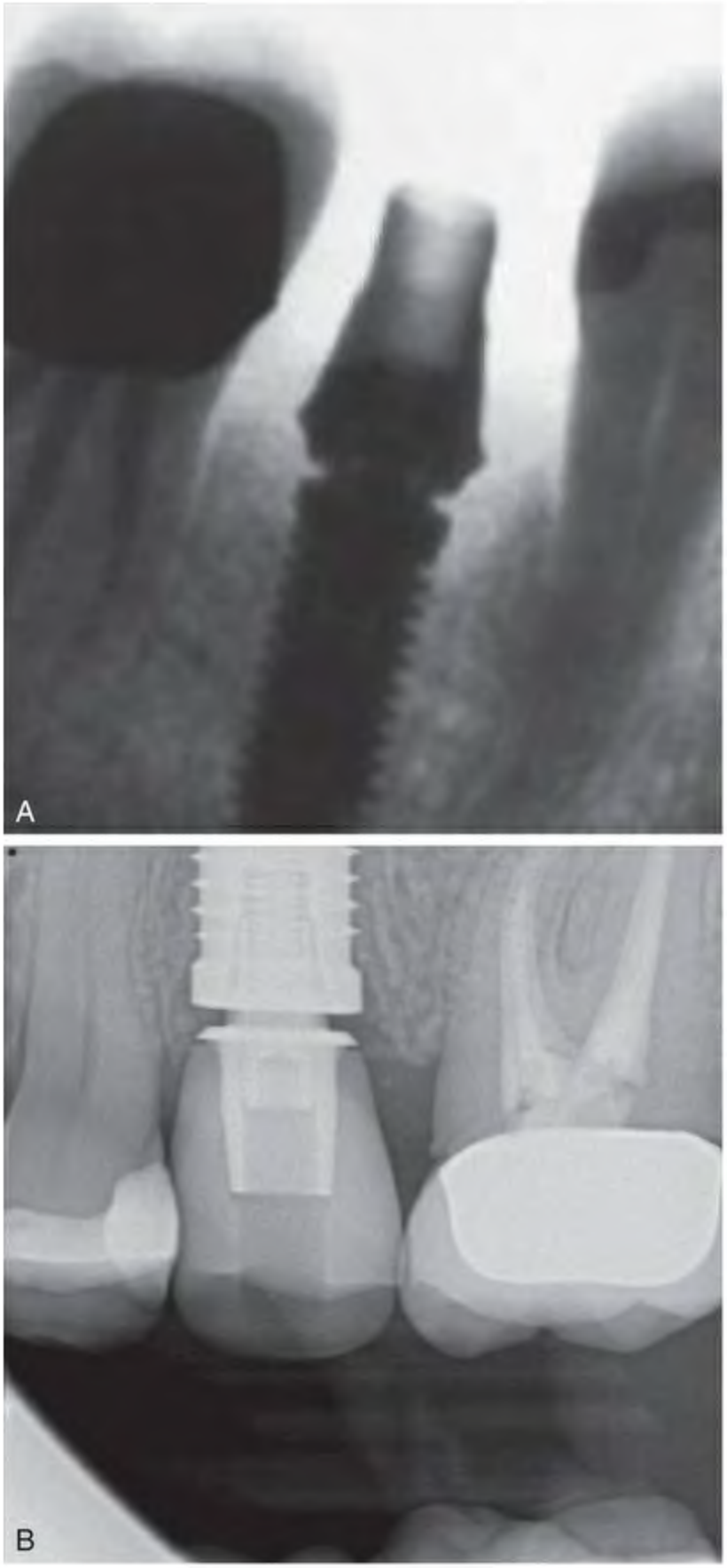

FIG 10.15 Tissue impingement. (A–B) Tissue prevents complete seating of abutment.

Etiology

Due to the tissue consistency around implants, relapse of the tissue results rather quickly, which may result in tissue impingement. This may even occur from leaving out the healing or prosthetic abutment on the implant for an extended amount of time.

Prevention

Prior to placing any abutment, make sure all tissue is removed from around the circumference of the implant. After placement of a prosthetic abutment or try-in of the final prosthesis, a periapical radiograph is recommended to confirm complete seating. If a gap is present on the radiograph between implant components, soft tissue impingement should be assumed.

Treatment

A tissue removal bur in a rotary handpiece, tissue punch, or laser of the appropriate size should be used to remove any tissue from around the implant or abutment. A radiograph should always be taken to verify complete seating.

Bone Impingement Between the Abutment and Implant

In two-stage implant surgery, it is not uncommon for bone overgrowth to be present over the top of the implant (cover screw). The excess bone must be removed to allow for proper seating of a cover screw, healing abutment, impression transfer, or final prosthetic abutment (Fig. 10.16).

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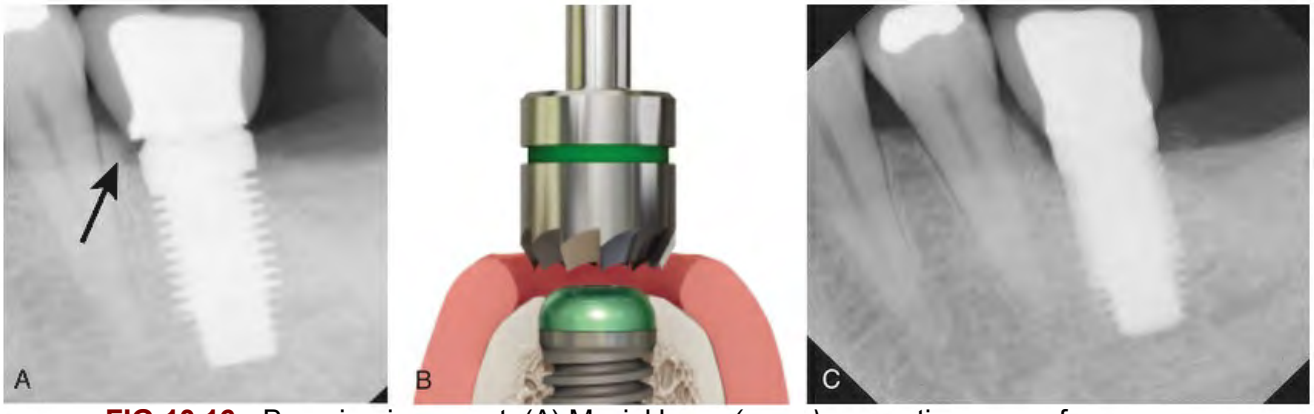

FIG 10.16 Bone impingement. (A) Mesial bone *(arrow)* preventing crown from complete seating. (B) End-cutting profiling bur is used to remove bone. (C) Removal of bone, complete seating of crown.

Etiology

Bony overgrowth or interference is most likely to occur when the implant is placed slightly below the crest of the bone. In some cases, when the ridge is uneven (higher lingual plate vs. buccal plate), the implant is placed at the level of the buccal bone; however, the lingual plate of bone will impinge on the abutment or cover screw. This will result in improper seating of the implant components.

Prevention

The implant should be placed at the level of the buccal and lingual heights of bone. If bone is present above the implant, the circumferential bone should be removed. Care should be exercised to avoid damaging the implant.

Treatment

A profiling bur to reduce the bone height easily removes the bone that prevents the proper seating of the abutment. A rotary handpiece with profiling bur (with cover screw attached) should not be used because damage to the implant body may result. A periapical radiograph will verify the proper seating of the implant.

Excessive Chronic Pain Around Implant Area

Chronic pain after implant placement that does not resolve will most likely have an inflammatory, nociceptive, or neuropathic component. Nociceptive and inflammatory pain will most likely occur in response to a noxious

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stimulation of sensory receptors by mechanical, thermal, or chemical trauma (e.g., osteotomy). Neuropathic pain, on the other hand, may be initiated or caused by a primary lesion or dysfunction in the nervous system. This may occur even in the absence of any noxious stimuli. Chronic neuropathic pain most likely involves both peripheral and central mechanisms.[54]

Etiology

Because the exact pathophysiology of chronic neuropathic pain is not known, many etiologic factors have been associated with this complication. Factors such as preoperative pain, preexisting pain conditions, and impairment in general physical features have been documented with persistent postoperative pain. Many psychologic factors such as anxiety, depression, fear of surgery, and psychic vulnerability have been related with the development of chronic pain. Additionally, many studies have shown women to be more likely to experience chronic pain syndromes, as well as patients above the age of 40, those with smaller-sized mandibles, smokers, diabetics, and those with advanced bone resorption (Fig. 10.17).

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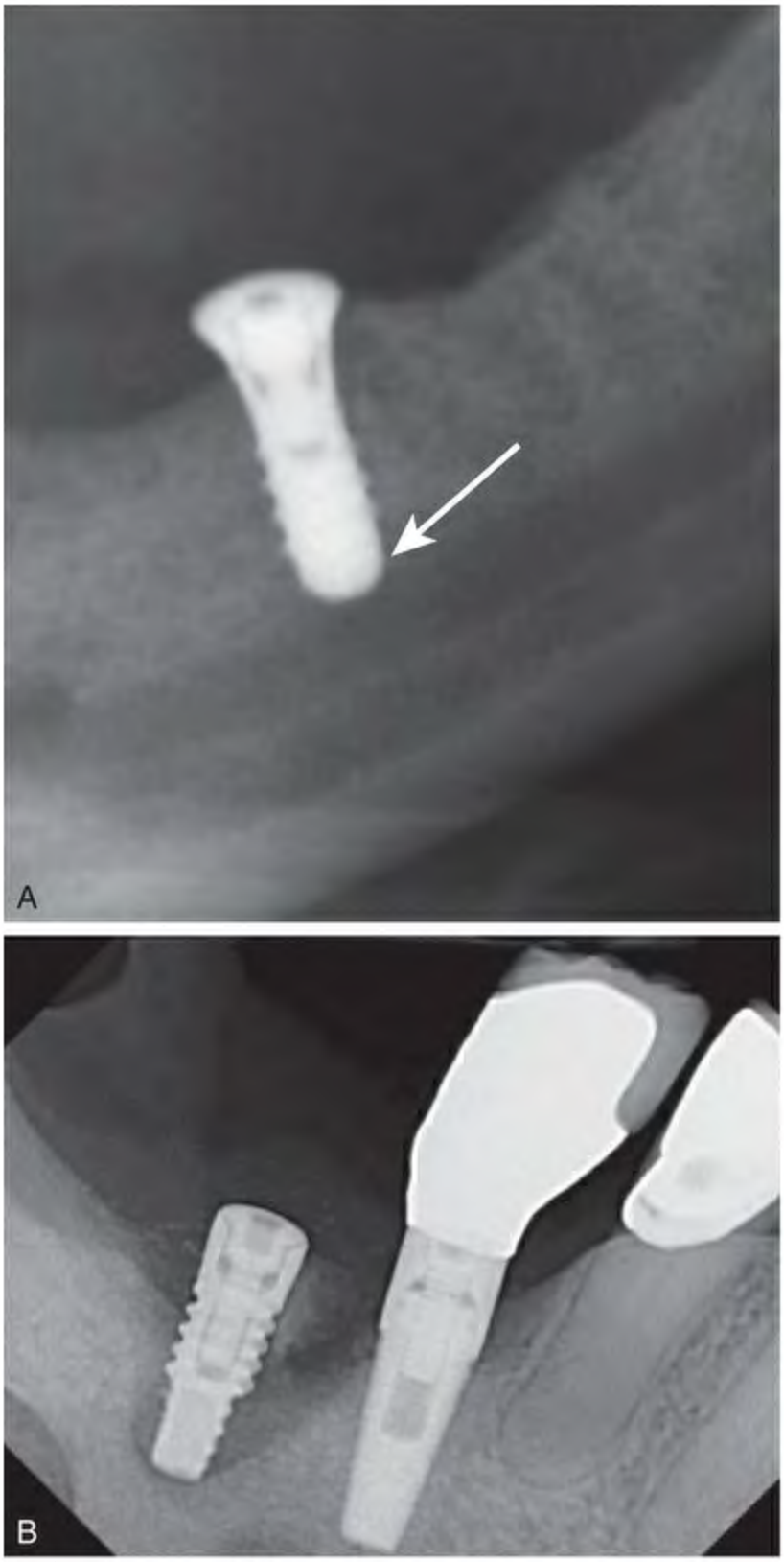

FIG 10.17 Chronic neuropathic pain most commonly occurs when implants are placed in close approximation to vital structures. (A) Inferior alveolar nerve *(arrow)*. (B) Failing implant that may cause chronic severe pain.

Prevention

To minimize the possibility of nerve damage during dental implant surgery, the implant dentist must be cautious around all vital structures (e.g., mental nerve). CBCT-based radiography should be used to determine the exact amount of available bone to avoid damage to nerve tissue.

Another complication that may lead to nerve injury is thermal damage produced by an implant drill. Significant care must be taken to minimize heat generation. The clinician should use minimal pressure, a sharp drill, and "bone dancing" when performing osteotomies, as well as copious irrigation. Neural tissue has been shown to be easily damaged by heat stimuli, reducing the ability of bone tissue to repair and regenerate.[55]

Management

The treatment of neuropathic pain is complicated and is not well understood. There exist many types of treatment modalities to manage chronic neuropathic pain.

Removal of Implant.

Renton et al showed that implants should be removed within 24 hours of placement if patients exhibit neuropathic pain. The early removal increases the probability of resolution of symptoms. In comparison, implants removed 3 to 90 days after placement showed no resolution of the neurosensory complications.[56]

Psychologic.

The psychologic status of the patient needs to be evaluated, ideally with a consultation by a clinical psychologist or psychiatrist. Psychologic variables may include depression, distress, ADHD, unrealistic treatment expectations, and background environmental factors.

Pharmacologic.

In the literature, there are various pharmacologic agents that have been attributed to the treatment of neuropathic pain.[57]

Tricyclic Antidepressants (amitriptyline, desipramine, and nortriptyline): The mechanism of action of these drugs is to inhibit the reuptake of monoamines and to block sodium channels along with exerting anticholinergic effects.

Serotonin and Norepinephrine Reuptake Inhibitors (duloxetine, venlafaxine): (SNRIs) are potent inhibitors of the reuptake of serotonin and norepinephrine, which are neurotransmitters that play an important role in the mood of the patient. They are popular in the treatment of major depression disorders and chronic neuropathic pain.

Anticonvulsants (gabapentin and pregabalin): The main mechanism of action is the decrease of central sensitization and nociceptive transmission.

Local Anesthetics: Although usually used as a diagnostic tool, local anesthetics have been shown to have therapeutic value in some instances of chronic neuropathic pain because of their membrane stabilization potential. Local anesthetics suppress sympathetic sprouting, which has been associated with NP.[58]

Topical Medications (lidocaine or benzocaine): Other medications, such as amitriptyline, carbamazepine, and ketamine, can be added to the mixture (with lidocaine) by a compounding pharmacy with the local anesthetics.

Opiates/Analgesics: Opiates have been shown to be ineffective in the treatment of neuropathic pain. Because this pain is chronic, the use of opiates is not recommended because of possible addiction.[59]

Pain Specialist.

Patients with the neuropathic pain that cannot be resolved surgically, pharmacologically, or psychologically should be encouraged to be evaluated at a chronic pain clinic or pain specialist.

Fractured Implant

Although rare with today's dental implants, fractured implant bodies may cause significant problems for both clinicians and patients. Dental implant fractures may be one of the major causes of late implant failures and may include possible medicolegal issues. Studies by Goodacre et al relate the risk of implant body fracture in the early to intermediate period for implants 3.75 mm in diameter to be approximately 1%, the abutment screw fracture risk at 2%, and the prosthetic screw risk at 4% (Fig. 10.18).[60]

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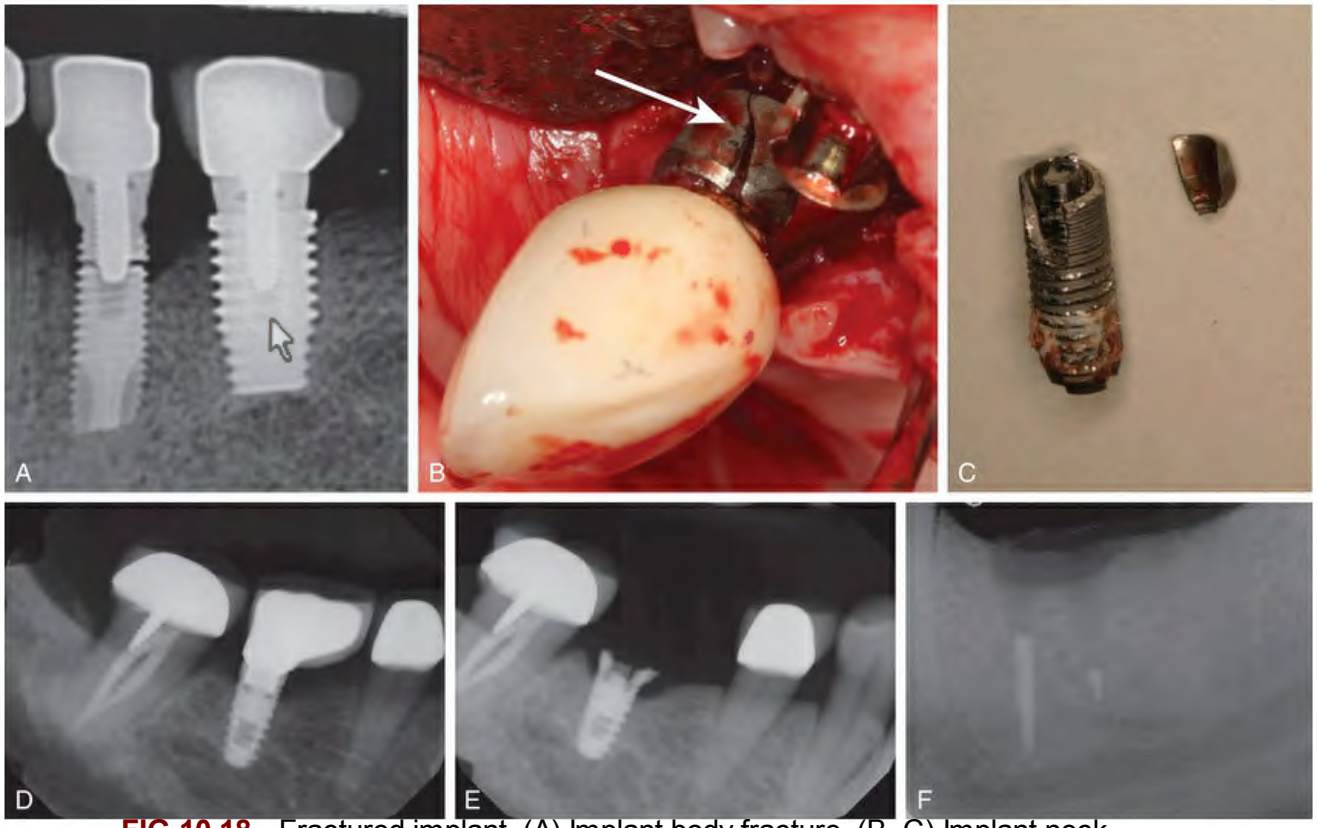

FIG 10.18 Fractured implant. (A) Implant body fracture. (B–C) Implant neck fracture. (D) Small diameter implant placed in a nonideal position, note mesial cantilever. (E) Because of small diameter implant, presence of mesial cantilever, internal hex neck fracture. (F) Two mini-implants fractured in the posterior mandible in close proximity to the mandibular canal.

Etiology

The incidence of implant body fracture dramatically increases when force conditions are greater. Cantilevers, angled loads, and parafunction increase the risk of fracture. The risk of fracture also increases over time. Typical mechanical failures are due to either static loads or fatigue loads. Static load (i.e., one load cycle) failures cause the stress in the material to exceed its ultimate strength after one load application. Fatigue load failures occur if the material is subjected to lower loads but repeated cycles of that load. The endurance limit or fatigue strength is the level of highest stress a material may be repetitively cycled through without failure. The endurance limit of a material is often less than one-half its ultimate tensile strength. Therefore, fatigue and ultimate strength values are related, but fatigue is a more critical factor, especially for patients with parafunction because they impose higher stress magnitude and greater cycles of load. Different materials have varying degrees of resistance to repeated loading and subsequent fatigue-related

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failures. The fatigue strength of titanium alloy (Ti-6Al-4V) is four times greater (and safer) than grade 1 titanium, and almost two times greater than grade 4 titanium. Long-term fracture of implant bodies and components may be dramatically reduced with the use of titanium alloy rather than any grade of commercially pure titanium (Fig. 10.19 and Table 10.6).

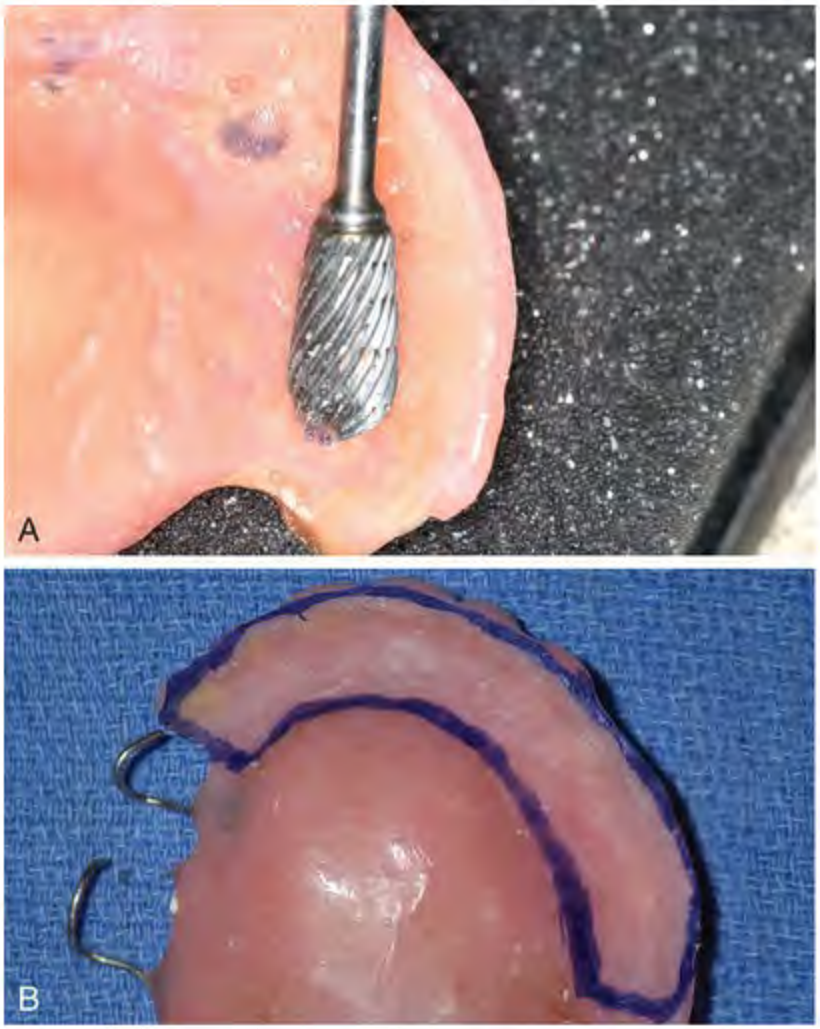

FIG 10.19 (A) Modification of prosthesis to include hollowing out implant site areas to maintain primary stress-bearing areas. (B) Flange removal and relief made over implant sites while maintaining primary stress-bearing area.

TABLE 10.6

Mechanical Properties for Different Grades of Titanium

Property	Grade 1	Grade 2	Grade 3	Grade 4	TI-6A1-4V
Tensile strength, min (MPa)	240	345	450	550	930
Yield strength, 0.2% offset, min (MPa)	170	275	380	483	860
Modulus of elasticity (GPa)	103	103	103	103	113

Grades 1 to 4, CP titanium; *Ti-6Al-4V*, titanium-vanadium alloy

From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.

Prevention

To reduce the possibility of implant body fracture, a titanium alloy implant should ideally be used. Parafunctional habits should be addressed with occlusal guards, narrow occlusal tables, no lateral contacts, and an ideal occlusal scheme.

Treatment

The ideal treatment for a fractured implant includes the removal and possible replacement of the implant. Alternative treatments include modification of the prosthesis to not include the implant and possible modification of the fractured implant (cementable abutment).

Excessive Pressure From an Interim Prosthesis

If the patient wears an interim prosthesis after implant or bone graft surgery, excessive pressure may result in the premature loading of the surgical site. Additionally, denture adhesive may lead to impaired healing with resultant incision line opening and possible failure of the implant or bone graft. Ideally, no interim prosthesis should be worn. However, this is unrealistic in many cases because some patients are more socially active and esthetically conscious.

Etiology

If the interim prosthesis does not have an occlusal stop (rest stop on teeth) or is not utilizing the primary stress-bearing areas (maxilla: horizontal palate; mandible: buccal shelf), normal occlusal forces will overload the surgical site. This may result in premature loading and implant morbidity including bone loss or failure of the implant.

Prevention

Patient Education.

If the patient demands to wear the prosthesis, they should be instructed to wear it as little as possible. Explaining to the patient the inherent disadvantages of wearing the prosthesis should be addressed. Patients should also be educated on the complications of the use of denture adhesive, especially if the adhesive is placed in approximation to the incision line.

Prosthesis Modification.

The labial flange and acrylic overlying the surgical site should be reduced to minimize any possible pressure on the surgical site. Care should be exercised to maintain the primary stress-bearing areas within the interim prosthesis to avoid any pressure to the surgical site.

Selection of Correct Reline Material

Hard reline material.

Generally, hard denture reline materials are made of modified poly (methyl methacrylate) acrylic (PMMA), which, because of the inherent hardness, should never be used postsurgically for relines.[61] Hard reline material in approximation to the surgical site may have detrimental effects on the implant site.

Soft reline material.

Soft relines have been classified as either acrylic or silicone. Silicone soft liners include heat-cured liners similar to Molloplast-B. This is a gamma-methacryloxypropyltrimethoxysilane heat-polymerized silicone.[61] Soft reline materials may be used; however, they should be relieved over the surgical site. Acrylic soft reline materials are usually cold-cured and also should be relieved over the incision area.

Tissue conditioner.

Tissue conditioners are soft elastomers that are classified as plasticized acrylics, which are composed of a poly (ethyl methacrylate) mixture of phthalate plasticizer and up to 25% ethanol. The enclosed plasticizer lowers the glass-transition temperature so the rigid acrylic resin becomes rubbery

and resilient.

Tissue-conditioning material, when mixed properly, results in a gel of the polymer and monomer with a resilient consistency. The resilient gel provides an excellent cushion for traumatized tissue adjacent to the intaglio surface of the hard, processed denture-base material. When the tissue-treatment liner is replaced frequently, the damaged intraoral supporting tissues can return to a state of health. Effective use of any tissue-treatment material may require replacement every 3 days for up to 30 days depending on the material. Eventually, these materials will become hard and rough and may harbor bacteria and fungus.

Before a tissue conditioner is applied, the intraoral tissues must be clean and dry. Although most dental materials should be mixed according to the manufacturer's instructions, the mixing instructions of some tissue-treatment materials can be altered depending on the desired viscosity and flow needed clinically. After the material is placed on the surface of a prosthesis and seated intraorally, the material is allowed to flow as the patient closes their bite into maximum intercuspation or appropriate interocclusal relation. After the material sets, excess amounts are trimmed using a sharp, heated knife or scalpel.

Placing a tissue conditioner in a prosthesis for frequent liner replacement is a relatively simple procedure, but a soft liner material that is not changed frequently, as per the manufacturer's recommendations, can cause excess pressure and tissue damage to the surgical site. Plasticizers can leach out, which will result in a hardened material. Thus the selection of tissue-conditioning material used is paramount to minimize loading of the implant or bone graft site.

Some of the most common tissue conditioners are Coe-Comfort (GC America Inc.), Lynal (DENTSPLY Caulk), and Visco-Gel (DENTSPLY International). When there is greater tissue mobility and inflammation (post implant placement or bone grafting), the use of a less viscous material (more flowable) is indicated. Thus, Visco-Gel is usually the tissue conditioner of choice because it has favorable flow characteristics, resists bacterial invasion, and is usually replaced every 30 days compared with other tissue conditioners, which need to be replaced every 2–3 days.

Treatment

Prosthesis Modification.

The internal surface of the prosthesis is aggressively relieved 3–5 mm over the surgical site. A common, but incorrect, method is relieving the entire intaglio surface of the prosthesis. This will result in overloading the surgical site area. The flanges should also be removed over the surgical site.

Tissue Conditioners.

The proper use of tissue conditioners should be adhered to because a thicker viscosity should be used to minimize migration of the tissue conditioner material (Fig. 10.19, see Box 10.3). Migration of the tissue conditioner material may lead to impingement into the incision line, which may result in impaired healing.

Box 10.3

Reline Technique

1. Prosthesis preparation: Remove sufficient acrylic from the tissue surface overlying the surgical site. A minimum of 1–2 mm is required for bulk of material and the ability for the material to flow. If a flange exists that may impinge on the surgical site, the flange should be removed.

2. Mix the tissue conditioner: Follow the manufacturer's recommendation for proper powder-to-liquid ratio. Additional powder may be added to thicken the mixture, thus reducing the flow of the material when the prosthesis is inserted. Water-soluble petroleum jelly is applied to facilitate easy removal of the excess material.

3. Seat the prosthesis in the mouth: Have the patient occlude in centric occlusion.

4. Trim the excess material: After sufficient setting time (≈10 minutes), the prosthesis is removed from the patient's mouth, and excess material is removed with a sharp knife or scalpel.

From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.

Trauma From Explantation of Implants

In some situations a failing implant or the position of the implant

necessitates removal with reinsertion in an ideal position. The following are possible reasons why dental implants may need to be removed:

- Mobility of the implant
- Extensive bone loss
- Chronic pain
- Advanced peri-implantitis
- Fractured implant
- Malpositioned implant

Complication

Taking an aggressive approach to remove an implant may lead to further bone loss and jeopardize the future site for reimplantation. Because an implant does not contain a periodontal ligament, placing too much force and pressure on it may lead to buccal or lingual plate failure. Loss of bony plates or excessive bone loss may result in the need for extensive bone augmentation in the future.

Treatment

The removal of dental implants is dictated by the location, amount of bone present, type of implant, and presence of mobility.

Mobile Implant.

The loss of the bone-implant integration necessitates immediate removal because infection and further loss of bone may result. In certain cases, the implant may migrate within tissue spaces or may be swallowed or aspirated.

Counter-torque Ratchet: This technique involves placing an abutment or an engaging extraction tool into the implant and reverse torqueing the implant counterclockwise. This technique is usually very atraumatic.

Convention Extraction Techniques: This method utilizes conventional forceps and elevators and should be used only with minimal luxation to prevent possible fracture of the buccal or lingual plate. After removal, all soft tissue should be removed from the implant site prior to grafting or reimplantation.

Nonmobile Implant.

A partial or fully integrated implant is usually more problematic and can be rather difficult to remove. Conventional extraction techniques should never

be used because they may lead to significant bone loss or fracture. If a final crown and abutment is present, they should be removed to allow for easier access.

Countertorque Ratchet: This technique involves placing an abutment or an engaging extraction tool into the implant and reverse torqueing the implant counterclockwise. This should be used only in poorly dense bone (~maxilla). Care should be exercised in higher-density bone because damage or fracture of the adjacent bone may occur with this type of removal technique. There are many factors affecting the ease of implant removal via the countertorque technique:

Hex (~D1-D2).

An internal hex implant is easier to remove via the countertorque method. External hex implants, because they engage coronal to the implant body, are more difficult to remove because of lack of leverage. Trilobe internal connections, especially those with smaller diameters, have been shown to fracture when greater than 45 N/cm of torque is applied.[62] Care should be exercised to prevent fracturing the implant upon removal.

Implant thread shape.

There are four types of implant thread designs: buttress, square, V-shaped, and reverse buttress. The square thread shape has the highest bone-implant contact (BIC) and will be the most difficult to remove via the countertorque method.

Implant body design.

A tapered implant design will be easier to remove than a square implant design. The thread depth and surface area decreases in the apical area, which minimizes the torque force necessary for removal.

Antirotational design.

Some implant designs contain a vent or opening, usually at the apical end, that will allow for bone growth integration. This will complicate the removal of a partially or fully integrated implant. A trephine or surgical bur technique may be indicated in the removal of these types of implants.

Reverse Screw Techniques: A reverse screw removal drill is utilized when the internal aspect of the implants (threads) are damaged or when the countertorque method is unsuccessful. Caution should be exercised with

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smaller-diameter internal implants (~3.0 mm) because fracture of the implant body may occur (Fig. 10.20).

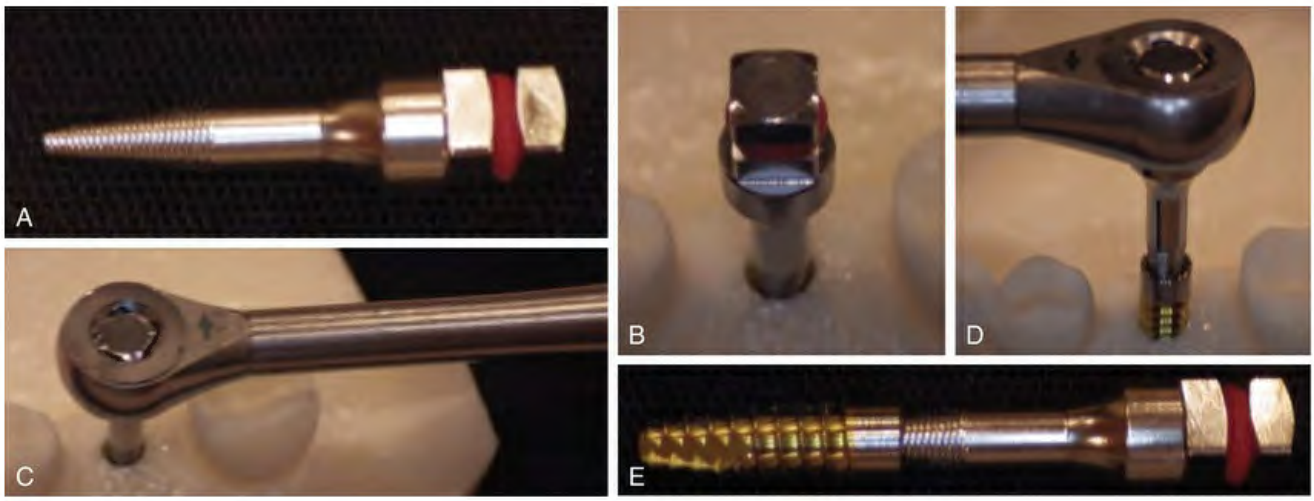

FIG 10.20 Reverse screw techniques. (A) Fixture removal screw. (B) Screw removal inserted into implant. (C) Counterrotate with torque wrench. (D) Implant will unscrew. (E) Implant attached to fixture removal screw.

High-Speed Burs: The use of a high-speed bur is a fast, efficient technique to remove an integrated implant. Ideally, a tapered surgical bur (extra long: 700 XXL) is used to minimize bone removal. The bur is used 360 degrees around the implant to a depth of one-half to three-fourths the length of the implant to be removed. Copious amounts of saline should be used to minimize thermal damage and the possibility of osteomyelitis. This helps to maintain bone and minimize damage to vital structures. After removal, the implant site should be irrigated to remove any particles (Fig. 10.21).

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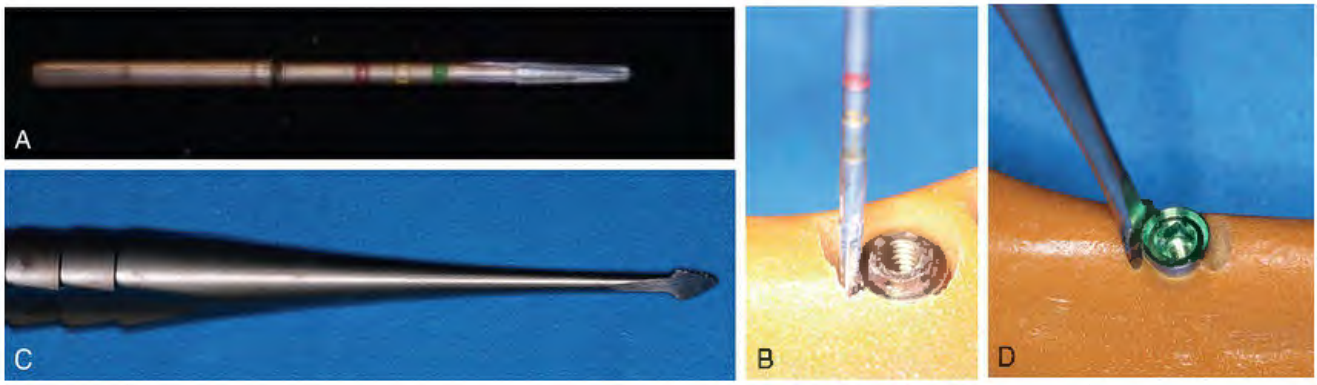

FIG 10.21 High-speed burs. (A) 700 XXL. (B) Mesial and distal slots one-half the depth of the implant. (C–D) Elevator is used with lateral movement to remove implant.

Piezo Surgical Units: A piezo surgical unit uses piezoelectric vibrations to cut bone tissue. By adjusting the ultrasonic frequency of the unit, it is possible to remove hard tissue while leaving soft tissue untouched by the process. Studies have shown that piezo units cause less soft tissue damage compared with other extraction techniques (Fig. 10.22).[63]

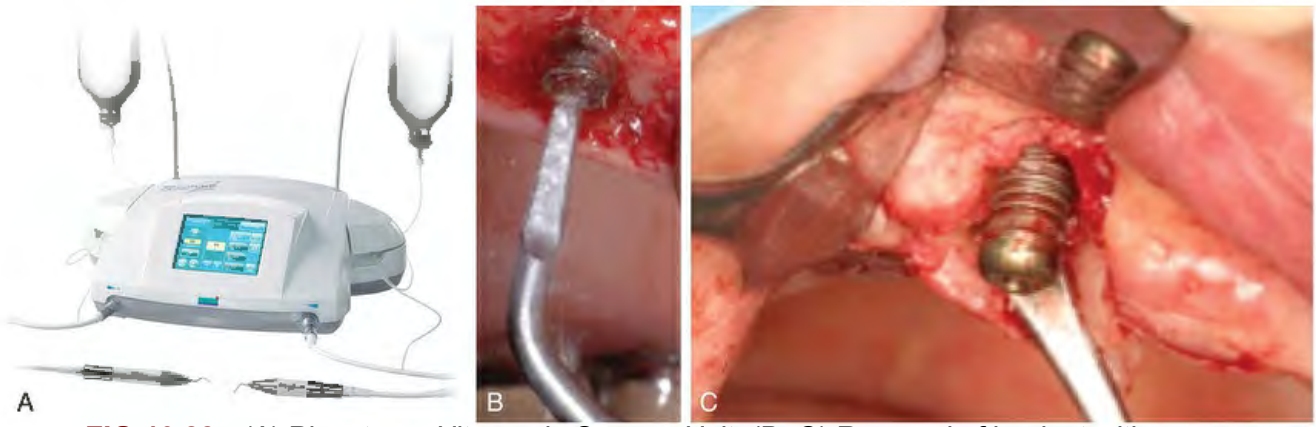

FIG 10.22 (A) Piezotome Ultrasonic Surgery Unit. (B–C) Removal of implant with piezo surgery unit. (A, Courtesy ACTEON North America, Mount Laurel, NJ.)

Trephine Burs: Trephine burs are barrel-shaped burs that have various diameters. The bur selected should be slightly larger than the implant crest module because too large of a trephine bur will result in excessive bone removal. Too small of a trephine may result in implant body particles being removed and becoming embedded in the implant site. Copious amounts of saline should be used to minimize thermal damage and the possibility of osteomyelitis. If the apex of the implant is in approximation to a vital structure, the trephine bur should not be used at the apex to avoid vital

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structure damage. After the implant is removed, the implant site should be irrigated to remove any retained particles (Fig. 10.23).

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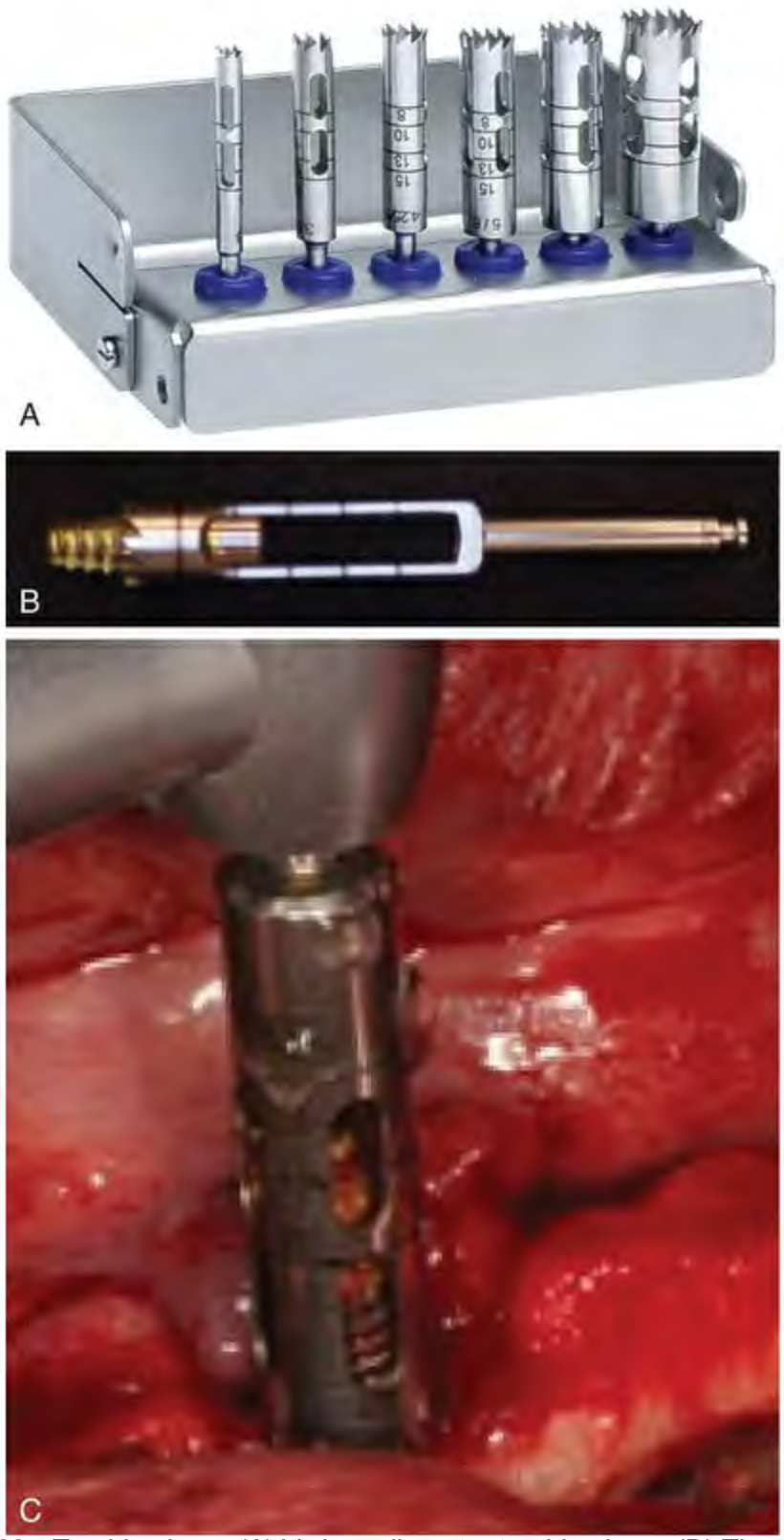

FIG 10.23 Trephine burs. (A) Various diameter trephine burs. (B) The smallest trephine that will encompass the implant should be used. (C) Surgical removal of implant. (A, Courtesy Société FFDM-PNEUMAT-Département Dentaire THOMAS, Bourges, Cedex France.)

Combination of Techniques: In some cases, it is prudent to remove bone one-

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half to three-fourths the length of the implant (using a trephine, piezo, or high-speed bur) along with the use of conventional extraction techniques or countertorque ratchet.

Displacement or Migration Complications

Displacement of Implants: Maxilla

Numerous case reports have been published concerning displacement (at the time of surgery) or migration (after surgery or prosthetic treatment) of implants into an adjacent space such as the maxillary sinus, ethmoid sinus,[64] sphenoid sinus,[65] frontal sinus,[66] orbit,[67,68] nasal cavity, and the anterior cranial base.[69]

Etiology

When dental implants migrate into the maxillary sinus, they may remain asymptomatic and unknown to the clinician. The timing of implant displacement into the maxillary sinus proper has been shown to range from the time of surgery to 10 years after prosthetic rehabilitation.[70] When implants are determined to be displaced into the maxillary sinus, immediate evaluation and removal should be rendered. If left untreated, the displaced implants may become calcified (antrolith) or migrate into adjacent anatomic areas. Case reports in the literature have documented displaced implants in the maxillary sinus and migrating into the various regions of the head and neck.

Maxillary Sinus[71].

All case reports discussing the migration of implants (either early or late migration) find that they originate in the maxillary sinus because of its anatomic location with respect to the maxillary posterior region. After displacement into the maxillary sinus, the dental implants have been reported to migrate to various anatomic areas (Fig. 10.24).

Maxillary Sinus Ostium[70].

The maxillary ostium is the main drainage location of the maxillary sinus into the nasopharynx. The mucociliary action of the maxillary sinus cilia propels any secretions through the ostium, into the infundibulum, through the hiatus semilunaris, into the middle meatus, and finally into the nasopharynx. The functional maxillary ostium has been documented to be approximately 2.4 mm in diameter, thus significantly smaller than a regular-sized dental implant.[72] The physiologic action of the maxillary sinus will transport the

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dental implant into the ostium area, most likely blocking the area and causing nonpatency. Nonpatency of the maxillary ostium will lead to infection or cause the implant to erode through the ostium to other anatomic areas (see Fig. 10.24).

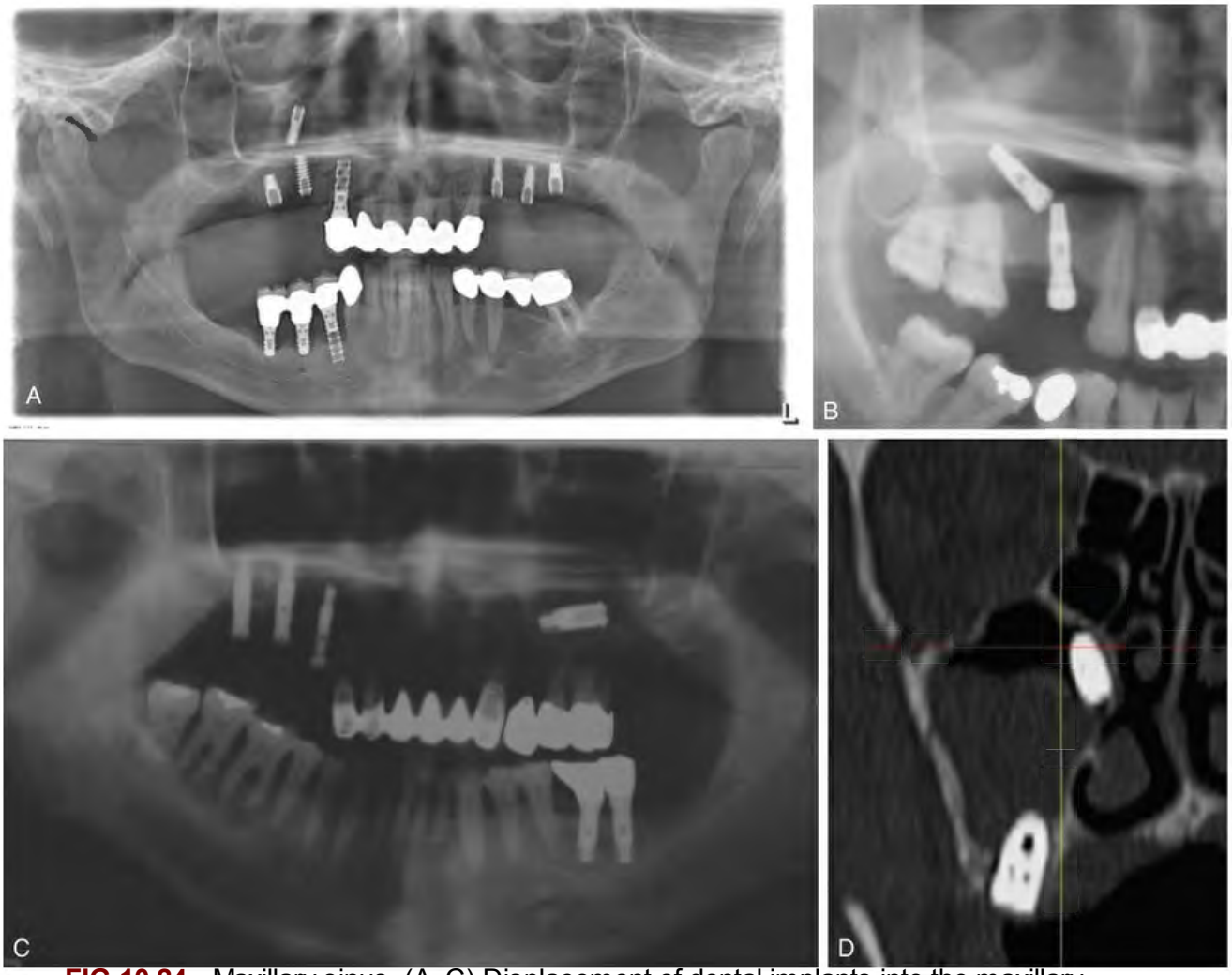

FIG 10.24 Maxillary sinus. (A–C) Displacement of dental implants into the maxillary sinus. (D) Displacement into the maxillary ostium causing nonpatency.

Nasal Cavity[73].

Dental implants may migrate from the maxillary sinus into the nasal cavity via extrusion through the ostium or erosion through the medial wall of the sinus (lateral wall of the nasal cavity). The medial wall of the maxillary is composed of a very thin layer of cortical bone (<0.5 mm) (Fig. 10.25).

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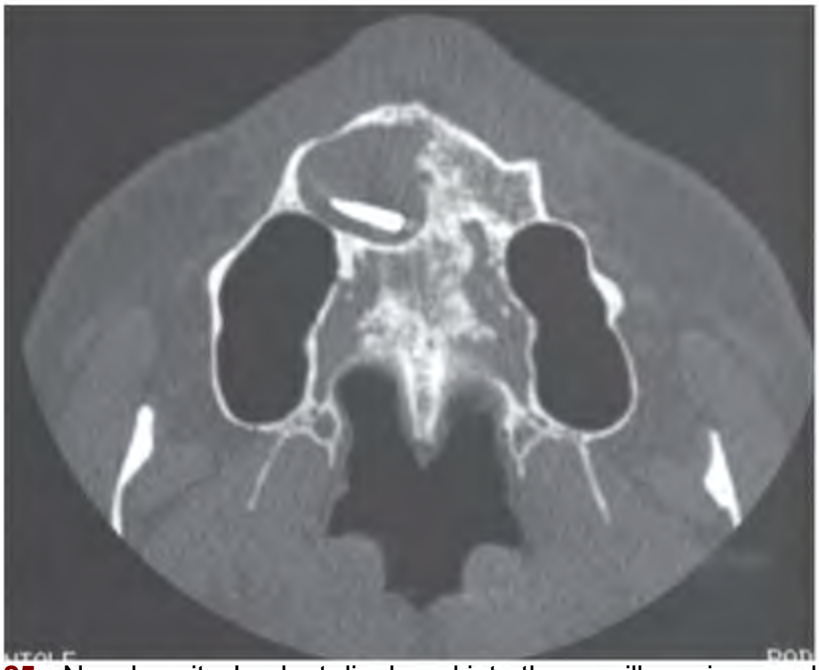

FIG 10.25 Nasal cavity. Implant displaced into the maxillary sinus and eroded through the medial wall of the maxillary sinus.

Ethmoid Sinus[64].

The bilateral ethmoid sinuses arise within the ethmoid bone and form distinct air cells superior to the maxillary sinus (between the orbits). These pyramidal air cells are divided by thin septa and bordered by the middle turbinate and the roof of the maxillary sinus. Dental implants may migrate to the ethmoid sinus via the ostium or erode through the superior wall of the sinus (Fig. 10.26A).

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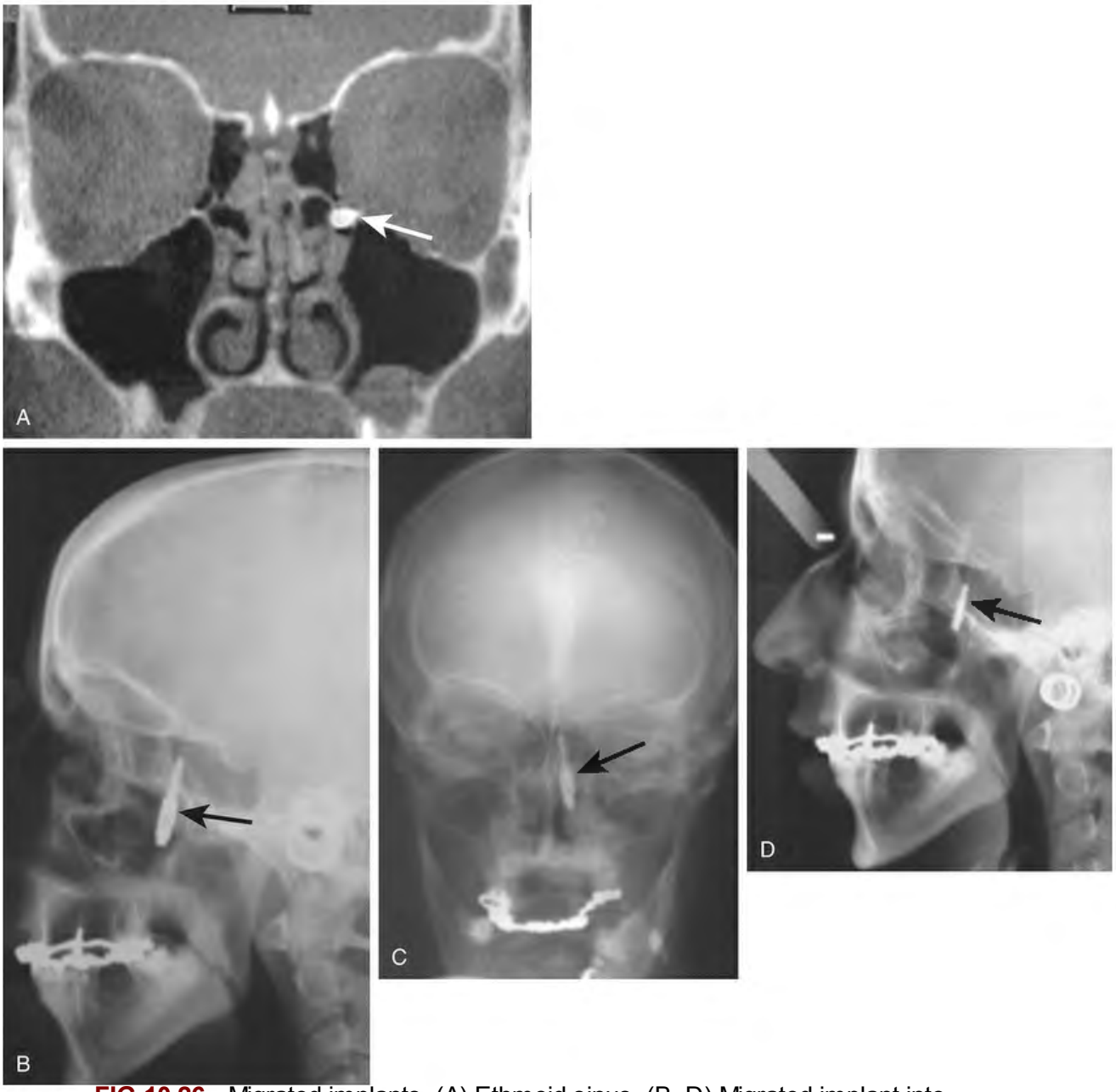

FIG 10.26 Migrated implants. (A) Ethmoid sinus. (B–D) Migrated implant into sphenoid sinus. (A, From Haben M, Balys R, Frenkiel S: Dental implant migration into the ethmoid sinus, *J Otolaryngol* 32:342–344, 2003; B–D, From Felisati G, Lozza P, Chiapasco M, et al: Endoscopic removal of an unusual foreign body in the sphenoid sinus: an oral implant, *Clin Oral Implants Res* 18:776–780, 2007.)

Sphenoid Sinus[74].

The sphenoid sinus originates in the sphenoid bone in the center of the skull. The pneumatization of the sphenoid sinus varies and may extend to the foramen magnum. The cortical walls vary in thickness with the anterosuperior wall being the thinnest. Dental implants may enter the sphenoid sinus ostium, which is located on the anterosuperior surface of the

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sphenoid bone and medial to the superior turbinate (Fig. 10.26B).

Orbital Area[75].

The floor of the orbit coincides with the roof (superior) wall of the maxillary sinus. The infraorbital nerve and blood vessels transverse this area. Implants may migrate from the maxillary sinus into the inferior wall of the orbit (superior wall of maxillary sinus) (Fig. 10.27).

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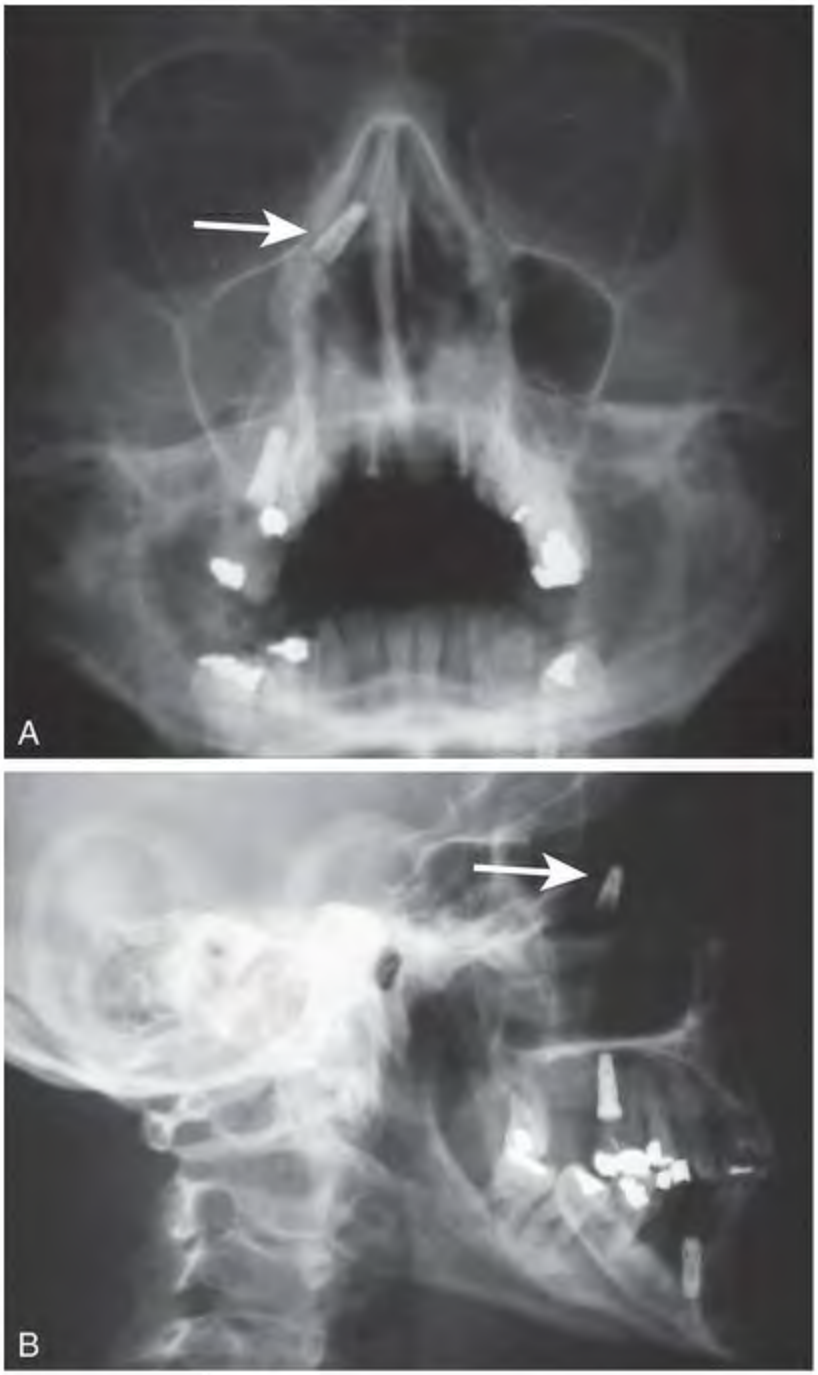

FIG 10.27 (A–B) Migrated implants into the orbital area. (From Griffa A, Viterbo S, Boffano P: Endoscopic-assisted removal of an intraorbital dislocated dental implant, *Clin Oral Implants Res* 21:778–780, 2010.)

Anterior Cranial Base[76].

The floor of the cranial cavity forms the skull base, which separates the brain from other skull structures. The skull base is subdivided into three regions: anterior, middle, and posterior. The anterior cranial base is formed by the orbital plates of the frontal bone, the cribriform plate of the ethmoid bone,

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and the wings of the sphenoid bone (Fig. 10.28).

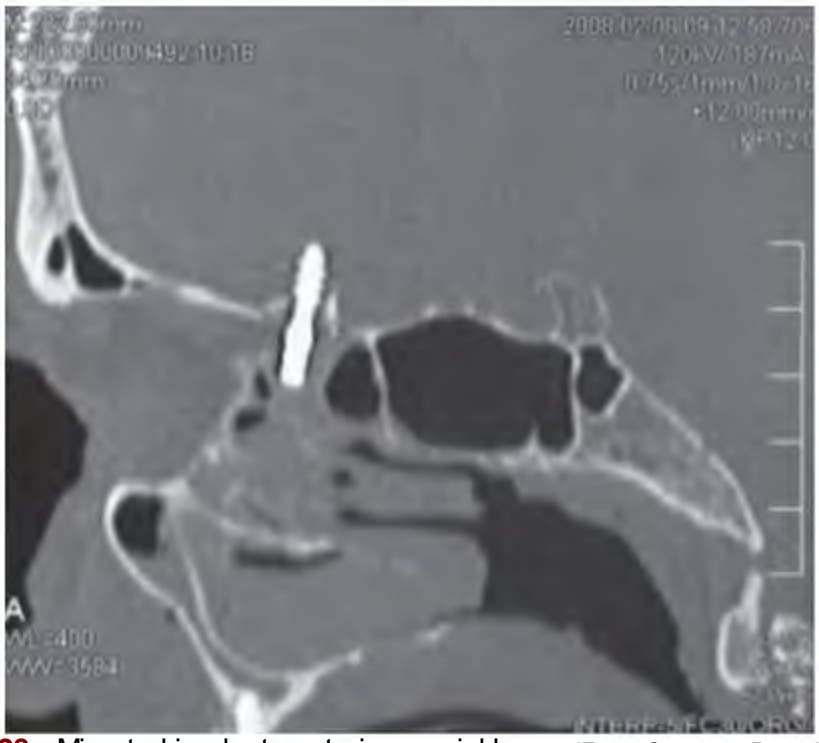

FIG 10.28 Migrated implants anterior cranial base. (From Cascone P, et al: Adental implant in the anterior cranial fossae, *Int J Oral Maxillofac Surg* 39:92–93, 2010.)

Early Displacement (At the Time of Surgery)

Poor Bone Quality.

In the posterior maxilla it is common for the bone quality to be poor (≈D4), consisting of very fine trabecular and no cortical bone. Because of the poor bone quality, the bone lacks density and strength and cannot maintain rigid fixation of the implant. Forces applied to the area or negative intrasinus pressure may lead to the migration of the dental implant into the maxillary sinus proper (Fig. 10.29).

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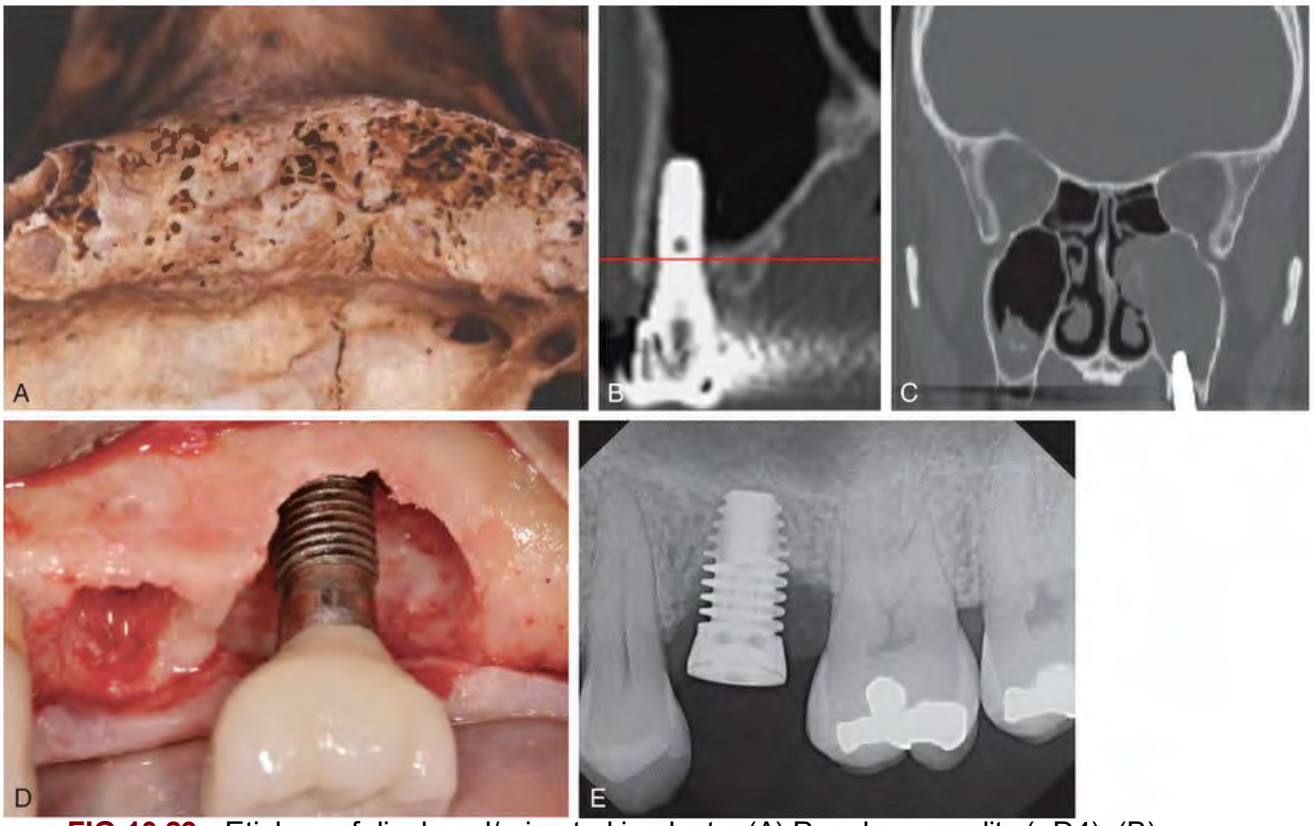

FIG 10.29 Etiology of displaced/migrated implants. (A) Poor bone quality (~D4). (B) Implant placement without bone graft. (C) Autoimmune/rhinosinusitis. (D) Peri-implantitis. (E) Implant with minimal surrounding bone that may lead to migration into the sinus cavity.

Poor Surgical Technique.

Because of the poor bone quality, if the osteotomy is prepared with a conventional drill sequence (e.g., routine, standard manufacturer's protocol), overpreparation of the osteotomy site will result. Because of the overpreparation, there will be insufficient bone at the crestal level to maintain rigid fixation and migration may occur. Therefore, underpreparation or the use of osteotomes should be utilized when preparing osteotomies in these compromised areas.

Implant Placement Without Bone Graft.

Treatment planning in the posterior maxilla should coincide with the Misch sinus augmentation protocol (SA-1–SA-4). For an implant to be placed without bone grafting, a minimum of 8–10 mm is required. Less than 8 mm of bone will predispose the implant to lack of rigid fixation and the possibility of mobility or migration. For the implant to be placed with bone grafting, a minimum of 5 mm of host bone is required for initial fixation.

Under-preparation of the osteotomy site is recommended to maintain as much bone for initial fixation of the implant.

Galindo-Moreno et al completed a retrospective study on migrated dental implants. They reported in 73% of the migrated implant cases, no bone grafting was completed in conjunction with implant placement. The average bone height for implant placement was approximately 5.2 mm. The mean length of the implants was 13.43 mm, which resulted in no bone contact of approximately 8.23 mm of the implant surface. Therefore, the main reason for implant migration was lack of bone grafting with insufficient bone for initial fixation.[76a]

Immediate Implant Placement.

With the popularity of immediate implants, there is a greater possibility of an implant being displaced into the maxillary sinus after the extraction of a multirooted maxillary molar. This is most critical in the first molar area, where the defect from the extraction results in minimal bone to maintain stability of the implant. In over two thirds of maxillary first molars, the palatal or mesiobuccal root is in approximation of the maxillary sinus floor.

Late (After Surgery) Migration

Negative Pressure.

When initial fixation of the implant is absent, changes in intrasinus and nasal pressure may intrude the implant into the maxillary sinus proper. Because of the compromised bone implant contact (BIC), changes in intrasinus and nasal air pressure may produce a suction effect, causing a negative pressure. This may result in the displacement of the implant into the maxillary sinus. Case studies have shown implants that have migrated into the maxillary sinus and expelled via the maxillary ostium and nose from the negative pressure.[77]

Autoimmune Reaction.

Many authors have discussed autoimmune reactions with the dental implant, which result in bone loss around the implant, loss of integration, and intrusion into the maxillary sinus.[78]

Occlusal Overloading.

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Because of the poor bone quality in the posterior maxilla, excessive occlusal force will result in bone loss or loss of fixation of the implant. Sufficient primary stability is an important factor upon placement of the implant. This should be followed by sufficient healing time, and strict adherence to progressive bone loading and implant-protected occlusion (see Chapter 17). This will involve avoiding shear forces (nonaxial) on the implant prosthesis and minimizing cantilever effects. In cases of severe parafunction, an occlusal guard is recommended after prosthetic completion.

Peri-Implantitis.

If peri-implantitis around a maxillary posterior implant is left untreated, loss of fixation may result, which will lead to insufficient fixation. This may result in the implant and prosthesis migrating into the maxillary sinus.

Prevention

To prevent displacement and migration of implants into the maxillary sinus, ideal treatment planning along with surgical technique (modified for the posterior maxilla) should be adhered to. A comprehensive preoperative evaluation of the posterior maxilla should be completed and the inherent unfavorable anatomic and possible pathologic conditions should be addressed when treatment planning in this area. The Misch sinus augmentation (SA-1 through SA-4) classification should be adhered to, so as to minimize the possibility of implant intrusion into the sinus proper.

Treatment

Treatment of migrated or displaced implants includes the immediate removal, which usually necessitates referral to an oral and maxillofacial surgeon (OMFS) or otolaryngologist (ENT). The most common approaches for removal of implants include the traditional Caldwell-Luc procedure, intraoral approach, or a transnasal approach with functional endoscopic sinus surgery. Pagella reported the use of an intraoral endoscopic (FESS—functional endoscopic sinus surgery) extraction of a metallic foreign body from the maxillary sinus.[79] Regev reported the use of the Caldwell-Luc operation (anterior maxillary wall approach) and also retrieval through an intraoral preparation site approach.[80] A multicenter study compared these three methods of removing implants from the paranasal sinuses. The conclusion verified that functional endoscopic sinus surgery in combination

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with an intraoral approach is the most ideal for removing implants or grafting materials.[81]

If the implant is not removed from the maxillary sinus, it may eventually exit via the natural ostium by way of the normal physiologic mucociliary transport. If the dental implant migrates through the ostium, the implant may be transported through normal physiologic channels in the paranasal sinuses. Many case reports exist in the literature showing the long-term effects of dental implants not retrieved, including chronic rhinosinusitis, fungal infections, and neoplastic changes (Fig. 10.30).[82,83]

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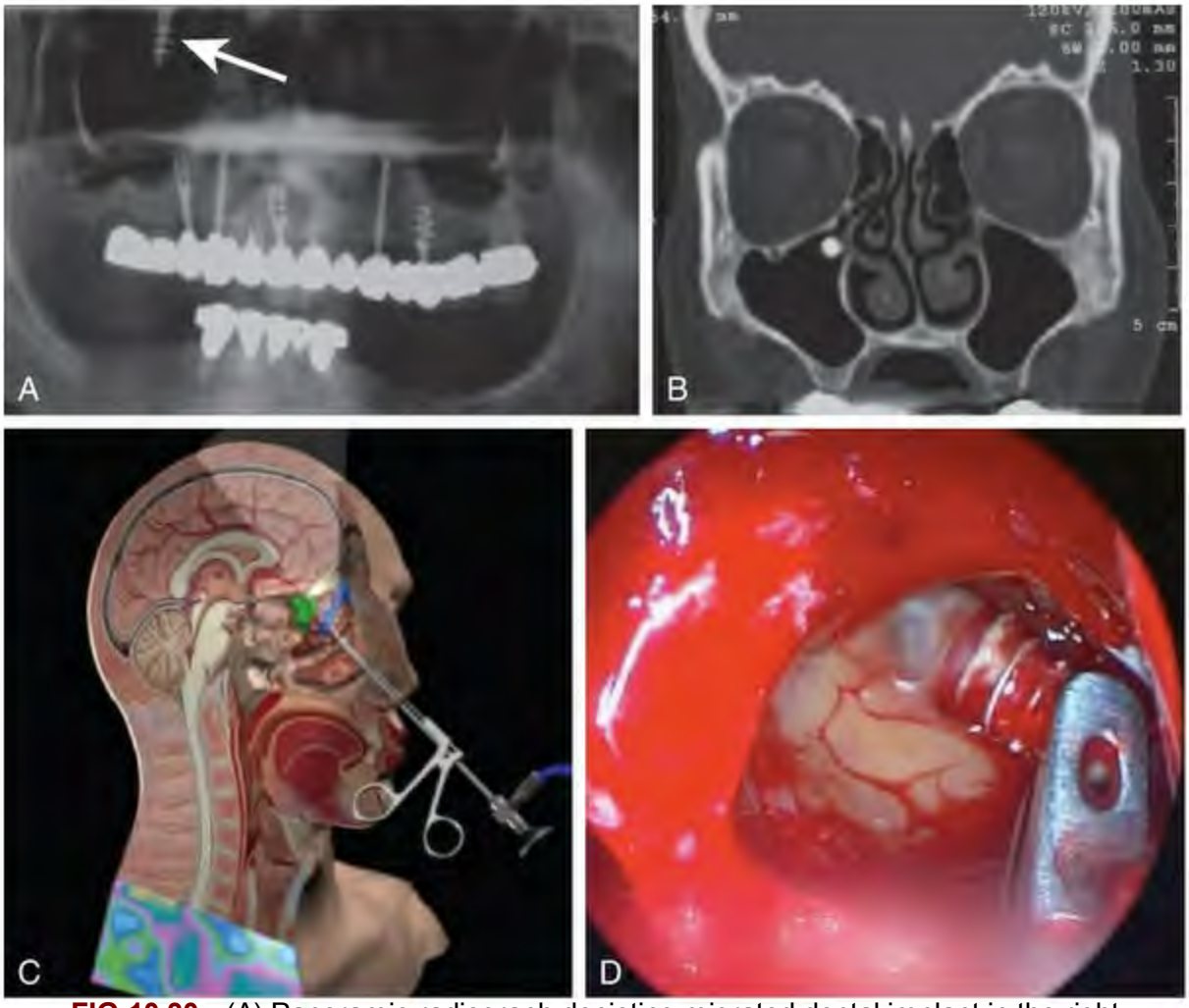

FIG 10.30 (A) Panoramic radiograph depicting migrated dental implant in the right sinus. (B) Coronal image showing implant in the maxillary ostium area. (C) Functional endoscopic sinus surgery (FESS) approach to retrieve implant. (D) Removal of implant from sinus cavity. (From Chiapasco M, Felisati G, Maccari A, et al: The management of complications following displacement of oral implants in the paranasal sinuses: a multicenter clinical report and proposed treatment protocols. *Int J Oral Maxillofac Surg* 38(12):1273–1278, 2009.)

Displacement of Implants: Mandible

Although uncommon, implants may be displaced and migration may occur in the mandible. This may occur from two mechanisms: (1) sublingual osseous undercuts and (2) focal osteoporotic bone marrow defects (Fig. 10.31A).

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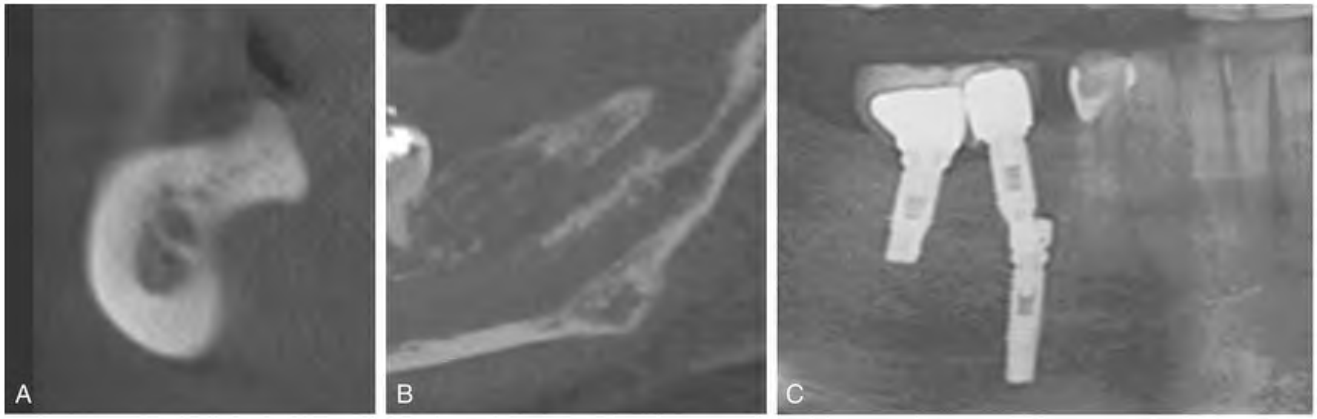

FIG 10.31 Mandibular displaced implants. (A) Sublingual posterior undercut. (B) Poor bone quality (marrow spaces). (C) Mandibular implant displaced into sublingual space.

Sublingual Undercuts

Because of the inherent sublingual undercuts in the posterior mandible, dental implants may be placed that result in a lack of bone for initial fixation of the implant. Due to the lack of fixation, the implant becomes displaced into the sublingual space. To prevent the mandibular displacement, the osseous contours of the bone should be evaluated with three-dimensional radiography (Fig. 10.31B). Because of these sublingual undercuts, implants are often contraindicated when these conditions are present.

Focal Osteoporotic Bone Marrow Defects

In middle-aged women, radiolucent lesions may be present, usually in the molar area, that are associated with a higher risk of implant displacement. The defects are generally asymptomatic and are mainly determined during CBCT evaluation of the posterior mandible. They are isolated or multifocal radiolucencies, several millimeters to centimeters in diameter, with ill-defined borders. Most cases are seen in edentulous sites (Fig. 10.31C).[84–86]

Migration of Allograft

Seok et al reported on a lateral wall sinus graft into a maxillary sinus with active infection. The allograft was completed with a known membrane perforation and preexisting maxillary sinus pathology. Shortly after the surgery the patient reported a submandibular swelling, which required the removal of the submandibular gland. Upon biopsy the submandibular lymphatic vessels contained bone graft material that originated from the

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maxillary sinus. It was concluded the graft material migrated from the maxillary sinus to the submandibular lymph nodes through the lymphatic vessels. The maxillary sinus lymphatic vessels drain through the natural ostium and via the nasal lymphatic vessels into the submandibular lymph nodes (Fig. 10.32A).[87] Treatment included the complete removal of the submandibular gland.

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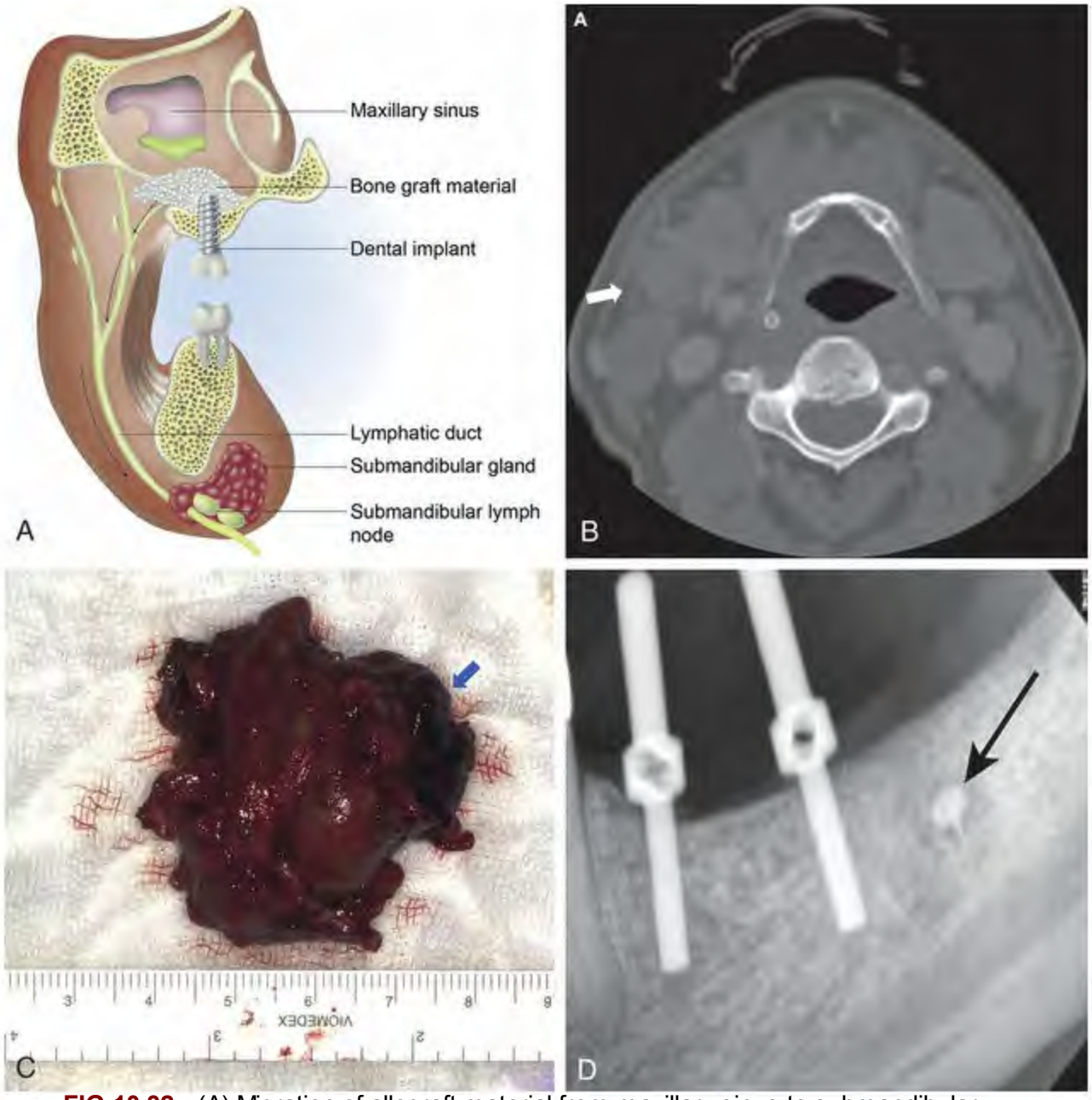

FIG 10.32 (A) Migration of allograft material from maxillary sinus to submandibular gland via lymphatic vessels. (B) Axial radiographic findings depicting enlarged submandibular lymph nodes *(arrow)*. (C) Macroscopic view of the removed right submandibular gland and lymph nodes. Necrotic changes in the lymph nodes were observed *(arrow)*. (D) Periapical radiograph depicting lack of fixation and radiolucency of the tack migrating posteriorly *(arrow)*. (A–C, From Seok, Hyun, et al: Migration of alloplastic bone graft material in infected conditions: a case study and animal experiment. *J Oral Maxillofac Surg* 72(6):1093, 2014.)

Bone Graft Tack Migration

Bone tacks are often used to fixate membranes, usually in combination with bone grafting procedures. In many instances, to minimize tissue trauma in

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removing the tacks, they are left in place after implant placement. Unfortunately, tacks can separate from the bone and migrate within the soft tissue and fascial spaces (Fig. 10.32B–C).[88] Therefore, it is recommended to remove the fixation tacks after bone healing is complete.

Migration of Dental Materials

When extracting maxillary molar teeth, care should be exercised to minimize the possibility of extruding material (e.g., impression material, reline material) in the maxillary sinus via an oral-antral communication. When oral-antral communication exists, dental materials that may be inadvertently extruded into the sinus proper. When this occurs, the material will become calcified within the maxillary sinus from the deposition of salt around the foreign body. The resultant calcified mass is an *antrolith*, which is a common cause of chronic rhinosinusitis (Fig. 10.33).[89]

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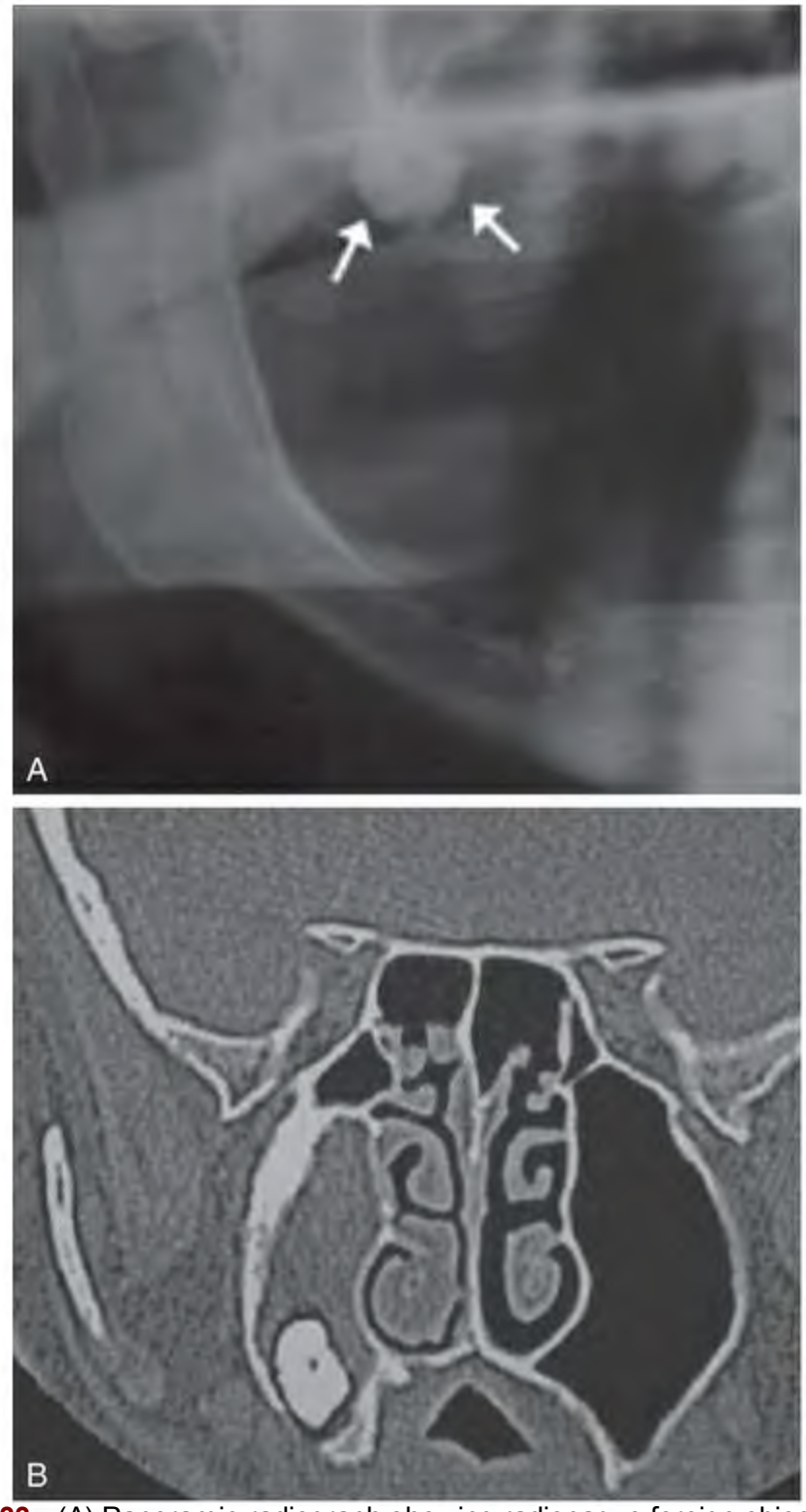

FIG 10.33 (A) Panoramic radiograph showing radiopaque foreign object in right maxillary sinus. (B) Coronal view depicting foreign body (reline material) and radiopaque maxillary sinus. (Evren OK, et al: Evaluation of the relationship between the maxillary posterior teeth and the sinus floor using cone beam computed tomography, *Surg Radiol Anat* 36:907–914, 2014.)

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Etiology

After extraction there are two main causes of material being introduced into the maxillary sinus. When an impression is taken or when a prosthesis is relined, if the clinician unknowingly places significant pressure upon seating the impression tray or prosthesis, the material, especially if it has low viscosity, may flow into the sinus via a communication. With respect to individual teeth, the first molar is the most common tooth to have roots in approximation to the sinus cavity. Studies have shown the palatal and mesiobuccal root to be in contact or perforating into the maxillary sinus approximately 66% of the time.[90] Therefore, after removal of the maxillary first molar, there is a high probability of communication with the maxillary sinus and special caution should be exercised prior to impression completion.

Prevention

When mixing the reline or impression material, an increased viscosity should be used as this will decrease the possibility of intrusion of material into the maxillary sinus (See Box 10.3 and Fig. 10.34).

FIG 10.34 (A) Special caution should be used when relining a prosthesis after maxillary posterior extractions as reline may be extruded into sinus cavity proper. (B) Ideal mixture consistency for reline material. (C) Final relined prosthesis.

Treatment

If reline material or any other type of dental material is extruded into the sinus, the patient should be referred to an otolaryngologist for evaluation and removal of the material. Patients should always be informed of this complication and the importance of removal.

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Summary

When a clinician completes implant therapy with a patient, regardless of the phase involved, it is paramount that follow-up care be continued. As described in this chapter, postsurgical complications may arise even in the best of initial operative situations. Prosthetic complications are also of concern, which necessitates a comprehensive follow-up program. The implant clinician who is aware of potential postoperative complications in all phases of implant therapy will be ready to treat any situation in a rapid and competent manner. An understanding of the necessity of maintaining close communication with the patient throughout the entire treatment process is crucial. Knowing the potential for these complications beforehand and communicating them to the patient, along with a using a strong follow-up protocol, gives the patient further confidence in the clinician should any circumstance arise. This is beneficial to reduce stress for the implant clinician and the patient, which minimizes the chances of medicolegal issues.

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Wound Dehiscence

Incision Line Opening

Jon B. Suzuki, Randolph R. Resnik

Primary soft tissue closure is a mandatory condition for the success of implant and grafting procedures. It ensures healing by primary intention and requires minimal soft tissue collagen formation and soft tissue remodeling, which minimizes postoperative discomfort. Incision line opening (ILO) is one of the most common complications resulting from dental implant surgery, occurring when a wound dehisces along a suture line (Fig. 11.1).

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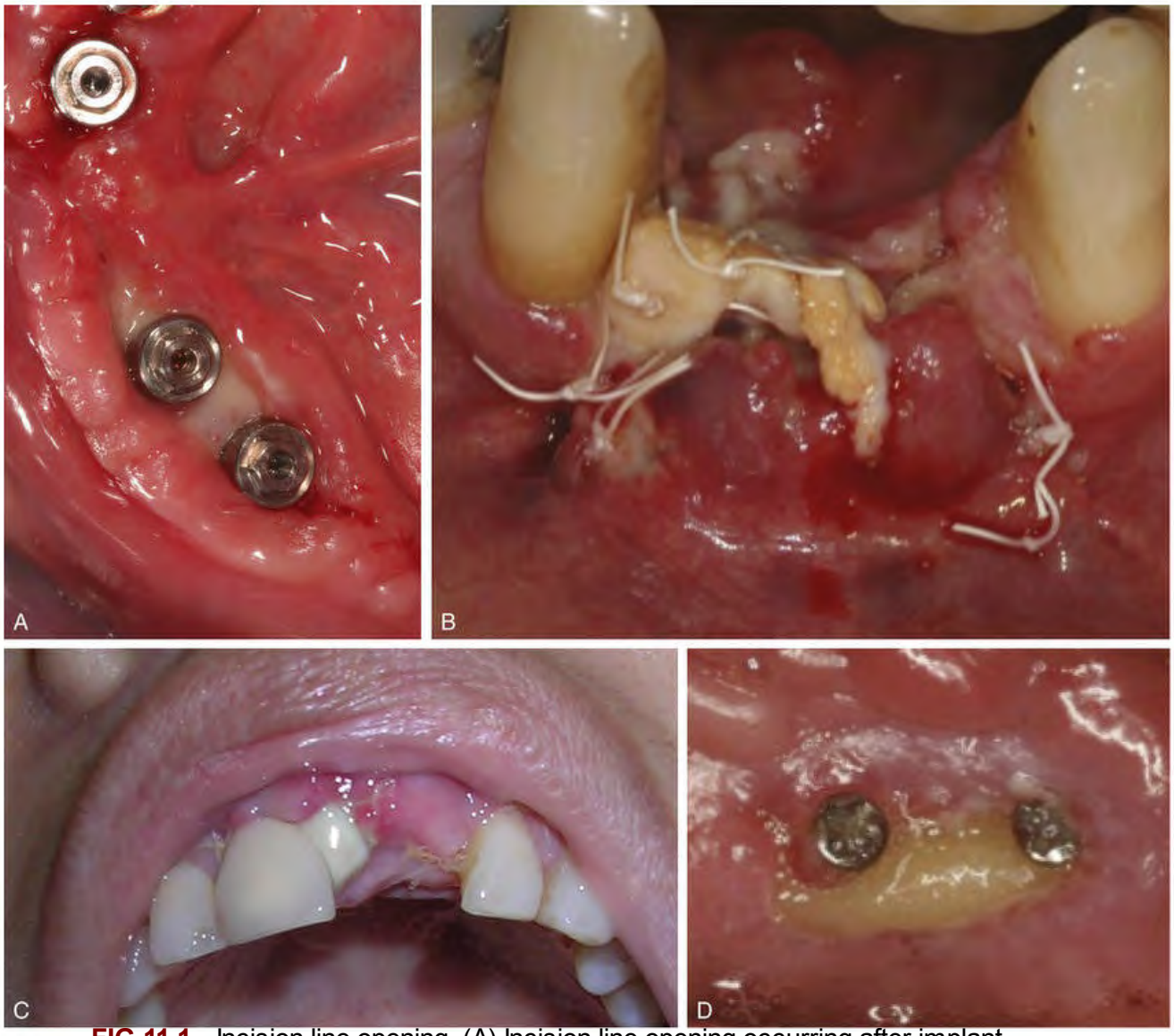

FIG 11.1 Incision line opening. (A) Incision line opening occurring after implant placement. (B) Post allograft incision line opening. (C) Membrane graft dehiscence. (D) Block graft with fixation screw exposure.

The prevalence of ILO has been shown in studies to range from 4.6% to 40% around submerged implants.[1,2] In a study by Mendoza, 37% had no ILO, while 43% had partial ILO, and 20% had complete incision line opening.[3] Soft tissue dehiscences (30%) have been shown to occur around membranes (barriers) when placed as part of guided bone regeneration procedures (GBR).[4] Therefore, incision line opening is a common postoperative complication after dental implant and bone grafting surgery. In this chapter the etiologic factors, prevention, and management of incision line opening will be discussed along with a treatment protocol that is procedure and time specific.

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Classification of Incision Line Opening Complications

When placing root form implants with a two-stage approach, spontaneous early exposure of submerged implants has the potential for complications that may affect healing and osseointegration of the implants. A classification and nomenclature system for these exposures is useful for communication and record keeping. Clinical wound opening has been categorized by Tal et al (Box 11.1 and Fig. 11.2).[2]

Box 11.1

Clinical Wound Opening Categories[2]

Class 0: The mucosa covering the implant is intact (see Fig. 11.2A).

Class 1: A breach in the mucosa covering the implant is observed. Oral implant communication may be detected with a periodontal probe, but the implant surface cannot be observed without mechanically interfering with the mucosa (see Fig. 11.2B).

Class 2: The mucosa above the cover screw is fenestrated; the cover screw is visible. The borders of the perforation do not reach or overlap the borders of the cover screw (see Fig. 11.2C).

Class 3: The cover screw is visible. In some areas of the cover screw the borders of the perforation aperture overlap the borders of the cover screw (see Fig. 11.2D).

Class 4: Cover screw is completely exposed. When exposure was detected or observed (Class 1 through 4), the patient was instructed to clean the exposed site by gently rubbing the mucosa with gauze soaked in 0.2% chlorhexidine solution twice daily (see Fig. 11.2E).

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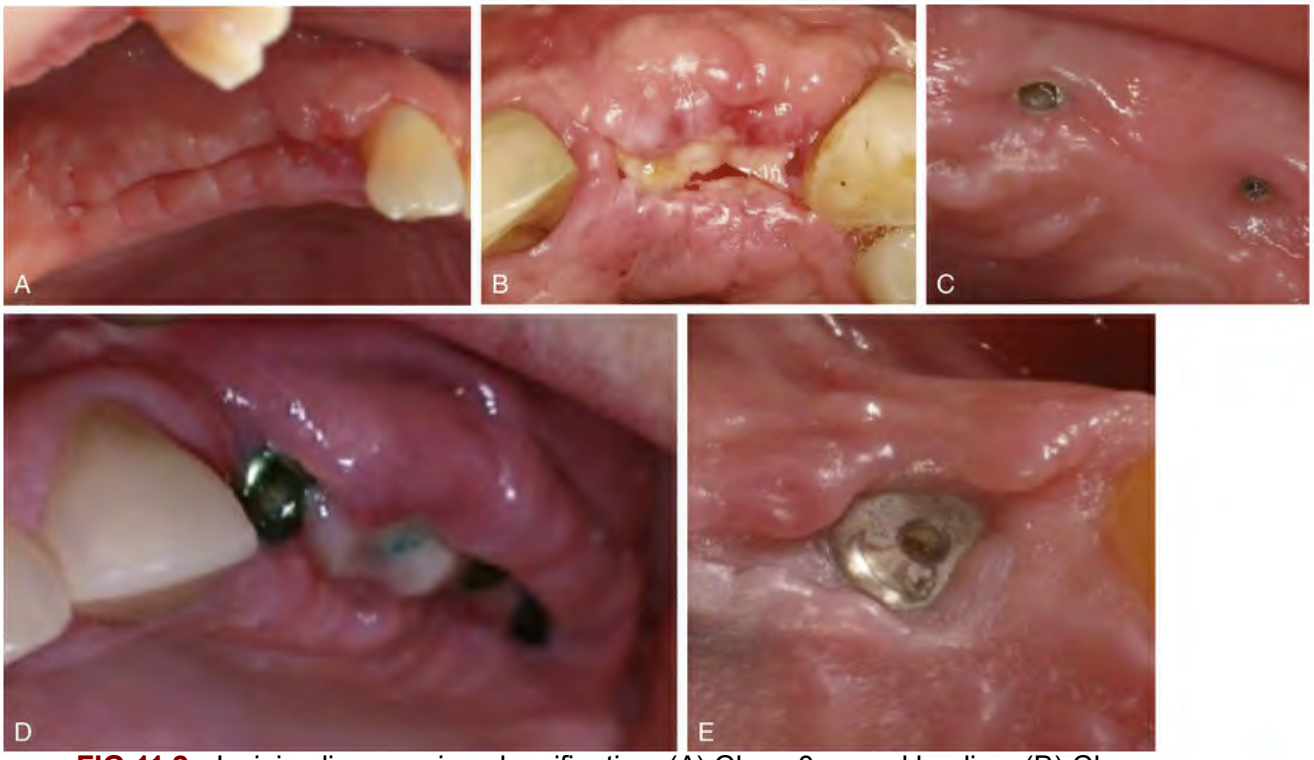

FIG 11.2 Incision line opening classification. (A) Class 0 wound healing. (B) Class 1 wound opening. (C) Class 2 wound opening. (D) Class 3 wound opening. (E) Class 4 wound opening.

Considering that spontaneous early exposures are complications that can potentially lead to mucositis or peri-implantitis, Barbosa proposed classification for spontaneous early exposure of submerged implants based on diagnostic methods and treatment modalities to prevent or intercept such complications. They suggested that implants with spontaneous exposure should immediately be surgically exposed as early as possible to prevent mucositis. A healing abutment should be placed after the cover screw is removed (Fig. 11.3).[5]

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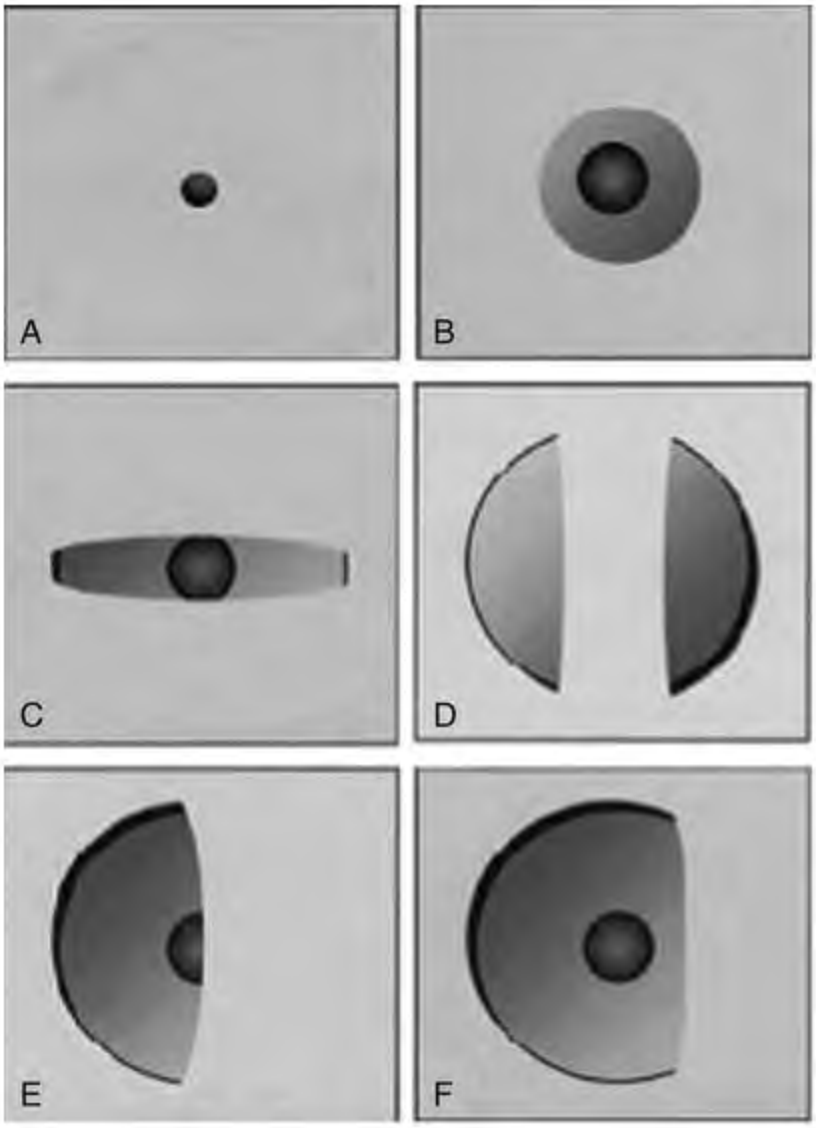

FIG 11.3 Barbosa Incision Line Opening Classification. (From Barboza EP and Caula AL: Diagnoses, clinical classification, and proposed treatment of spontaneous early exposure of submerged implants, *Implant Dent* 11(4):331–337, 2002.)

Morbidity Consequences of ILO With Implants and Bone Grafting

The resultant consequences of ILO can vary depending on the type of implant or bone grafting procedure. For implant placement with good initial fixation, primary closure is favored for one-stage surgery with placement of a permucosal abutment. For bone augmentation procedures, primary closure is of paramount importance for clinicians when performing GBR techniques and autogenous onlay grafting procedures. When incision line opening occurs during autogenous block grafting, there tends to be a greater

potential for delayed healing, loss of graft particles into the oral cavity, and increased risk of infection.

Exposure of nonresorbable membranes add additional risk of infection and unsatisfactory results. If guided bone regeneration is performed in conjunction with implant placement, ILO may also lead to loss of the implant. ILO most likely will result in a bacterial smear layer on the implant body, which may inhibit bone formation. Bone resorption resulting from infection may require implant removal. The same degree of ILO, without simultaneous implant placement, could possibly be managed and compensated for by bone expansion, use of slightly narrower implants, increased number of implants, and/or additional augmentation.

Immediate Implants

Dental implants have become an accepted treatment modality with immediate placement into fresh extraction sockets. ILO is typically not an issue when implants are placed in intact sockets with minimal voids because primary closure is not necessary. Situations where implants are placed in nonintact sockets concomitant with bone grafting would be classified according to the dimension and architecture of osseous defects (similarly to delayed implant placement). ILO in alveolar ridges with combined implant placement and significant augmentation may be more vulnerable to compromised outcomes.

Esthetic Consequences

In addition, ILO can negatively affect esthetic clinical outcomes. The placement of implants simultaneous with regenerative procedures adds the risk of a functional and esthetically compromised result. For multistage bone augmentation procedures, primary soft tissue healing allows for most predictable outcomes. Incision technique, flap design, soft tissue handling, and avoidance of transitional prosthesis pressure are key factors in avoiding ILO.

Postoperative Care

Wound dehiscence may be associated with increased discomfort and the need for closer monitoring. More postoperative appointments are required. These are financially nonproductive and negatively impact practice profitability. Some patients may seek care or a second opinion due to loss of

confidence in the primary clinician. The lack of knowledge or experience on behalf of the secondary clinician can potentially lead to legal action against the primary treating doctor. When ILO occurs, the clinician should be proactive in follow-up care and educating the patient on the complication consequences.

Classification and Types of Wound Healing

Wound healing is an intricate process in which the body's tissue repairs itself after injury (surgical wound). Despite having similar healing mechanisms, it is generally observed that wounds in the oral mucosa heal faster and with less scarring than extraoral wounds.[6]

Phases of Wound Healing

Surgical wound healing, whether by normal or delayed healing, will occur in three phases. Wound healing is not a linear process; rather it progresses differently depending on many patient-related factors. The three phases of wound healing are (1) inflammatory phase, (2) proliferation phase, and (3) maturation phase.

Inflammatory Phase.

The inflammatory phase is the body's natural response to a surgical injury. It is characterized by a vascular and inflammatory response including local vasoconstriction for the first 5 to 10 minutes followed by a local vasodilatory response. This phase takes place the first few days after injury.

Within the first few minutes after injury, platelets adhere to the site, become activated, and aggregate. These events are followed by activation of the coagulation cascade, which forms a clot of aggregated platelets in a mesh of cross-linked fibrin protein. The blood vessels in the wound bed contract, forming a clot, which promotes hemostasis. The clot formed has two functions: it temporarily protects the denuded tissues and serves as a provisional matrix for cell migration.

The blood clot consists of cellular components of blood (including red and white blood cells and platelets) in a matrix of fibrin, plasma fibronectin, vitronectin, and thrombosporin.[7] Once hemostasis is achieved, dilation of the blood vessels will result, allowing white blood cells, growth factors, antibodies, enzymes, and nutrients to invade the surgical wound. At this stage the characteristic signs of inflammation may be seen: erythema, heat,

edema, pain, and functional disturbances. At the cellular level, neutrophils and macrophages will initiate a host response, which will lyse and devitalize the necrotic tissue. The strength of the wound relies mainly on the integrity of the fibrin clot. Bacteria and cell debris are phagocytized and removed from the wound by white blood cells.[8]

Proliferation Phase.

The proliferation phase is characteristic with the formation of new granulation tissue, which is mainly comprised of collagen and extracellular matrix. The proliferation phase begins within 24 hours after injury and may last 3 to 12 days. It is characterized by angiogenesis, collagen deposition, granulation tissue formation, epithelialization, and wound contraction. Epithelialization may be completed in 24 to 48 hours in primary closed wounds or delayed for 3 to 5 days in wounds healing by secondary intention. In angiogenesis, vascular endothelial cells form new blood vessels. In fibroplasia and granulation tissue formation, fibroblasts grow and form a new, provisional extracellular matrix (ECM) by excreting collagen and fibronectin. Concurrently, reepithelialization of the epidermis occurs, in which epithelial cells proliferate and migrate over the wound bed, providing cover for the new tissue.

For healthy granulation tissue to form fibroblasts, there must be adequate levels of oxygen and nutrients available, which are supplied by the blood vessels. Characteristics of healthy granulation tissue include a granular and uneven surface that is pink and does not bleed easily. Epithelial cells will begin to resurface on the surgical wound, which is termed *epithelialization*.

Maturation Phase.

Maturation phase is the final phase in the healing process and occurs when the wound has closed. The remodeling of collagen from type III to type I will occur. During wound contraction, myofibroblasts decrease the size of the wound by gripping the wound edges and contracting, using mechanisms that resemble smooth muscle cell contraction. The wound scar gains strength and volume, and erythema decreases. Complete scar maturation and final tensile strength generally take 12 to 18 months. When the cells' roles are close to complete (no longer needed), they are removed by apoptosis.[9] During maturation and remodeling, collagen is remodeled and realigned along tension lines. There will also be a reduction in the cellular activity as well as

the number of blood vessels (Fig. 11.4).[10,11]

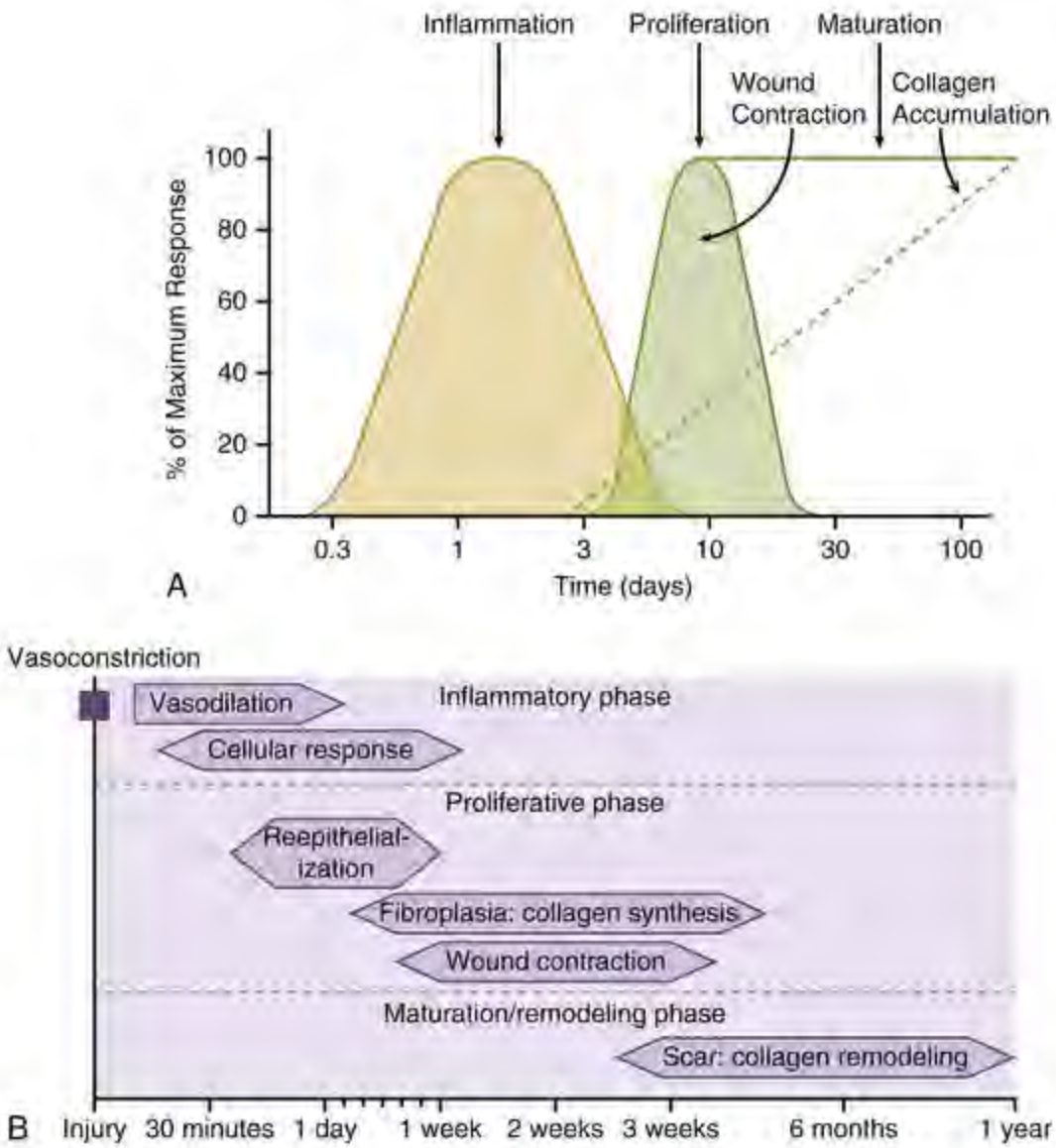

FIG 11.4 (A–B) Time-related phases of wound healing showing various components of the healing process.

Knowledge of the healing rates of the soft and hard tissues is useful to determine if a patient is healing on schedule. The time for wound repair subsequent to surgery is tissue specific:

Epithelium: heals at a rate of 0.5 to 1 mm per day (after a 12-hour lag time)

Connective tissue: heals 0.5 mm per day

Bone: heals at a rate of 50 μm per day, 1.5 mm per month

Mucoperiosteal flap: adheres to bone (or soft tissue flap) by a fibrin clot (0 to 24 hours).[12]

Types of Wound Healing

With respect to wound healing, there exist three types: (1) primary intention, (2) secondary intention, and (3) tertiary intention.

Primary Intention.

With few exceptions, surgical procedures for dental implantology involve surgical flaps, which ideally result in healing by primary intention. Healing by primary intention results when the wound edges are approximated and stabilized by sutures. Soft tissue flaps are usually maintained in positions that are "passive" and tension free. A common complication resulting in incision line opening is for the clinician to utilize sutures to actively reposition mucoperiosteal flaps. This may result in excessive tension placed on the flaps and may lead to ischemia and flap necrosis, which will usually result in incision line opening.

Achieving the goal of primary intention for closure will allow for hemostasis, less potential for infection and bone necrosis, along with improved patient comfort. When ILO occurs, the only way for the wound to heal is via secondary intention, which may lead to increased morbidity.

Wound healing is a complex and intricate process where the skin or tissues repair after injury. In the case of normal skin, the epidermis and dermis exist in a steady-state of equilibrium, forming a protective barrier against the external environment. Once the protective barrier is broken, the physiologic process of wound healing is immediately set in motion. The general principles of healing and the cellular and molecular events observed in extraoral sites also apply to healing processes that take place following oral surgical procedures.[13]

Secondary Intention.

When wounds dehisce or ILO has occurred, the wound undergoes healing by secondary intention. Secondary intention is healing by the body's natural mechanisms, without surgical intervention. This typically occurs in large wounds with traumatic tissue loss or avulsion, so that wound edges are widely separated and cannot be apposed. Healing occurs by clot formation, granulation, deposition of collagen, and eventual epithelialization. Wound

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contracture brings the wound margins together (Fig. 11.5).

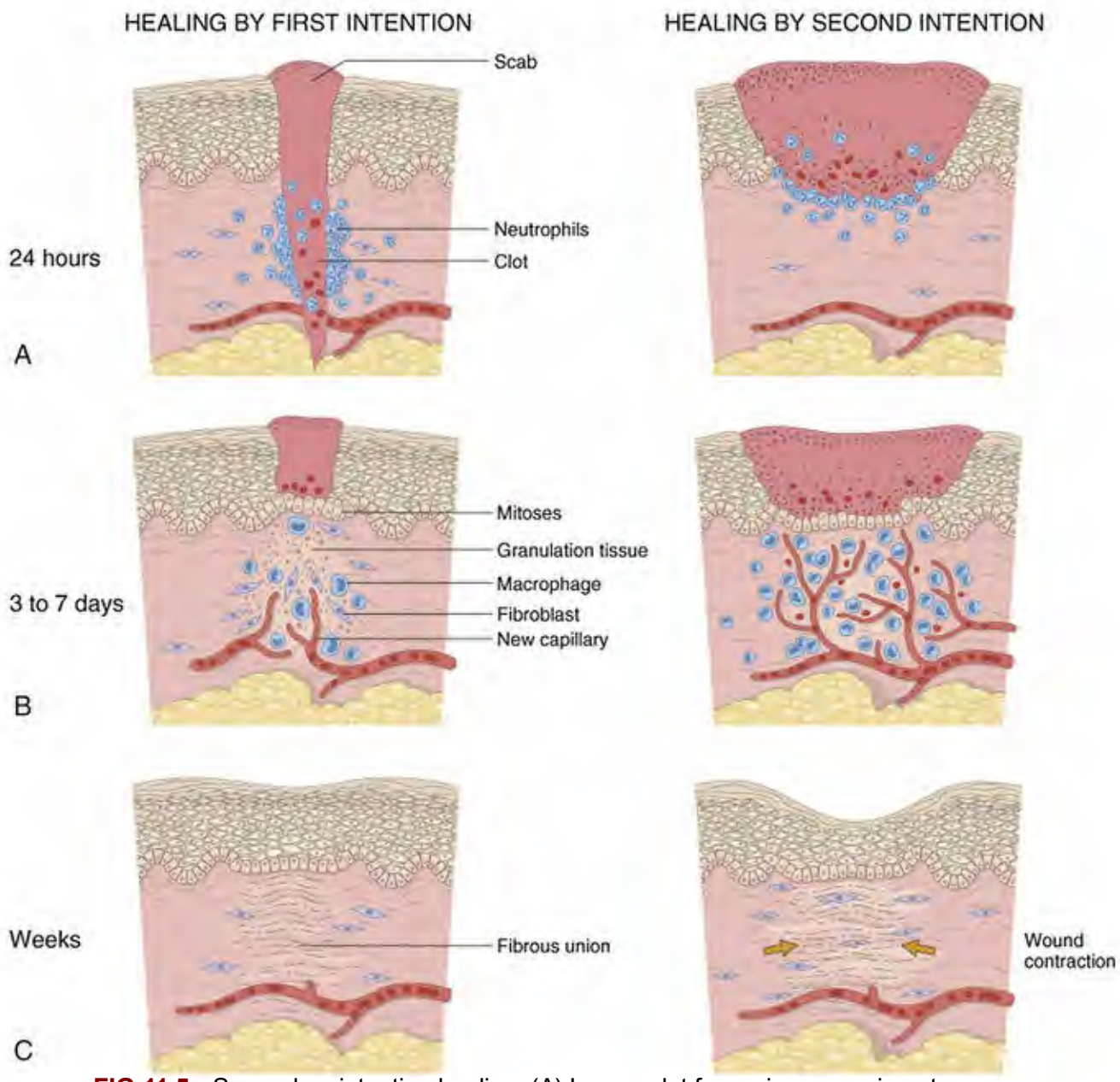

FIG 11.5 Secondary intention healing. (A) Larger clot forms in comparison to primary intention within the first 24 hours. (B) Within 3–7 days, an increase in inflammation, angiogenesis, macrophages, and fibroblasts are present, which result in slower healing in comparison to primary intention. (C) Final healing results in wound contraction. (From Kumar V, Abbas AK, Aster JC: *Robbins & Cotran pathologic basis of disease*, ed 9, Philadelphia, 2015, Saunders.)

Tertiary Intention.

A third type of healing has been described as tertiary intention. Tertiary

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intention healing occurs when primary closure is delayed, allowing the wound to granulate for a short period of time. The wound is then reapproximated manually or by another technique. This method has been termed *delayed primary closure* and can be used to debride an infected, acute wound prior to closure.[14] This type of healing is uncommon with respect to dental implants and bone grafts.

Factors That Affect Wound Healing/Incision Line Opening

Saliva

As concluded by animal studies, wound healing in oral mucosa is faster and results in less scarring in comparison to extraoral sites. Oral wound healing is enhanced by factors present in saliva and by specific microflora of the oral cavity.[15] Additionally, the properties of cells involved in tissue regeneration in oral mucosa are unique and share properties of fetal cells.[16] The observations suggest that several cell functions important in tissue repair are shared by fetal and gingival fibroblasts, which differ from dermal fibroblasts.

Gingival fibroblasts are phenotypically unique cells in adult tissue and may contribute to the rapid healing of oral wounds with minimal scarring in the gingiva. It is also apparent that saliva provides a unique environment in the mouth conducive to rapid tissue repair. Reports indicate delayed healing of oral wounds in patients with xerostomia or sialadenectomized animals.[17]

There are several physicochemical factors in saliva that favor gingival wound healing. These include appropriate pH, ionic strength, and presence of ions such as calcium and magnesium required for healing. Lubrication of oral mucosa provided by saliva is also beneficial for wound healing.

The advantageous effects of maintaining a moist wound environment include prevention of tissue dehydration and cell death, accelerated angiogenesis, and increased breakdown of fibrin and tissue debris. The use of hydrocolloid occlusive dressings may facilitate cutaneous wound healing. Saliva-treated wounds undergo shorter inflammatory reactions and faster epithelial coverage, as well as faster connective tissue regeneration. Moisture and ionic strength may be primary factors in saliva that promote tissue repair and are important for overall wound healing. This potential is probably due to the presence of several elements in saliva including growth factors and bacteria.[18]

Treatment Implications

Saliva is advantageous for wound healing. Patients who exhibit xerostomia or salivary gland disorders are predisposed to wound healing complications. Salivary substitutes and more frequent recall examinations are warranted.

Bacteria

The oral cavity harbors larger numbers of bacteria, with over 500 bacterial species having been identified in the oral cavity. It is clear that bacteria affect wound healing in the oral cavity, and it is well established that wounds colonized by pathogenic bacteria have delayed healing.[19] Clinicians are aware of painful complications in extraction wound repair that result from bacterial infection.

It is well recognized that small concentrations of bacteria may increase rates of wound healing. In 1921, Carrel reported that wounds of dogs treated with selected concentrations of *Staphylococcus aureus* healed faster than untreated wounds. Several studies have confirmed the observation using other bacterial species. Larjava found that proliferation of gingival fibroblasts in culture was increased by *Prevotella intermedius* but decreased with similar concentrations of *Porphyromonas gingivalis*.[20] Interestingly, there was great variation in this effect between fibroblast populations obtained from different patients. These findings imply that the potential for periodontal repair depends both on bacterial flora and the individual cell populations of periodontal wounds.

Treatment Implications

Wound healing may be delayed and directly influenced by bacteria type. The use of the antimicrobial 0.12% chlorhexidine rinses is advantageous to decrease bacterial induced incision related issues. Additionally, the use of systemic prophylactic antibiotics should be utilized during the pre- and postoperative treatment phase.

Systemic Diseases

Systemic diseases are a vital component of treatment planning and implant therapy. Specific systemic diseases and conditions affect wound healing and bone metabolism, either of which can have a direct impact on the success of implant therapy. Diabetes mellitus is a major endocrine disorder commonly reported by approximately 10% patients. With diabetes-associated insulin deficiency or metabolism defects, glucose remains in the bloodstream and increases blood glucose levels. Diabetic patients are at risk to develop infections and vascular complications. The healing process is affected by impaired vascular function, impaired cell chemotaxis, and impaired

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neutrophil function. Protein metabolism is decreased, and healing of soft and hard tissue is delayed. Nerve regeneration is altered, and angiogenesis is impaired.

Many non–life-threatening diseases and conditions require medications for definitive management or control of potential wound healing complications. Common examples include anticoagulants, immunosuppressants, and bisphosphonates. Bleeding problems encountered when incising and reflecting tissue for passive closure may be complicated by anticoagulants.

However, given the potential life-threatening complications of discontinuing anticoagulants such as warfarin, this is usually not recommended as long as the therapeutic drug levels are within normal limits. However, special attention must be devoted to good surgical technique and use of appropriate local hemostatic measures to control bleeding.

Two classes of immunosuppressants frequently prescribed for patients are glucocorticoids (e.g., prednisone) and cytostatics (chemotherapeutic agents). The negative impact of these medications on wound healing can be mitigated by appropriate patient selection, timing of treatment, and medical consultation.

Bisphosphonates can also lead to wound dehiscence following surgery. These drugs act by suppressing and reducing bone resorption by osteoclasts and are used to treat bone disorders including osteoporosis, metastatic bone cancer, and Paget disease (JBS figures on bone metabolism). After surgery involving the jaws, bone exposure may develop rather than the normal soft tissue closure healing mechanisms.[21] This is common with more potent nitrogen-containing intravenous bisphosphonates, and the prevalence is lower with oral bisphosphonates.[22] However, the clinician must be able to differentiate bone exposure of this bisphosphonate origin and insufficient flap closure or postextraction bony spicule formation.

Treatment Implications

Systemic diseases play a significant role in the healing process after dental implant and bone-grafting procedures. The most common systemic disease that affects healing is diabetes, which, if uncontrolled, may lead to significant postoperative healing issues. Additionally, many medications including anticoagulants, immunosuppressants, and bisphosphonates may increase the risk of surgical wound healing. This underscores the importance of a thorough medical consultation prior to any implant surgical procedure.

Local/Lifestyle-Related Factors

Smoking

In the United States, approximately 45 million adults and 21% of the population smokes cigarettes. Approximately 23% of men and 19% of women smoke cigarettes. Tobacco use has been implicated in many adverse systemic outcomes, including tooth loss and dental implant failure.[23] In fact, the entire stomatognathic system suffers from the effect of tobacco byproducts.

Tobacco smoke decreases polymorphonuclear leukocyte activity, resulting in lower motility, a lower rate of chemotactic migration, and reduced phagocytic activity. These conditions contribute to a decreased resistance to inflammation, infection, and impaired wound healing potential.[24]

Smoking is also associated with decreased calcium absorption. Additional findings demonstrate a reduced mineral content in the bone of aging smokers and, to a greater degree, in postmenopausal female smokers. The association of tobacco with intraoral carcinoma is well recognized.

When incision line opening after surgery occurs, smoking delays secondary wound healing, may contaminate bone grafts, and contributes to early bone loss during healing. Treatment planning for any type of dental implant surgery should emphasize the need for smoking cessation protocols.

Alcohol Use

Ethyl alcohol is one of the most widely used mood-altering drugs in the world. More than 95% of smokers also drink alcohol. Alcoholism has been associated with diseases such as liver and metabolic dysfunction, bone marrow suppression resulting in bleeding complications, predisposition to infection, and delayed soft tissue healing.[25] The direct effect on bone includes decreased formation, increased resorption, decreased osteoblast function, decreased wound healing, and increased parathyroid hormone secretion, which leads to lower bone density. However, it has been shown that withdrawal of alcohol can reverse the negative effects on osteoblast function in a matter of days.[26] Additionally, the use of alcohol immediately after surgery may predispose the surgical wound to decreased healing.

Obesity

Obesity is a major challenge for health care personnel caring for these patients. Obesity is a chronic disease, emerging as a major epidemic public

health problem. In 2008, 35% of adults (age 20+) were overweight (body mass index [BMI] ± 25 kg/m^2), and the prevalence of obesity (BMI ≥30 kg/m^2) has doubled since 1980, affecting an estimated 502 million people.

In general, obese patients are at increased risk for wound healing complications such as seroma, hematoma, infection, and wound dehiscence. Cardiovascular problems associated with this condition may contribute to ischemia by providing insufficient oxygen and nutrients to the tissue, which may lead to tissue necrosis.

Respiratory issues may impair vital capacity and tidal function, which by compromising tissue oxygenation may adversely affect wound healing. The higher incidence of infection and the likelihood of other concomitant chronic nonhealing wounds may diminish immune and healing responses. Oral wound healing may also be affected by obesity.[27] Suvan and coworkers found that BMI and obesity appeared to be independent predictors of poor response following periodontal therapy.[28] In addition, technical difficulties in operating on obese patients, including extended operating times, may increase risk of wound contamination. Because of patient positioning, airway complications may result.

Treatment Implications.

Lifestyle-related issues such as alcohol use and smoking may decrease wound healing after dental implant and bone grafting procedures. It is imperative the patient be informed that these lifestyle issues may lead to slower wound healing and an increased possibility of incision line opening. Additionally, physical characteristics may predispose the patient to complication related issues.

Periodontal Biotype

Although some studies report minimal long-term effects of tissue biotype on bone grafting and implant success, thicker biotypes may prevent tissue breakdown or tears during suturing. Tissue augmentation should be considered for patients with preexisting thin tissue biotypes. With thick biotype tissue, there exists more keratinized tissue, which results in better healing, easier suturing, and less likelihood of wound breakdown.

Treatment Implications

The patient's tissue biotype should always be evaluated prior to surgery.

Patients with a thin biotype may need soft tissue augmentation prior to or in conjunction with dental implant and bone grafting procedures. Patients with compromised tissue biotypes may predispose the patient to esthetic related issues, especially if located in the esthetic zone (e.g., maxillary anterior).

Postoperative Issues

Despite meticulous surgery, deliberate or accidental behavior patterns by patients may contribute to incision line opening. Failure to modify the diet to a soft consistency or attempted visualization of surgical sites may traumatize or place increased tension on the incision, resulting in incision line dehiscence. It is also paramount that the clinician modify any transitional prosthesis that may come in close approximation with an incision line, while also advising the patient on the proper use of these prostheses, which may include cessation early in the healing process. Poor decision making with these postoperative issues increases the risk of incision line trauma and breakdown.

Treatment Implications

Postoperative instructions should be given in writing and verbally to the patients before and after surgery to ensure compliance. Patients should be educated on the use of denture adhesives in approximation to the surgical wound because this will most likely decrease healing and lead to incision line opening.

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Prevention of Incision Line Opening

Good Surgical Technique

To minimize and promote optimum wound healing and decrease the possibility of incision line opening, the following surgical principals should be adhered to.

Incision in Keratinized Tissue

The primary incision should ideally be located be in keratinized tissue whenever possible. This permits increased wound surface area and a resultant increase in vascularity to the incision. Not only does this reduce the initial intraoral bleeding, it also severs smaller blood vessels and reduces postoperative edema, which may add tension to the incision line. If there is 3 mm or more of attached gingiva on the crest of the edentulous ridge, the incision bisects this tissue. This places half of the attached gingiva width on each side of the incision. If there is less than 3 mm of attached keratinized tissue on the crest, the incision is made more lingually so that at least 1.5 mm of the attached tissue is placed to the facial aspect of the implant. This concept is very important in the posterior mandible because attached tissue is needed to prevent tension and pulling from the buccinator muscle (Fig. 11.6).[29]

FIG 11.6 Incision bisecting attached tissue.

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Broad-Based Incision Design

The apex or tip of the flap should never be wider than the base (e.g., converge from base to the apex). This will maintain adequate vasculature that will prevent ischemic necrosis to the flap, decreasing the possibility of incision line opening. The length of the flap should generally not exceed twice the width of the base. Additionally, the base of the flap should not have significant pressure or be excessively stretched or twisted, which may compromise the blood supply (Fig. 11.7).[30]

FIG 11.7 Flap design showing a broad-based design allowing for minimal tension on the flap.

Allow for Adequate Access

The flap should be large enough to provide adequate visualization of the surgical site and allow for the insertion of instruments to perform the surgical procedure. If the flap is too small, a retractor will not be able to maintain the flap without excessive pressure. Excessive retraction pressure will lead to increased inflammation, which may compromise the healing of the incision line (Fig. 11.8).

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FIG 11.8 Flap should allow for adequate access to decrease tissue trauma with minimal tissue tension.

Vertical Release Incision to Maintain Blood Supply and Decrease Tension on Flap

The blood supply to the reflected flap should be maintained whenever possible. The primary blood supply to the facial flap, which is most often the flap reflected for an implant or bone graft, is from the unkeratinized mobile mucosa. This is especially true where muscles of facial expression or functional muscles attach to the periosteum. Therefore, vertical release incisions are made to the height of the mucogingival junction, and the facial flap is reflected only 5 mm above the height of the mucogingival junction. Both of these incision approaches maintain more blood supply to the facial flap. In addition, incisions and reflection in the mobile alveolar mucosa increase flap retraction during initial healing, which may contribute to incision line opening and may increase risk of scar formation and delayed healing of the incision line as a consequence of reduced blood supply.

Vertical release incisions should not be made over bony prominences (e.g., canine eminence) because this will increase tension on the incision line and may increase the possibility of incision line opening (Fig. 11.9).

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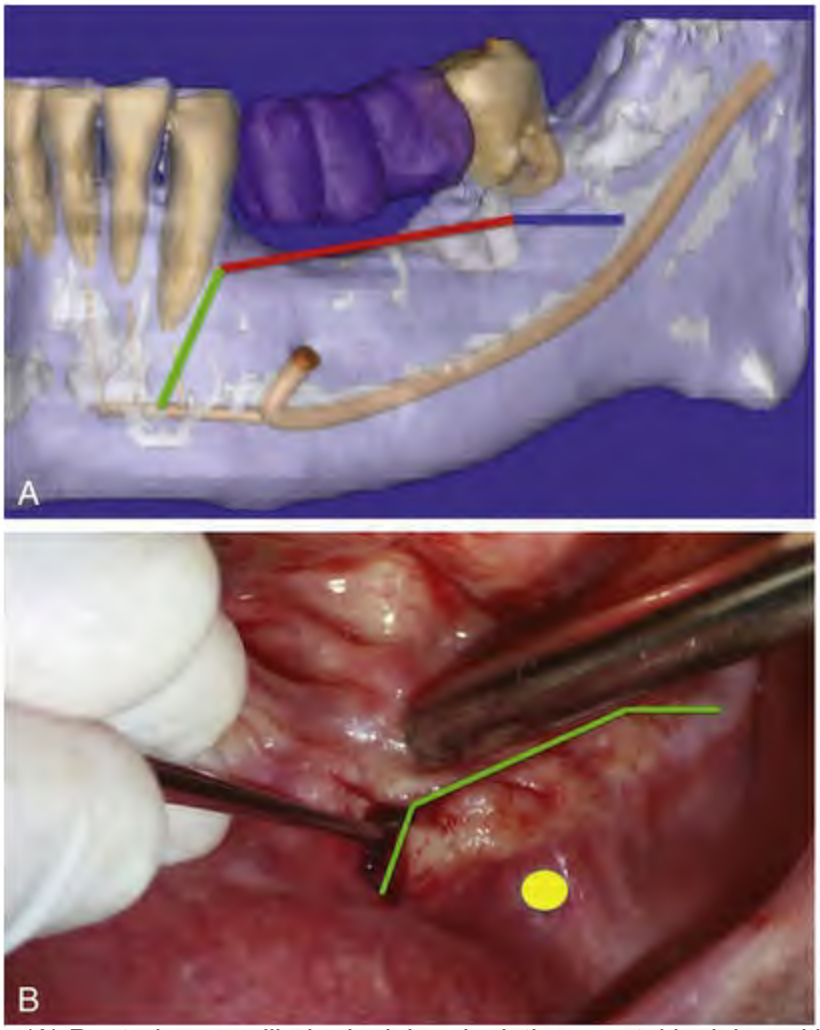

FIG 11.9 (A) Posterior mandibular incision depicting crestal incision with anterior and posterior release. (B) Clinical image of incision in posterior mandible.

Maintain Flap Margins Over Bone

The soft tissue flap design should also have the margins of the wound over host bone whenever possible. This is especially important when approximating tissue over bone grafts or barrier membranes. The host bone provides growth factors to the margins and allows the periosteum to regenerate faster to the site. The margins distal to the elevated flap should have minimal reflection. The palatal flap and the facial tissues distal to the reflected flap should not be elevated from the palatal bone (unless augmentation is required) because the blood supply to the incision line will be delayed. In addition, the unreflected flap does not retract during initial healing, which could place additional tension on the incision line. The soft tissue reflection distal to the graft site may be split thickness to maintain periosteum on the bone around the incision line. This improves the early

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vascularization to the incision line and adhesion of the margins to reduce retraction during initial healing (Fig. 11.10).

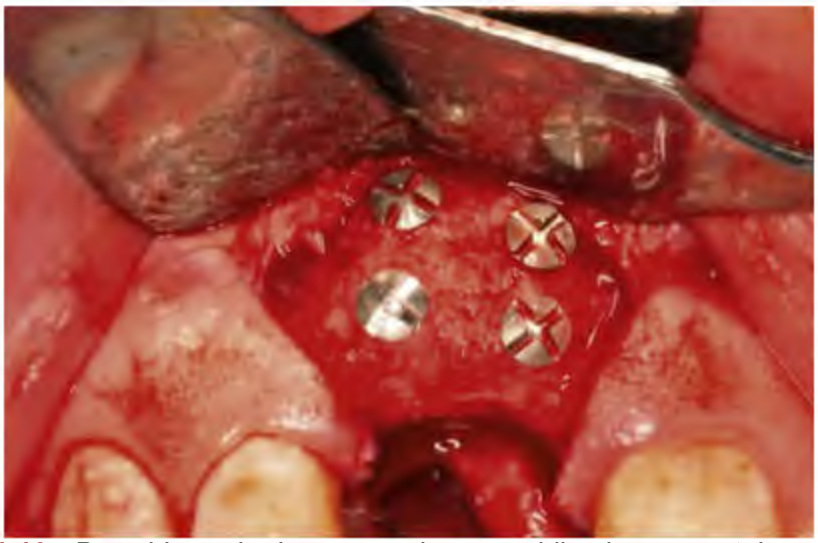

FIG 11.10 Broad-based release over bone avoiding boney protuberances.

Clean, Concise Incision

A clean incision is made through the tissue in one direction with even pressure of the scalpel. A sharp blade of proper size (i.e., #15 blade) should be used to be make clean, concise incisions without traumatizing the tissue from repeated passes or strokes. Tentative strokes, especially in different planes, will increase the amount of damaged tissue and increase the amount of bleeding. Long, continuous strokes are preferable to shorter, inconsistent, and interrupted strokes.[31]

Sharp dissection will minimize trauma to the incision line, which will result in easier closure. Ideally, the incision should always be over bone. Care should be noted of vital underlying nerves, blood vessels, and associated muscles. Scalpel blades dull rather easily, especially when used on bone and tissue with greater resistance. The clinician should change blades when dulling is suspected to decrease tissue trauma.

The incision should be made with the blade held perpendicular to the epithelial surface. This will result in an angle that produces square wound margins that are easier to reorient during suturing and less likely for surgical wound necrosis to occur (Fig. 11.11).

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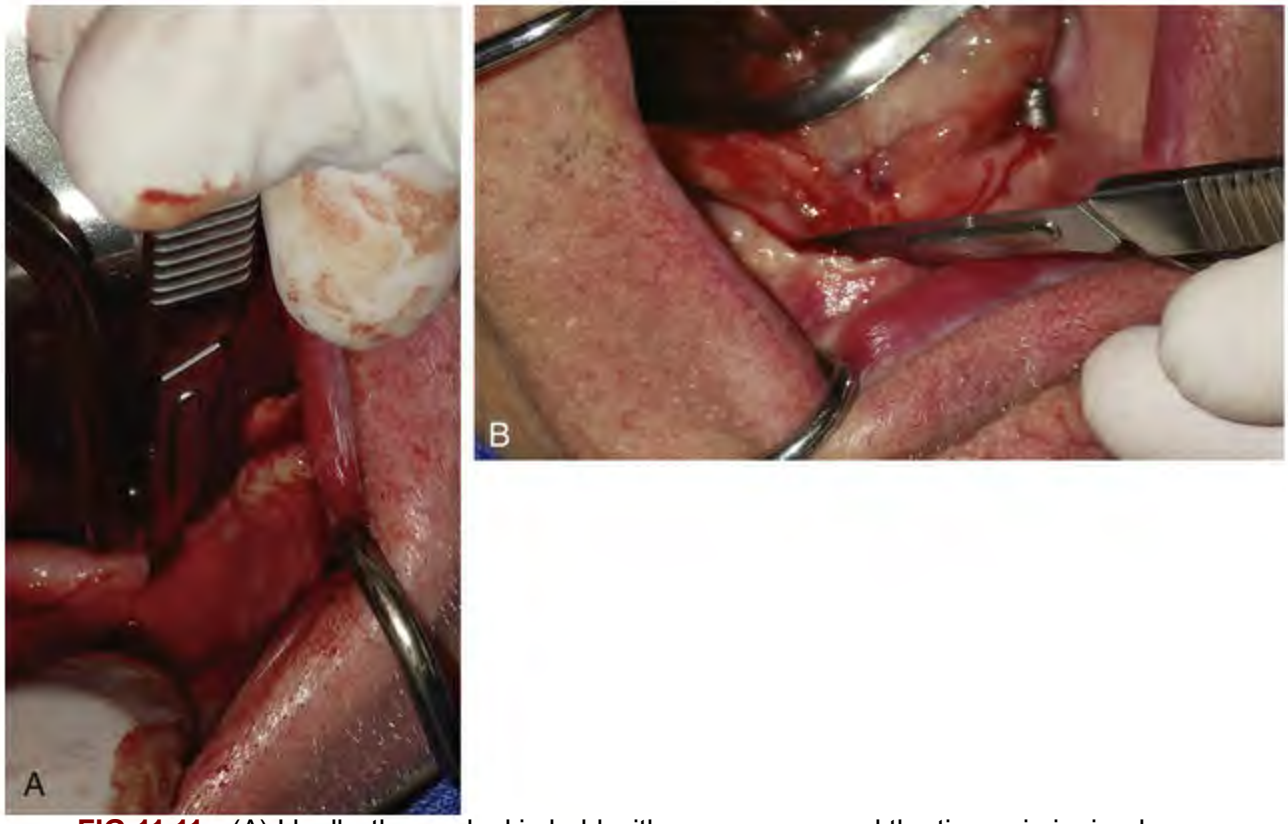

FIG 11.11 (A) Ideally, the scalpel is held with a pen grasp and the tissue is incised perpendicular to the tissue. Sufficient pressure should be used to verify contact with the bony ridge. (B) Incorrect use of scalpel with the scalpel not perpendicular to the tissue.

Full Thickness Reflection and Ideal Flap Elevation

Ideally, the flap should be full thickness and include the surface mucosa, submucosa, and the periosteum. The periosteum is necessary for healing; the replacement of the periosteum in its original position will increase healing.

Tissue elevation should be completed with extreme care. To minimize trauma to the soft tissue, meticulous handling is required. Proper use of appropriate tissue forceps, avoidance of excessive suctioning by the assistant, and "tieback" sutures all contribute to improved flap management. Nonlocking tissue pick-ups, also called "thumb forceps," are commonly held between the thumb and two or three fingers of one hand. Spring tension at one end holds the grasping ends apart until pressure is applied. These forceps are used to hold tissues in place when applying sutures and to gently retract tissues during exploratory surgery. Dressings or draping flaps may be relocated without using hands or fingers. Tissue forceps can have smooth tips, cross-hatched tips, or serrated tips (often called "mouse's teeth"). Serrated forceps used on tissues will cause less tissue damage than smooth

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surface forceps because the surgeon can grasp with less overall pressure. Smooth or cross-hatched forceps are used to move dressings, remove sutures, and perform similar tasks.

During flap elevation, elevators should rest on bone and not on soft tissue. Care should be exercised to not continuously suction the tissue because this may irritate and traumatize the tissue margins. Use of variable-suction tips with fingertip control can help minimize tissue damage. After flap replacement, it is advantageous to apply pressure to the tissue for several minutes to minimize blood clot thickness and to ensure bleeding has stopped (Fig. 11.12).

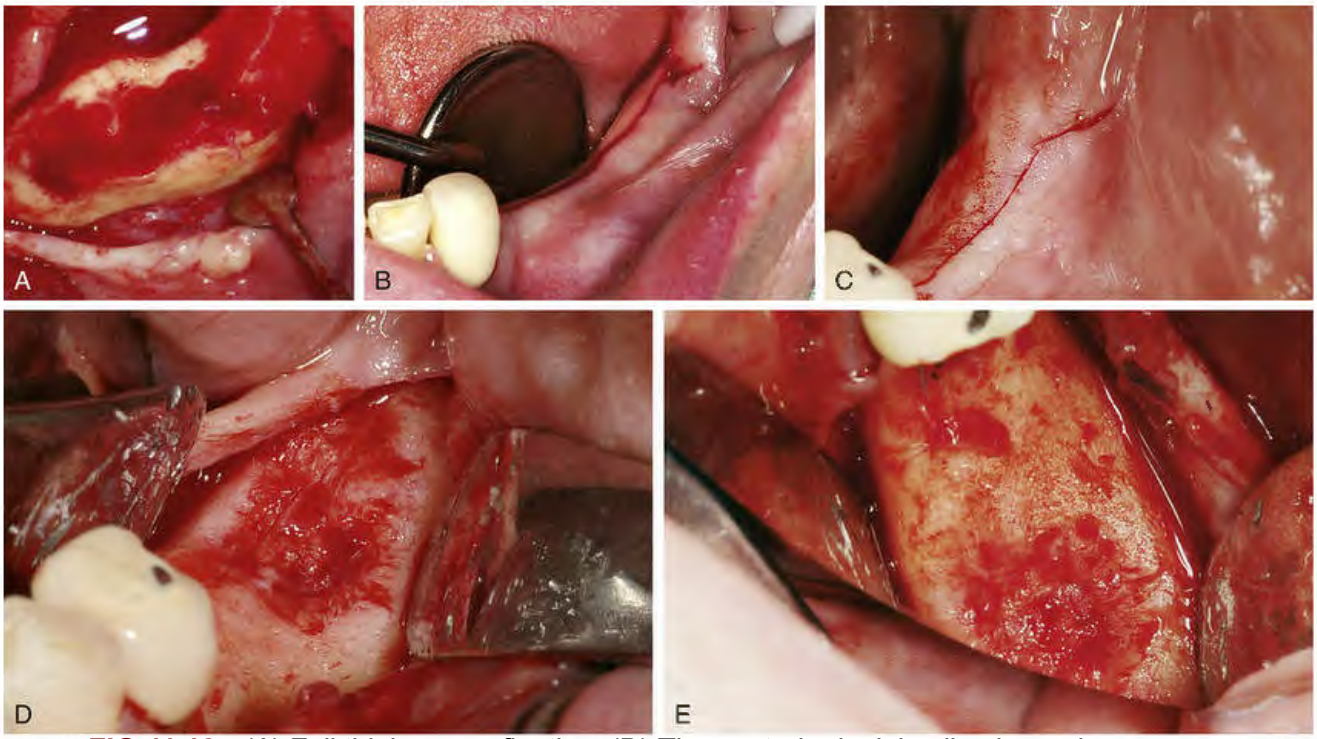

FIG 11.12 (A) Full thickness reflection. (B) The posterior incision line is made on the crest of the edentulous ridge and often extends to the distal of the canine. (C) The distal release incision extends lateral to the retromolar pad, along the ascending ramus. (D) The lingual flap is first reflected off the crest. (E) The facial flap is reflected and, when a computed tomography scan is not available, usually exposes the superior aspect of the mental foramen. (B–E, From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Minimizing surgical operating time will directly benefit soft tissues and will reduce the risk of infection.[32] The tissue retractors should be selected and placed in a position to prevent undue pressure on tissues. Maintaining the retractors on bone and not on the tissue will minimize trauma to the

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tissue. Excessive pressure and tension on the tissue flap will impair blood circulation alter the physiologic healing of the surgical wound and predisposes the wound to bacterial colonization.

Papilla-Saving Incisions

The interproximal soft tissue in sites next to adjacent natural teeth may be classified into three categories: (1) papillae have an acceptable height in the edentulous site, (2) papillae have less than acceptable height, or (3) one papilla is acceptable and the other papilla is depressed and requires elevation. When the interproximal papilla has an acceptable height, “papilla-saving” incisions are made adjacent to each neighboring tooth. The vertical incisions are made on the facial aspect of the edentulous site and begin 1 mm below the mucogingival junction, within the keratinized tissue. Extending the vertical incisions beyond the mucogingival junction increases the risk of scar formation at the incision site. The full-thickness incision then approaches the crest of the edentulous site, leaving 1.0 to 1.5 mm of the interproximal papilla adjacent to each tooth. The vertical incisions are not wider at the base than the crestal width of tissue. This permits the facial flap to be advanced over the implant or short and adjacent to a permucosal extension (PME) at the conclusion of the procedure, with no voids at the incision line and primary closure (Fig. 11.13).

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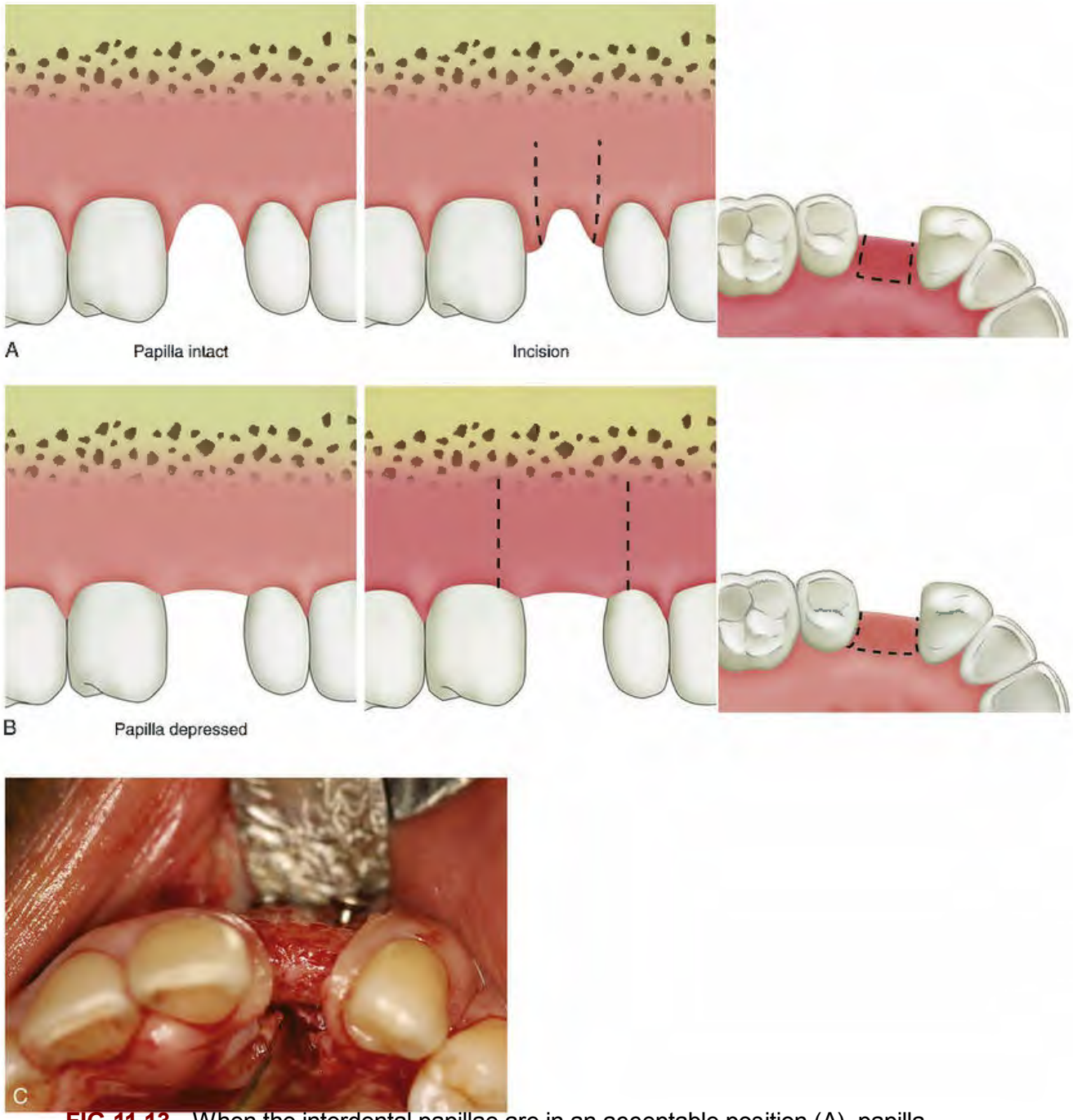

FIG 11.13 When the interdental papillae are in an acceptable position (A), papilla-saving incisions are made to minimize soft tissue reflection. The incisions are vertical to allow primary closure. When the papillae are depressed, the vertical release incisions include the papilla in the edentulous site. In situations with a more depressed soft tissue, facial soft tissue and papillae over each adjacent tooth are also reflected. The crestal incision is on the palatal incline on the ridge (B). (C) Clinical image depicting papilla-sparing incision. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Hemostasis

Hemostasis is important for many reasons, such as providing a clean surgical

field for accurate dissection and flap elevation, along with decreasing trauma. Bleeding can occur from arteries, veins, or capillaries and may result in diffuse, continuous oozing. Ideally, complete hemostasis should be achieved prior to the closure of the wound. If not, the continuous bleeding or hematoma will prevent the apposition of the surgical wound. There are many mechanical, thermal, and chemical methods that may be used to achieve adequate hemostasis. Care should be noted that the use of active or passive hemostatic agents, along with electrocauterization of the wound margins, may decrease the normal physiologic healing of the wound margins and predispose the site to infection and possible wound dehiscence. If hemostatic agents are used (e.g., cellulose), they should be removed after hemostasis is accomplished because this may interfere with surgical wound healing.

Prevent Desiccation of the Tissue

The tissues should be maintained in a moist environment without prolonged periods of desiccation. If drying of the tissues occurs, there is less likelihood that complete wound closure will occur. If the tissue margins become desiccated, periodic irrigations with sterile saline (0.9% sodium chloride) or a saline-moistened gauze may be used.

Relieving Tissue (Tension Free)

Excessive flap tension is the most frequent etiologic factor causing incision line opening. This is best prevented by appropriate incision and flap design, the use of periosteal releasing incisions, and blunt dissection (“tissue stretching”). Past techniques to expand tissue primarily used a more apical tissue reflection and horizontal scoring of the periosteum parallel to the primary incision. Historically, the vestibular approach by Branemark allowed for optimal visualization of anatomic landmarks, suturing remote from the surgical area, complete tissue coverage, as well as predictable primary closure and healing.[33] The postoperative disadvantages of this approach include distortion of the vestibule and other anatomic landmarks, edema, difficult suture removal, and cumulative patient discomfort.[34] Langer and Langer documented the use of overlapping partial thickness flaps. This approach results in extension of the coronal aspect of the buccal or palatal flap, allowing primary intention closure around the site in an overlapping manner.[35] This is usually effective for primary closure when less than 5-mm

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advancement of the flap is necessary (Fig. 11.14).

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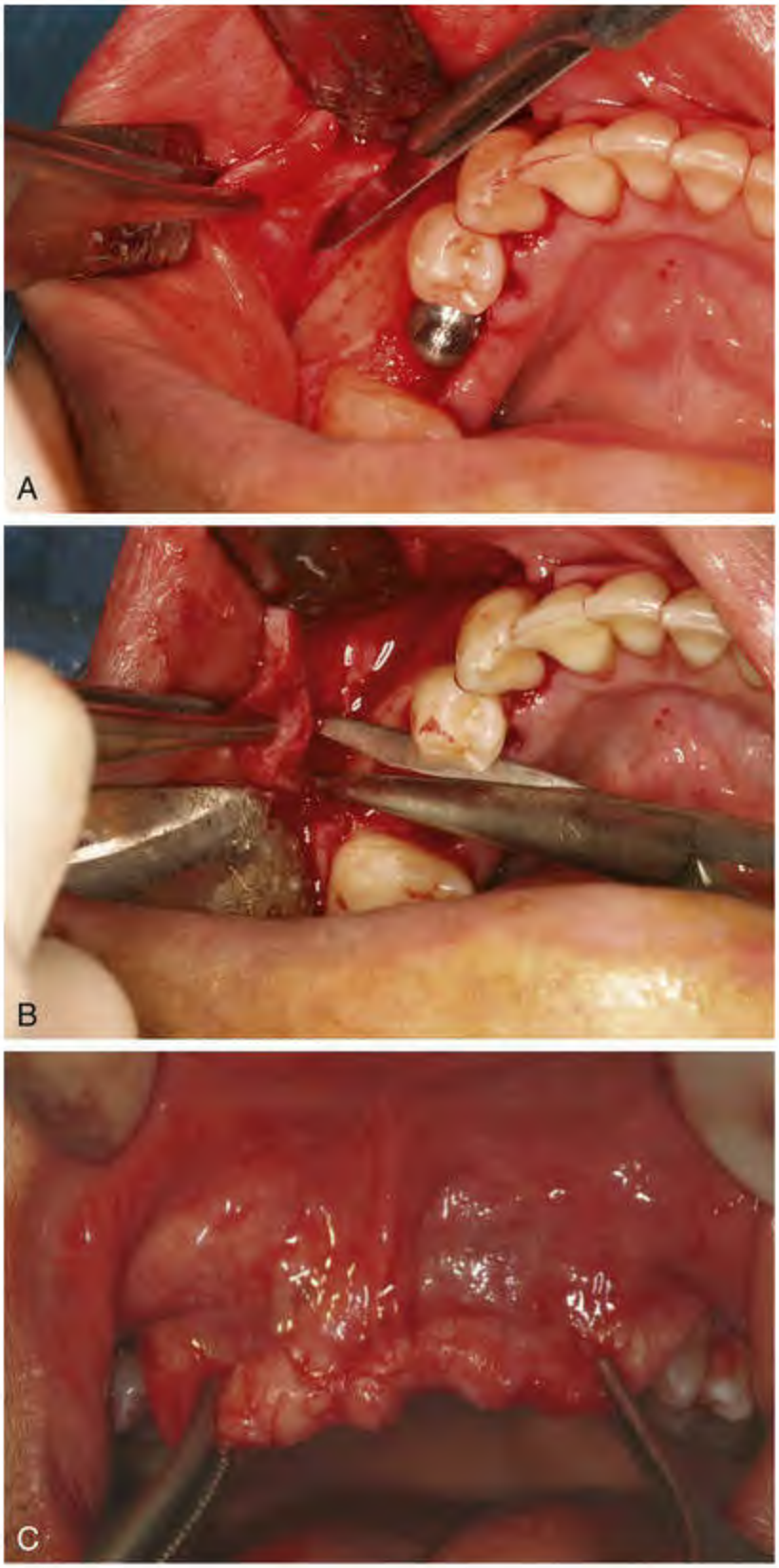

FIG 11.14 Stretchering or relieving the tissue for primary closure. (A) Periosteum scored with #15 blade. (B) Blunt dissection with Metzenbaum scissors. (C) Relieved tissue allowing for tension-free closure.

A submucosal space technique developed by Misch in the early 1980s is an

effective method to expand tissue over larger grafts (greater than 15 × 10 mm in height and width) (Box 11.2).[36]

Box 11.2

Submucosal Space Technique[36]

Procedure

1. The full-thickness facial flap first is elevated off the facial bone approximately 5 mm above the height of the vestibule.

2. One incision with a scalpel, 1 to 2 mm deep, is made through the periosteum parallel to the crestal incision and 3 to 5 mm above the vestibular height of the mucoperiosteum. This shallow incision is made the full length of the facial flap and may even extend above and beyond the vertical release incisions. Care is taken to make this incision above the mucogingival junction; otherwise, the flap may be perforated and delay soft tissue healing.

3. Soft tissue scissors (e.g., Metzenbaum) are used in a blunt dissection technique to create a tunnel apical to the vestibule and above the unreflected periosteum. The scissors are closed and pushed through the initial scalpel incision approximately 10 mm deep, then opened slowly.

4. This submucosal space is parallel to the surface mucosa (not deep toward the overlying bone) and above the unreflected periosteum. The thickness of the facial flap should be 3 to 5 mm because the scissors are parallel to the surface. This tunnel is expanded with the tissue scissors several millimeters above and distal to the vertical relief incisions.

5. The submucosal space is developed and the flap is advanced the distance of the "tunnel" and draped over the graft to approximate the tissue for primary closure without tension. Ideally, the facial flap should be able to advance over the graft and past the lingual flap margin by more than 5 mm. The facial flap may then be returned to the lingual flap margin and sutured. This soft tissue procedure is performed before preparing the host region for any type of bone grafting or augmentation around an implant (Fig. 11.15).

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The utility of periosteal incision for gaining flap release was studied by Park.[37] He found flaps could be advanced up to 171.3% (more than one and a half times longer than its original length) by two vertical incisions and a periosteal releasing incision (PRI) under a minimal tension of 5 g, while one or two vertical incisions without PRI could advance the flap only 113.4% and 124.2%, respectively. These results suggested that PRI can be predictably used to attain tension-free primary closure under a minimal pulling tension of flaps.

Confirm Cover Screw Completely Tightened (Two Stage)

A common postoperative complication that leads to incision line breakdown and infection is the inadequate placement of the cover screw for two-stage implant procedures. Any microgap between the cover screw and implant leads to bacterial colonization and tissue irritation. This will most likely result in swelling directly over the implant. Prior to suturing, the cover screw should be checked to confirm total seating (Fig. 11.16).

FIG 11.16 (A) Surgical cover screw not fully seated. (B) Radiograph showing incomplete seating of cover screw. (C–D) Soft tissue swelling with exudate over implant site.

Utilization of Ideal Suturing Materials and Techniques

The objective of the proper suturing of the surgical wound is to position and secure the margins of the incisions to promote ideal and optimal healing.

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The goal of the suture material and technique is to hold the margins of the wound in close apposition until the wound has healed enough to withstand normal functional tension and stress on the incision line. If surgical wounds are not properly approximated, separation of the margins will occur, which leads to increased postsurgical morbidity. The clinician must select a suture with qualities that include high tensile strength, tissue biocompatibility that prevents tissue irritation, ease of knot tying, and the ability to prevent minimal knot slippage (Table 11.1).

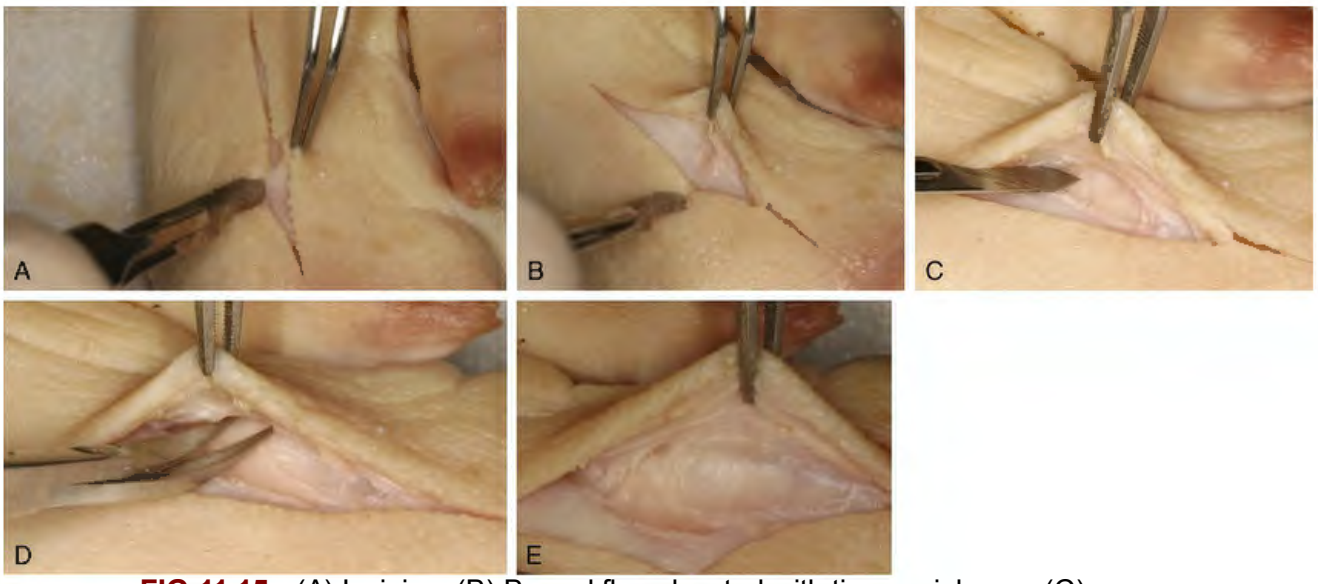

FIG 11.15 (A) Incision. (B) Buccal flap elevated with tissue pick-ups. (C) Periosteum scored with #15 blade (parallel to flap). (D) Blunt dissection with Metzenbaum scissors (parallel to flap). (E) Tension-free flap.

TABLE 11.1
Various Suture Characteristics[58]

Suture	Types	Color of Material	Raw Material	Tensile Strength Retention in Vivo	Absorption Rate	Tissue Reaction	Contraindications	Warnings
Surgical Gut	Plain	Yellowish-tan blue dyed	Collagen derived from healthy mammals (i.e., cow, sheep)	Lost within 3–5 days. Individual patient characteristics can affect rate of tensile strength loss	Digested by proteolytic body enzymes within 7–10 days	Moderate	Should not be used in tissues that heal slowly and require support or under high-tension areas	Absorbs relatively quickly
Surgical Gut	Chromic	Brown Blue dyed	Collagen derived from healthy mammals.	Lost within 7–10 days. Individual patient	Digested by body enzymes within 7–10 days	Moderate, but less than plain surgical gut	Being absorbable, should not be used where	Protein-based absorbable sutures

			(i.e., cow, sheep). Treated to resist digestion by body tissues	characteristics can affect rate of tensile strength loss			prolonged approximation of tissues under stress is required	have a tendency to fray when tied
Coated VICRYL (polyglactin 910)	Braided	Violet undyed (natural)	Copolymer of lactide and glycolide coated with polyglactin 370 and calcium stearate	Approximately 60% remains at 2 weeks. Approximately 30% remains at 3 weeks. (Dependent on the type)	Minimal until about 40th day. Essentially complete between 60–90 days. Absorbed by slow hydrolysis	Mild	Even though a high tensile strength, may not be sufficient for high-stress areas	None known
PDS (polydioxanone)	Monofilament	Violet Clear	Polyester polyethylene terephthalate coated with polybut	Approximately 70% remains at 2 weeks. Approximately 50% remains at 4 weeks. Approximately 25% remains at 6 weeks	Minimal until about 90th day. Essentially complete within 210 days. Absorbed by slow hydrolysis	Slight	Being absorbable, should not be used where prolonged approximation of tissues under stress is required	None known
Surgical Silk	Braided	Black White	Natural protein fiber of raw silk spun by silkworm (i.e., fibroin)	Loses all or most in about 1 year	Usually cannot be found after 2 years. Encapsulation by fibrous connective tissue may result	Acute inflammatory reaction	Should not be used in any area where suture removal would be difficult	Slowly absorbs, tissue reaction
e-PTFE	Monofilament	White	Cytoplast	Nonresorbable	Nonresorbable	Biologically inert Comfortable to patients	None	None
Surgical Steel	Monofilament Multifilament	Silver Metallic	An alloy of iron-nickel-chromium	Indefinite	Nonabsorbable: remains encapsulated in body tissues	Low	Should not be used when a prosthesis of another alloy is implanted	May corrode and break at points of bending, twisting, and knotting
ETHILON Nylon	Monofilament	Black Green Clear	Polyamide polymer	Loses 15% to 20% per year	Degrades at a rate of about 15% to 20% per year	Extremely low	None	None
NUROLON Nylon	Braided	Black White	Polyamide polymer	Loses 15% to 20% per year	Degrades at a rate of about 15% to 20% per year	Extremely low	None	None
MERSILENE Polyester Fiber	Braided	Green White	Polyester polyethylene terephthalate	Indefinite	Nonabsorbable: remains encapsulated in body tissues	Minimal	None	None
ETHIBOND Polyester Fiber	Braided	Green White	Polyester polyethylene terephthalate coated with polybutilate	Indefinite	Nonabsorbable: remains encapsulated in body tissues	Minimal	None	Has not been evaluated in ophthalmic surgery
PROLENE Polypropylene	Monofilament	Clear Blue	Polymer of propylene	Indefinite	Nonabsorbable: remains encapsulated in body tissues	Minimal transient acute inflammatory reaction	None	None

Suture Type

Absorbable

Absorbable sutures are very popular and advantageous in implant dentistry because of the elimination of a suture removal appointment. There are two types of resorbable sutures: natural and synthetic.

Natural.

Natural sutures are mainly broken down by body enzymes. The most common natural sutures are the plain and chromic gut (Fig. 11.17).

FIG 11.17 (A) Plain gut. (B) Chromic gut.

Plain gut.

Plain gut is a monofilament derived from highly purified collagen from sheep intestinal submucosa. It is highly antigenic, losing 50% of tensile strength after 24 hours. Gut has unpredictable absorption because of the enzymes and macrophages that break it down. This type of suture has been shown to have a high incidence of tissue reactions, which impede healing.

Chromic gut.

Chromic gut is also derived from purified collagen from sheep intestinal submucosa that is treated with chromic salts, which decrease absorption. This material is highly antigenic and loses 50% of tensile strength after 5 days. As a monofilament it causes significant tissue reactivity. Chromic gut causes inflammation, loses tension, and resorbs too quickly to maintain soft tissue approximation over an augmented site. It is not recommended when

the tissues are advanced for a bone augmentation.[38] Hypersensitivity reactions have been shown to occur because of the chromate particles present in the suture.[39]

Synthetic.

Synthetic sutures are broken down by hydrolysis because of their hydrophobic nature. The most common synthetic, absorbable suture in implant dentistry is polyglycolic acid (PGA) (Fig. 11.18).

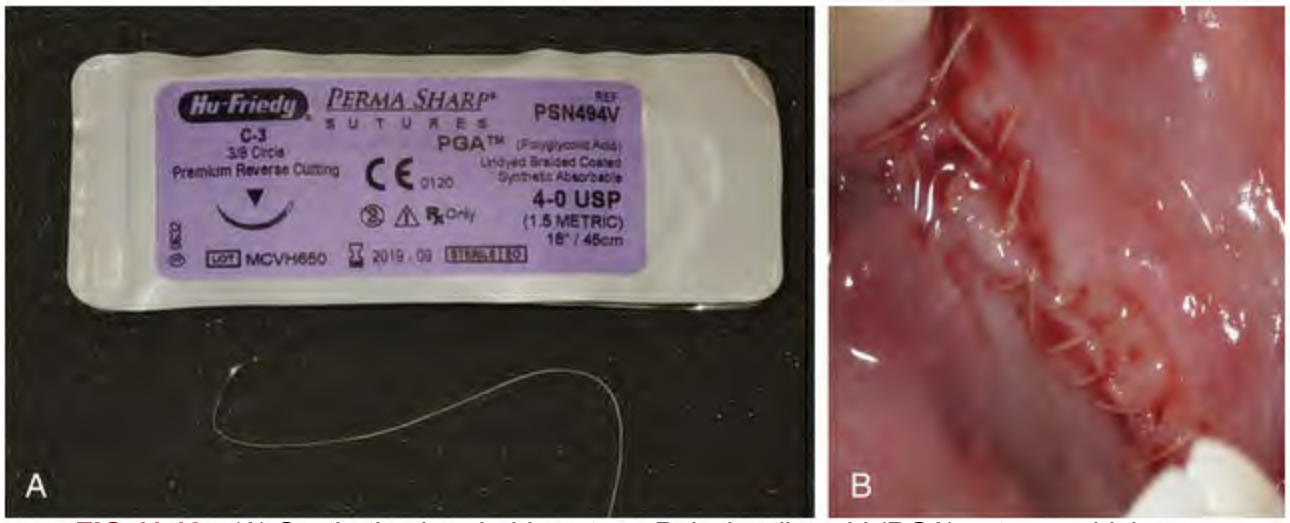

FIG 11.18 (A) Synthetic absorbable suture: Polyglycolic acid (PGA) sutures which are supplied in various resorption rates. (B) Clinical image of PGA suture, which has the advantage of being resorbable and having excellent tensile strength.

Polyglycolic acid (Vicryl).

Because PGA sutures are absorbed by hydrolysis breakdown, they are not affected by a low pH. Because they are manufactured by synthetic polymers, their resorption is slower and they will maintain the incision line with a tensile strength much longer than most suture materials. This suture material will maintain sufficient tension over the first 2 weeks (75%), 50% after 3 weeks, and 25% after 2 weeks.[40] PGA sutures have varying resorption rates, which consist of regular breakdown (≈21–28 days) and fast absorbing (≈7–14 days). The suture material is inert and has a relatively low tissue reaction.

Nonabsorbable.

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Nonabsorbable sutures are composed of manmade materials, which are not metabolized by the body. The most commonly used nonresorbable suture in dentistry is a natural fiber, silk, which undergoes a special manufacturing process to make it adequate for its use in surgery. Other nonabsorbable sutures are made of artificial fibers (e.g., polypropylene, polyester, nylon), which may contain coatings to enhance their performance characteristics (Fig. 11.19).

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FIG 11.19 Nonabsorbable sutures. (A) Silk. (B) Wicking present on silk sutures. (C) Polypropylene. (D) Polyester. (E) Polytetrafluoroethylene (PTFE). (F) Clinical image of PTFE suture.

Silk: Over time, silk has been the most universally used suture material in dentistry because of its low cost and ease of handling. However, silk has many disadvantages with respect to implant dentistry. First, it is nonresorbable and must be removed. Because silk is a multifilament, is has been shown to "wick," which results in accumulating bacteria and fluid to the surgical wound. And lastly, silk has been shown to release less tension during early retraction of the flap from healing, along with eliciting greater inflammation reactions, which may contribute to incision line opening more

often than synthetic materials.[41,42]

Polypropylene (i.e., prolene): This suture, which is a monofilament, will not lose tensile strength over time. It is inert, has very little tissue reaction, possesses a low coefficient of friction, passes through tissue very easily, and has good knot security. The main disadvantage of this suture material tissue is irritation from the cut ends of the suture material.

Polytetrafluoroethylene: The polytetrafluoroethylene (PTFE) suture material is a monofilament, which has a relatively high tensile strength and is nonwicking (low bacteria accumulation). Additionally, PTFE sutures have good handling qualities, are easy to tie with excellent knot security, are soft and comfortable for patients, and are biologically inert. The main disadvantage of PTFE is that it is very expensive. PTFE sutures are slippery and have poor frictional resistance to knot loosening. At least seven equally tensioned, flat square throws are required to produce a secure knot when using PTFE material.

Suture Qualities

The selection of the suture material should be made with regards to the location and type of surgical procedure provided. However, an ideal suture material should exhibit:

High Tensile Strength

High tensile strength is the measured force, in pounds, that the suture will withstand prior to breaking. A suture material with low tensile strength will lead to suture breakdown, which will most likely compromise the healing of the incision line. The tensile strength of the tissue to be sutured will ideally determine the tensile strength of the suture selected. The tensile strength of the suture should be at least as strong as the tensile strength of the tissue being sutured.

Low Tissue Reactivity

Tissue reaction from the suture material has been shown to be exhibited through an inflammatory response, which will usually develop during the first 2 to 7 days after suturing the tissue. The suture material selected should have an inherent low tissue reactivity.[42a] Low tissue reactivity means that the suture material should exhibit a minimal inflammatory response, which will not delay wound healing nor increase infection rate. Tissue reaction is

reflected through an inflammatory response, which develops during the first 2 to 7 days after suturing the tissue.[1-3] Several studies published over the past four decades have reported that synthetic materials exhibit a superior behavior to oral tissues in terms of tissue inflammatory reactions compared to nonsynthetic suture material.

Absorbable

Absorbable suture material allows for the convenience of no suture removal. These types of sutures undergo degradation and absorption in the tissues; thus the sutures do not have to be removed. There are two mechanisms of degradation of absorbable sutures: enzymatic breakdown or degradation by hydrolysis (PGA). Sutures derived from a biologic origin (i.e., plain and chromic gut) are digested by intraoral enzymes. Usually these types of sutures lose their tensile strength very fast (within days of surgery) and are not ideal for dental implant procedures. Secondly, these sutures may break down even faster when the intraoral pH is low. A decreased pH may result from infection, medications, metabolic disorders, or dry mouth. Trauma from suture removal may sometimes lead to incision line opening.

Treatment Implications.

The ideal suture material should exhibit a high tensile strength, low tissue reactivity, and be absorbable. In implant dentistry, this would include the use of PGA or polyglycolic acid. A nonresorbable alternative would be a PTFE suture (e.g., Cytoplast), which exhibit a high tensile strength and is nonwicking.

Suture Size

Surgical threads are classified by diameter ranging from 1 to 10, with the highest number being the smallest thread size. In implant dentistry, the most common diameter is 3-0 for incision lines and 4-0 or 5-0 around tissue release margins or areas that exhibit thinner tissue. In some situations, a 2-0 suture will be used, usually as a tie-back for the lingual tissue when performing mandibular surgery. Ideally, the smallest-diameter suture material that will adequately hold the tissue in approximation should be used. As diameters of suture decrease, so do their respective tensile strengths.

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Suture Needle

The surgical needle is composed of three parts: (1) point, (2) needle body, and (3) swaged end. The needle is type is classified by the curvature, radius, and shape. The most commonly used suture needles in implant dentistry are the ⅜ and ½ circle needles.[43]

The ⅜ needle allows for the passage of the needle from buccal to lingual in one pass. The ½ is usually used in more restrictive areas such as maxillary molars and in periosteal and mucogingival surgery.[44] The clinician should always be aware that there exist two types of needle designs: reverse cutting and conventional. In implant dentistry, the reverse cutting should always be used because this will minimize severing of the tissues. The reverse cutting needle has a smooth inner curvature with its third cutting edge located on its convex (outer) edge (Fig. 11.20).

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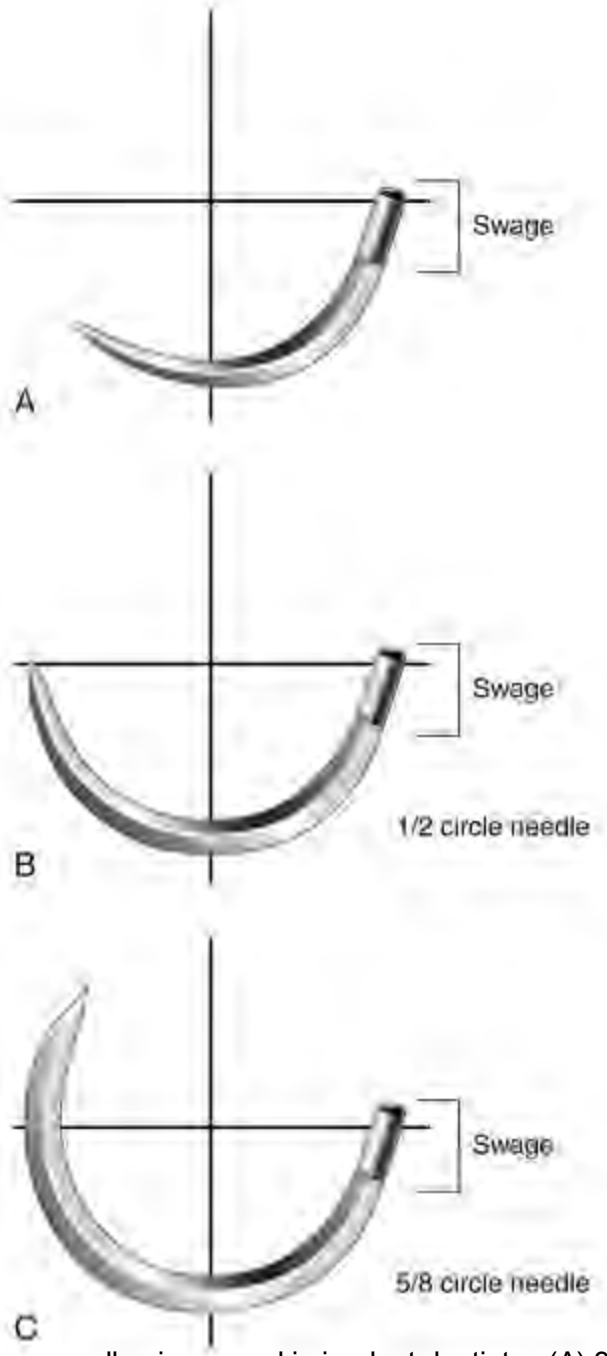

FIG 11.20 Various needle sizes used in implant dentistry. (A) 3/8 circle. (B) 1/2 circle. (C) 5/8 circle.

Suturing Technique

Interrupted

Simple Loop.

The simple loop is the most common suture used in implant dentistry. It is

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used to approximate mobile surgical flaps in edentulous areas. Each suture is tied and cut after insertion through the tissue. The disadvantage of this suture is it is more time consuming than a continuous suture. However, it does have the advantage that, if one of the sutures would loosen or break, the remaining sutures would most likely hold the wound together to minimize wound dehiscence (Fig. 11.21).

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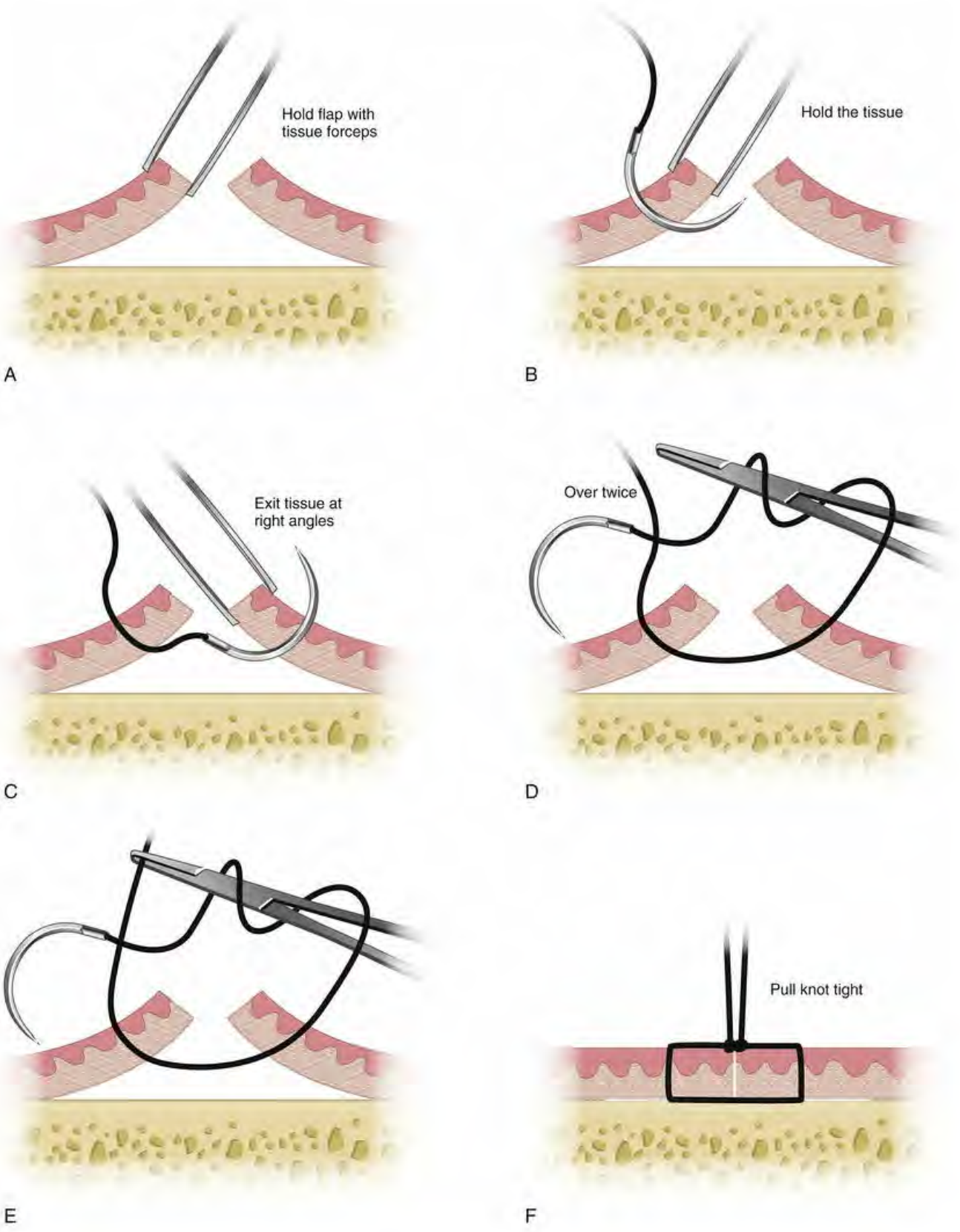

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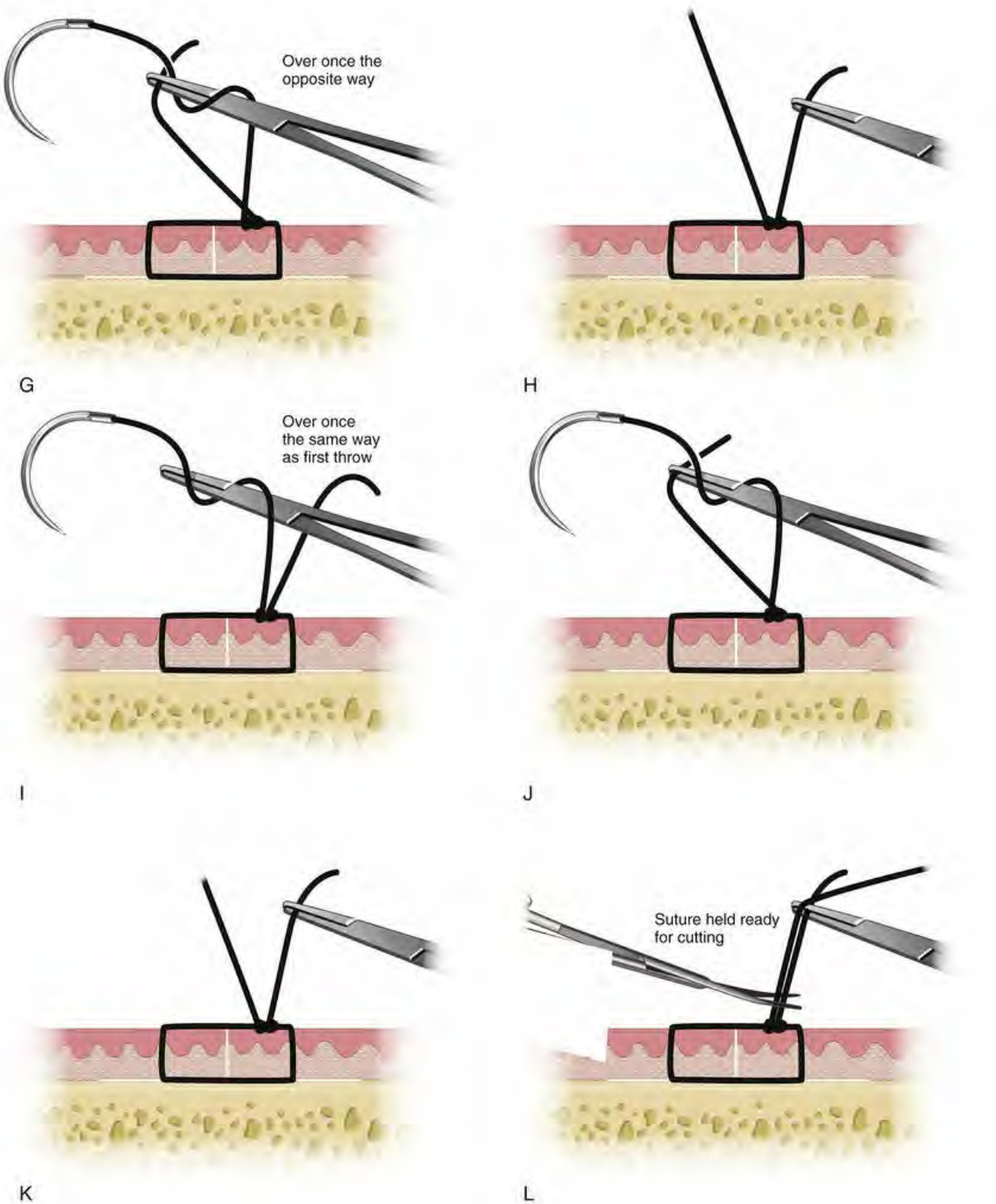

FIG 11.21 Simple interrupted suture. (A) Tissue is held with tissue pick-ups. (B) Enter tissue at a 90-degree angle. (C) Exit tissue at a 90-degree angle. (D) Two throws over needle holders. (E) Needle holders engage opposite end of suture. (F) First knot is pulled tight to lay flat. (G) One throw the opposite way from first throw. (H) Second knot is secured. (I) One throw, the same way as the first throw. (J) Needle holders engage opposite end of suture. (K) Third knot secured. (L) Suture ends are cut approximately 3 mm in length.

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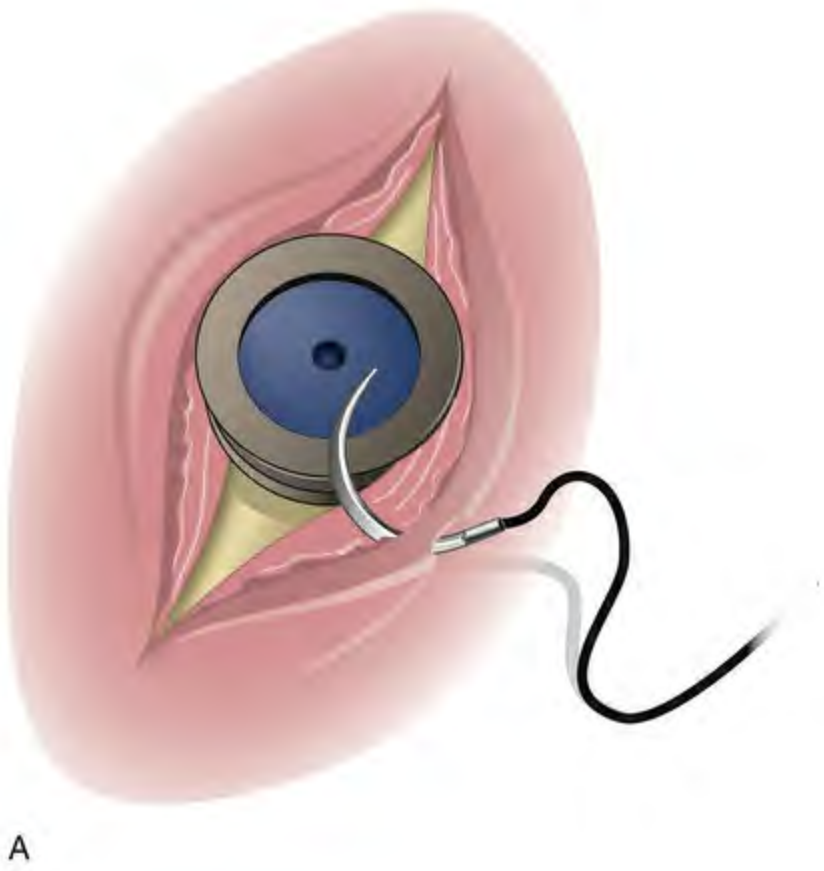
Figure-Eight.

The figure-eight suture is placed as a simple loop on the buccal; however, on the lingual, the needle passes through the outer aspect of the flap. The main disadvantage of the figure-eight is the suture material is interposed between the flaps after full closure. The figure-eight suture is most commonly used with extraction sites and around papilla (Fig. 11.22).



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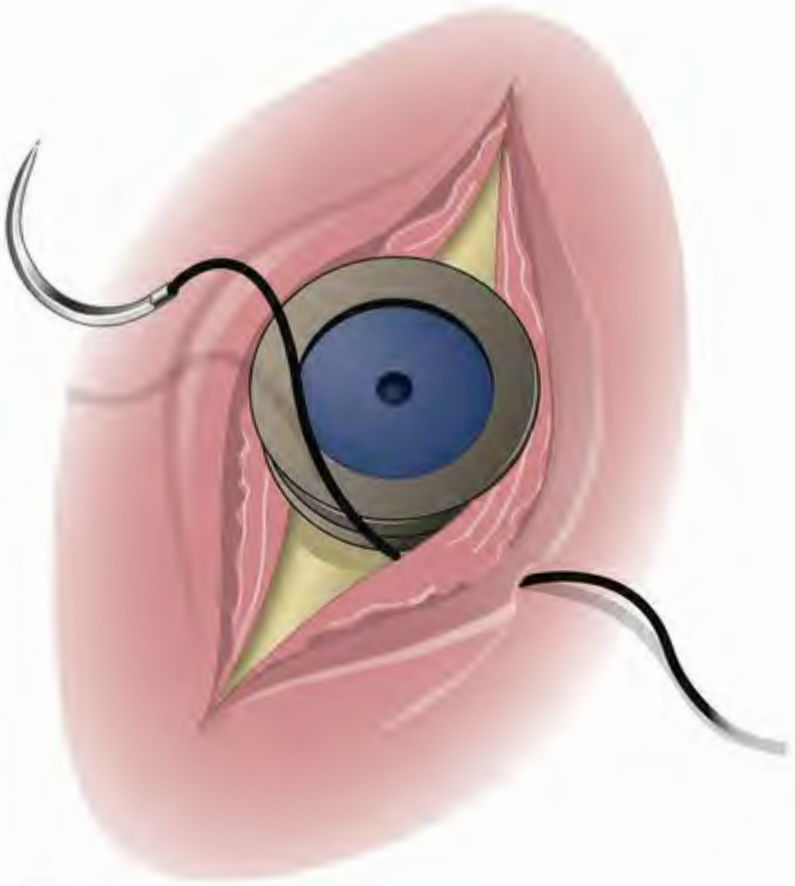

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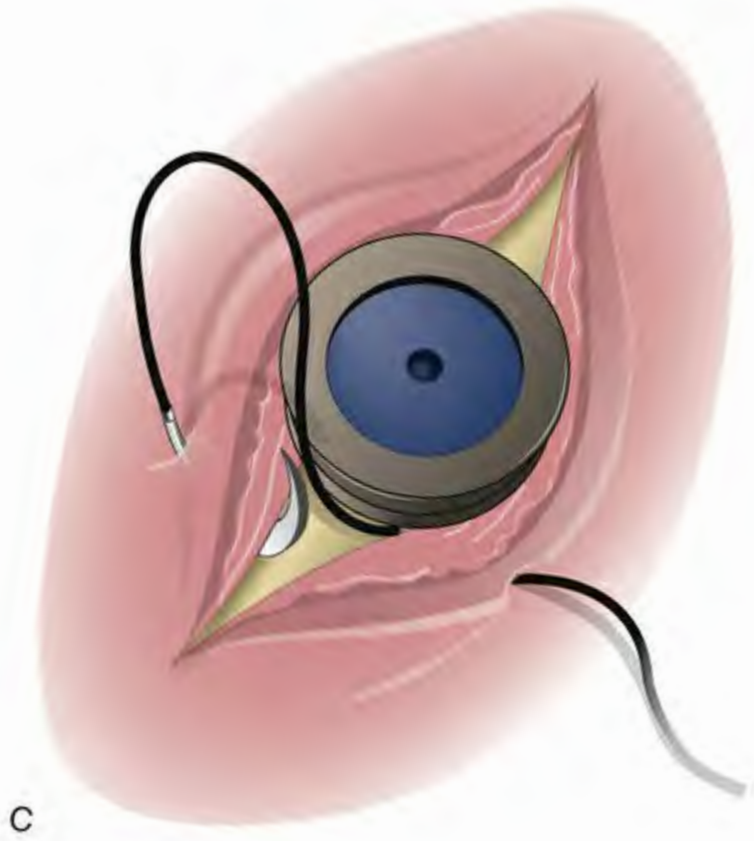

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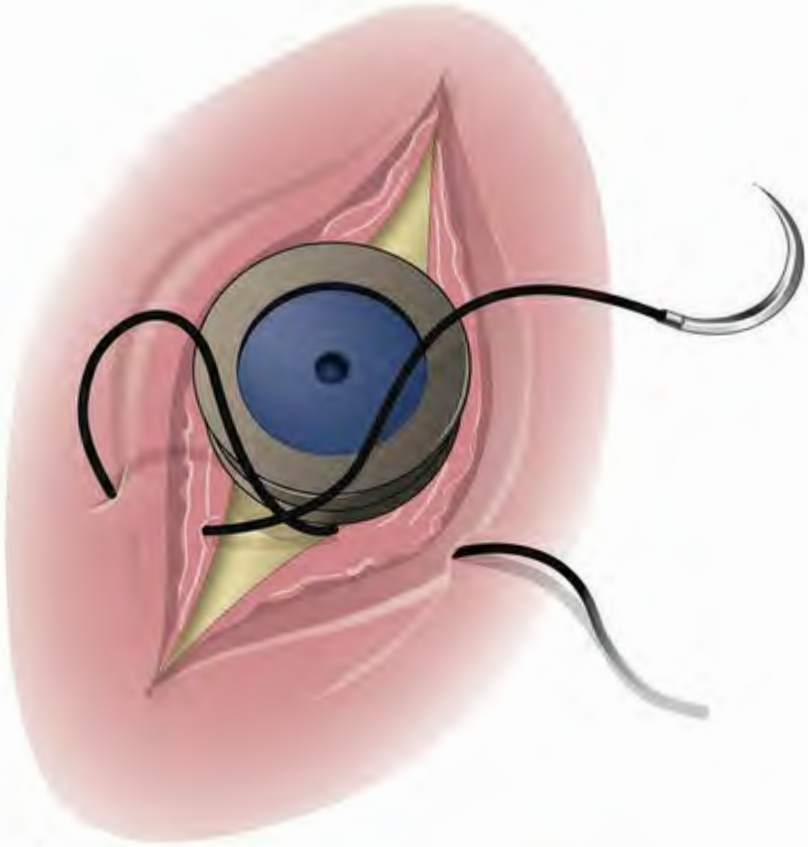

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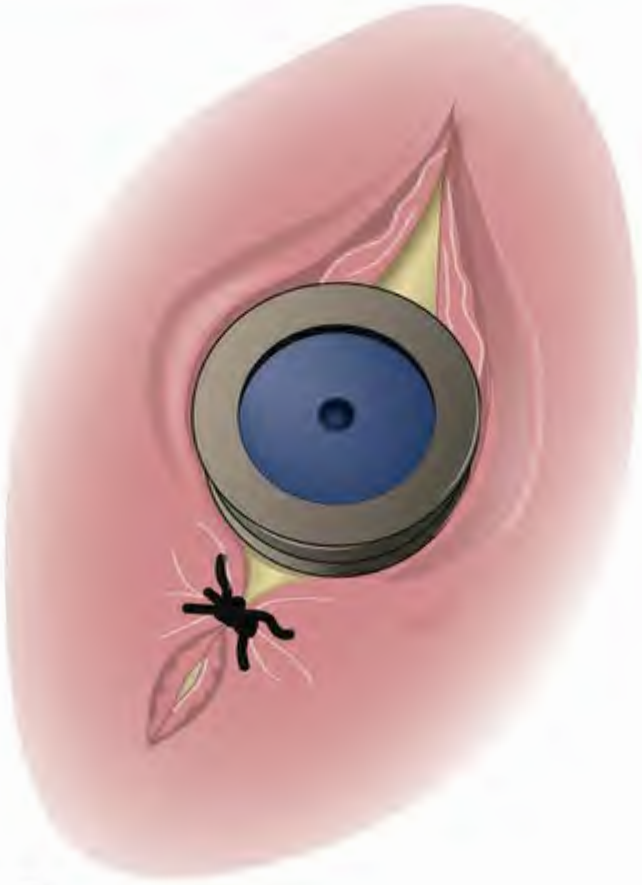

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FIG 11.22 Figure-eight suture. (A) Enter buccal tissue at 90 degrees. (B) Do not enter lingual flap. (C) Enter from lingual at 90 degrees. (D) Do not enter buccal flap. (E) Tie suture ends.

Second Stage Surgery: Permucosal Abutment Suturing.

A modification of the interrupted suture may be completed upon second stage surgery with a permucosal abutment that has a suture groove. A suture groove 3 to 5 mm above the platform connection may be incorporated in the healing abutment (e.g., External implant system, previously known as the Maestro dental system [BioHorizons IPH, Inc.]) (Fig. 11.23A). When the tissue requires apical repositioning or when it is 3 to 4 mm thick and may grow over the healing abutment, the suture groove may be used (see Fig. 11.32). A suture is placed next to the healing abutment. Tissue forceps lift the suture from the incision line, and the suture is then rotated to form a loop. The loop is placed over the enlarged healing abutment and into the suture groove or under the healing cap. The suture may then be tied, securing the tissue at the height of the suture groove (see Fig. 11.33). A similar technique is used on the other side of the healing abutment. These two sutures (one on each side) hold the tissue at the level of the suture groove and prevent it from lifting up and over the healing cap during soft tissue healing.

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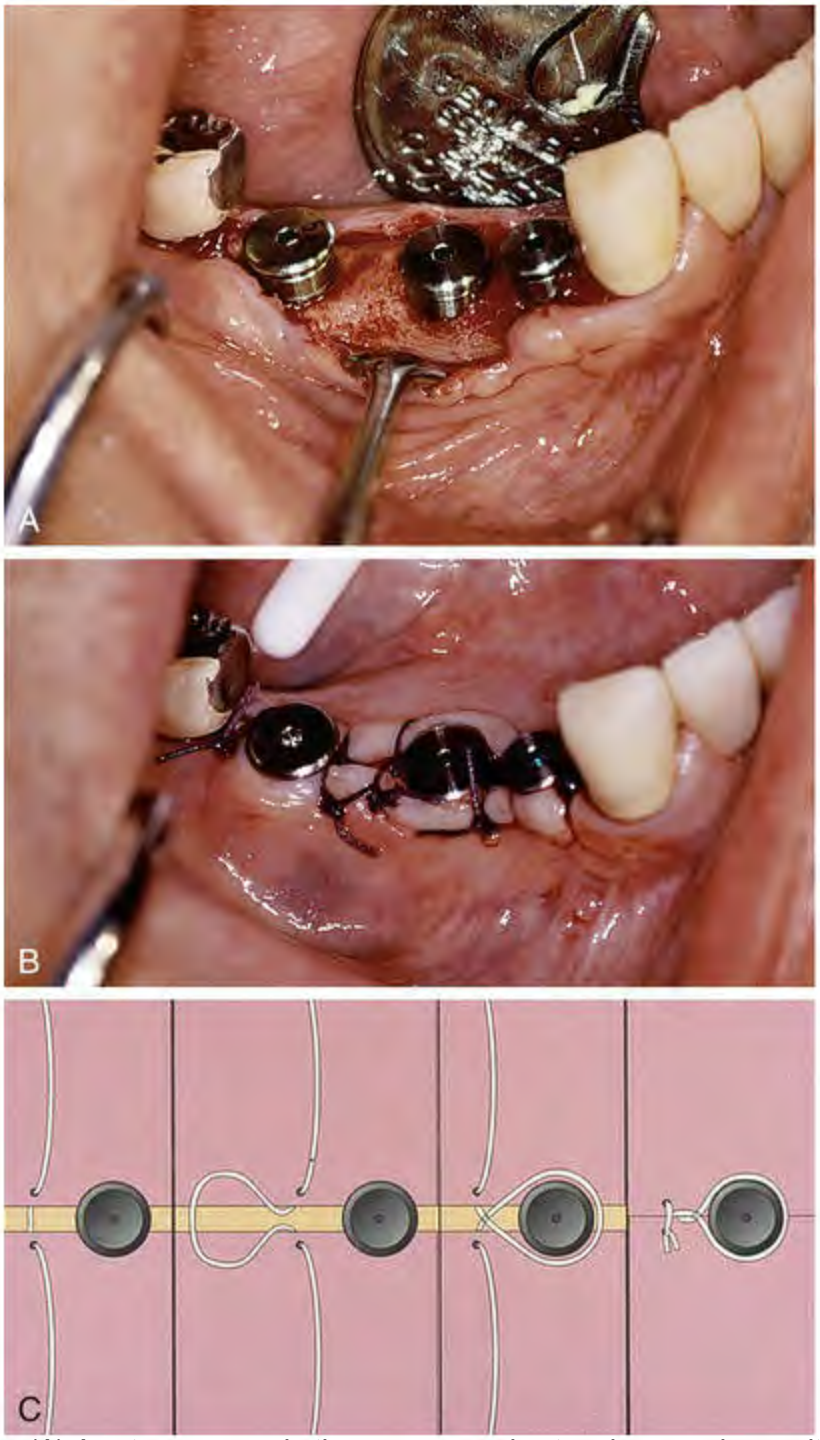

FIG 11.23 (A) A suture groove in the permucosal extension may be positioned 3 to 5 mm above the bone. (B) The suture groove helps to apically reposition the tissue, so it will remain less than 3 to 5 mm thick, to reduce the sulcus depth. (C) The suture groove in the permucosal extension may be used to loop the suture around the groove and tie the tissue at a more apical position. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Continuous

Soft tissue spans necessitating four or more interrupted sutures are best

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approximated with continuous nonlocking sutures. This suture design places less tension on the suture line and soft tissue and allows faster vascularization of the reflected soft tissue flaps. However, whether locking or nonlocking, this suture knot has a tendency to loosen with uneven distribution of tension, which results in a compromise to the integrity of the suture knot (Fig. 11.24).

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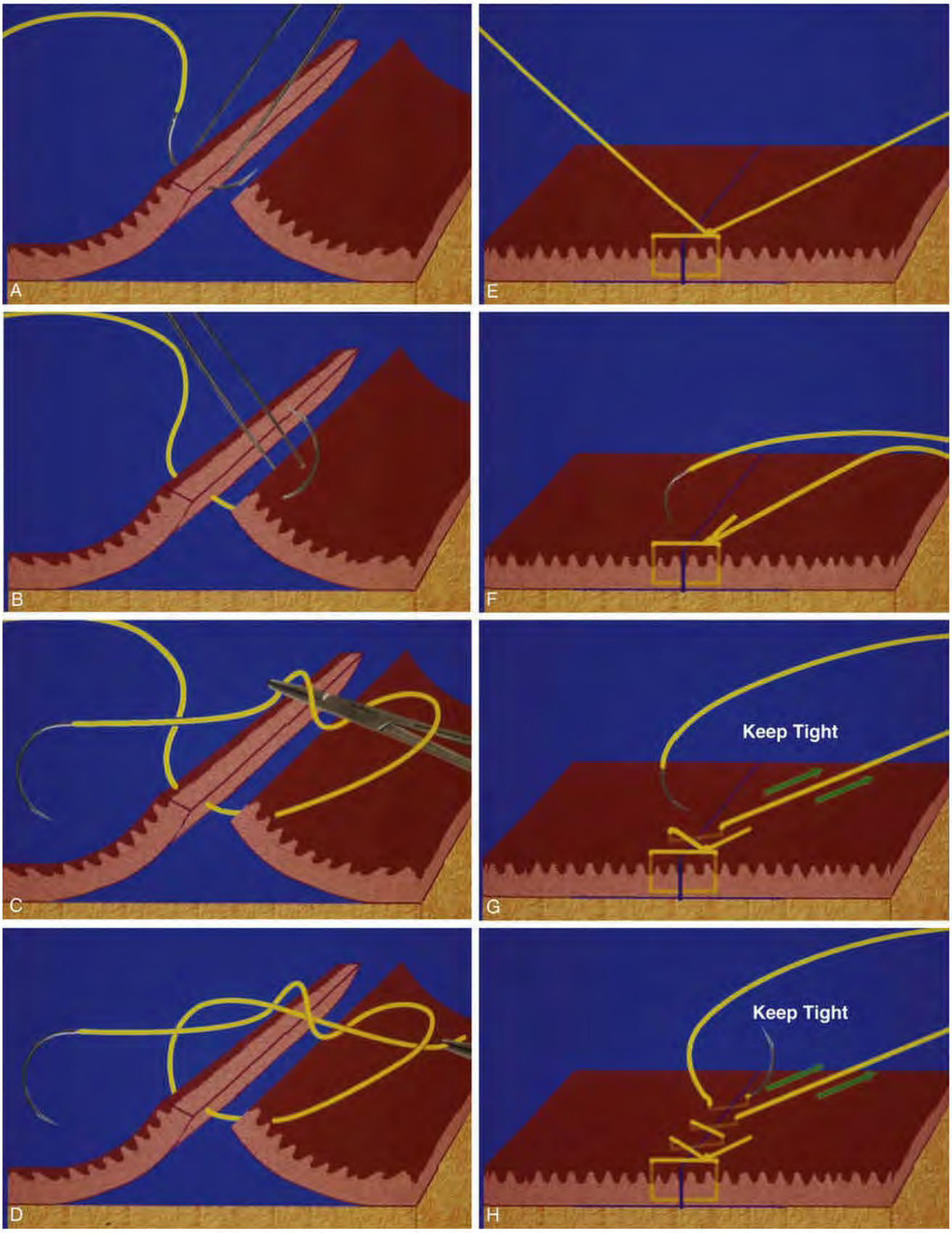

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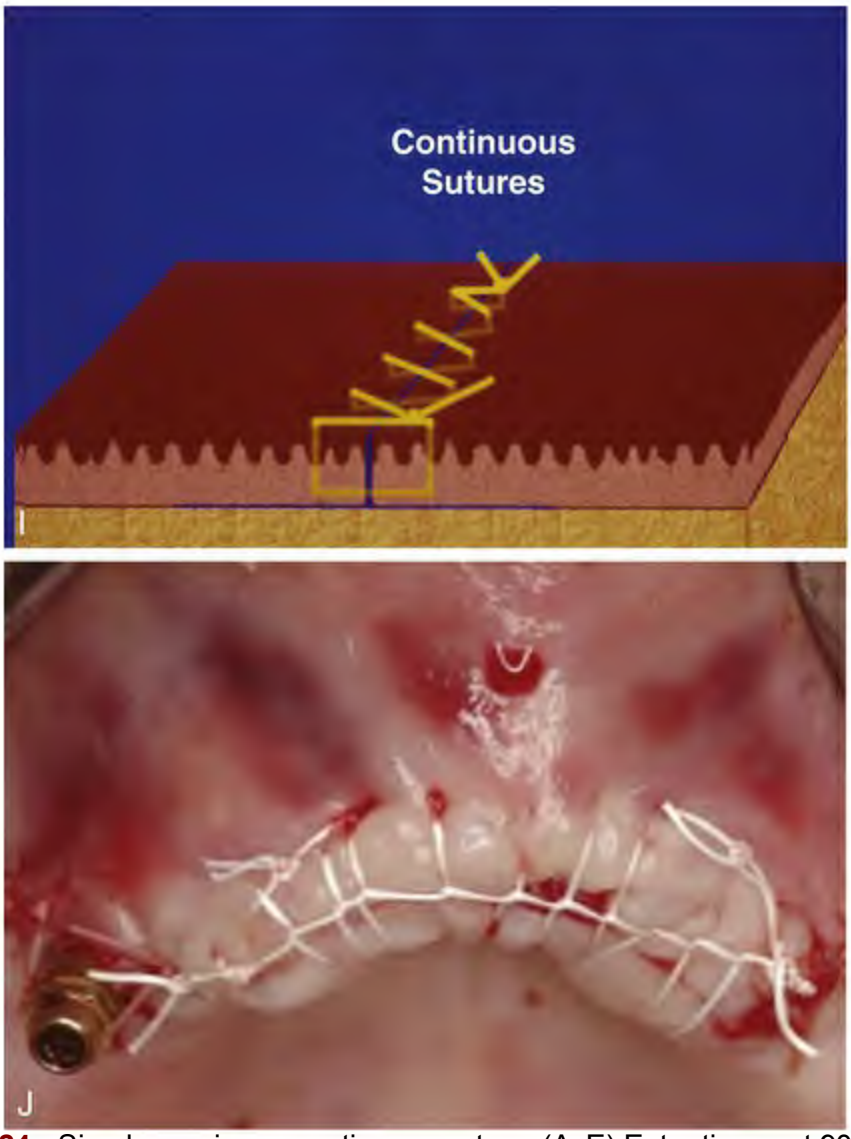

FIG 11.24 Simple running or continuous suture: (A–E) Enter tissue at 90 degree and use the same protocol as a simple interrupted suture. (F) Instead of both strands (ends) being cut, only cut the short strand leaving a 2–3 mm tail. The second stitch should be made approximately 3 mm from the first suture. (G–H) Multiple stitches are made encompassing the entire incision line. (I) The last stitch is not pulled completely through the tissue. Instead the loop is held with the needle holder and used as the short strand in order to tie off the distal end of the suture closure. (J) Clinical Image of Continuous Suture.

Horizontal/Vertical Mattress

Mattress sutures are a variation of the interrupted suture and are used most commonly where there exists muscle pull or high tension. This type of suturing technique will evert the surgical wound edges, which keeps the epithelium away from underlying structures and maintains the tissue flaps to the underlying structures (i.e., dental implant, graft material, membrane).[45]

There are two types of mattress suture, horizontal and vertical. Both of

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these suture types allow for greater tension to be applied on the soft tissue closure without risk of tearing the soft tissue flap. It should be emphasized they are not used to obtain primary closure when tension on the soft tissue flaps is present at surgery. The tissues should rest passively together before suturing. However, during functional/parafunctional movement of the tissues, the tension on the incision line may be reduced with a horizontal mattress suture. They are often used in the mandible when the floor of the mouth is in proximity to the lingual flap and the tissue is thin. They may also be used on a facial flap with a strong muscle pull on the soft tissue. In addition, horizontal mattress sutures evert the soft tissue margin and ensure primary closure without epithelium entrapment. A combination of a few horizontal mattress sutures with a continuous suture may be indicated to close large soft tissue spans (Figs. 11.25 and 11.26; Box 11.3).

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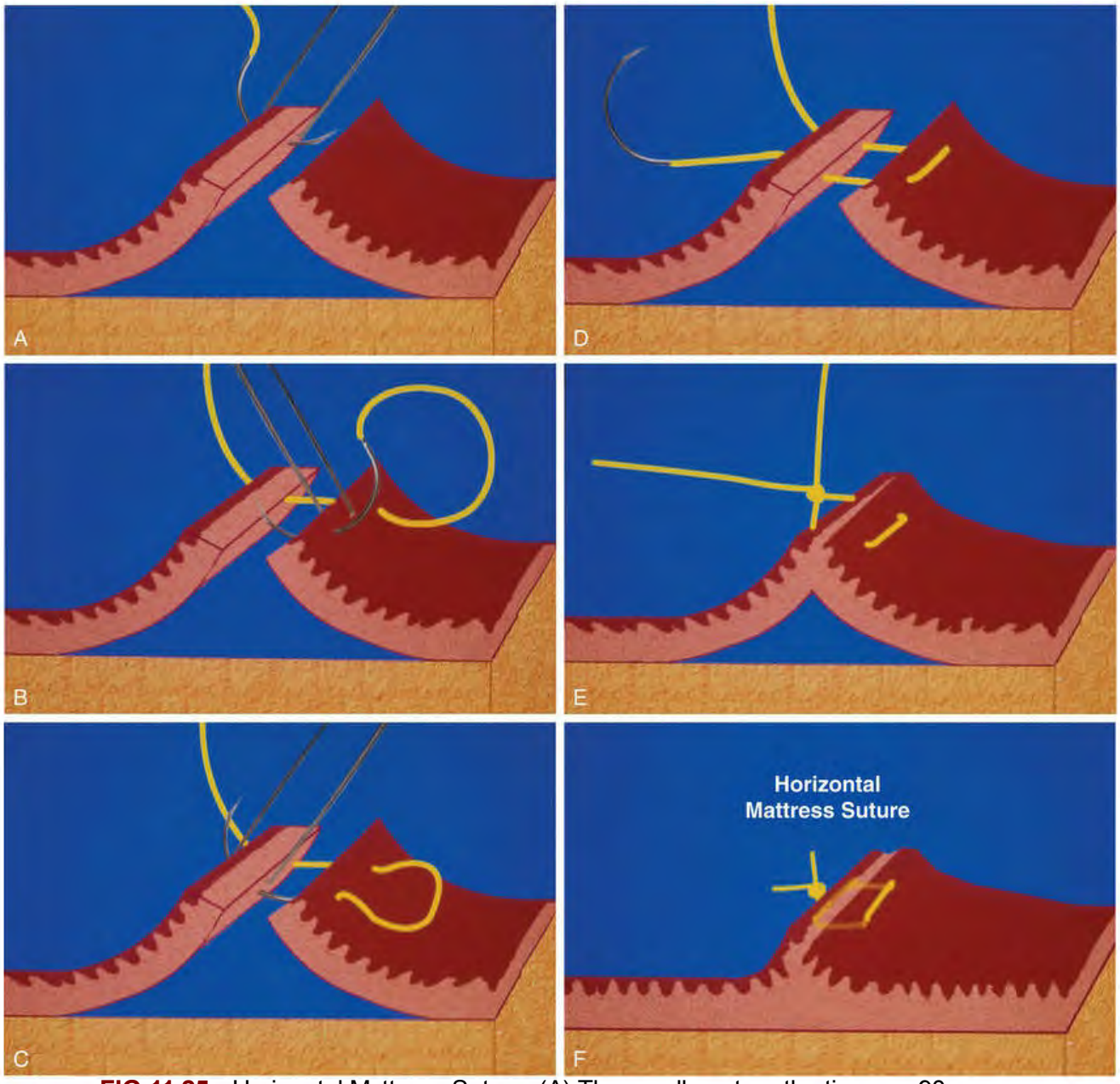

FIG 11.25 Horizontal Mattress Suture: (A) The needle enters the tissue a 90 degrees and exits on the lingual side of the incision. (B–E) The needle is then placed backwards in the needle holder and is inserted approximately 4 mm farther down from the first stitch. The needle passes from the far side to the near side (buccal). (F) The suture is then tied gently on the side of the wound where the suturing originated.

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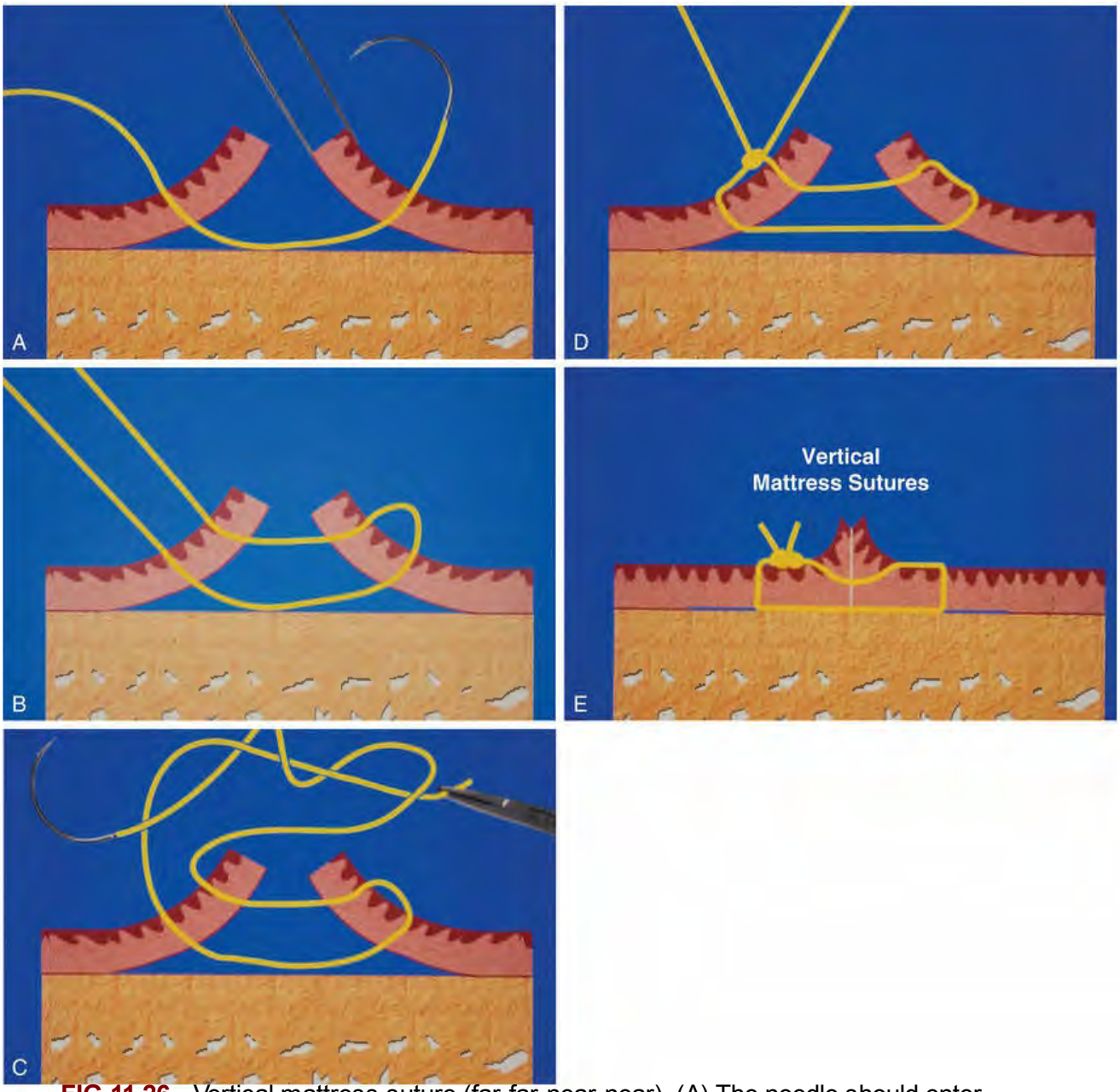

FIG 11.26 Vertical mattress suture (far-far-near-near). (A) The needle should enter the tissue a 90 degrees approximately 5–6 mm from the margin of the incision and exits on the opposite side (same distance on the lingual aspect of the tissue as the facial). (B–C) The needle is placed backwards in the needle holder and enter the lingual tissue towards the buccal (approxiamtely ½ the distance from the incision line. (D–E) The stitch is then tied off on the facial aspect.

Box 11.3

Basic Suturing Principles

1. Suture from mobile to immobile tissues: Allows for better control and

manipulation of the tissue (Fig. 11.27A).

2. Don't hold needle at swage: This may result in bending of the needle (Fig. 11.27B).

3. Enter tissue at 90 degrees: This allows for easier passage of the needle through the tissue and prevents tearing (Fig. 11.27C).

4. Keep fingers in needle holder (index finger for security): Usually the thumb and index fingers are used to hold the needle holder. The fingers should always remain in the needle holders because this will expedite the suturing process along with allowing for better control (Fig. 11.28A–B).

5. Enter 2–3 mm and exit from tissue margin: Less than 2 mm will lead to tearing of the tissue margin (Fig. 11.29)

6. Suture 3–5 mm apart: Too many sutures will impair blood supply to the incision line and increase possibility of ILO (see Fig. 11.29).

7. First throw must lie flat: After the first loop is tied, it is mandatory the loop lie flat. If folded, the loop will lose tension and knot security will be lost. Final tension of the first tie should be as horizontal as possible (Fig. 11.30).

8. Avoid excessive tension: Tying knots too tight leads to tissue ischemia and ILO. Knot tension should not cause tissue blanching. In tying the knot, a "sawing" motion should be avoided because this will result in weakening the integrity of the suture,

9. Evert tissue, not invert: This makes it less likely that ILO will occur (Fig. 11.31).

. Cut sutures approximately 2–3 mm at completion of knot: Less than 2 mm leads to loss of knot tension and more than 3 mm leads to patient irritation. When the ends are too long, patients will tend to irritate the area with their tongue (Fig. 11.32).

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. Completed knot: The final knot should be tight and firm so that slippage will not occur. Ideally, the smallest knot possible should be used to prevent tissue and foreign body reactions.

Suturing Instruments

It is imperative the implant clinician have a complete understanding of the instrumentation utilized in the suturing technique.

Tissue Pick-Ups

The goal of the tissue pick-up is to hold tissue (i.e., flap) while suturing. Care should be exercised not to crush or sever the tissue. There are various types of tissue pick-ups with the serrated being the most popular. The 1 × 2 tip will usually result in tearing of the tissue, especially when the tissue is thin (Fig. 11.33).

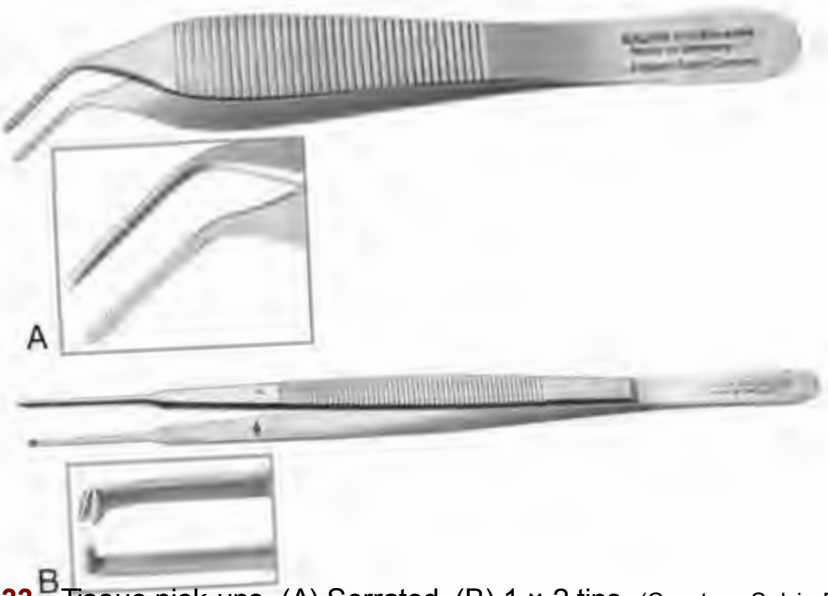

FIG 11.33 Tissue pick-ups. (A) Serrated. (B) 1 × 2 tips. (Courtesy Salvin Dental Specialties, Inc., Charlotte, NC.)

Needle Holders

Most needle holders are made from stainless steel, titanium, and tungsten

carbide tipped. The tungsten carbide tipped needle holders tend to deform the suture needle the least amount. Correct use of needle holders includes:

- Always use the appropriate-size needle holder for the size of the needle. The larger the needle size, the wider and heavier the needle holders should be. In contrast, with thinner tissue with a smaller size needle and suture material, smaller, more delicate needle holders are recommended (e.g., Castroviejo).
- Avoid placement of the needle holders near the swage or eye of the needle. Needles should be grasped approximately ¼ to ½ their length from the swaged area.
- Check the alignment of the needle holder tips, making sure there is no opening between the tips. The needle should not be able to rock, twist, or turn within the needle holder tips.
- Always close the needle holder on the first or second ratchet. If the needle is grasped too tightly, the needle may break or weaken. Hemostats should never be used as a replacement for needle holders because they will damage the suture needle and material (Fig. 11.34).

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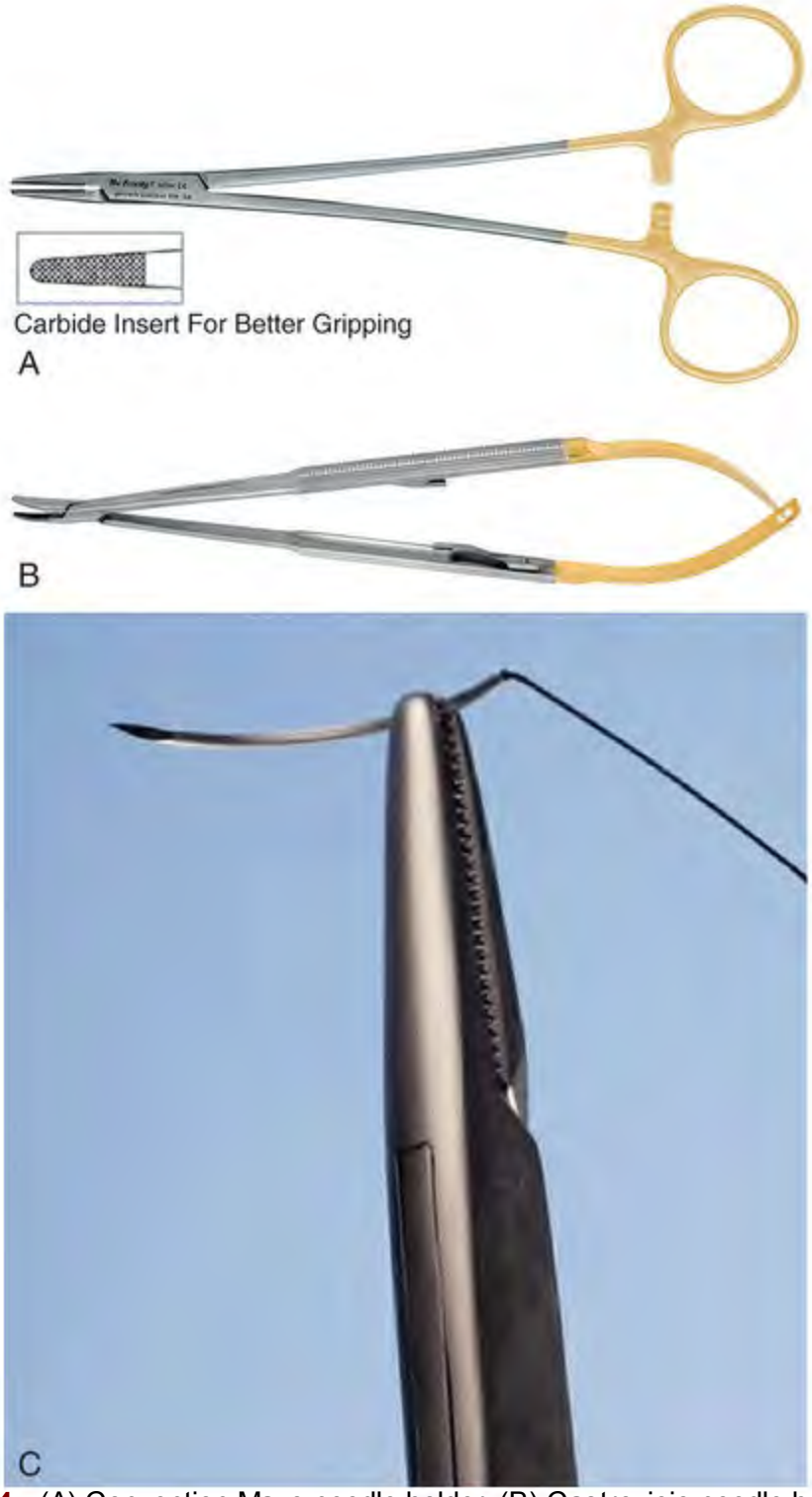

FIG 11.34 (A) Convention Mayo needle holder. (B) Castroviejo needle holder. (C) Ideal needle holder placement. (A–B, Courtesy Hu-Friedy Mfg. Co., LLC, Chicago, IL.)

Suture Scissors

There exist many different types of scissors that may be used in the suturing process. There are straight, curved, and special suture scissors that are used

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for cutting sutures, especially for removing sutures postoperatively (Fig. 11.35). When using suture scissors to cut the ends of the tied knot, make sure both tips of the scissors are visible to avoid inadvertently cutting tissue beyond the suture.

FIG 11.35 (A) Various types of straight vs. curved scissors. (B) Postoperative scissors. (A, From Trott AT: *Wounds and lacerations: emergency care and closure*, ed 3, Philadelphia, 2005, Mosby. B, From Salvin Dental Specialties, Inc., Charlotte, NC.)

Suturing Knots

Surgical suture knot tying is the most important aspect of suturing and often the most common problematic area. Surgical knots in the oral cavity must be particularly secure to overcome the potential of loosening with saliva and normal function.[46] There are three components of a sutured knot: (1) loop, which is created by the knot; (2) knot, which is composed of multiple throws, each which represents a weave of two strands; and (3) ears, which are composed of the cut ends of the suture.[47] For knots to be effective, they must contain all three parts and possess attributes of both knot security and loop

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security. Knot security is defined as the efficacy of the knot at resisting slippage when load is applied. This depends on three factors: friction, internal interference, and slack between suture throws.

Loop security is the ability to maintain a tight suture loop as a knot is tied.[48] Any tied knot may have good knot security but poor loop security (a loose suture loop). Loose suture loops may be ineffective in approximating tissue edges to be secured.

Ideally, the knot should have minimal volume and be tied so that it fails only by breakage, rather than by slippage. A three-throw surgeon's knot square (2/1/1) should be used.[49]

Security of the knot will depend on the material used, the depth and location of the wound, and the amount of stress that will be placed on the wound postoperatively. Operator experience is an important factor because considerable variation may result between knots tied by different surgeons and even between knots tied by the same individual on different occasions (Fig. 11.36).[50]

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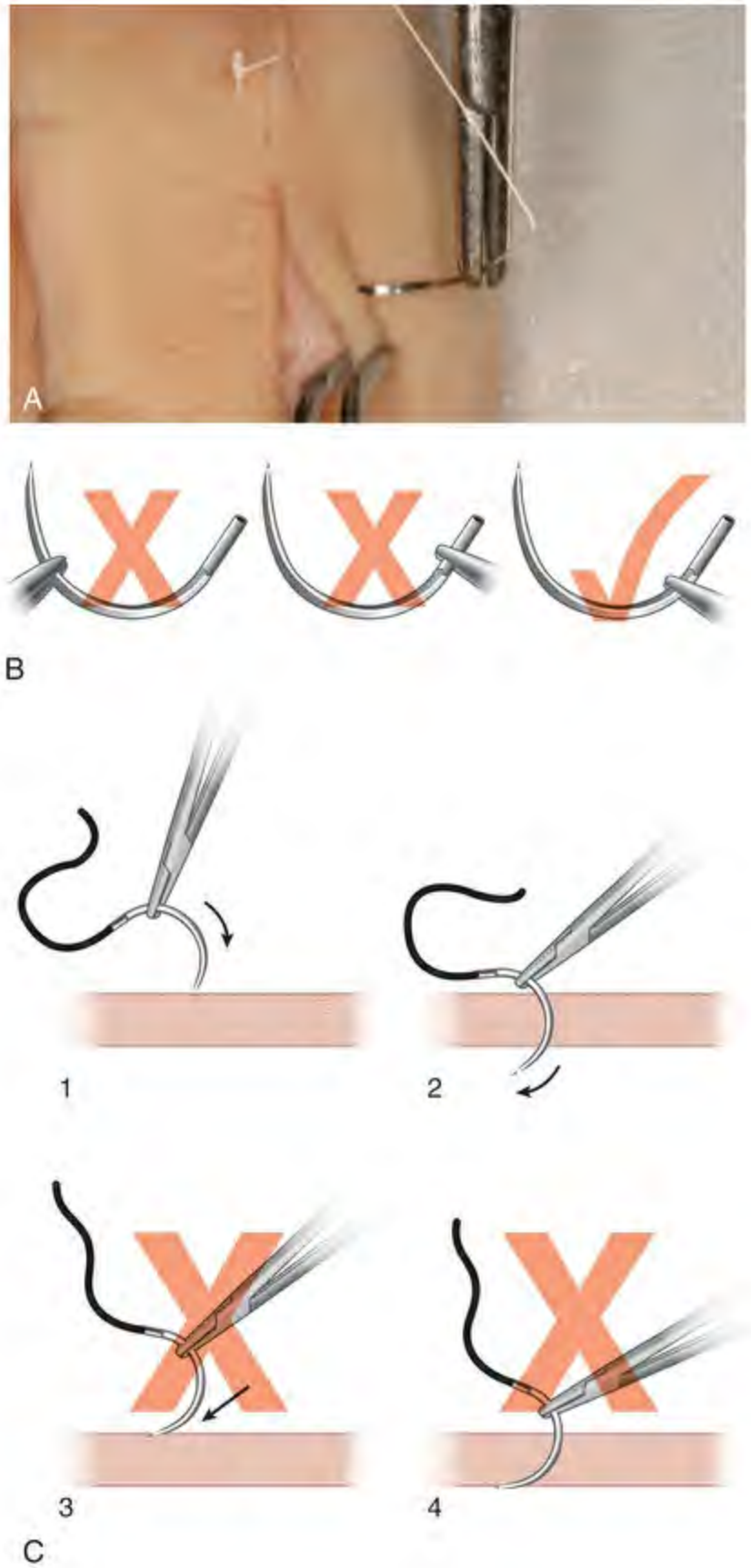

FIG 11.27 (A) Always suture from mobile to immobile tissue. (B) Never hold the needle at the swage to avoid fracturing the needle. (C) Always enter the tissue at a 90-degree angle.

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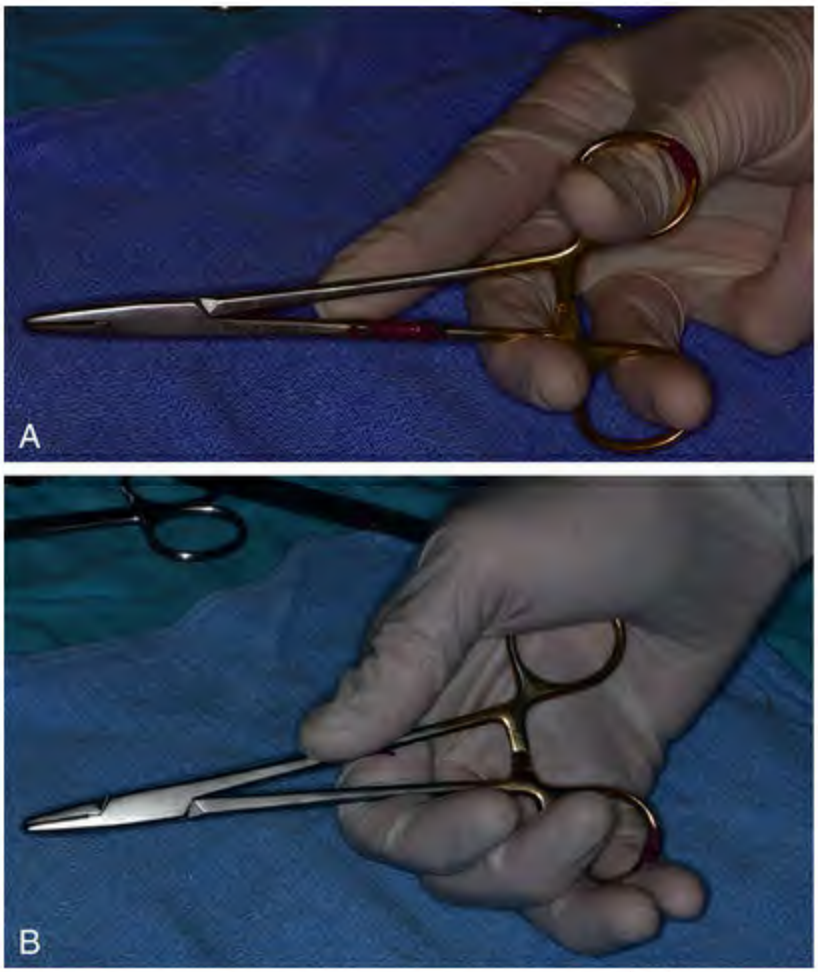

FIG 11.28 (A) Proper needle holder hand position. Index finger and thumb should always remain in needle holders. (B) Incorrect hand position using a palm grasp, which leads to inadequate control.

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FIG 11.29 Enter the tissue with greater than 2 mm to avoid tearing. Multiple sutures should be placed no closer than 3–5 mm apart.

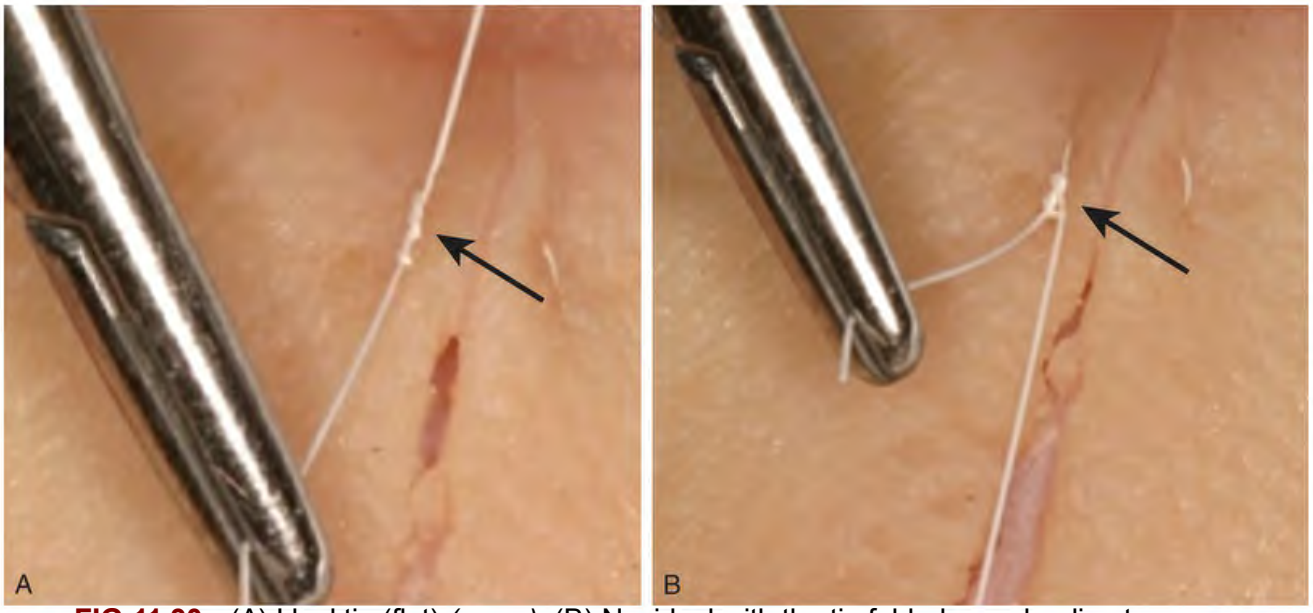

FIG 11.30 (A) Ideal tie (flat) *(arrow)*. (B) Nonideal with the tie folded over, leading to loss of tension *(arrow)*.

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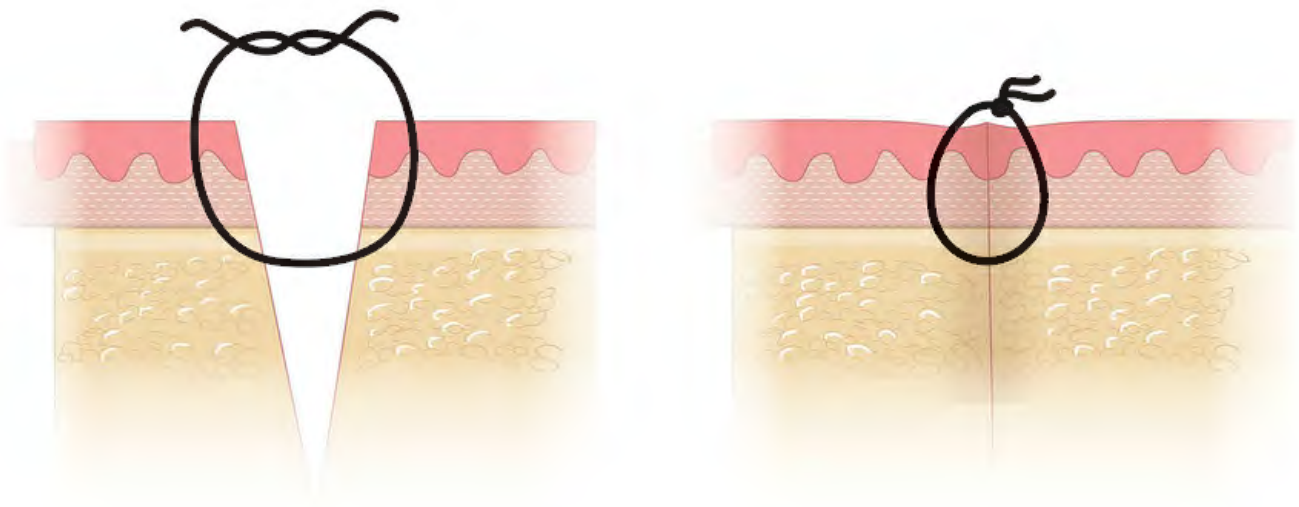

FIG 11.31 Always evert the tissue, not invert.

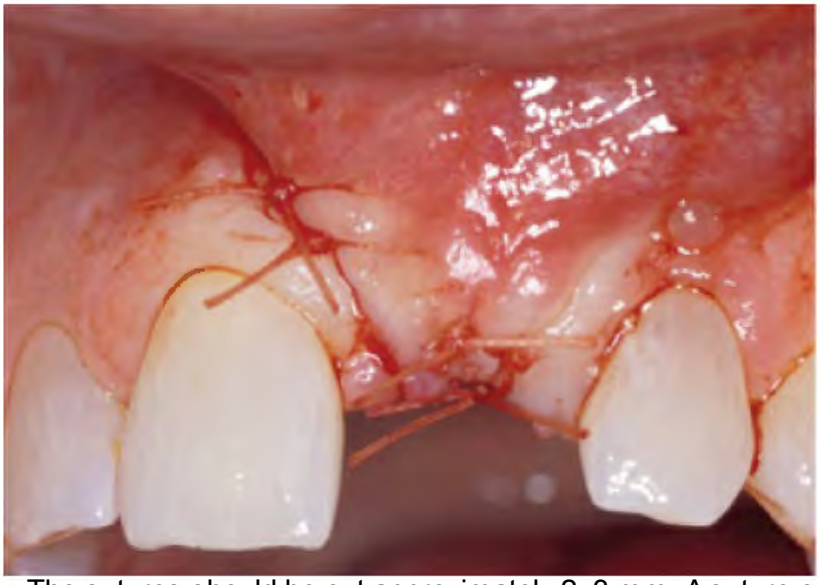

FIG 11.32 The sutures should be cut approximately 2–3 mm. A suture edge that is too long will unravel, which can cause irritation for the patient.

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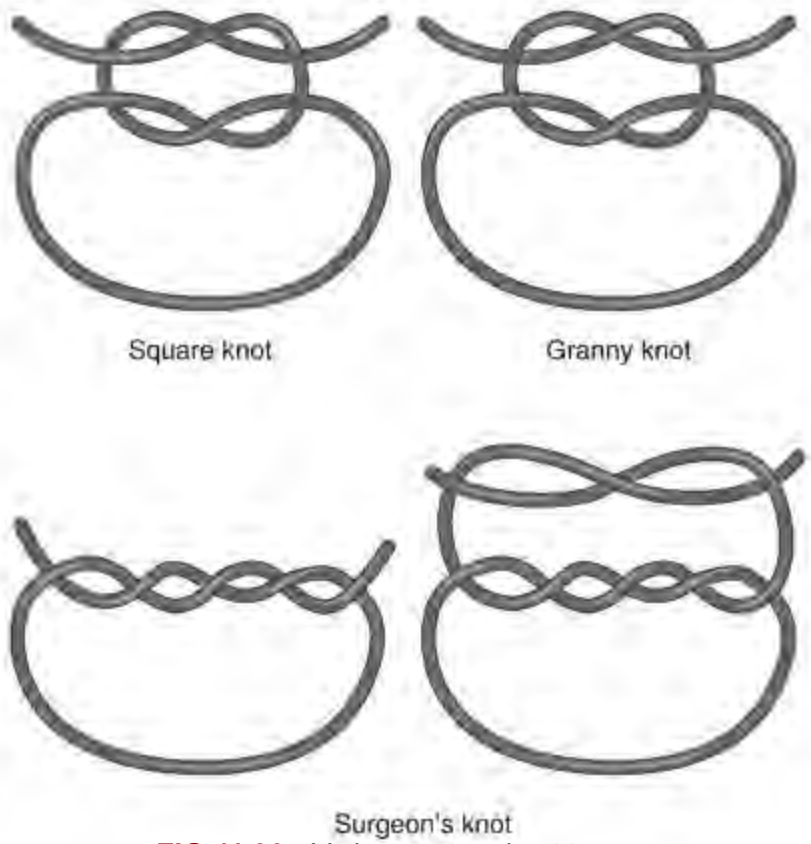

FIG 11.36 Various suture knot types.

Treatment Implications

The type of surgical knot is directly related to the suture material being used. When using silk, e-PTFE, chromic, or plain gut, a slip (granny) knot should be used. With synthetic resorbable and nonabsorbable synthetic suture materials, a modified surgeon's knot is recommended.[51] For most dental implant procedures, the surgical knot of choice is the modified surgeon's knot. The basic surgeon's knot is composed of two overhand knots. The first overhand knot is a double (i.e., composed of two loops or throws) and the second overhand knot is a single (loop) wound in the opposite direction. Additional knot security can be achieved with the common modification to the surgeon's knot consisting of the addition of a third knot (composed of two loops) in the same direction as the first loop.[52]

Bone Graft (Particulate) Material in Incision Line

No particulate graft material should be present in the incision line during initial primary closure because this will delay soft tissue healing. Once the tissues are sutured, the incision line is inspected for any bone graft particles

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between the soft tissue margins (Fig. 11.37).

FIG 11.37 Bone graft material must be removed from within the incision line to prevent wound dehiscence.

Decreasing "Dead Spaces"

Gentle pressure is applied to the reflected soft tissue flaps for 3 to 5 minutes. This pressure may reduce postoperative bleeding under the flap, which may cause "dead spaces" and delayed healing. Any stagnant blood under the flap is "milked" from under the soft tissue by gentle pressure. This also allows the fibrin formation from the platelets to help "glue" the flap to the graft site (Fig. 11.38).

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FIG 11.38 Gentle light pressure to minimize dead spaces after suture completion decreases the possibility of bacteria accumulation.

Decrease Inflammation

Systemic corticosteroids or nonsteroidal antiinflammatory medications (NSAIDs) may be administered before and after surgery to decrease soft tissue edema because edema has been shown to contribute to incision line opening.

Transitional and Interim Prosthesis Design

Occlusal forces applied to a removable prosthesis over a healing implant or graft site may also cause incision line opening of soft tissues and delay wound healing. Without appropriate adjustment, these forces can easily result in ILO by compressing the surgical area during function before suture removal. The potential for crestal bone loss is increased during any graft healing or around implants during stage I healing, which may lead to implant failure from early loading. Although use of such prostheses should be discouraged, other strategies to minimize or eliminate this possibility would include extensive relief of the intaglio surface, flange elimination, and use of tissue conditioners. Much more preferable provisional tooth replacement(s) would be either tooth or implant (transitional) supported (Fig. 11.39).

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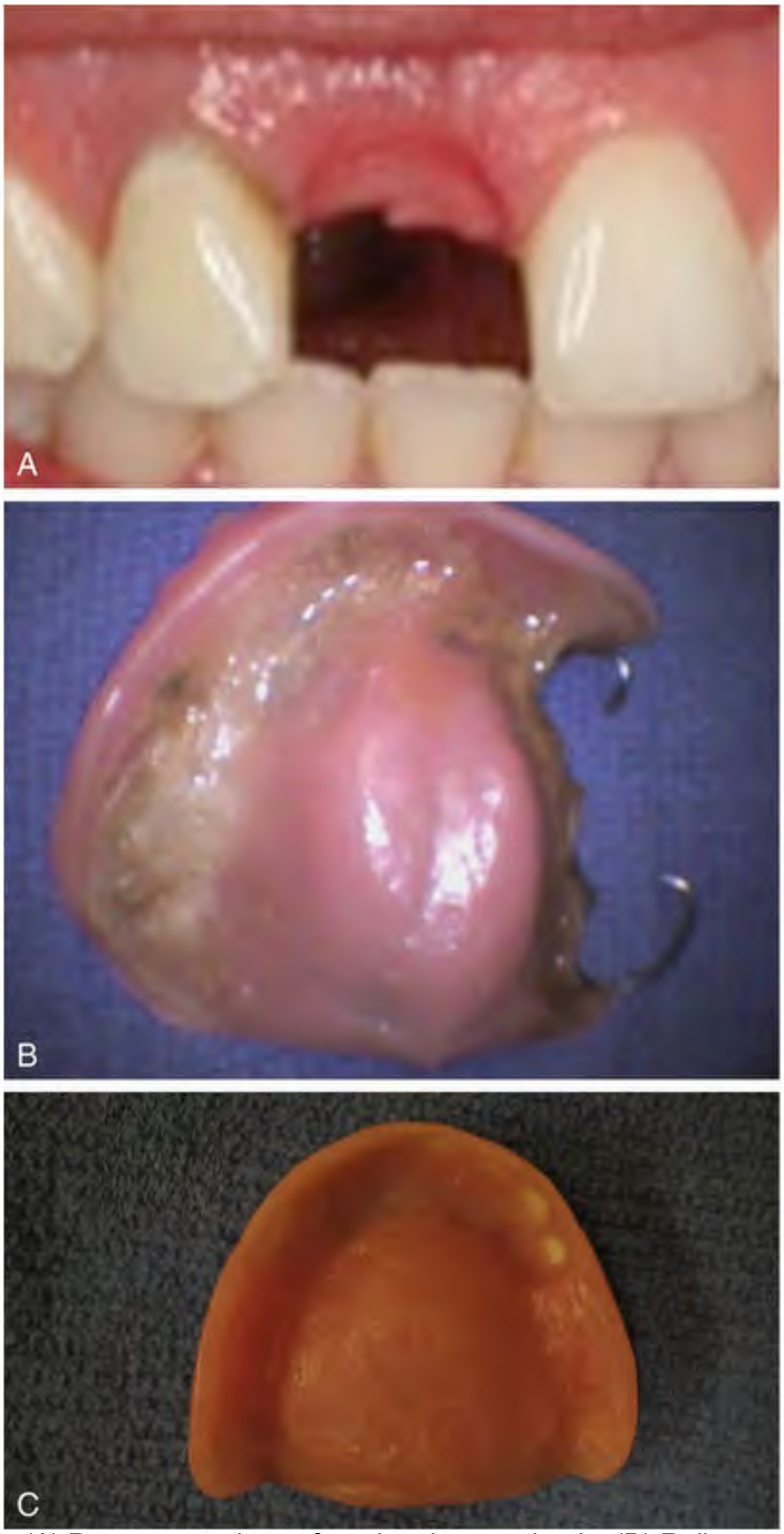

FIG 11.39 (A) Pressure on tissue from interim prosthesis. (B) Reline material may develop fungus growth. (C) Primary stress-bearing area (e.g., maxilla: palate; mandible: buccal shelf) must be maintained.

Other examples of fixed transitionals would include the bonding of natural tooth crowns or denture teeth to the teeth bounding the edentulous space

and modification of existing fixed partial denture, i.e., pontic shortening. Removable transitional prostheses such as an Essix retainer or Snap On Smile prosthesis are frequently utilized due to their rigid support and resultant lack of pressure on the incision line. A resin-bonded fixed restoration can also be fabricated to provide improved function, especially when crestal bone regeneration is performed.

The prosthesis may depress the interdental papillae of adjacent teeth. As a result, a resin-bonded fixed prosthesis is fabricated for the extended healing, and a removable device may be used short term for cosmetic emergencies (if the prosthesis debonds).

When a resin-bonded restoration is used, the adjacent teeth are not prepared and the device is bonded to teeth below the centric occlusal contacts. The interdental papillae are often depressed after initial socket healing. This type of transitional restoration for the single-tooth implant has the multiple benefits of being off the soft tissue drape, the developing bone augmented site, and the healing implant-bone interface. Several options to the resin-bonded device permit these goals. An Essix appliance is an acrylic shell, similar to a bleaching tray, that has a denture tooth attached to replace the missing tooth. This prosthesis is the simplest treatment for tooth replacement postsurgery.

When an adjacent tooth requires a crown in the overall treatment plan, the adjacent tooth may be prepared and a cantilevered transitional fixed partial denture with a pontic over the surgical site may be used. When the patient requires orthodontics, a denture tooth and an attached bracket may be added to the orthodontic wire. A cast-clasp RPD with indirect rest seats, which prevents rotational movements on the surgical site, is an excellent option.

Atraumatic Suture Removal

Etiology

Removing sutures too early or traumatically may result in incision line opening and causing a delayed healing leading to morbidity of the implant or bone graft.

Prevention

Normally, nonresorbable sutures or extended absorbable sutures are removed within 10–14 days after surgery. Suture removal should include the following steps:

1. Patient rinses lightly with 0.12% chlorhexidine gluconate.

2. With tissue pick-ups, hold up the knot end of the suture and cut the suture closest to the tissue. Care should be exercised to not traumatize or irritate the surgical wound.

3. Gently pull the suture out with the knot outside of the tissue. Do not pull the knot through the tissue to remove.

4. Have the patient rinse with 0.12% chlorhexidine. Evaluate and make sure the interim prosthesis does not impinge on the surgical wound (Fig. 11.40).

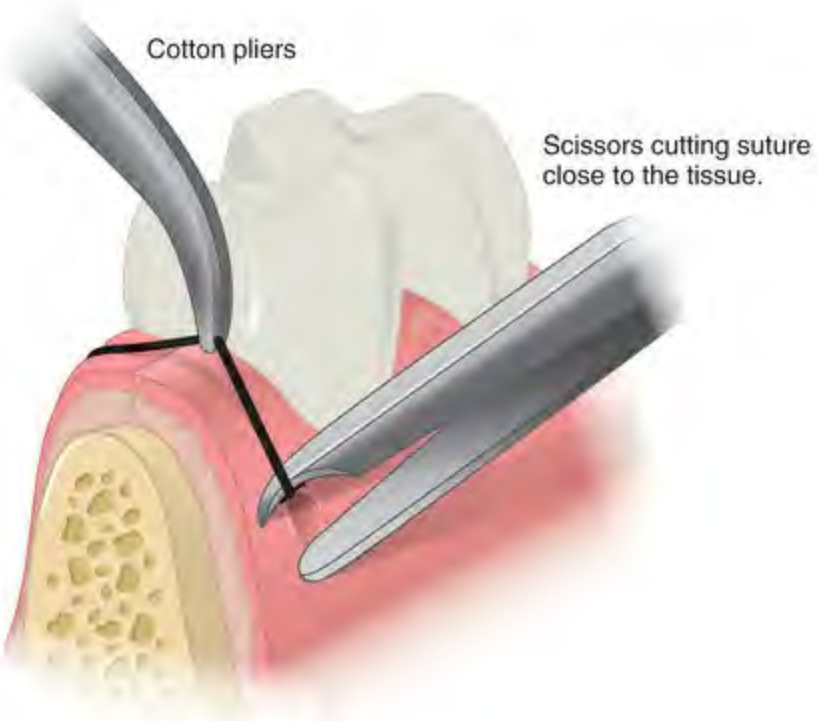

FIG 11.40 Suture scissors to remove sutures atraumatically.

Decrease the Possibility of Infection

Antibiotics

An important complication to prevent after implant surgery is infection. Infection can lead to a multitude of problems, including pain, swelling, loss of bone, and possible failure of the implant. Because of the risk of morbidity from infections, antimicrobial therapy is an essential component of the

surgical protocol. A high microbial burden in a wound increases the host's inflammatory response to the area.

Bacteria release endotoxins and metalloproteases that destroy the extracellular matrix of healing connective tissues and cause cell lysis. Bacterial infection and increased inflammation can lead to further tissue damage. Bacteria also compromise wound healing by competing with the healing tissue for nutrients and oxygen.[53]

It is prudent to address chronic or acute periodontal or endodontic infections prior to implant surgical procedures. Prophylactic use of antimicrobials in the form of antibiotics and antimicrobial rinses has significant benefits for prevention of infections following implant surgical procedures.

Postoperative surgical wound infections may have a significant impact on the well-being of the patient and implant survival. Documented cases of potential consequences of infection range from increased pain and edema to patient mortality. One of the main causes of dental implant failure may be bacterial contamination at implant insertion.

Antimicrobial Rinse

Another modality for antimicrobial prophylaxis for implant surgery is the use of an oral rinse, (e.g., 0.12% or 0.2% chlorhexidine digluconate). Chlorhexidine gluconate is a potent antibacterial rinse that causes lysis by binding to bacterial cell membranes. It has high substantivity, which permits it, at high concentrations, to exhibit bactericidal qualities by causing bacterial cytoplasm precipitation and cell death.

In the oral cavity, chlorhexidine has been shown to have biologic substantivity and slow release from tissue surfaces over a 12-hour period. In vitro studies have reported inhibitory effects of chlorhexidine on cultured epithelium and cell growth. Clinical studies have not supported the laboratory findings.

In contrast, chlorhexidine has been demonstrated to be an effective adjuvant in reducing biofilm, enhancing gingival health, improving soft tissue healing, treating periodontal disease, preventing alveolar osteitis, improving tissue healing after extractions, and reversing peri-implantitis, while showing no adverse effects on implant surfaces. When evaluating the effect of preoperative chlorhexidine before dental implant surgery, a significant reduction in the number of infectious complications (2 to 1) is realized and a sixfold reduction in implant failures in comparison to no use

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of chlorhexidine controls has been reported (Fig. 11.41).

FIG 11.41 0.12% Chlorhexidine Gluconate (Courtesy 3M Corporate, St. Paul, MN.)

Aseptic Technique

To prevent conditions likely to result in infection, a controlled, well-monitored aseptic setting should be achieved for the surgical procedure. The aseptic surgical site includes proper disinfection and draping procedures of the patient, hand scrubbing, sterile gowns worn by all surgical members, and maintenance of complete sterility of the instrumentation.

Decreased Surgical Time

Another important surgical factor related to postoperative infection is the duration of the surgical procedure. This factor has been shown to be the second most critical risk factor (after wound contamination) affecting postoperative infection rates.[18] Surgical procedures lasting less than 1 hour have an infection rate of 1.3%; procedures in excess of 3 hours increase the infection rate to more than 4%. It is postulated that the rate of infection doubles with every hour of the procedure.

Clinician Experience and Skill

The skill and the experience of the surgeon with the placement of implants have been shown to be significant in postoperative infections and implant failures. A recent study has reported that less experienced surgeons (<50 implants placed) have a 7.3% increase in failure rates in comparison to experienced surgeons.

Diet and Supplements

Aside from routine postoperative instructions specific to diet, the use and potential benefits of supplements is a frequent topic of inquiry from patients. Significant vitamin and trace mineral deficiencies are rarely seen in patients with acute wounds in whom healing is rapid and uncomplicated. However, in patients who have chronic disease and who may have inadequate diets, vitamin deficiencies may play a significant role in delaying wound healing. In general, if the nutritional status of a patient is in question, supplemental doses of several key vitamins should be recommended. These medications are inexpensive and have a very low rate of morbidity if given in therapeutic doses.

Vitamin C

Vitamin C, oxygen, ketoglutarate, and iron are essential cofactors for the enzymes prolyl hydroxylase and lysyl hydroxylase, both of which are required for normal collagen metabolism. Vitamin C is important in aerobic metabolism. Fibroplasia is especially sensitive to vitamin C deficiency. This is dramatically demonstrated in patients who suffer from scurvy, in which wounds fail to heal, fracture nonunions occur, and healed wounds dehisce.

Vitamin A

Vitamin A deficiency is known to impair wound healing even when steroids are not being used.[54] Vitamin A is an important part of wound healing through cellular reproduction and cellular differentiation. Additionally, Vitamin A reduces the risk of wound infection as it is essential for proper immune system function and management of inflammation.

Vitamin B

Vitamin B complex consists of eight water-soluble vitamins found in meat, dairy, vegetables, fish, and cereals. Vitamin B complex helps to promote cell proliferation and maintain healthy skin and muscle tone, increase metabolic rate, and enhance immune and nervous system function. Deficiencies in vitamin B may impair wound healing, antibody formation, white blood cell function, and bacterial resistance. They are associated with several disorders, many of which have skin manifestations.

Thiamine

Thiamine is associated with decreased wound healing and breaking strength. B-complex vitamins and cobalt are essential cofactors for many enzyme systems.

Vitamin E

Vitamin E deficiency on wound healing has not been well described. However, the use of Vitamin E has been shown to improve wound tensile strength in patients whose wounds had been exposed to ionizing radiation. Vitamin E may reduce the peroxidation of lipids caused by radiation. In large doses, vitamin E may be detrimental to wound healing and should not be given if the patient does not have a clear deficiency.[55]

Copper

Copper is needed for lysyl amine oxidase, and calcium is needed as a cofactor for the normal function of granulocyte collagenase and other collagenases.

Zinc

Zinc deficiency retards both fibroplasia and epithelialization. A common element in numerous enzymes found in the human body, zinc is needed for

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DNA replication and is a coenzyme for DNA polymerase and reverse transcriptase. Cells with a rapid cellular turnover rate are most severely affected by zinc deficiency.

Reduction of Local Factors

Adverse/destructive oral habits can contribute to wound dehiscence with or without an interim prosthesis. Patients with parafunctional habits should be identified during the early phases of treatment planning. Occlusal overload, even on a well-adjusted interim prosthesis, can transmit harmful forces to the underlying tissues.

A cascade of complications may result, beginning with wound dehiscence, and lead to lack of integration or failure of hard and/or soft tissue augmentation procedures. The causes of parafunction or nonfunctional tooth contact have been classified into six categories: (1) local, (2) systemic, (3) psychologic, (4) occupational, (5) involuntary, and (6) voluntary.[56] Local factors include tooth form or occlusion, as well as soft tissue changes such as ulcerations or pericoronitis.

Psychologic causes occur with the greatest frequency and are associated with the release of emotional tension or anxiety. Included in this category are nail biting, cheek biting, and sucking habits. Occupational factors for professionals such as physicians, dentists, athletes, and precision workers may lead to parafunction, as well as for the seamstress or musician who develop altered oral habits. The fifth cause of parafunctional force is involuntary movement that provokes bracing of the jaws, such as lifting of heavy objects or sudden stops while driving. Examples of voluntary causes include chewing gum or pencils, bracing the telephone between the head and shoulder, and pipe smoking.

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Management of Incision Line Opening

In the dental implant literature, there are two treatment recommendations discussed with respect to incision line opening. The first is to allow the surgical wound to heal via secondary intention with the use of antimicrobials and hygiene measures (Box 11.4). The second treatment modality is to resuture the opened surgical wound, which is not recommended by the authors (Table 11.2).

Box 11.4

Secondary Intention Protocol

Clinician

1. Relieve prosthesis to have no buccal flange and no contact on the surgical wound area.
2. Maintain stress-bearing areas on the prosthesis with the use of a tissue conditioner; however, material should be removed from the dehisced area.
3. Locally clean the dehiscence area with 0.12% chlorhexidine.
4. Closer observation of the patient to include recall appointments a minimum of once a week for the first month.

Patient Instructions

1. Nonvigorous rinse with 0.12% chlorhexidine twice daily, plaque control.
2. Minimize the use of interim prosthesis.
3. No direct mastication on the area of dehiscence.
4. Avoid smoking and the use of alcohol.
5. Avoid peroxide and alcohol-based mouth rinses.
6. Avoid acidic foods.

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7. Avoid inspection of dehiscent site (pulling on lip to see area).

8. Do not use any denture adhesive with the interim prosthesis.

TABLE 11.2
Management of Incision Line Opening

	Treatment	
Surgical Procedure	**Early (<1 Week)**	**Late (~>3 Weeks)**
Implant: One Stage	Secondary intention protocol (resuture ONLY if favorable conditions)	Secondary intention protocol
Two Stage	Secondary intention protocol	• Remove overlying tissue with tissue punch bur or scalpel • Place permucosal extension (≈1 mm above tissue; higher extension may lead to excessive force on the implant) Fig. 11.42
Particulate graft	Secondary intention protocol	Secondary intention protocol
Block graft	Secondary intention protocol	• Check for mobility of graft • Reduce sharp bony edges • Freshen wound edges with diamond bur
Membrane: collagen (regular)	Secondary intention protocol	Secondary intention protocol
Collagen (extended)	Secondary intention protocol	Secondary intention protocol Trim excess membrane above tissue level with scissors
Acellular dermal matrix (Alloderm)	Secondary intention protocol	Secondary intention protocol Trim excess membrane above tissue level with scissors
Nonresorbable (cytoplast, titanium)	Secondary intention protocol	• Remove membrane if chronic tissue irritation or infection • Ideally, attempt to maintain for at least 6 weeks

To allow the site to heal by secondary intention, there needs to be significant discipline and patient cooperation for a successful outcome. This treatment technique is dictated by many variables such as health of the existing tissue, tissue thickness, location, age of the patient, and size of the dehiscence. The technique includes the following:

Resuturing Protocol

Resuturing is the more difficult and unpredictable technique. When attempting to resuture a fresh wound, usually the epithelium is thin and friable, which often leads to tearing of the incision line. This may result in a larger dehiscence or infection. If completed, the margins of the tissue should be “freshened” with a scalpel or a diamond bur. Greenstein has recommended that, when the dehiscence is small and occurs within 24 to 48 hours, the clinician may immediately resuture the dehiscence. Once the wound is large (2 to 3 cm) or the time elapsed is more than 2 to 3 days, it becomes more difficult for the margins of the wound to be excised and resutured.[57] It is the authors' recommendation to be cautious with resuturing incision lines that may end up resulting in increased morbidity of the

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surgical wound.

As stated earlier, there exist many variables when evaluating a wound dehiscence. Two of the most important factors are the type of surgical procedure that was completed and the length of time since the dehiscence occurred. Therefore, a procedure-specific protocol has been established that is dependent on the timing of the dehiscence (early [within first 2 to 3 days] vs. late [≈4 weeks after surgery]) (Fig. 11.42).

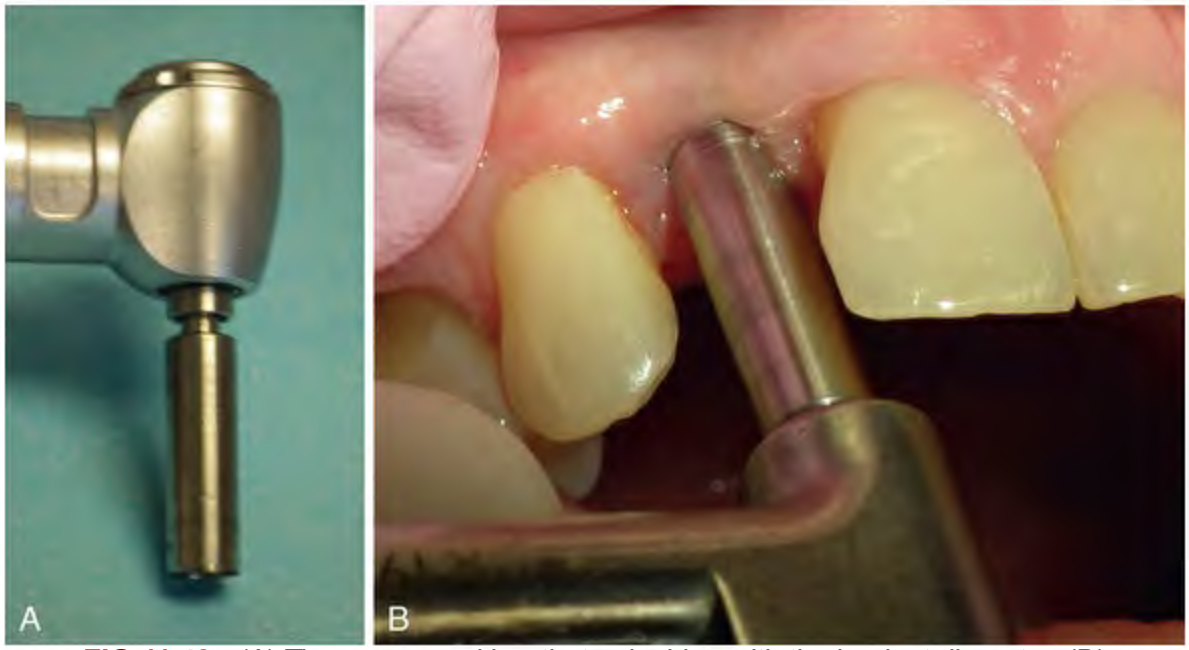

FIG 11.42 (A) Tissue removal bur that coincides with the implant diameter. (B) Removing the excess tissue with a latch handpiece.

Summary

The majority of highly experienced implant surgeons will attest that one of the greatest difficulties that they encountered during their respective learning curves was the maintenance of incision lines during and after surgery. Implant surgery, and especially bone grafting procedures, commonly cause a situation where hard tissue volumes will be larger than the soft tissue that originally covered the site. This soft tissue must be manipulated to prevent incision line opening. Managing this phenomenon during surgery is a skill, and one that requires great surgical fundamentals and practice.

Despite our best efforts, incision line opening does occur from time to time. When a wound opens and implant/graft contents become exposed to

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the oral environment, a situation occurs that demands extreme care in order to preserve the chances that the overall surgical outcome is a desirable one. The contents of this chapter will help lay a groundwork for the clinician to manage these situations in a way that will ensure successful outcomes despite the complication.

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12

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Bone Grafting Complications

Stephen Caldwell

The goal of any dental implant procedure is to restore the patient to optimal form, function, and esthetics. Through the combined efforts of a great number of clinicians and researchers, guidelines have been established in regards to proper implant numbers and positioning based on possible prosthetic designs. The patient's existing bone volume often makes the proper placement and positioning of implants difficult, if not impossible. Ideal treatment planning in implant dentistry often requires the correction of significant alveolar ridge defects in regions where dental implants are indicated to support critical prostheses. Alveolar ridge defects are caused by a variety of factors including developmental anomalies, trauma, and most commonly, tooth extraction. Following tooth loss, a predictable resorptive process of the alveolar bone occurs in both a horizontal and vertical dimension.[1,2]

The loss of alveolar bone can pose a challenge both from the perspective of supporting a conventional removable prosthesis or placement of dental implants in an ideal position for functional and esthetic results. Prior to development of effective bone grafting techniques, implants were placed in regions where there was available bony support, often leaving the restorative dentist with the task of restoring an implant in a less-than-ideal position within the arch. The success of implant dentistry today has been largely related to the advent of bone augmentation techniques that allow regeneration of an ideal ridge form and placement of implants in their ideal functional and esthetic positions.[3-7]

The augmentation of bone volumes through grafting is a highly technique-sensitive process. It requires meticulous surgical skill, practice, and knowledge to become proficient in creating predictable bone growth prior to implant placement. Complications are plentiful in this discipline, leading to treatment delays, patient and provider frustration, as well as possible neurosensory, vascular, and infectious issues. The dental implant surgeon must have a firm understanding of the limitations of various bone grafting techniques to develop appropriate treatment plans. Clinicians must be able to not only prevent complications during the procedure, but also properly

address these issues should they arise.

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Treatment Planning

Failure to Understand Bone Resorption

Etiology.

Treatment planning implant-supported restorations in edentulous spaces requires a clear understanding of the resorptive patterns of bone loss. As a ridge resorbs, available bone for support of dental implants disappears, preventing placement of implants in key locations for restorative success. After tooth loss, the initial pattern of bone resorption starts with loss of the lateral (buccal) aspect of the ridge, eventually leading to a decrease in vertical ridge height. As this resorptive process occurs, the position of implant-supported restorations can be changed substantially secondary to the new interarch relationship between the maxilla and the mandible. For instance, the loss of maxillary posterior teeth with the accompanied loss of the buccal bony width will often lead to development of a posterior crossbite. This is compounded as the mandible deteriorates into a division C or D ridge, resorbing until the remaining mandibular basal bone is actually positioned laterally, away from the remaining maxillary bone (Fig. 12.1).

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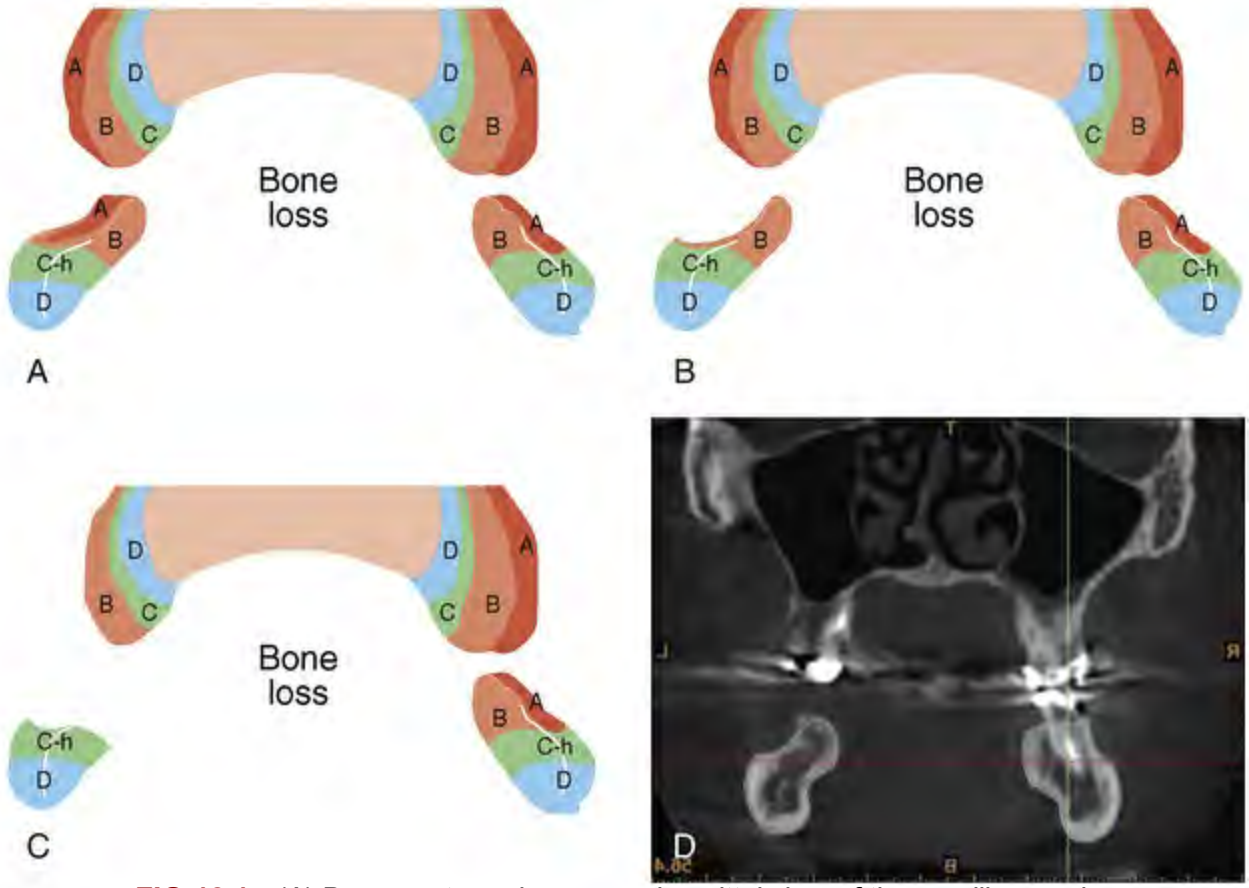

FIG 12.1 (A) Bony contours in a normal sagittal view of the maxillary and mandibular arches. (B) The initial resorption of bone in the lower arch destroys the lateral aspect of the lower ridge. (C) Further loss in the lower arch leaves the remaining bone in a more lateral position than the maxillary arch. Lateral resorption in the maxilla leaves the remaining bone in a more medial position than the lower arch. (D) The same sagittal view of a patient's CBCT scan depicts the same resorption pattern that is seen in B.

The treatment planning process must start with a reasonable assessment of the extent of the bony deficiency and the capacity of a regenerative procedure to create adequate support for implants in their ideal positions for comfort, aesthetics, function, and support. As the extent of bone regeneration is evaluated, care must be taken from the beginning stages to identify the expected positions of each restoration or prosthesis using accurate restorative wax-ups. Evaluation of the relationship between the required restorative positions and the bony deficiency will then provide insight into the volume and shape of the bone that will need to be generated. At this stage, the most predictable surgical approach and bone graft material (e.g., autograft, allograft, xenograft) is selected to ensure adequate bone support can be developed for ideal implant placement.

Complication.

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In site assessment treatment planning, complications often result when the clinician fails to understand the relationship between the limitations of various regenerative grafting techniques and the predictable development of the required bone contours and bone volume needed for overall restorative success. It is not possible to treat every defect with simple or limited techniques because this discipline requires a variety of approaches to meet the reality of advanced bone resorption. When the incorrect technique is utilized, inadequate bone volume will be regenerated, leading to either compromised restorative results or a potential failure of the prosthesis. These problems not only compromise the local grafting site, but they can also destroy bone around surrounding teeth, creating a worse situation than was originally encountered.

Prevention.

In an ideal setting, prevention starts with total awareness of ridge preservation and limiting bone loss before major ridge defects occur. This starts with atraumatic extraction techniques, aggressive socket grafting, and communication with the whole implant team in respect to the need for timely preservation of the ridge. The longer the patient remains without an implant in an extraction site, the greater the chance that adjunctive grafting procedures will be necessary. For patients with long-term edentulism, the surgeon needs to be fully aware of the mechanisms of bone resorption to understand the current underlying bony architecture and to correctly choose a grafting protocol that will build the correct volume for the intended prosthesis. A working knowledge of ridge resorption and expertise in the use of effective diagnostic imaging to accurately assess bone volumes gives the clinician the opportunity to correctly organize a reasonable and predictable implant treatment plan (Fig. 12.2).

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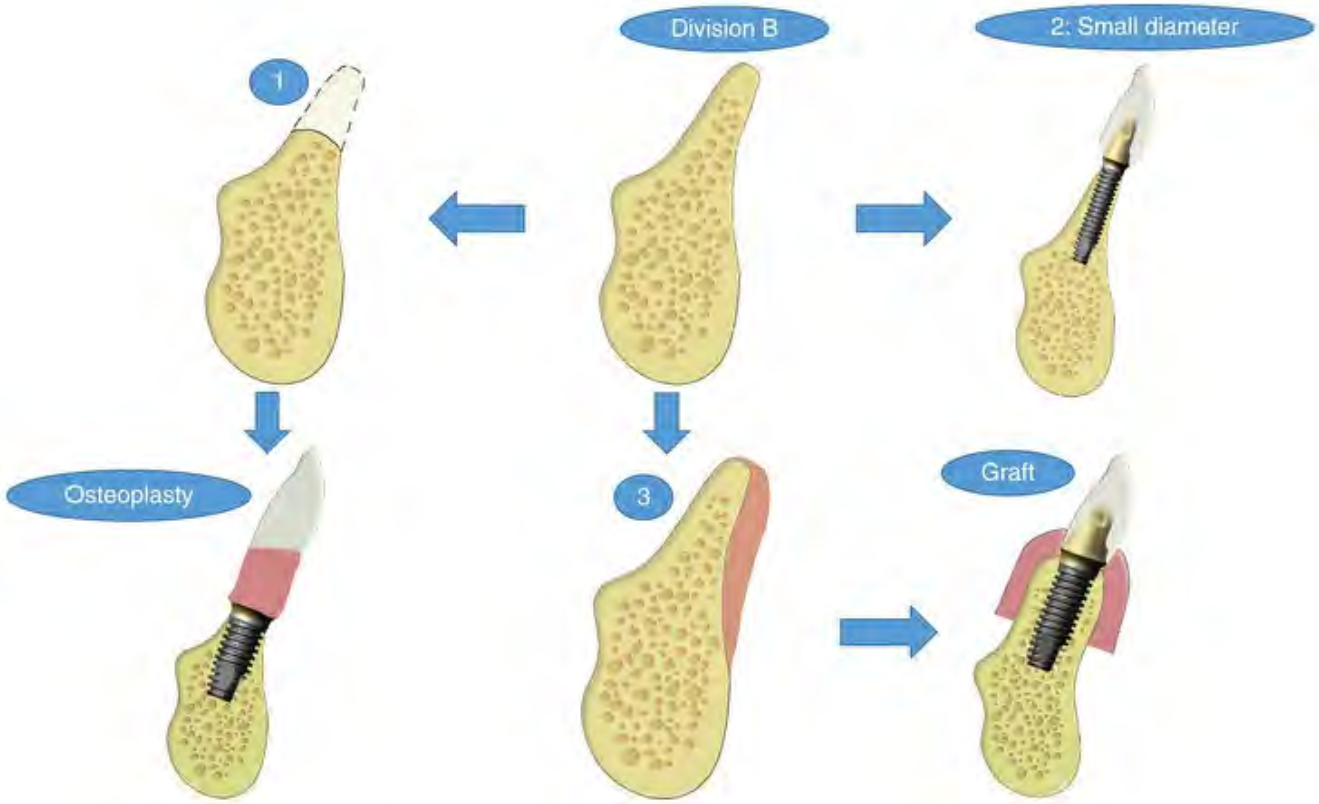

FIG 12.2 This series of images presents a decision tree that should be considered in each case when routes of treatment planning are being considered. For example, in a Division B ridge, many treatment options are possible, including osteoplasty, Division B implants, or bone grafting. Each of the treatment options has advantages and disadvantages that should be evaluated. As one can see, each treatment option will dictate the final restoration (e.g., FP1, FP2, or FP3).

Failure to Understand the Need for Bone Grafting

Etiology.

Success in any implant prosthesis requires the implants to be placed in positions that provide ideal aesthetics, function, comfort, and support. To be successful in the development of a favorable prosthesis, the number and positions for implants in an edentulous space must be determined with a careful analysis of the relationship between the restorative prosthesis and the forces that will be exerted on the final prosthesis. This is then associated with the functional and esthetic aspects of the case, ultimately dictating the relationship between the implants, bone, and opposing forces. All of these factors must be considered in planning support for a prosthesis that functions well while maintaining the bone volume around its implant abutments. Clinicians too often try to bypass the grafting process, either to save time or because they are not experienced in advanced grafting

techniques. Insufficient bone in recipient sites leads to placement of implants with inadequate diameters, short lengths, or in insufficient numbers. Compromises like these eventually lead to significant damage around an implant and the prosthesis it supports. Due to the fact that resorption occurs in every edentulous site, the need for adjunctive bone grafting is very common and is often vital for a successful outcome (Fig. 12.3).

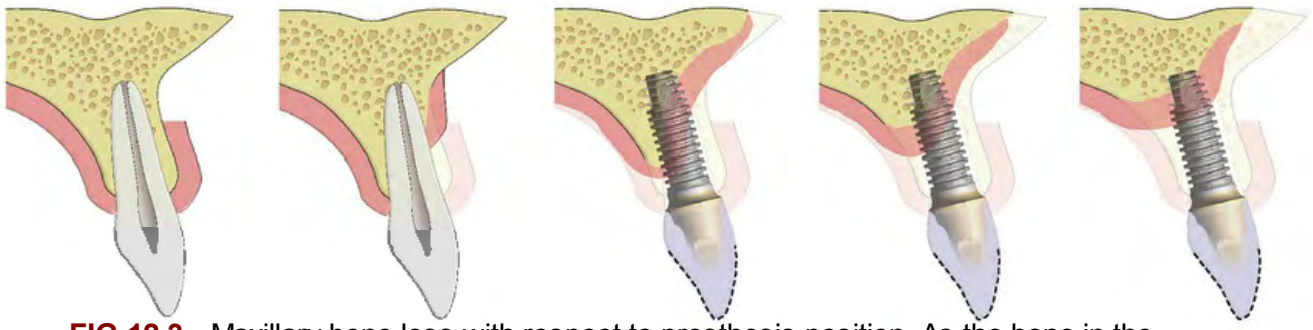

FIG 12.3 Maxillary bone loss with respect to prosthesis position. As the bone in the premaxilla resorbs, the vertical and horizontal soft tissue support around teeth and implants disappears. This exposes the body of a failing implant or requires the incorporation of pink porcelain in the treatment plan for a new implant.

Complication.

Failure to recognize the need for bone grafting leads to numerous treatment issues, ranging from esthetic complications to implant and prosthetic failure. Placing implants of suboptimal sizes or in less than ideal numbers to bypass the grafting process is a compromise that often leads to force-related failures of implant components, the prostheses itself, or accompanied bone loss. Ultimately, prosthetic and implant morbidities may result.

Prevention.

A multidisciplinary approach should be taken to assess the optimal prosthetic solution for the patient, based on the patient's wishes, available bone, and other factors. When the prosthetic plan has been established, the clinician should begin planning the implant positions required to execute the prosthetic option. Once the sites for implants have been determined, the associated sites are evaluated for foundational support in the required positions. If inadequate bone is available to successfully place an implant in a key location for the prosthesis, grafting should then be included in the

treatment plan to build the appropriate bone volumes.

Underestimation of Bone Required for Grafting of the Defect

Etiology.

One of the most difficult components of bone augmentation treatment planning is learning how to predict the amount of bone that will actually be required to develop the proper foundational support that the restorative treatment plan requires. Evaluation of the clinical situation, review of two-dimensional radiographs, assessment of models with restorative wax-ups, and information from cone beam computed tomography (CBCT) imaging all play a role in determining where bone will be required and how much bone will be needed to successfully graft the site. This is important when autogenous bone is incorporated into the regenerative process, and failure to clearly consider the difficulty of this bone harvest can lead to an eventual shortfall in the graft's success.

Complications.

In cases where the implant clinician fails to properly develop adequate bone volumes for grafting and implant positioning, reflection of tissue over the grafted site will reveal inadequate bony support for the intended implant size and position. At this time, critical decisions must be made to prevent the chance of compromising the overall case success due to this shortfall. The best solution is to stop and regraft the site, but this causes inconvenience for the patient, embarrassment for the surgeon, and an overall increase in the treatment time and expense. The alternative is to ignore the deficiency, placing the implant in a deficient site that ultimately limits the implant size or forces improper placement of the implant in an alternative position. Successful restorative cases require discipline and cutting corners leads to disappointed patients.

Prevention.

The use of CBCT imaging along with proper diagnostic casts allow the clinician to implement a proper prosthetic plan. The restorative wax-up can easily be interlaced into the CT imaging software for assessment of the bone volumes needed for proper implant support in key positions. Once the

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dimensions and volume of the graft have been determined, proper application of bone grafting techniques and materials is necessary to ensure that the intended volume can be achieved. At this point, the patient should be educated on the details of the regenerative procedures and a timeline of treatment. Advanced grafting procedures delay completion of the final prosthesis, and patients should be aware of the extent of the inconvenience that will need to be tolerated during this surgical sequence. Sites for autogenous grafts should also be evaluated to ensure there is adequate donor bone available to produce the bone foundation needed to execute the treatment plan (Figs. 12.4 and 12.5).

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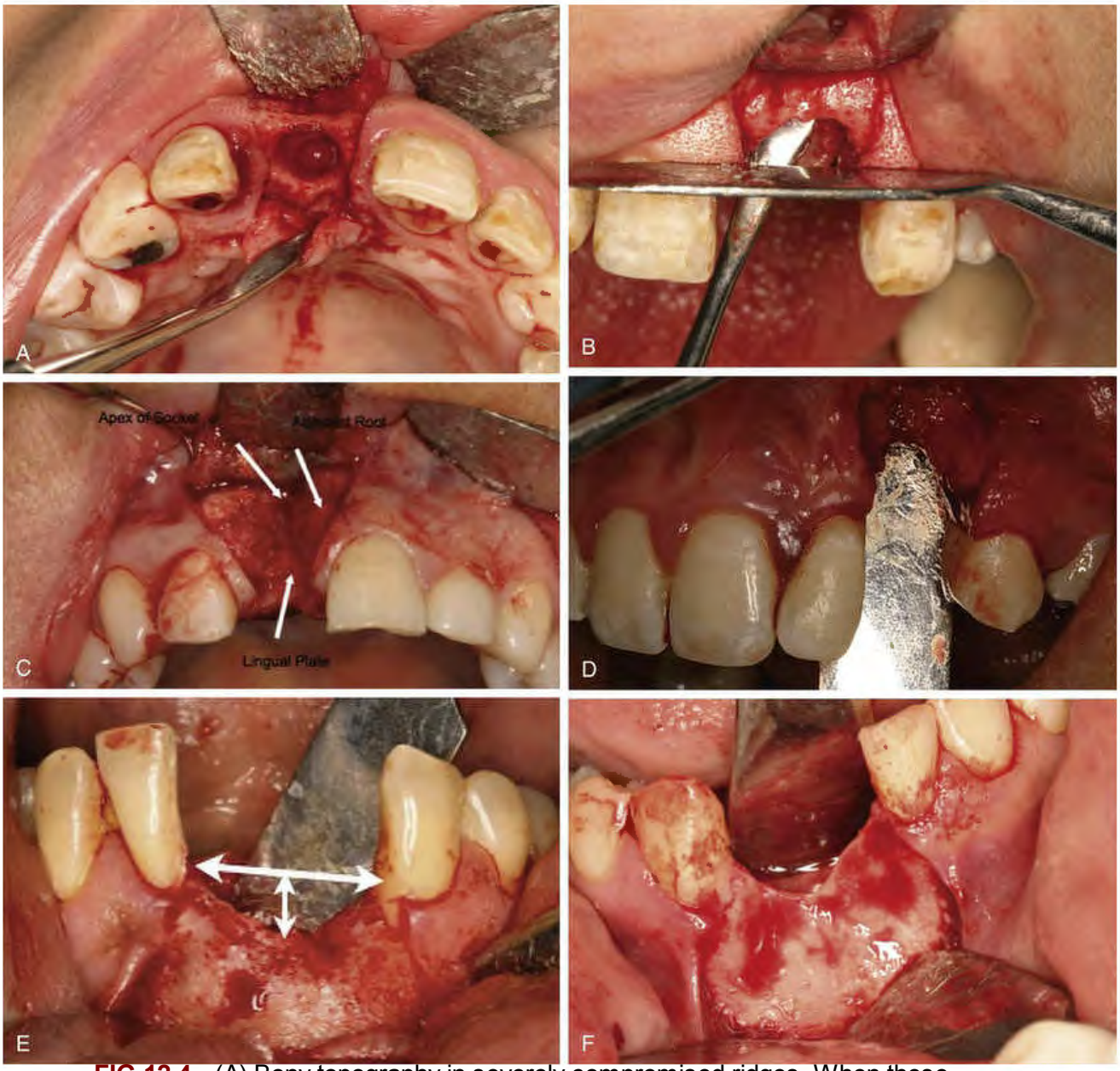

FIG 12.4 (A) Bony topography in severely compromised ridges. When these regions are being considered for restorations, consideration of the three-dimensional relationship of bone loss vs. adjacent tooth positioning is important. (B) Severe vertical resorption requires regeneration to avoid problems with support, aesthetics, and poor healing. (C) Complete loss of the facial cortical plate requires planning for support and development of significant width. (D) Defects that destroy both the facial and palatal cortical plates limit the choice of regenerative procedures that can be used. (E–F) When there is a sharp declining ridge adjacent to a natural tooth, placement of an implant 1.5 mm away creates a failing situation beginning at time of the initial implant placement. As time passes, both the tooth and the implant will be compromised. Stepping the implant away from the natural tooth can limit this proximity problem, but then the implant body is too low and the design and loading of the prosthesis begins to be problematic.

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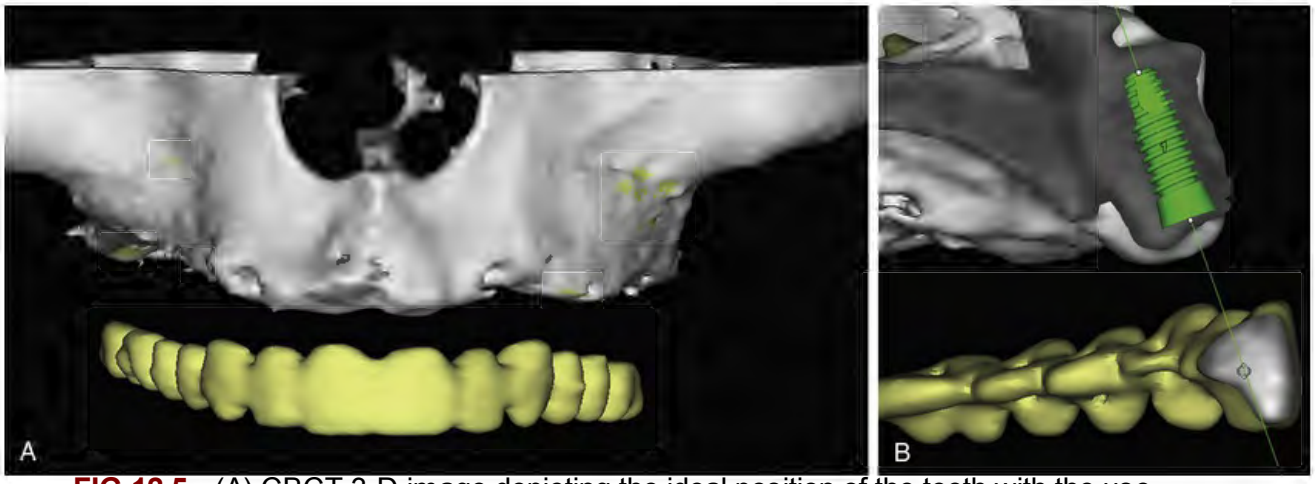

FIG 12.5 (A) CBCT 3-D image depicting the ideal position of the teeth with the use of a barium sulfate radiopaque template. (B) Sagittal view showing relationship of ideal implant placement, amount of hard tissue loss, and the ideal position of the tooth to be replaced.

Failure to Evaluate the Tissue Biotype in Treatment Planning

Etiology.

Patient-to-patient comparisons of the soft tissue drape surrounding the natural teeth often demonstrate significant differences in color, surface consistency, tissue thickness, and overall aesthetics. This is emphasized when a very thin and friable tissue drape surrounds an anterior tooth. Differentiation of patients into either a "thick biotype" or a "thin biotype" is a critical tool that can be used during anterior implant–related treatment planning. Cook and Mealey demonstrated the most simple way to determine tissue biotype is through the visibility of a periodontal probe in the sulcus of an anterior tooth. A patient with a thick biotype will not show any translucence of the probe through the sulcular tissue. In contrast, a thin biotype will allow visualization of the coloration of a probe through the sulcular tissue. A patient with a thick biotype has tissue with a robust pink, stippled appearance. This dense tissue drape forms a thick layer of tissue that is very forgiving when dental restorations are placed around natural teeth and when dental implants are involved. The thin biotype patient, however, presents a much more difficult challenge. These patients have a thinner labial plate thickness, a narrower keratinized tissue width, a greater distance from the CEJ to the initial alveolar crest, and there is visibility of a periodontal probe through the sulcus. As teeth migrate out of position or

rotate in the arch, the prominence of the roots can increase, complicating the soft tissue situation even more. Thin layers of tissue around the maxillary anterior teeth require meticulous planning to hide underlying crown margins. In the case of implants, problems related to the translucence of the dark hue of the implant body and the abutment can significantly complicate the aesthetics surrounding the final restoration (Fig. 12.6).[58]

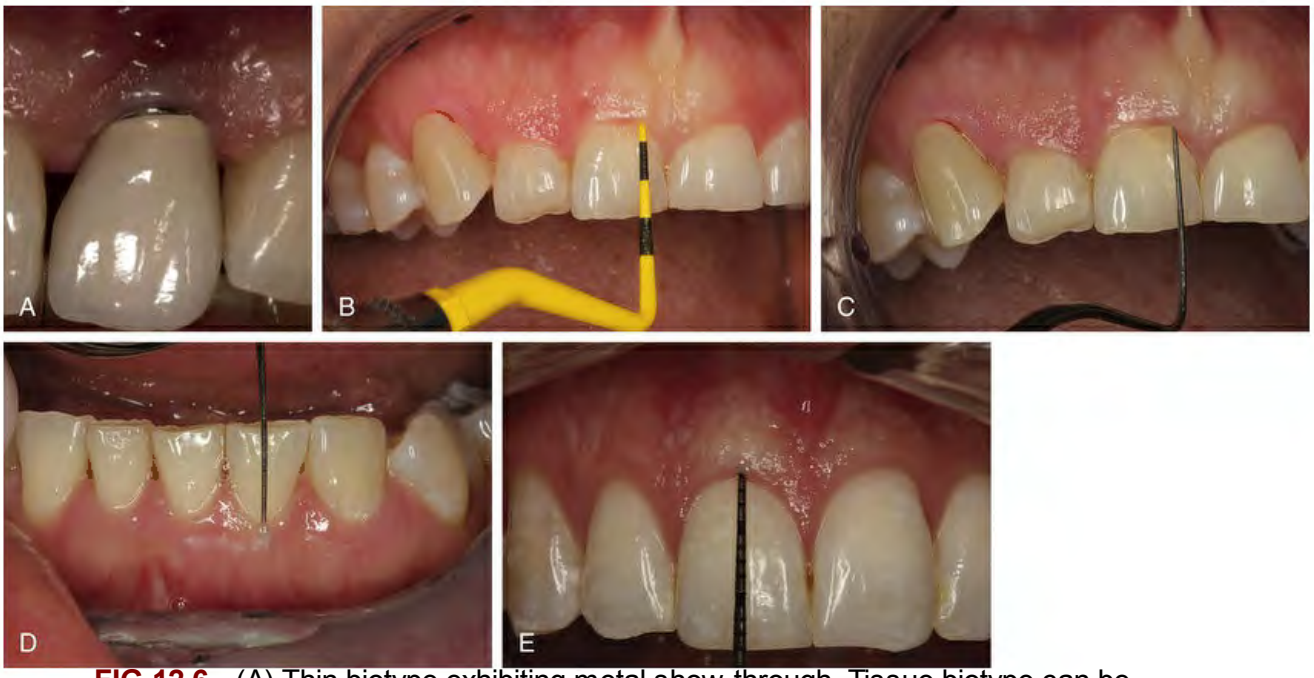

FIG 12.6 (A) Thin biotype exhibiting metal show-through. Tissue biotype can be defined by the translucence of a probe through the sulcus. (B) Thick biotype yellow probe. (C) Thick biotype with dark probe. (D) Intermediate biotype with visible probe through sulcular tissue. (E) Thin biotype with probe.

Complication.

When there is no consideration of the biotype of a patient, esthetic complications can occur, especially in the anterior regions. Thin biotype patients tend to be more prone to recession, and thin tissue may result in a bluish-gray hue at the gumline of the implant restored tooth. If recession or slight bone loss occurs, the facial aspect of the implant can be exposed, leaving a similar dark hue to the overlying tissue and the patient with a poor esthetic and embarrassing presentation.

Prevention.

When a clinician is aware of tissue biotype, it is possible to plan ahead procedurally to maintain or possibly change the biotype, leading to optimal esthetic outcomes. Patients with a very thin biotype can be evaluated for intra-operative supplementation using connective tissue grafts and facial bone grafts to create a more forgiving tissue drape over the implant site. As thicker cortical bone volumes promote thicker biotypes, the bony architecture and soft tissue drape may be modified in an esthetic zone prior to implant placement and restoration. Advance planning also provides the implant team an opportunity to inform the patient about these issues and to point out potential esthetic complications prior to commencing treatment. A patient's expectations must be addressed, especially if they are not interested in grafting to modify the tissue type (Fig. 12.7).

FIG 12.7 The thick biotype in this case has completely masked the location of the anterior implant.

Treatment.

Correction of thin biotypes requires tissue augmentation to create a thick, dense layer of fibrous tissue over the implant body and any deficiencies involving the adjacent natural teeth. Connective grafting procedures are readily available to increase the thickness of the tissue drape in situations like this. Subepithelial connective grafting procedures may utilize either palatal connective tissue or acellular dermal matrix (i.e., AlloDerm [BioHorizons IPH, Inc.]) as the source of donor tissue. The thick layer of connective tissue is inserted into the deficient regions with tunneling procedures, allowing the repositioned tissue flap to provide the blood supply

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to the developing graft site. The use of the subepithelial approach allows the implant clinician to produce a final tissue tone and color that matches the adjacent natural tissue. Earlier applications of “free tissue grafting procedures” utilized the epithelial layer of the palate as the donor site. This usually creates zones of thicker keratinized tissue with a distinctly white color that is not acceptable from an aesthetic standpoint when utilized in the anterior maxilla. Most anterior treatment plans today also incorporate the addition of layers of allograft or bovine graft particles with membrane coverage to limit excessive bone remodeling in these critical regions. These concepts are critical in “immediate implant” cases where many cases require both soft tissue and hard tissue supplementation (Fig. 12.8).

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FIG 12.8 Subepithelial connective tissue grafting to cover grey color translucence on facial of an implant site. (A) Preoperative. Grey color on facial of implant body. (B) CT graft. (C) Tissue graft insertion into tissue tunnel on facial of implant site. (D) Immediate postoperative. (E) Final photo showing resolution of improper tissue color.

Procedural Technique Complications

Failure to Understand Limitations of Regenerative Materials

Etiology.

Successful ridge augmentation requires consistent development of bony foundational support that allows the restorative prosthesis to be placed in an ideal position for proper aesthetic and functional success. As the regenerative technique is chosen, grafting materials and isolation techniques must be clearly understood from the surgeon's standpoint to prevent inadequate graft development or unpredictable stability of the graft site as the prosthesis is loaded and maintained. The current approaches to ridge augmentation consist of a variety of techniques including guided bone regeneration (GBR), onlay block grafting, ridge splitting, distraction osteogenesis, or a combination of these techniques.[5,6,8,9] GBR with autogenous bone, bone harvested from the same individual, is considered by some to be the gold standard for alveolar ridge augmentation.[10] The use of allografts requires timely substitution of these primarily osteoconductive particles with vital bone, and the consistency of the resulting ridge must be dense enough to withstand the forces generated during the preparation of the osteotomy and insertion of the implant. Incorporation of osteoinductive graft materials into the procedure promotes the development of strong bony ridges, and the overall substitution process can be shortened. Autogenous bone provides the most active osteoinductive properties, as does the use of bone morphogenic protein (BMP) and other growth factors.[55]

Complications.

A clinician who is not well versed in the limitations of the variety of graft materials may fall into the trap of a “one size fits all” approach to treatment. When significant defects require large volumes of bone, autogenous grafting may also be necessary. Allograft procedures are often used to spare the patient potential discomfort related to a secondary donor site. However, allograft in some cases will not develop a sufficient volume of bone to allow ideal implant placement and an aesthetic restoration. Complications usually arise when a graft is placed using a technique or with materials unsuited for the demands of the bone defect. Poor results eventually lead to increased

treatment times, a loss of patient confidence in the surgeon and increased treatment costs.

Prevention.

The prevention of potential graft failures and poor augmentation volumes starts with a clear understanding of the anatomical, restorative, and aesthetic requirements for this specific defect. These factors must be matched to the best utilization of available grafting materials, membrane choices, techniques for space maintenance, and site protection. An effective bone regenerative material that has been matched with a predictable membrane creates the foundation for the rest of the restorative treatment plan.

GBR Membranes

Nonresorbable.

The ideal GBR membrane is a biocompatible material capable of excluding epithelium without eliciting an immune reaction that might interfere with bone regeneration. Membranes are typically classified as resorbable or nonresorbable. Nonresorbable membranes include titanium foils, expanded polytetrafluoroethylene (e-PTFE) and dense polytetrafluoroethylene (d-PTFE) with or without titanium reinforcement. Studies of GBR procedures utilizing titanium-reinforced nonresorbable membranes have shown great success with horizontal and vertical alveolar ridge augmentation because of their ability to maintain space, minimize graft mobility, and exclude epithelium.[11-21] Disadvantages of nonresorbable membranes include the need for reentry procedures for membrane removal and frequent postoperative infections that may follow premature membrane exposure.[20,22] Various studies have shown premature membrane exposures typically result in increased morbidity and decreased bone regeneration in GBR procedures. Recent reports of d-PTFE use have demonstrated that membrane exposure does not always dictate failure of the developing graft. If the d-PTFE membrane can be maintained for at least 6 weeks, removal at that time or later will often be followed with development of a reasonable bony ridge. This is different than earlier cases, where e-PTFE membranes allowed bacterial invasion of the entire graft site through the larger pore sizes found in the e-PTFE membranes. The smaller pore size in the d-PTFE membrane prevents direct passage of bacteria through the membrane. Subsequently altered bone development may tend to

be limited to the surrounding margins where the membrane was exposed (Fig. 12.9).[22,54]

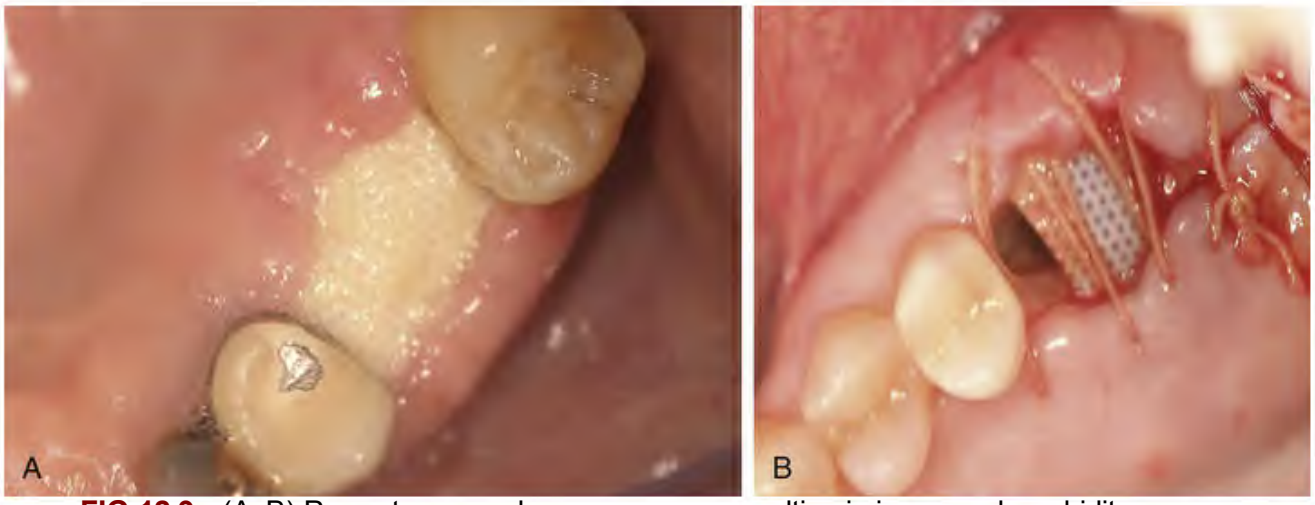

FIG 12.9 (A–B) Premature membrane exposure resulting in increased morbidity.

Resorbable.

In order to overcome these limitations, resorbable membranes have become a popular alternative because they are biodegradable and are less likely to become infected in the event of an exposure.[23-26] Resorbable membranes are typically made of polyesters (e.g., polyglycolic acid [PGA], polylactic acid [PLA]) or tissue-derived collagens (e.g., AlloDerm GBR, Ossix Plus). AlloDerm is an acellular dermal matrix originally developed in 1994 to be used as a skin allograft for burn patients.[27] It has been used in the medical and dental literature as an allograft for various procedures because of its ability to rapidly vascularize and to increase soft tissue thickness. In the dental literature, AlloDerm has been successfully used for root coverage, thickening of soft tissues, and guided bone regeneration.[24,28-30] AlloDerm GBR is a thinner version (thickness ranges from 0.5–0.9 mm) of the original AlloDerm product (thickness ranges from 0.9–1.6 mm), specifically designed for GBR. AlloDerm GBR has been successfully used as a barrier membrane and has also been shown to significantly increase soft tissue thickness by 45% and 73% from baseline at 6 months and 9 months, respectively (baseline 0.55 ± 0.16 mm to 0.80 ± 0.26 mm at 6 months and 0.95 ± 0.28 mm at 9 months; $p < 0.0033$), when used as a barrier membrane for GBR of horizontal alveolar ridge deficiencies.[29]

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Aside from soft tissue exclusion and clot stability, space maintenance is key to the success of GBR and can be accomplished in various ways using titanium-reinforced membranes, titanium mesh, particulate graft material, block grafts, dental implants, or tenting screws/pins.[5,31,11,12,32-35] Nonresorbable[5,19,34-37] and resorbable tenting screws[38] have been used to aid in space maintenance in various horizontal and vertical ridge augmentation studies. The tenting screws are typically used as "tent poles" to support the membrane, decrease graft mobility, and relieve external pressure on the graft[55] (Fig. 12.10).

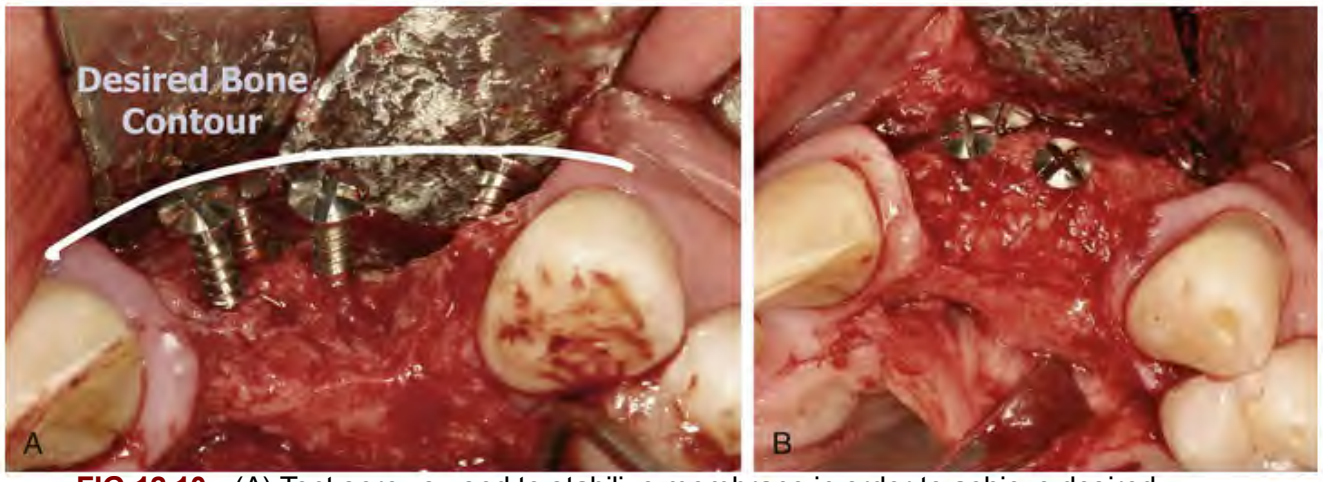

FIG 12.10 (A) Tent screws used to stabilize membrane in order to achieve desired contour. (B) Postoperative image depicting bone growth to ideal contours.

Types of Bone Grafting Material

Autogenous Bone.

Autogenous bone is still considered by many to be the gold standard graft material for GBR because of its osteogenic, osteoinductive, and osteoconductive properties.[6,10,39] Autogenous bone is commonly harvested intraorally from the ramus and symphysis, but is associated with increased morbidity related to a second surgical site, unpredictable graft resorption, and graft mobility.[5,10,13,40-44] The anatomy of the posterior edentulous ridge can limit the shape and volume of donor bone available for harvesting autogenous blocks.[44] Many times the autogenous block and recipient site require such extensive preparation in order to obtain intimate contact between the graft and recipient site that a large percentage of the harvested

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bone cannot be utilized.[43] Some clinicians have advocated crushing the autogenous block graft into a particulate autogenous graft to allow for more conservative recipient site preparation, complete utilization of the harvested bone, and a decreased volume of bone that will need to be harvested, thereby decreasing the morbidity of the procedure (Fig. 12.11).[17,45]

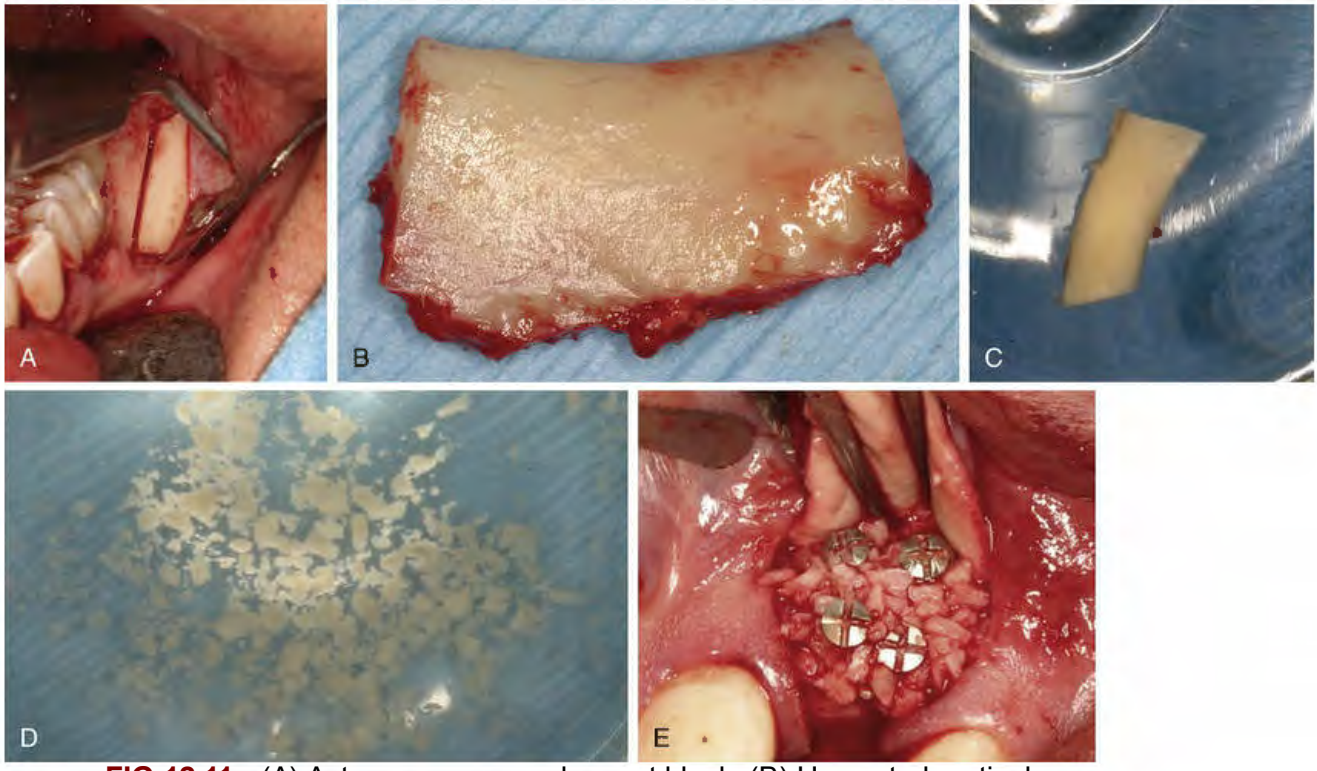

FIG 12.11 (A) Autogenous ramus harvest block. (B) Harvested cortical ramus block. (C) Block stored in sterile saline. (D) Block reduced to particulate fragments. (E) Particulate fragments placed in donor site.

Allografts.

In order to overcome the limitations related to the availability of autogenous bone volume, various bone substitutes, including xenografts (material harvested from another species), alloplasts (inert synthetic material), and allografts (material harvested from another individual of the same species), are being used as adjuncts for GBR with successful clinical and histologic outcomes.[6,8,13] Some clinicians have advocated combining autogenous bone with the various bone substitutes.[16,23,45,46] The potential benefits of adding particulate autogenous bone to an allograft are the addition of osteogenic and osteoinductive growth factors to the osteoconductive properties of a

bone substitute. The use of this combination allows for a reduction in the amount of autogenous bone harvested, decreasing the morbidity and postoperative discomfort for the patient.

Xenografts.

Xenografts are graft materials that are taken from a donor of one species and grafted into a recipient of another species. This type of graft material heals via osteoconduction. Simian et al found that the addition of deproteinized bovine bone mineral (Bio-Oss) to autogenous particulate resulted in greater vertical augmentation than particulate autogenous material alone. Urban has combined bovine particles with autogenous bone in the development of large volumes of vertical and horizontal bone in severely compromised regeneration sites. The incorporation of the bovine product is planned for extended support of the graft volume, following with a timely turnover into vital bone as the graft matures (Fig. 12.12).[16,47]

FIG 12.12 Lack of bone turnover. This mature graft site demonstrates the presence of bovine particulate graft material that has not been replaced by vital bone. The goal of any regenerative procedure is to develop as much vital bone as possible prior to loading an implant.

Alloplasts.

The use of alloplasts is not currently recommended for major ridge augmentation. Successful grafting requires that the source of the grafting particles be readily available for consistent replacement with vital bony cells. Alloplastic approaches tend to leave a very granular ridge form that tends to

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fall apart as the osteotomy is prepared and the implant is inserted. Approaches have been utilized where alloplasts were added to FDBA (freeze dried bone allograft) or DFDBA (demineralized freeze dried bone allograft), but overall, the use of alloplasts is not recommended when significant regeneration is required.[55]

Incorrect Choice of Regenerative Technique in Respect to the Severity of the Defect

Etiology.

The literature today provides a multitude of surgical approaches that are available for regeneration of deficient implant sites. These would typically include particulate grafts, BMP graft combinations, block grafts, and the use of ridge-splitting techniques. The implant team must carefully consider each clinical situation to determine which technique will most predictably develop the needed bony support for the restorative treatment plan. In this assessment, the anatomy of the defect will often lead to the choice of a particular approach due to the ease of graft placement or the limitations of using a rigid graft in a highly irregular recipient site. Recipient sites with a very irregular surface are preferably approached with a particulate approach, and cortical blocks are best utilized where a smooth bed can be prepared for close adaptation of the block to the underlying defect.

The depth of the vestibule is a significant factor when evaluating defects. The use of an autogenous block is much easier when the vestibule is very deep and there is adequate room for adaptation of the entire length of the cortical graft. Placement of a block in a shallow defect can sometimes be difficult because of anatomic limits that will force graft placement higher above the ridge than the bone on the adjacent natural tooth. This can result in incision line opening, graft exposure, and a compromised healing process (Fig. 12.13).

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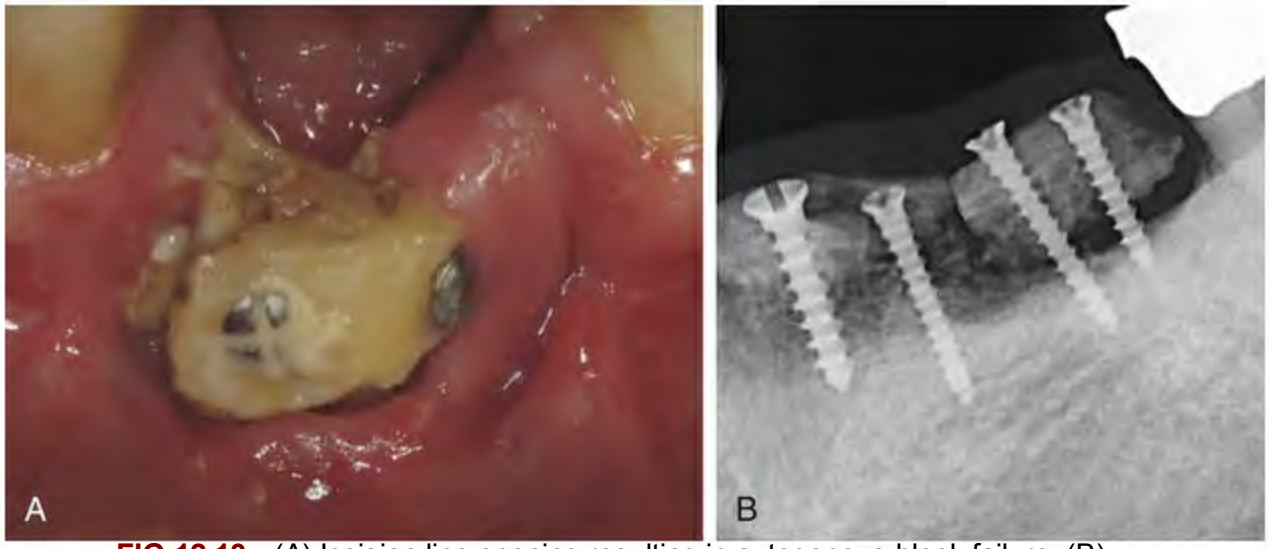

FIG 12.13 (A) Incision line opening resulting in autogenous block failure. (B) Autogenous block failure resulting from nonunion of the blocks and host bone.

If a particulate graft is utilized, lateral support of the graft will need to be incorporated into the procedure to provide and maintain space for the regenerative process to be completed. This same spacial support and protection prevents the graft particles from slipping laterally during the healing process (Fig. 12.14).

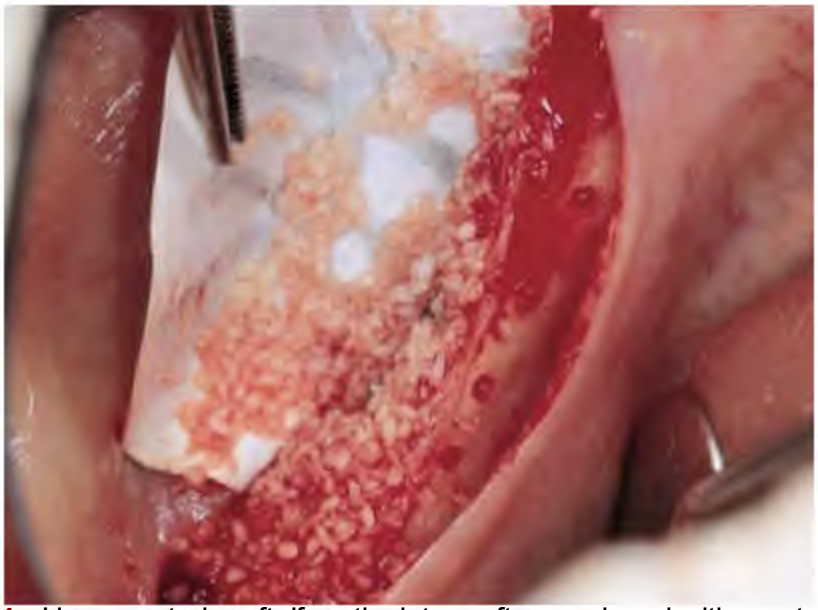

FIG 12.14 Unsupported graft. If particulate grafts are placed with no stabilization support (i.e., tent screws) results may be unpredictable.

The use of a "ridge splitting" approach should only be considered when the apical region of the site is thick enough to allow expansion of the cortical

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wall laterally without fracturing the expanded cortical plate at the most inferior point of the split. This is particularly relevant in the maxillary anterior region where the thin width at the base of the site is often not substantial enough for a predictable split. Care must be taken to ensure the ridge split and graft will allow enough width for an implant with the required diameter. Ridge splits in a maxillary anterior region that is shaped with a proclined angulation can often lead to the placement of an implant with a severely angled emergence profile. This emergence angle then requires the use of an angled abutment to compensate for the malpositioning. Cases like this are better suited for use of an augmentation approach that thickens the ridge in both the coronal and apical regions. The additional apical augmentation developed in these techniques will create a better emergence profile for the implant and the restoration, leading to better patient satisfaction (Fig. 12.15).

FIG 12.15 Ridge split technique. Allograft in association with ridge splitting to increase compromised ridges in width. (From González García R, Monje F, Moreno C: Alveolar split osteotomy for the treatment of the severe narrow ridge maxillary atrophy: a modified technique. *Int J Oral Maxillofac Surg* 40(1):57–64, 2011.)

Complications.

Failure to choose the proper regenerative approach will often result in a poor postoperative ridge form that will not be amenable to an ideal implant placement and an acceptable emergence profile. Choice of the incorrect technique may lead to a graft that is susceptible to complications related to continuous isolation and stabilization of the graft during the entire healing

process. These problems usually stem from issues related to strain on the incision line, movement of the temporary prosthesis, migration of the graft materials, or overzealous attempts to over-grow bone.

Prevention.

The implant clinician must develop a familiarity with the indications for each of the different types of grafting procedures, and incorporating that knowledge into a working treatment plan. With the aid of 3-D imaging, the clinician can complete a comprehensive evaluation of the extent of the bony defect. A treatment plan must then be developed, taking into consideration the overall size of the defect, the ability of the recipient site's tissue to be expanded, and the presence of a temporary prosthesis, and the overall size of the defect. Included in this strategy would be the choice of possible donor sites, graft materials, suture type and technique, and the space maintenance method (Figs. 12.16 to 12.18).

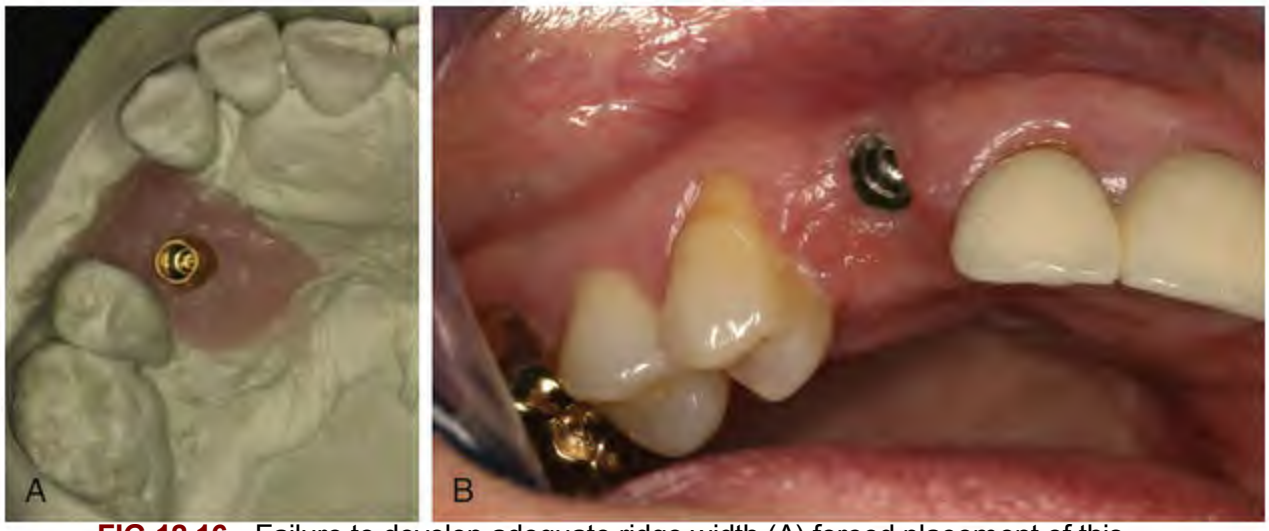

FIG 12.16 Failure to develop adequate ridge width (A) forced placement of this implant in a very poor occlusal position (B).

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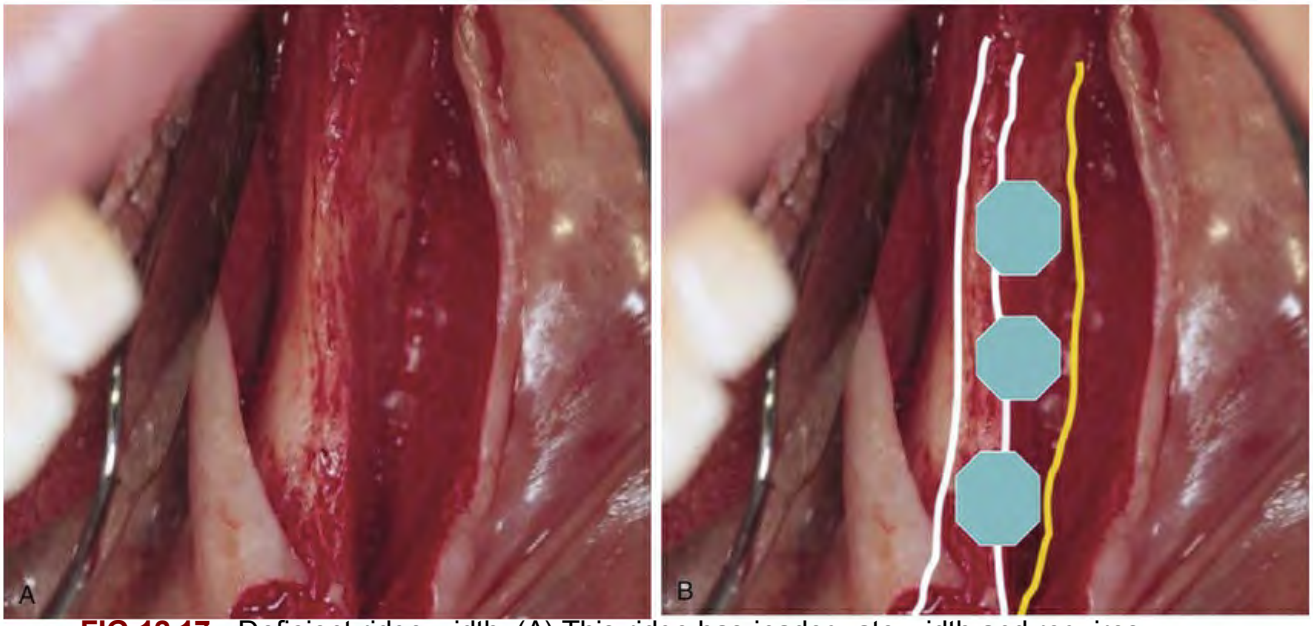

FIG 12.17 Deficient ridge width. (A) This ridge has inadequate width and requires augmentation. (B) Visualization of the required width demonstrates the volume of bone that will be needed for proper implant placement.

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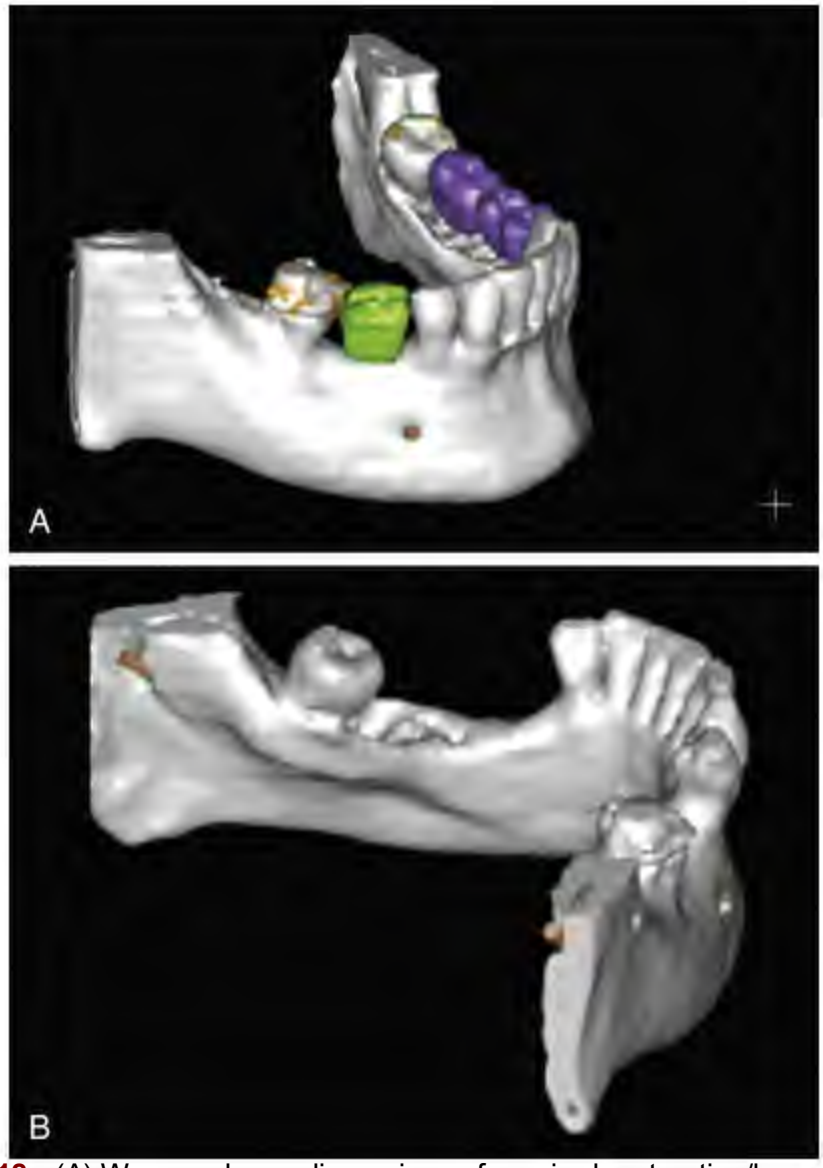

FIG 12.18 (A) Wax-up shows dimensions of required restoration/bone. (B) 3-D model shows distinct undercut of mandible below implant site.

Intraoperative Complications

Poor Incision Line Design

Etiology.

Incision design is one of the keys to a predictable regenerative result. Ideal incision designs provide complete access to the surgical site without compromising the integrity of the surrounding tissue. As the incision is planned, the anatomy of the adjacent papilla must be considered to prevent any damage that will compromise the aesthetics and function of the tissue postoperatively. The patient's biotype and the amount of keratinized tissue is always reviewed, and any deficiencies of attached tissue must be accounted for in the incision design. The incision must be planned in a way that keeps incision lines away from critical regions where graft particles or blocks could become exposed. Observation of sound surgical principles in preparation of incisions is critical for maintenance of the blood supply to all of the involved tissues. Wide-based incisions are always important to prevent interruptions in the vascular supply to the flap.

Complication.

Failure to properly plan the incision design of a flap during grafting can pose numerous issues, chiefly related to incision line opening postoperatively. Incision line opening exposes the regeneration site to an influx of oral pathogens, soft tissue ingrowth, and loss of the graft materials that were intended to be isolated during the maturation process. Failure to preserve the integrity of the papilla during incision line design eventually leads to compromised aesthetics around the final restoration. An initial incision without a consistent depth may create a split-thickness flap, leading to tissue shredding and the involvement of vital structures located within the flap. Incisions through zones with limited keratinized support can leave large expanses of mucosa along the incision line. Thin mucosa is very difficult to predictably suture to the adjacent flap, often leading to an open incision days later. Lastly, failure to make broad-based releasing incisions may compromise the blood supply to the flap, causing tissue ischemia.

Prevention.

The coronal incision is usually placed on the crest of the ridge, favoring a location closer to the palatal aspect if possible. In regions where the

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keratinized tissue is limited, the incision should at least “split” the distance between the two edges of the keratinized tissue. It is always best to try to keep incision lines away from areas that are key to regenerative volume and protection. When possible, the papillae should be preserved. If there is a good papilla present, the incision should be designed to avoid involvement of the papilla or it should be moved to the adjacent interproximal space. If the papilla is absent or is flat, the incision can be directly adjacent to the root approximating the graft or it can be moved to the adjacent space. Moving the releasing incision to the adjacent interproximal space also moves the incision line away from the grafting site, limiting complications if the wound opens up postoperatively. Extending to the adjacent interproximal space can sometimes lead to difficulty in advancement of a tension free flap over the graft site, but this can be released with additional steps.

The releasing incision should always be prepared with a wider base than its coronal width to preserve the apical blood supply to the flap. As the flap is reflected, it is critical that the complete periosteal layer be reflected with the flap, avoiding maceration of the tissue during the releasing process. Attention to the thickness of the flap and careful use of the scalpel and instruments is important at this stage. By keeping instruments firmly against bone during the flap-releasing process, the clinician ensures a proper full-thickness flap release.

Incision lines should be prepared with vertical releasing incisions that are several millimeters away from the lateral border of the graft site. When an incision line opens around a graft site, the open region can directly contaminate the underlying graft particles, preventing proper regeneration of the bony defect. By moving the incision away from the critical regeneration site, the possibility of this type of contamination can be limited to some degree (Figs. 12.19 to 12.22).

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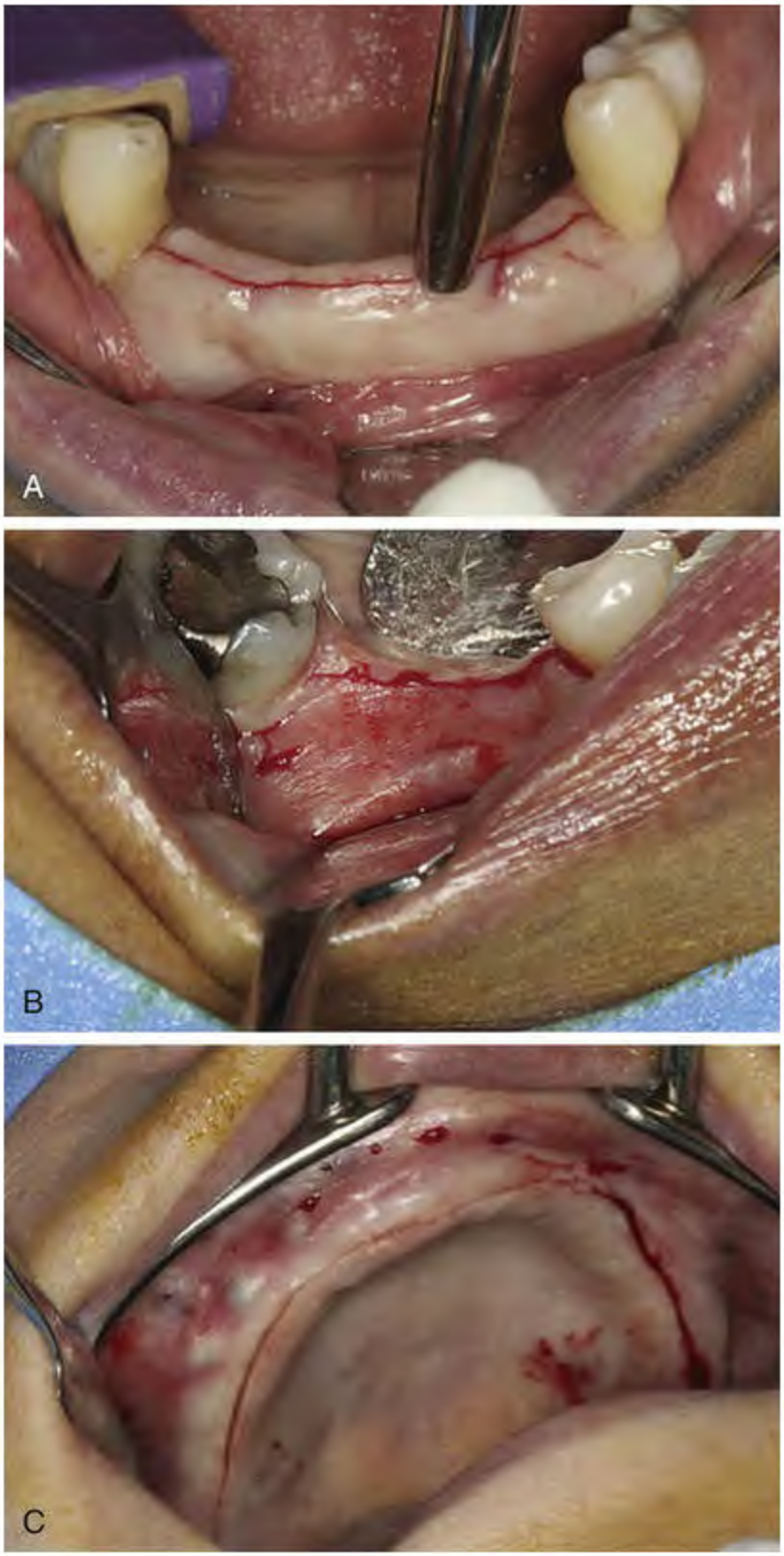

FIG 12.19 Incision design. (A) Typical crestal incision with keratinized attachment. (B) Crestal incision, preserving the limited amount of keratinized tissue. (C) Crestal full arch incision designed to preserve the limited facial zone of keratinized tissue.

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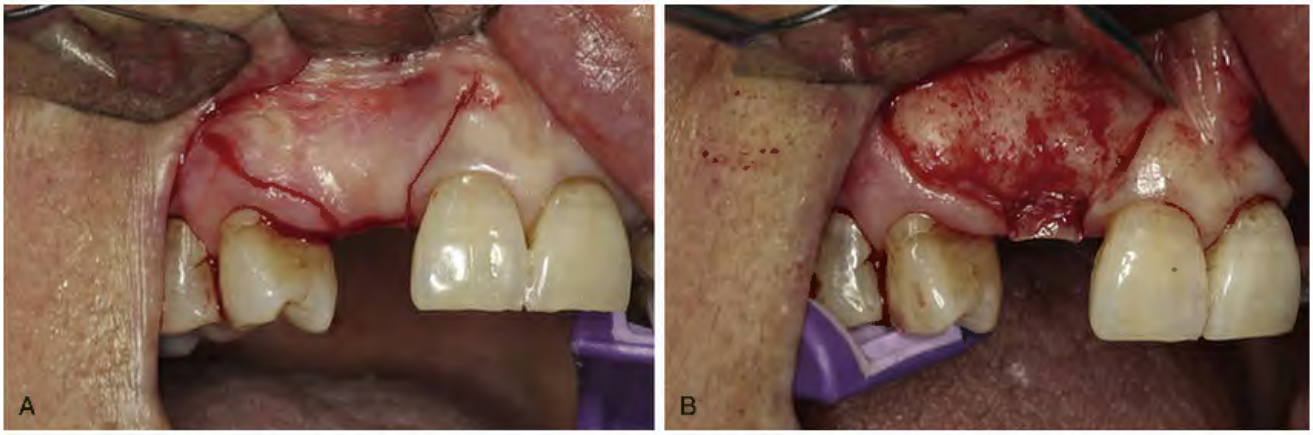

FIG 12.20 Release incisions. A papilla sparing incision with vertical releasing incisions (A) that swing laterally away from the critical graft site (B), limiting the chance of graft compromise in the case of an open incision line.

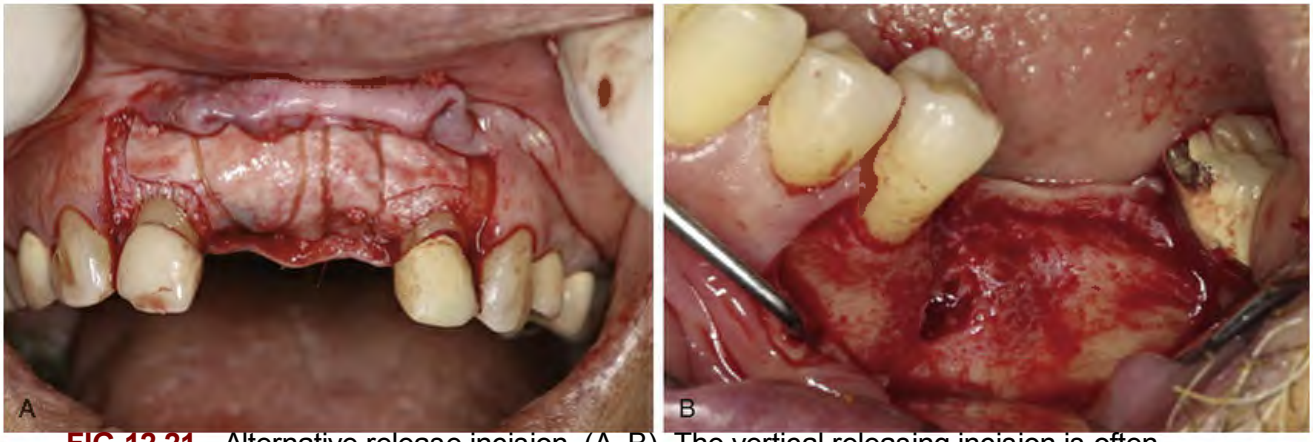

FIG 12.21 Alternative release incision. (A–B), The vertical releasing incision is often moved laterally to the adjacent papilla space. This prevents problems related to incision line opening from directly complicating the critical graft development in key positions.

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FIG 12.22 Poor release design. Incision line should be moved laterally away from critical development sites *(arrow)*.

Torn Lingual Flap

Etiology.

The tissue thickness on the lingual aspect of the mandible is very thin and friable. This tissue can be easily torn during reflection of the flap and manipulation of the tissue during the grafting procedures. Resultant "buttonhole" openings may compromise the blood supply to the surrounding tissue that is needed for coverage over the graft site, leading to compromised results postoperatively.

Complication.

Tearing or buttonholing the lingual flap leads to exposure of the graft site and the possibility of margin necrosis coronal to the tear. This exposure may lead to total graft failure (Fig. 12.23).

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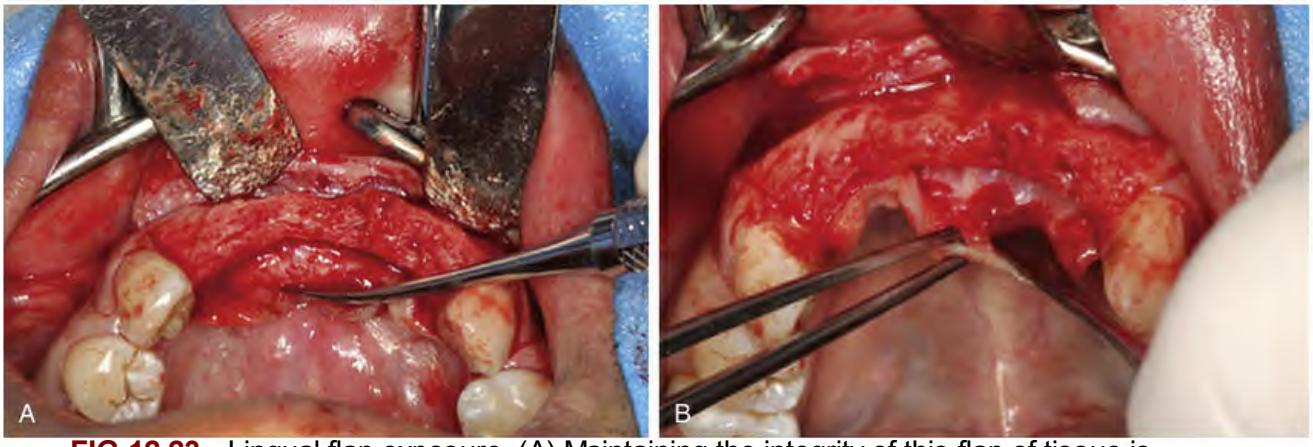

FIG 12.23 Lingual flap exposure. (A) Maintaining the integrity of this flap of tissue is very important in a regenerative procedure because it is very easy to tear the flap during its initial reflection or to buttonhole the flap during its manipulation over a bulky graft site. (B) If this occurs, it is very difficult to mend the tear, potentially compromising the closure of the graft site or predisposing the region to incision line opening over the healing graft.

Treatment.

If the lingual flap is torn during the procedure it can sometimes be repaired using 5-0 chromic suture, approximating the edges of the tear and preventing tension on the weak site. It is recommended to use a collagen membrane below these fenestrations to assist with healing and to isolate the graft materials. Maintenance of the blood supply to the tissue flap is important; thus tension should be minimized to the flap.

Prevention.

Preparation of the initial incision line must be extended completely through the tissue and through the periosteum. At the time of the initial separation of the flap margin from the bone, care must be taken to obtain a clean release of the complete flap margin from the bone. Shredding the flap margin at this time leads to poor control during the rest of the flap release and ultimately to increased chances of tearing the partial-thickness flap. Curettes or retractors must be utilized to create an even release and reflection of the full flap throughout this process.

Difficulty Releasing the Flap for Tension-Free Closure

Etiology.

Successful augmentation procedures require maintenance of an intact tissue closure along the incision line during the healing process. One of the most common surgical complications that a clinician will experience early in their learning curve is incision line opening. The failure of maintaining this union is directly related to an inadequate release of all tension on the tissue flap as it is stretched over the widened graft space. Clinicians will find that it is impossible to pull a tissue flap over any sizeable graft site without first altering the integrity of the flap itself. Examination of the exposed inner surface of a reflected flap reveals a smooth shiny layer called the periosteum. The periosteum is comprised of a thin firm layer of dense tissue that has no elastic fibers. This binding layer limits any significant elongation of the flap as it is stretched over a graft site. A simple incision through this dense tissue "releases" this tight band of pressure on the underlying tissue flap. The tissue directly below the periosteum is primarily comprised of elastic-type fibers, and once the periosteum has been released, the entire flap can be stretched. This simple releasing incision ultimately allows tension-free closure over the graft site.

Complication.

A flap covering a graft that does not have complete release of pressure on the two margins of the flap will often pull open during the healing process (incision line opening). Tension on the flap compromises the blood supply to the tissue along the suture line that is under pressure. This pressure leads to necrosis and eventual separation of the two edges of the flap closure. Once this has occurred, the flap cannot be sutured back into place and the graft site is open for contamination and tissue ingrowth. The success of bone grafting is largely dependent on the maintenance of space for bone development and isolation of the graft particles during the slow process of osteogenesis. Soft tissue ingrowth, bacterial contamination, and migration of graft particles predictably compromise regenerative results.

Prevention.

The typical graft site requires that the overlying flap be released enough for extension of the flap at least 5 mm beyond the edge of the adjacent margin for a tension-free flap closure. The only way to achieve this free flap release is the use of a shallow incision though the periosteal layer, allowing the elastic fibers of the underlying flap to stretch over the graft site.

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Treatment.

Tension-free flap release technique: A scalpel with a #15 blade is used to prepare a very shallow incision through the periosteum from the anterior to the posterior border of the graft site. As the incision is prepared, a clear separation of the borders of the incision line can be seen. It is not necessary to make a deeper incision because the underlying tissue can be freely released with the tip of sharp scissors (e.g., Metzenbaum). The closed scissor tip is placed into the incision, parallel to the flap itself. The ends are then opened, spreading the tissue as the ends separate. This is repeated until the flap can be freely extended at least 5 mm past the border of the lingual incision line of the graft site. The use of the spreading scissor tips reduces the need to cut underlying tissue and possibly vital structures like vessels or nerves. Tissue flaps in the maxillary and mandibular anterior regions usually require extensive release of the flap for tension-free closure over most graft sites. The posterior regions do not typically require extensive release and dissection. Care must be taken to prevent over thinning the flap or perforating the flap with a "buttonhole" (Figs. 12.24 to 12.26).

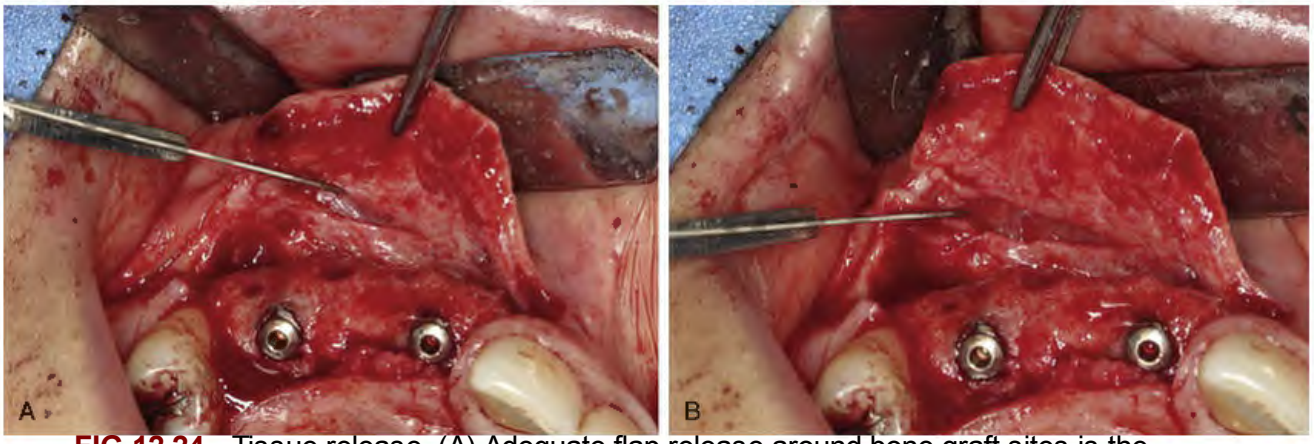

FIG 12.24 Tissue release. (A) Adequate flap release around bone graft sites is the most critical step for tension-free flap closure and predictable graft success. A single shallow incision through the periosteum is prepared inside the flap. (B) The clear separation of the periosteal edges as the flap is extended and the elastic fibers allow the flap to stretch.

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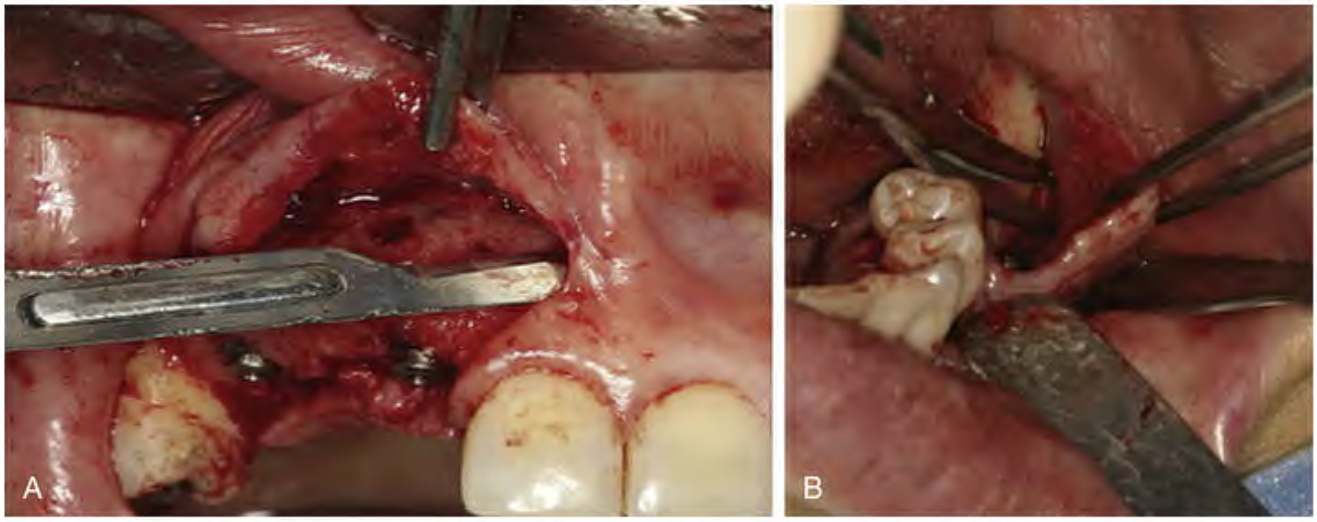

FIG 12.25 Extended periosteal release. (A) The incision is extended on the mesial and distal aspect of the graft site to allow adequate mobility of the flap when it is extended. (B) After dissection of the periosteal release with sharp scissors, the flap can be freely extended over the graft site. This release must be completed until the flap can be moved at lease 5 mm beyond the lingual aspect of the graft site.

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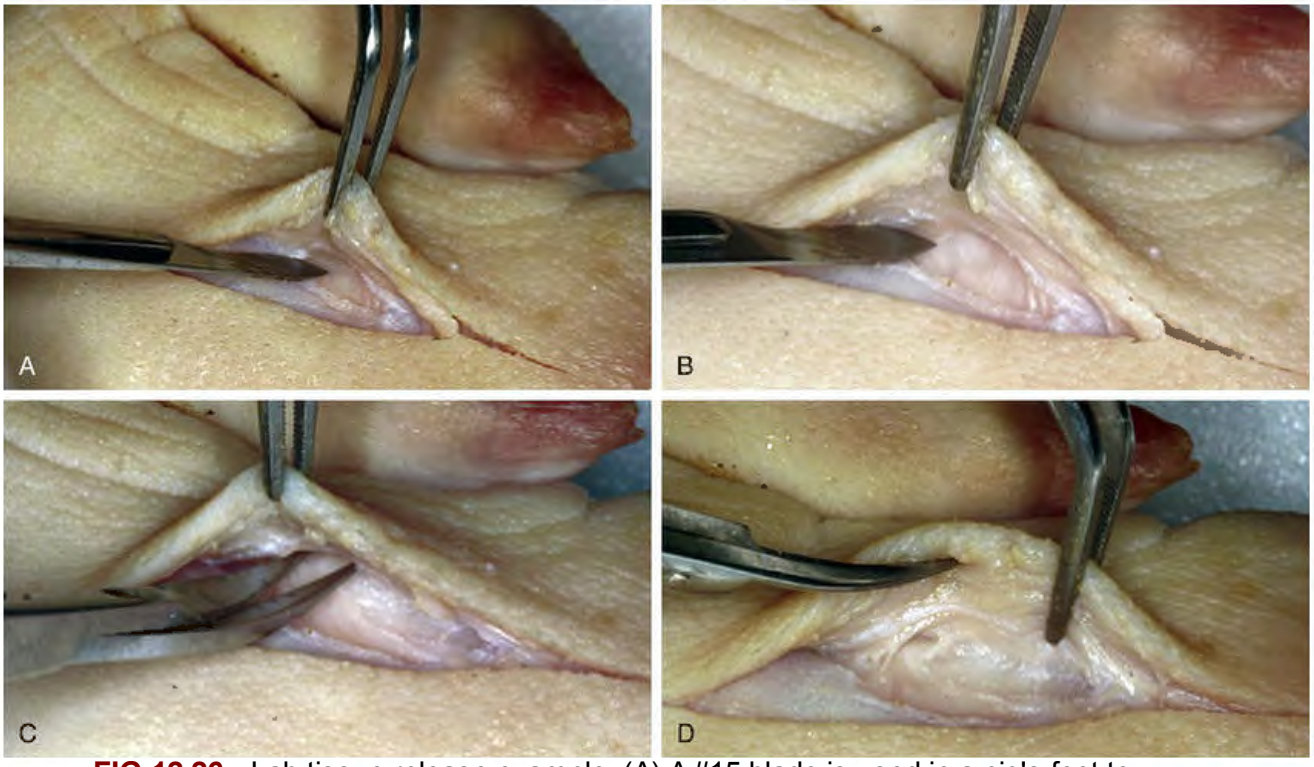

FIG 12.26 Lab tissue release example. (A) A #15 blade is used in a pig's foot to demonstrate the initial incision through the periosteum. (B) The incision is extended and you can see how the distance between the two edges continues to widen. (C) A pair of sharp pointed surgical scissors is placed parallel to the flap. They are pointed into the tissue in a closed position and as they are opened they gently stretch and release the elastic fibers of the flap. This prevents damage from cutting this tissue with a scalpel trying to release the flap. (D) As the release is completed, you can see a clear separation between the thicker layer and the released inner portion of the flap.

Inadequate Vertical and Horizontal Space Maintenance in Graft Sites Utilizing Membranes

Etiology.

The field of advanced implant dentistry went through a complete paradigm shift when the first augmentation procedures were introduced. Until that time, implants were placed in the islands of bone that were discovered at the time of flap reflection. This limited preoperative treatment planning to a great extent and subsequently the role of the restorative dentist was at many times very difficult. Implants often emerged at odd angles creating a variety of long-term support and restorative issues. The majority of bone grafts initially were designed around block grafting techniques where significant volumes of bone were regenerated horizontally and in limited cases in a

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vertical dimension. Block grafting is still used by many surgeons, but these procedures require surgical expertise and the morbidity can sometimes be an issue from the patient's standpoint.

Particulate grafting was initially introduced utilizing non-resorbable e-PTFE membranes. This approach used titanium struts to prevent collapse of the membrane into the critical regenerative space. The titanium could be trimmed and shaped into contours that produced the bony support required for the predetermined restorative plans. Nonresorbable membranes were used to some extent, but they were generally limited to production of 1–3 mm of bone thickness. These limitations were directly related to the limited number of ways that the space between the recipient bone and the suspended membrane could be supported. In most cases, one or two bone fixation screws were placed in strategic sites, maintaining enough space for smaller graft sites.

In recent years, alternative approaches have centered around expanded use of membrane/fixation screw techniques, introduction of nonresorbable d-PTFE membranes with titanium struts, titanium mesh, temperature molded and welded membranes, along with other similar approaches. The key principle in each one of these techniques centers on the use of an occlusive membrane to maintain a defined space between the recipient bone and the overlying gingival/connective tissue flap. This space must be isolated from outside cellular downgrowth, and the flap covering the defined space must be completely supported throughout the regenerative process. Each technique has its own advantages in relation to defining the final shape of the ridge, and each approach has its own issues in respect to maintaining a sealed layer over the graft site while the bone is developed. All of these graft techniques require 5 to 6 months for maturation of the graft site. Over this timeframe various situations contribute to pressure on the graft site and breakdown of the incision lines and membrane edges.

Deficient ridges occur when one or more of these principles is violated. Any mobility of the membrane will disrupt the cellular development process, beginning with interruption of the initial clot stability. Graft particles that are not confined or protected will tend to shift to a region that has less pressure or movement. The coronal aspects of all graft sites are very important because the bone around the platform of an implant carries a great deal of the occlusal load. Failure to define and maintain this dimension leads to a narrow width at the coronal aspect. A deficient ridge width like this will many times create a dehiscence on the facial or lingual aspect of an implant.

This bony deficit subjects the remaining bone to additional stress and also disrupts the delicate soft tissue attachment around the abutment. Success in all of these approaches requires development of large volumes of bone, overbuilding regions where possible. Under-estimation of the required bony support often leads to thin facial bony coverage over an implant body. It is our experience that you really never have too much bone. All bone will go through a constant remodeling process and all too often, facial bone will thin over time. This facial thickness will eventually tend to thin out over the threads of the implant, altering aesthetics and possibly implant support. Membranes that are not rigidly fixed in place tend to move out of position and some varieties resorb early in the regenerative process, allowing invasion of tissue, bacteria, or movement of the graft materials. Each one of these seemingly small issues can compromise the whole regenerative process.

Complication.

Areas where a particulate graft shifts or where a supporting membrane collapses typically heal in a manner that does not provide the expected ridge shape and dimension established during the restorative planning process. The clinician is forced to either compromise the implant position or abort the implant aspect of the procedure. This delays implant placement until adequate supporting bone can be developed with additional grafting. Implants that are placed in compromised recipient sites are prone to complications when the prosthesis is loaded and bone remodeling occurs.

Prevention.

GBR techniques utilize an occlusive barrier membrane between the alveolar bone and the gingival epithelium/connective tissue to prevent epithelial down-growth into the alveolar ridge defect. The occlusive barrier membrane allows for osteogenic cells from the adjacent alveolar bone to colonize the blood clot and to induce bone regeneration.[31,47] Aside from soft tissue exclusion and clot stability, space maintenance is the key to the success of GBR. Screw-supported barrier membranes may be utilized for development and maintenance of this regenerative space. This same vertical support can be achieved using titanium-supported membranes, titanium mesh, or any other approach that creates and holds an open, isolated space for bone to occupy.

Bone fixation screws.

Space maintenance can be accomplished utilizing bone fixation screws as vertical and horizontal supports for isolation of bone graft particles and support of occlusive membranes. The required graft volume and spatial dimensions determine the number and positioning of these screws. Screws are anchored in the recipient site as needed to form a dome over the graft site that matches the height of bone needed for proper implant placement. Placement of graft materials without defining space maintenance will usually lead to variable postoperative bone volumes and often deficient bony support on the facial and lingual aspect of the coronal aspects of the implant platform. A thin or granular bone consistency at the coronal aspect will lead to a dehiscence on the facial or lingual aspect of the implant platform.

Titanium supported d-PTFE.

The use of titanium supported d-PTFE membranes has demonstrated development of significant amounts of bone in everything from minor defects to extensive vertical defects with through-and-through cortical destruction. Earlier use of e-PTFE (Gore Tex [W. L. Gore & Associates, Inc.]) membranes showed serious compromises in final graft volumes if any portion of the membrane was exposed. This failure was largely related to the large pore size in the e-PTFE membrane. The pores in the e-PTFE were large enough for bacterial passage through the membrane itself, resulting in altered bone growth throughout the region (5–25 μ). The success in grafting with d-PTFE can be related to the small (<2 μ) pore size of d-PTFE, where bacterial invasion though the membrane itself is blocked.[58] Exposed sites in d-PTFE cases show no side effects related to invasion of bacteria directly through the membrane and into the developing bone. Exposed sites can still present problems related to invasion around the edges of the exposed membranes. It has been described that d-PTFE membrane exposure cases need to be maintained for at least 6 weeks before the membrane can be safely removed. Removal of the membranes earlier than this exposes the contents to bacterial ingrowth and this usually results in a significantly altered final graft result. Exposed d-PTFE should be maintained with chlorhexidine rinses and careful hygiene around the exposure sites. Care should be taken to prevent any movement of the membranes with temporary appliances.[54,56]

Titanium mesh.

Mesh support techniques use a piece of thin titanium mesh that is shaped into the external form of a desired ridge shape required for implant positioning. The advantage of this technique is directly related to providing rigid fixation of a formed template over a volume of grafting material, assuring maintenance of space required for graft development. It is used with either a particulate graft or with BMP that has been mixed with a graft and sponge mixture. If the integrity of the soft tissue flap can be maintained throughout the healing process, significant bone volumes have been consistently reproduced. If the flap margin or other region of the overlying flap exposes the titanium mesh, the predictability of the final graft volume can be compromised.

Treatment.

Treatment for dealing with an inadequate ridge follows one of two approaches. The first option involves placement of implants in the compromised bony foundation, grafting additional bone over the exposed implant threads at the time of implant placement. This technique often leads to varied results. If the exposure of the implant body is within the contours of the surrounding basal bone, grafting will be much more predictable than in cases where the implant contour extends beyond the surrounding basal bone. The presence of a blood supply, supporting bony protection, and adequate coverage of the remaining surfaces of the implant are critical. The second option requires postponement of the implant insertions, attempting additional augmentation, and placement of the implants after adequate bone has been regenerated. This approach is the most predictable for a successful long-term result. (Figs. 12.27 to 12.32).

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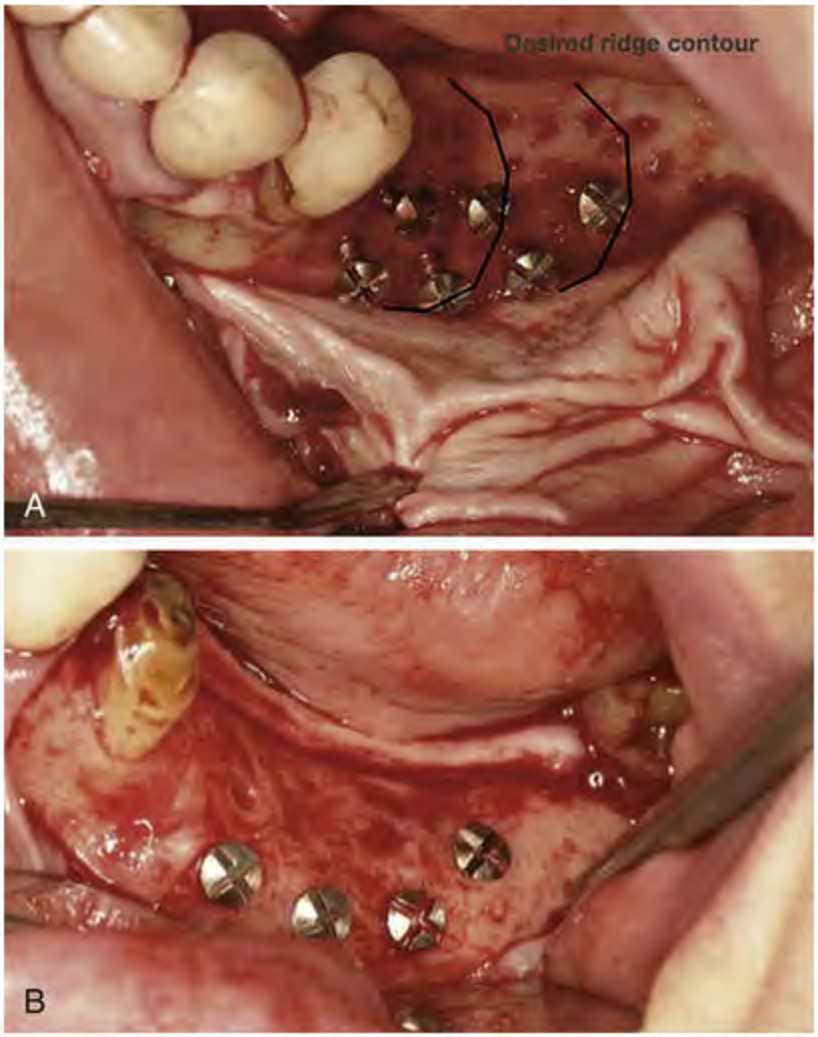

FIG 12.27 Bone screws for ridge contour. (A) Bone fixation screws are used to define the topography of the prescribed bony ridge prior to placement of the bone graft materials. (B) The mature graft postoperatively has grown up to the level of the heads of the fixation screws. This demonstrates the principle of “space maintenance,” and the ability of the body to fill in isolated spaces as long as the graft is supported and tissue ingrowth is prevented during the healing process.

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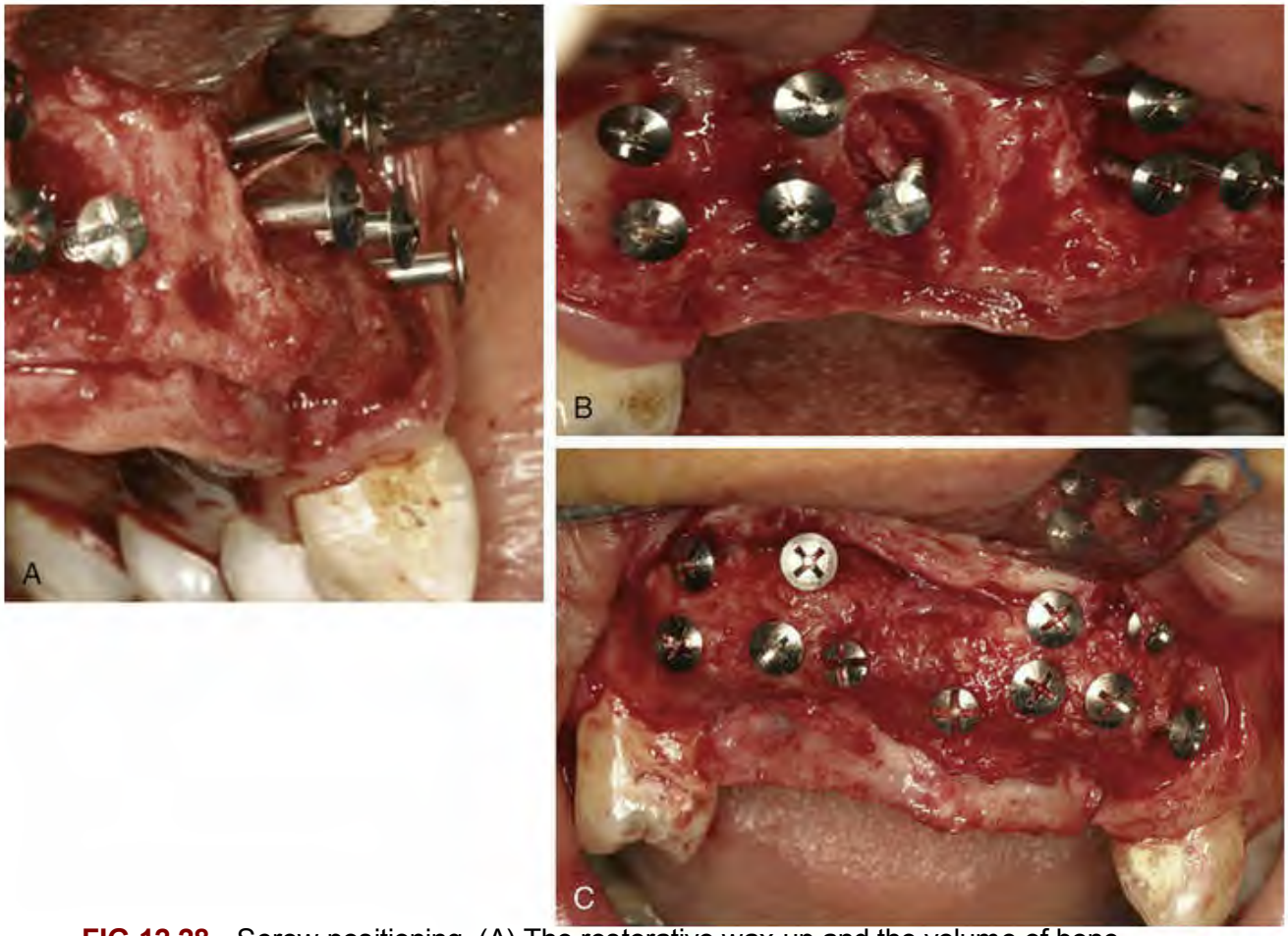

FIG 12.28 Screw positioning. (A) The restorative wax-up and the volume of bone that will be required to allow proper placement of the implants determine the position of the screw heads. This approach is very helpful when the recipient site has an irregular surface like the residual periapical lesion. (B) The screw placed in the deep defect will assure adequate bone development in this severely compromised area. (C) Postoperative healed ridge.

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FIG 12.29 In this matured graft site, bone has completely filled in the space around the varied screw positions, creating a substantial bony ridge for implant placements.

FIG 12.30 Postoperative ridge with additional width.

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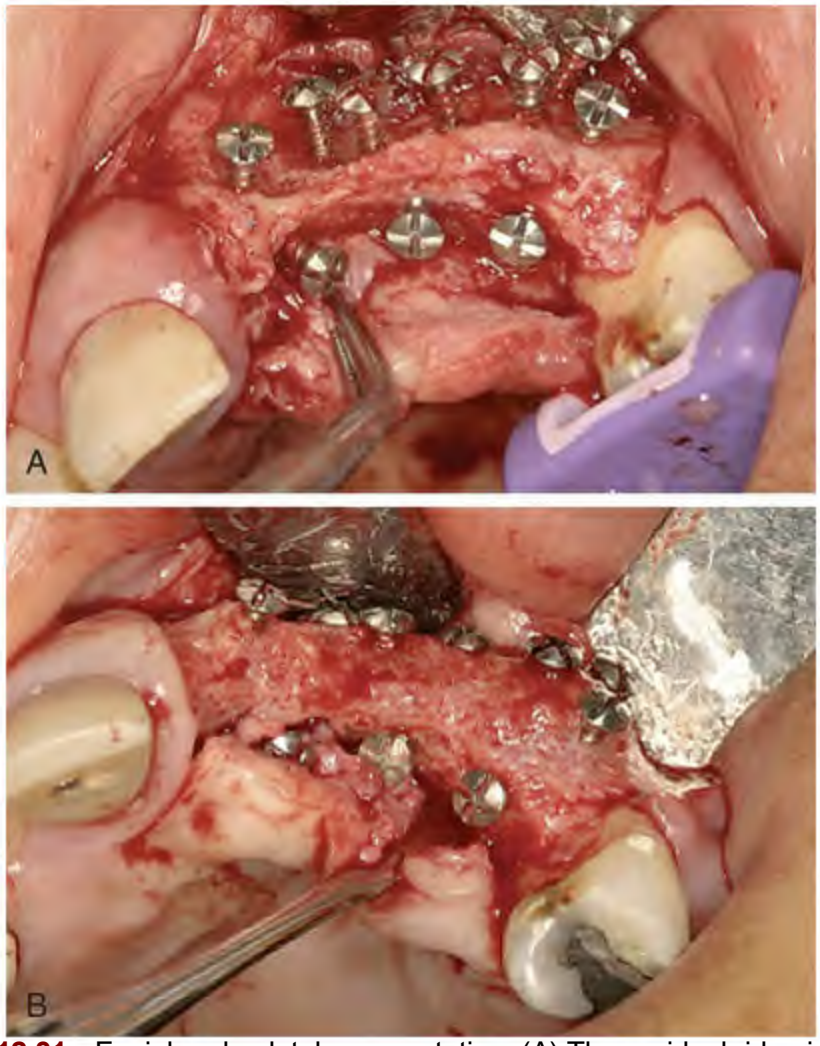

FIG 12.31 Facial and palatal augmentation. (A) The residual ridge in this photograph is close to 2 mm in its most narrow region, requiring both facial and palatal regeneration. The fixation screws define the specific area that will be regenerated with the grafting process. (B) Strategic positioning of fixation screws allows the surgeon to outline exactly where bone will be developed. The volume of the graft is no longer an issue because particulate grafts fill up a defect regardless of the irregular surfaces involved.

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FIG 12.32 Titanium mesh can easily become exposed if a sharp edge works its way through the soft tissue flap. This can be maintained during the healing process, but this can often compromise the graft development process.

Particulate Grafts

Exposure of the Bone Fixation Screw During the Healing Process

Etiology.

Bone fixation screws in regeneration sites sometimes become exposed during the healing process, potentially leading to bacterial invasion around the neck of the screw. Careful attention to the timelines of the screw exposure and the type of regenerative process is important in these situations.

- **Block Grafts**. Exposures involving a fixation screw in a block graft case do not allow many options related to screw removal. The most important concept in block grafting is rigid fixation of the block itself throughout the regenerative process. Therefore, removal of the exposed screw could result in a total graft failure. These situations must be maintained as well as possible with maintenance of the exposed screw.
- **Particulate Grafts.** Exposure of fixation screws in particulate grafting occurs when the head of the screw works its way through the overlying membrane and eventually perforates through the thin layer of the mucosa that covers the graft site. This typically happens when the screw head has a thin diameter that perforates through the membrane and eventually through the tissue. Particulate grafting techniques use these fixation screws to support the membrane and to define the shape of the desired bony contours. The use of a screw with a “wide head” is found to be important for predictable results. The type of membrane used for graft isolation also makes a significant difference when perforation of the screw through the membrane is a concern. AlloDerm GBR tends to be very resistant to membrane perforation during the healing process, whereas collagen membranes are soft when moistened and tend to perforate and tear if strain is placed on the hydrated membrane.

Complication.

Perforation of a membrane allows the ingress of foreign matter and fibrous soft tissue cells into the graft site, causing a disruption in the bone regeneration process. If the head of the screw pushes through the soft tissue and is exposed, bacterial contamination may result, potentially leading to graft infection and possible failure.

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Prevention.

The head of the bone fixation screws should have a wide and smooth diameter that provides enough surface area to support the membrane and to limit abrasion against the overlying mucosal layer. A small head will tend to work its way through a membrane when it is placed under tension or where a delicate membrane is being utilized. The typical bone fixation screw has a diameter of 1.5 mm, and the head of the screw should be as wide as possible.

Treatment.

Exposed screw heads should be maintained with chlorhexidine rinses until the surrounding soft tissue has healed. It is recommended that the screws in particulate techniques be removed at this time to eliminate the possibility of contamination of the graft through the opening around the shaft of the screw. If the screw is preventing pressure on the graft in respect to the use of a removable prosthesis, retention of the screw could be considered. Under no circumstances should efforts be made to cover the screw by repositioning the soft tissue (Fig. 12.33).

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FIG 12.33 Tent screws. (A) Larger screw heads are more likely to grow bone than smaller sized screws. Note the lack of bone around the small-headed screw on the far right side of the photo. (B) Example of “wide headed fixation screw.” (C) Fixation screws come in various width shanks and lengths. (D) The heads of the fixation screws are often visible through the thin mucosa covering the healing graft site. This is not a complication and no special treatment is needed. (E–F) Exposed fixation screws.

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Membrane Placement Too Close to Adjacent Teeth

Etiology.

GBR techniques routinely require placement of occlusive membranes in the proximity of natural teeth. This requires the implant surgeon to clearly understand the principles related to the positioning of nonresorbable membranes and resorbable membranes in relation to natural root surfaces.

- **Nonresorbable Membranes**. Membranes used in early GBR were nonresorbable e-PTFE membranes, and these were typically trimmed to allow 2 mm of space between the GBR membrane and the root of the adjacent natural tooth. This allows soft tissue attachment around the biological width of the tooth and anchorage of tissue around the occlusive barrier. The use of d-PTFE today requires observation of these same rules of maintenance of 2 mm between the edge of the membrane and the side of an adjacent root surface. GBR techniques using titanium mesh requires 2 mm of clearance from the root of a tooth due to similar issues.
- **Resorbable Membranes**. In GBR techniques utilizing resorbable membranes, the 2 mm rule is not a critical factor and resorbable membranes can be placed directly against the roots of the adjacent teeth without causing a membrane failure. Titanium mesh itself is separated from the root of a tooth due to similar issues (Fig. 12.34).

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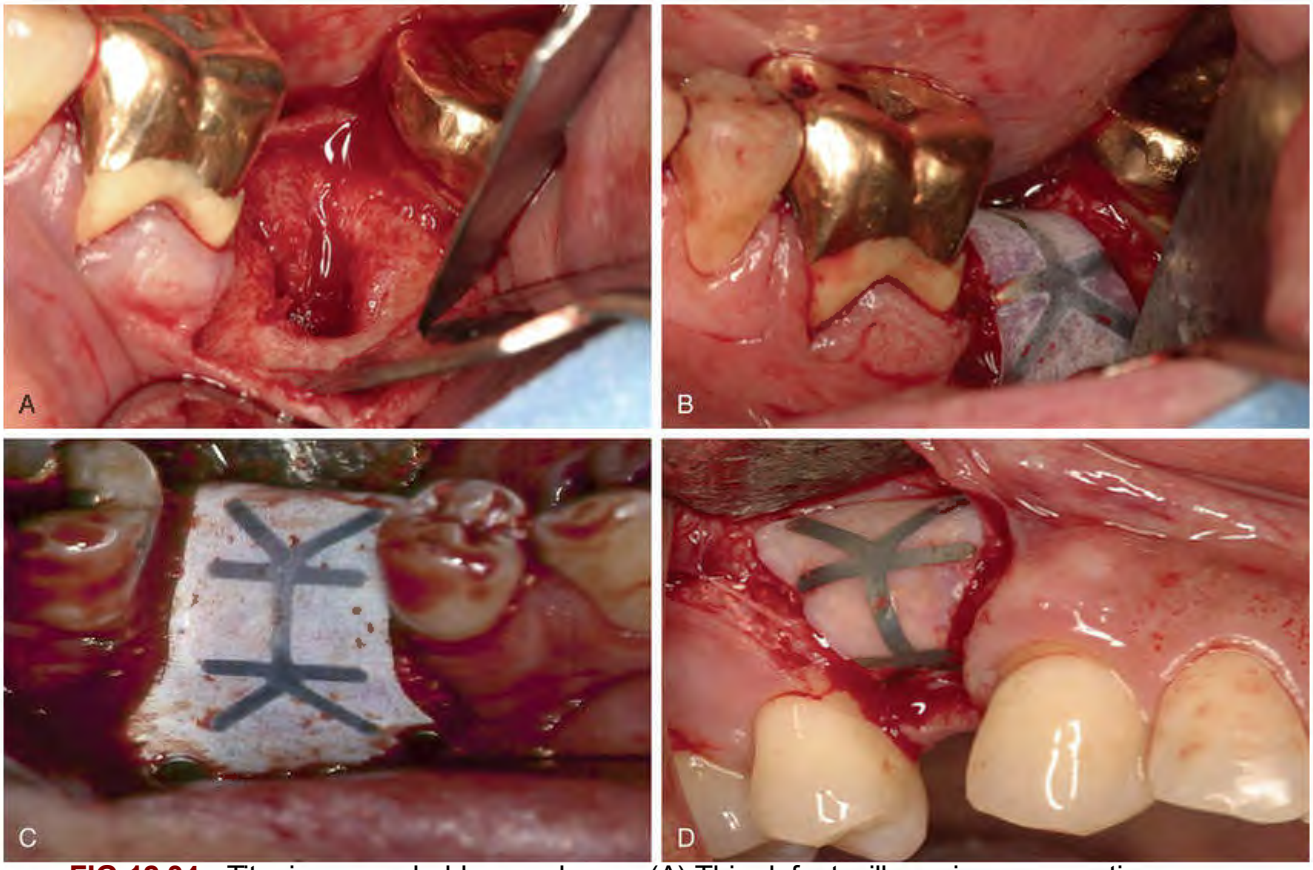

FIG 12.34 Titanium resorbable membrane. (A) This defect will require regeneration of the missing buccal plate, and a nonresorbable membrane will be used for space maintenance. (B) The support of the titanium struts prevents collapse of the membrane into the defect during the healing process. (C) Titanium reinforced membranes are placed with the edges 2 mm away from the adjacent roots to allow for proper attachment of the soft tissue around the adjacent root. (D) The margin of the membrane is probably too close to the incision line, potentially leading to problems with incision line opening.

Complication.

Placing resorbable membranes too close to the adjacent tooth roots can allow direct contamination of the membrane through the interproximal space, contributing to tissue ingrowth and bacterial infection of the graft. Titanium struts that are positioned close to the interproximal root surfaces will often lead to membrane exposure and a compromised graft volume in the region. The only complication with placing resorbable membranes directly against natural roots is related to primary wound closure in the root proximity. Membranes must be smooth and they should allow the overlying flap to be adapted evenly around the neck of a tooth root.

Prevention

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Nonresorbable membranes.

Nonresorbable membranes should be placed 2 mm from roots of adjacent teeth if possible. Titanium supported membranes should be selected in a form that does not have lateral struts that will be positioned in the proximity of a tooth root. Newer membranes are now being designed in arrangements that allow support over the interproximal ridge without the need for lateral struts in these critical interproximal regions.

Resorbable membranes.

Resorbable membranes are not required to be separated from the adjacent roots in most cases. Acellular dermal matrix does not appear to need to be separated from root surfaces, keeping in mind that this same membrane is used in routine periodontal procedures for root coverage.

The most important concept in augmentation procedures is total membrane coverage of grafting materials from the time of membrane placement to completion of the graft maturation process. Success is directly related to the overall management of the soft tissue flap during flap closure. A successful case starts with the incision, continues with proper flap reflection of an intact periosteal layer, proper membrane positioning, and completion with a tension-free flap closure (Fig. 12.35).

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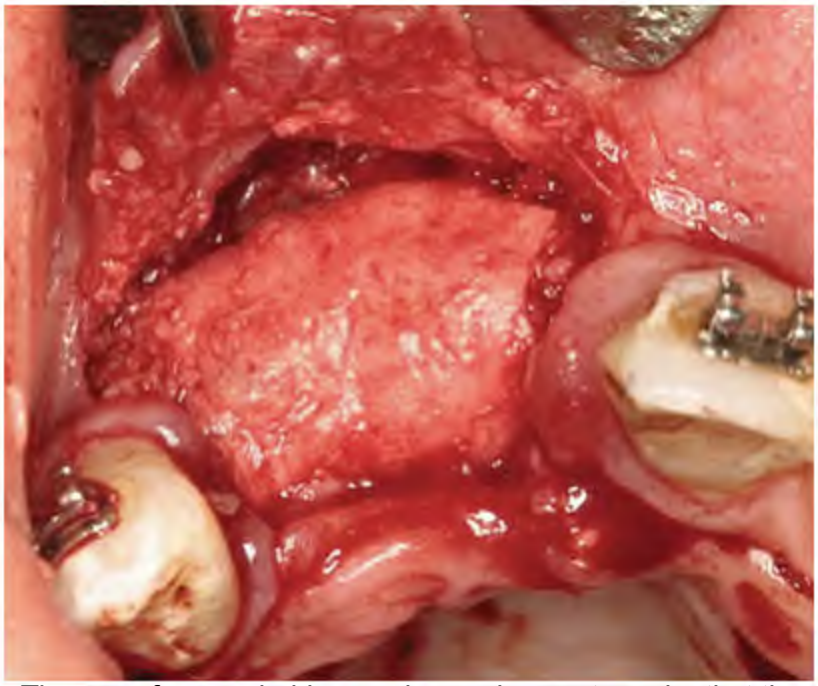

FIG 12.35 The use of a resorbable membrane does not require that the edge of the membrane be separated from the adjacent tooth roots.

Graft Infection

Etiology.

Graft materials resorb very rapidly at a lower pH condition, with hydroxyapatite crystals dissolving at a pH of 5.5 or less. Infectious environments may contain a pH of 2 or less, which can cause the rapid dissolution of a graft. Infection may be caused by lack of aseptic surgical technique, incision line opening, or infection from adjacent dental infections.

Complication.

The presence of a localized infection in a bone graft will cause dissolution of the graft material, contributing to a graft failure. The severity of this failure can vary depending on the duration of the infection and the onset of the contamination.

Prevention.

The use of proper surgical technique is vital in the preventing surgical contamination. Preoperative antibiotic regimens, chlorhexidine scrubs, and aseptic technique will limit bacterial contamination at the time of surgery. The introduction of antibiotics into the graft medium may also be included

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to minimize bacterial invasion. Proper suture technique and flap design are grafting fundamentals that prevent incision line opening that can also expose the graft to the oral microflora. Lastly, the clinician should ensure that all space maintenance components (nonresorbable membranes, titanium mesh, tenting screws) are free from sharp edges that may perforate the mucosa postoperatively, allowing the ingress of bacteria into the graft.

Treatment.

Postoperative examinations must be routinely scheduled, especially during the initial stages of wound healing. The patient must be instructed in hygiene techniques that minimize strain on the incision line, and postoperative chlorhexidine rinses can be used to manage the bacterial microflora. If incision line opening occurs, the patient must be placed on a chlorhexidine rinsing protocol to keep the graft site clean until the granulation is complete. If the patient experiences purulence from the site or general malaise, antibiotic protocols must be commenced immediately. Non-resorbable membranes can be maintained for an initial 6 week timeframe unless the site becomes infected. If this occurs, the membrane should be removed before the situation advances (Fig. 12.36).

FIG 12.36 Exposure of this titanium mesh has been complicated by graft site infection. Exposed titanium mesh in this situation will greatly complicate proper development of a normal papilla on the distal of the lateral incisor.

Block Grafts: Symphysis Bone Grafts

Inadequate Symphysis Bone Volume for a Graft

Etiology.

The use of monocortical grafts in the repair of ridge defects usually requires the harvest of substantial amounts of thick cortical bone to provide a graft thickness greater than 3 mm. The symphysis provides the potential for harvesting thicker sections of bone when compared to the ramus, where the average amount of donor bone does not exceed 3 to 4 mm in thickness. Normal variations in the cross-sectional anatomy of the symphyseal region in multiple patients require careful preoperative assessment of the region before surgical intervention is initiated. Prior to CBCT imaging, clinicians were generally forced to use lateral cephalograms or early cross-sectional imaging to predict the thickness of bone in these regions. Today, CBCT cross sections provide a precise measurement of the thickness of the donor site, and any anomalies can be identified preoperatively.

Prevention.

Spherical CT imaging or CBCT imaging is the recommended approach for assessment of the anatomy and thickness of bone in the region of the symphysis or ramus. It is recommended to measure the actual distance from the facial cortical plate to the lingual plate to first make sure that this will provide enough bone for the required recipient site and secondarily to provide a guide to the surgeon for the depth of the preparation cuts into the cortical bone during the harvest. If cross-sectional imaging is not available, use of a lateral cephalogram or a 2-D occlusal film can provide some basic idea of the anatomy of the region.

Cross-sectional imaging allows a realistic assessment of a potential donor site, and measurements on the 3-D image can be prepared before surgery is commenced. Assessment of the thickness of the cortical bone must be considered, and cases without any medullary bone need to be identified. The lack of sufficient medullary space may prevent separation of the facial and lingual cortical plates during the graft harvest and the potential for sectioning completely through the lingual plate increases as blind harvesting is attempted.

Complication.

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Complications may arise when inadequate donor bone is present. This may result in inadequate graft volume/thickness, poor density of the graft, and increased donor site morbidity. Life-threatening situations have been documented when fractures have occurred, leading to the lingual mandibular symphysis being displaced into the sublingual space, ultimately interfering with the airway. When the preparation of a block graft harvest extends through both the facial and lingual cortical plates, the block is free to be drawn to the lingual aspect as pressure on the block is applied by muscle attachments. The region of bone around the genial tubercle is directly attached to the genioglossus and geniohyoid muscle attachments. If the graft is no longer attached to the surrounding mandibular bone, it will be drawn completely through the mandible and into the space below the tongue (Figs. 12.37 to 12.39).

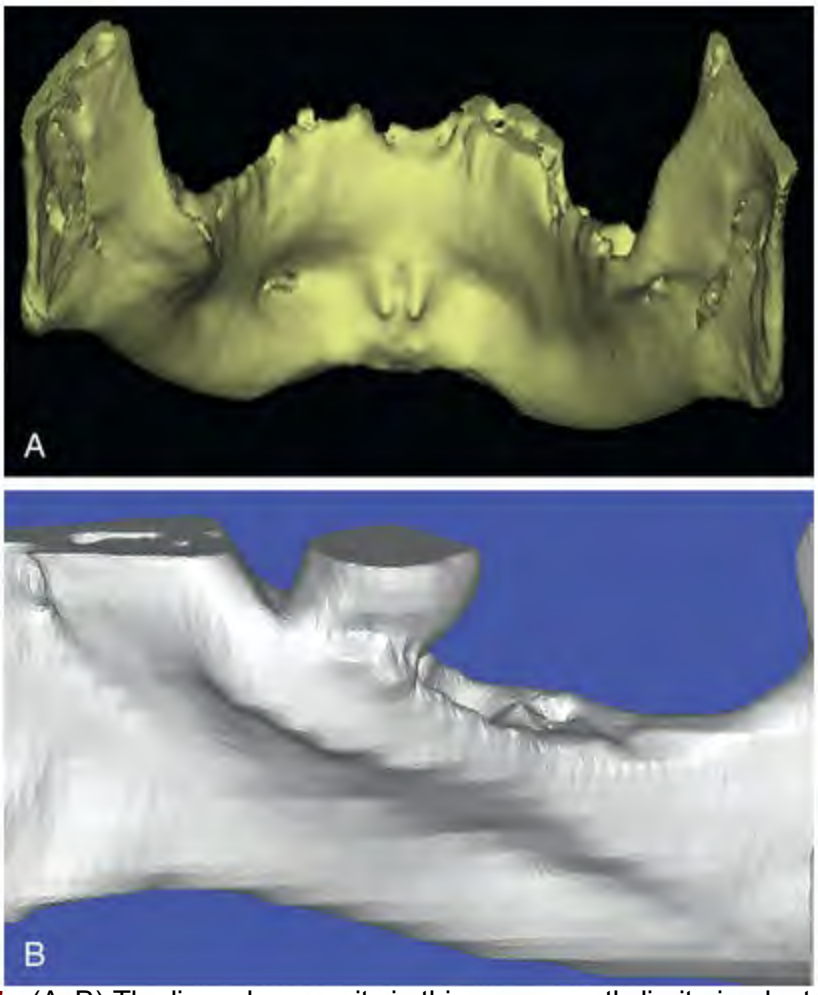

FIG 12.37 (A–B) The lingual concavity in this case greatly limits implant treatment planning.

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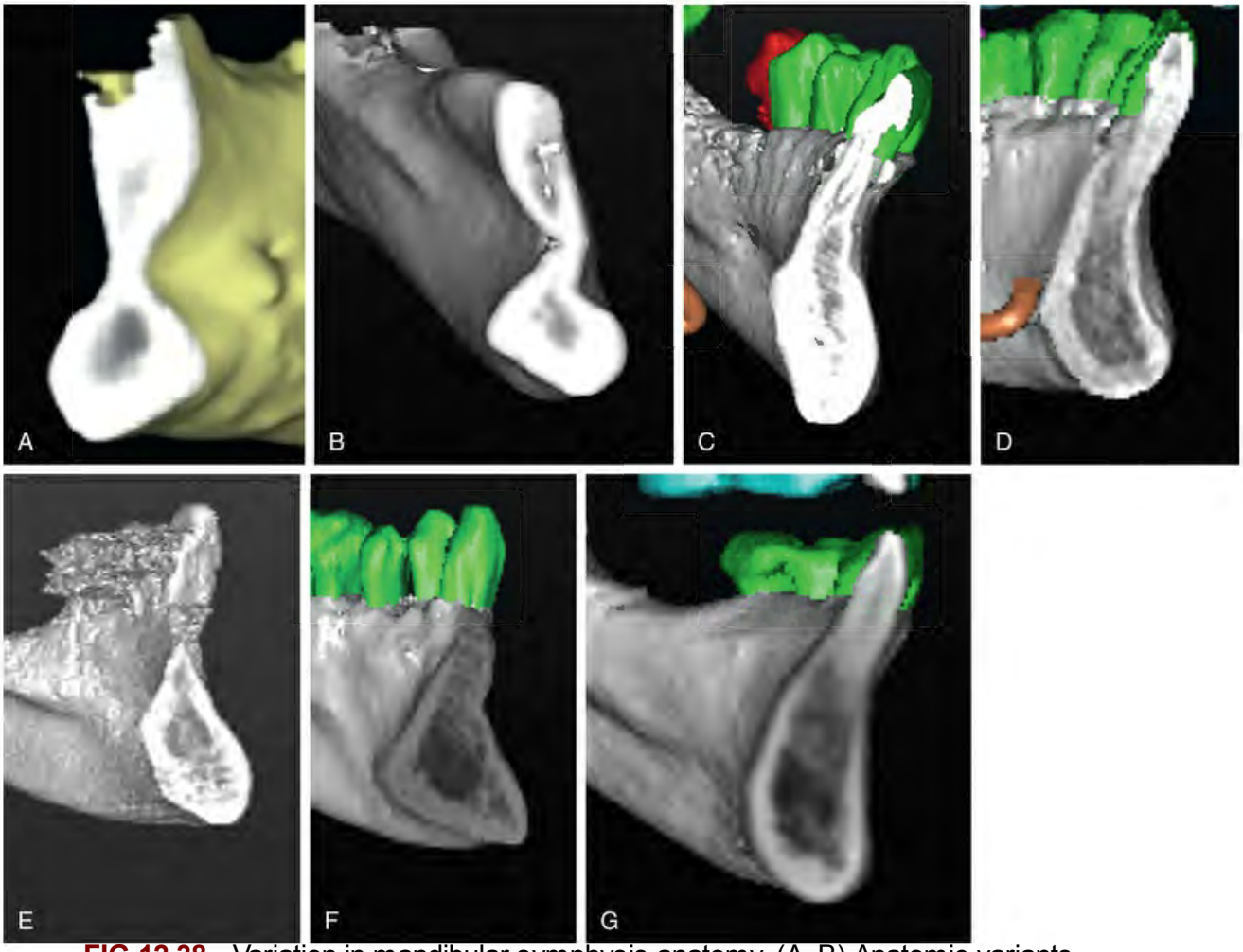

FIG 12.38 Variation in mandibular symphysis anatomy. (A–B) Anatomic variants (hourglass mandible). (C–D) Narrow buccal-lingual width. (E–G) Poor bone density.

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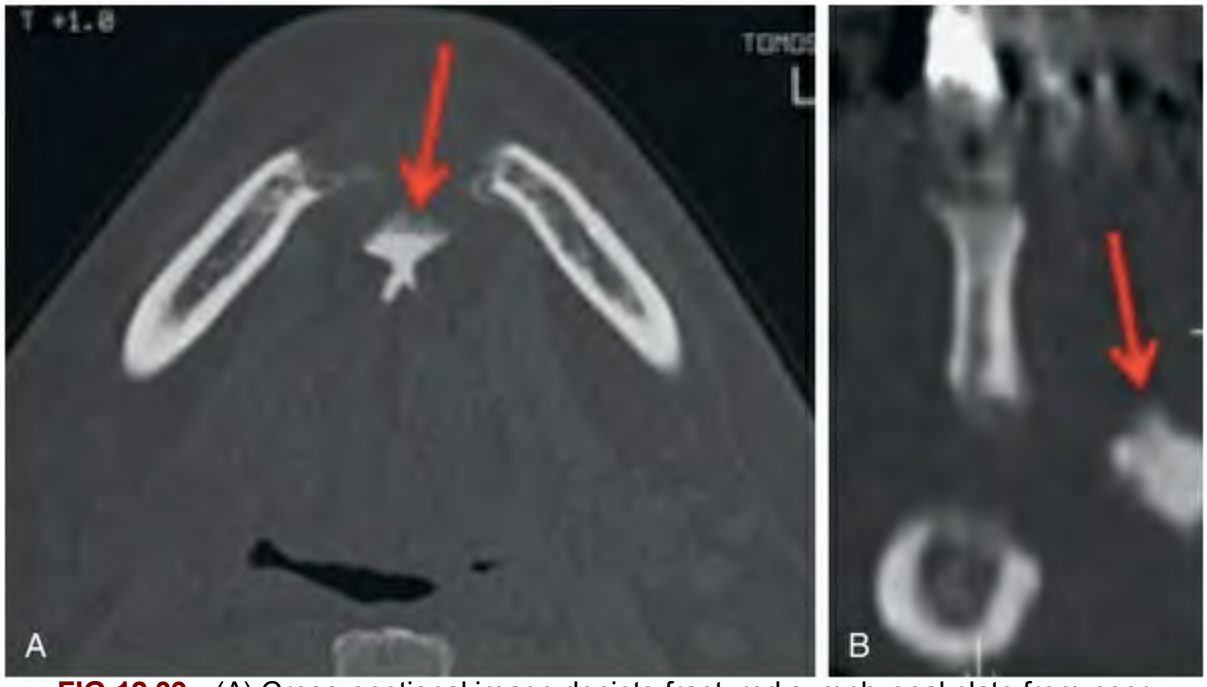

FIG 12.39 (A) Cross-sectional image depicts fractured symphyseal plate from poor patient selection of a symphysis graft. (B) Axial view. (From Cordaro L, Rossini C, Mijiritsky E: Fracture and displacement of lingual cortical plate of mandibular symphysis following bone harvesting: case report. *Implant dentistry* 13(3):202–206, 2004.)

Bleeding/Neurosensory Complications

Complication.

When a cortical graft and the surrounding medullary bone are harvested in the symphyseal region, the underlying neurovascular components are often compromised. These disruptions to the nerves and blood vessels may be accompanied by varied neurologic sensations along with possible significant bleeding immediately following the graft harvest.

Etiology/Prevention

The incisive canal.

The space between the mental foramina has been known for years to be a safe zone for bone harvesting because of the lack of vital structures that can be affected by grafts taken from this region. A thorough understanding of the neurologic and vascular anatomy in this region is critical for the prevention of complications during and after surgery in the symphyseal region. Generally, there is a relative absence of sensory deficit to the lip and chin after implants are placed in this region as compared to cases involving

the posterior quadrants. However, this can sometimes give rise to a complication if the lingual plate is perforated or if complications develop while harvesting large bone grafts from this region.

Studies have shown that, with digital volumetric tomography, in 100% of the cases reviewed, there is the presence of an "incisive branch" of the inferior alveolar nerve that branches off at the mental foramen, passing interiorly to the midline of the symphysis. It has also been commonly recognized that an "anterior loop" may exist, which is an anterior extension of the mental nerve in relation to the mental foramen. This anterior loop of the mental nerve is subject to injury when implants are placed in approximation to the mental foramen. The "incisive branch" of the inferior alveolar nerve course veers toward the lingual plate as it approaches the midsymphyseal region. In the midline area the incisive nerve in most cases will join the nerve from the contralateral side.[48]

When block grafts are harvested from the chin, cortical blocks are resected. In the process, additional medullary bone around the site is scraped out of the space between the cortical plates. While taking this additional medullary bone, the clinician may inadvertently resect the incisive nerve and blood supply. If these neurovascular channels are disrupted, significant bleeding can occur, and the patient will potentially complain postoperatively about altered sensation to the incisors. This is not a painful sensation, but it is disruptive, causing patients to generally describe the incisors as having a "woody feeling." This series of complications can usually be avoided by refraining from aggressive harvesting of medullary bone surrounding the donor site.

Studies have shown the incidence of neuropraxia following the harvesting of block grafts from the ramus vs. the symphysis. After 18 months, more than 50% of the patients with harvest sites in the symphysis still had altered sensation. None of the patients in the ramus donor group reported any symptoms at 18 months.[48]

Lingual artery.

The incisive neurovascular bundle is found to join other vascular structures in the midsymphyseal region. The genioglossus muscle attaches to the genial tubercle in the midline, and the lingual artery courses through the lingual foramen at the genial tubercle. The lingual artery is approximately 1 to 2 mm in diameter, and cross-sectional views clearly show its anastomosis with the incisive canal at this point.

The preparation of a grafting osteotomy in the midline can potentially resect these blood vessels if they fall in the path of the vertical preparation. If this occurs, the sectioned extension of the lingual artery can prolapse back into the floor of the mouth. The severed vessel may release arterial blood flow in the sublingual space, potentially raising the tongue to a point that compromises the airway. Immediate emergency intervention to maintain the airway is critical, and in some cases this requires use of a tracheostomy until the blood flow has been controlled.

Superior genial foramen.

Miller found additional anterior foramina with a diameter of around 2 mm that anastomosed with the incisive canal. Substantial bleeding reported in the symphysis during flap reflection may be attributable to these larger vessels.[26] These bleeding points have previously been described as "nutrient canals," indicating that they had no sensory component. Injury to these vessels can be avoided by limiting the apical extension of flaps during grafting and related procedures close to the symphysis.

Incorrect Size and Shape of Block Graft

Etiology.

The recipient surface anatomy of a bony defect is typically irregular in its size and shape, which presents the clinician with a challenge as it pertains to grafting. In areas where block grafts are necessary to build appropriate bone volume, the clinician must make a choice whether to modify the shape of the block or the recipient site to ensure a proper integration and resolution of the defect. An ideal graft/recipient position eliminates as much space between the two surfaces as possible.

Complication.

Failure to properly adapt a cortical graft to closely approximate the recipient bed will often lead to a gap that could inhibit early angiogenesis and eventually osteogenesis. A block that is "inlayed" into the recipient site limits this gap and allows proper integration of the newly forming bone into the recipient bed. Rocking of a cortical graft will invariably lead to a failed union of the cortical graft with the recipient bed. Micromovement of any graft leads to poor results, if not outright failure.

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Prevention.

A thorough examination of the anatomy of the bony defect is required to determine the dimensional volume of bone needed for proper support of the implant in the required restorative position. This dimensional volume must then be realistically assessed to make sure that the donor site will provide a graft with adequate bone thickness for the size and shape of the defect. When a recipient site requires more than 4 mm of bone, grafting from the ramus area is not indicated. Anatomic limitations of the ramus in this region limit the thickness of the graft to 3 to 4 mm. Larger grafts in the ramus can impinge on the safety zone around the surrounding vital structures.

All fibrous tissue must be removed from the surface of the recipient site using a course, round acrylic bur (e.g., 10-12 round bur). The bed of the graft site is then aggressively shaped to provide a flat-surfaced base for the graft. If possible, the block should be recessed into the ridge for support and for improved integration into the native bony ridge. The reshaping of the recipient bed stimulates a regional acceleratory phenomenon (RAP), improving the chances of a strong bond between the block and the recipient bed.

Block preparation.

Preparation of the cortical block should be completed with as little reduction of the volume of the block as possible. The block not only provides a source of cells with osteogenic potential, but it also promotes bone development through the concept of “barrier by bulk.” The natural remodeling of bone over time will reduce any excess bone bulk, so in this situation, bony excess is not a problem (Figs. 12.40 to 12.43).

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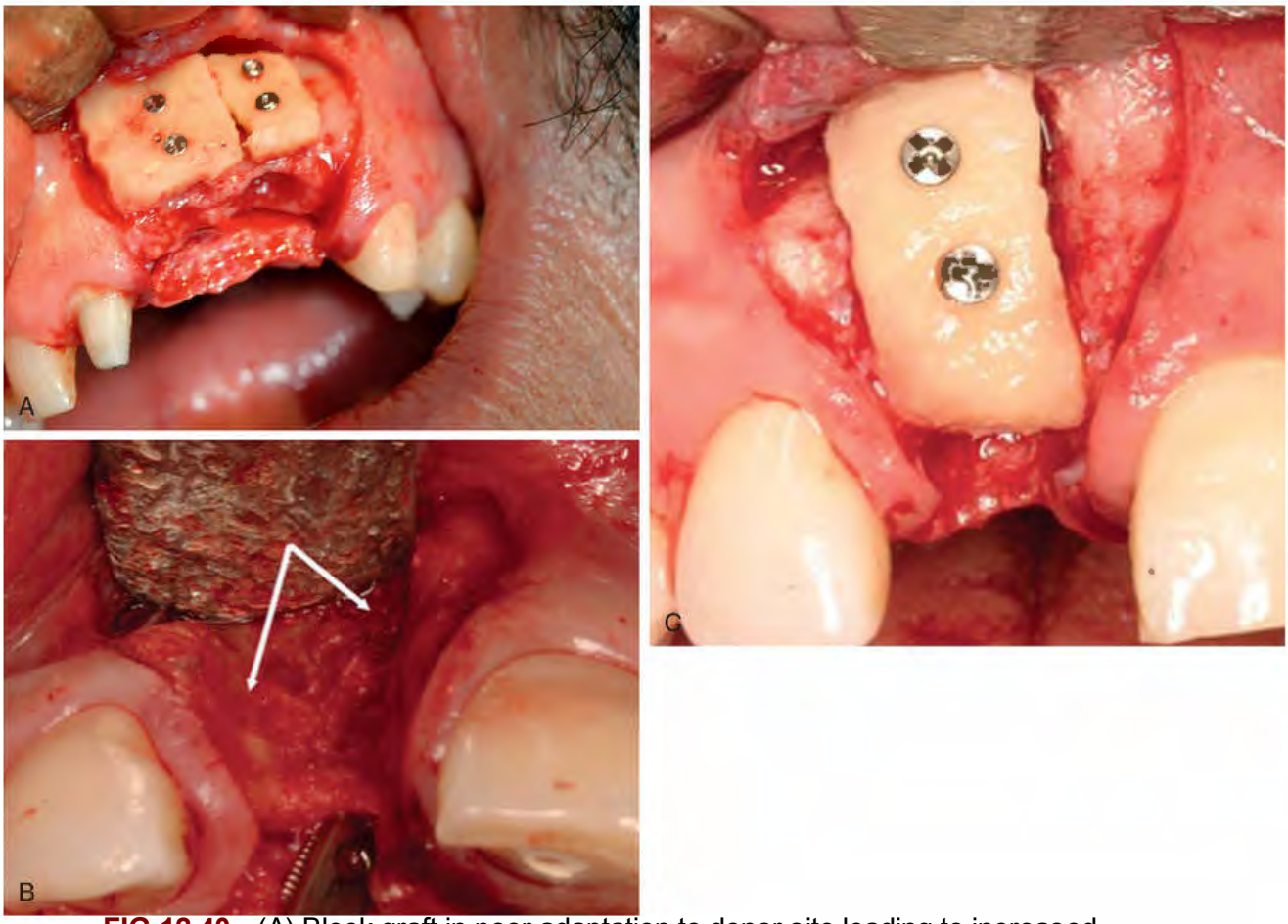

FIG 12.40 (A) Block graft in poor adaptation to donor site leading to increased chance of nonunion. (B) Recipient site is modified to allow for seating of the cortical, allowing no movement. (C) The recipient site has been shaped to receive the block graft in a smooth recipient bed.

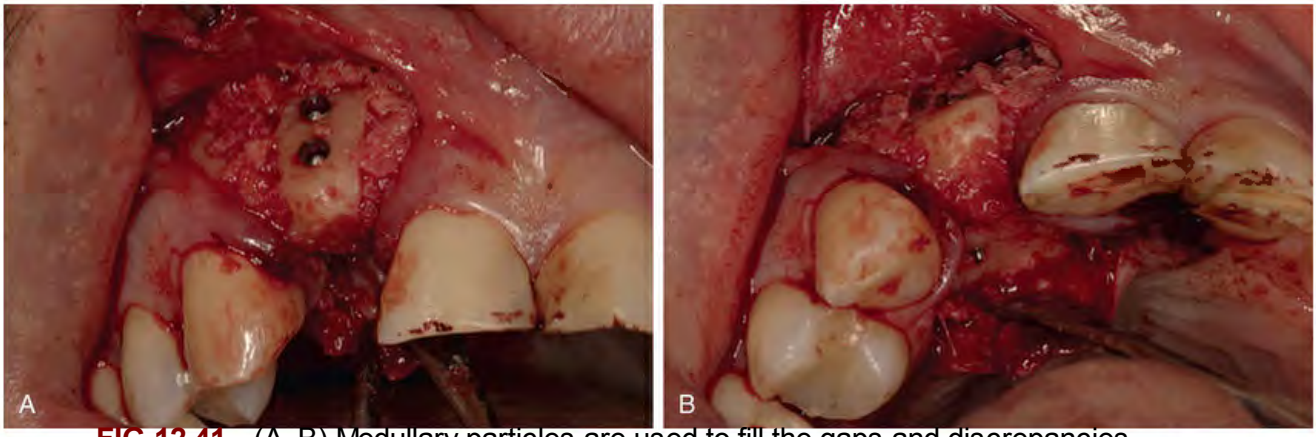

FIG 12.41 (A–B) Medullary particles are used to fill the gaps and discrepancies around a block graft.

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FIG 12.42 A very thick graft that has been mortised into a wide buccal defect in the first molar region.

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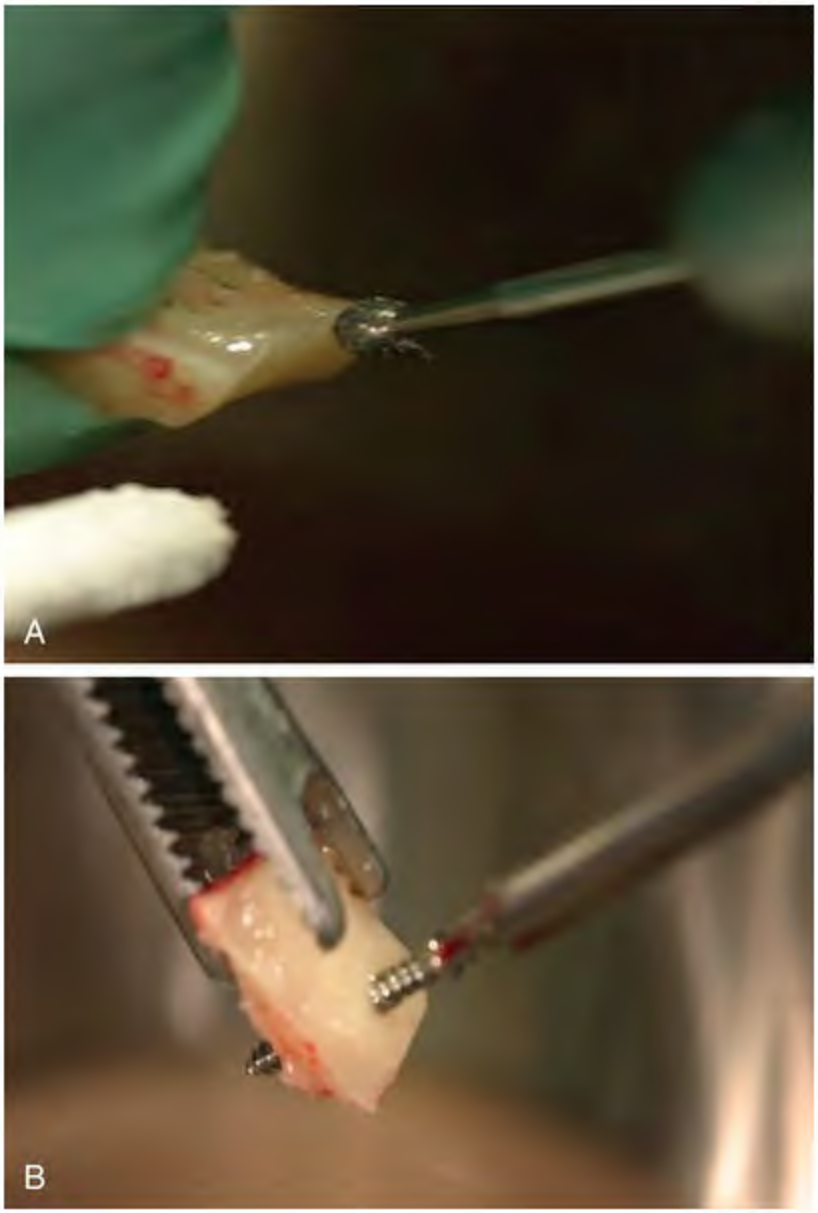

FIG 12.43 Block graft modification. (A) All sharp edges should be beveled with a round carbide or diamond bur under copious irrigation. (B) Fixation screws should always be pre-drilled prior to inserting graft. This will allow for ideal placement and stability when fixating graft.

Loss of Bone Fragments During Break-Up of Cortical Blocks

Etiology.

The use of dense cortical bone in ridge augmentations has always presented a problem when an irregularly surfaced cortical graft needs to be trimmed and reshaped for adaptation in a graft site. In the case of particulate grafting,

the complete piece of cortical bone must be broken into small pieces before it can be used. Control of the graft particles during this process is critical because loose particles can be easily lost or contaminated as the graft is processed. Autogenous bone harvests are challenging, and loss of critical bone particles and blocks can cause unnecessary time delays and patient discomfort if additional bone needs to be harvested to replace a contaminated block.

Complication.

Pieces of harvested bone can be lost if they are not contained during the preparation of the cortical grafts. Processing of pieces of bone in these situations often results in the loss of “bone particles” that fly off the rongeurs or pieces of the graft that become contaminated as they come in contact with surrounding surfaces. Entire blocks have fallen out of surgical fields in the past, totally preventing their use in graft procedures.

Prevention/Treatment.

The particulate grafting technique described in this chapter requires that a piece of a cortical block be completely broken up into small particles that are then packed into irregular bony defects. These small particles tend to “shoot out” of the ronguers if they are not carefully contained. The best way to eliminate the loss of these cortical particles is to fill a clear, shallow glass beaker or bowl with saline. The block is then submerged in the saline and double-action ronguers are used to break it up into the particle size needed for the procedure. The saline slows escaping particles in the same manner that water slows the movement of a bullet that is fired into water (Fig. 12.44).

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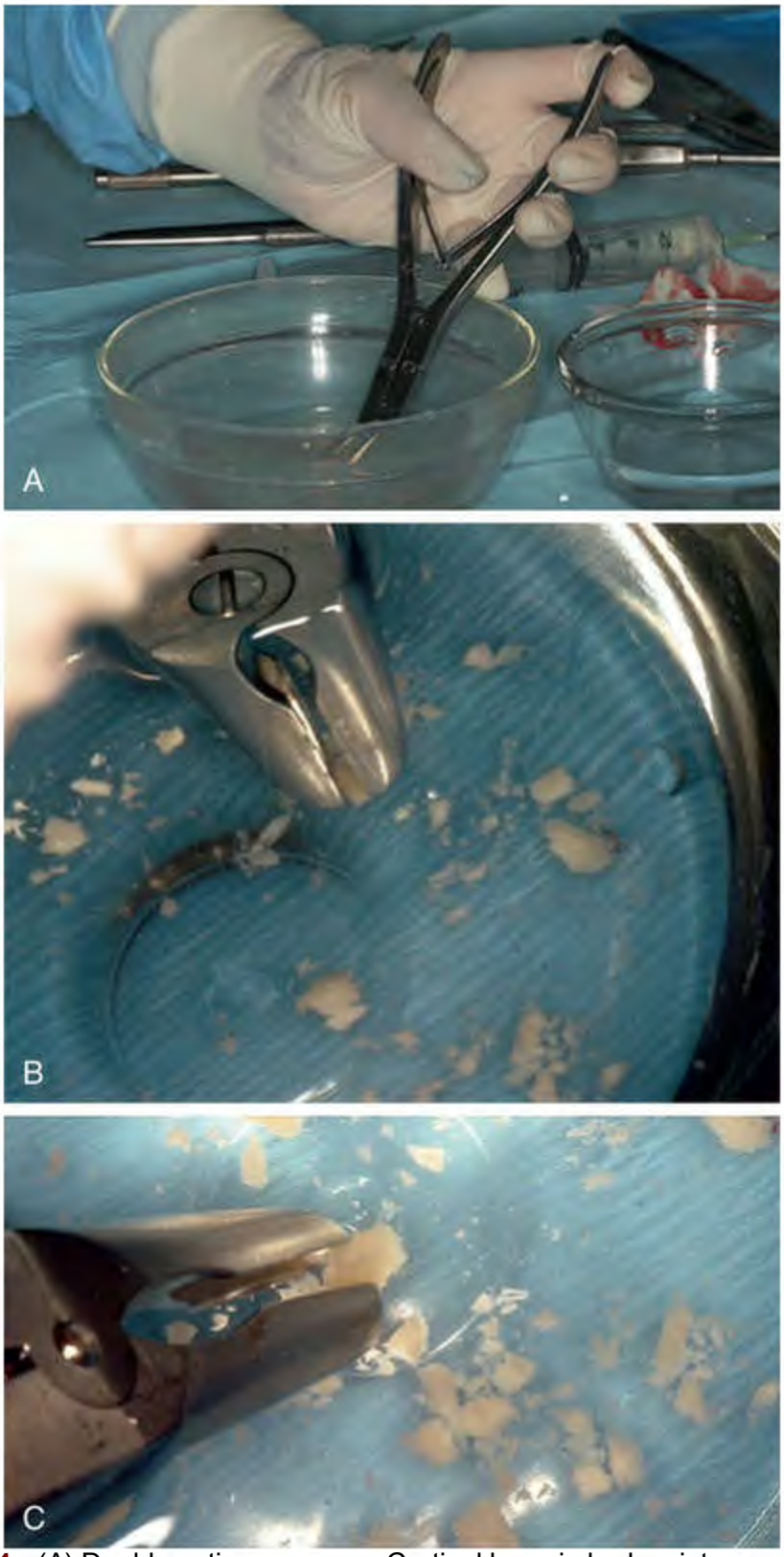

FIG 12.44 (A) Double action ronguers. Cortical bone is broken into small particle sizes. (B) Use the sides of the ronguers at the end of the beak for larger pieces. Use the ends for smaller particles that are not too dense. (C) Keep the block under the water level to prevent loss of particles during this process.

Ultrasonic Piezosurgery–Related Tissue Injury

Etiology.

The use of ultrasound technology in dentistry first began in the 1950s, and in the last 20 years piezosurgery units have been developed using low-frequency ultrasound (10–60 kHz) for the selective cutting of bone. Traditional bone drilling with motorized drills is easily available to clinicians; however, cutting bone with a drill can generate excessive amounts of heat in dense bone, potentially damaging the surrounding tissue. A surgical drill that comes in contact with blood vessels, nerves, or sinus membranes can also cut or damage adjacent vital structures. The use of piezosurgery in implant surgery has been a welcome alternative to motorized drills in many applications. At the lower ultrasonic frequencies used for piezosurgery, surgical inserts cut through hard, mineralized bone but do not damage the surrounding soft tissue or generate high amounts of heat. Piezosurgery has been especially useful in implant surgery, where bone must be cut in close proximity to a nerve or blood vessel. Use of the piezosurgery inserts generally allows the clinician to perform these bone alterations without damaging or cutting delicate tissues that come in direct contact with the ultrasonic insert.

Complication.

As piezosurgery has been utilized over many years, it has been reported by practitioners that the inserts should not be allowed to function while in direct contact with the soft tissue flap. Earlier surgical units were reported to "heat up the insert tip" during use, and irritations or burns on the soft tissue flap were sometimes detected.

Prevention.

This altered tissue issue has not been evident in updated piezosurgery units, but careful attention must be directed to protection of surrounding soft tissue during ultrasonic insert use. Instructors describe this as an abrasive phenomenon caused by the rapid ultrasonic movement of the tip against the soft tissue. Care must be taken to keep the tissue flap away from the ultrasonic inserts.

Treatment.

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Development of any abrasive or burn-type lesion should be treated symptomatically, just as any other oral burn or abrasive lesion would be treated. If there are any signs of more serious damage, more involved treatment may require appropriate referrals for wound care (Figs. 12.45 and 12.46).

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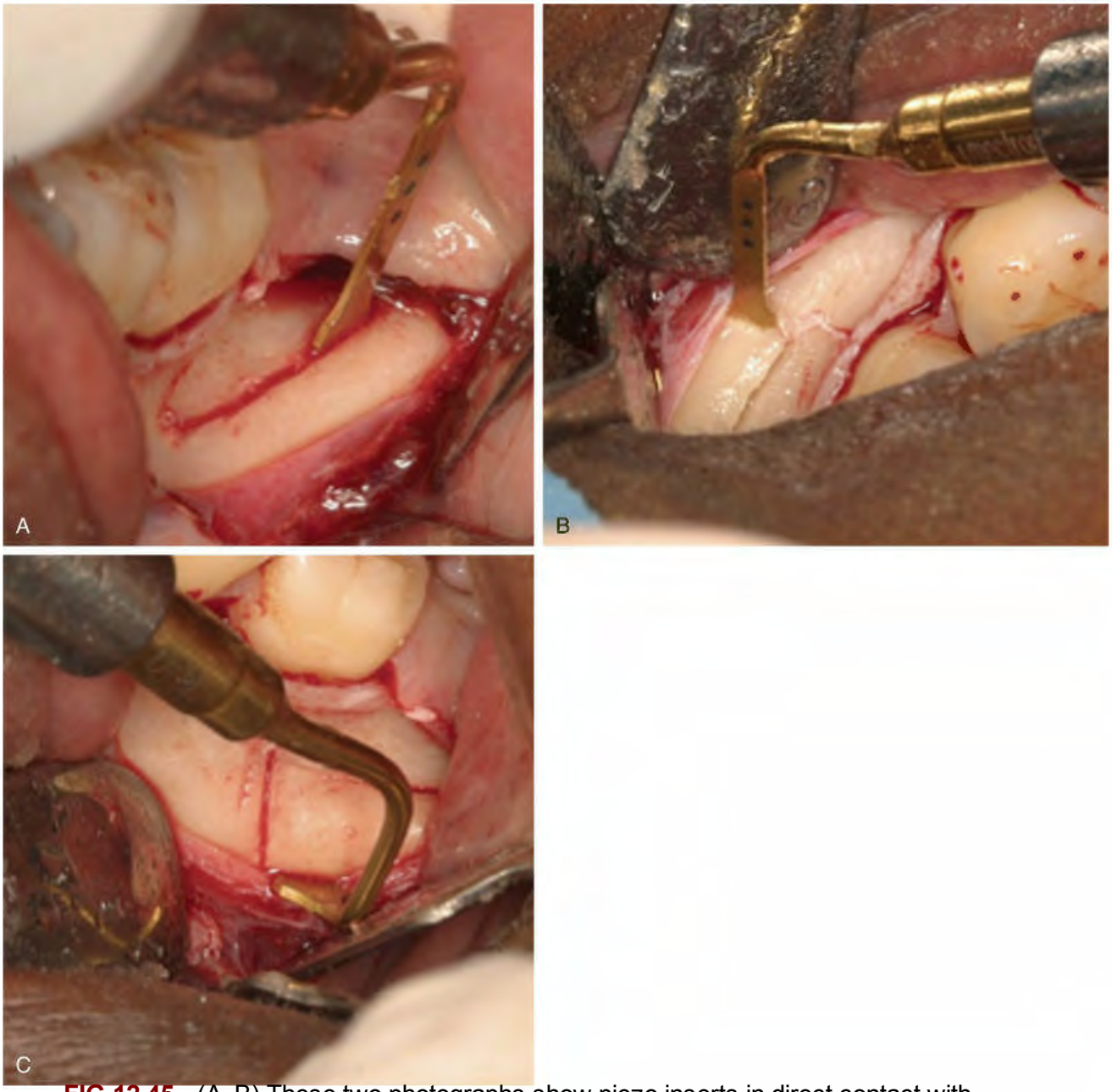

FIG 12.45 (A–B) These two photographs show piezo inserts in direct contact with the adjacent soft tissue flap. The inserts of piezoelectric hand pieces should not be allowed to lie directly against the adjacent soft tissue during bone preparation. Damage to the soft tissue related to the vibration of the insert against the tissue has been reported. (C) Full retraction of the buccal flap provides access for the apical insert while harvesting a block graft.

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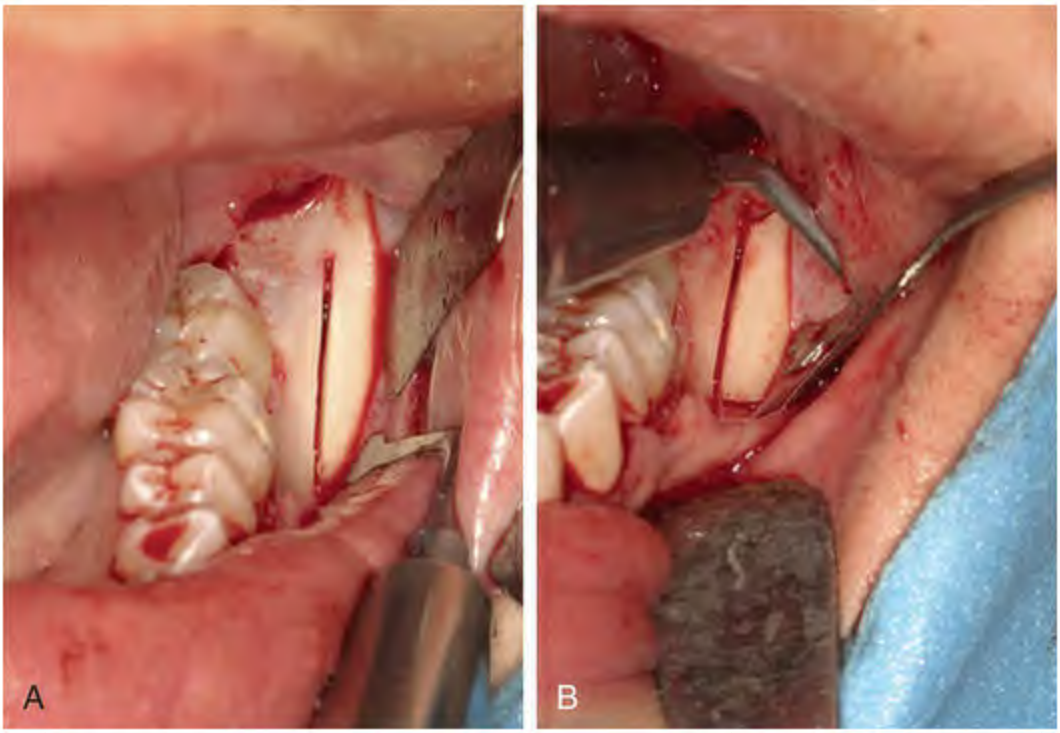

FIG 12.46 (A) The piezoelectric inserts are separated from the surrounding soft tissue with "Pritchard retractors" and wide flap access. (B) Two retractors retract the tissue while the piezo insert prepares the bone.

Chin Graft Closure Complications

Etiology.

The closure of a chin graft donor site is a very delicate process, with periodic incidences of incision line opening postoperatively. The chin presents a unique situation because tension from the surrounding musculature places constant pressure on the healing wound in a chin graft donor site. The mentalis has multiple insertions into the symphysis area that predispose the region to incision line opening.

Complication.

If incision line opening occurs, healing will be compromised, resulting in pain, inflammation, possible infection, and a potential loss of the graft.

Prevention.

It is recommended that a careful review the thickness and integrity of the tissue covering the lower incisors be completed before deciding whether to use a sulcular incision or a vestibular incision for access to the donor site.

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The “biotype” of the tissue can provide insight into the best approach for surgical access and wound closure. If there is bountiful thick tissue around the teeth with no recession, a sulcular incision provides adequate access for harvesting the graft and closure is relatively simple. If the incisors have thin and friable tissue, it is better to utilize a vestibular approach for chin graft access. This will ultimately prevent any postoperative recession on these already compromised incisors. Tension on the flap of a patient with a thin biotype can easily strip the healing tissue away from the teeth, exposing bone that will then slowly be covered with granulation tissue growth over time.

In cases where a vestibular incision is required, care must be taken to secure the attachment of the mentalis where possible. This limits direct tension on the incision line and, subsequently, the incidence of incision line opening. The type of suturing technique recommended is a two-level vestibular closure. The muscle is sutured initially, followed by the mucosal tissue (Fig. 12.47).

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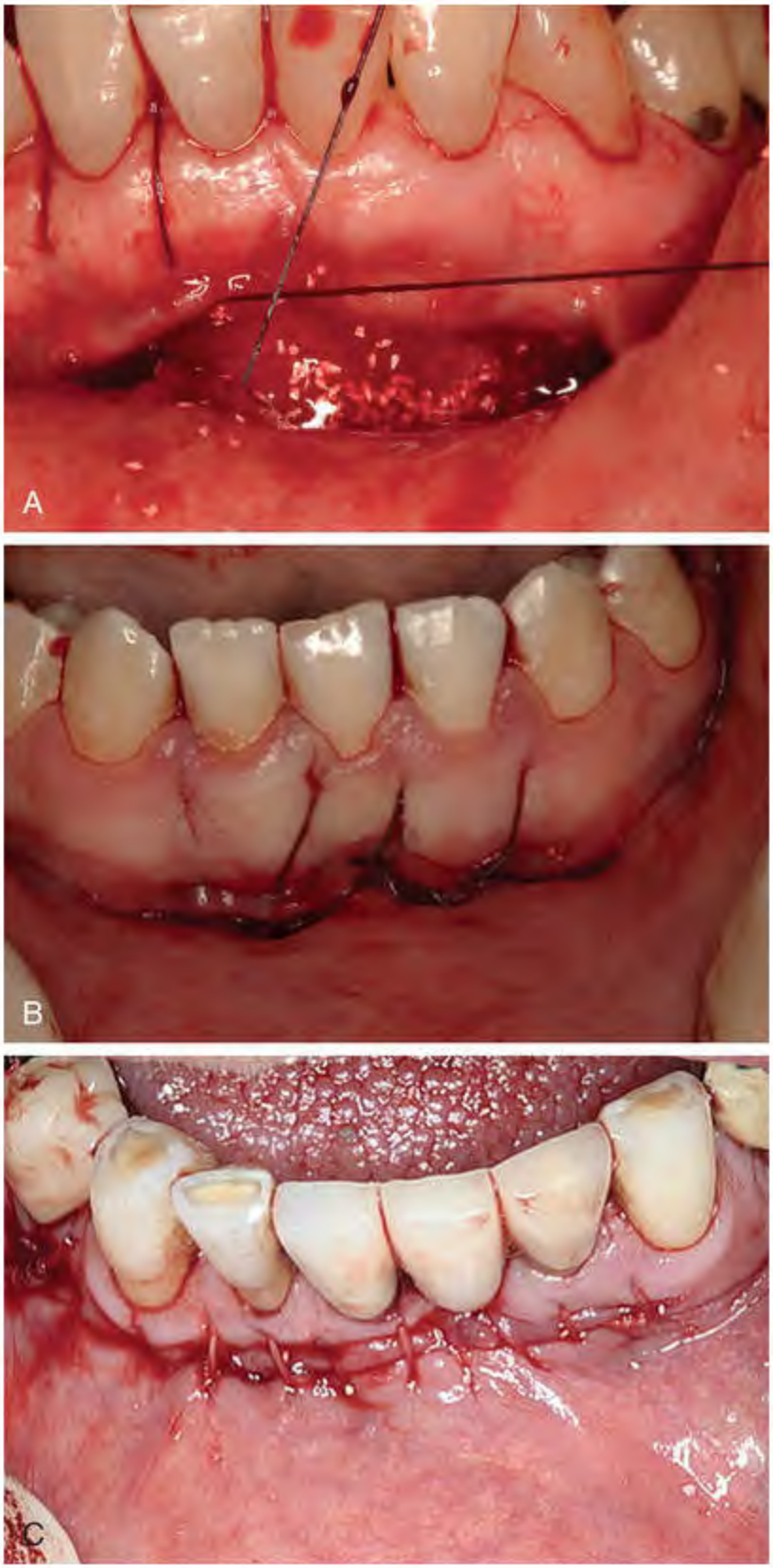

FIG 12.47 (A) Two-layer closure. (B) Tension on the flap during chin graft closure site may be reduced with the use of a two-layer approach. This image shows the use of suspensory sutures that first pass through the mentalis muscle on each side of the symphysis and then around the neck of the incisors before tying the knots. This prevents any strain on the outer portion of the flap closure at the superficial

level. (C) Another example of the superficial layer of the flap closure where the keratinized tissue around the teeth is used for good anchorage.

Soft Tissue Changes (Ptosis) After Symphysis Graft

Etiology.

One of the main patient concerns when confronted with the prospect of symphysis grafting is a change in facial or soft tissue appearance. The idea of having a permanent bony chin defect or ptosis contributes to a patient's apprehension regarding this procedure.

Complication.

The main concern of patients after a symphysis graft is a postoperative change in the soft tissue contour of the chin. In the literature, there exists no evidence of a statistically significant incidence of dehiscence or chin ptosis after a symphysis graft.

Prevention.

Avoid degloving the mentalis muscle by maintaining the facial and inferior aspects of the mandible and the lingual aspect of the inferior border of the mandible during flap refection. Additionally, to prevent lower lip height reduction and vermilion zone inversion, the integrity of the periosteum to the inferior reflection should not be deeper than one third of the total distance from the vermilion border to the mucogingival junction. An extraoral bandage or pressure dressing may be utilized postoperatively for support and to help with compression of the wound.

Neurosensory Changes After Symphysis Graft

Complication.

Neurosensory deficits of the third branch of the trigeminal nerve are very rare in association with symphysis grafts. However, it is a common sequela to have neurosensory changes in the mandibular anterior teeth.

Etiology.

Because the second terminal branch of the inferior alveolar nerve (incisive

branch) terminates in the anterior mandibular area, it is not uncommon to sever this section of the nerve during osteotomy preparation. However, because the incisive nerve is only a sensory nerve to the incisor teeth, this usually results in only a “dullness” in sensation. Hoppenreijs et al showed a negative pulpal response in 16% of patients with total resolution in 6 to 12 months.[49,50]

Prevention.

The superior portion of the harvest site should be prepared at least 5 mm below the level of the incisor root tips. Care must be taken to avoid the longer roots of the cuspids as each end of the harvest pattern is prepared. Aggressive harvesting of the medullary portion of the symphysis should be minimized in the superior aspects if possible to limit damage to neural pathways through the region. Most importantly, complete patient education must be conducted “prior to” the surgery informing the patient about potential sensory changes that could occur. The patient should be aware that they could feel a dullness or “woody” feeling of the mandibular anterior teeth following surgery. This can be temporary or a permanent condition, but it has never been described as a particularly annoying feeling. Very rarely is there an indication for endodontic therapy, as the vitality of the teeth returns to normal (Fig. 12.48).

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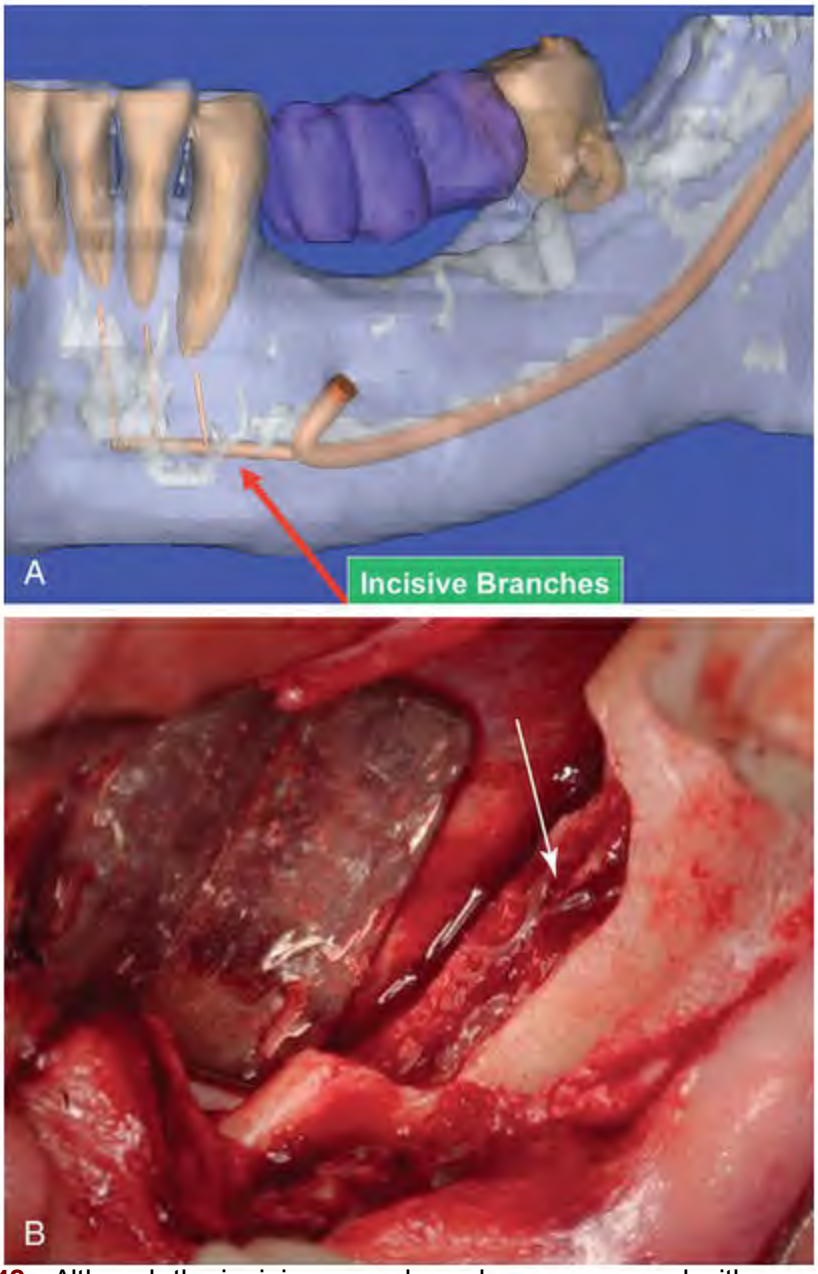

FIG 12.48 Although the incisive nerve branches are severed with a symphysis graft, reinnervation usually occurs within 2 to 4 months.

Improper Superior Margin Location: Symphyseal Graft

Complication.

Devitalization of the lower incisors may occur during preparation of the superior aspect of the osteotomy for a symphysis graft if it is improperly positioned (e.g., too close to mandibular incisor root apices).

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Etiology.

The superior margin of the block osteotomy should not be placed any closer than 5 mm below the longest root in the incisor region, and it must avoid damage to the longer roots of the adjacent cuspids. It is important to preoperatively assess the thickness of the cortical bone in these cases, especially with smaller patients and women with osteoporosis. These patients are more likely to have a very thin cortical plate overlying a medullary component that is difficult to harvest for grafting.

Prevention.

A CBCT exam will reveal the exact location of the apices of the incisors and the adjacent cuspids. If the cuspids extend too far apically, the symphysis graft may be harvested in two blocks, thereby minimizing trauma to the cuspids (Fig. 12.49).

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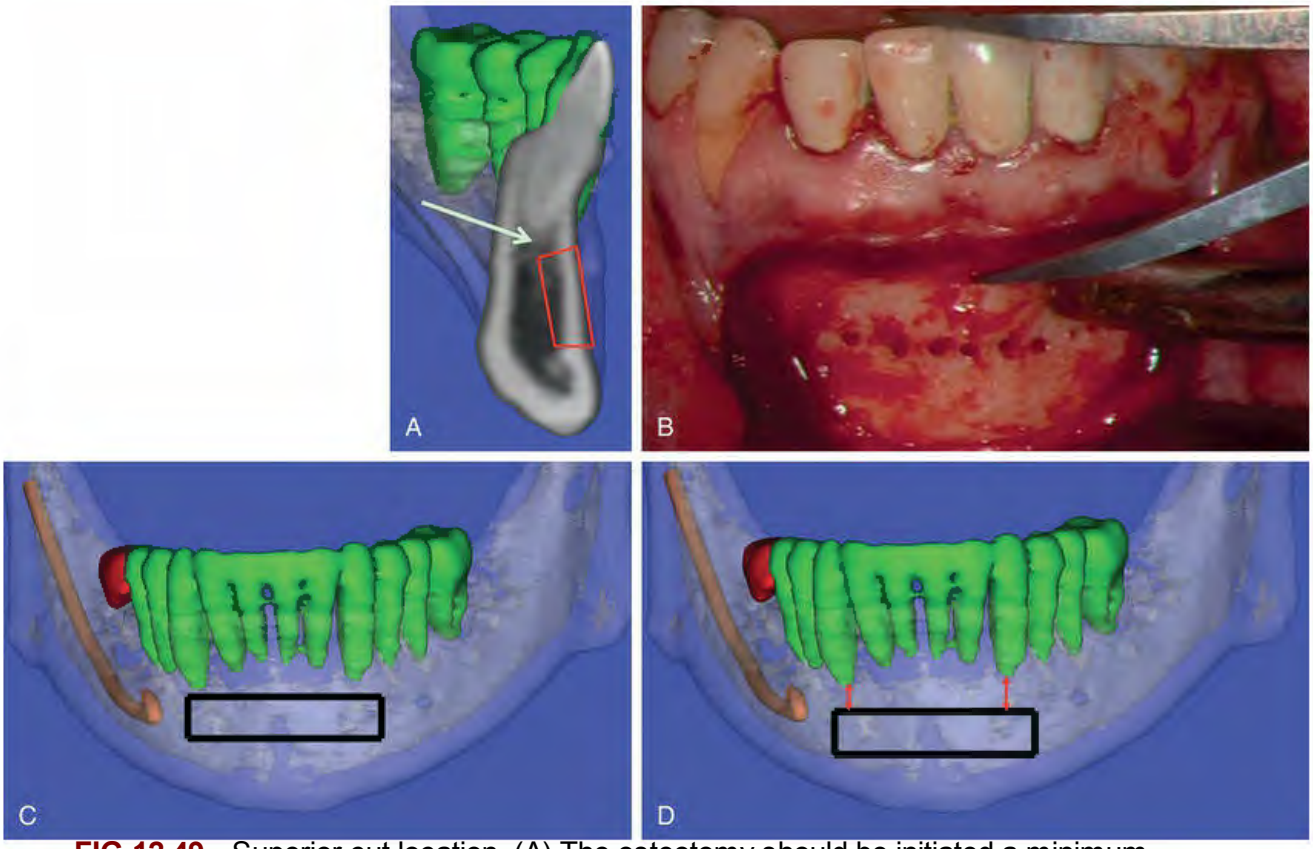

FIG 12.49 Superior cut location. (A) The osteotomy should be initiated a minimum of 5.0 mm inferior to any of the natural teeth apexes *(arrow)*. This will avoid devitalization and trauma to the teeth. (B) Care should be noted with cuspids roots, which may impinge on osteotomy location. (C) Ideal location of superior cut. (D) The superior cut must positioned away from the apex of the cuspids.

Block Grafts: Ramus Bone Grafts

Poor Ramus Candidate

Etiology.

The mandibular ramus is a common site for harvesting block grafts because the area provides a supply of dense cortical bone that can be shaped to fit numerous defects. Compared to the symphysis region, bone harvests from the ramus usually results in fewer postoperative complications. Despite this, there are patients with anatomic restrictions that make them poor candidates for ramus graft harvesting.

Complication.

The main complication related to ramus grafting is the possibility of significant damage to the inferior alveolar nerve (IAN) where its course passes directly adjacent to the external oblique ridge (buccal shelf). Patients who have an IAN location 10 mm or less from the external oblique have a much greater chance of a nerve impairment during a graft harvest from that region. Additionally, this limited dimension limits the amount of bone that is available for harvesting. The clinician may damage the associated nerves with an aggressive harvest in an attempt to get an adequate volume of bone.

Prevention.

CBCT analysis can provide the clinician with a clear picture as to how viable the ramus site is from a nerve injury prevention standpoint as well as the chance of acquiring a sufficient volume of bone for grafting. Measurements should be taken to assess the anterior-posterior (A-P) width of the ramus, the distance from the external oblique and ramus body to the IAN, and the overall width of the posterior ramus. With these CBCT images, the clinician can evaluate whether or not the patient has sufficient bone available for grafting (Fig. 12.50).

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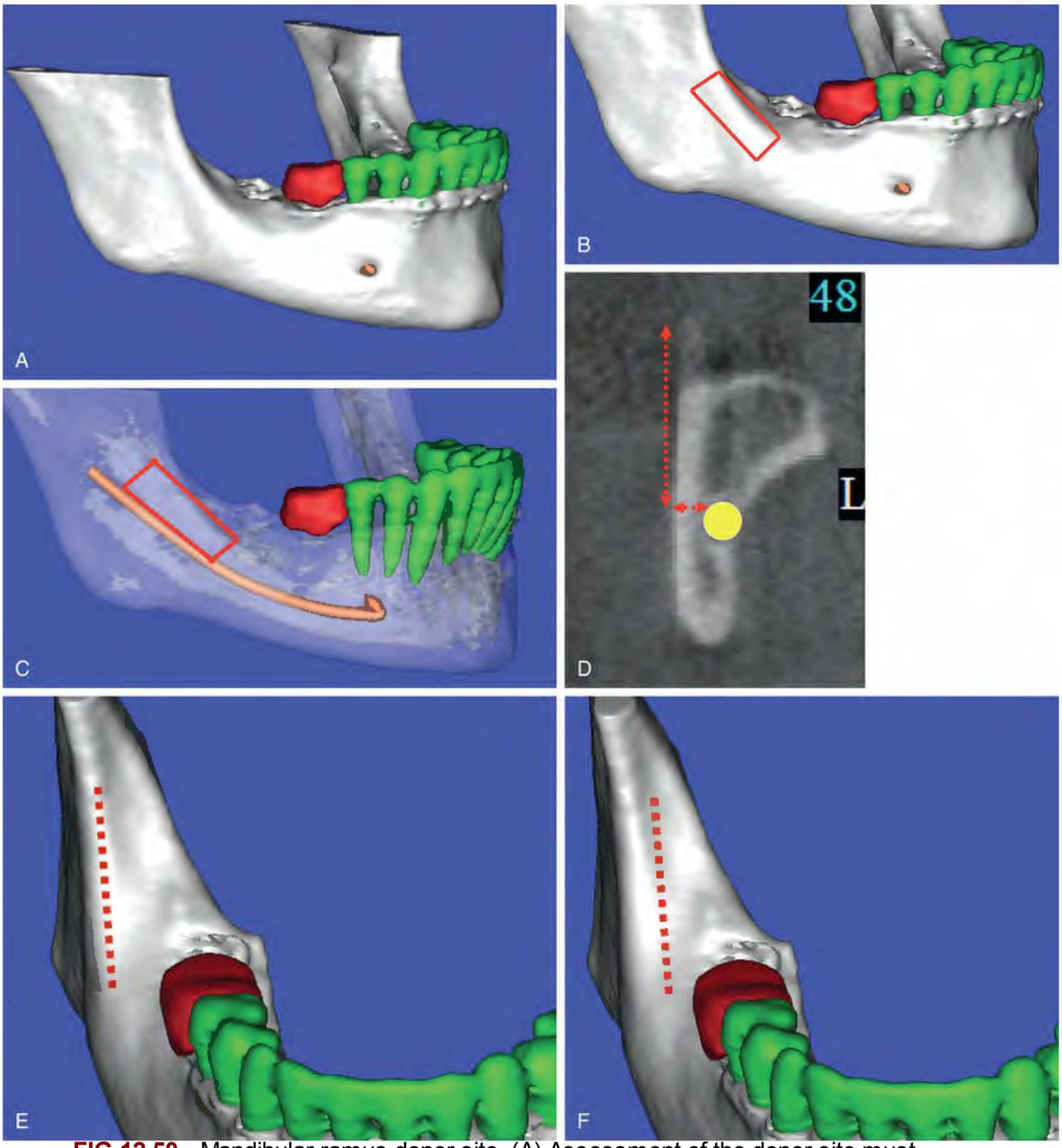

FIG 12.50 Mandibular ramus donor site. (A) Assessment of the donor site must include the amount of available bone, external oblique ridge, and the location of the mandibular canal. (B) Mandibular ramus graft outline form. (C) Radiolucent image depicting ramus graft cuts in association with the inferior alveolar canal. (D) Cross-section anatomy showing nerve location. (E) Complication including inadequate thickness of graft. (F) More ideal position (~4 mm) from lateral border.

Failure to Decorticate the Host Bone

Etiology.

Detachment of a block graft due to an integration failure may be caused by a lack of sufficient preparation of the recipient site during the grafting process. Many recipient graft sites are covered with dense cortical bone, particularly in the mandible, and proper angiogenesis and eventual osteogenesis requires passage of the cellular components through this dense bone.

Complication.

As an implant is placed into an osteotomy that has been prepared in a block graft site, expanding pressure is exerted around the circumference of the surrounding bone. If a block graft is not fully integrated into the underlying bone, it will separate and the block will detach. A similar situation is found in particulate grafting if the developed ridge is not dense and is not fully integrated to the recipient site. In this situation, the particulate graft does not have sufficient density to allow for adequate implant support and the lateral aspect of the newly regenerated ridge will crumble around the coronal aspect of the implant as the implant is inserted into the osteotomy.

Prevention.

All recipient sites must be thoroughly decorticated with a bur to not only open a pathway for cellular passage of the osteogenic cells through the dense cortical bone but also to stimulate the RAP in the region. It is highly suggested that the same drill size for the fixation screws be used for these deep penetrating holes and that adequate bleeding be present to ensure passage of the bone growth factors into the site (Fig. 12.51).

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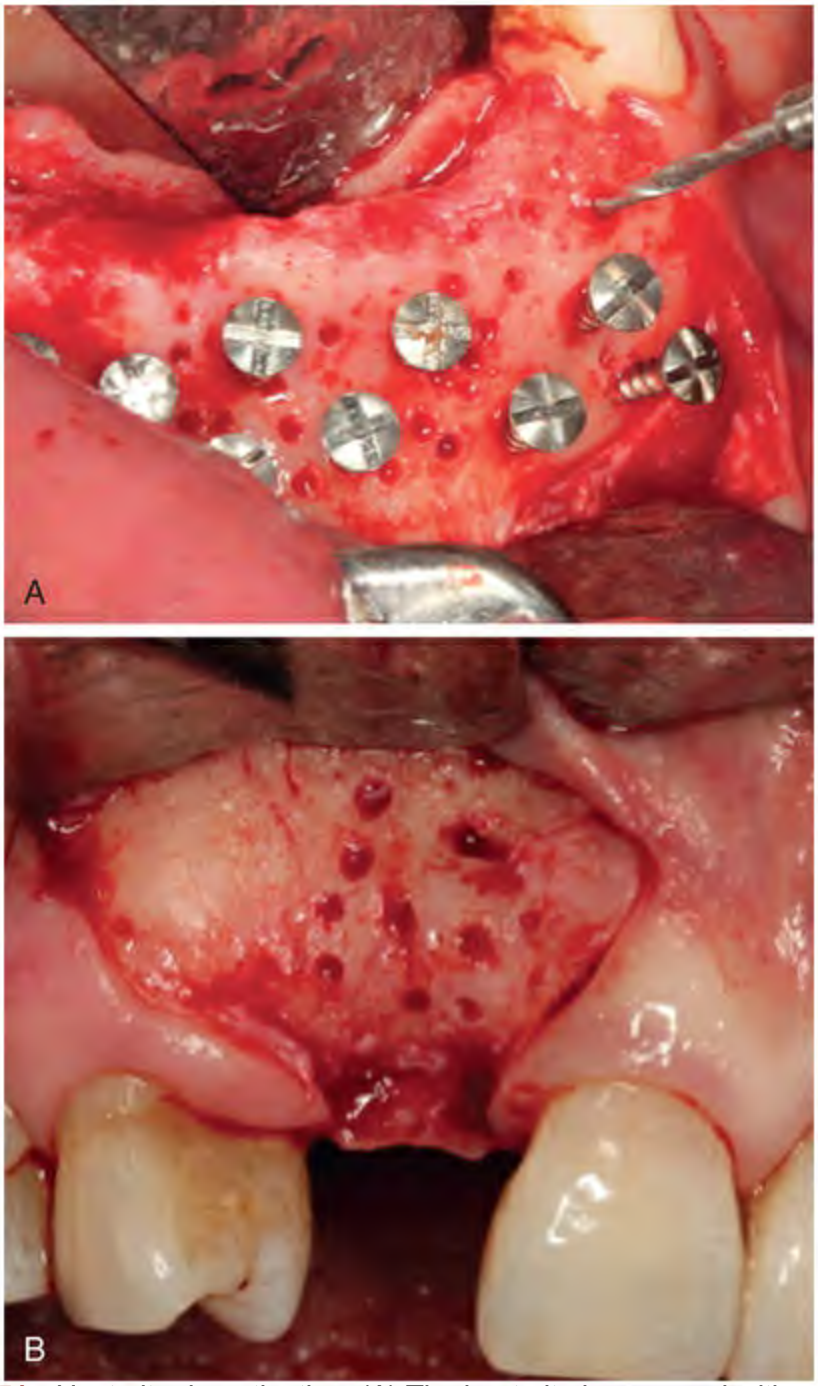

FIG 12.51 Host site decortication. (A) The host site is prepared with a tapered cross-cut fissure bur (e.g., 169 L) to initiate angiogenesis. (B) The decortication must be deep enough to cause bleeding, thus allowing blood vessels into the area.

Mobility of the Block (Fig. 12.52 A and B)

Complication.

Mobility of an autogenous or allograft block during the healing process will almost always result in a graft failure. Mobility of the block prevents proper

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integration of the newly forming bone, and eventually it will lead to soft tissue invasion between the block and the recipient site. Rigid fixation of the block graft to the recipient bone site is critical for success in the regenerative process.

FIG 12.52 Bone graft failure. (A) Incision line opening resulting in failure of graft. (B) Removal of graft after non union and resulting mobility.

Etiology.

Although regeneration with block grafting is related to the concept of "barrier by bulk," micromovement will often contribute to a weak bond between the cortical graft and the recipient site. This will potentially cause

the block to separate from the ridge as pressure is placed on the interface between the native bone and the integrated block as a result of the implant being inserted into the osteotomy. The most common cause for graft mobility is insufficient fixation or pressure from a prosthesis postoperatively.

Prevention.

Initial fixation of a block graft must be attained when the block is originally placed in the recipient site. Any movement of the block during the healing process will disrupt the formation of a stable clot around the migrating cells, and a loose block will not integrate into the host bone. Ideally, two fixation screws should be used in every block graft, eliminating any micromovement of the block during the healing process. The recipient site should be prepared for close approximation of the surface of the block graft to the recipient site. The block should be inlaid into the recipient site, and particles of medullary bone or allograft should be packed around the circumference, filling any discrepancies. The temporary prosthesis should be adjusted to prevent any contact with the graft site and the buccal flange should be removed on any removable appliance to limit micromovement.

Fixation screws should be engaged into the underlying bone enough to provide rigid support of the graft. A longer shaft on the supporting screw may be necessary to obtain ridge fixation in soft bone. The screws should have a self-threading tip, and the preparation hole should be prepared deep enough to prevent the shaft of the screw from bottoming out in dense cortical bone. Excess insertion pressure on a screw passing into very dense bone without adequate depth preparation can contribute to the head of the screw snapping off during its insertion. Most updated fixation screws have a pointed self-threading screw tip that helps with screw insertion.

Treatment.

If micromovement of the block graft occurs during surgery, the block should be removed and the screws should be replaced with longer or wider fixation screws. If the movement occurs during the healing phase, the block should be monitored carefully to see if by chance it continues to integrate. If the movement continues, a decision will have to be made to remove the graft, attempting a second graft at a future time (Figs. 12.53, 12.54, and 12.55).

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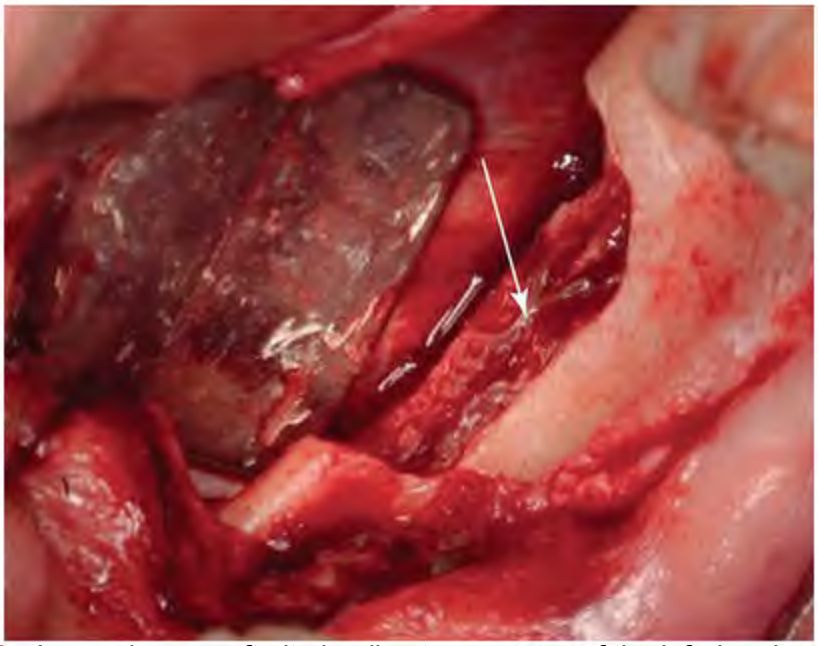

FIG 12.53 Large donor graft site leading to exposure of the inferior alveolar nerve *(arrow)* with associated neurosensory impairment.

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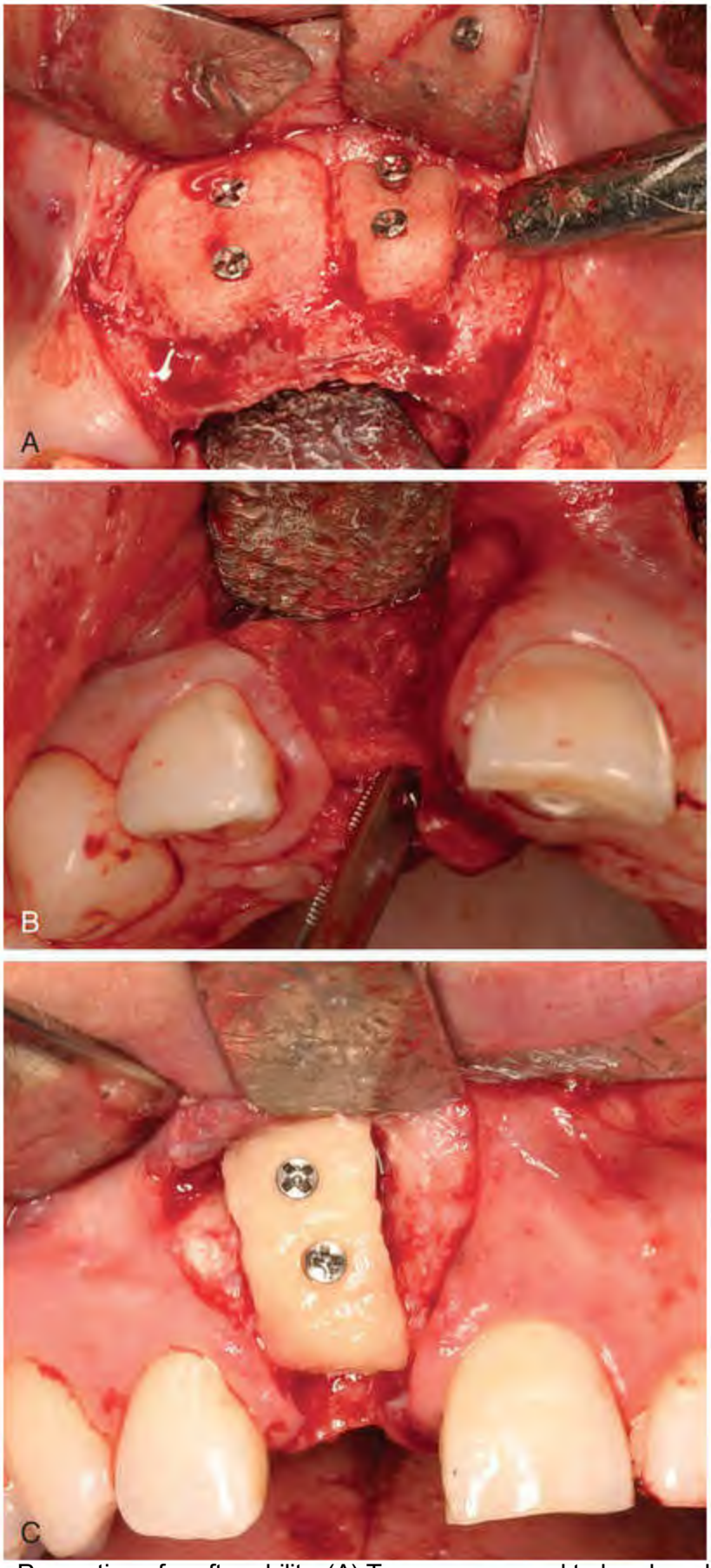

FIG 12.54 Prevention of graft mobility. (A) Two screws need to be placed to prevent

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micromovement during healing. (B) The donor site needs to be prepared to minimize "rocking" of the graft when fixated. (C) Block graft securely fit into host site.

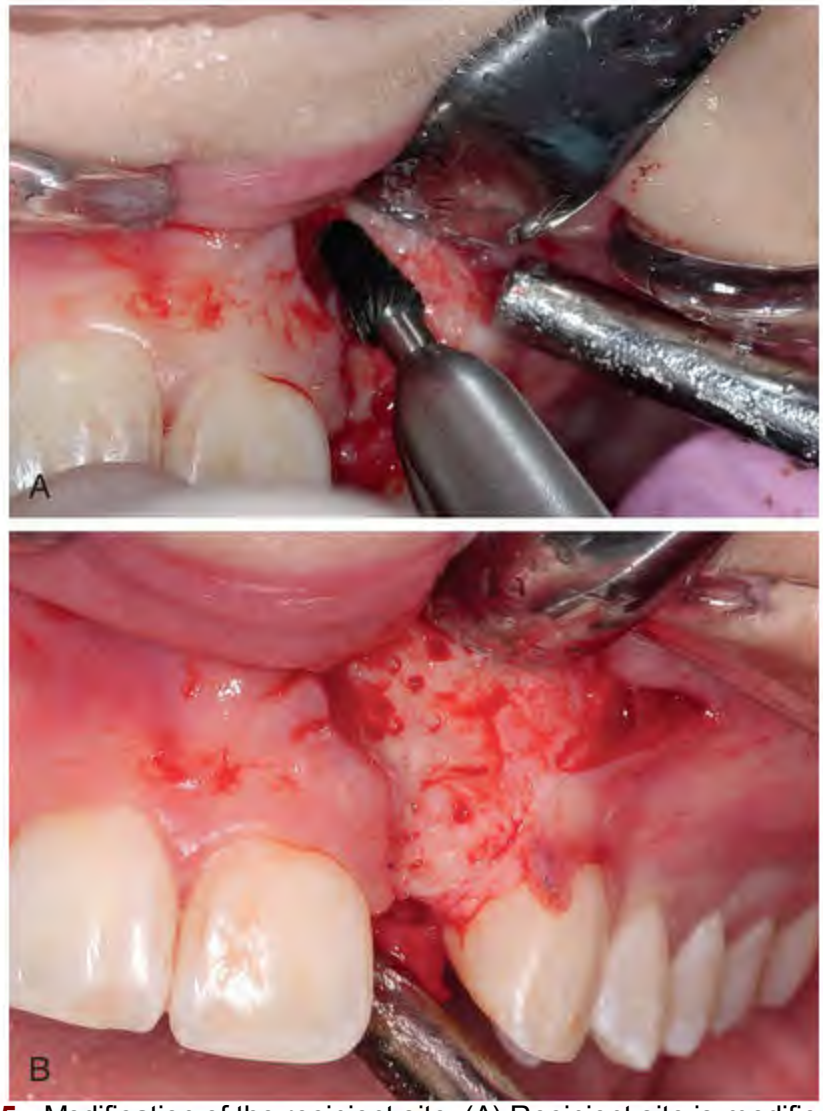

FIG 12.55 Modification of the recipient site. (A) Recipient site is modified to allow passive fit of block graft. (B) Final contoured recipient site prior to fixation of block graft.

Storing Graft in Incorrect Medium (Fig. 12.56)

Etiology.

During graft surgery an ideal scenario would allow the clinician to immediately transfer harvested graft material directly into the recipient site. In many cases, this is not possible, requiring the use of a storage medium to

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safely store graft material (autograft or allograft) prior to usage. Due to its separation from a blood supply, the cells inside of the graft are vulnerable to death and must be stabilized during storage for the graft to survive.

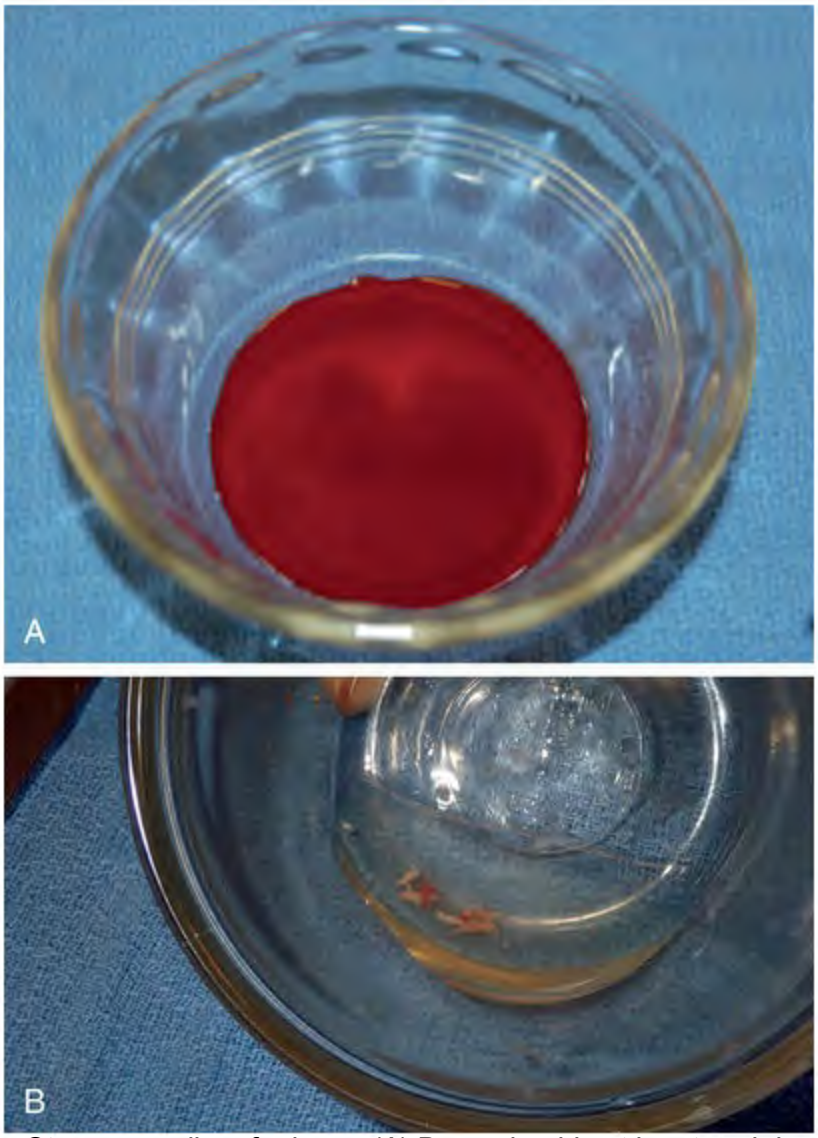

FIG 12.56 Storage medium for bone. (A) Bone should not be stored dry or in blood as this will lead to cell death. (B) Ideally, bone should be stored in sterile saline.

Complication.

Storing graft material in a medium that is not isotonic will cause the viable cells inside of the graft to die. This loss of living cells eliminates many of the advantages of using autogenous bone in this particular surgical procedure.

Prevention.

Saline provides a perfect isotonic environment for the short-term storage of bone grafting material. A glass dish of sterile saline (i.e., 0.9% sodium chloride) should be used for this process. Avoid the use of distilled water because its hypotonic nature will cause cell lysis within the graft. Another medium to avoid is the patient's own blood because hemolytic breakdown products inside the blood will lower the pH of the solution, causing cellular death.

Soft Tissue Irritation From an Overextended Fixation Screw

Etiology.

Bone fixation screws are routinely placed in the bony ridge for various reasons during implant-related surgery. It is not uncommon to find the end of a screw extending beyond the lingual or palatal cortical plate. When this occurs, there is a potential for the overextended screw to cause discomfort.

Complication.

Overextended screws can be a source of irritation to the thin soft tissue on the lingual aspect of the mandible. The movement of the thin mucosa and tongue against the sharp point of the screw can cause quite a bit of discomfort. This is not usually an issue in the maxilla, where the thicker nature of the palatal tissue acts as a protective buffer.

Prevention.

Screw placement should be followed by both a visual inspection of the opposing surface of cortical bone and a digital review of any potential problems areas that will need correction.

Treatment.

The only way to treat an overextended screw involves reflection of a flap to provide access for removal of the overextension or removal of the complete screw. Screw removal is not usually a reasonable solution because that would require reflection of the tissue overlying the maturing graft site and disruption of the graft as the screw is removed (Fig. 12.57).

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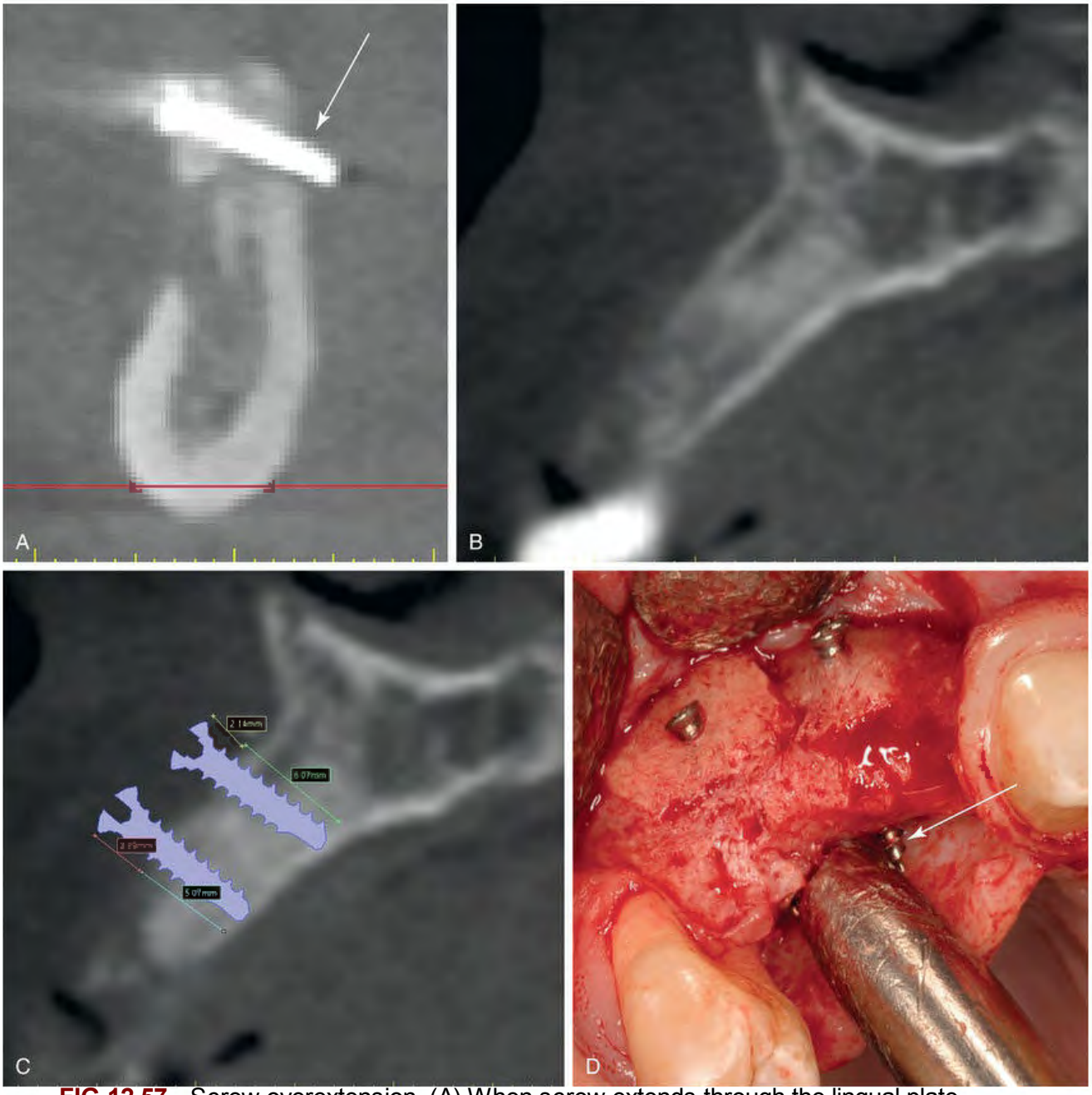

FIG 12.57 Screw overextension. (A) When screw extends through the lingual plate *(arrow)*, this will often result in pain and discomfort for the patient. (B) Preoperative evaluation for fixation screw. (C) Ideally, the fixation screw should exhibit bicortical stabilization and the length measurements may be determined via CBCT measurements. (D) The protruding tip of this fixation screw has be visualized.

Block Separation From Bony Ridge During Implant Placement

Etiology.

Bone grafting always involves the development of newly regenerated bone

into an existing recipient site. In the case of a block graft, the cortical block assists with the augmentation process through the concept of "barrier by bulk." In this process, the block serves a role in maintaining space during early angiogenesis and osteogenic development into and throughout the cortical block. As this process occurs, the presence of gaps between the recipient site and the dense block requires prolific development of bone to fill the gap and to grow into the donor bone. Failure to fully integrate these two entities creates a situation where the donor block can fracture off the ridge as pressure builds during insertion of the implant, spreading the two sections of bone apart.

Complication.

If the block separates from the ridge during implant placement, the graft must be replaced. Attempts to place implants in a failed graft site are doomed to fail because there simply will not be sufficient ridge width for proper placement of the implants.

Prevention.

The recipient site should be completely cleared of any fibrous tissue remnants with a coarse bur, and the recipient bone should be aggressively decorticated to open pathways for osteogenic cellular ingrowth. The dense recipient site should be recontoured to provide a close adaptation between the inner surface of the block and the recipient bed where it will be fixed in place. This disruption of the recipient bone will stimulate the RAP, promoting good bony integration into the host site (Figs. 12.58 to 12.60).

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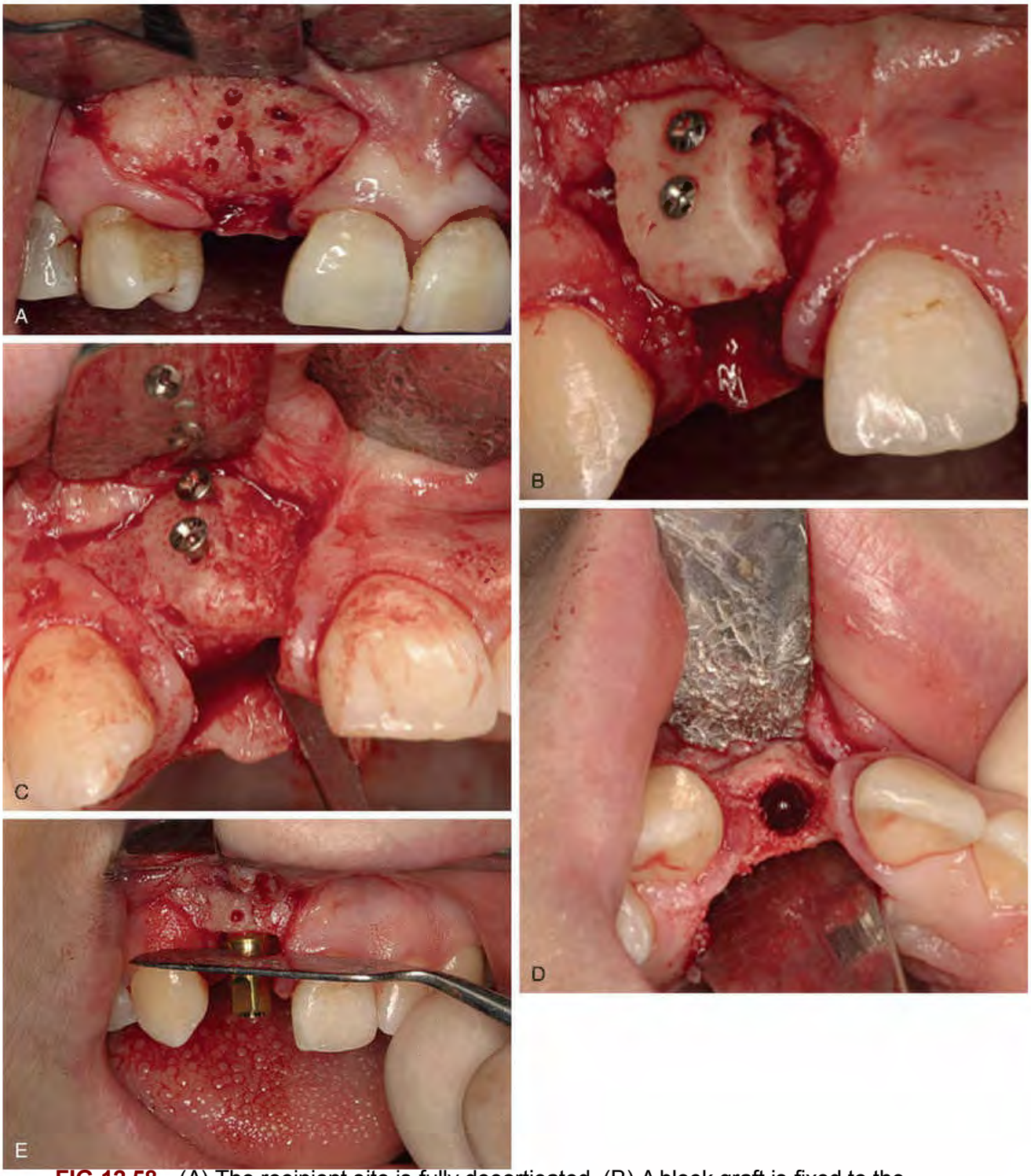

FIG 12.58 (A) The recipient site is fully decorticated. (B) A block graft is fixed to the recipient site. Note the adaptation of the graft to the bone. This is necessary to ensure an ideal integration of the new bone with the autogenous block. (C) The block has completely integrated with the existing ridge providing a strong foundation that can resist the strain of separation of the two pieces during implant placement. (D) Osteotomy preparation including the cortical graft site. To minimize separation, the block should be stabilized during preparation. (E) Implant insertion.

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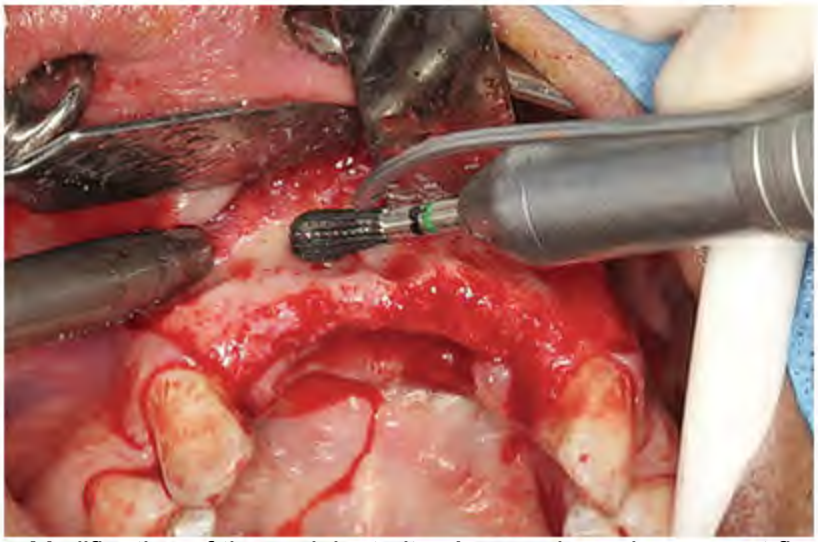

FIG 12.59 Modification of the recipient site. A pear-shaped cross-cut fissure bur is used to remove fibrous tissue from the recipient site. This procedure will remove any soft tissue and also roughen the outer bone surface allowing for a better integration between the block and host bone.

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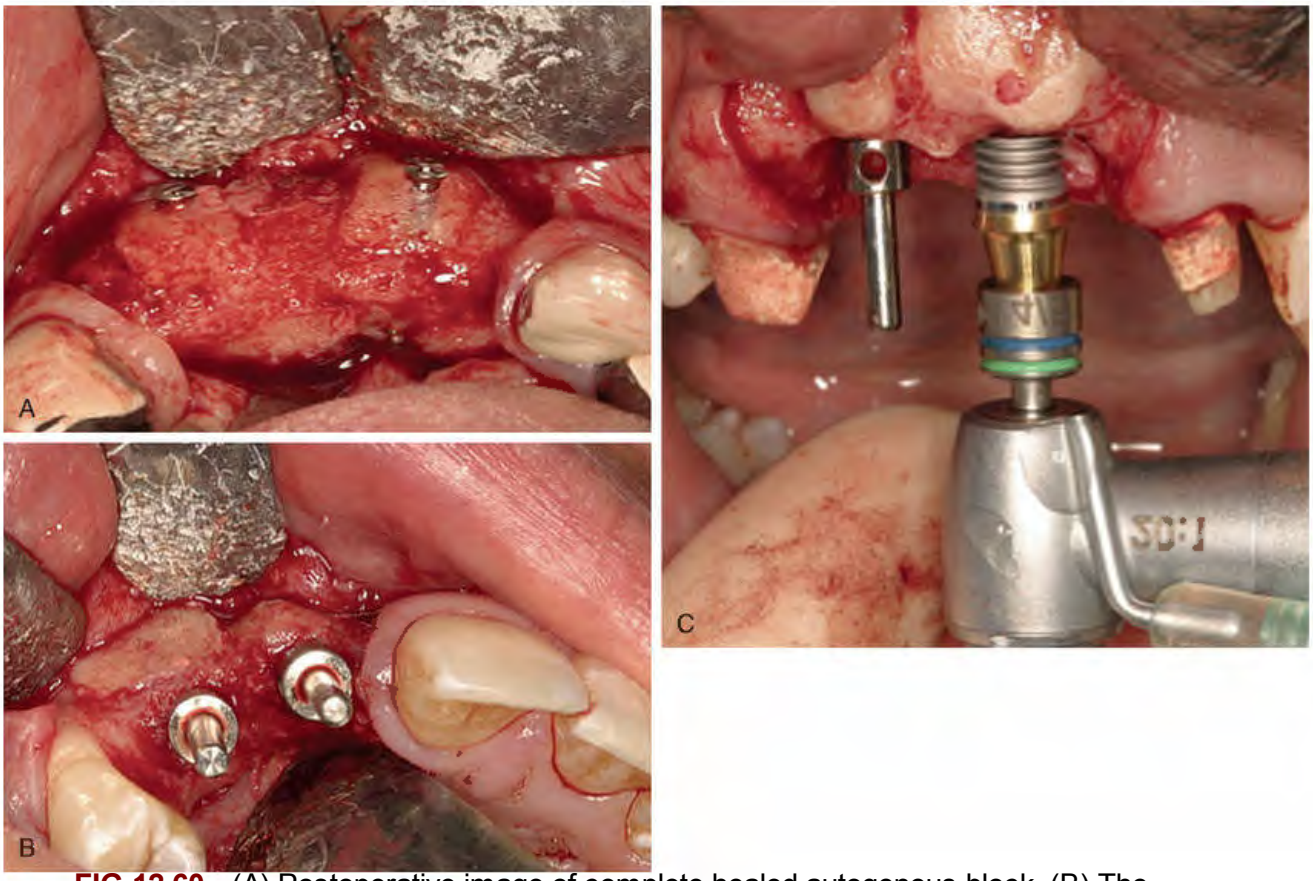

FIG 12.60 (A) Postoperative image of complete healed autogenous block. (B) The indicator pins have been inserted in the osteotomies. Because the implant is slightly larger in diameter than the osteotomy, pressure is exerted around the circumference of the osteotomy as the implant is inserted. (C) Care is exercised to not undersize the osteotomy as this may fracture the graft upon insertion.

Nasopalatine Canal/Incisive Foramen Involvement in Regeneration Sites

Etiology.

Implant restorations in the anterior maxillary region present one of the most difficult challenges in dentistry today. The combination of aesthetic demands, biomechanical/functional issues, and phonetic challenges require implant placement in ideal positions. The incisive foramen is the exit site of the nasopalatine canal where the terminal branch of the descending palatine artery and nasopalatine nerve pass into the oral cavity. The proximity of the incisive foramen and the path of the canal must be evaluated in all maxillary incisor implant treatment plans because there can be significant variations in the size, position, and angulation of the nasopalatine canal and the exiting foramen. As the bone around the maxillary central incisors resorbs, the zone

of available bony support moves palatally, frequently encroaching on the incisive foramen.

Prevention.

Defining the dimensions and pathway of the nasopalatine canal with CBCT imaging allows the surgeon to decide if implants can be placed within the required restorative space or if augmentation will be needed for ideal placement. This is particularly important in cases involving immediate implants because the lingual angulation of the immediate implant osteotomy could potentially fenestrate into the incisive canal. A fenestration in the side of an osteotomy allows neural/fibrous tissue invasion into the osteotomy, retarding bone growth and rigid fixation of the implant. Axial CBCT images provide the most accurate view of the size, shape, and location of the canal in respect to the possible implant sites. Use of CBCT cross sections and 3-D images can also help determine the positions and dimensions of this important anatomic variant. The clinician must be aware of a possible widening of the canal above the level of the foramen, creating a fenestration between the canal and the osteotomy in the more apical regions of the osteotomy. As the cross sections of the CBCT are reviewed, the possible presence of a nasopalatine cyst should be ruled out, and edentulous arches should be reviewed for an enlarged foraminal dimension, as is often noted. The positions of implants in central incisor regions where the foramen is involved should be adjusted distally where an FP-1 restoration does not require a specific placement. This slight adjustment distally prevents fenestration on the mesiopalatal line angle, where this deficiency most likely will occur (Fig. 12.61).

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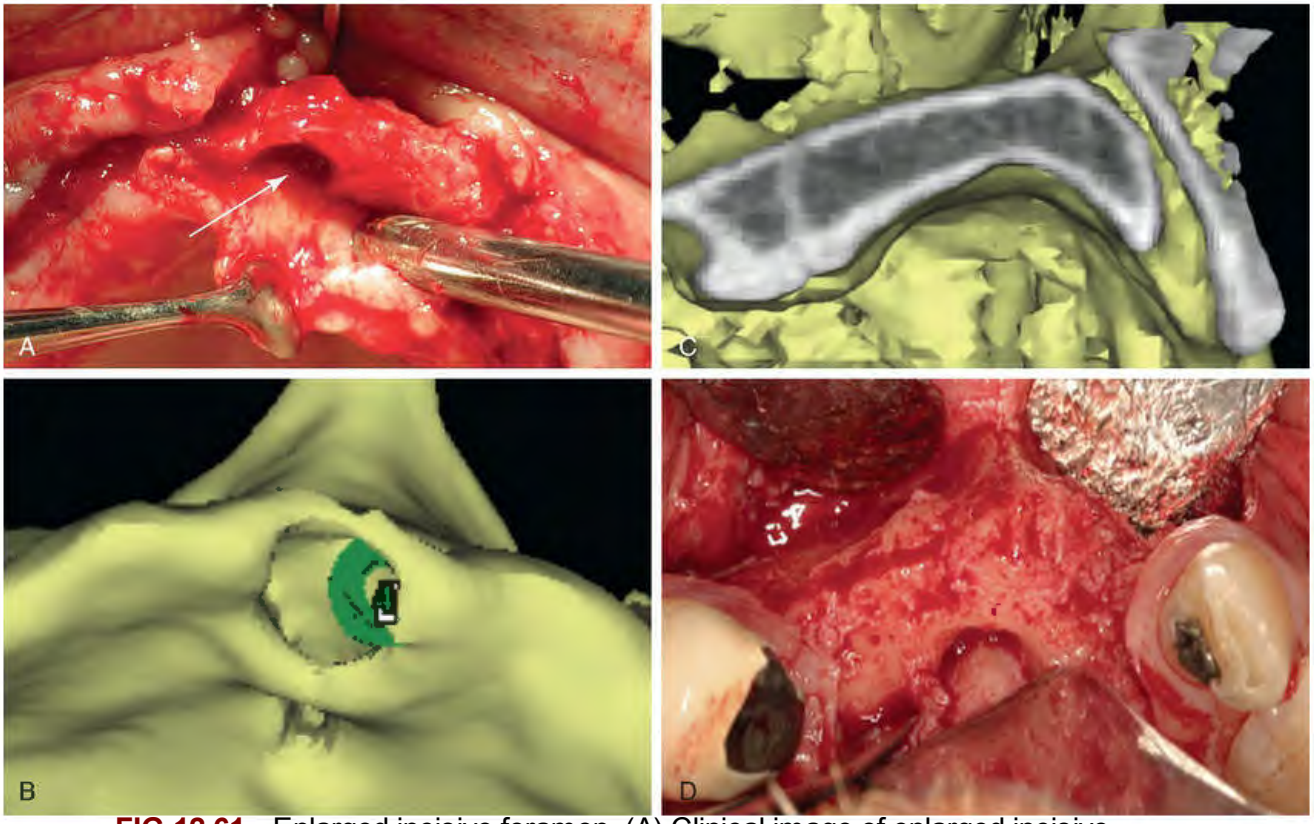

FIG 12.61 Enlarged incisive foramen. (A) Clinical image of enlarged incisive foramen. (B) CBCT 3-D image depicting implant placement impinging on the canal. (C) Cross section of incisal foramen. (D) Enlarged incisive foramen limiting space for implant placement.

Complication.

Severe bone resorption on the facial aspect of the maxilla reduces the ridge thickness to surprising extents, often leaving only a thin ridge that is positioned well to the palatal aspect of the required location for a central incisor implant. It should be kept in mind that a line between the cingula of the two cuspids passes directly over the incisal foramen. Subsequently, if an implant is placed this far palatally, the emergence profile will originate at a significantly proclined angle and the complete restoration will be palatally positioned. Cases like this require that the seriously deficient ridge be regenerated prior to implant placement.

An osteotomy that fenestrates into the nasopalatine canal opens the site to neural and fibrous tissue invasion at the interface of the implant and the exposure. This will lead to a failure to integrate and loss of the implant. A significant invasion into the canal could lead to excessive bleeding during surgery that is usually self-limiting with pressure and time.

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Treatment.

Regions that are determined to be deficient will require facial augmentation using techniques that are capable of generating enough lateral/vertical bone volume for proper implant placement and restorative success. Cases where the implant can be moved slightly in a distal direction can sometimes prevent the need for major augmentation. Another option is the obliteration and grafting of the nasopalatine canal, which can aid in providing significant bone volume for implant placement (Fig. 12.62).

FIG 12.62 Implant placement and grafting into the incisal foramen.

Postoperative Complications

Excessive Pressure on Ridge Augmentation Sites Caused by Temporary Prostheses

Etiology.

The successful maturation of a bone graft site requires that the area be completely protected from micromovement and disruption of the covering membrane or block material. Micromovement of 25 μm can decrease the final graft volume as much as 40%. The most common source of daily pressure on a site comes when the patient's transitional appliance has contact with the surface of the graft site.

Complication.

Micromovement on a localized region of a graft site will consistently yield compromised results in the mature graft development, if not full graft failure. It is imperative to take measures to prevent any movement of the graft during healing.

Prevention.

A transitional appliance (flipper or removable partial denture) must be modified to eliminate any significant contact with the graft site. It is recommended that these removable devices be avoided if possible. If a removable appliance is absolutely necessary, all buccal flanges should be removed and, if possible, the acrylic should be altered to create regions of support on the lingual surfaces of the adjacent teeth. Occlusal rests should be utilized, or in cases where this is not possible, there must be good adaptation of the prosthesis to direct the forces to alternative stress-bearing areas (tissue areas away from graft site that take the pressure off the graft site).

Essix appliances allow at least temporary replacement of teeth in narrow span regions, allowing long-term appliances to be fabricated after the initial healing process has been completed. However, the Essix appliance does have the disadvantage of esthetics, fracture and wear issues, or discoloration. The Snap-On Smile appliance (Den-Mat Holdings, LLC) has been used successfully over longer-span edentulous regions with aesthetics that seem to be acceptable to most patients (Figs. 12.63 to 12.66).

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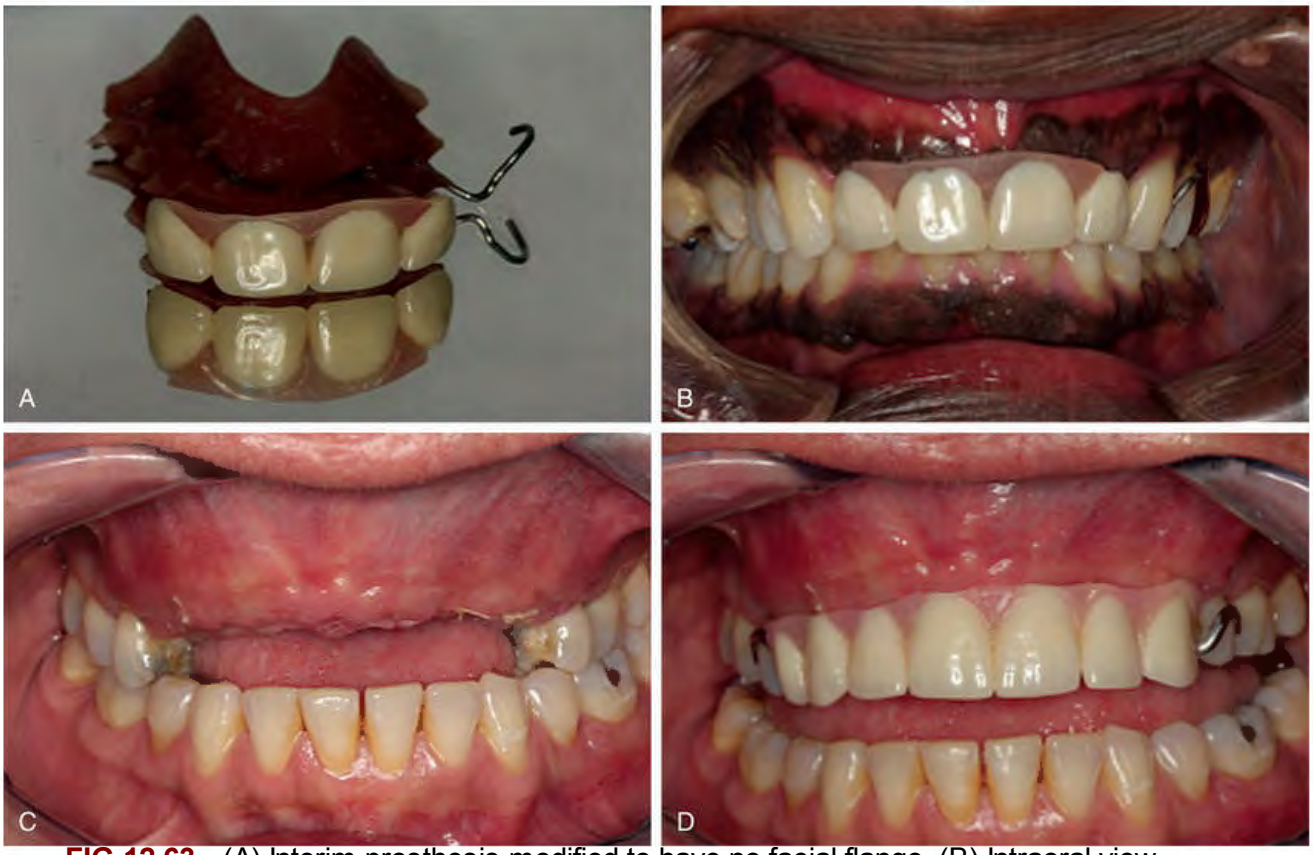

FIG 12.63 (A) Interim prosthesis modified to have no facial flange. (B) Intraoral view showing no facial impingement. (C) Interim prothesis modified. (D) Postoperative graft site showing no line of demarcation on tissue.

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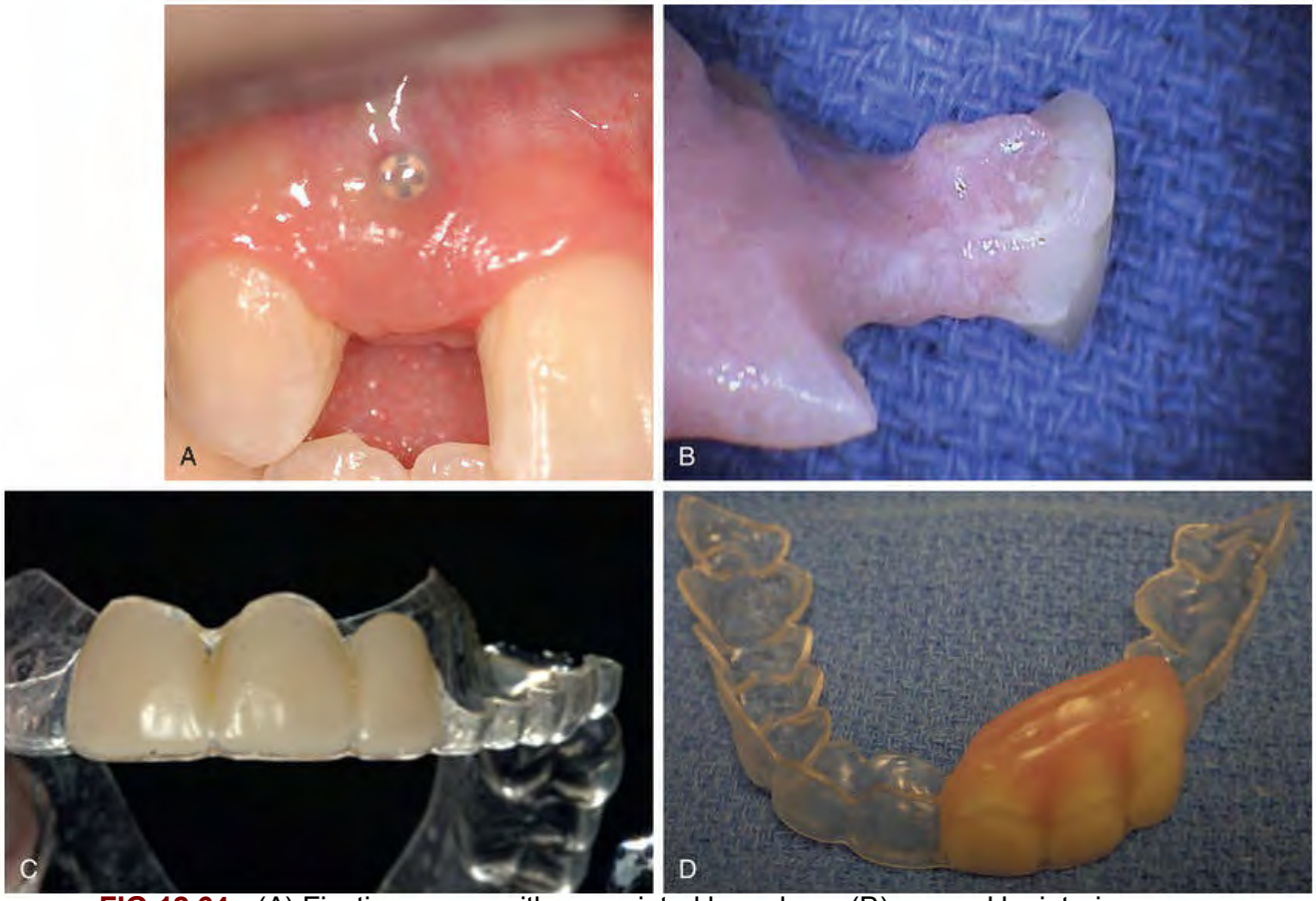

FIG 12.64 (A) Fixation screw with associated bone loss, (B) caused by interim prostheses with protrusion placing pressure on graft. (C) Essix appliances allow at least temporary replacement of teeth in narrow span regions, allowing long-term appliances to be fabricated after the initial healing process has been completed. However, the Essix appliances do have disadvantages in respect to limited esthetics, fractures, and discoloration. If adjusted properly, it will not allow any pressure on the graft site. (D) Essix appliance with added acrylic that encompasses soft tissue defect.

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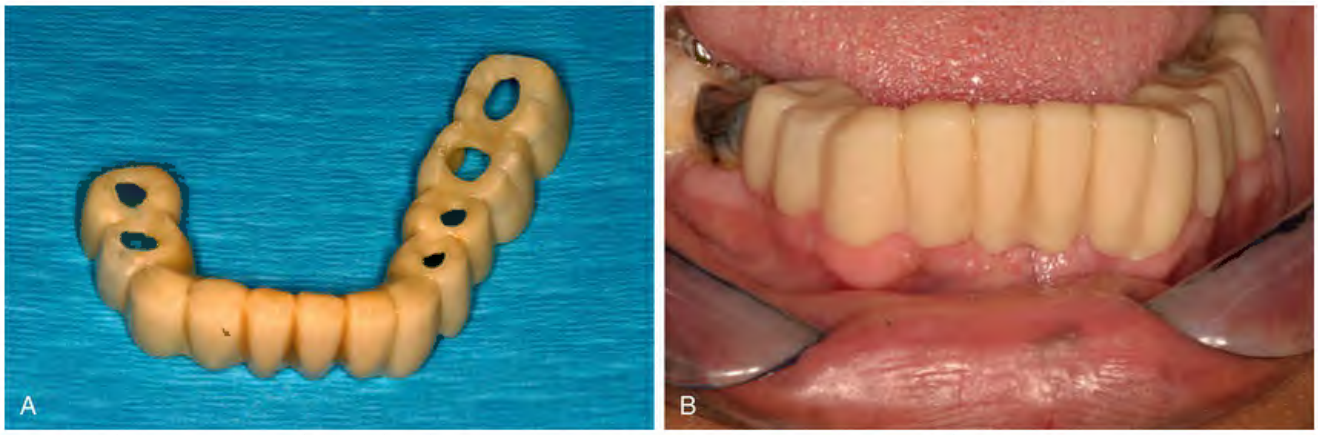

FIG 12.65 The Snap-On Smile appliance has been used successfully over longer span edentulous regions with aesthetics that seem to be acceptable to most patients. (A–B) Snap-On Smile used to replace teeth #22 to 27. The acrylic surrounding the adjacent teeth prevents any contact between the anterior pontics and the underlying graft site.

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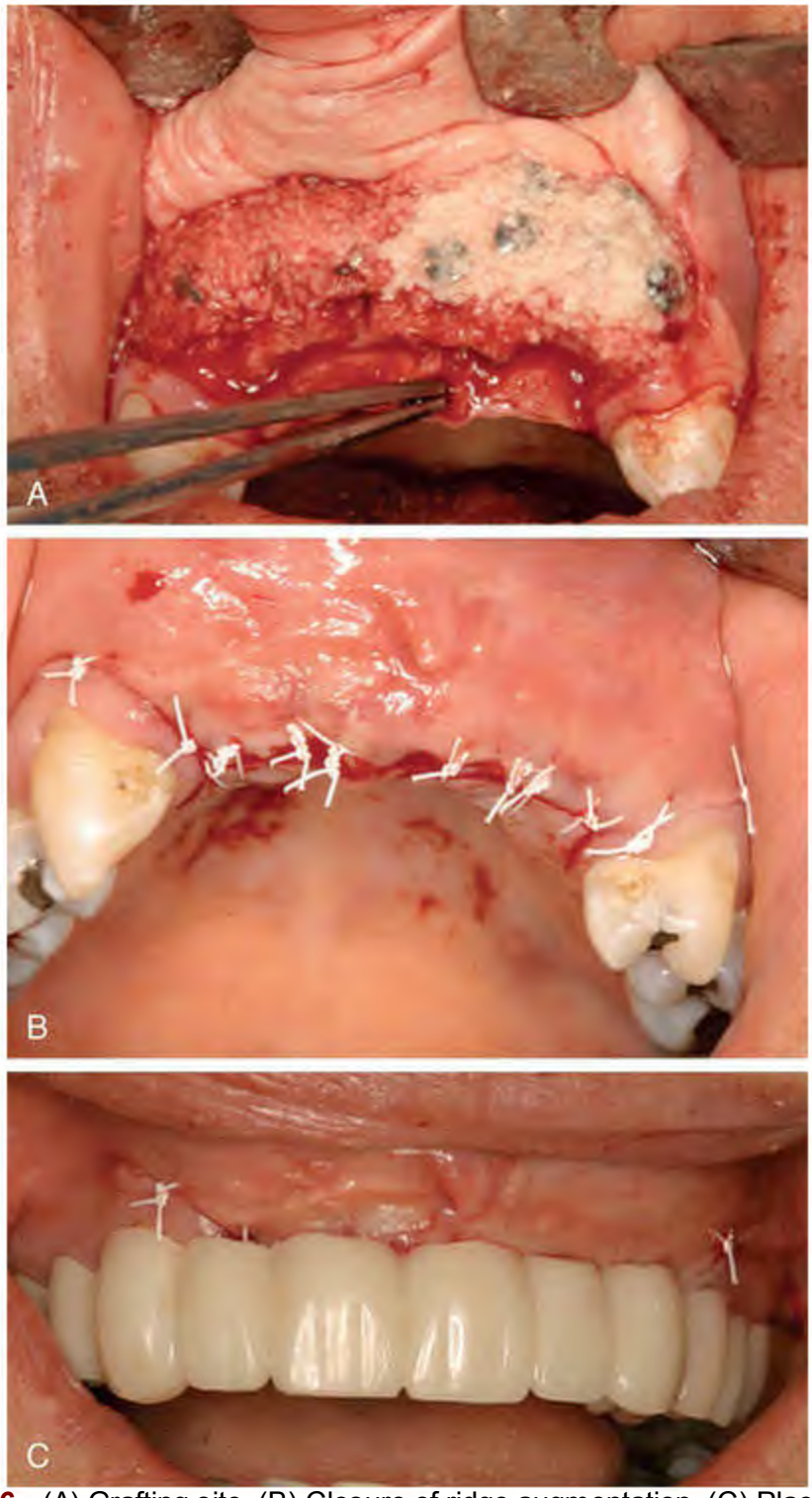

FIG 12.66 (A) Grafting site. (B) Closure of ridge augmentation. (C) Placement of Snap-On Smile over the closed graft site to protect augmentation site during the healing process.

Lack of Attached Tissue Covering the Ridge Augmentation

Etiology.

Ridge augmentation techniques require that the soft tissue covering the graft site be released in the buccal vestibule to free the flap for a tension-free closure over the expanded graft site. In most cases, this will move the keratinized portion of the tissue flap to the top of the ridge with altered mucosal positioning. The elevated mucogingival junctional line will often leave an extension of loose tissue along the facial aspect of the edentulous ridge that will not be restoratively acceptable. This tissue discrepancy will need to be addressed before the restorative phase of treatment, reestablishing the proper arrangement of keratinized tissue along the restorative margin with the mucosa in its normal apical position. A minor correction like this not only eliminates an aesthetic problem, but it also prevents a mucosal tissue band on the facial aspect of the implant restoration.

Complication.

As the mucogingival junction in a healing augmentations site is evaluated, it is often noted that the remaining keratinized tissue over the grafted site is now palatally/lingually positioned. The complete buccal aspect of the ridge in these cases is covered with loose and mobile mucosa, contributing to restorative and esthetic issues.

Prevention.

The clinician must be aware of the restorative implications of the soft tissue related changes that can occur during augmentation procedures. Unattached mucosa that is stretched over restorative areas provides an esthetically unacceptable and restoratively difficult situation. This can be addressed with either preoperative tissue grafting or it can be corrected after the graft site has completed its healing process. The preoperative approach utilizes a large autogenous palatal tissue graft over the edentulous region prior to completion of the ridge augmentation procedure. The newly developed wide keratinized tissue band usually covers the augmentation site without requiring extensive movement of the mucogingival junctional level as the widened graft site is covered. If grafting is not completed preoperatively, tissue management can be incorporated into the surgical sequencing, ultimately developing proper tissue aesthetics and attachments. Discussions with the patient should be conducted prior to implant placement to make

sure they are well informed about the expected need of additional procedures that could be necessary in correction of soft tissue complications.

Treatment.

Management of high attachment levels of mucosa over previous augmentation sites requires either pre-operative tissue grafting or postgrafting tissue management. If there is an expected deficiency, one of these options will need to be chosen:

- **Option 1.** Postgrafting approaches are organized around development of a new zone of thick keratinized tissue that will not only provide a strong attachment apparatus that will surround the implant abutment but will also allow a favorable emergence profile and better interproximal tissue papilla heights. The preferred method in our experience involves use of either autogenous connective tissue or the thicker type of AlloDerm (acellular dermal matrix) that is placed during the implant surgery. At the time of implant placement, a layer of connective tissue or AlloDerm is placed over the area of concern to prepare a thicker soft tissue foundation. After the healing process has been completed, a simple split-thickness dissection of the mucosa is used to expose the underlying layer of dense tissue formed by the previously grafted connective tissue. The repositioned mucosa is then sutured apical to the exposed region with 5-0 chromic sutures. The resulting matured layer of tissue will typically have a normal keratinized consistency and appearance. In cases where the tissue covering the augmentation site is very thin, efforts should be made to develop 3 mm of tissue thickness around the neck of the implant. This may involve use of more than one layer of connective tissue or AlloDerm on top of the ridge. This is especially relevant in the upper and lower posterior regions where large amounts of tissue have been drawn over a wide augmentation site. Tomas Linkevivius has shown that very thin tissue around implant attachment zones is much more prone to circumferential bone loss than implants in patients with a thick biotype and 3 mm or more of tissue thickness around the neck of the implant.[51]
- **Option 2.** Dr. Esteban Urban describes another approach that is completed after the implants have been placed in a postregeneration site. In his technique, no grafting is completed at the time of implant placement or before the grafting procedure. Instead, he describes use of a split-thickness flap over the zone of mucosal attachment, leaving the periosteum intact. A

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large piece of “mucograft” is sutured into place, covering all but a thin zone at the level of the mucosal suture line. A narrow piece of autogenous palatal tissue is sutured over this apical zone to create a protective band of keratinized tissue that limits relapse movement of the mucosa over the region that was covered with mucograft. This region should granulate in with keratinized tissue. The thickness of tissue in this approach will not be as deep as the option 1 approach, where more than one layer of connective can be placed over the implant site itself.[52]

- **Option 3.** Free tissue grafting can be completed prior to augmentation of a region, using autogenous palatal tissue. In this approach, the recipient site is prepared with a split-thickness dissection, leaving the periosteum intact. The palatal graft is harvested from the palatal tissue adjacent to the molars, avoiding the rugae in the anterior region. One advantage of harvesting tissue in this manner is the surgeon's ability to gauge how thick the final tissue needs to be and harvesting an appropriate graft from the donor site. This creates a wide zone of thick keratinized tissue over the entire region. Unfortunately, the postgrafted tissue has a white color tone related to the density and fibrous nature of the palatal graft donor site. This discrepancy prevents use of this approach in anterior augmentation sites where the tissue color and surface contour is important (Figs. 12.67 to 12.70).

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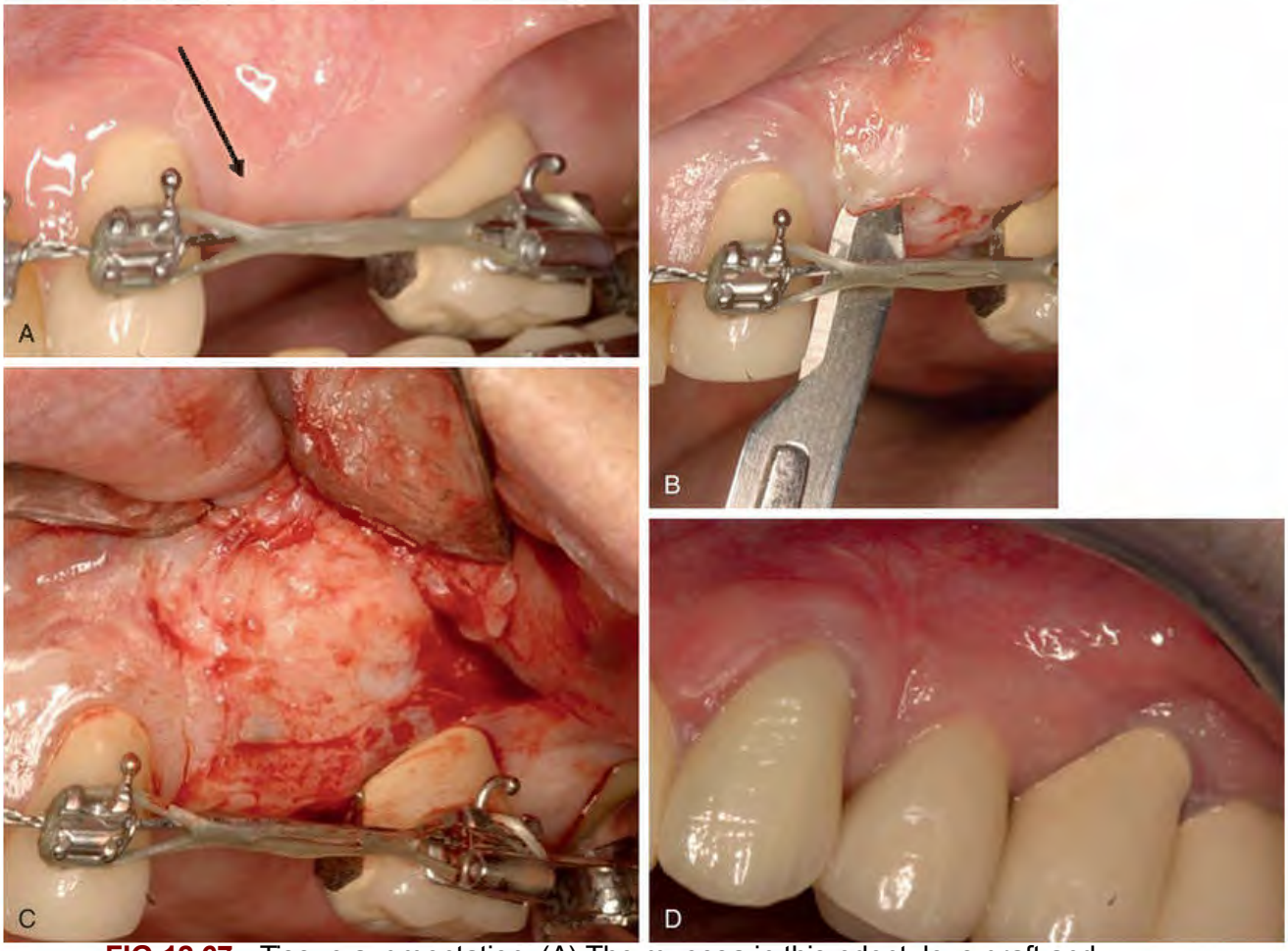

FIG 12.67 Tissue augmentation. (A) The mucosa in this edentulous graft and implant site extends to the top of the alveolar ridge *(arrow)*. A layer of AlloDerm dermal matrix is placed over the implant site at the completion of the stage I procedure. The mucosa must be repositioned apically prior to the restorative stage of this implant sequence. (B) A #15 scalpel blade is used to prepare a split-thickness incision on the buccal aspect between the two natural teeth. This is prepared in a fashion that separates the mucosa overlying the thick layer of AlloDerm. (C) The thick nature of the underlying AlloDerm as the elastic fibers are being removed over its surface is shown. (D) The final restoration in place, and the band of thick, keratinized tissue along the buccal aspect of the #12 implant.

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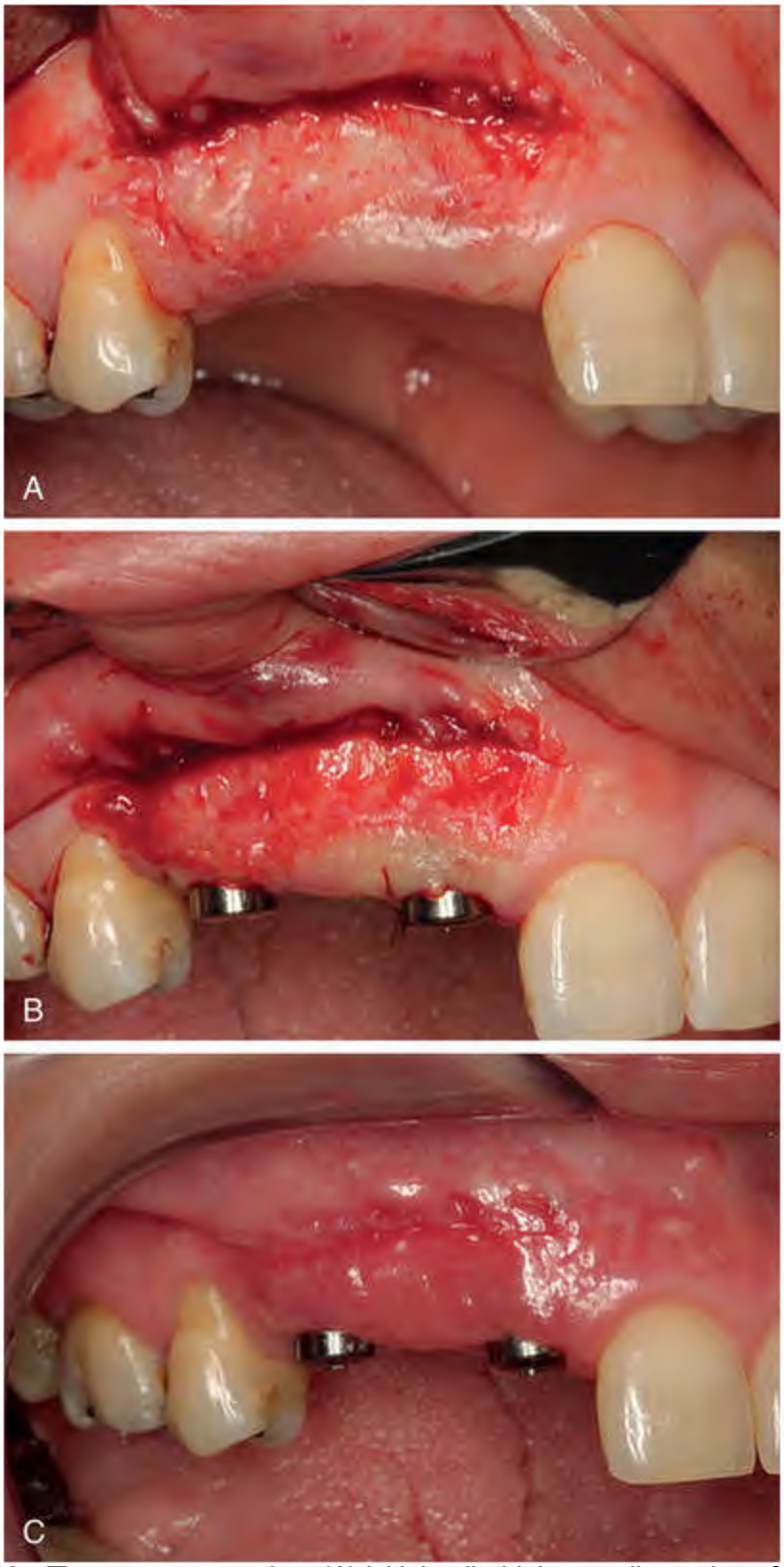

FIG 12.68 Tissue augmentation. (A) Initial split-thickness dissection of mucosa covering AlloDerm layer with 5-0 chromic sutures anchoring the mucosa below the level of the exposed AlloDerm layer. (B) Stage II uncover of two implants in this same region. (C) Two week postoperative view of the healing zone of AlloDerm.

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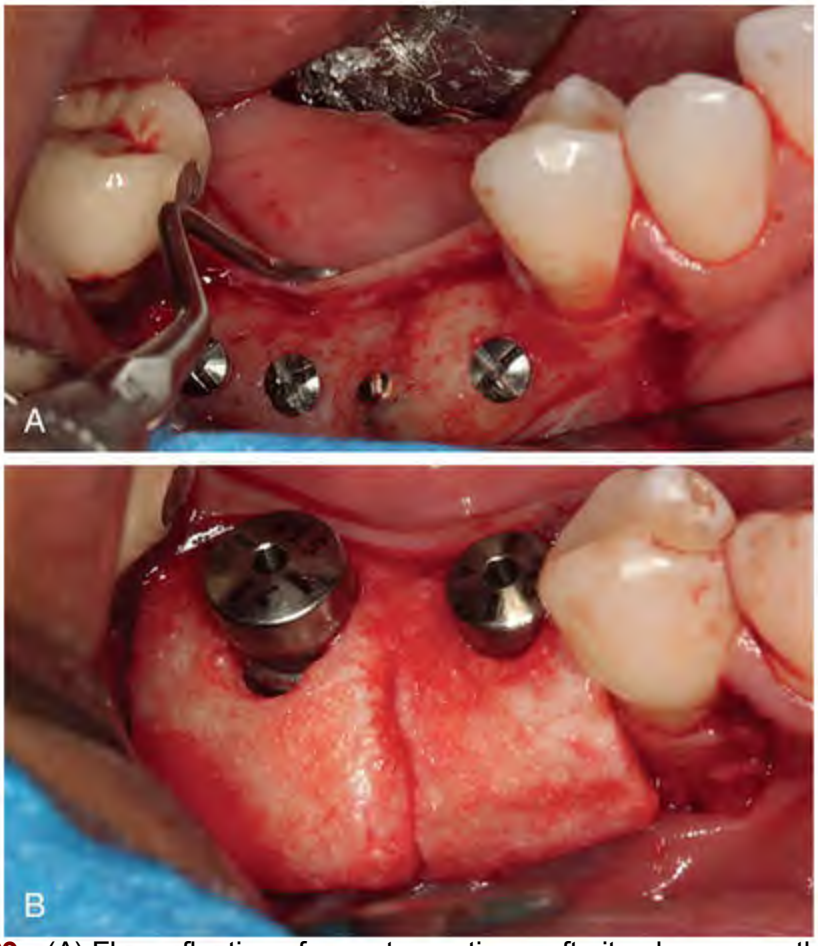

FIG 12.69 (A) Flap reflection of a postoperative graft site shows very thin tissue over the ridge with very little remaining keratinized tissue. (B) A blanket of AlloDerm is placed over the implants like a poncho. The flap is then closed over the AlloDerm, allowing apical positioning of the tissue at a later date.

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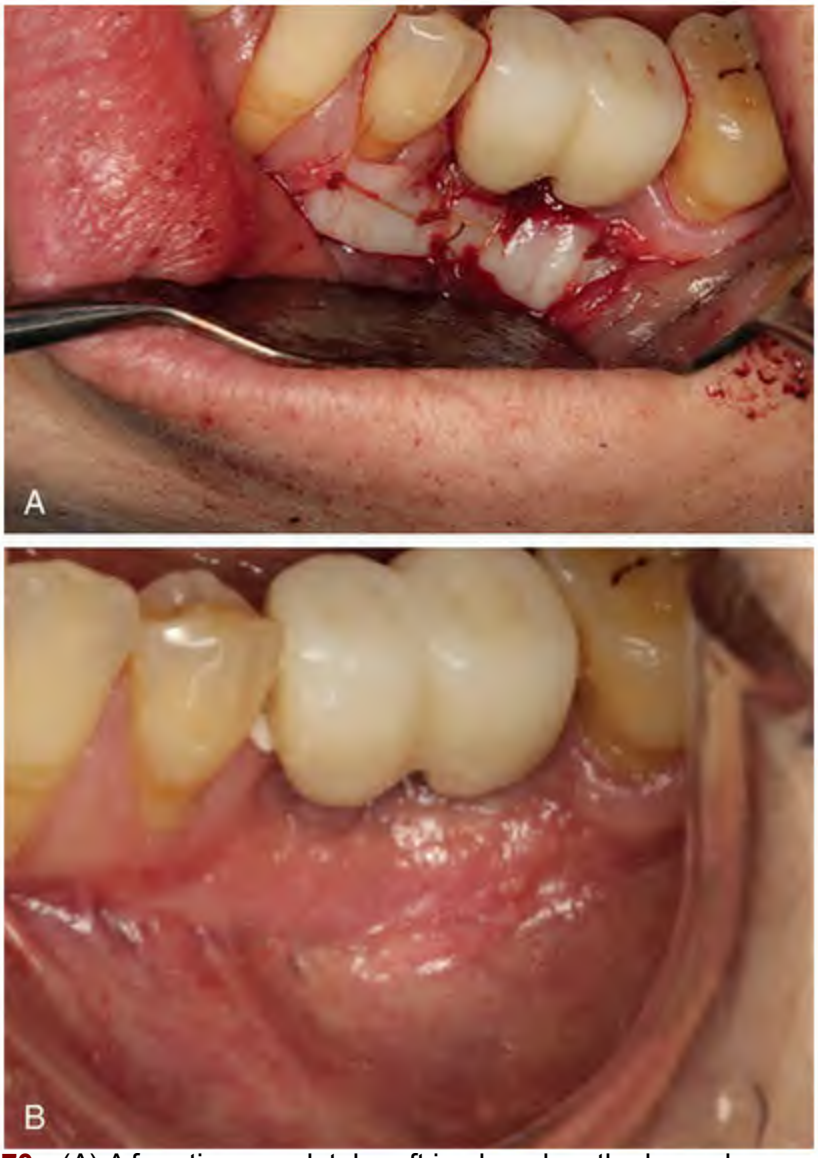

FIG 12.70 (A) A free tissue palatal graft is placed on the buccal aspect of two implants that did not have adequate attached keratinized tissue. (B) Three-week healing in the grafted site. Note the wide zone of keratinized tissue that is already developing on the buccal aspect of the implants.

Bone Density Variations in Ridge Augmentations

Etiology.

The sole purpose of ridge augmentation and bone grafting is to develop a dense stable volume of bony support for implants of appropriate sizes and numbers that are placed in the locations specified by the restorative plan. The quality and density of the final graft development is important because a weak and granular implant osteotomy site is more susceptible to crumbling during implant insertion. These granular ridges can also resorb when the

implant is loaded and stress is placed on the coronal aspect of the implant/bone interface. As clinicians plan augmentation procedures, they must understand the limitations of the materials that they are using and the techniques that are going to be utilized. Misch created a system of bone densities for implants, ranging from D1 (hardest) to D4 (softest/most porous).[53] These divisions encompass the acceptable ranges for the placement and rigid fixation of implants. Successful regeneration procedures develop a final osteotomy site that provides adequate bone volume in a dense, firm, manageable form that has a large number of vital bone cells that will easily integrate with the titanium implant body.

Complication.

When an augmentation procedure is not completed using sound surgical principles or when an inappropriate graft material is used, the completed implant site may present with an inadequate bone density for rigid fixation of the implant. The bone in these compromised sites will have a granular appearance and feel. This lack of density indicates the lack of adequate bone turnover from the original nonvital graft particles into a final dense bony consistency with a high percentage of vital bone cells. Regenerative failures will have to be regrafted, lengthening the treatment time, the overall costs, and frustrating the implant patient and the entire implant team.

Prevention.

Success in bone grafting of all types requires a thorough knowledge of the variety of grafting materials that are available and their capacity to be readily replaced with vital bone on a timely basis. A clear understanding of the concepts of osteoinduction and osteoconduction is critical for predictable grafting success. Use of totally osteoconductive graft materials will significantly alter the time required for substitution of vital bone for the nonvital products found in the donor graft. The incorporation of autogenous bone into this process adds the osteoinductive capacity of autogenous bone into the osteogenic process, accelerating the turnover into vital bone and potentially creating a better ridge consistency upon maturation. Demineralized freeze-dried bone allograft (DFBA) has some osteoinductive capacities, and the addition of a grafting material with this potential should improve the outcome of the grafting procedure. The use of bovine products has similar advantages and can be used to improve outcomes as long as its

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properties are understood.

Grafting materials are also categorized into cortical or cancellous particles and mineralized or demineralized particles. Each type of particle has properties that can be applied to specific clinical situations, but choosing the wrong material may compromise the complete grafting result (Figs. 12.71 to 12.74).

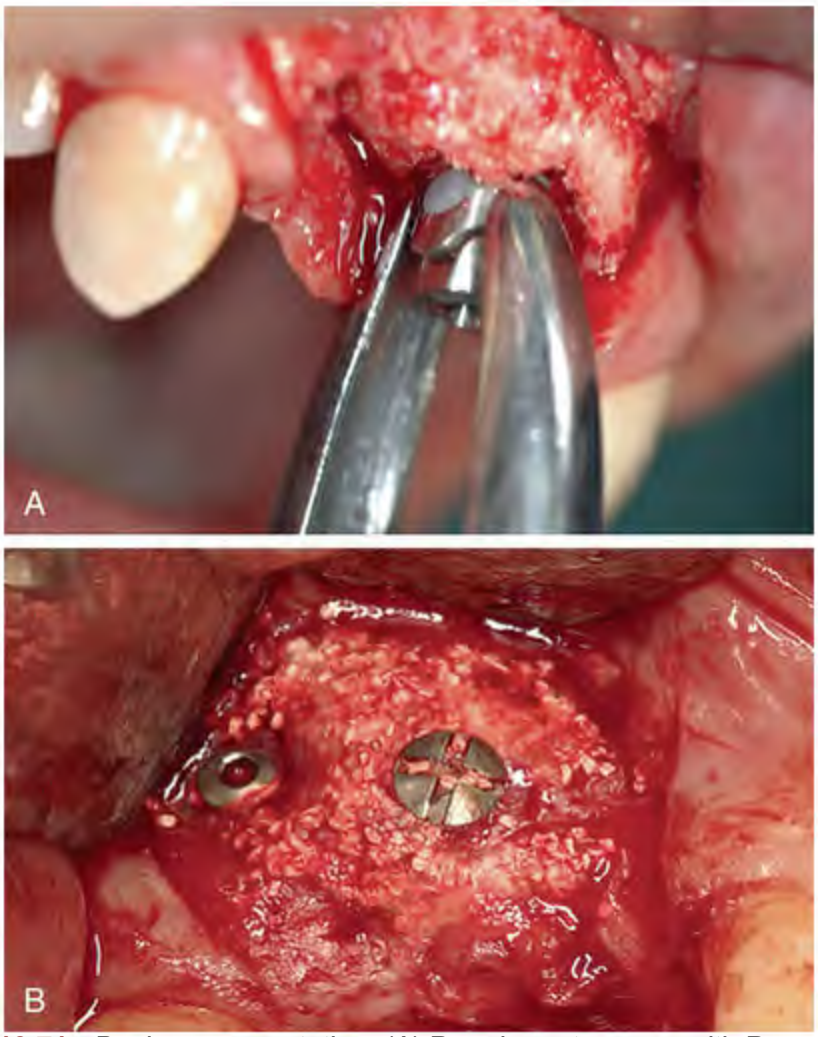

FIG 12.71 Bovine augmentation. (A) Poor bone turnover with Pepgen15 (DENTSPLY Tulsa Dental Specialties) ridge augmentation site. (B) Osteograf 300/Grafton Matrix (Osteograf 300/Grafton Matrix) graft site.

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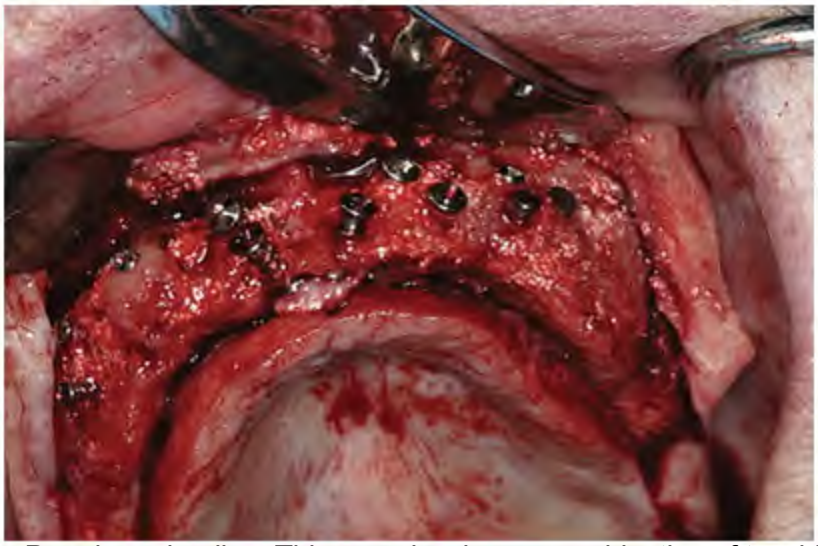

FIG 12.72 Poor bone healing. This case involves a combination of two block grafts in the cuspid positions with particulate grafting using FDBA and a bovine product. Note the healed ridge consistency and the varied density of the graft. Consistent turnover of the grafting materials was not predictable.

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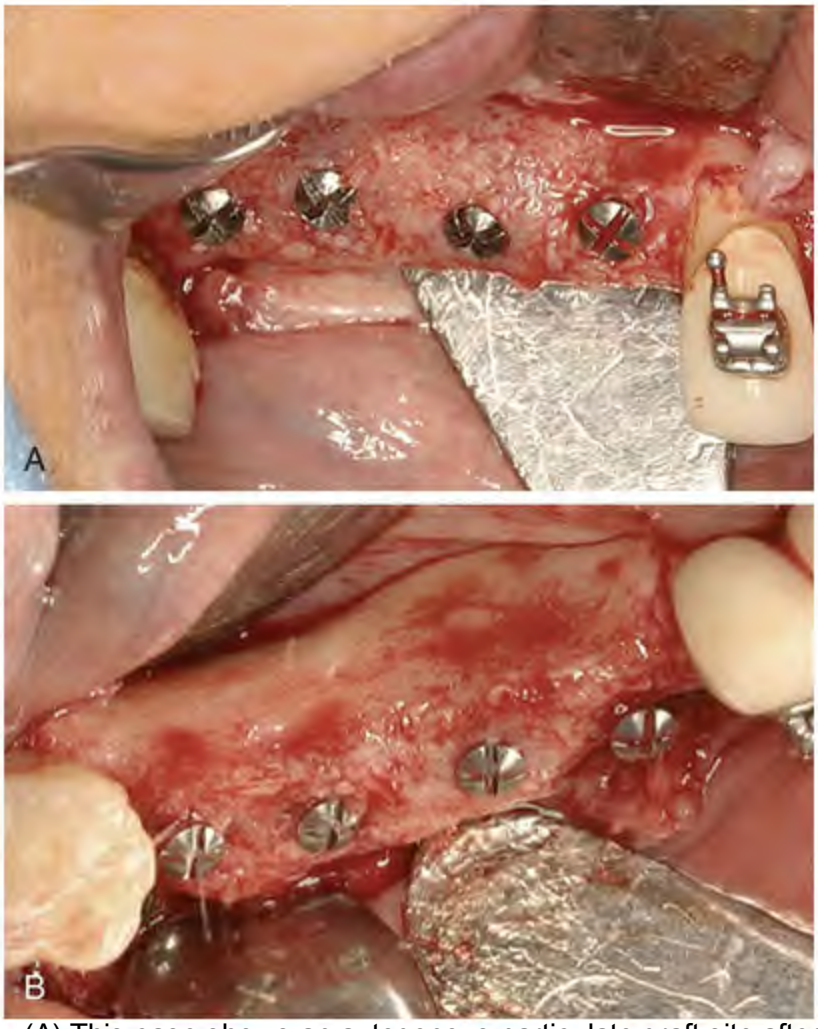

FIG 12.73 (A) This case shows an autogenous particulate graft site after 5 months of maturation. (B) Note the very dense consistency of the graft and the lack of any "grainy" regions in the final ridge form.

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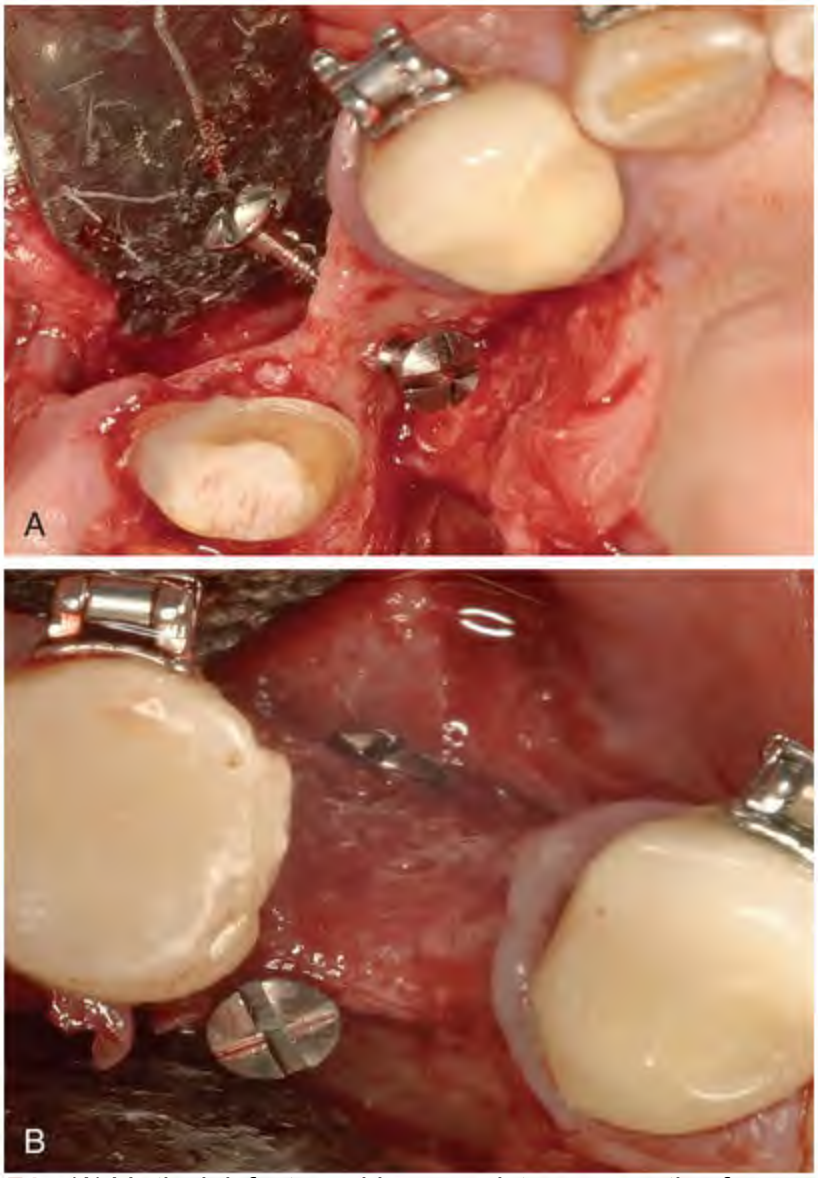

FIG 12.74 (A) Vertical defect requiring complete regeneration for reasonable implant treatment planning. (B) Autogenous particulate graft results in vertical ridge regeneration.

Difficulty Releasing the Tissue Flap From Underlying Tenting Screws

Etiology.

Flap reflection is a basic procedure that is common in all surgical applications. Correct tissue manipulation allows the flap to be released and reflected without tearing or damaging the underlying periosteal layer. The use of bone fixation screws in particulate grafting techniques creates a complicated situation for flap reflection because the fibrous tissue layer of

the periosteum surrounds the head of the screw and any exposed portion of the neck of the screw. When the flap is drawn away from a screw insertion site, this fibrous layer must be cut and the binding tissue must be released before the flap can continue to be drawn away from the region.

Complication.

Flap reflection in screw-supported regeneration sites will reveal tissue that binds around the heads of the supporting screws. This binding attachment cannot be easily drawn over the screw heads, and there is a potential to create perforations or tears in the flap as it is released.

Treatment.

Flap reflection in this situation starts with a simple full thickness crestal incision that is prepared over the graft site. Flap release is initiated with a sharp curette that is used to release the flap and to reflect the periosteum, scraping side to side until the full flap can be elevated. As the flap is released, the bone fixation screws must be freed from the thick layer of fibrous tissue that adheres to the screw head. A #12 scalpel is used to cut the fibrous layer over the screw, and the curette is then used to continue the flap release until another screw is encountered. Once the flap has been completely released, the fixation screws are accessible for removal before placing the implants (Figs. 12.75 to 12.78).

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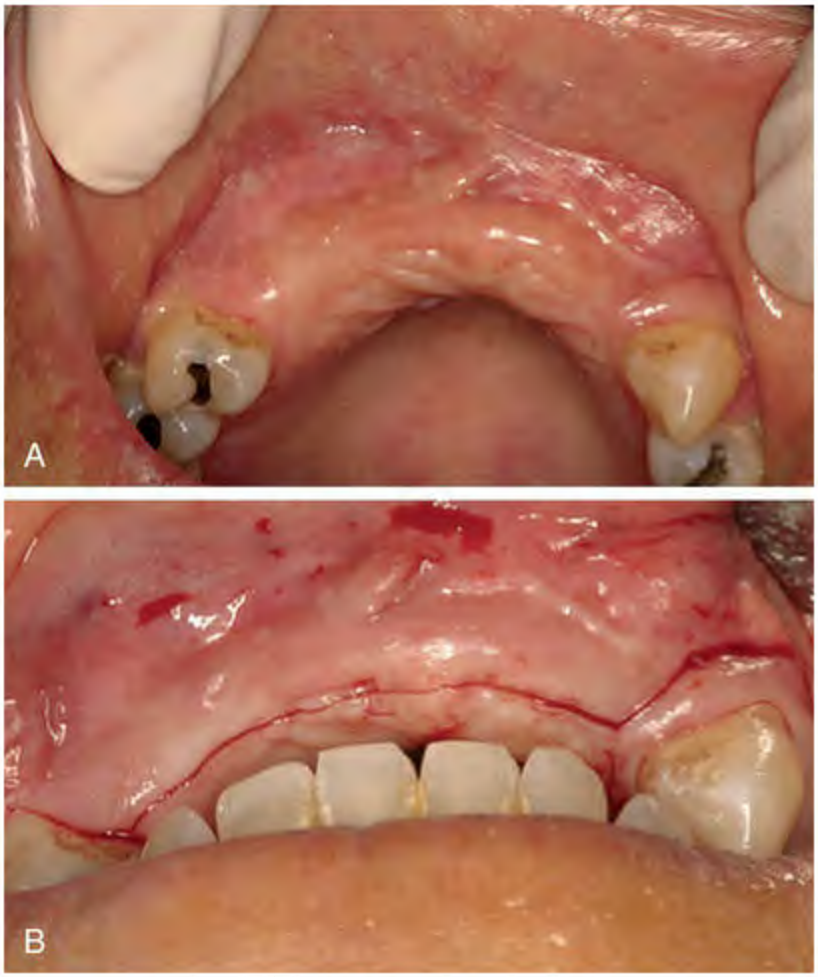

FIG 12.75 Postoperative graft incision. (A) Incision is made to maintain as much attached tissue of facial of ridge. (B) An incision is made with release incisions. It is usually advantageous to go over the incision multiple times with a #15 blade to prevent a split thickness reflection.

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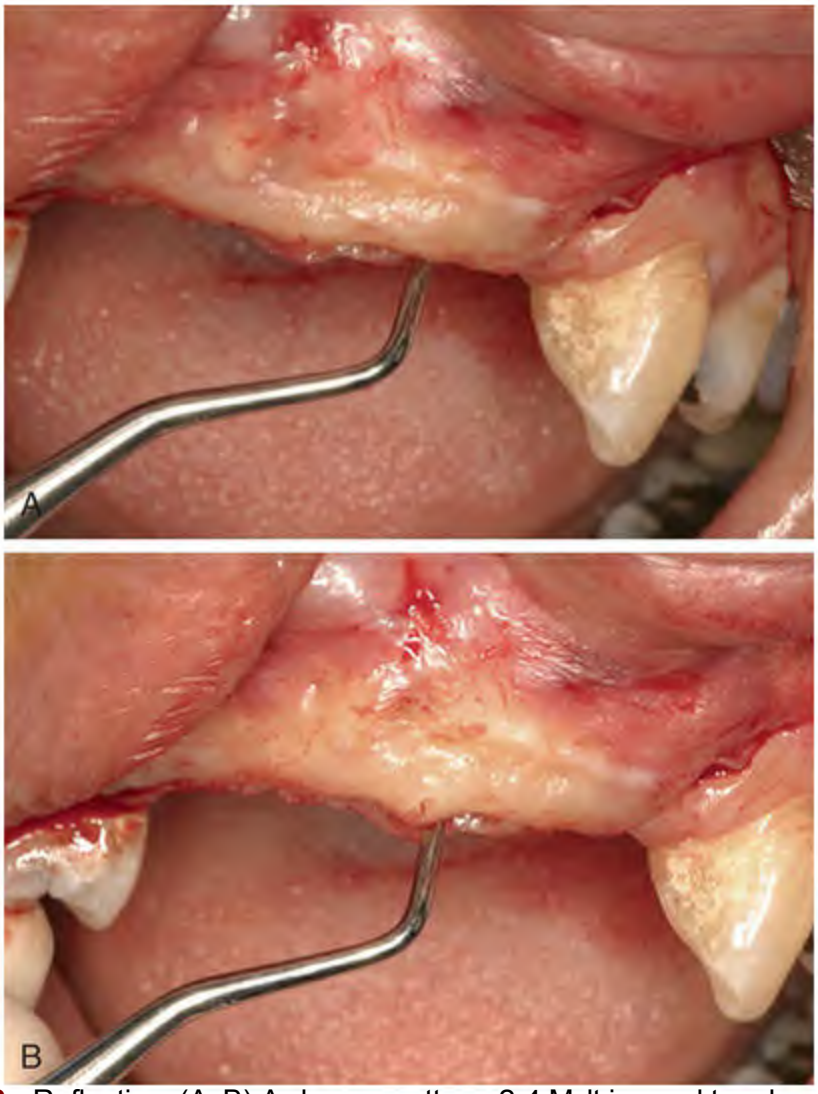

FIG 12.76 Reflection. (A–B) A sharp curette or 2-4 Molt is used to release the flap and to reflect the periosteum, scraping side to side until the full flap can be elevated (e.g., full thickness).

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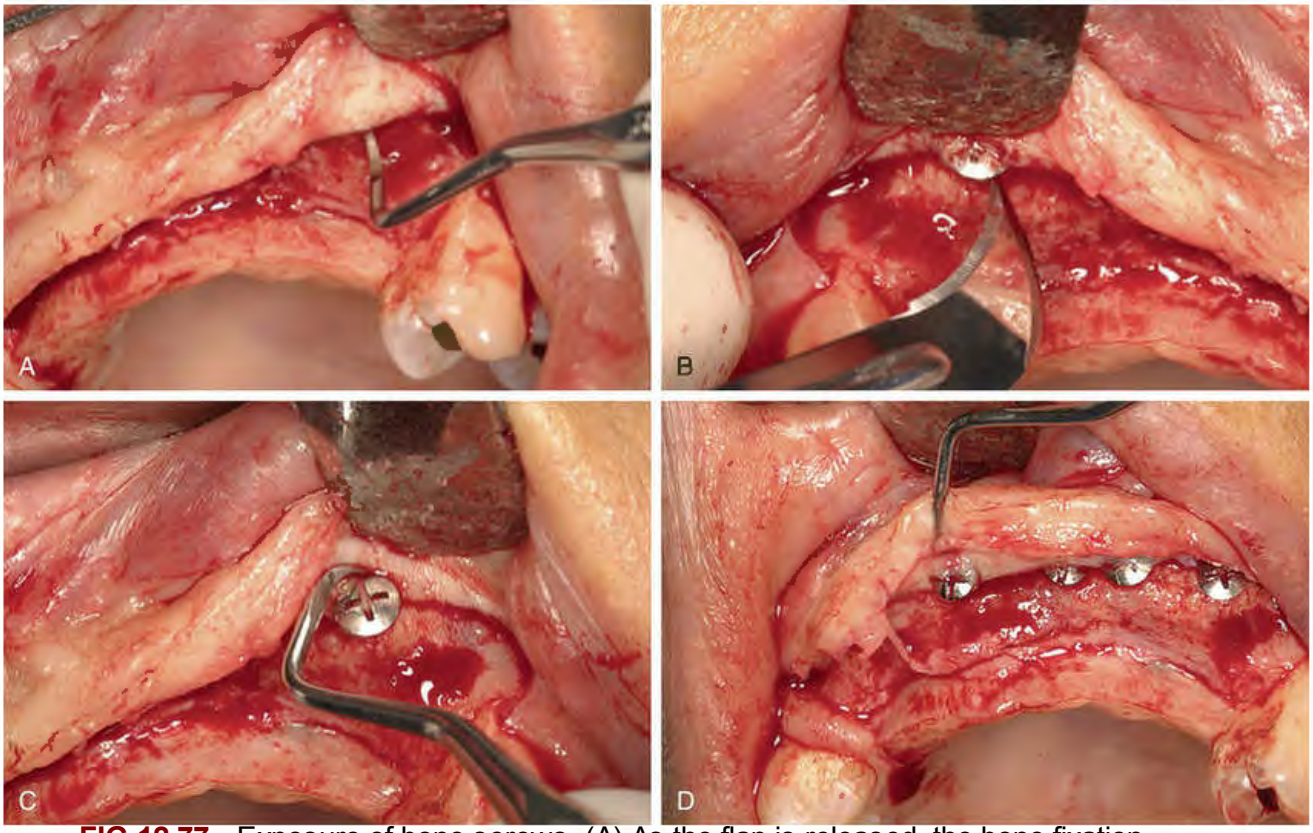

FIG 12.77 Exposure of bone screws. (A) As the flap is released, the bone fixation screws must be separated from the thick layer of fibrous tissue that adheres to the screw head. (B) #12 scalpel is used to sever the fibrous layer over the screws. (C–D) A curette is then used to continue the flap release until all screws are accessed.

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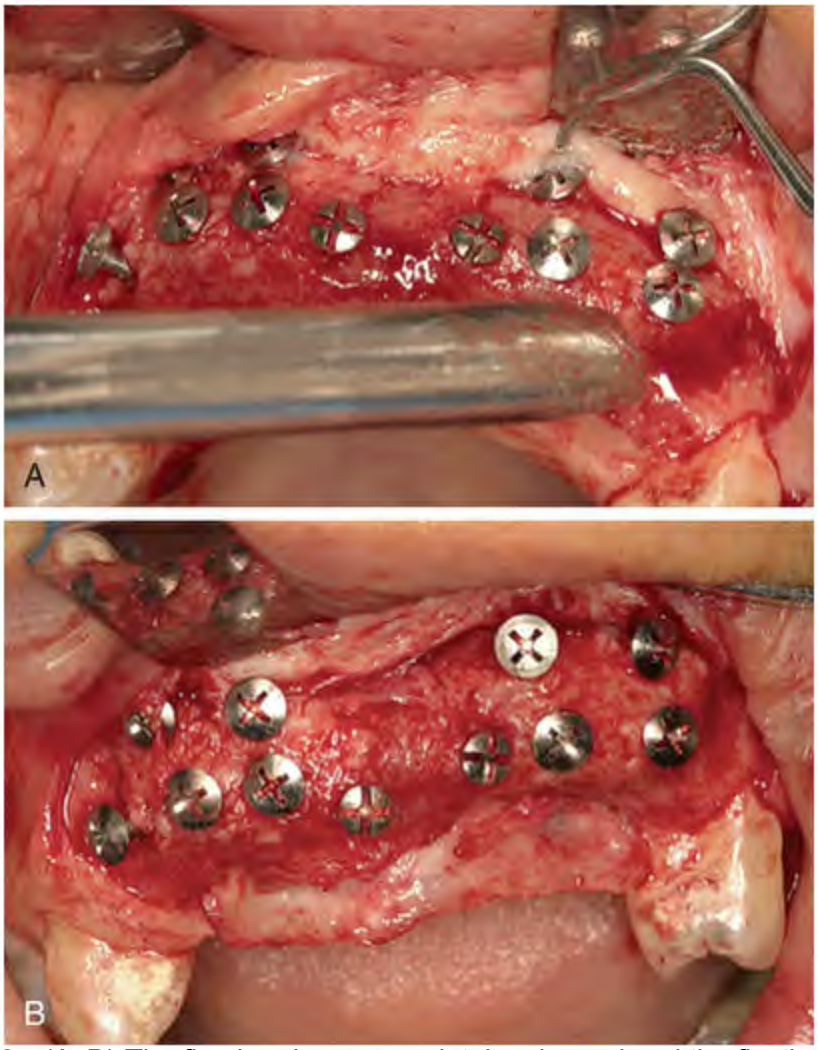

FIG 12.78 (A–B) The flap has been completely released and the fixation screws are accessible for removal (before placing the implants).

Incision Line Opening in Bone Grafting Sites

Etiology.

Maintenance of complete soft tissue coverage over healing bone grafting sites is one of the most important principles that must be observed for predictable grafting success. Any time that the healing graft site is exposed to the oral flora during the healing process, there will be some type of compromised change in the final graft site volume and in its overall integrity. Incision line opening with compromised graft results can often be a major limiting factor in successful implant placement.

Complication.

Incision line opening can compromise even the most carefully planned regeneration site, and most of these graft sites will require additional grafting at a later time if an actual complication develops. An open incision line introduces numerous potential complications into the healing process. First, the introduction of microorganisms into a graft site through an open incision leads to an infection in the healing graft site. Exposure of the graft particles and the presence of purulence is an indication of impending failure of the graft. The infection lowers the pH in the graft site, causing a breakdown of the graft particles and eventually compromising the resulting ridge volume. Secondly, an open incision line may allow exposure and breakdown of the barrier membrane, contributing to fibrous tissue ingrowth into the graft site. Lastly, there exists a potential for particulate graft materials to escape the graft site, resulting in an inadequate bone volume in the final proposed implant site.[57]

Prevention.

Tension-free tissue coverage can be most effectively managed from the standpoint of overall flap management throughout the surgical procedure. A clinician's experience in manipulation of soft tissue affects this aspect of bone regeneration more than any other part of bone regeneration surgery. As the clinician gains more experience in delicate tissue management and begins to understand the maintenance of a tension-free flap closure, problems with graft and membrane exposure will become a very uncommon occurrence.

Lack of tension-free closure.

The most common cause of an exposed membrane along an open incision line is directly related to the lack of a tension-free closure of the flap. All bone graft sites require that the overlying tissue flap be stretched over the wide bulk of the graft at the completion of the procedure. This stretching tension places pressure on the sutures along the incision line. If the flap has not been adequately released, this pressure will eventually lead to necrosis of the tissue around the sutures, leading to an open incision postoperatively.

The inner surface of a reflected flap is lined with the periosteum: a thin, dense layer of tissue that cannot be stretched. It is impossible to stretch the soft tissue flap over a graft site without first severing this layer of tissue. This “tissue release” is accomplished by preparing a clear and continuous

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releasing incision through the periosteum, exposing the underlying elastic layers of tissue that can then be released for expansion of the flap over the enlarged graft site. As this incision perforates the periosteal layer, the two edges clearly separate, allowing the elastic tissue below the periosteum to stretch. A sharp pair of Metzenbaum scissors is then placed into the space below the periosteum, and as the scissor tips are opened, the tissue easily releases and the edges separate farther. This is repeated until the complete flap is stretched over the graft site and 5 mm beyond the opposite flap margin.

Treatment.

In the event of an incision line opening, the patient should be placed on a frequent monitoring protocol to observe the status of the graft material and any grafting hardware present. The oral microflora must be managed with the use of daily chlorhexidine rinses. The clinician must not attempt to suture the site again because healing margins along incision lines feature tissue that cannot, at that time, support the pressure of another suture under tension (Figs. 12.79 to 12.82).

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FIG 12.79 Incision line opening. (A–B) Postoperative incision line opening with membrane exposure.

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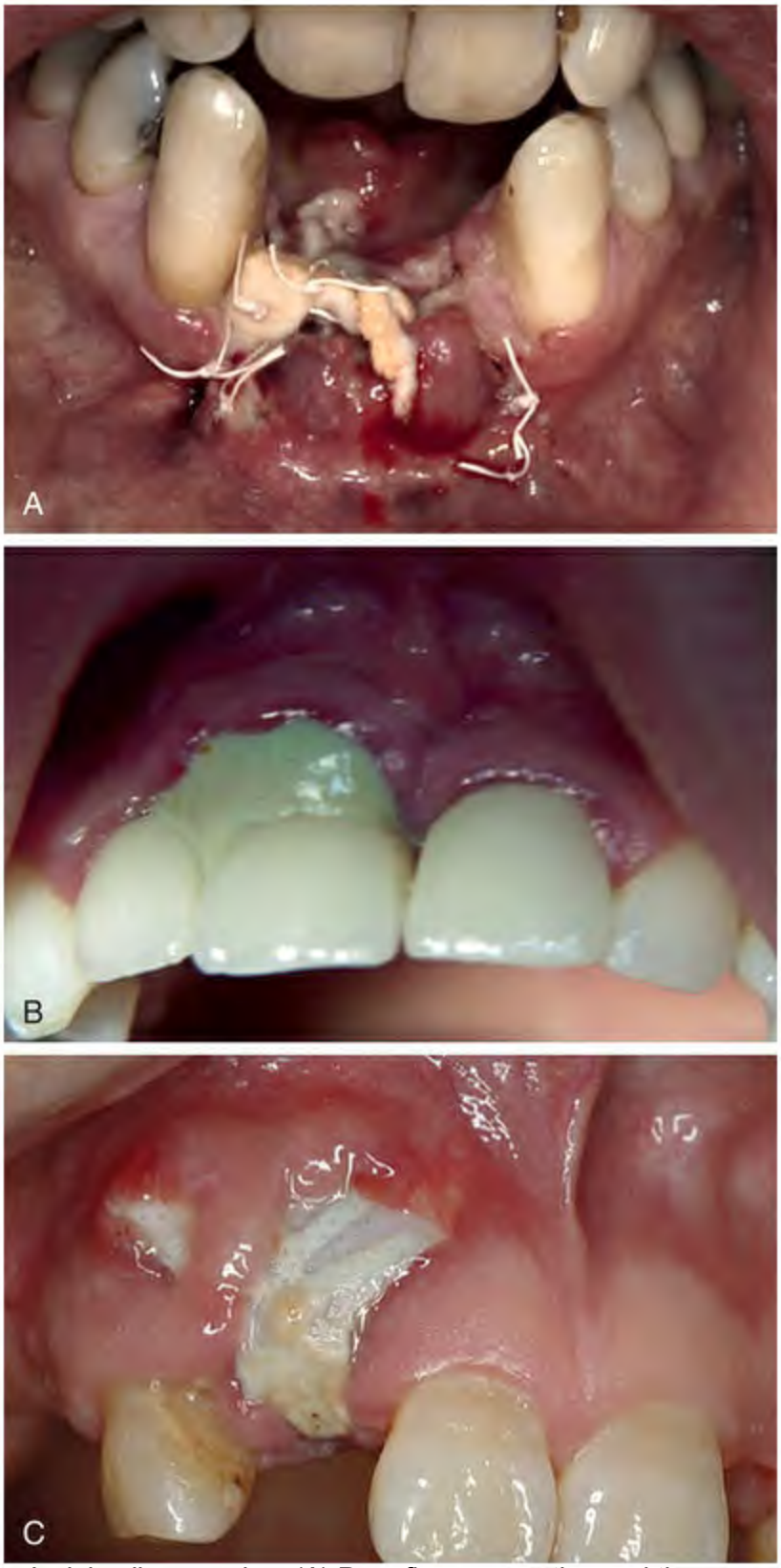

FIG 12.80 Incision line opening. (A) Poor flap preparation and tissue necrosis has resulted in complete membrane exposure. (B) A lack of tension-free closure and pressure from an interim prosthesis has resulted in membrane exposure. (C) This non-resorbable membrane has been exposed. It will need to be maintained for at least 6 weeks to attempt to salvage the underlying graft.

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FIG 12.81 (A) A lower anterior graft site is exposed during the healing process. (B) The AlloDerm membrane allows maintenance of the exposure site while the tissue slowly covers the exposed membrane.

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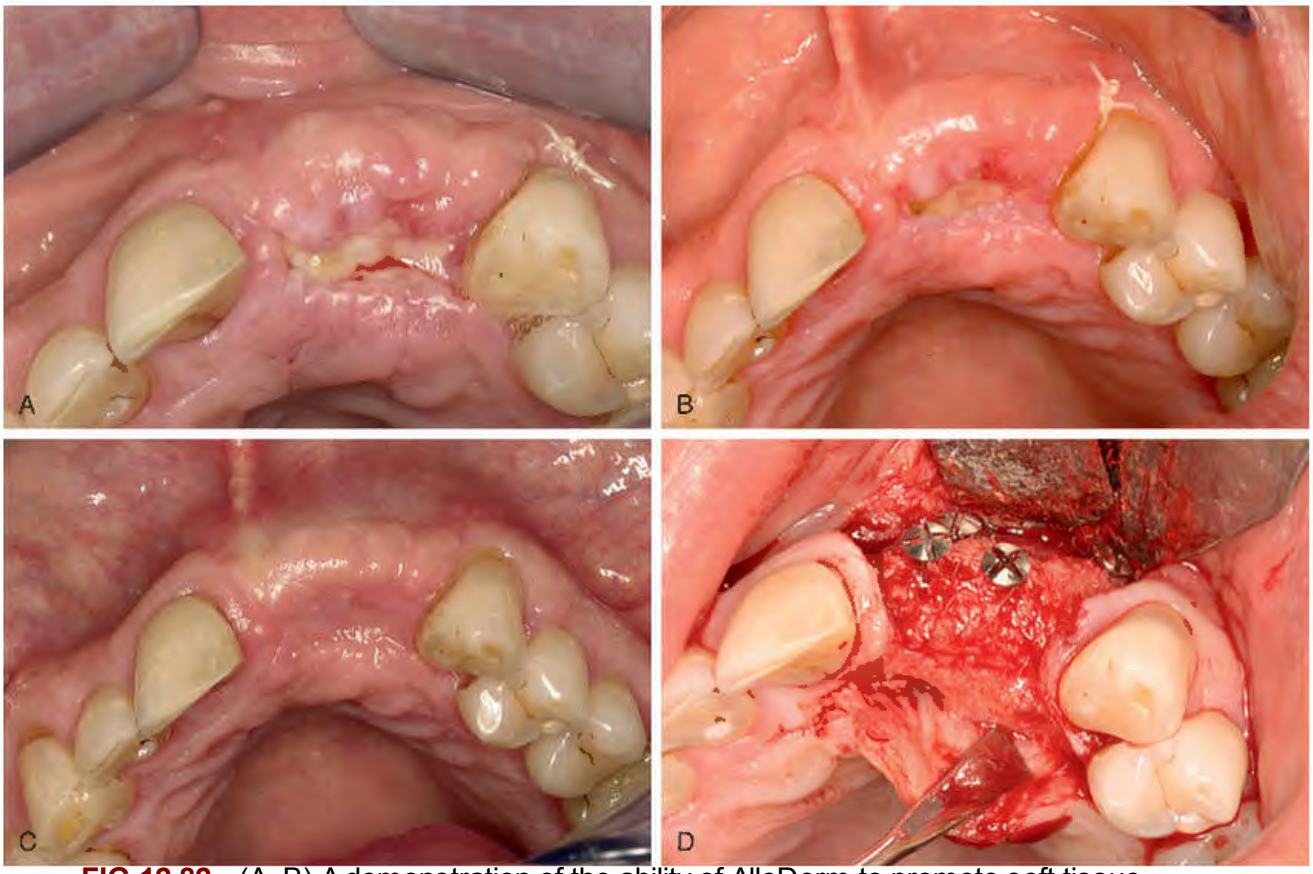

FIG 12.82 (A–B) A demonstration of the ability of AlloDerm to promote soft tissue closure over a significant membrane exposure that occurred while grafting the maxillary anterior teeth. The patient is instructed to keep the area clean with the use of chlorhexidine. (C) The mature graft site with complete regeneration of bone to the level of the fixation screw heads. (D) The exposure in this case did not compromise the final graft volume at all.

Inadequate Volume of Facial Bone Regeneration With Particulate Graft

Etiology.

Augmentation of a bony ridge requires assessment of the required position of the final restoration prior to the regenerative procedure. This dictates how much bone will be needed to support an implant in the proper position for an ideal emergence profile of the crown. It is highly recommended that the augmentation be planned to overbuild the facial bony contour enough to account for any alterations of the graft volume that may occur during the healing process and for additional postoperative support on the facial of the graft site. Thin bone on the facial aspect of any implant site is prone to remodeling and eventual resorption down the face of the implant body.

Although there is bone on the facial aspect of the implant in a thin graft site, this bone is susceptible to the natural stresses along the coronal 5 mm of the implant, potentially leading to future problems.

Complication.

A lack of adequate facial bone regeneration leads to a site that may be prone to the development of a dehiscence during implant placement or inadequate support of the implant during loading and long-term use. Continued breakdown like this eventually leads to the need for repair of the exposed implant body or possible implant removal.

Prevention.

Planning is a vital ingredient in the prevention of this complication. The site should be evaluated via CBCT to assess the current volume of bone and to plan the appropriate implant that will ensure stability and function during loading. Anterior implant sites should also be assessed for the necessary angulation required to ensure a proper emergence profile. Once the implant site and prosthetic design have been chosen, the clinician may choose the proper graft technique to ensure adequate bone thickness. Ideally, after implant placement 1.5 mm of bone should be present between the facial aspect of the implant and the facial plate.

Space maintenance in a graft site is critical for predictable graft development. The definition of this final graft outer contour must be established with rigid support using a titanium-supported membrane, tenting screws, titanium mesh, or other means of space support. Loose graft particles under a free membrane tend to shift, and the coronal aspect of the graft site will thin out, leading to a pointed and deficient ridge form.

Knowledge of the properties of membranes used during grafting will ensure that the graft is free from fibrous tissue ingrowth. It is highly recommended to use a membrane that has a long lifespan and will stand up under the pressure of graft coverage, suturing, and postoperative pressure on the graft site.

Good periosteal flap release and tension-free closure allows the surgeon to use larger-volume grafts without the fear of incision line opening. Pressure on a graft site from a temporary removable appliance must be monitored because it has the potential to reduce the final graft volume secondary to micromovement of the graft.

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Treatment.

If an implant is placed in a regeneration site where the facial bone is thin or appears to be at risk due to a poor granular consistency, it is recommended that it be grafted at the time of the implant placement. A layer of allograft or xenograft should be placed over the entire region of weak bone, and a collagen membrane should be placed over the particulate graft before closure. An increased healing time before uncovery and loading should be considered to allow better graft maturation (Fig. 12.83).

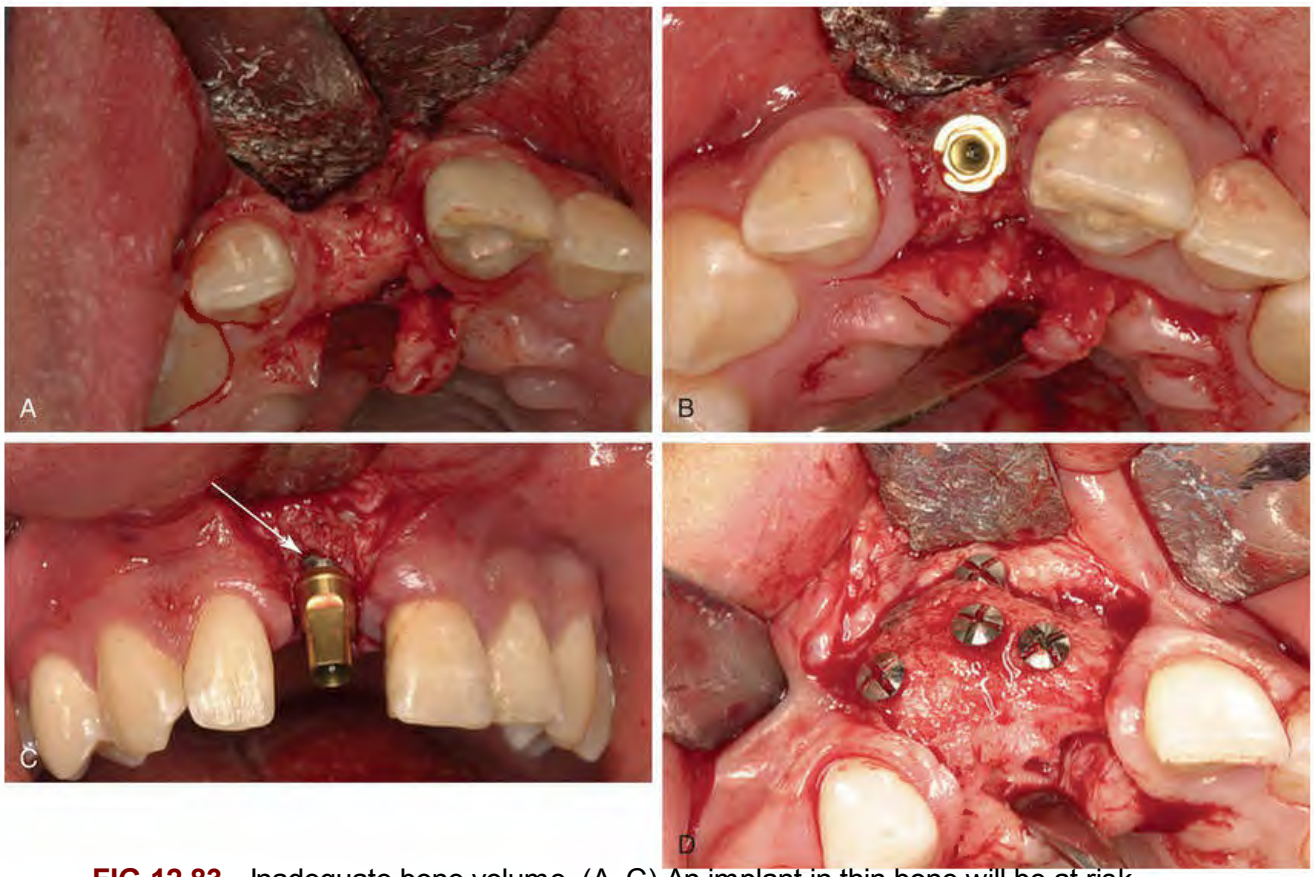

FIG 12.83 Inadequate bone volume. (A–C) An implant in thin bone will be at risk when strain is directed to the granular facial bone. This has the potential to develop a dehiscence. (D) An ideal and successful regeneration site provides an excess of facial bone and the ability of the surgeon to place the implant in an ideal aesthetic and functional position.

Postgraft Implant Placement: Inadequate Bone Width at Implant Apex

Etiology.

Regardless of the graft technique or material used, the clinician may encounter a situation where the apical portion of the implant site is sometimes deficient due to inadequate development of apical bone or the lack of apical extension of the bone graft. Implants in typical osteotomy sites are positioned so the apex of the implant will remain within the bony architecture. In some cases an apical fenestration will occur, and additional procedures will be needed to maintain predictable bony support.

Complication.

An apical fenestration in an implant osteotomy occurs when the length of the osteotomy exceeds the length of available bony support. This creates a situation that most likely will lead to a lack of fixation, stability under load, and potential implant morbidity.

Prevention.

Augmentation procedures are designed to add horizontal width to a deficient ridge. This lateral dimension needs to be regenerated in a manner that provides support to the entire length of the proposed implant. Whether an onlay cortical graft is utilized or a membrane procedure is planned, the length of the graft must extend apically to a level that prevents a fenestration of the implant at the time of surgical placement. Attention to detail in bone grafting is important from a three-dimensional standpoint because the clinician has good visualization in the coronal portion of the graft site, but the apical region is usually out of sight. It is difficult to extend the bulk of graft materials into the apical regions during graft placement, and the maintenance of space in the cramped space is required if any significant bone volume is to be developed. The quality of bone in the apical region and over the facial aspect of the implant is very important from a density standpoint because this critical region of support will bear the strain when the implant restoration is loaded. Deficiencies or regions of thin bone often lead to the formation of a dark coloration of the tissue on the facial aspect of the implant, compromising the aesthetics of the entire case.

Apical fixation.

Many authors have debated the need for fixation of the membrane, but it has been the experience of the authors that rigid fixation of the membrane is important for the establishment and maintenance of the apical location of

the graft volume. Membranes are easily fixed into position utilizing bone tacks or screws, but suturing the membrane to the periosteum is another technique that can be used. It is important to note that ALL bone tacks should be removed at the time of implant placement to prevent dislodgment at a later time. It has been shown that loose tacks have the potential of migrating through the soft tissue into the proximity of vital structures.

The best sites for anchorage of the membrane are located at the most apical corners of the membrane, anterior and posterior to the graft site. All fibrous tissue must be removed from the recipient site, and the tack or suture fixes the membrane at that point. It is not recommended to anchor the membrane between these two sites unless the graft involves a very wide space where the membrane tends to move coronally and the graft could be exposed. In that case, strategic anchorage is recommended.

Lingual/palatal membrane fixation.

The membrane should ideally be fixed into position on the lingual or palatal aspect to ensure that there is no movement of the membrane if the incision line opens up or the graft is shifted by the temporary prosthesis. Fixation with bone tacks on the lingual aspect is often difficult from an access standpoint. A lingual or palatal suture can maintain a firm hold on the membrane from that direction while the flap is closed.

Treatment.

If the initial graft is too short and there is an apical exposure, the apical region must be augmented with particulate graft or additional cortical bone with membrane coverage to cover the fenestration. The use of freeze-dried bone allograft or bovine particulate bone along with a collagen membrane has been recommended for isolation of the graft (Figs. 12.84 to 12.88).

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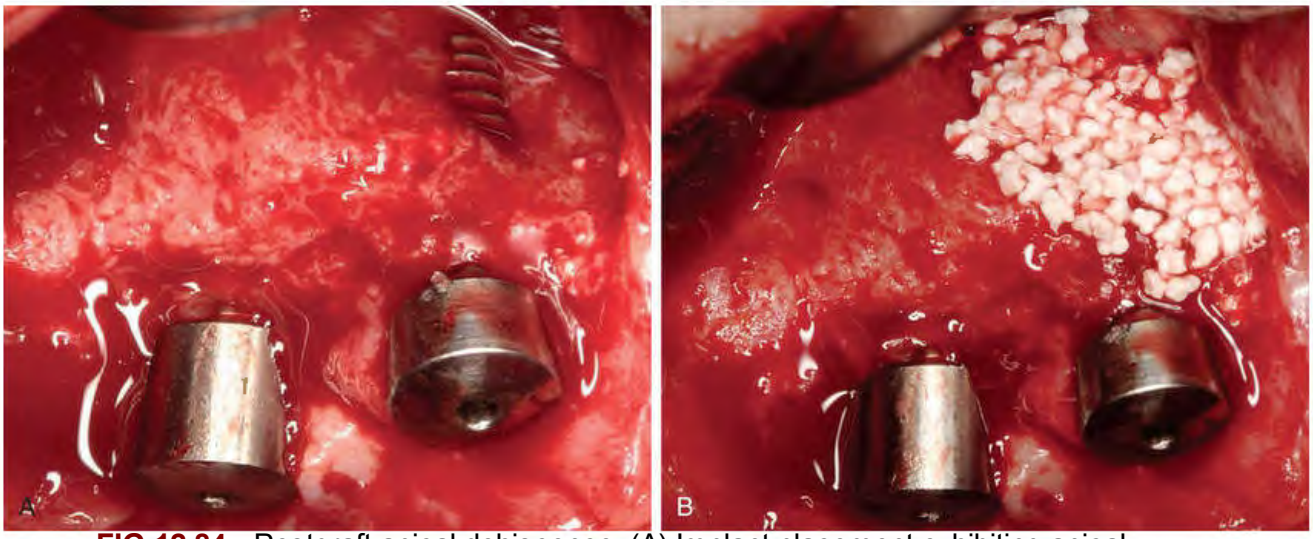

FIG 12.84 Postgraft apical dehiscence. (A) Implant placement exhibiting apical dehiscence. It is treated with an allograft and collagen membrane. (B) Grafting defect with allograft. (From Peñarrocha-Oltra D, Peñarrocha-Diago M, Balaguer-Martínez J, et al: Full-arched fixed prosthesis supported by four implants in patients with recessive dystrophicepidermolysis bullosa. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 112(2):e4–10, 2011.)

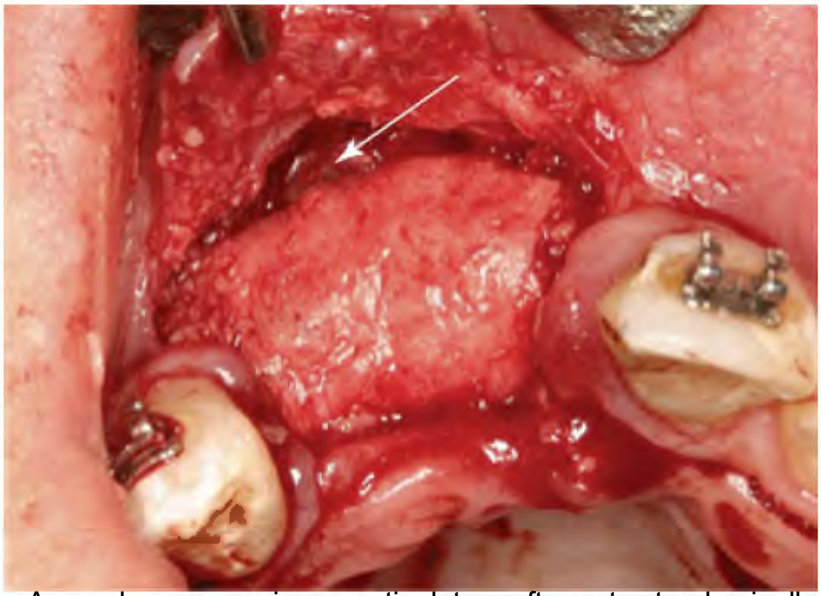

FIG 12.85 A membrane covering a particulate graft must extend apically enough to maintain isolation of all graft materials.

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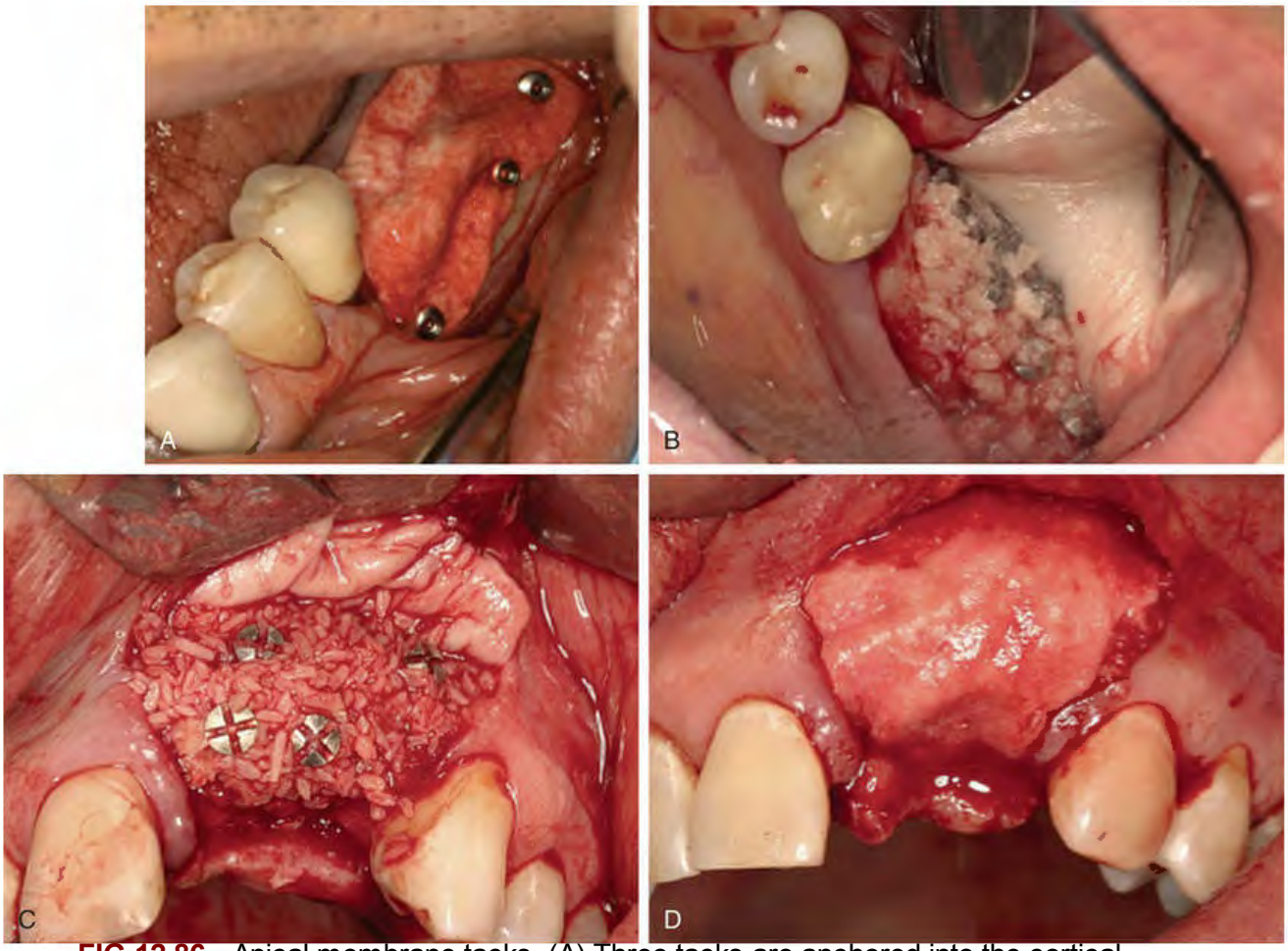

FIG 12.86 Apical membrane tacks. (A) Three tacks are anchored into the cortical bone, apical to the deepest portion of the particulate graft. (B) Demonstration of volume of bone that needs to be isolated in a membrane procedure. (C–D) Care must be exercised in making sure adequate graft material is present apically to prevent implant dehiscence.

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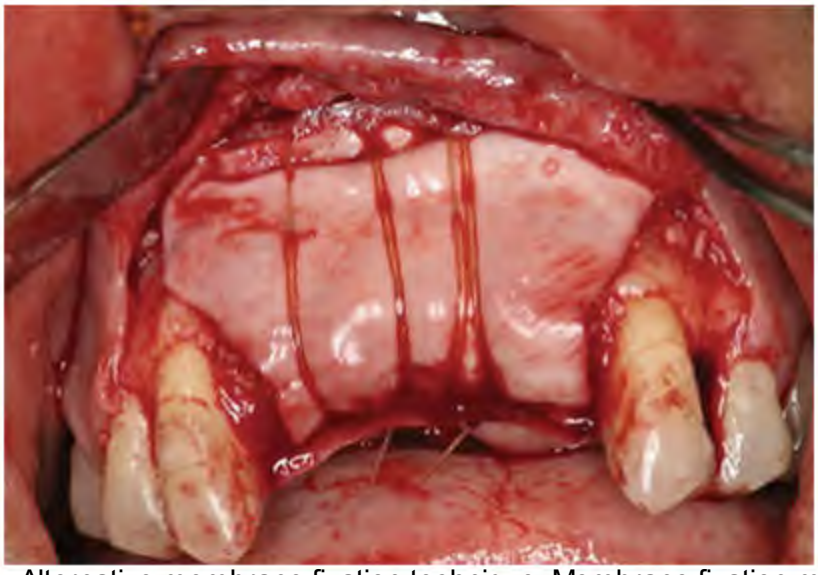

FIG 12.87 Alternative membrane fixation technique. Membrane fixation may also be obtained with apical sutures attached to the periosteum, which help limit any migration of the membrane or allograft material.

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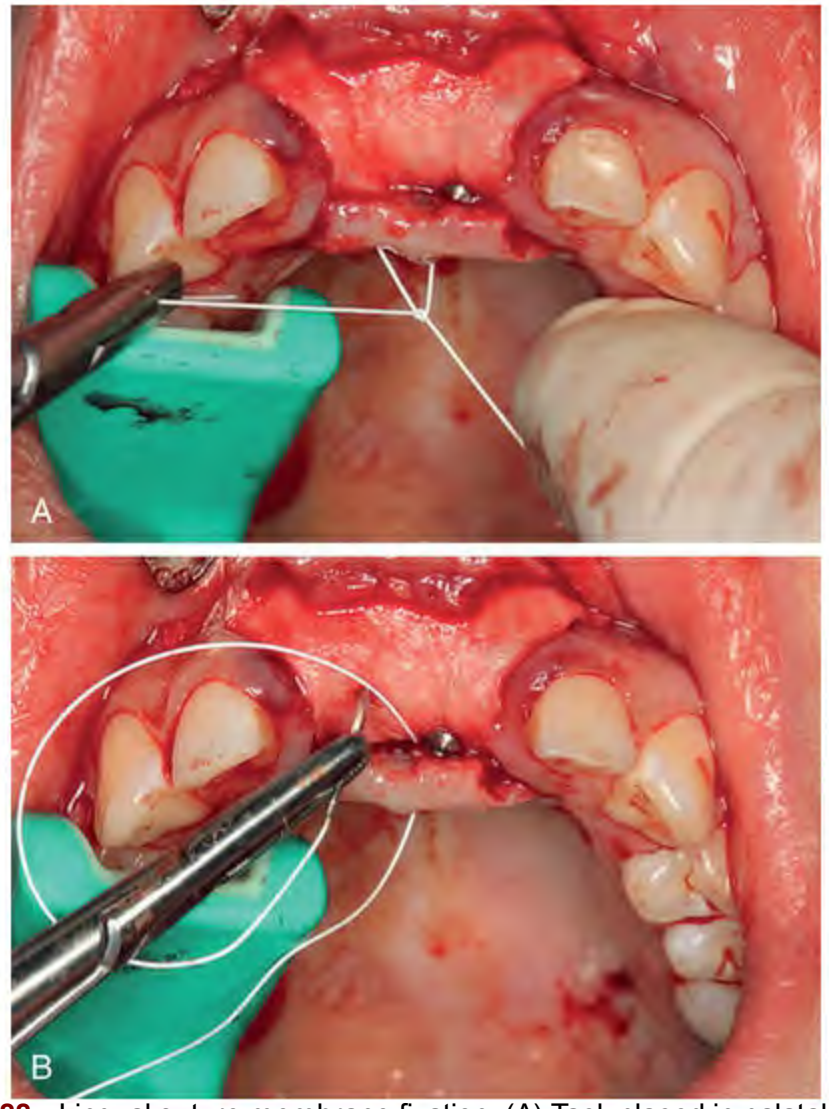

FIG 12.88 Lingual suture membrane fixation. (A) Tack placed in palatal cortical plate with suture started through the palatal flap, passing below the flap and back through the membrane. (B) The suture is then passed back from beneath the flap and out again.

Bone Growth Over Bone Fixation Screws

Etiology.

During particulate grafting or when particulate bone is added over block grafts, excess amounts of the graft particles can often stimulate formation of bone over the supporting fixation screws. This is usually a layer of soft bone that can easily be removed with a curette for access to the screw head. Location of the various screws can be pinpointed using periapical radiographs if needed. It is necessary to remove these screws if implants are treatment planned for that region.

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Complication.

If a screw is not removed from the graft site, it may interfere with osteotomy preparation or implant placement.

Prevention.

There is really no significant problem that is related to bone overgrowth and no real precautions need to be taken to prevent this situation. Knowledge of the number and location of the screws along with radiographic evaluation of the site will prevent the clinician from leaving a graft screw in place.

Treatment.

The location of the hidden screw is confirmed with a radiographic exam and with a clinical survey of the surface of the mature graft site. The bone directly over a hidden screw is sometimes slightly discolored by the translucence of the darker screw through the bone, pinpointing its location. This same bone is often not quite as dense as the surrounding bone, allowing light dissection of the region until the head of the screw is located (Fig. 12.89).

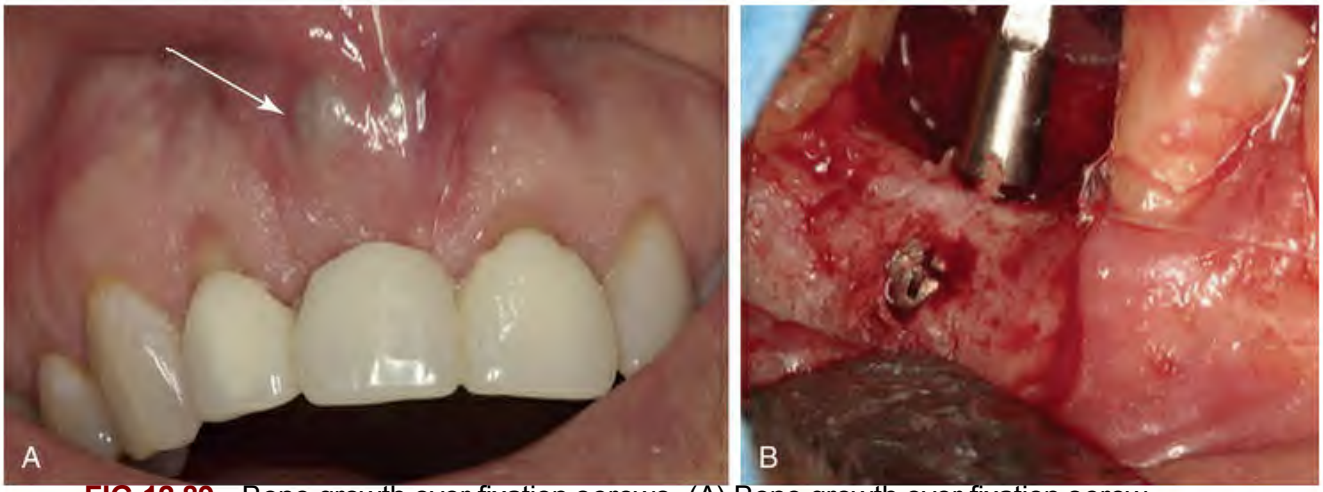

FIG 12.89 Bone growth over fixation screws. (A) Bone growth over fixation screw *(arrow)*. Bone should be ideally removed with an explorer or curette. (B) The location and number of screws should always be documented. In this example, the screw was identified only after implant placement.

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Summary

To provide optimal treatment to patients on a daily basis, the implant clinician must become well versed in the concepts of bone regeneration. The fact is that more patients than not will require some manipulation of bone volume prior to implant placement if the clinician desires to provide a restoration with proper form, function, and aesthetics.

The discipline of bone grafting encompasses many different approaches with varying materials and techniques. As the clinician begins to master the complete assortment of these techniques, the likelihood of a successful regeneration outcome will become very predictable. This is based on the fact that a great variety of bone defects are encountered in a clinical setting requiring different approaches to ensure that appropriate bone volumes are achieved.

Along with the knowledge and clinical expertise in these procedures, the implant clinician must also be equipped with a clear understanding of proper management of the various complications that may arise during these highly technique-sensitive operations. The common theme in complication prevention with bone grafting involves accurate preoperative assessment, a clear grafting strategy, and sufficient skill during the operation (especially concerning flap reflection and tension-free closure). This must then be followed with appropriate postoperative measures including interim prosthesis modification and monitoring.

The human body is capable of amazing feats as it pertains to the regeneration of bone volumes; however, conditions must be favorable for the process to work correctly. These principles of grafting, with minimized complications, have added a very important skill to the array of techniques that allow today's patients the opportunity to achieve optimal dental health and aesthetic restorative care.

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Posterior Maxilla Complications

Randolph R. Resnik

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Anatomy

Maxillary posterior partial and complete edentulism are among the most common conditions in dentistry. Thirty million people in the United States, or 17.5% of the adult population, are missing all of their maxillary teeth. In addition, 20% to 30% of the adult partially edentulous population older than 45 years is missing maxillary posterior teeth in one quadrant, and 15% of this age group is missing the maxillary dentition in both posterior regions. Approximately 40% of adult patients are missing at least some maxillary posterior teeth.[1]

The maxillary posterior edentulous region presents many unique and challenging situations in implant dentistry. Most noteworthy surgical methods include maxillary sinus grafts to increase available bone height, onlay grafts to increase bone width, and modified surgical approaches to insert implants in areas with poorer bone density. Grafting of the maxillary sinus to overcome the problem of reduced vertical available bone has become a very popular and predictable procedure over the last decades. This grafting procedure has been proven to provide the clinician with adequate bone volume to place an implant of ideal size and proper orientation. However, this anatomic area is responsible for more complications in oral implantology than any other region in the oral cavity.

Anatomic Disadvantages to the Posterior Maxilla

Pneumatization of the Maxillary Sinus

After posterior tooth loss, the maxillary sinuses enlarge, which presents a unique problem for implant placement. A continued increase of osteoclastic activity within the periosteum of the maxillary sinus (Schneiderian membrane) results in expansion. An elevated positive pressure within the sinus will also increase alveolar bone atrophy allowing for pneumatization, thus decreasing the available bone for implant placement.[2] An inverse relationship between sinus pneumatization and the remaining alveolar bone exists due to remodeling and the normal/pathologic status of the dentoperiodontal apparatus (Fig. 13.1).

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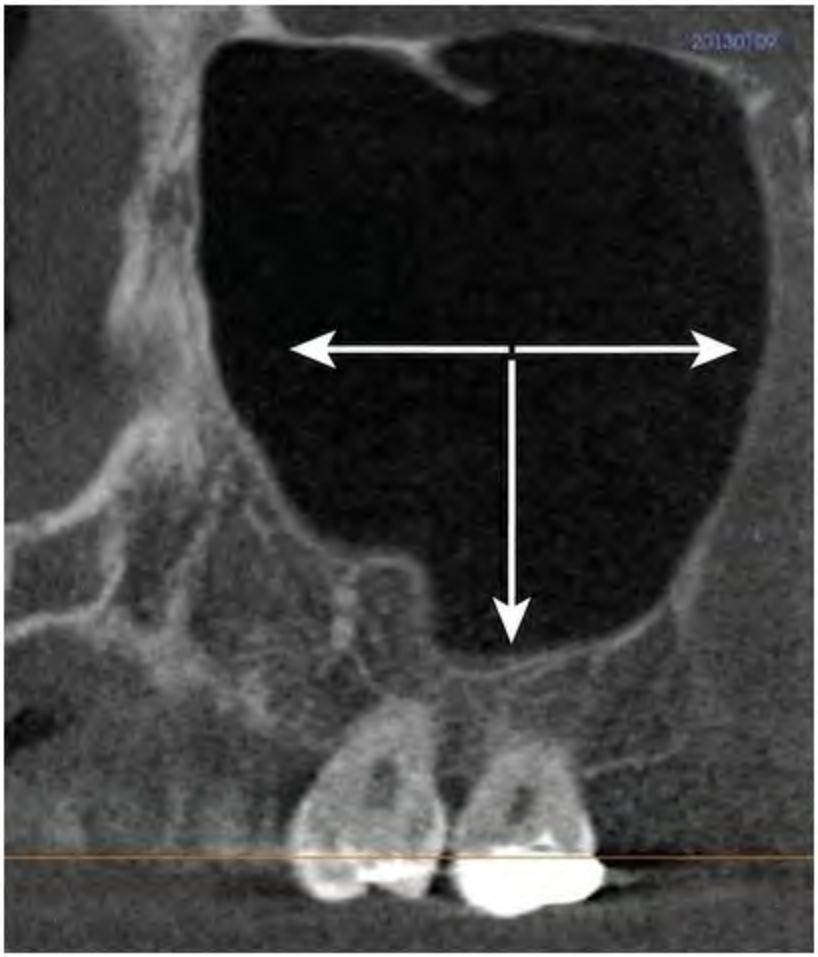

FIG 13.1 Pneumatization can be significant even with teeth present as the maxillary sinus increases in size, leaving less available bone for implant placement.

Clinical Implication.

The net result of maxillary sinus pneumatization is the deficiency in bone height for implant placement, thus requiring augmentation for increased bone quantity for future implant placement. With proper grafting techniques to increase bone volume, this anatomic area may be restored to a more predictable biomechanical location for future implant placement. If grafting is not completed where bone quantity is not adequate, an increased morbidity may result with failure or migration of implants.

Ridge Width/Lingual Repositioning

The maxilla has an inherently thinner facial cortical plate in comparison to other areas of the mouth (e.g., mandible) because of rapid resorption after tooth loss. The loss of maxillary posterior teeth results in an initial decrease in bone width at the expense of the labial bony plate. This process occurs at a

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faster rate than in any other region of the oral cavity.[3] The resorption phenomenon is accelerated by the loss of vascularization of the alveolar bone and existing fine trabecular bone type. However, because the initial residual ridge is inherently wide in the posterior maxilla, even with a 60% decrease in the width of the ridge, adequate-diameter root form implants usually can be placed. As further time passes, the ridge shifts toward the palate until the ridge is resorbed into a medially positioned narrower bone volume.[4] The posterior maxilla continues to progressively remodel toward the midline as the bone resorption process continues.

Clinical Implications.

Because of the less than ideal width of bone, buccal-lingual implant placement may not be ideal. Studies have shown that it is possible to perform ridge augmentation to increase width at the time of sinus grafting, but there is an increased rate of morbidity and implant failure when compared to sinus grafting alone. Due to the more lingual position of the ridge, implants will be placed more lingual than is ideal. Prosthetically, this will often result in the buccal cusp of the final restoration being cantilevered facially to satisfy esthetic requirements at the expense of biomechanics in the moderate to severely atrophic ridges (Fig. 13.2).[1] In some severe resorption cases, the posterior maxillary implants are more ideally restored in a crossbite occlusion.

FIG 13.2 In the posterior maxilla the buccal plate resorbs faster than any other area of the oral cavity. As resorption progresses from division A to B to C to D, the residual ridge is positioned more lingual. This results in the eventual implant being placed more lingual, potentially in crossbite with the mandibular posterior teeth or at a nonideal angle.

Bone Density

The bone quality in the posterior maxilla is usually poorer than in any other intraoral region. Bone strength is directly related to its density, and the low-

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density bone of this region is often five to ten times weaker compared with bone found in the anterior mandible.[5] The various bone densities directly influence the bone-implant contact (BIC) percent, which accounts for the transmission of forces to the bone. The posterior maxilla most commonly exhibits D4 bone (Misch classification), which has the greatest biomechanical elastic modulus difference when compared with titanium under load. D4 bone is characterized by fine trabeculae with very little cortical bone. Implants placed into D4 bone are most susceptible to bone loss and increased morbidity. As such, strategic surgery techniques (e.g., under-preparation, use of osteotomes) when placing implants in the posterior maxilla to increase BIC are suggested.

Clinical Implications.

Because the BIC is least in D4 bone, the stress patterns (i.e., from biomechanical force) in this bone type migrate farther toward the apex of the implant. As a result, bone loss is more pronounced and occurs more apically along the implant body, while in denser bone types (D1), one would see only crestal bone loss. As a result the lateral cortical BIC to stabilize the implant is often insufficient. To increase BIC and success with posterior maxilla implants, the surgical and prosthetic technique requires modification; under preparation of the surgical site, use of osteotomes, greater healing periods, and progressive bone loading during the prosthetic phase of treatment (Fig. 13.3).

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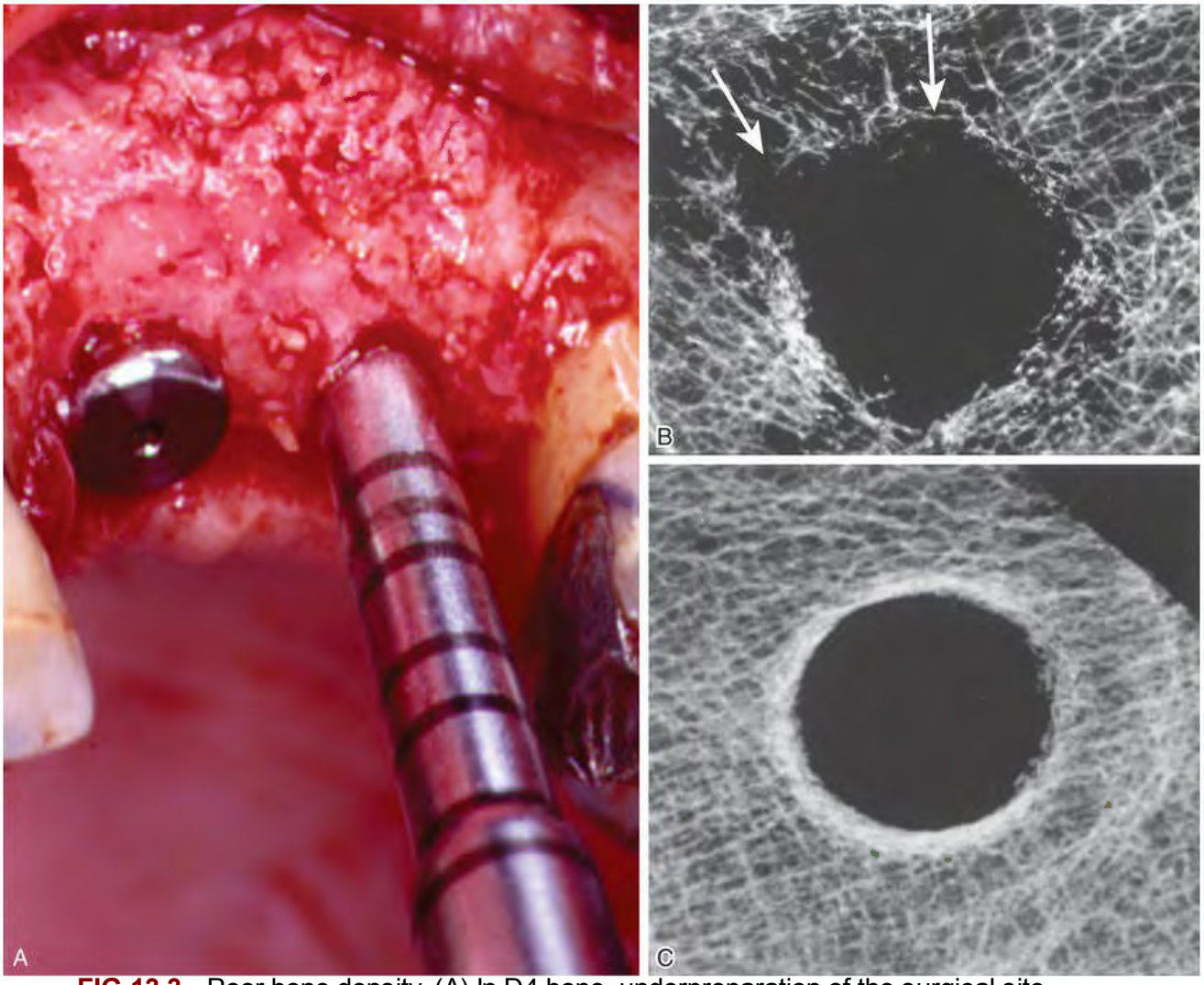

FIG 13.3 Poor bone density. (A) In D4 bone, underpreparation of the surgical site along with the use of osteotomes increases the BIC of the implant, increasing the prognosis of the implant. (B) A conventional drilling procedure uses an extraction technique that removes bone from the site. Note the jagged periphery of the osteotomy site. (C) With the use of osteotomes, bone compaction results in a better quality osteotomy and increased BIC for dental implant healing.

Anatomic Location

Because of the anatomic location (posterior maxilla), adequate surgical access is often a difficult problem because of a lack of interocclusal space. With the length of the handpiece and surgical drill often exceeding 40 mm, the posterior maxilla is one of the most difficult areas to complete a successful osteotomy. The implant clinician is often unable to drill the osteotomy with the correct angulation (Fig. 13.4) because of the opposing occlusion.

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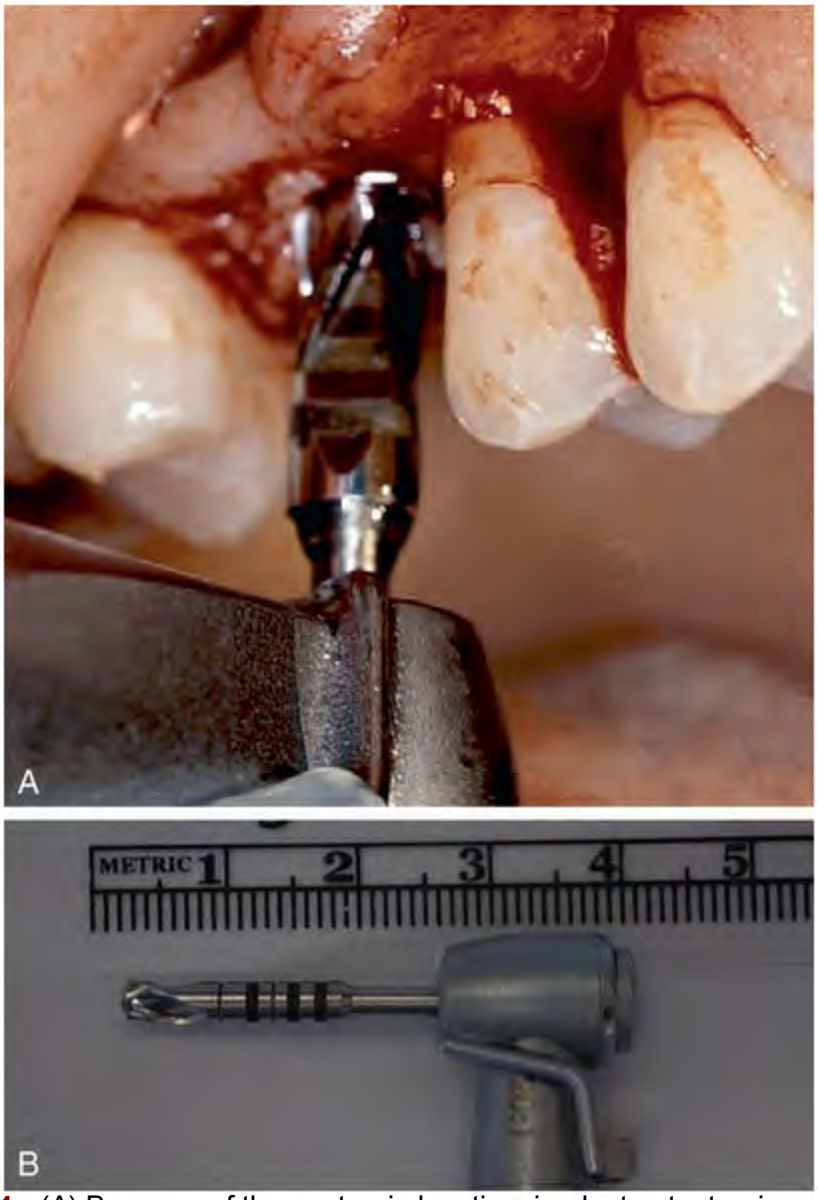

FIG 13.4 (A) Because of the anatomic location, implant osteotomies are often complicated in the posterior region because of lack of interocclusal space. Nonideal implant angulation often results. (B) Implant drills + handpiece often exceed 40 mm, which can make access very difficult.

Clinical Implications.

The implant surgeon is often confronted with lack of interocclusal space, increasing the difficulty in all aspects of the surgical procedure. Visibility is diminished in the posterior maxilla, especially when increased bleeding occurs. This area also becomes very uncomfortable for the patient, especially if there is a positive gag reflex.

The lack of space also presents an issue with utilizing surgical templates, especially those guided by cone beam computed tomography (CBCT),

because minimal space is available to accommodate the surgical drill along with the surgical template. However, newer surgical templates have been fabricated with the buccal aspect of the drilling tubes removed (buccal access), which allows the implant clinician additional space to prepare the osteotomy.

Predisposition to Pathology

The paranasal sinuses, especially the maxillary sinus, have been shown to be very susceptible to various disease processes. Studies have shown that in approximately 46% percent of asymptomatic patients requiring augmentation in the maxillary sinus, some degree of pathology exists.[6] The pathology can range from incipient membrane inflammation to fully opacified sinuses.

Clinical Implications.

The implant clinician must have a working knowledge of the maxillary sinus anatomy, anatomic variants, and associated pathology. It is imperative the patency of the maxillary ostium be determined prior to placement of an implant or bone graft into the maxillary sinus. To minimize postoperative morbidity, the clinician must understand the indications for otolaryngologist (ENT) referral and clearance prior to any procedures that would involve grafting procedures into the maxillary sinus.

Understanding Paranasal Sinus Anatomy and Physiology

To decrease the morbidity of treatment in the posterior maxilla, knowledge of the important structures of the area must be attained. The implant clinician should evaluate these structures to determine normal anatomy and verify any presence free of anatomic variants and pathology (Fig. 13.5).

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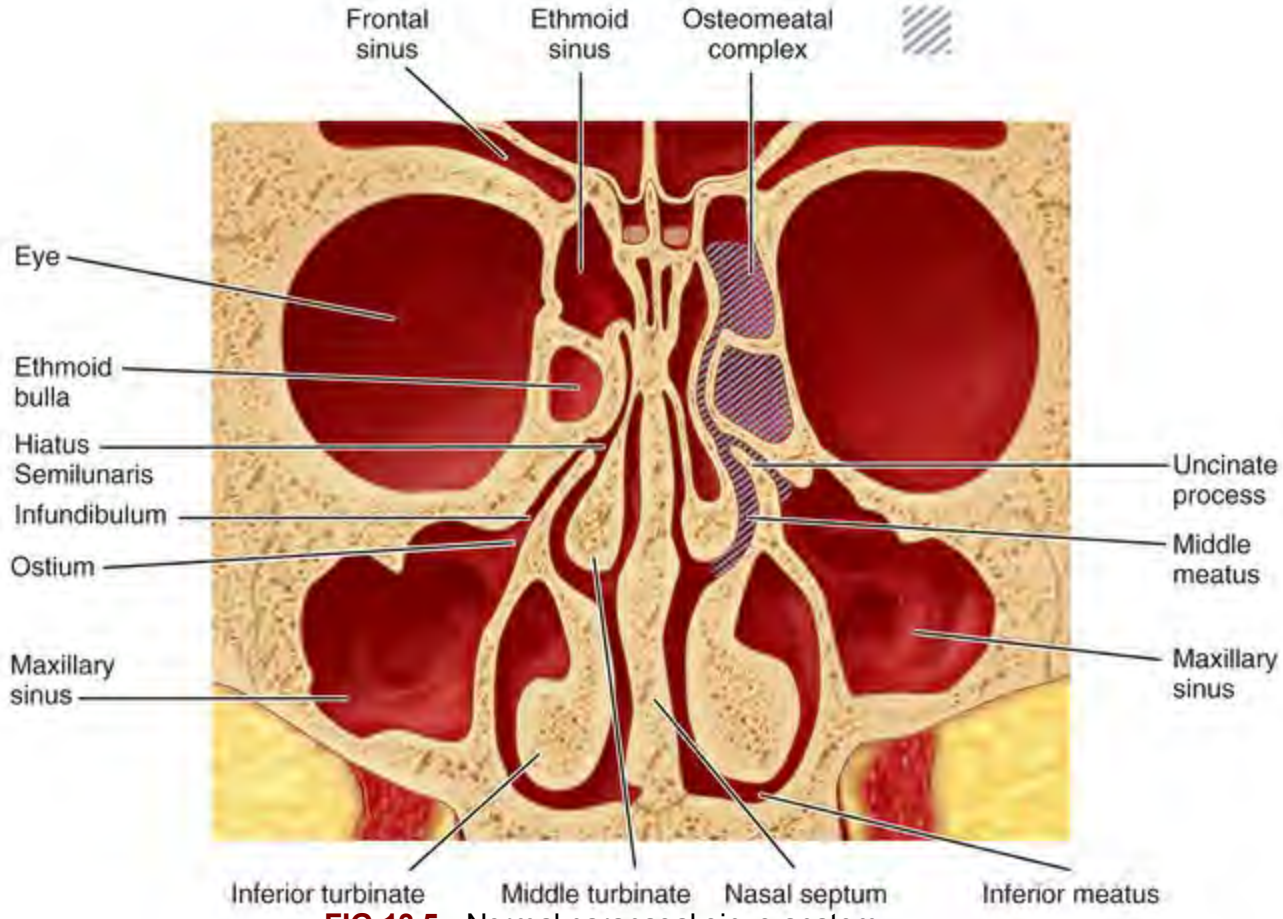

FIG 13.5 Normal paranasal sinus anatomy.

Osteomeatal Complex

The osteomeatal unit is composed of the maxillary ostium, ethmoid infundibulum, anterior ethmoid cells, hiatus semilunaris, and the frontal recess, which encompasses the area of the middle meatus. This common channel allows for air flow and mucociliary drainage of the frontal, maxillary, and anterior ethmoid sinuses. Blockage in this area leads to impaired drainage of the maxillary, frontal, and ethmoid sinuses, which may result in rhinosinusitis and postoperative complications after implant or grafting procedures.

Clinical Implications.

Radiographic identification of the osteomeatal complex and related structures must be evaluated to prevent potential postoperative complications. Pathology or variations within the osteomeatal complex may lead to postoperative sinus graft morbidity or implant complications due to compromised mucociliary drainage (alteration of normal sinus physiology) of

the maxillary sinus.

Maxillary Ostium

The main drainage avenue of the maxillary sinus is through the maxillary ostium. The primary ostium is located in the superior aspect of the sinus medial wall and drains its secretions via the ethmoid infundibulum through the hiatus semilunaris into the middle meatus of the nasal cavity. The infundibulum is approximately 5 to 10 mm long and drains via ciliary action in a superior and medial direction. The ostium diameter averages 2.4 mm in health; however, pathologic conditions may alter the size to vary from 1 to 17 mm.[1]

The maxillary ostium and infundibulum are part of the anterior ethmoid middle meatal complex, the region through which the frontal and maxillary sinuses drain, which is primarily responsible for mucociliary clearance of the sinuses to the nasopharynx. As a result, obstruction in one or more areas of the complex will usually result in rhinosinusitis or lead to morbidity of the graft or implant.

Clinical Implications.

Patency of the maxillary ostium is most crucial pre- and postoperatively during maxillary graft sinus surgery to prevent infection and morbidity of the graft. Evaluating the patency of the ostium via a CBCT is easily accomplished with evaluation of serial cross-sectional images. A prophylactic regimen including antibiotics and corticosteroids should always be utilized when grafting or during implant placement in the sinus proper to maintain patency of the ostium during the postoperative period.

Schneiderian Membrane

The epithelial lining of the maxillary sinus is a continuation of the nasal mucosa and is classified as a pseudostratified, ciliated columnar epithelium, also called respiratory epithelium. The epithelial lining of the maxillary sinus is much thinner and contains fewer blood vessels than the nasal epithelium. This accounts for the membrane's pale color and bluish hue. Five primary cell types exist in this tissue: (1) ciliated columnar epithelial cells, (2) nonciliated columnar cells, (3) basal cells, (4) goblet cells, and (5) seromucinous cells. The ciliated cells contain approximately 50 to 200 cilia per cell. In a healthy maxillary sinus the cilia cells assist in clearing mucus

from the sinus and into the nasopharynx. The nonciliated cells compose the apical aspect of the membrane, contain microvilli, and serve to increase surface area. These cells have been theorized to facilitate humidification and warming of inspired air. The basal cell's function is similar to that of a stem cell that can differentiate as needed. The goblet cells in the maxillary sinus produce glycoproteins that are responsible for the viscosity and elasticity of the mucus produced. The maxillary sinus contains the highest concentration of goblet cells in comparison with the other paranasal sinuses. The maxillary sinus membrane also exhibits few elastic fibers attached to the bone[7] (no tenacious attachment is usually present), which simplifies elevation of this tissue from the bone during grafting procedures. The thickness of the sinus mucosa in health varies, but is generally 0.3 to 0.8 mm.[8] In smokers, it varies from very thin and almost nonexistent to very thick, with a squamous type of epithelium.

Radiographic Evaluation.

A CBCT scan of normal, healthy paranasal sinuses reveals a completely radiolucent (dark) maxillary sinus. Any radiopaque (whitish) area within the sinus cavity is abnormal, and a pathologic condition should be suspected. The normal sinus membrane is radiographically invisible, whereas any inflammation or thickening of this structure will be radiopaque. The density of the diseased tissue or fluid accumulation will be proportional to varying degrees of gray values.

Clinical Implications.

Maintaining the integrity of the sinus membrane is crucial in decreasing postoperative complications, including loss of graft material and the possibility of infection. Many factors may alter the physiology of the sinus mucosa such as viruses, bacteria, and foreign bodies (implants). Care should be taken to minimize membrane perforations during surgery. If perforations occur, appropriate repair treatment protocols should be adhered to (see Sinus Perforations).

Mucociliary Drainage

Normal mucociliary flow is crucial to maintaining the healthy physiology of the maxillary sinus. In a healthy sinus an adequate system of mucus production, clearance, and drainage is maintained. The key to normal sinus

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physiology is the proper function of the cilia, which is the main component of the mucociliary transport system. The cilia move contaminants toward the natural ostium and then to the nasopharynx. The cilia of the columnar epithelium beat toward the ostium at 15 cycles per minute, with a stiff stroke through the serous layer, reaching into the mucoid layer. They recover with a limp reverse stroke within the serous layer. This mechanism slowly propels the mucoid layer toward the ostium at a rate of 9 mm per minute and into the middle meatus of the nose.[8]

In health, mucoid fluid is transported toward the ostium of the maxillary sinus and drains into the nasal cavity, eliminating inhaled small particles and microorganisms. This mucociliary transport system is an active transport system that relies heavily on oxygen. The amount of oxygen absorbed from the blood is not adequate to maintain this drainage system; additional oxygen has to be absorbed from the air in the sinus. This is why the patency of the ostium is crucial in maintaining the normal transport system.

Various elements may decrease the number of cilia and slow their beating efficiency. Viral infections, pollution, allergic reactions, and certain medications may affect the cilia in this way.[9] Genetic disorders (e.g., dyskinetic cilia syndrome) and factors such as longstanding dehydration, anticholinergic medications and antihistamines, cigarette smoke, and chemical toxins also can affect ciliary action (Fig. 13.6).

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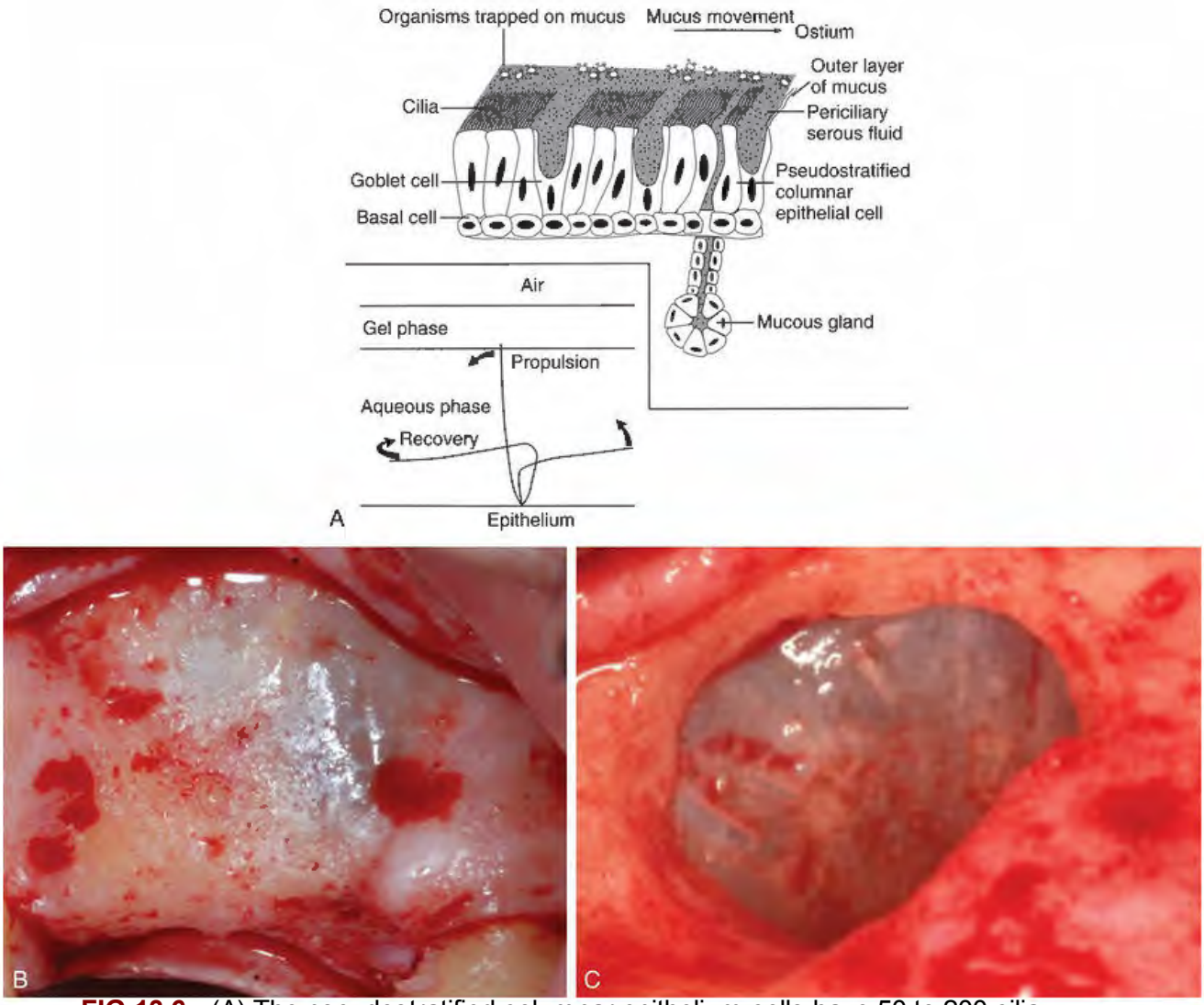

FIG 13.6 (A) The pseudostratified columnar epithelium cells have 50 to 200 cilia per cell that beat toward the ostium to help clear 1 L of mucus from goblet and mucous glands each day from the sinus. In health the mucous has two layers: a bottom serous layer and top mucoid layer. The cilia beat with a stiff stroke in the mucoid layer toward the ostium and a relaxed recovery stroke within the serous layer. (B) Clinical image depicting the thinness of the lateral wall and showthrough (dark blue) of the Schneiderian membrane. (C) The bluish hue of the membrane after lateral wall window preparation.

Clinical Implications.

An alteration in the sinus ostium patency or the quality of secretions can lead to disruption in ciliary action, which may result in rhinosinusitis.

For clearance to be maintained, adequate ventilation is necessary. Ventilation and drainage is dependent on the osteomeatal unit, which is the main sinus opening. Ciliary movements of ciliated epithelial cells dictate clearance of the maxillary sinus. It is important to maintain the patency of

the maxillary ostium and the osteomeatal complex in the postoperative period.

The physiologic mucociliary transport system may be compromised by abnormalities in the cilia, which include a decrease in overall ciliary number and poor coordination of their movement. This altered physiology may result in an increased morbidity of implant placement or bone graft healing. Therefore, it is crucial that the mucociliary drainage mechanism be maintained throughout the postoperative treatment period. This is most likely accomplished with good surgical technique, evaluation and treatment of prior drainage issues, and strict adherence to the use of pharmacologic agents (e.g., antibiotics, corticosteroids).

Maxillary Sinus Flora

There is much debate on the bacterial flora of the maxillary sinus. Maxillary sinuses have been considered to be sterile in health; however, bacteria can colonize within the sinus without producing symptoms. In theory, the mechanism by which a sterile environment is maintained includes the mucociliary clearance system, immune system, and the production of nitric oxide within the sinus cavity. In recent endoscopic studies, normal sinuses were shown to be nonsterile, with 62.3% exhibiting bacterial colonization. The most common bacteria cultured were *Streptococcus viridans, Staphylococcus epidermidis,* and *Streptococcus pneumonia*.[10] The culture findings for secretions in acute maxillary sinusitis yielded high numbers of leukocytes, *S. pneumoniae,* or *Streptococcus pyogenes,* with *Haemophilus influenzae* being recovered from the purulent exudates with lower numbers of staphylococci. Other reports have indicated the bacterial flora of the maxillary sinus consists of nonhemolytic and alpha-hemolytic streptococci, as well as *Neisseria* spp. Additional microorganisms identifiable in various quantities belong to staphylococci, *Haemophilus* spp, pneumococci, *Mycoplasma* spp, and *Bacteroides* spp. This is important to note because the sinus graft procedure often violates the sinus mucosa, and bacteria may contaminate the graft site leading to post-operative complications.[1]

Clinical Implications

Sterile technique.

The implant clinician must understand the importance of reducing the bacterial count and possible microorganisms that may initiate infections in

the maxillary sinus. A strict aseptic technique should be adhered to during any surgical procedures that invade the maxillary sinus proper. This will minimize the possibility of bacterial colonization within the graft, which may lead to increased morbidity.

Antibiotic.

The type of bacteria inhabiting the sinus is very important because it dictates what antibiotic is prescribed preoperatively, postoperatively, and therapeutically in case of infection. The most common bacteria present in the sinus must be susceptible to the specific antibiotic to prevent infection and decrease the morbidity of the graft. The antibiotic selected should not be the clinician's "favorite" but should be the most ideal antibiotic, which is specific for the involved bacteria. Ideally, Augmentin (875/125 mg) has been shown to be most effective in the maxillary sinus.

Blood Supply

The vascular supply in the maxillary sinus is a vital part of the healing and regeneration of bone after a sinus graft and healing of a dental implant. The blood supply to the maxillary sinus comes directly from the maxillary artery, which emanates from the external carotid artery. The maxillary artery supplies the bone surrounding the sinus cavity and also the sinus membrane. Branches of the maxillary artery, which most often include the posterior superior alveolar artery and infraorbital artery, form endosseous and extraosseous anastomoses that encompass the maxillary sinus. The formation of the endosseous and extraosseous anastomoses in the maxillary sinus is termed the *double arterial arcade*. Studies have shown vascularization of postgraft material to depend on the intra- and extraosseous anastamoses, along with the blood vessels of the Schnedierian membrane, which is supplied by the posterior superior alveolar artery and the infraorbital artery along the lateral wall.[11]

There exists different factors that alter the vascularization in this area. With increasing age the number and size of blood vessels in the maxilla decrease. As bone resorption increases, the cortical bone becomes thin, resulting in less vascularization. As the lateral wall becomes thinner, the blood supply to the lateral wall and lateral aspect of the bone graft comes primarily from the periosteum, resulting in a compromised vascularization to the region.

Extraosseous Anastomosis.

Extraosseous anastomosis is found in approximately 44% of the population and is usually in close approximation to the periosteum of the lateral wall. The extraosseous anastomosis is superior to the endosseous unit, which is approximately 15 to 20 mm from the dentate alveolar crest.

Complication prevention.

To minimize vascular trauma to the extraosseous anastomosis, surgical and anatomic considerations should be addressed. Ideally, vertical incisions should be made as short as possible to decrease the possibility of blood vessel damage. It is crucial to gain adequate access to the lateral aspect of the maxilla, and the periosteum should be reflected full thickness with great care. Haphazard reflection may lead to severing or damage to the anastomosis with resultant postoperative edema.

Treatment implication.

Severing of the extraosseous anastomosis may result in significant increased bleeding during the surgical procedure. This intraoperative complication may give rise to impaired visibility for the clinician along with increased surgery duration. Additionally, postoperative complications such as pain, edema, and ecchymosis may result from the severing of these blood vessels.

If trauma to these vessels occurs, direct pressure or the use of electrocautery may be used. However, electrocautery may potentially cause membrane damage or necrosis. If severe bleeding occurs, curved Kelly hemostats are used to clamp the bleeding vessel followed by ligature placement. A slowly resorbable suture with high tensile strength such as Vicryl is recommended.

Intraosseous Anastomosis.

The intraosseous anastomosis is found within the lateral wall of the sinus, which supplies the lateral wall and the sinus membrane. In an edentulous maxilla with posterior vertical bone loss, the endosseous anastamosis may be 5 to 10 mm from the edentulous ridge. The endosseous artery has been shown to be observed on CBCT scans in approximately one half of the patients requiring a sinus graft.[12] However, anatomic cadaver studies have shown the prevalence to be 100%.[13] In 82% of cases the most common anatomic location was observed between the canine and second premolar

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region.[14] However, with a long-term edentulous patient with a thin lateral wall, the artery may be atrophied and almost nonexistent.

Complication prevention.

Surgical, radiographic, and anatomic considerations should be addressed to minimize trauma to these blood vessels. The CBCT radiographic identification is extremely important in identifying these blood vessels prior to surgery so preparation may be made. Radiographically, smaller anastomoses will not be seen if the pixel size (~1.0 mm) is less than one-half the size of the anastamosis vessel. Using a 0.3 or 0.4 CBCT pixel size for radiographic evaluation will most likely show the smaller anastomoses.[15]

Studies have shown that in 20% of lateral wall osteotomies, significant bleeding complications may occur.[16] This is mainly due to the anastomosis being greater than 1.0 mm in diameter. It has been shown that vessels larger than 1.0 mm are more problematic and associated with significant bleeding, whereas smaller vessels (<1.0 mm) are usually insignificant and easily managed (Fig. 13.7).

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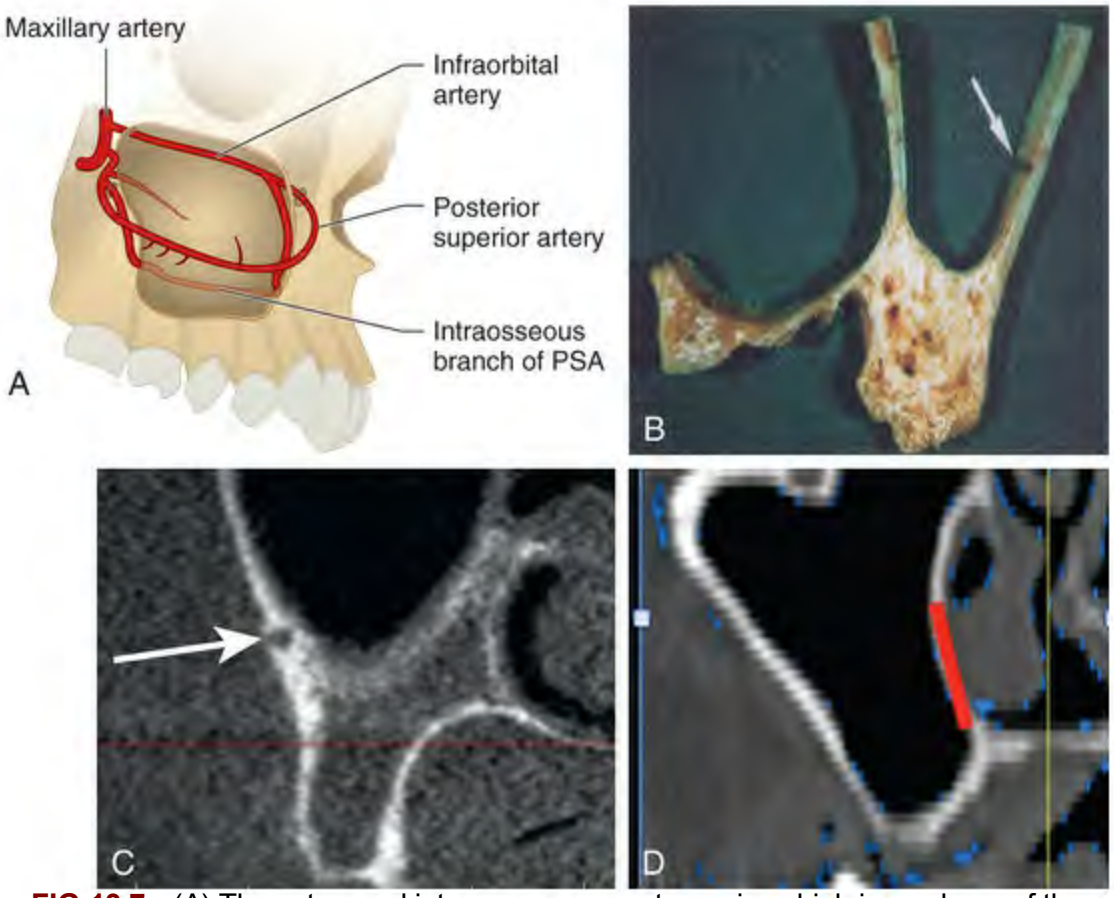

FIG 13.7 (A) The extra- and intraosseous anastomosis, which is made up of the infraorbital and posteriorsuperior artery. (B) Intraosseous notch *(arrow)* containing the intraosseous anastomosis, which comprises the posterior superior artery and infraorbital artery. (C) Cross-sectional CBCT image depicting intraosseous anastamosis *(arrow)*. (D) Posterior lateral nasal artery location in the medial wall of the maxillary sinus.

Treatment implication.

In most cases, bleeding is a minor complication and of short duration; however, in some instances it may be significant and difficult to manage. To control bleeding, there are many possible treatments: (1) the patient should be repositioned into an upright position and pressure applied with a surgical sponge; (2) electrocautery may be used, although this may lead to membrane necrosis and perforation with possible migration of graft material; (3) a second window may be made proximal to the bleeding source to gain access to the bleeding vessel, especially if location cannot be obtained from the original window; and (4) cutting the bone and vessel with a high-speed diamond with no irrigation (which cauterizes the vessel). (See Bleeding Chapter)

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Posterior Lateral Nasal Artery.

A posterior lateral nasal artery (branch of the sphenopalatine artery that also rises from the maxillary artery) supplies the medial aspect of the sinus cavity. The medial and posterior walls of the maxillary sinus mucosa receive their blood supply from the posterior lateral nasal artery.

Complication prevention.

During sinus graft surgery the clinician may be in close approximation to this artery when elevating the membrane off the medial wall. Care should be exercised to minimize trauma to this area because aggressive reflection of the membrane may result in trauma to the blood vessel or perforation into the nasal cavity.

Treatment implication.

Trauma to this artery may cause significant bleeding in the sinus proper and also within the nasal cavity. Because the medial sinus wall is very thin (usually one-half the thickness of the lateral wall), aggressive membrane reflection may result in trauma leading to bleeding issues (see Chapter 7).

Sphenopalatine/Infraorbital Arteries.

The sphenopalatine artery is also a branch of the maxillary artery and enters the nasal cavity through the sphenopalatine foramen, which is near the posterior portion of the superior meatus of the nose. As the sphenopalatine artery exits the foramen, it branches into the posterior lateral nasal artery and the posterior septal artery.[17] Additionally, the infraorbital artery enters the maxillary sinus via the infraorbital fissure in the roof of the sinus and ascends cranially into the orbital cavity. Because of the anatomic locations of these blood vessels, it is rarely a concern with respect to sinus graft surgery.

Complication implications.

The sphenopalatine and infraorbital blood vessels are usually not problematic for bleeding complications during lateral-approach sinus elevation surgery because of their anatomic locations. However, incorrect incision locations and aggressive reflection may damage the blood vessels. If bleeding does occur, it is usually easily controlled with pressure and local hemostatic agents.

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The Anatomic Significance of the Maxillary Sinus Walls

The maxillary sinus features six bony walls, each of which contain important anatomic structures that may cause complications during maxillary sinus graft surgery. The implant clinician should have a strong understanding and foundation of these structures in the preoperative assessment prior to surgical procedures (Fig. 13.8).

FIG 13.8 The six bony walls of the maxillary sinus: anterior, medial, lateral, superior, posterior, and inferior walls.

Anterior Wall

The anterior wall of the maxillary sinus consists of thin, compact bone extending from the orbital rim to just above the apex of the cuspid. With the loss of the canine, the anterior wall of the antrum may approximate the crest of the residual ridge. Within the anterior wall and approximately 6 to 7 mm below the orbital rim, with anatomic variants as far as 14 mm from the orbital rim, is the infraorbital foramen. The infraorbital nerve runs along the roof of the sinus and exits through the foramen. The infraorbital blood vessels and nerves lie directly on the superior wall of the sinus and within the sinus mucosa. The infraorbital nerve gives sensory innervation to the soft tissue from the lower border of the orbit to lateral of the nose to the upper lip (Fig.

13.9A).

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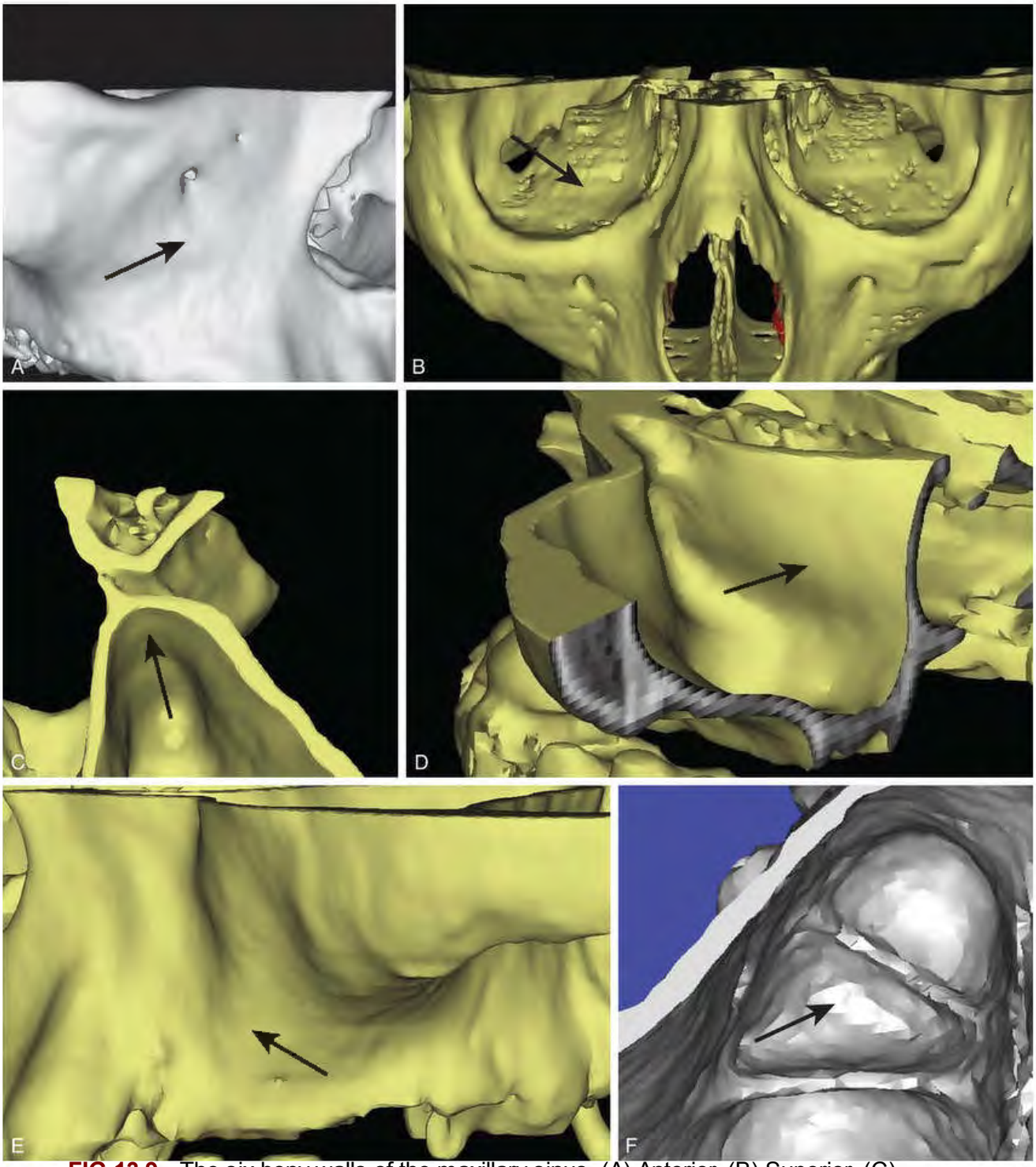

FIG 13.9 The six bony walls of the maxillary sinus. (A) Anterior. (B) Superior. (C) Posterior. (D) Medial. (E) Lateral. (F) Inferior.

Complication Implications

Sinus infection.

Tenderness to pressure over the infraorbital foramen or redness of the

overlying skin may indicate inflammation of the sinus membrane from infection or trauma, which may contraindicate graft surgery until resolution.

Nerve impairment.

In patients exhibiting anatomic variants, neurosensory impairment may occur during retraction of this area leading to neurapraxia type injuries. The use of worn, sharp-edged retractors should be avoided when reflecting tissue superiorly in this area. Within the anterior wall of the sinus, the thinnest part is the canine fossa, which is directly above the canine tooth. The anterior wall of the maxillary sinus may also serve as surgical access during Caldwell-Luc procedures to treat a preexisting or post–sinus graft, pathologic condition.

Superior Wall

The superior wall of the maxillary sinus coincides with the thin inferior orbital floor. The orbital floor slants inferiorly in a mediolateral direction and is convex into the sinus cavity. A bony ridge is usually present in this wall that houses the infraorbital canal, which contains the infraorbital nerve and associated blood vessels. Dehiscence of the bony chamber may be present, resulting in direct contact between the infraorbital structures and the sinus mucosa (Fig. 13.9B).

Complication Implications

Infection.

Ocular symptoms may result from infections or tumors in the superior aspects of the sinus region and may include proptosis (bulging of the eye) and diplopia (double vision). When these problems occur, the patient is closely supervised and a medical consult is advised to decrease the risk of severe complications that may result from the spread of infection in a superior direction. Superior-spreading infections may lead to significant ocular problems or brain abscesses. As a result, when ocular or cerebral symptoms appear, aggressive therapy to decrease the spread of infection is indicated. Overpacking the maxillary sinus with bone graft material during a sinus graft may result in pressure against the superior wall if a sinus infection develops.

Posterior Wall

The posterior wall of the maxillary sinus corresponds to the pterygomaxillary region, which separates the antrum from the infratemporal fossa. The posterior wall usually has several vital structures in the region of the pterygomaxillary fossa, including the internal maxillary artery, pterygoid plexus, sphenopalatine ganglion, and greater palatine nerve. The posterior wall should always be identified on the radiograph. When a posterior wall is not present, a pathologic condition (including neoplasms) is to be suspected (Fig. 13.9C).

Complication Implications

Bleeding.

Common donor sites to obtain autogenous bone for sinus augmentation procedures include the tuberosity area. Special consideration should be taken on the posterior extent of the tuberosity removal. Aggressive tuberosity removal may lead to bleeding in the infratemporal fossa (pterygoid plexus), resulting in life-threatening situations.

Pterygoid implants.

It should be noted that pterygoid implants placed through the posterior sinus wall and into this region might approach vital structures, including the maxillary artery. A blind surgical technique to place a pterygoid implant through the posterior wall may have increased surgical risk. However, they are of benefit primarily when third or fourth molars are needed for prosthetic reconstruction or sinus grafts are contraindicated and available bone posterior to the antrum is present.

Medial Wall

The medial wall of the antrum coincides with the lateral wall of the nasal cavity and is the most complex of the various walls of the sinus. On the nasal aspect the lower section of the medial wall parallels the lower meatus and floor of the nasal fossa; the upper aspect corresponds to the middle meatus. The medial wall is usually vertical and smooth on the antral side. Located in the superior aspect of the medial wall is the maxillary or primary ostium (Fig. 13.9D).

Complication Implications

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Verify patency.

The patency of the ostium must be ascertained prior to surgery to prevent postoperative complications. This is easily verified via coronal or cross-sectional images on CBCT surveys. Of utmost importance is the patency of the ostium, which must be maintained throughout the postoperative period. If ostium patency is compromised, increased morbidity of the graft will occur as the mucociliary action of the maxillary sinus will be compromised.

Accessory ostia.

Smaller, accessory or secondary ostia may be present that are usually located in the middle meatus posterior to the main ostium. These additional ostia are most likely the result of chronic sinus inflammation and mucous membrane breakdown. They are present in approximately 30% of patients, ranging from a fraction of a millimeter to 0.5 cm, and are commonly found within the membranous fontanelles of the lateral nasal wall.[18] Fontanelles are usually classified either as anterior fontanelles (AFs) or posterior fontanelles (PFs) and are termed by their relation to the uncinate process. These weak areas in the sinus wall are sometimes used to create additional openings into the sinus for treatment of chronic sinus infections. Primary and secondary ostia may, on occasion, combine and form a large ostium within the infundibulum.

Lateral Wall

The lateral wall of the maxillary sinus forms the posterior maxilla and the zygomatic process. This wall varies greatly in thickness from several millimeters in dentate patients to less than 1 mm in an edentulous patient. A CBCT examination will reveal the osseous thickness of the lateral wall, which is crucial in defining the osteotomy location and preparation technique. Patients exhibiting increased parafunction forces will have thicker lateral walls (Fig. 13.9E).

Complication Implications

Varying thickness.

The lateral wall thickness of the maxilla has been noted to be extremely variable, with some cases being nonexistent. This will lead to an increased possibility of membrane perforation, even occurring on reflection. In contrast, the lateral wall may be very thick, which is usually seen with patients that exhibit parafunction and have just recently lost the posterior

teeth. In these situations, lateral wall sinus grafting becomes very difficult because of the cortical thickness.

Bleeding.

The lateral wall houses the intraosseous anastamosis of the infraorbital and posterior superior alveolar artery, which may lead to a bleeding complication because this area is the site for osteotomy preparation of the lateral wall sinus graft procedure.

Inferior Wall

The inferior wall or floor of the maxillary sinus is in close relationship with the apices of the maxillary molars and premolars. The teeth usually are separated from the sinus mucosa by a thin layer of bone; however, on occasion, teeth may perforate the floor of the sinus and be in direct contact with the sinus lining. Studies have shown that the first molar has the most common dehiscent tooth root, occurring up to approximately 30% of the time.[19] In dentate patients the floor is approximately at the level of the nasal floor. In the edentulous posterior maxilla the sinus floor is often 1 cm below the level of the nasal floor (Fig. 13.9F).

Complication Implications

Irregular floor.

Radiographically, the sinus inferior floor morphology is easily seen via 3-D imaging. The floor is rarely flat and smooth; the presence of irregularities and septa should be determined and their exact locations noted. Irregular floors are most often seen after teeth are extracted, leaving residual bony crests that increase risk of perforation because of the difficulty in membrane reflection. In some cases, the bony crests are not even seen on the CBCT evaluation.

Septa.

Complete or incomplete bony septa may exist on the floor in a vertical or horizontal plane. Approximately 30% of dentate maxillae have septa, with three fourths appearing in the premolar region. Complete septa separating the sinus into compartments are very rare, occurring in only 1.0% to 2.5% of maxillary sinuses.[20] The presence of septa complicate lateral wall sinus graft procedures, which leads to an increased likelihood of membrane perforation.

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Anatomic Variants

Numerous anatomic variants arise that may predispose a patient to postsurgical complications. When these conditions are noted, a pharmacologic discipline may be altered and/or implants may be placed after the sinus graft has matured, rather than predisposing them to an increased risk by inserting them at the same time as the sinus graft.

Nasal Septum Deviation

The nasal septum is a bony partition and cartilage within the nasal cavity. The cartilage is termed the quadrangular cartilage and the bones are comprised of the maxillary alveolar crest, vomer bone, and the perpendicular plate of the ethmoid. A deviated septum occurs when the cartilaginous ridge leans to the right or left, resulting in an obstruction of the nasal passages that separates the right and left nasal cavities. The *nasal septum* is the bone and cartilage in the nose that separates the *nasal cavity* into the two *nostrils*. Normally, the septum lies centrally, and thus the nasal passages are symmetrical.[5] Studies have shown a prevalence of septal deviation in up to 70% of the population.[21] A deviated septum may be diagnosed by evaluating the coronal or 3-D CBCT images (Fig. 13.10A).

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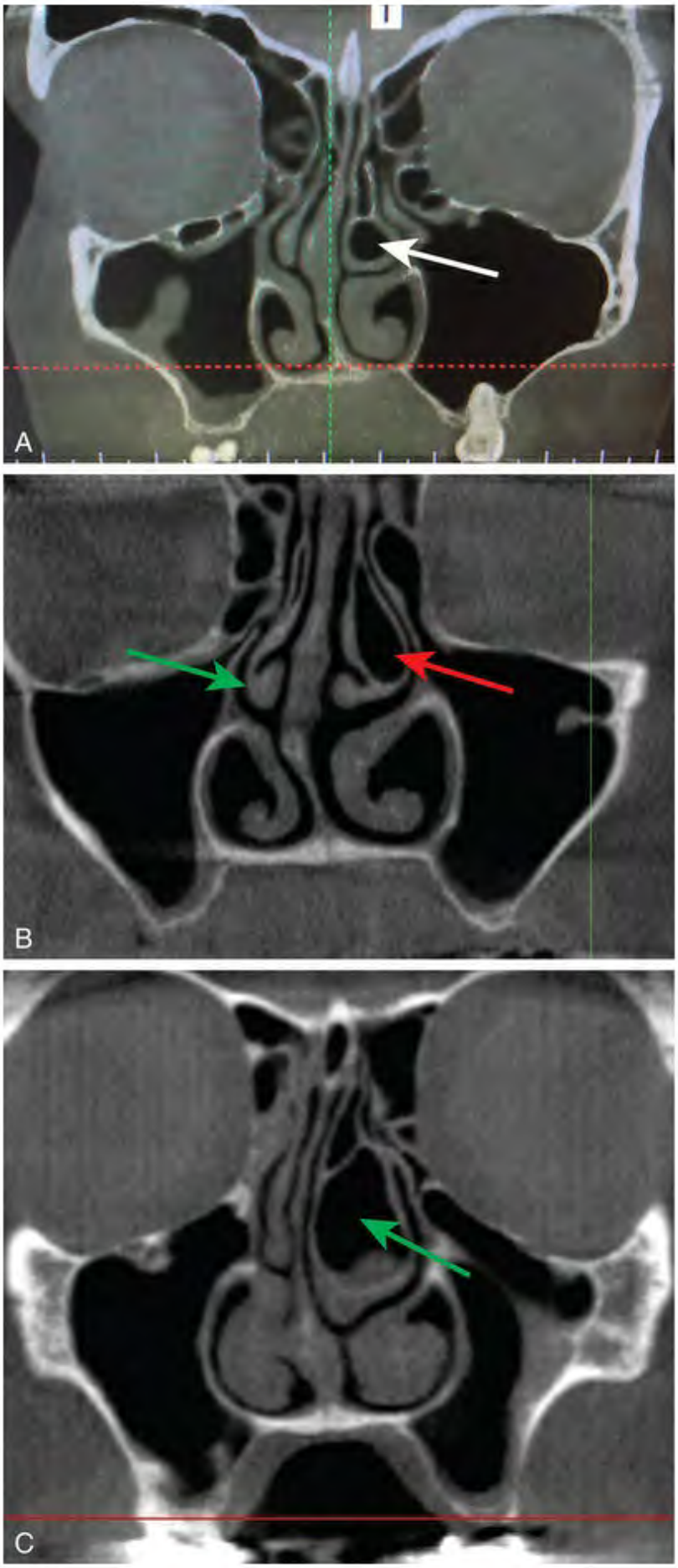

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FIG 13.10 (A) Concha bullosa *(arrow)* and deviated septum. (B) Large left-sided concha bullosa *(red arrow)*, deviated septum to the right, and paradoxical middle turbinate *(green arrow)*. (C) Paradoxical middle turbinate *(green arrow)* exhibiting concavity toward the septum, which may lead to clearance issues.

Complication Implications

Ostium blockage.

When this bony structure is maligned or deviated, the patient may be at risk of postoperative complications. This bony variant in extremes may cause obstruction of the osteomeatal complex, which results in inflammation from air turbulence, causing increased mucosal drying and particle deposition. If deviation is significant, or if preoperative sinus pathology is present, an ENT consultation is recommended. It should be noted that the ipsilateral side usually will have normal clearance issues and less of a possibility of postoperative complications.

Concha Bullosa

The middle turbinate plays a significant role in the proper drainage system of the maxillary sinus. Normally, this bony structure is lined by nasal respiratory mucosa. A variation of the middle turbinate is a *concha bullosa*, which is a pneumatization (air bubble) within the middle turbinate. The most ideal CBCT image to diagnose a concha bullosa is a coronal image. This variant has been shown to be present in approximately 4% to 15% of the population (Fig. 13.10A–B).[22]

Complication Implications

Ostium blockage.

When a concha bullosa is present, the implant clinician should carefully confirm the patency of the maxillary ostium and any pathology in the maxillary sinus. A concha bullosa may decrease the size of the middle meatus, interfering with normal mucociliary flow out of the maxillary sinus. Normally, this variant does not require surgical correction unless patency issues are present for which ENT evaluation and correction are indicated. Usually, corrective surgery includes a turbinectomy, which is the turbinate being reduced in size by endoscopic nasal surgery.

Paradoxical Middle Turbinate

Another variant within the middle turbinate is a paradoxically curved middle turbinate, which presents as a concavity toward the septum (backwards), decreasing the size of the meatus. Normally, the convex side of the middle turbinate will be oriented towards the midline or septum. A paradoxical middle turbinate is most easily seen on a CBCT coronal image with a prevalence of approximately 26% (Fig. 13.10C).

Complication Implications

Ostium blockage.

When present, the implant clinician should carefully confirm the patency of the maxillary ostium and any pathology in the maxillary sinus. The paradoxical middle turbinate may place pressure on the uncinate process, leading to a non-patent maxillary sinus ostium. A paradoxical middle turbinate may decrease the size of the middle meatus, interfering with normal flow out of the maxillary sinus.

Uncinate Process Variants

A deflected uncinate process (either laterally or medially) can narrow the ethmoid infundibulum, which affects the patency of the osteomeatal complex. Perforations may also be present within the uncinate process, leading to communication between the nasal cavity and ethmoid infundibulum. In addition, the uncinate process may be pneumatized and is a common area for ENT intervention in the treatment of chronic rhinosinusitis.

Complication Implications

Ostium blockage.

A deflected uncinate process may lead to narrowing of the flow out of the ostium, causing patency issues. When present, the implant clinician should carefully confirm the patency of the maxillary ostium and any pathology in the maxillary sinus. A deflected uncinate process may decrease the size of the middle meatus, interfering with normal flow out of the maxillary sinus. This may lead to post-operative complications after implant or bone graft surgery in the maxillary sinus.

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Haller Cells

Haller cells, also known as infraorbital ethmoidal air cells or maxilloethmoidal cells, are pneumatized ethmoidal air cells. They project from the orbital floor and arise most often from the anterior ethmoids in approximately 34% of the population.[23] Hallers cells are most easily seen on coronal images.

Complication Implications

Increased incidence of rhinosinusitis.

In most cases, Haller cells are asymptomatic and generally are associated with an increased incidence of rhinosinusitis. They may become infected and potentially extend into the orbit. Additionally, Haller cells may compromise the patency of the maxillary sinus ostium and also have been associated with chronic polypoid disease, which both may compromise and predispose to postsurgical disease (Fig. 13.11).

FIG 13.11 Haller cells. The arrows define Haller cells, which are air cells beneath the ethmoid bulla and along the roof of the maxillary sinus. This anatomical variant may compromise the mucociliary drainage of the maxillary sinus.

Supplemental Ostia

A supplemental ostium or secondary ostia may occur between the maxillary sinus and the middle meatus, which is often found in the posterior fontanelles (PF). The prevalence of supplemental or accessory ostia is approximately 18% to 30%. On occasion, these secondary ostia may be encountered during the membrane elevation off of the medial wall of the antrum, prior to placement of the sinus graft.

Complication Implications

Recirculation.

Because these secondary openings are usually located posterior and inferior to the natural ostium, they may predispose the patient to rhinosinusitis by the recirculation of infected secretions from the primary meatus back into the sinus cavity. The presence of supplemental ostia may increase morbidity for maxillary sinus graft patients. When observed, a piece of collagen is placed over the site to prevent graft material from entering the nasal cavity.

Maxillary Hypoplasia

Hypoplasia of the maxillary sinus may be a direct result of trauma, infection, surgical intervention, or irradiation to the maxilla during the development of the maxillary bone. These conditions interrupt the maxillary growth center, which produces a smaller than normal maxilla. The negative pressure within the maxillary sinus resulting from chronic ostial obstruction impedes the pneumatization process of the sinus, resulting in hypoplasia. Usually, a malformed and positioned uncinate process is associated with this disorder, leading to chronic sinus drainage problems. Maxillary sinus hypoplasia has been reported in 1.73% to 10.4% of patients with sinus symptoms; however, it is sometimes asymptomatic.[24]

Complication Implications

Predisposition to disease.

Although patients with hypoplastic maxillary sinuses exhibit a greater incidence of sinus pathology and clearance issues, the impact on the placement of implants in this area is negligible. Because of the smaller size of the sinus, there is a greater volume of available bone, negating the need for augmentation procedures. Usually, implant placement may be completed well below the inferior border of the sinus (Fig. 13.12).

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FIG 13.12 Hypoplastic maxillary sinus has a high incidence of associated pathology *(arrow)*; however, it will usually have adequate bone for implant placement.

Inferior Turbinate and Meatus Pneumatization (Big-Nose Variant)

A rare anatomic variant, which has a significant impact on implant treatment planning, is an inferior meatus pneumatization, or big-nose variant. When the nasal cavity pneumatizes posteriorly, it will reside over the alveolar residual ridge. This condition is most likely seen on a CBCT panoramic image. The prevalence of this condition has been documented to be approximately 3%.

Complication Implications

Lack of bone for implant placement.

When the patient has this condition, the maxillary sinus is lateral to the edentulous ridge. When inadequate bone height is present below this structure, a sinus graft does not increase available bone height for an implant. If a clinician is unaware of this variant, the implant may inadvertently be placed into the nasal cavity above the residual ridge and has been shown to penetrate the inferior meatus and contact the inferior turbinate. A sinus graft is usually contraindicated with this patient condition because the sinus is lateral to the position of the implants. Instead, an onlay graft is required to increase bone height and width (Fig. 13.13).

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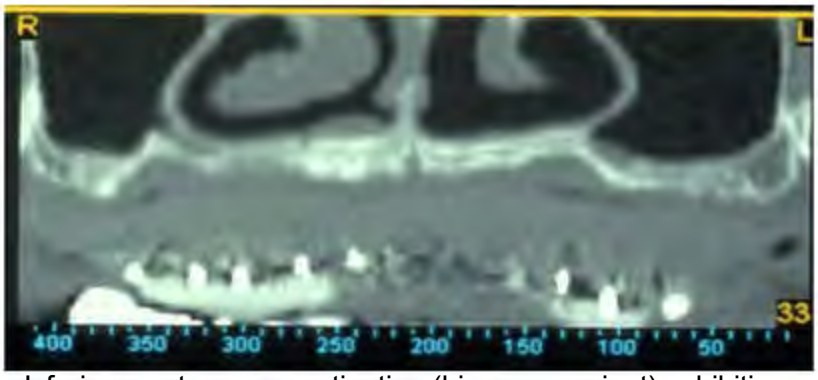

FIG 13.13 Inferior meatus pneumatization (big-nose variant) exhibiting extension of the nasal cavity posterior.

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Pathology

Pathologic conditions associated with the paranasal sinuses are common ailments and afflict more than 31 million people each year. Approximately 16 million people will seek medical assistance related to rhinosinusitis, yet it is one of the most commonly undiagnosed diseases in clinical practice. Potential infection in the region of the sinuses may result in severe complications such as chronic rhinosinusitis, orbital cellulitis, meningitis, osteomyelitis, and cavernous sinus thrombosis. In fact, paranasal sinus infections account for approximately 5% to 10% of all brain abscesses reported each year.[25]

A preexisting, pathologic, maxillary sinus condition is a contraindication for many procedures that alter the sinus floor before or in conjunction with sinus grafting and/or implant insertion. The risk of postoperative infection is elevated and may compromise the health of the implant and the patient. Pathologic conditions, either preoperative or postoperative, of a maxillary sinus should be evaluated, diagnosed, and treated if indicated.

Pathologic conditions of the maxillary sinus may be divided into five categories: (1) inflammation, (2) cystic conditions, (3) neoplasms, (4) fungal, and (5) antroliths/foreign bodies. Studies have shown approximately 45% of the asymptomatic population has a subclinical pathologic condition in the maxillary sinus. A study completed at the Misch International Implant Institute evaluated over 1000 consecutive prospective candidates for maxillary sinus augmentations. The results concluded 32.7% of asymptomatic patients had maxillary sinus pathologic conditions on CBCT scan evaluation. Because of this high incidence, it is highly recommended that a thorough radiographic evaluation be completed on all prospective sinus elevation patients (Fig. 13.22).

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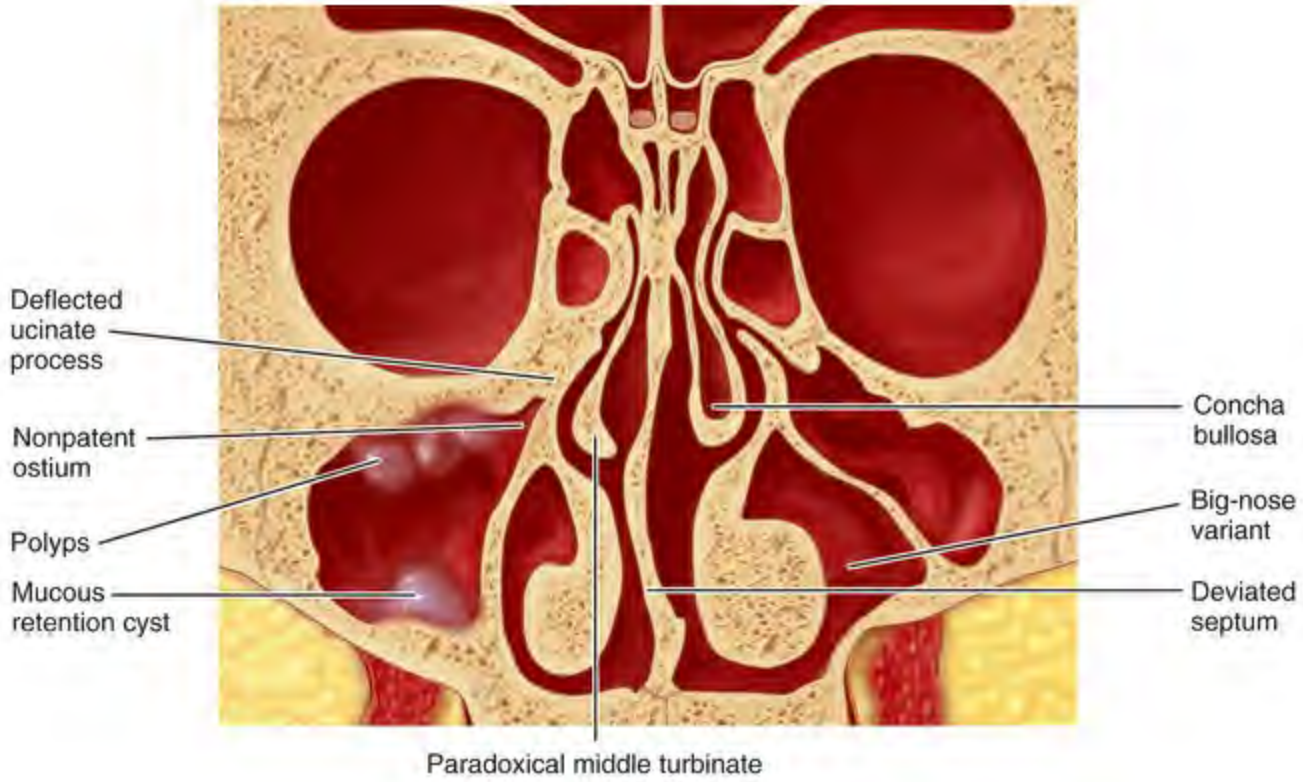

FIG 13.22 Summary of most common pathologic conditions.

Inflammatory

Odontogenic Sinusitis (Periapical Mucositis)

Odontogenic rhinosinusitis occurs when the maxillary sinus membrane is violated by infection of teeth or pathologic lesions of the jaws. The intimate approximation of the roots of the maxillary posterior teeth to the floor of the sinus may result in inflammatory changes of the periodontium or surrounding alveolar bone. These changes may initiate the development of pathologic conditions in the maxillary sinus.

Etiology.

Odontogenic rhinosinusitis is caused by a periapical abscess, cyst, granuloma, or periodontal disease that results in an expansile lesion within the floor of the sinus. Other causes include sinus perforations during extractions and foreign bodies (e.g., gutta-percha, root tips, amalgam). Odontogenic rhinosinusitis is often polymicrobial, with anaerobic streptococci, *Bacteroides* spp, *Proteus* spp, and coliform bacilli being involved. Studies have reported that approximately 30% to 40% of chronic sinusitis cases may have some odontogenic origin when teeth are present in the

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posterior maxilla.[26] Approximately 42% of the time, one or more roots of the maxillary first molar root will protrude into the sinus cavity along with 40% of second molars roots.[27]

Radiographic Appearance.

Periodontitis may produce generalized sinus mucosal hyperplasia, which is seen as a radiopaque band that follows the contours of the sinus floor. A localized periapical mucositis reveals a thickening of the mucous membrane adjacent to the offending tooth and, on occasion, a perforation through to the floor of the sinus. This radiographic appearance has been termed a halo effect (Fig. 13.14A).

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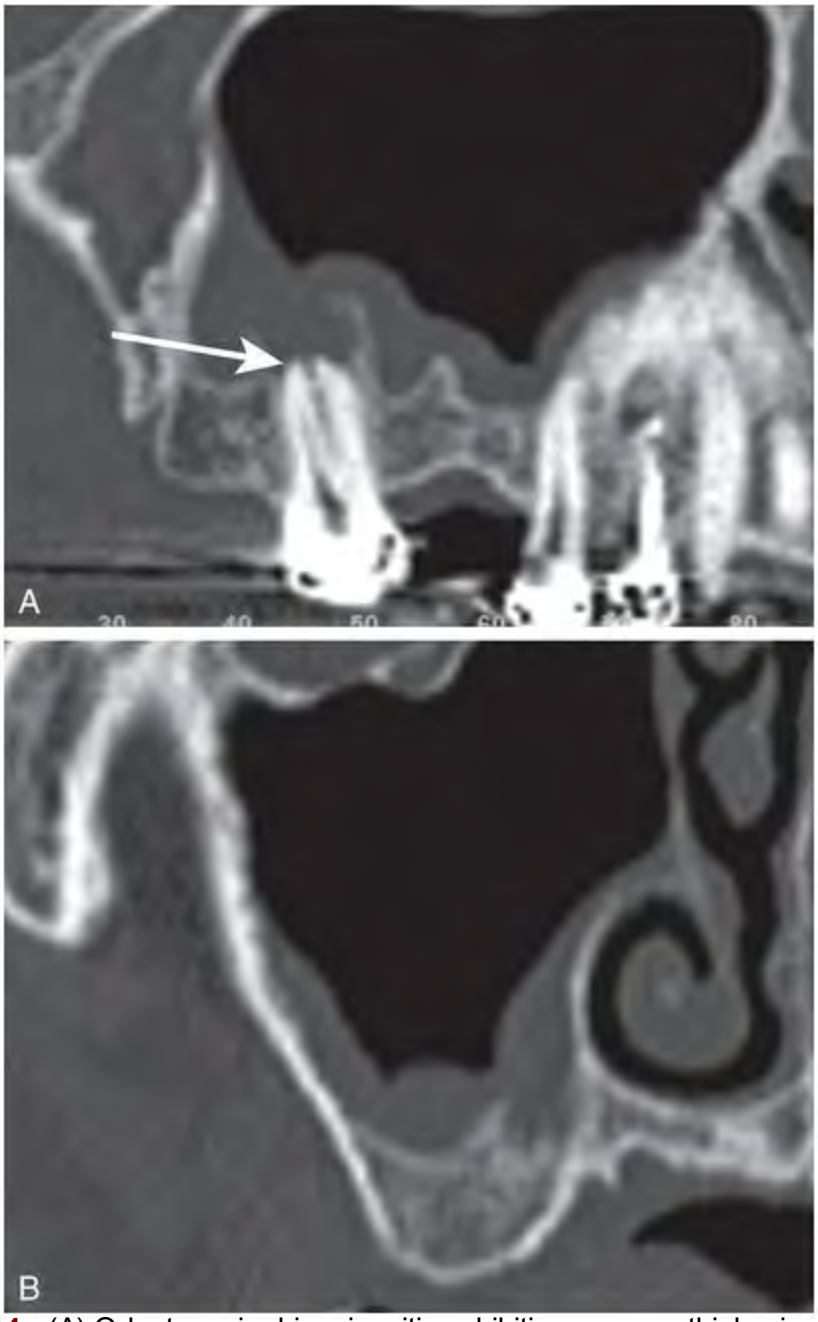

FIG 13.14 (A) Odontogenic rhinosinusitis exhibiting mucosa thickening with the presence of bony septa *(arrow)*. (B) Thickened mucosa generalized on the inferior floor of the sinus.

Differential Diagnosis.

Odontogenic rhinosinusitis presents with a thickening of the mucous membrane adjacent to a diseased tooth exhibiting a radiographic radiopaque band. This condition may be confused with acute rhinosinusitis or mild mucosal thickening. However, in odontogenic rhinosinusitis, the patient has teeth in the posterior maxilla and will usually exhibit symptoms related to

the teeth (e.g., pain from a posterior tooth or a recent extraction, exudate around the existing natural posterior teeth).

Treatment.

Before sinus augmentation or implant placement, the tooth or teeth involved should be treated periodontally or endodontically, or extracted. After intraoral soft tissue healing and resolution of the pathologic condition, the sinus graft procedure may be performed with minimal risk of postoperative complications. A CBCT scan should be taken approximately 12–16 weeks postoperatively to determine sinus status, including sinus ostium patency.

Acute Rhinosinusitis

The most common sinusitis in the maxillary sinus is a nonodontogenic pathologic condition resulting in inflammation and infection termed *acute rhinosinusitis*. The signs and symptoms of acute rhinosinusitis are rather nonspecific, making it difficult to differentiate from the common cold, influenza type of symptoms, and allergic rhinitis. Usually patients will present with symptoms such as purulent nasal discharge, facial pain and tenderness, nasal congestion, and possible fever. Acute maxillary rhinosinusitis results in 22 to 25 million patient visits to physicians in the United States each year, with a direct or indirect cost of 6 billion US dollars.[25]

Etiology.

Acute rhinosinusitis is an inflammatory process that extends from the nasal cavity after a viral upper respiratory infection. Microbiologic cultures have shown the most common pathogens causing acute rhinosinusitis to be *Streptococcus pneumoniae, Haemophilus influenzae,* and *Moraxella catarrhalis.* These pathogens include approximately 20% to 27% beta-lactamase–resistant bacteria. *Staphylococcus aureus* has also been cited with the microbiology of acute rhinosinusitis. However, this pathogen is usually seen only in nosocomial (hospital-induced) sinusitis and is unlikely to be seen in elective sinus graft patients.

The most important factor in the pathogenesis of acute rhinosinusitis is the patency of the ostium.[28] Mucous production within the sinus is usually abnormal in quality or quantity, along with a compromised mucociliary transport. In an occluded sinus, an accumulation of inflammatory cells, bacteria, and mucus exists. Phagocytosis of the bacteria is impaired with

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immunoglobulin (Ig)-dependent activities decreased by the low concentration of IgA, IgG, and IgM found in infected secretions.

The oxygen tension inside the maxillary sinus has significant effects on pathologic conditions. When the oxygen tension in the sinus is altered, rhinosinusitis occurs. Growth of anaerobic and facultative organisms proliferate in this environment. Many factors may alter the normal oxygen tension within the sinuses. A direct correlation exists between the ostium size and the oxygen tension in the sinus. In patients with recurrent episodes of sinusitis, oxygen tension is often reduced, even when infection is not present. As a consequence, a history of recurrent acute rhinosinusitis is relevant to determine whether an implant may be at increased risk when inserted at the same time as the sinus graft.

Radiographic Appearance.

The radiographic hallmark in acute rhinosinusitis is the appearance of an *air-fluid level*. A line of demarcation will be present between the fluid and the air within the maxillary sinus. If the patient is supine (CBCT), the fluid will accumulate in the posterior area; if the patient is upright during the imaging, the fluid will be seen on the floor and be horizontal. Additional radiographic signs include smooth, thickened mucosa of the sinus, with possible opacification. In severe cases, the sinus may fill completely with supportive exudates, which gives the appearance of a completely opacified sinus. With these characteristics the terms *pyocele* and *empyema* have been applied (Fig. 13.15A–B).

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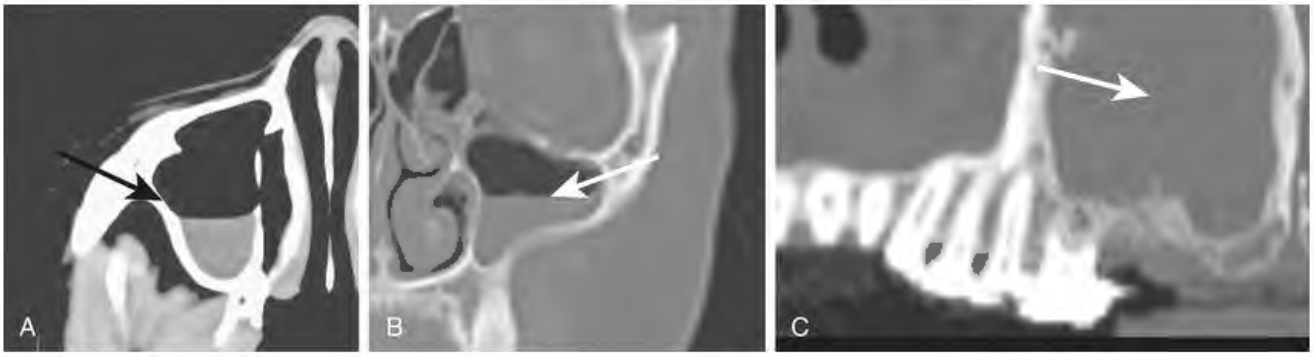

FIG 13.15 (A) Axial CT scan shows an air-fluid level in the right antrum. The attenuation of this fluid is less than that of muscle and typically is watery sinus secretions. This could represent an acutely obstructed sinus, a sinus with poor drainage in a chronically supine (unconscious) patient, or a patient who had a recent antral washing for sinusitis. (B) Coronal CT scan shows a typical air-fluid level in the left antrum with minimal mucosal thickening and obstruction of the ostiomeatal unit. Some mucosal disease is also present in the left ethmoid and right maxillary sinuses. Clinically, this patient had acute sinusitis. (C) Chronic rhinosinusitis may result in a completely opacified maxillary sinus. (A–B, From Som PM, Curtin HD: *Head and neck imaging*, ed 5, St. Louis, 2011, Mosby.)

Differential Diagnosis.

Radiographically, the appearance of an air-fluid level is present with acute rhinosinusitis. The differential diagnosis of acute rhinosinusitis and prolonged viral upper respiratory infection are very similar. However, a classic air-fluid level in the maxillary sinus will give rise to the confirmation of acute rhinosinusitis. Additionally, viral rhinosinusitis will usually improve within 7–10 days, whereas acute bacterial rhinosinusitis most likely will persist for longer than 10 days.[29]

Treatment.

Because acute rhinosinusitis is one of the most common health problems today, patients having sinus augmentation procedures should be well screened for a past history and current symptoms. Even though acute rhinosinusitis is a self-limiting disease, a symptomatic patient should be treated and cleared by the physician before grafting procedures. These patients are also more prone to postoperative rhinosinusitis. As a result, a more conservative approach is to complete the sinus graft and allow for several months of healing before the placement of the implant.

Chronic Rhinosinusitis

Chronic rhinosinusitis is a term used for a sinusitis that does not resolve in 6

weeks and also has recurrent episodes. It is the most common chronic disease in the United States, affecting approximately 37 million people. Symptoms of chronic sinusitis are associated with periodic episodes of purulent nasal discharge, nasal congestion, and facial pain.

Etiology.

As maxillary rhinosinusitis progresses from acute to chronic, anaerobic bacteria become the predominant pathogens. The microbiology of chronic rhinosinusitis is very difficult to determine because of the inability to achieve accurate cultures. Studies have shown that possible bacteria include *Bacteroides* spp, anaerobic gram-positive cocci, *Fusobacterium* spp, as well as aerobic organisms (*Streptococci* spp, *Haemophilus* spp, *Staphylococcus* spp).[30] A recent Mayo Clinic study showed that in 96% of patients with chronic sinusitis, active fungal growth was also present.[31]

Radiographic Appearance.

Chronic rhinosinusitis may appear radiographically as thickened sinus mucosa, complete opacification of the antrum, and/or sclerotic changes in the sinus walls (which give the appearance of denser cortical bone in the lateral walls). Chronic rhinosinusitisis is usually diagnosed from coronal CBCT images.

Treatment.

Medical evaluation and clearance by a physician experienced in sinus pathology is highly recommended for patients with chronic maxillary rhinosinusitis before sinus grafting because significant bacterial resistance and fungal growth is highly probable. Fungal infections may be difficult to treat and control, and serious complications may result in postoperative sinus graft patients. It is imperative that chronic rhinosinusitis patients be cleared by an ENT because these types of patient may be contraindicated for sinus graft surgery (Fig. 13.15C).

Allergic Rhinosinusitis

Etiology.

Allergic rhinosinusitis is a local response within the sinus caused by an irritating allergen in the upper respiratory tract. This allergen may be a cause

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of acute or chronic rhinosinusitis. This category of sinusitis may be the most common form, with 15% to 56% of patients undergoing endoscopy for sinusitis showing evidence of allergy. This condition often leads to chronic sinusitis in 15% to 60% of patients.[32] The sinus mucosa becomes irregular or lobulated, with resultant polyp formation.

Radiographic Appearance.

Polyp formation related to allergic rhinosinusitis is usually characterized by multiple, smooth, rounded, radiopaque shadows on the walls of the maxillary sinus. Most commonly, these polyps are located near the ostium and are easily observed on a CT or CBCT examination. In advanced cases, ostium occlusion, along with displacement or destruction of the sinus walls may be present, with a radiographic image of a completely opacified sinus.

Treatment.

Special attention must be given to these patients to ensure a patent ostium and lack of bacterial resistance. Close postoperative supervision is highly recommended. The polyp, if enlarged, may be removed before the sinus graft by an ENT. This may be performed through an anterior Caldwell-Luc approach or by an endoscopic procedure through the ostium.

Allergic rhinosinusitis patients often have a greater risk of complications related to an increase in allergen production. Because sinus grafting is an elective procedure, the time of year for the surgery may be altered to decrease the postoperative infection risk. For example, if hay fever or a grass allergy is related to the patient's sinusitis, the sinus graft surgery should be performed in the season or seasons that have least risk to aggravate the sinus mucosa (i.e., winter or fall) (Fig. 13.16).

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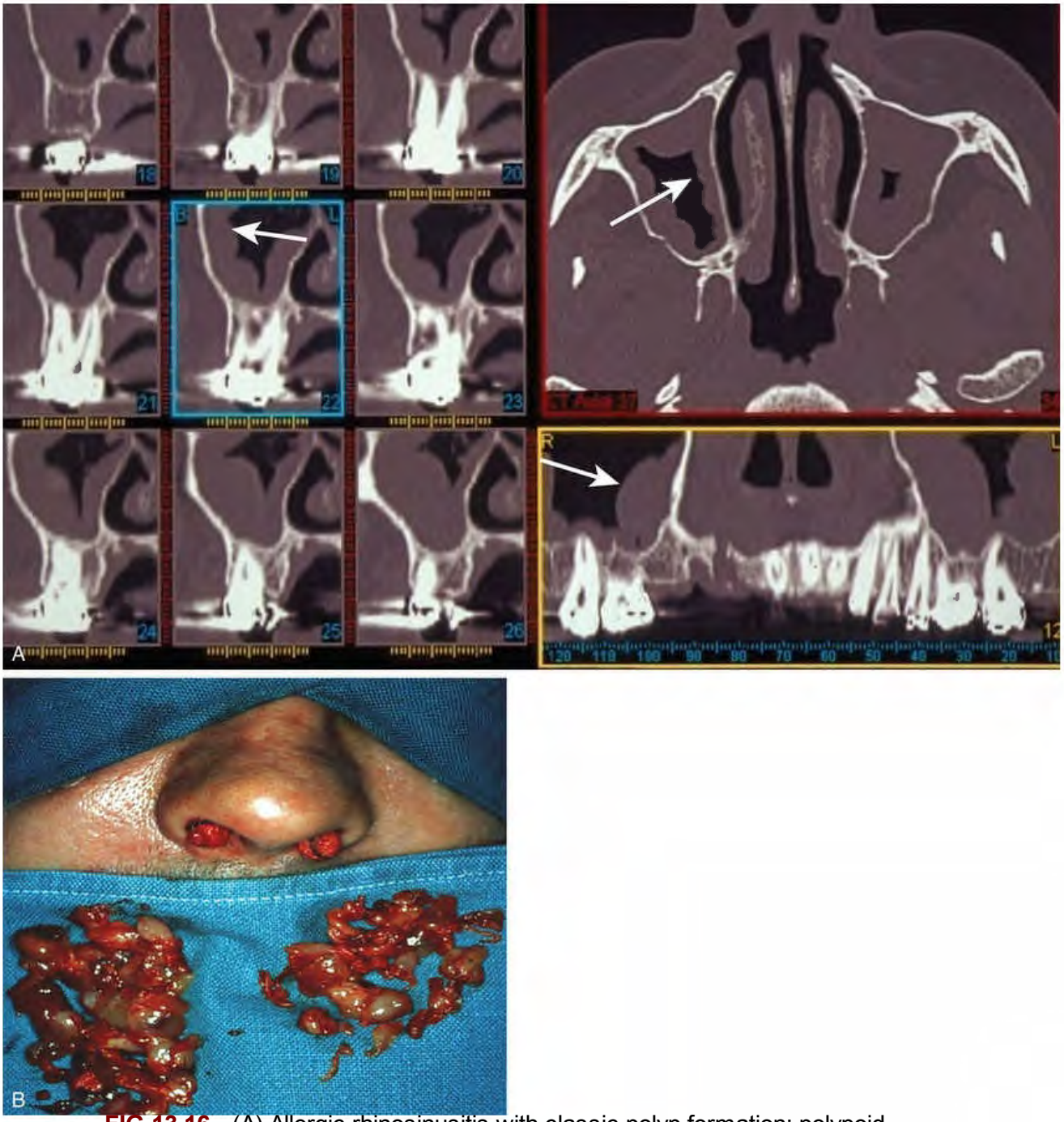

FIG 13.16 (A) Allergic rhinosinusitis with classic polyp formation; polypoid pathology circumferentially on sinus walls. (B) Surgical removal of polyps.

Cystic Lesions

Cystic lesions are a common occurrence in the maxillary sinus, and studies have reported a prevalence range of 2.6% to 20%.[34] They may vary from microscopic lesions to large, destructive, expansile pathologic conditions, which include pseudocysts, retention cysts, primary mucoceles, and

postoperative maxillary cysts.

Pseudocysts (Mucous Retention Cyst)

The most common cysts in the maxillary sinus are mucous retention cysts. After much controversy, in 1984, Gardner[35] distinguished these cysts into two categories: (1) pseudocysts and (2) retention cysts. Pseudocysts are more common and are of much greater concern during sinus graft surgery, compared with retention cysts. Pseudocysts reoccur in approximately 30% of patients and are often unassociated with sinus symptoms. As a consequence, many physicians do not treat these lesions. However, when their size is larger than 10 mm in diameter, pseudocysts may occlude the maxillary ostium during a sinus graft procedure and increase the risk of postoperative infection.

Etiology.

A pseudocyst is caused by an accumulation of fluid beneath the periosteum of the sinus mucosa, which elevates the mucosa away from the floor of the sinus, giving rise to a dome-shaped lesion. Pseudocysts have also been termed *mucosal cysts*, *serous cysts*, and *nonsecreting cysts*. Damage to the capillary walls from bacterial toxins (e.g., diseased tooth) results in the loss of intravascular proteins and fluid. The accumulation of the exudate in the connective tissue forms areolar spaces that will coalesce into a single cavity that is lined by fibroblasts, not from epithelium. Thus, pseudocysts are not true cysts because they lack an epithelial lining. The cause of the fluid is bacterial toxins from the sinus mucosa or from odontogenic sources. Histologically, the pseudocyst appears as a smooth, light blue, translucent structure filled with a thin, clear, yellowish fluid.[35a]

Radiographic Appearance.

Pseudocysts are depicted radiographically as smooth, homogenous, dome-shaped, round to ovoid, well-defined radiopacities. Pseudocysts do not have a corticated (radiopaque) marginal perimeter and are always located on the floor of the sinus cavity (Fig. 13.17A–B). In rare cases, the pseudocyst can completely opacify the sinus cavity.

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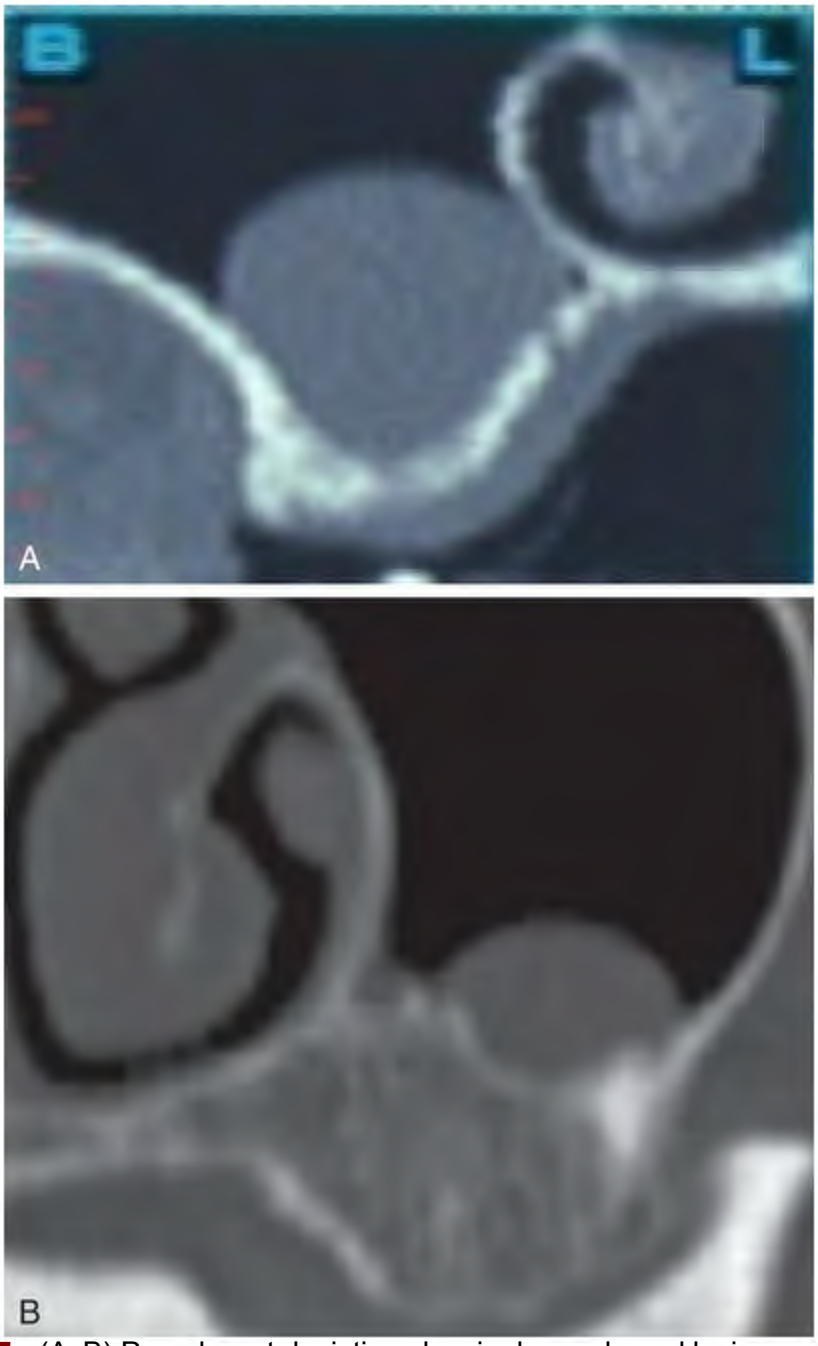

FIG 13.17 (A–B) Pseudocyst depicting classic dome shaped lesion on the sinus floor.

Treatment.

Pseudocysts are usually not a contraindication for sinus graft surgery. If a large pseudocyst is present, the elevation of the membrane during a sinus graft may raise the cyst to occlude the ostium. In addition, on elevation or placement of the grafting material, the cyst may be perforated, allowing fluid within the cyst to contaminate the graft. Large cysts of this nature should be

drained and allowed to heal before or in conjunction with sinus elevation surgery. Most often, an ENT physician should evaluate this condition before the sinus graft. If a pseudocyst is less than 8 mm, less concern is needed and the fluid may be drained in conjunction with sinus grafting, depending on the surgeon's experience in the treatment of this condition. This should be accomplished with care to prevent membrane perforation. A strict recall evaluation of these previously infected areas following sinus graft surgery is in order because reoccurrence of a pseudocyst is common. Many studies have shown the successful placement of dental implants in conjunction with the presence of pseudocysts.[35b-d] In rare cases, the pseudocyst may present with clinical symptoms such as headache or pain that may require surgical intervention.

Retention Cysts

The second type of mucous retention cyst is termed a retention cyst. Retention cysts may be located on the sinus floor, near the ostium, or within antral polyps. Because they contain an epithelial lining, researchers consider them to be mucous secretory cysts and “true” cysts. Retention cysts are often microscopic in size.

Etiology.

Retention cysts result from partial blockage of seromucinous gland ducts located within the connective tissue underlying the sinus epithelium. As the secretions collect, they expand the duct, producing a cyst that is encompassed by respiratory or cuboidal epithelium. They may be caused by sinus infections, allergies, or odontogenic conditions.

Radiographic Appearance.

Retention cysts are usually very small and not seen clinically or radiographically. In rare instances, they may achieve adequate size to be seen in a CT image and may resemble the appearance of a small pseudocyst.

Treatment.

No treatment for retention cysts exists before or in conjunction with a sinus graft and/or implant insertion.

Primary Maxillary Sinus Mucocele

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A primary mucocele is a cystic, expansile, destructive lesion that may include painful swelling of the cheek, displacement of teeth, nasal obstruction, and possible ocular symptoms.[36]

Etiology.

The primary mucocele arises from blockage of the maxillary ostium by fibrous connective tissue. Because of the compromised drainage, the mucosa expands and herniates through the antral walls. The primary mucocele is classified as a cyst because of the epithelial lining, which contains mucin. As the mucoid secretions increase, the protein content of the cyst results in the molality increasing, which attracts more fluid to the lesion. As the hydrostatic pressure increases, the mucocele becomes elevated, resulting in pressure necrosis and bony erosion.[35a]

Radiographic Appearance.

In the early stages, the primary mucocele involves the entire sinus and appears as an opacified sinus. As the cyst enlarges, the walls become thin and eventually perforate. In the late stages, destruction of one or more surrounding sinus walls is evident (Fig. 13.18).

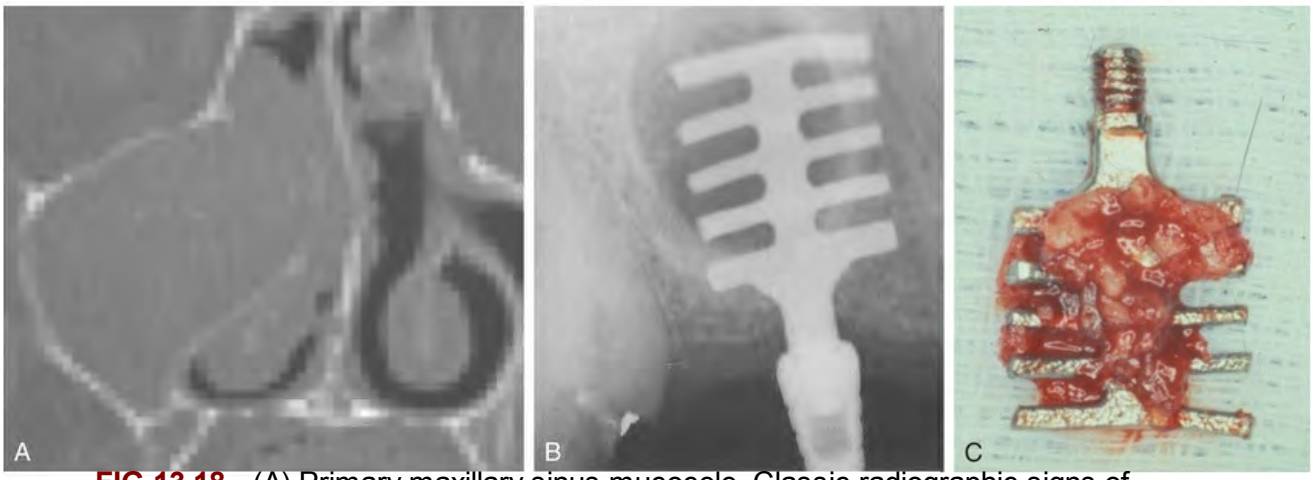

FIG 13.18 (A) Primary maxillary sinus mucocele. Classic radiographic signs of opacified sinus with expansion of the bony walls. (B) Secondary mucocele (surgical ciliated cyst). (C) Blade implant removed with cystic tissue identified to be a surgical ciliated cyst.

Treatment.

This type of lesion requires ENT evaluation and treatment. Surgical removal (e.g., enucleation) of this cyst is indicated before any bone augmentation procedures.

Postoperative Maxillary Cyst (Secondary Mucocele)

A postoperative maxillary cyst of the maxillary sinus is a cystic lesion that usually develops secondary to a previous trauma or surgical procedure in the sinus cavity. It has also been termed a *surgical ciliated cyst, postoperative maxillary sinus mucocele,* or a *secondary mucocele*.[37]

Etiology.

A postoperative maxillary cyst develops as a direct result of trauma or past history of surgery within the maxillary sinus. The cyst is derived from the antral epithelium and mucosal remnants that previously were entrapped within the prior surgical site. This separated mucosa results in an epithelium-lined cavity in which mucin is secreted. The antrum becomes divided by a fibrous septum in which one part drains normally, whereas the other part is composed of the mucocele. It is relatively rare in the United States; however, it constitutes approximately 24% of all cysts in Japan, mainly due to a high incidence of rhinosinusitis.

Radiographic Appearance.

The cyst radiographically presents as a well-defined radiolucency circumscribed by sclerosis. The lesion is usually spherical in the early stages, with no bone destruction. As it progresses, the sinus wall becomes thin and eventually perforates. In later stages, it will appear as two separated anatomic compartments (Fig. 13.18B–C).

Treatment.

Surgical ciliated cysts should be enucleated before any bone augmentation procedures. If observed after the sinus graft, they should be enucleated and regrafted for future implant placement.

Neoplasms

Maxillary sinus neoplasms are relatively rare in United States and are more common in Asia and Africa. They comprise less than 1% of all malignancies,

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with poorly differentiated squamous cell carcinoma being the most common. Most neoplasms of the maxillary sinus remain asymptomatic and sometimes will mimic rhinosinusitis.[37a]

Etiology.

Primary malignant tumors within the maxillary sinus are usually caused by squamous cell carcinomas or adenocarcinomas. Signs and symptoms of malignant disease are related to the surrounding sinus wall that the tumor invades and includes swelling in the cheek area, pain, anesthesia or paresthesia of the infraorbital nerve (e.g., anterior wall), and visual disturbances (e.g., superior wall). These tumors in the sinus are usually nonspecific and give rise to a variety of consequences, including opacified sinuses, soft tissue masses in the sinus, as well as sclerosis, erosion, or destruction of the walls of the sinus. Sixty percent of squamous cell carcinomas of the paranasal sinuses are located in the maxillary sinus, usually in the lower one half of the antrum. Clinical signs in the oral cavity reflect the expansion of the tumor and an increased mobility of the involved teeth. Invasion of the infratemporal fossa is also possible. [25]

Radiographic Appearance.

Radiographic signs of neoplasms may include various-sized radiopaque masses, complete opacification, or bony wall changes. A lack of a posterior wall on a radiograph should be a sign of possible neoplasm (Fig. 13.19).

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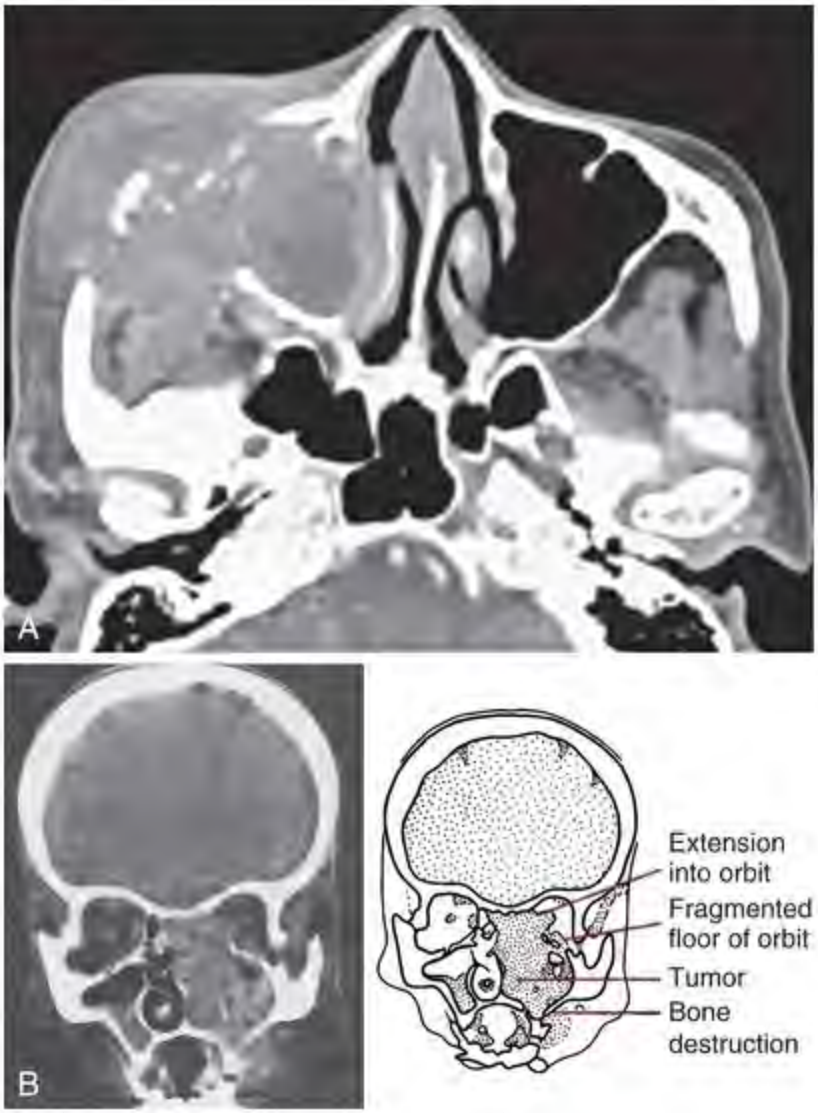

FIG 13.19 Squamous cell carcinoma. (A–B) Carcinomas showing radiopaque lesions extending into the walls.

Treatment.

Any signs or symptoms of a lesion of this type should be immediately referred for medical consultation. Implant placement or sinus grafts in areas affected by neoplasms are contraindicated.

Fungal Rhinosinusitis (Eosinophilic Fungal Rhinosinusitis)

Granulomatous rhinosinusitis is a very serious (and often overlooked) disorder within the maxillary sinus. Patients who have fungal rhinosinusitis are thought to have had an extensive history of antibiotic use or chronic

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exposure to mold or fungus in the environment, or are immunocompromised. The most common classification of fungal rhinosinusitis includes: (1) invasive and (2) noninvasive, which is based on histopathological evaluation of the fungi. The invasive classification includes: (1) acute invasive (fulminant), (2) granulomatous invasive, and (3) chronic invasive. The noninvasive diseases include: (1) saprophytic fungal infestation, (2) fungal ball, and (3) fungus-related eosinophilic.[37b]

Etiology.

Fungal infections are usually caused by aspergillosis, mucormycosis, or histoplasmosis.[33] Chronic rhinosinusitis patients should always be evaluated for granulomatous conditions, because a high percentage of fungal growth exists in this patient population. Of concern in these patients is that eosinophils are activated that release major basic protein (MBP) into the mucus, which attacks and destroys the fungus. However, this results in the membrane being irritated and possibly irreversibly damaged, which allows bacteria to proliferate.

Differential Diagnosis.

Three possible clinical signs may differentiate fungal sinusitis from acute or chronic rhinosinusitis: (1) no response to antibiotic therapy; (2) soft tissue changes in sinus associated with thickened reactive bone, with localized areas of osteomyelitis; (3) association of inflammatory sinus disease that involves the nasal fossa and facial soft tissue. In some cases, a positive diagnosis may require mycologic and histologic studies.

Radiographic Appearance.

Fungal rhinosinusitis is usually unilateral (78% of cases) with bony destruction being very rare. Within the sinuses, the presence of mild thickening to complete opacification may be present. In most cases, varying degrees of density (“double-densities”) are seen (Fig. 13.20).

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FIG 13.20 Fungal rhinosinusitis with radiopaque fungal ball *(arrow)*.

Treatment.

Patients with a history or current knowledge of fungal rhinosinusitis should be referred to their physician or otolaryngologist for treatment and surgical clearance. Treatment usually involves debridement and therapy with an antifungal agent, such as amphotericin B. The history of fungal rhinosinusitis contraindicates elective sinus graft surgery in many cases.

Antroliths

Maxillary Sinus Antroliths

Maxillary sinus antroliths are the result of complete or partial encrustation of a foreign body that is present in the sinus. These masses found within the maxillary sinus originate from a central nidus, which can be endogenous or exogenous.[38]

Etiology.

The majority of endogenous sources are of dental origin, including retained roots, root canal sealer, fractured dental instruments, and dental implants. Additionally, bone spicules, blood, and mucus have been reported to cause

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antroliths. Reports in the literature of exogenous sources include paper, cigarettes, snuff, and glue.[39] Although most antroliths are asymptomatic, they often are associated with rhinosinusitis.

Radiographic Appearance.

The radiographic appearance of a maxillary antrolith resembles either the central nidus (e.g., retained root, dental implant) or appears as a radiopaque, calcified mass within the maxillary sinus (Fig. 13.21A–B).

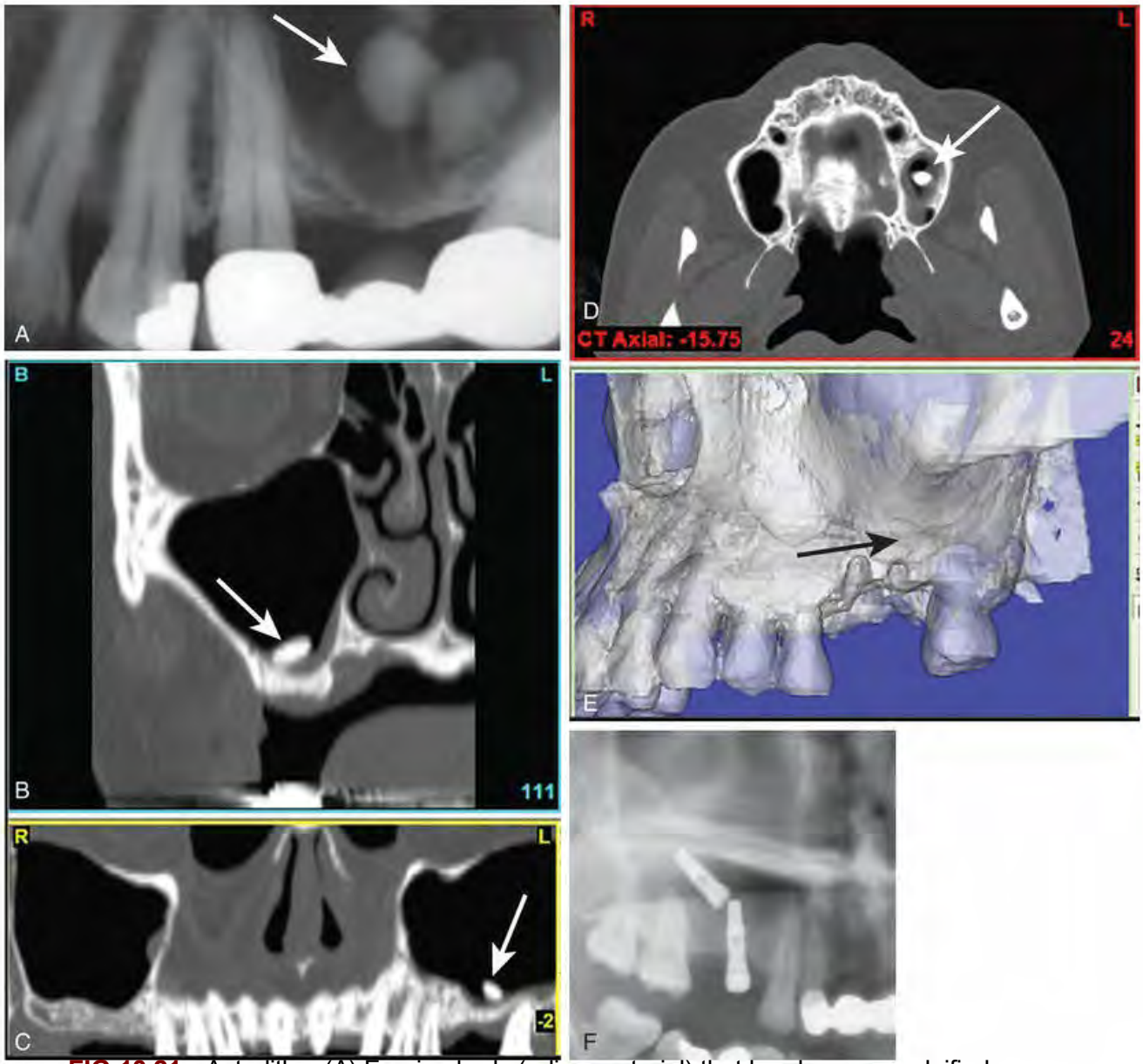

FIG 13.21 Antroliths. (A) Foreign body (reline material) that has become calcified. (B–E) Tooth root antrolith. (F) Migrated implant into the maxillary sinus proper.

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Differential Diagnosis.

Because the calcified antrolith is composed of calcium phosphate ($CaPO_4$), calcium carbonate salts, water, and organic material, it will be considerably more radiopaque than an inflammatory or cystic lesion.[40] The central nidus of the antrolith is similar to its usual radiographic appearance.

Treatment.

Before sinus augmentation and implant placement, the antrolith should be surgically removed. If rhinosinusitis exists, the sinus cavity should be allowed to heal completely before sinus augmentation procedures. In rare asymptomatic situations, the antrolith may be removed, sinus membrane opening sealed, and sinus graft performed at the same surgery.

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Treatment Plan Complications

Not Taking CBCT

In implant dentistry today, a thorough CBCT evaluation of the paranasal sinuses should be completed before placement of implants in the posterior maxilla that violates the maxillary sinus. Of utmost importance is the evaluation and confirmation of ostium patency. Many factors may preclude the sinus to ostium blockage, including pathology, anatomic variants, and foreign bodies. An implant clinician performing sinus augmentation procedures should become well versed in identifying these occurrences during CBCT examination.

Complication Prevention

If implant placement or bone graft procedures are indicated in the posterior maxilla that will violate the maxillary sinus proper, the superior limits of the CBCT should include the ostium to verify patency. If the scan is limited in the superior positioning, ostium patency cannot be accurately ascertained. If pathology is present, the scan will be useless for ENT evaluation if the ostium evaluation is inadequate. This will most likely necessitate a new scan ordered by the ENT.

Treatment Planning Away From Augmentation

Many doctors place themselves at risk when they treatment plan “away” from the maxillary sinus. Because of the inherent disadvantages of the posterior maxilla (e.g., poor bone density, inadequate bone quantity, higher occlusal forces), a decreased success rate and increased implant morbidity exists, especially if treatment plans are compromised. Some of the most common treatment options that would be a compromise would include mini-implants, shorter implants, placing implants at a nonideal angle to avoid the sinus, and zygomatic implants.

These methods are not without their own pitfalls because they pose biomechanical dilemmas to the implant in the prosthetic phase (Fig. 13.23).

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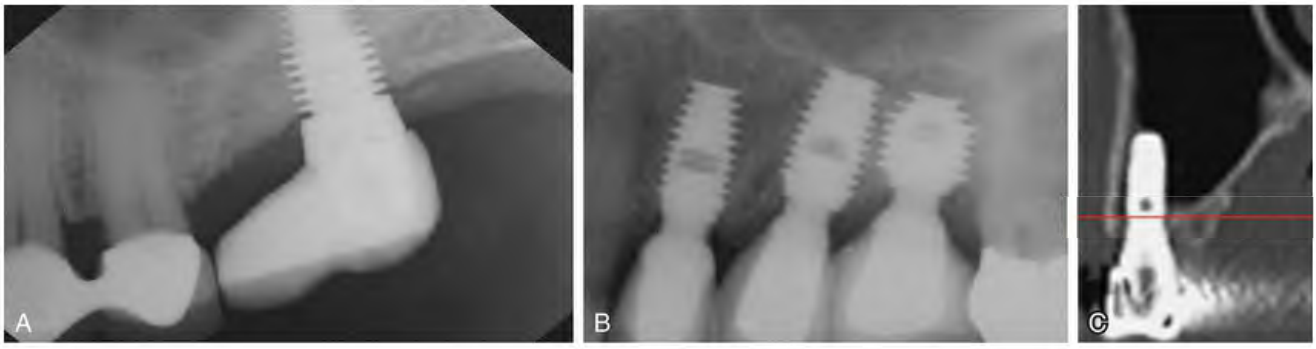

FIG 13.23 Treatment planning to avoid the sinus. (A) Avoiding the sinus via posterior placement and angulation resulting in a significant cantilever which predisposes to a biomechanical failure. (B) Shorter implants. (C) Placement into the sinus without grafting.

Complication Prevention

In 1984, Misch postulated various treatment approaches to the posterior maxilla based on the amount of bone below the antrum, and later to include the available bone width that was related to implant design (Fig. 13.24).[41] In the Misch SA (Sinus Augmentation) classification, the treatment modality is dependent on the available bone height between the floor of the antrum and the crest of the residual ridge in the region of the ideal implant locations. The SA protocol also suggested a surgical approach, ideal bone graft material (layering technique), and a timetable for healing before prosthetic reconstruction.

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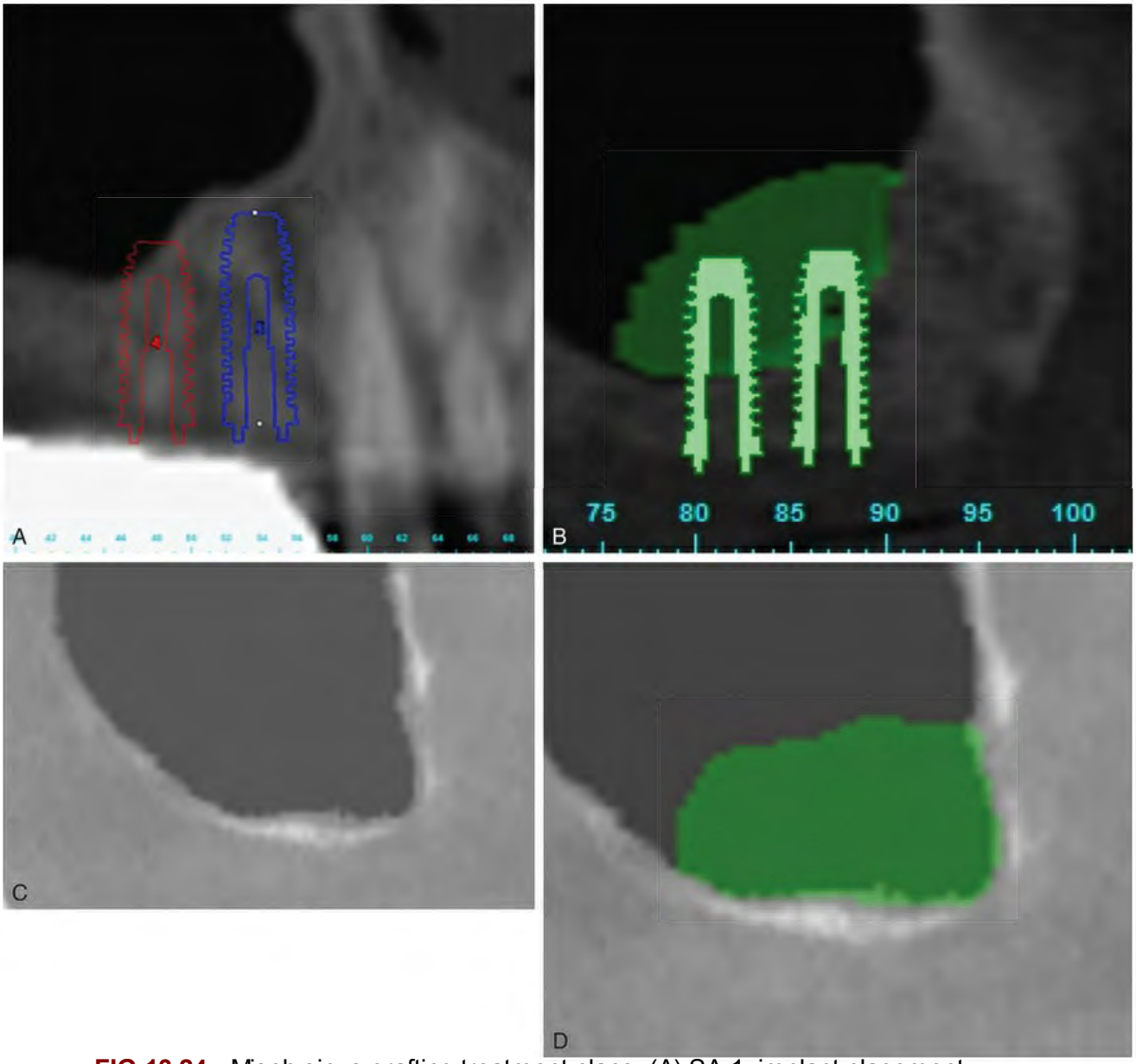

FIG 13.24 Misch sinus grafting treatment plans. (A) SA-1: implant placement without entering the maxillary sinus proper (blue), SA-2: implant placement with minimal penetration into the maxillary sinus, (B) SA-3I: Implant placement at the same time as sinus augmentation, (C–D) SA-4: lack of host bone (<5 mm) requires bone grafting prior to implant placement.

SA-1.

The first Misch SA treatment option, SA-1, occurs when sufficient bone height is available to permit the placement of endosteal implants following a conventional surgical protocol. Because the quality of bone in the posterior maxilla often is D3 or D4 bone (poorer quality), bone compaction to prepare the implant site is common. The use of osteotomes allow for the osteotomy site to be increased in size while allowing for the bone to be laterally

compacted. This permits a more rigid initial fixation of the implant and also increases the bone implant contact (BIC) after initial healing.

Because the maxillary sinus is not violated and the physiology is not changing during an SA-1 approach, it is less critical to evaluate the sinus before implant insertion. The contraindications for sinus graft surgery (e.g., maxillary sinus pathology) do not apply for implant insertion when adequate bone is present below the sinus for implants of adequate size to support the load of the prosthesis. Although a common axiom in implant dentistry is to remain 2 mm or more from an opposing landmark, this is not necessary in the SA region.

Endosteal implants in the SA-1 category are allowed to heal in a nonfunctional environment for approximately 4 to 8 months, which mainly is dependent on the bone density, type of bone graft material, and quantity of graft needed. Special care should be utilized in preventing premature loading of the implants in the posterior maxilla because of the poor bone quality. Therefore, the prosthetic interim prosthesis should be adjusted to prevent overloading. After healing, the prosthetic phase of treatment should include progressive loading, especially if the bone present is D3 or D4.

SA-2.

The second SA option in the Misch SA classification, SA-2, is selected when 10 to 12 mm of vertical bone is present (2 mm less than the minimum height in SA-1). To obtain the 12 mm of vertical bone necessary for improved implant survival (ideal implant length = 12 mm) in ridges of adequate width (division A), the antral floor is partially elevated through the implant osteotomy. The SA-2 surgical approach elevates the floor of the maxillary sinus from 0–2 mm. Even though the sinus floor is minimally altered, this will still change the physiology mucociliary clearance within the maxillary sinus. A preexisting pathologic condition or nonpatent ostium of the sinus should be addressed prior to implant placement because the implant site may be subject to retrograde infection.

The endosteal implant osteotomy is prepared as determined by the density of bone protocol, which is most commonly D3 bone. The depth of the osteotomy is prepared approximately 1 to 2 mm short of the inferior floor of the maxillary sinus. When in doubt of the height dimension, the osteotomy should err on a shorter length to prevent the possibility of membrane perforation. The implant osteotomy procedure should be continued to the same depth (short of the antral floor), until the final width is obtained for

implant placement.

A flat-end or cupped-shape osteotome of the same diameter as the final osteotomy is selected to infracture the floor of the sinus. Caution should be exercised when selecting the appropriate osteotomes as sinus osteotomes are a different shape than osteotomes used for bone spreading. The osteotome is inserted and tapped firmly into the osteotomy in 0.5- to 1.0-mm increments beyond the initial depth before reaching its final vertical position. This should not extend more than 2 mm beyond the prepared implant osteotomy. A slow, careful elevation of the sinus floor is less likely to perforate the sinus mucosa. Because this technique ends with a greenstick-type of fracture, the unprepared bone and sinus membrane over the broad-based osteotome will be elevated to form the new sinus floor.

SA-3.

The third approach to the maxillary posterior edentulous region, SA-3, is indicated when a minimum of 5 mm of vertical bone and sufficient width are present between the antral floor and the crest of the residual ridge. SA-3 sinus augmentation consists of utilizing the Tatum lateral maxillary wall approach and is performed superior to the residual alveolar bone within the confines of the maxillary sinus. After the lateral-access window and membrane are rotated in and upward to a superior position, a mixture of autogenous bone and allograft (layered technique) material are placed in the space previously occupied by the sinus. There are two types of sinus augmentation techniques, the SA-3I (immediate) and SA-3D (delayed) (Box 13.1).

Box 13.1

SA-3 Immediate Vs. SA-3 Delayed Technique

Immediate Implant Placement (SA-3I)

When the endosteal implants are inserted at the same time as the sinus graft, the following conditions should exist:

- Greater than 5 mm bone height
- Greater than 6 mm bone width

- D3 bone quality or better
- No sinus pathologic condition
- No history of recurrent sinusitis
- No relative contraindications
- No or small sinus membrane tear during surgery, completely sealed with collagen
- No parafunction on removable soft tissue-borne prosthesis

Delayed Implant Placement (SA-3D)

Implants should not be inserted at the same time as the sinus graft when the following conditions exist:

- Less than 6 mm bone width
- D4 bone quality
- Treated sinus pathologic condition within last few months
- History of recurrent sinusitis (especially when treated with recurrent antibiotic medications)
- Relative contraindications (smoking, medically compromised patient)
- Medium to large tear in the sinus membrane during the graft surgery
- Parafunction on overlying removable prosthesis

SA-4.

In the fourth option for implant treatment of the posterior maxilla, SA-4, the SA region for future endosteal implant insertion is first augmented, allowed to heal, then implants are placed at a later date. This option is indicated when less than 5 mm remains between the residual crest of bone and the floor of the maxillary sinus. The SA-4 corresponds to a larger sinus cavity along with less host bone on the lateral, anterior, and distal regions of the

graft because the antrum generally has expanded more aggressively into these regions. The inadequate vertical bone in these conditions decreases the predictable placement of an implant (i.e., insufficient bone for initial implant fixation) at the same time as the sinus graft, and less recipient bone exists to act as a vascular bed for the graft. Therefore, with fewer bony walls, a less favorable vascular bed, minimal local autologous bone, and larger graft volume, a longer healing period is mandated with a slightly altered surgical approach.

Systemic Issues: Smoking

Smoking is known to be associated with an increased susceptibility to allergy and infections because it interferes with the ciliary function and secretory immunity of the nasorespiratory tract. In the maxillary sinus, this may have effects on both immune exclusion and suppression because IgA and IgM responses are reduced, whereas IgE responses are increased. Smoking is believed to disturb bone graft healing because it reduces local blood flow by increasing peripheral resistance and by causing increased platelet aggregation.[42] By-product chemicals of smoking, such as hydrogen cyanide and carbon monoxide, have been shown to inhibit wound healing, as does nicotine, which inhibits cellular proliferation. Tobacco may interfere directly with osteoblastic function, and strong evidence exists of decreased bone formation in smokers. In addition, smokers have a significant reduction of bone mineral content. Bone mineral density can be reduced two to six times in a chronic smoker. Overall, smoking may contribute to poor available bone quality and poor healing capacity resulting from vascular and osteoblastic dysfunction.

Smoking is a relative risk factor and has been linked to reduced implant survival outcomes. In an 8-year follow-up study of 13,147 implants placed in 4316 patients, Busenlechner and colleagues[43] found a threefold failure rate increase in smokers compared with nonsmokers. In a recent systematic review, Pjetursson and colleagues found there was almost twice the rate of implant failures in smokers as compared with nonsmokers.[44]

Treatment Implications

Smoking may represent a relative contraindication because of the risk of wound dehiscence, graft infection and/or resorption, and a reduced probability of osseointegration. It is recommended, however, that if a

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decision to proceed with surgery has been made, that patients refrain from smoking at least 14 days before surgery (the time it takes for nicotine to be cleared systemically) and 4 to 6 weeks after surgery. Patients may be referred to their primary physician for the implementation of a smoking cessation program. Moreover, smokers should sign a detailed informed-consent form (both verbally and written) in which risks connected to smoking are clearly explained (See Smoking Cessation Techniques in Chapter 2).

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Intraoperative Complications

Inadequate Anesthesia: V2 Block

In sinus graft surgery, it is advantageous to anesthetize all structures in the general area for the comfort of the patient and hemostasis. The maxillary division of the trigeminal nerve (V2) exits through the foramen rotundum, transverses in the pterygopalatine fossa anterior though the inferior orbital fissure into the posterior maxilla. This nerve innervates all maxillary teeth, gingival tissue, soft tissue of the midface, nasal cavity, and maxillary sinuses, thus encompassing the entire area of interest for sinus graft surgery.

Technique

The technique for achieving anesthesia to all of the above structures with one injection is via the greater palatine canal. The anesthetic needle is inserted through the greater palatine foramen and is advanced into the inferior portion of the pterygopalatine fossa. To assist in locating the greater palatine foramen, an open-bore instrument (e.g., the rounded back end of a mouth mirror handle) can be used to mark the location over the foramen. Pressure is applied with this instrument along the palatal tissue, at the union of the residual ridge and hard palate, in the region of the second molar (approximately 1 cm lingual). The instrument will "fall into" a concavity, which will mark the area over the foramen opening. A long, $1\frac{1}{2}$-inch needle is introduced into the foramen from the opposite side of the mouth and negotiates the canal for approximately 1 inch (depending on length of canal) as anesthetic is slowly administered (Fig. 13.25).

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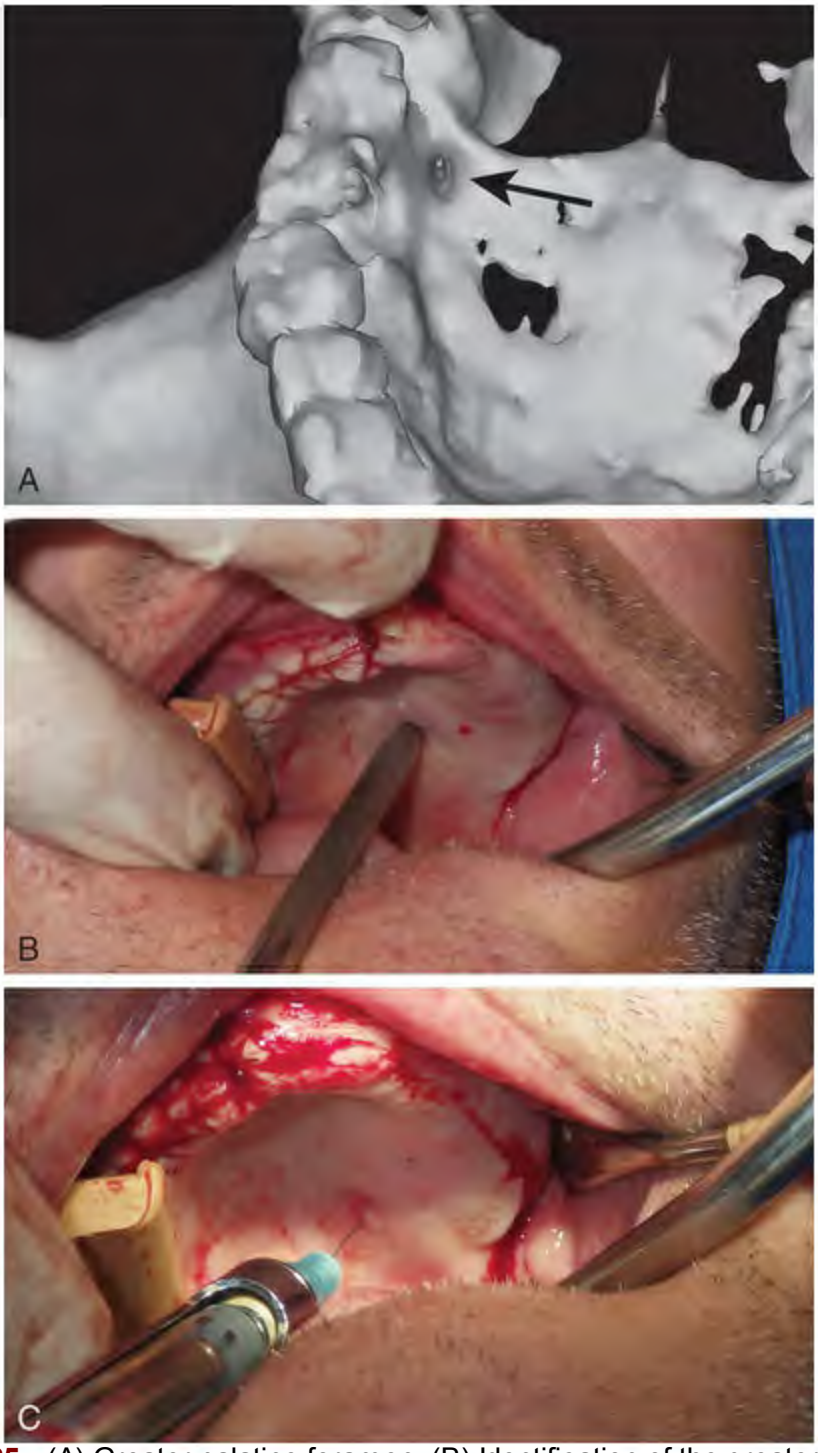

FIG 13.25 (A) Greater palatine foramen. (B) Identification of the greater palatine foramen via the end of a mirror handle, (C) V2 block anesthesia.

Complication Implications

If improper needle positioning occurs, many complications may arise. Errors in medial positioning can lead to nasal bleeding; a needle placed too superior can cause diplopia; incorrect posterior placement can cause coughing;

incorrect placement also results in insufficient anesthesia at the surgical site. Care should be made to prevent intravascular injections (aspiration), which may lead to systemic effects and possible hematoma formation.

Incorrect Window Osteotomy Location

The overall design of the lateral-access window is determined after the review of the CBCT scan, which helps determine the thickness of the lateral wall of the antrum, the position of the antral floor from the crest of the ridge, the location of teeth, as well as the presence of septa on the floor and/or walls of the sinus. The main goal of window design and location is that the graft MUST encompass the area in which future implants will be placed.

Lack of Grafting Area

If the outline of the window is not ideal, the final location of the graft material will not encompass the area needed for future implant placement. Implant placement will result in voids and lack of bone surrounding the implants. This may lead to inadequate integration, loss of implants, or migration of implants into the sinus proper.

Osteotomy Window Made Over Host Bone

If the window location and osteotomy is not made within the confines of the sinus proper, the lateral window will not be able to be infractured. Therefore, osteotomy preparation over host bone will not allow access to the sinus cavity and membrane (Figs. 13.26 and 13.27). This results in extended surgical time and removal of valuable host bone needed for initial implant stability (e.g., inferior border).

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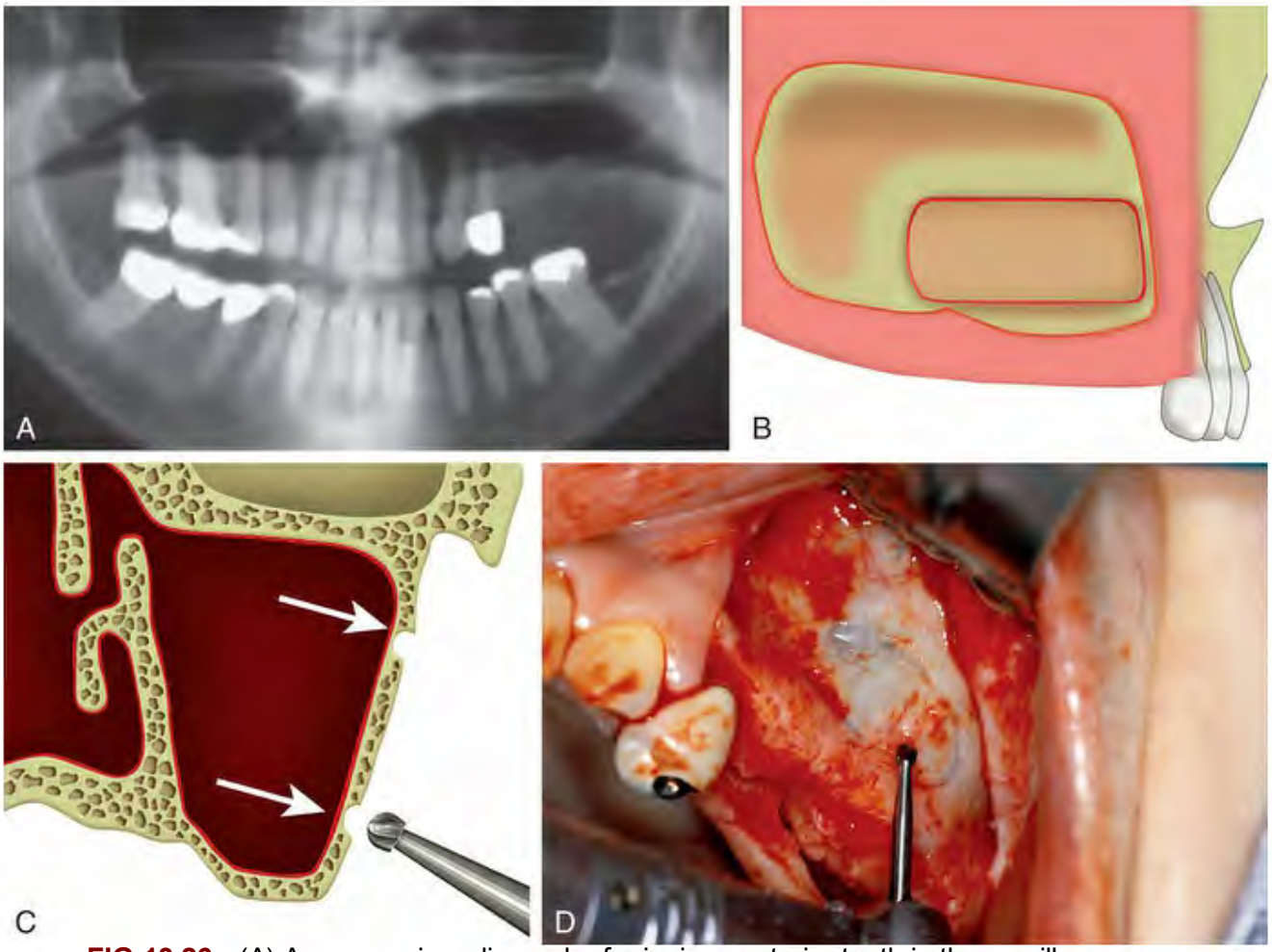

FIG 13.26 (A) A panoramic radiograph of missing posterior teeth in the maxillary left region; 5 to 10 mm of bone exists below the maxillary sinus floor. (B) The lateral maxilla is reflected and reveals the zygomatic process, tuberosity, and lateral maxilla. The Tatum access window is 2 to 5 mm above the antral floor, 2 to 5 mm from the anterior wall, 15 mm long and 10 mm in height. (C) The carbide drill should not perforate the lateral maxilla, which will tear the sinus membrane. A paintbrush stroke is used to outline the access window. (D) A #4 to #6 diamond is used in a straight or contraangle handpiece and deepens the score line of the access window until a bluish hue or bleeding is observed.

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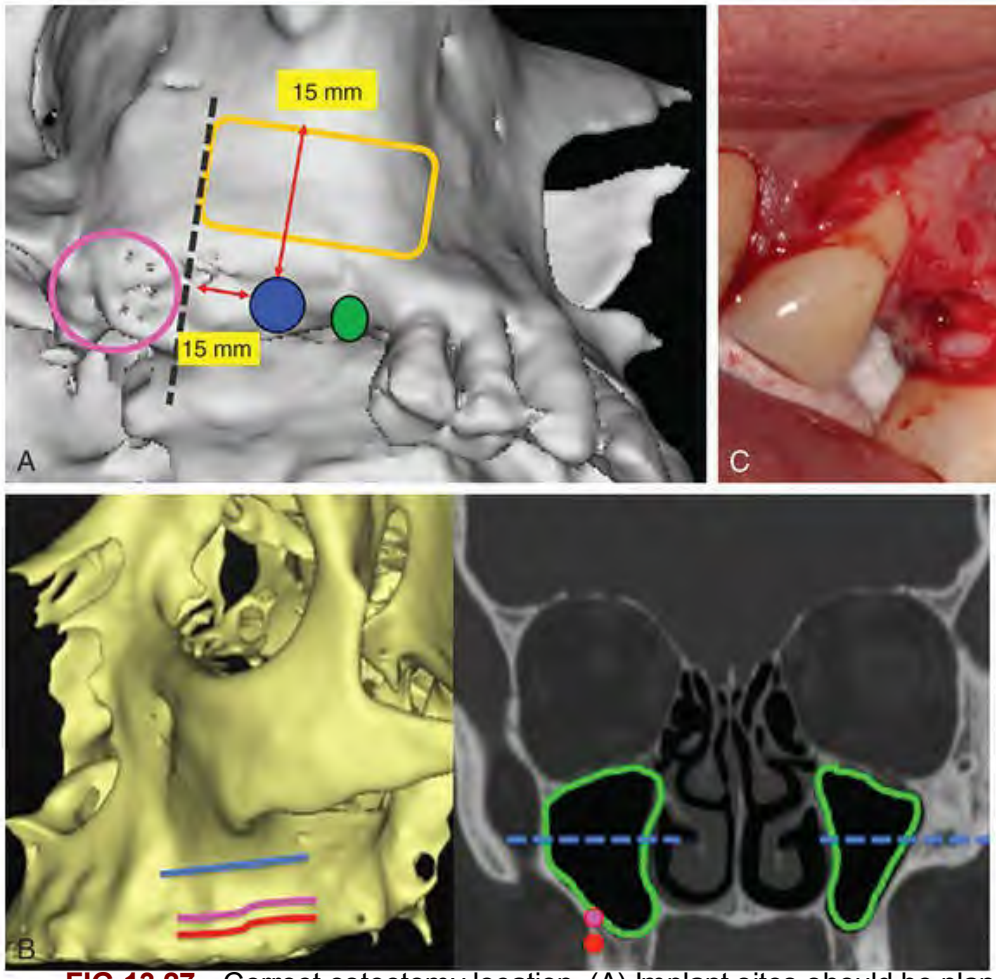

FIG 13.27 Correct osteotomy location. (A) Implant sites should be planned out prior to window osteotomy. Superior window cut should be 15 mm and parallel to the residual ridge, and care should be taken to not remove the tuberosity less than 5 mm from the distal aspect of the most distal implant. (B) Osteotomy should always be placed within the confines of the sinus; if made over host bone, window infracture will not be able to be accomplished. (C) Always note the location of the adjacent roots *(arrow)* to avoid damage and devitalization.

Damage to Existing Tooth Root

Caution should be exercised to make the window at least 2 millimeters from any adjacent tooth root and within the sinus proper. Encroaching on a tooth root may devitalize the tooth, leading to possible endodontic treatment or internal/external resorption. It is not uncommon for this to occur with dilacerations or multiple-rooted premolar teeth (see Fig. 13.27C).

Prevention

To ensure ideal bone grafting placement, an ideal window outline must be performed.

Inferior.

The inferior score line of the rectangular access window on the lateral maxilla is placed approximately 1–2 mm above the level of the antral floor. If the inferior score line is made at or below the level of the antral floor, infracture of the lateral wall will be very difficult, leading to possible membrane perforation. If the inferior score line is made too high (>5 mm) above the sinus floor, a ledge above the sinus floor will result in a blind dissection of the membrane on the floor. This will lead to a higher incidence of membrane perforation. The inferior osteotomy should follow the outline of the maxillary sinus inferior border (Fig. 13.28B).

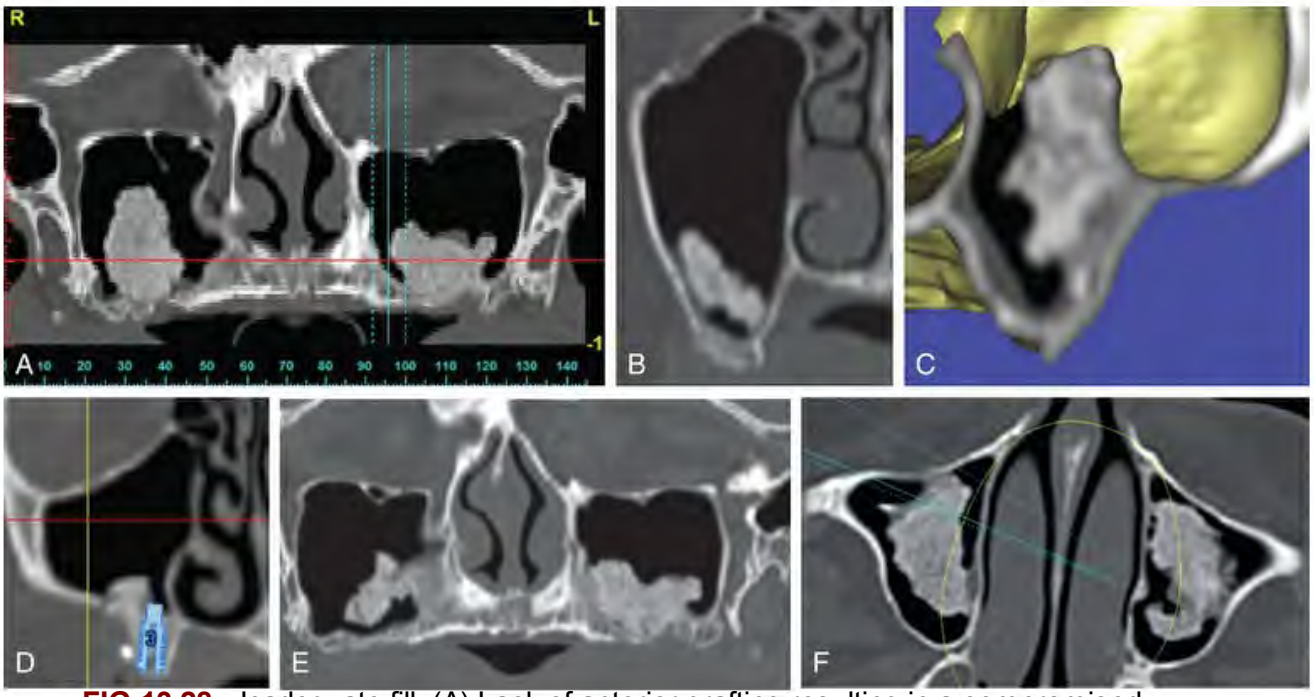

FIG 13.28 Inadequate fill. (A) Lack of anterior grafting resulting in a compromised anterior site for implant placement. (B) Inferior, superior and medial defect. (C–D) Lack of medial grafting resulting in implant placement in soft tissue. (E) Lack of posterior bone grafting. (F) Lack of lateral bone grafting.

Superior.

The most superior aspect of the lateral-access window should be approximately 15 mm superior to the alveolar crest. This will allow a buffer zone of 3 mm, as the ideal length of an implant placed in a sinus graft is 12 mm. A soft tissue retractor (Seldin) placed above the superior margin of the lateral-access window helps retract the facial flap and prevents the retractor's

inadvertent slip into the access window, which may damage the underlying membrane of the sinus. The superior score line should always be parallel to the alveolar crest (Fig. 13.28B).

Anterior.

The anterior vertical line of the access window is scored approximately 2–3 mm distal to the anterior vertical wall of the antrum. If the sinus access window outline is difficult to determine in relation to the sinus cavity, it should err over the antrum rather than over the bone around this structure. Additionally, the anterior wall should always be identified to minimize a void in the area of future implant placement. If the membrane is not released from the anterior wall, an anterior defect may result. If a defect results, remediation in this area is very difficult with a high degree of morbidity.

When teeth are present anteriorly, they made be used to determine the exact location of the anterior vertical osteotomy location (Fig. 13.28A).

Posterior.

If the window location is not extended far enough posterior, future implant placement may result in inadequate bone fill, leading to remediation or change of implant site location to a less favorable location. The posterior score line should extend approximately 5 mm distal to the last implant being proposed. Care should be noted to make sure the window is far enough distal to allow the implant to be encompassed in bone. Additionally, the extent of tuberosity removal used for donor bone should be determined in relation to the most distal implant site. The tuberosity harvest, if made too close to the implant site, may compromise placement (Fig. 13.28E).

Aggressive Osteotomy Preparation

The osteotomy window should be prepared with either a #6 or #8 carbide or diamond bur, or with a Piezosurgery unit. Care must be taken to slowly score the outline of the osteotomy window while looking for the appearance of the bluish-hued membrane. Once the membrane has been visualized, light tapping on the bony window with the end of a mirror handle can alert the clinician to areas where the lateral wall is still attached.

Complication

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Not pausing to check for the mobility of the bony window can place the clinician in danger of penetrating too deep within the lateral wall and perforating the membrane. Perforating the membrane complicates the procedure and increases the morbidity (Fig. 13.29A–B).

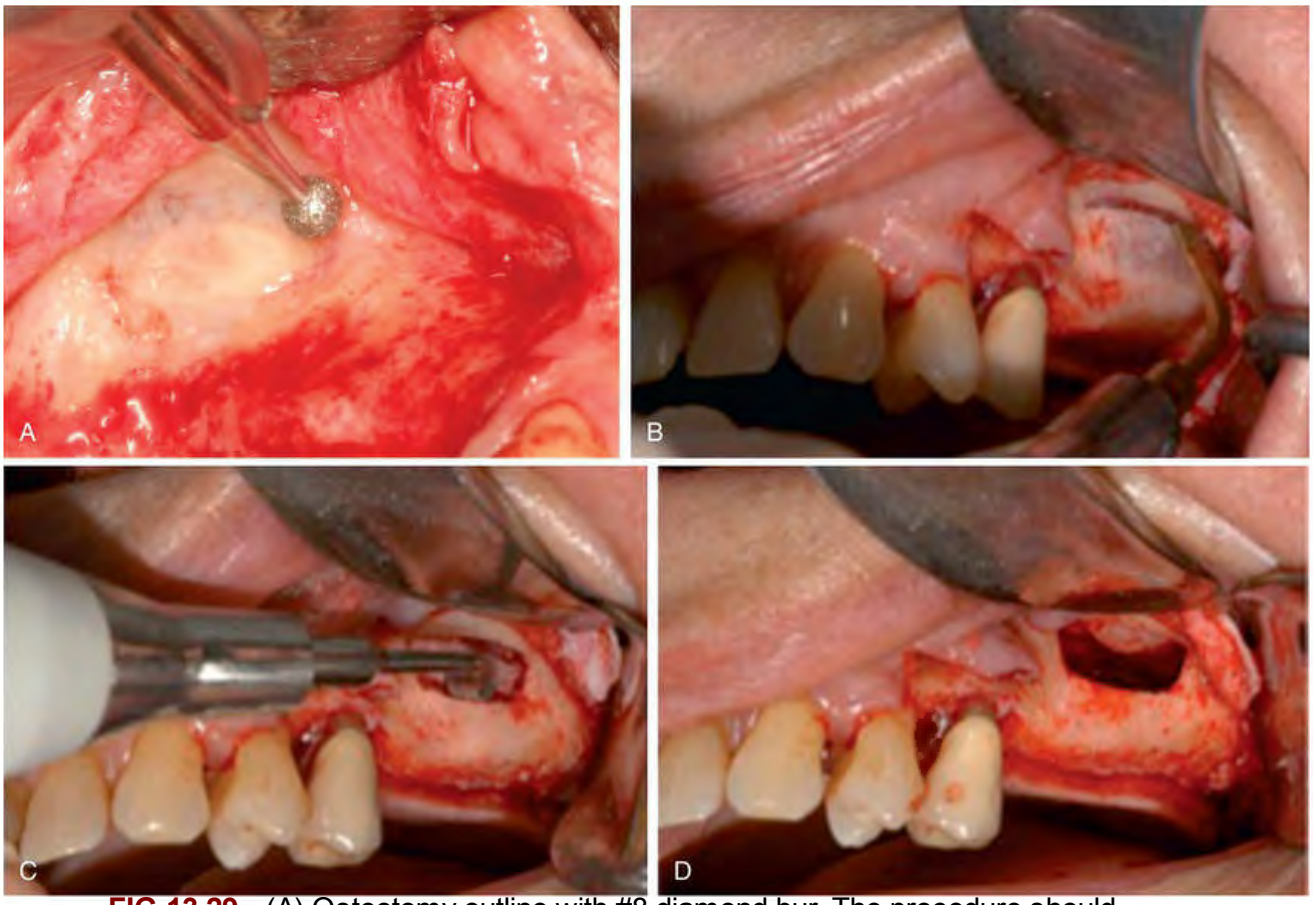

FIG 13.29 (A) Osteotomy outline with #8 diamond bur. The procedure should include the use of a feather touch to minimize perforation. (B–D) A safer technique, that minimizes perforation, is the use of piezosurgical unit.

Prevention

To prevent overpreparation of the osteotomy, the implant clinician should select the ideal instrumentation for procedure. Usually, clinicians early on their learning curve should utilize a piezotome unit for osteotomy preparation. This technique has the least possibility of perforating the sinus membrane. A carbide bur should be cautiously utilized, as this technique has the highest possibility of membrane perforation.

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Overfilling of the Sinus

The goal of the sinus bone graft is to obtain adequate vertical height of bone to place endosteal implants with long-term success. The maximum length requirement of an implant with adequate surface of design is rarely more than 12 mm, and as a result the goal of the initial sinus graft is to obtain at least 12 mm of vertical bone from the crest of the ridge. This usually requires the bottom one half to one third of the sinus to be filled with graft material because most sinuses approximate 35 mm in height. A CBCT scan (i.e., and interactive treatment planning) of the sinus prior to surgery may be used to estimate the amount of graft material required for the ideal volume of sinus graft material. The average volume of the maxillary sinus is approximately 15 ml.[45] Care should be noted to the amount of graft material placed into the sinus.

Complication

Overfilling the sinus can result in blockage of the ostium, especially if membrane inflammation or the presence of a thickened sinus mucosa exists. This may lead to a chronic rhinosinusitis.

The majority of sinus graft overfills do not have postoperative complications. If, however, a postoperative sinus infection occurs without initial resolution, reentry and removal of a portion of the graft and changing the antibiotic protocol may be appropriate (Fig. 13.30).

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FIG 13.30 Overfilling of the sinus cavity with bone graft material may lead to blockage of the ostium causing a rhinosinusitis.

Inadequate Fill: Density (Voids)

Postoperatively, voids in sinus grafts complicate and increase implant placement morbidity. This situation may result in a soft tissue interface with the implant and a decreased likelihood of success may result.

Prevention

When grafting after elevation of the membrane, a sinus syringe (or 1- or 3-ml syringe) may be used to introduce the material into the sinus. The material should be introduced in an inferior-anterior angulation in small increments (most distant first). This will ensure the graft material is introduced to all reflected areas. Introducing increments of a larger volume may result in voids. Additionally, a serrated packing instrument should be used to pack the bone until push-back resistance is achieved. Insufficient packing results in voids, and excessive pressure results in too dense of a fill for blood vessel integration and angiogenesis to occur.

Medial.

If the medial wall is not reflected, a resultant defect will result. Since implant placement trajectory is usually angled to the medial, implant placement may result in lack of bone around the implant. Additionally, the medial wall is a significant resource for blood supply, allowing for better healing of the graft.

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Care should be noted to make sure graft material is packed in a medial direction to have contact with the medial wall.

Lateral.

The lateral wall should be grafted to at least the original contour. If not, a defect will result in tissue invagination, which increases morbidity and possible infection. This is why a membrane is placed over the lateral wall after sinus graft augmentation: to minimize loss of graft material and osseous regeneration to the original bony contour (Fig. 13.31).

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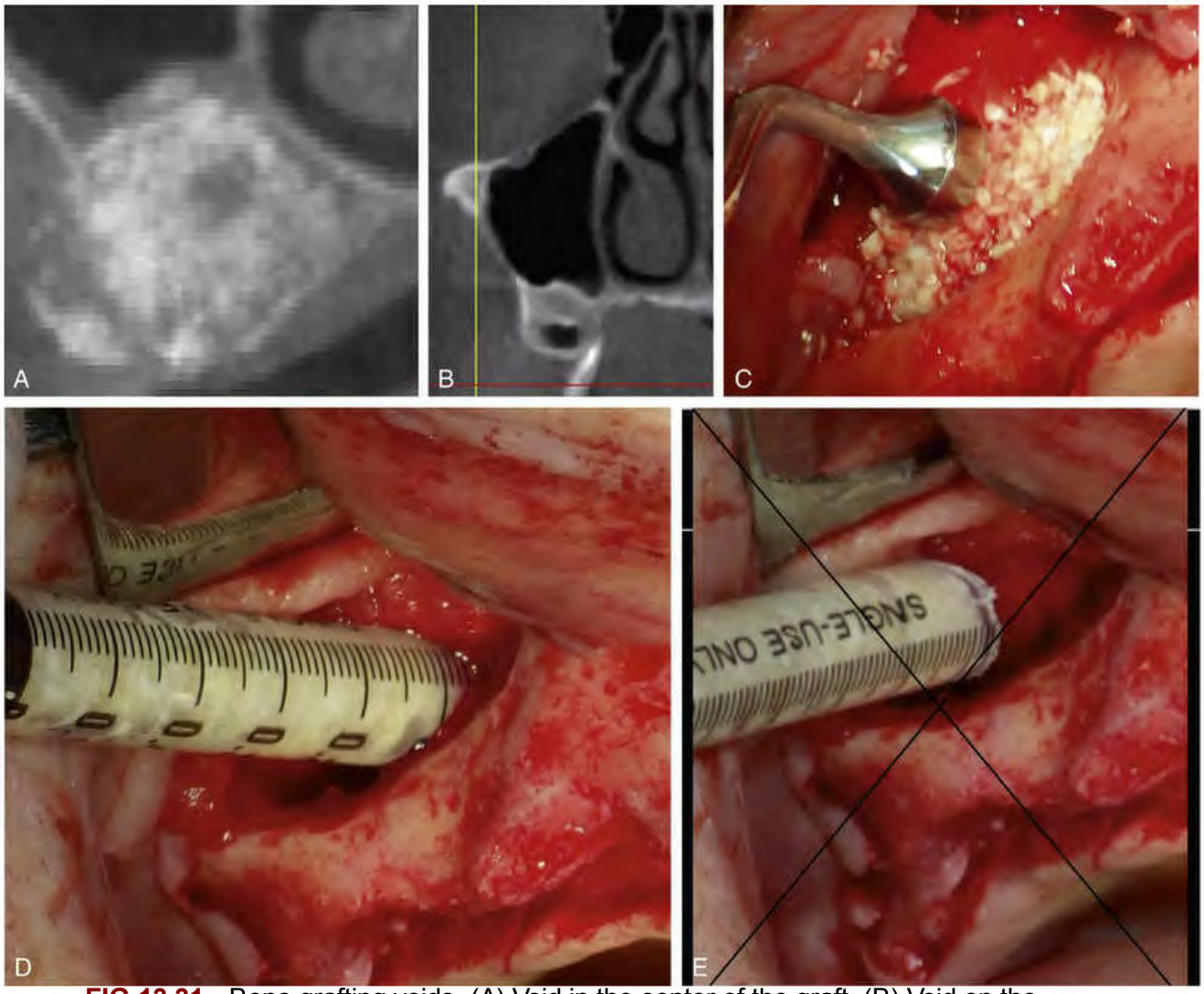

FIG 13.31 Bone grafting voids. (A) Void in the center of the graft. (B) Void on the floor of the sinus. (C) Graft material should be placed incrementally and packed firmly with a serrated sinus graft packer. (D) Prevention of voids include grafting with a syringe in an "inferior" and "anterior" direction, which minimizes the possibility of intruding the graft material. (E) Incorrect technique grafting in a superior direction which may lead to intruding the lateral wall with resultant grafting voids.

Aggressive Tuberosity Removal

The tuberosity is a common donor site to be used as a source of autogenous bone with the layering technique of bone grafting. The use of autogenous bone allows for more predictable bone growth and decreases healing time. The addition of an autogenous component in sinus grafting is most important when a lack of sufficient host bone is present (SA-4) because the less host bone there is, the less blood will be supplied to the region for healing. Tuberosity bone is ideal for sinus grafting because the cancellous nature of this bone allows it to be moldable with less chance to migrate.

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Treatment Implications

Correct Location.

The thicker soft tissue in the tuberosity region can mislead the assessment of this donor site. The tuberosity area should be evaluated with a CBCT examination, most easily measured on the coronal or panoramic image. The anatomic limits of this area include the maxillary sinus, pterygoid plates, adjacent teeth when present, and the greater palatine canal. A vertical incision is made posteriorly at the lateral aspect of the maxilla. It extends anteriorly across the tuberosity into the molar region. After reflection of a mucoperiosteal flap, bone may be harvested from the tuberosity with a rongeur, chisel, or trephine drill.

Exposure of Posterior Sinus Cavity.

Care should be used to not inadvertently expose the posterior sinus cavity because of excessive bone removal. This may lead to oroantral communication and possibly an opening for bacterial contamination, which may increase the morbidity of the graft area.

Harvest Too Far Posterior.

Harvesting the tuberosity too far posterior may lead to potential bleeding issues. This aggressive harvest may result in hemorrhage from the tributary vessels of the pterygoid plexus, such as the deep facial vein or posterior superior alveolar vessels. This can result in bleeding into the pterygomaxillary and infratemporal spaces, which may result in a hematoma via the inferior orbital fissure (Fig. 13.32).[46]

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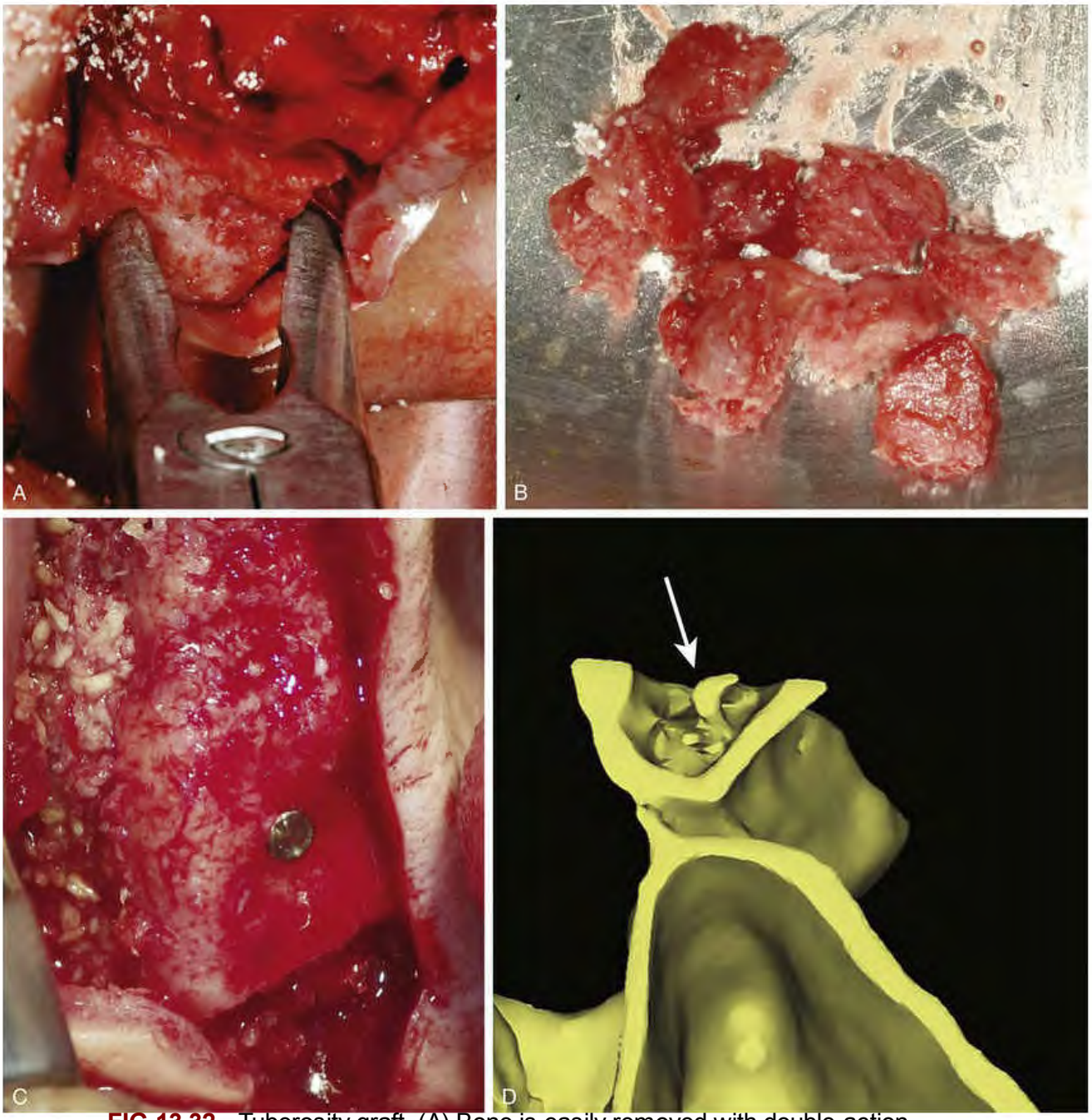

FIG 13.32 Tuberosity graft. (A) Bone is easily removed with double-action rongeurs. (B) Cancellous bone grafted from tuberosity. (C) Note demarcation of the donor site. Care should be exercised not to harvest too close to a planned implant site. A bone track is placed in the location of the most distal implant site for ease of site identification after graft healing. (D) Posterior area depicting the close approximation of the infratemporal fossa, medial and lateral pterygoid plates.

SA-2 (Osteotome Technique) Complications

The SA-2 approach (also termed *transalveolar approach, osteotome sinus floor elevation, Summers technique,* or the *Crestal approach*) may be considered a

more conservative and less invasive sinus grafting technique (Fig. 33.33). This procedure is performed through the alveolar crest of the edentulous ridge at the inferior border of the maxillary sinus. It involves elevating the sinus membrane, creating a "tent" and providing space for graft placement. The membrane is elevated and the area is grafted blindly, with the disadvantage of an uncertainty of possible perforations of the sinus floor (Schneiderian) membrane. The following are complications of this technique.

Patient Selection: Inadequate Bone

It is recommended that at least 10 mm of host bone be present below the sinus for this technique. If inadequate height and width of bone is present, rigid fixation is compromised, and the implant may become mobile and possibly migrate into the sinus proper. Additionally, an oblique sinus floor, septa, pathology, or nonpatent ostium may increase possible morbidity or may contraindicate the osteotome technique.

Overpreparation of Osteotomy

Because of the poor bone quality present in the posterior maxilla (D4 Bone), D4 type of bone, inadequate bone strength, along with lack of cortical bone, alters the initial primary stability. Lack of stability leads to possible migration or displacement of the implant into the maxillary sinus or surrounding areas.

Sinus Membrane Perforation

Because of the closed nature of this technique, perforation of the membrane is usually impossible to determine (i.e., unless a postoperative CBCT examination is performed). Because of irregular antral floors, septa, adhesions, and pathology, tears in the membrane are definitely more frequent than what most report. Perforation leads to possible infection and morbidity of the graft and implant.

Access

Because of compromised interocclusal space, in some patients, closed sinus graft procedures may be problematic because of access problems. To make the surgery easier, bite blocks along with the use of off-angle osteotomes may be used. Patient opening for a long period of time may lead to muscle trismus or complications within the temporomandibular joint (TMJ).

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Use of Incorrect Osteotomes

The use of straight osteotomes is not ideal because specially made (maxillary posterior) offset osteotomes are designed to be more user-friendly and work more efficiently. The use of piezoelectric osteotomy preparation allows for a more controlled osteotomy with low perforation risk (Fig. 13.33).

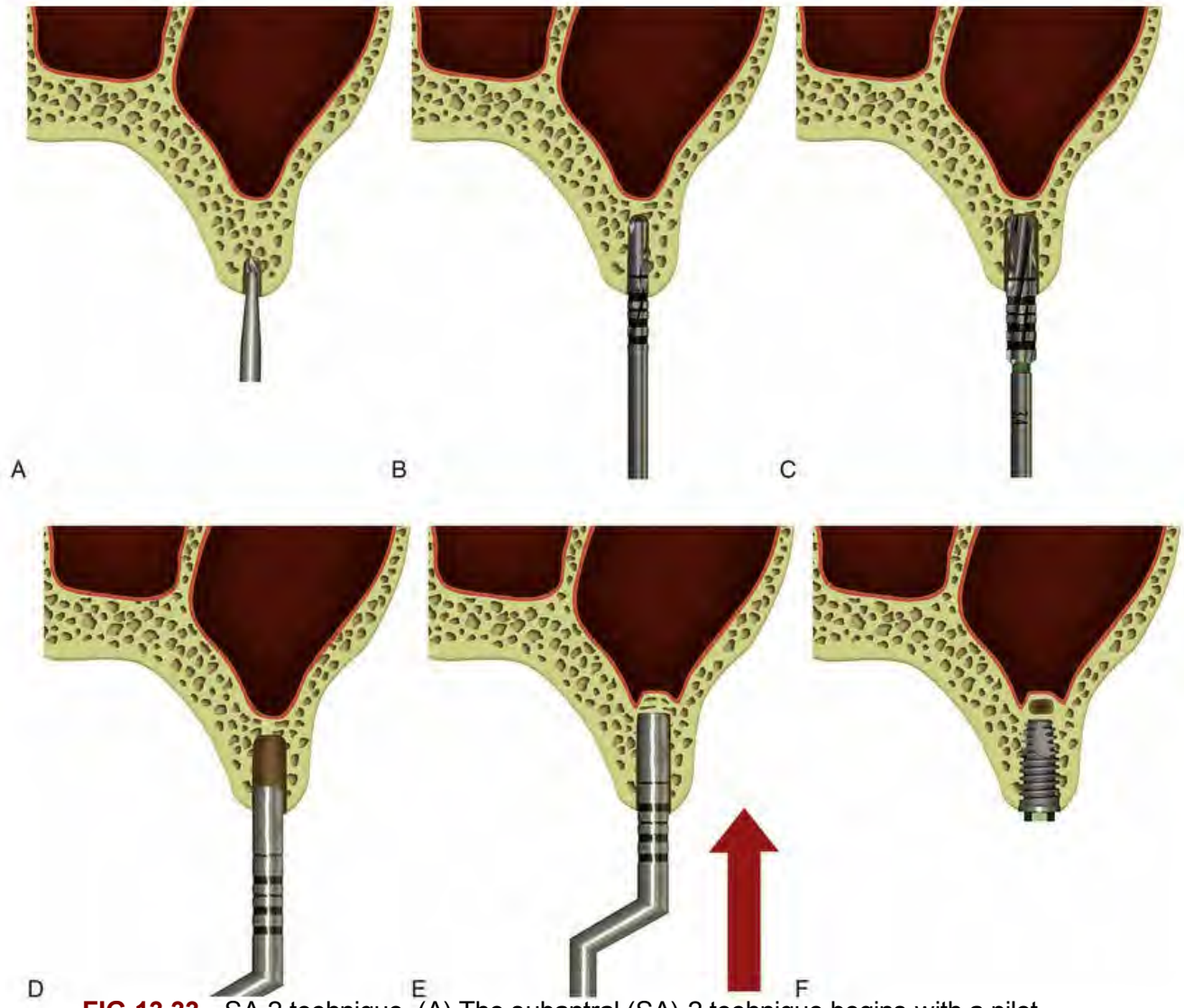

FIG 13.33 SA-2 technique. (A) The subantral (SA)-2 technique begins with a pilot bur to mark the implant site. (B) A 2-mm twist drill prepares the osteotomy 1 to 2 mm short of the sinus floor. (C) A final osteotomy width is sequentially obtained, remaining 1 to 2 mm short of the antral floor. (D) A flat-ended osteotome, the same diameter as the final osteotomy size, is used within the site. (E) A surgical mallet is used to gently and slowly tap the osteotome 1 to 2 mm through the sinus floor. The osteotome raises the floor and 1 to 2 mm of bone with the sinus mucosa over the implant site. (F) An implant is inserted into the osteotomy and extends 0 to 2 mm above the surgical sinus floor.

Final Osteotome Should Only Be Used Once

Entering the osteotomy multiple times leads to increasing the diameter of the osteotomy and causing decreased primary stability. Usually, undersizing the osteotomy allows for better fixation along with increasing the amount of bone present at the implant interface. Poor bone quality (e.g., D4) can be changed to a D3 or D2 via the osteotome technique.

Graft With Small Increments of Material

Grafting too much material at once will prevent the placement of the implant into the osteotomy to full length. Ideally, no more than 0.2 cc of bone should be placed at once, necessitating multiple osteotome grafting techniques.

Benign Paroxysmal Positional Vertigo

Benign paroxysmal positional vertigo (BPPV) has been shown to have a direct correlation with osteotome sinus floor elevation.[47] Studies have shown this postoperative complication to be relatively high at 3%.[48] From the pounding and repeated force from the osteotomes, calcium carbonate crystals are dislodged and settle in on the cupula of the semicircular canal (cupulolithiasis). They strike nerve endings in the semicircular canals, which produces position- or motion-induced vertigo.[49]

Diagnosis.

The symptoms associated with BPPV include vertigo and nausea, which are precipitated by positional changes of the head. This disorder may resolve in days or may prolong for months.

Management.

Many treatments have been proposed for the treatment of BPPV including drugs, surgery, and vestibular rehabilitation exercises. However, one of most common and predictable procedures is the Epley procedure, which is usually performed by an ENT physician. While sitting on the examination table, the patient's head is rotated in various directions. The result of this procedure is that the calcium carbonate crystals are dislodged from the semicircular canal to the utricular cavity, resolving the BPPV (See Chapter 10).

Membrane Perforations

The most common complication during sinus graft surgery is tearing or creation of an opening in the sinus membrane, which has been reported in a wide range of 10% to 60% of surgeries.[50] Perforation of the sinus membrane may predispose the patient to additional complications such as infection, migration/loss of graft material, and possible loss of implants.

Etiology

The etiology of sinus membrane perforation includes: (1) lack of membrane present, (2) preexisting perforation, (3) tearing during scoring of the lateral window, (4) tearing during elevation of the membrane, (5) adhesions, (6) poor technique and access osteotomy sites, (7) narrow sinus in buccal-lingual dimension, and (8) previous pathologic condition.

Prevention

Surgical Armamentarium.

There are many different techniques when scoring the lateral wall during the sinus graft procedure. The use of round carbide burs (#6 or #8) has the advantage of increased efficiency and speed of window preparation. However, round carbide burs have the disadvantage of chattering and increased perforation. Using a round diamond bur (#6 or #8) is a much safer technique because perforation of the membrane is less common, which may be advantageous to surgeons early on their respective learning curves. However, because this technique reduces the bone more slowly, surgery time is increased. The use of a piezotome will decrease chances of perforation and is the safest technique with the least amount of morbidity available for scoring of the window.

Size of Access Window.

In general, the larger the window size, the less chance of membrane perforation. However, in some cases, the size of the window is dictated by adjacent teeth or anatomic variants. If the window needs to be increased in size, a second window can be made or the use of Kerrison rongeurs utilized. The increased size window allows for easier reflection of the membrane.

Narrow Sinuses.

In general, the more narrow the sinus, the more difficult the graft process

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and the greater the chance of perforation. Usually the narrowest part of the sinus is in the anterior region; however, some sinuses are inherently small in a buccal-lingual dimension. To prevent perforation, the lateral wall may be removed to minimize trauma to the membrane.

Osteotomy Line Angles.

The corners of the access window should always be rounded, rather than at right or acute angles. If the corner angles are too sharp, membrane perforation may occur when elevating the window. Additionally, the osteotomy cuts should be deep enough that the window is free, prior to elevation of the membrane.

Thickness of Membrane.

On average the Schneiderian membrane is approximately 1.0 mm in thickness. In general, the thinner the membrane, the greater chance of perforation. The thickness of the membrane should be ascertained prior to the surgery to determine the exact areas of concern or caution. On a CBCT scan, the thickness of the membrane will be depicted as varying levels of grey around the periphery of the sinus. In health the membrane will not be seen on a CBCT scan. Studies have shown that membranes less than 1.5 mm in thickness have a 31% perforation rate in comparison to thicker membranes with a rate of 16.6%.[51] Additional studies show a direct relationship between thicker periodontal biotypes and increased membrane thickness, which lead to a decreased perforation rate.[52]

Keep Curette on Bony Floor.

When reflecting the membrane off the floor of the sinus, always keep the curette on bone because this will reduce the chance of perforation. If you place pressure directly on the membrane, the chances of perforation will increase (Fig. 13.34), especially when the membrane is thinner.

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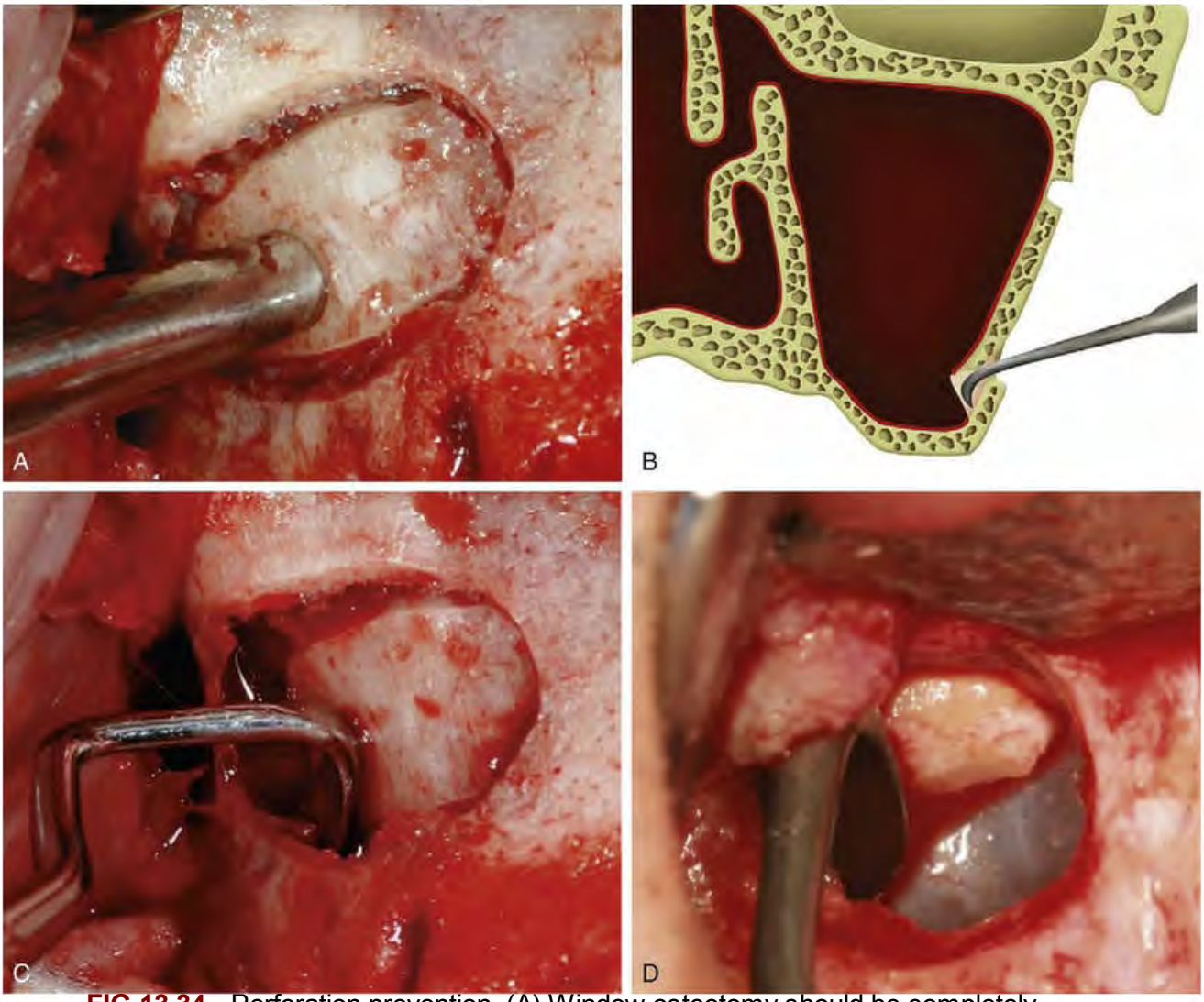

FIG 13.34 Perforation prevention. (A) Window osteotomy should be completely through the bone to prevent perforations. (B–D) The currette should alway be kept on the bone. The membrane does not have a tenacious adherence to the bone, therefore it is easily elevated.

Treatment

Alter Surgery Technique.

Once the tear or perforation is identified, the continuation of the sinus elevation procedure is modified. The sinus membrane should be elevated off all the bony walls of the antrum, despite the mucosal tear. If a portion of the membrane is not elevated away from a sinus wall, the graft material will be placed on top of the membrane, preventing the bone graft from incorporating with the bony wall. The perforation of the sinus membrane should be sealed to prevent contamination of the graft from mucus and

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contents of the sinus proper while preventing the graft material from extruding into the sinus proper.

Small Perforation.

The surgical correction of a perforation is initiated by elevating the sinus mucosal regions distal from the opening. Once the tissues are elevated away from the opening, the membrane elevation with a sinus curette should approach the tear from all sides so that the torn region may be elevated without increasing the opening size. The antral membrane elevation technique decreases the overall size of the antrum, “folding” the membrane over on itself and resulting in closure of the perforation. A piece of resorbable collagen membrane (e.g., CollaTape [Zimmer Dental Inc.]) is placed over the opening to ensure continuity of the sinus mucosa before the sinus bone graft is placed. The collagen adheres to the membrane and seals the SA space from the sinus proper (Fig. 13.35).

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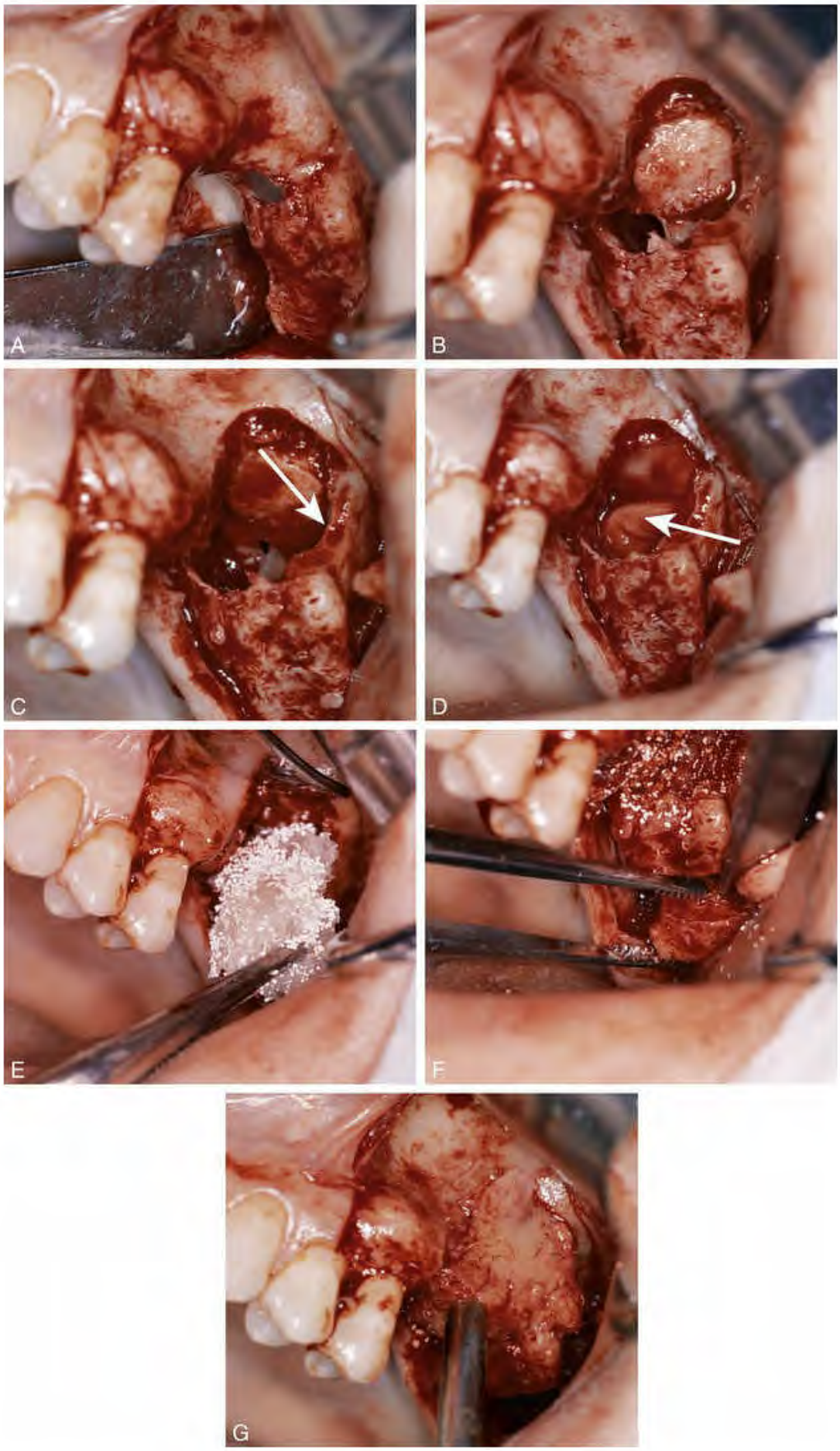

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FIG 13.35 (A) The bony opening in the lateral maxilla contributes to a maxillary sinus membrane tear on reflection of the soft tissue. (B) The lateral-access window is designed and elevated distal to the mucosal opening. (C) The sinus membrane elevation peripherally around the tear makes the opening smaller *(green arrow)*. (D) A piece of collagen is placed over the membrane. (E) The sinus graft procedure is completed. Care is taken to prevent overfilling the sinus. (F) The tuberosity is harvested. (G) The tuberosity is placed on the sinus floor and lateral wall.

Large Perforation.

If the sinus membrane tear is larger than 6 mm and cannot be closed off with the circumelevation approach, a resorbable collagen membrane of a longer resorption cycle (BioMend Extend— ~4 months) may be used to seal the opening. The remaining sinus mucosa is first elevated as described previously. A piece of collagen matrix is cut to cover the sinus tear opening and overlap the margins more than 5 mm. Once the opening is sealed, the sinus graft procedure may be completed in routine fashion. However, care should be exercised when packing the sinus with graft material. After a perforation, the graft is easily pushed through the collagen-sealed opening and into the sinus proper, so a periosteal elevator may be placed at the top of the graft site and under the perforation. The graft material is then gently inserted and pushed toward the sinus floor and sides but not toward the top of the graft (Figs. 13.36 and 13.37).

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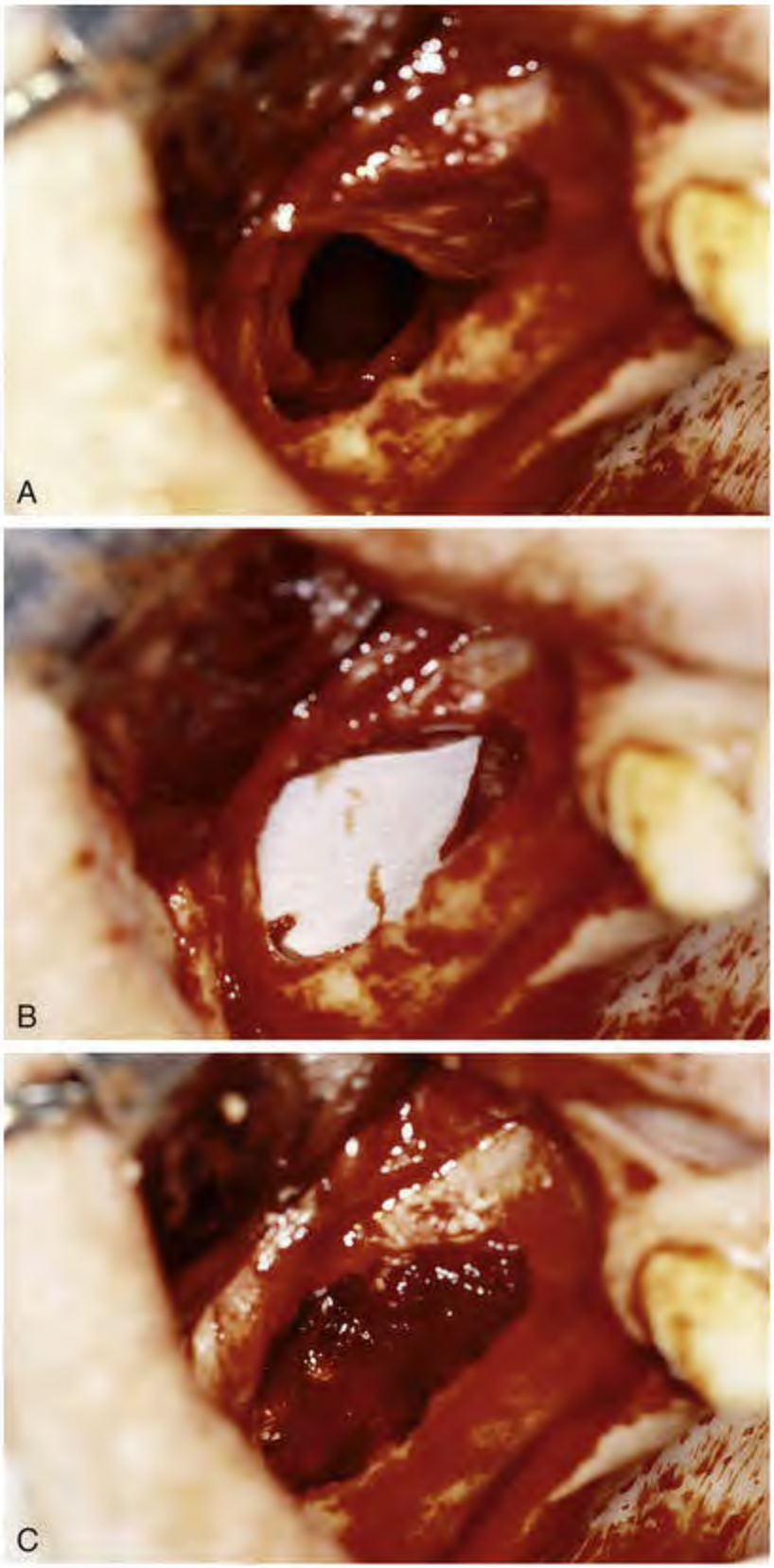

FIG 13.36 (A) When the opening in the sinus mucosa is greater than 6 mm, the tissues distal are elevated, but often the remaining mucosal margins do not approximate each other. (B) A dry piece of extended resorbing collagen (BioMend [Zimmer Dental Inc.]) is placed over the sinus membrane opening. (C) A parenteral form of antibiotic moistens the membrane along with antibiotic being added to the

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allograft material decreases the potential for infection.

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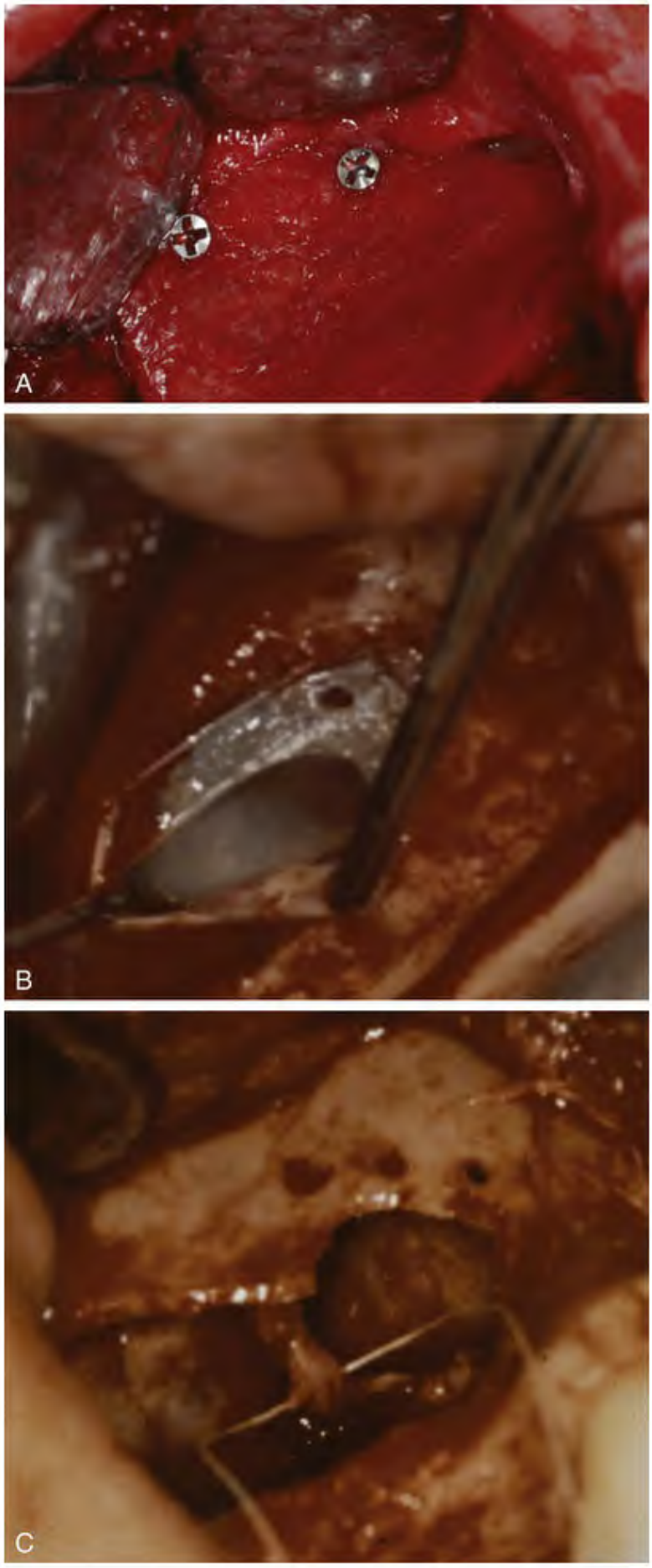

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FIG 13.37 (A) Fixated extending resorbing membrane superiorly prevents migration of the grafting material. (B) Large perforation, (C) Membrane sutured with 6-0 vicryl suture material.

Local Antibiotic.

A greater bacterial risk of penetration into the graft material exists through the torn membrane. It is imperative that local antibiotic (pure form) be added to the particulate graft material. In addition, mucous may invade the graft and affect the amount of bone formation. Graft material may leak through the tear into the sinus proper, migrate to and through the ostium, and be eliminated through the nose or obstruct the ostium, preventing or altering normal sinus drainage.

Monitor Postoperatively.

Care must be exercised to minimize potential postoperative complications. The patient should be instructed to refrain from drinking through a straw and sneezing or blowing their nose. They must take all prophylactic medications as prescribed and be warned of possible bleeding/graft material through the nostril within the first 24 hours.

Abort Implant Placement in SA-3I Patients.

When a sinus membrane perforation has occurred during a SA-3 immediate (sinus graft + implant placement) approach, it is prudent to delay implant insertion. Placement of implants is deferred for at least 2 months (in an SA-3 option) to allow for healing of the membrane and the gingival tissues on the edentulous crest. Risks of the sinus graft entering the sinus proper increase when implants are inserted into the grafted site. The waiting period before implant insertion permits assessment of postsurgical complications and graft consolidation before the implants are inserted.

Antral Septa

Antral septa (buttresses, webs, and struts) are the most common osseous anatomic variants present in the maxillary sinus. Underwood, an anatomist, first described maxillary sinus septa in 1910, and these bony variants are sometimes called Underwood septa. Septa vary in location, orientation, number, size, and thickness, and may influence the positioning of dental

implants in the posterior maxilla. They complicate the creation of the lateral window along with reflection of the membrane. The presence of antral septa has been reported to increase the risk of membrane perforation significantly.[53] The presence of septa, along with the determination of their location and orientation, is most easily seen via a CBCT survey. Evaluation of the 3-D or cross-sectional images give the clinician the most accurate information.

Etiology

Underwood postulated the etiology of these bony projections derived from three different periods of tooth development and eruption. Krennmair et al[54] further classified these structures into two groups: primary, which are a result of the development of the maxilla, and secondary, which arise from the pneumatization of the sinus floor after tooth loss.

The septa may be complete or incomplete on the floor, depending on whether they divide the bottom of the sinus into compartments. The shape of an incomplete maxillary sinus septum often resembles an inverted gothic arch that arises from the inferior or lateral walls of the sinus. In rare instances, they may divide the sinus into two compartments that radiate from the medial wall toward the lateral wall.

The most common location of septa in the maxillary sinus has been reported to be in the middle (second bicuspid–first molar) region of the sinus cavity. CT scan studies have shown that 41% of septa are seen in the middle region, 35% in the posterior region, and 24% in the anterior region.

Complication

Sinus septa may create added difficulty at the time of surgery. Maxillary sinus septa can prevent adequate access and visualization to the sinus floor, and inadequate or incomplete sinus grafting is possible. These dense projections complicate the surgery in several ways. After scoring the lateral-access window in the usual fashion, the lateral-access window may not greenstick fracture and rotate into its medial position. The strut reinforcement is also more likely to tear the membrane during the releasing of the access window. The sinus membrane is often torn at the apex of the buttress during sinus membrane manipulation because it is difficult to elevate the membrane over the sharp edge of the web, and the curette easily tears the membrane at this position. However, because septa are mainly composed of cortical bone,

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immediate implant placement may engage this dense bone, allowing for strong intermediate fixation. Moreover, septa allow for faster bone formation because they act as an additional wall of bone for blood vessels to grow into the graft.

Management

The modification to the surgery is variable depending on its location. The septum may be in the anterior, middle, or distal compartment of the antrum.

Anterior.

When the septum is found in the anterior section, the lateral-access window is divided into sections: one in front of the septa and another distal to the structure. This permits the release of each section of the lateral wall after tapping with a blunt instrument. The elevation of each released section permits access into the exact location of the septum to continue the mucosal elevation. The window (lateral wall) may also be removed to prevent trauma to the membrane.

The mucosal tissue may often be elevated from the lateral walls above the septum. The curette may then slide down the side walls and release the mucosa from the bottom half of the septum on each side. The sinus curette should then approach the crest of the buttress from both directions, up to its sharp apex. This permits elevation of the tissue over the web region without tearing the membrane (Fig. 13.38).

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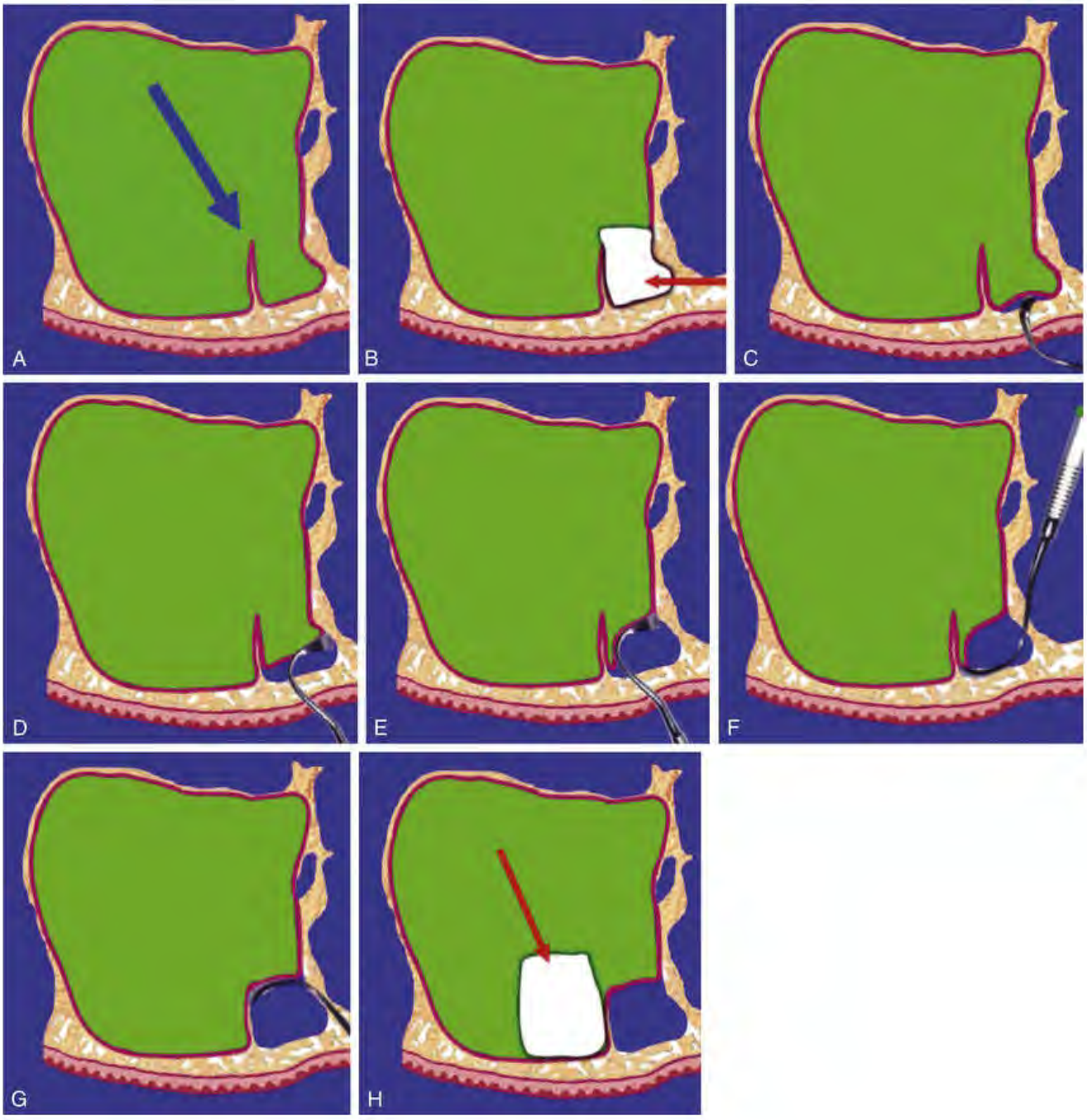

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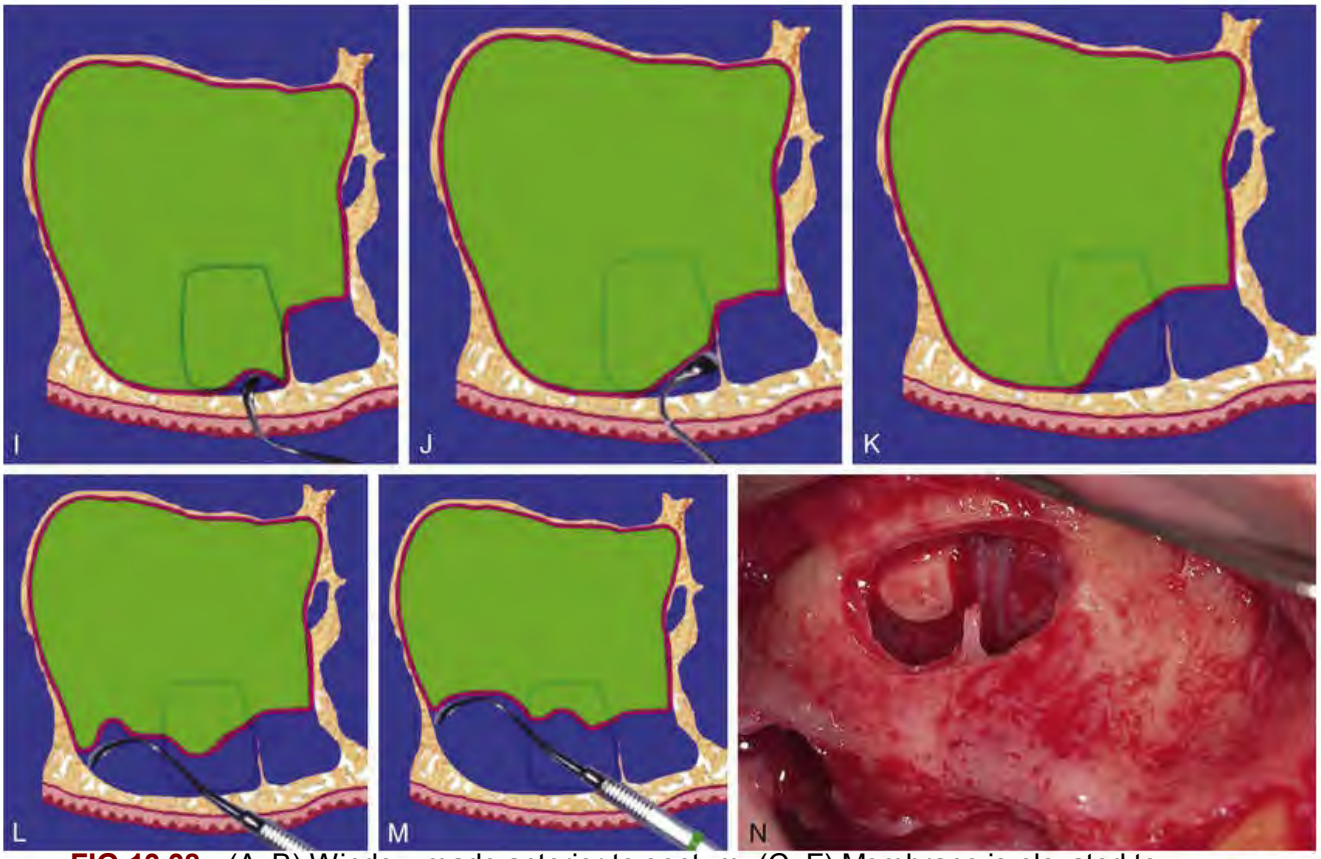

FIG 13.38 (A–B) Window made anterior to septum, (C–F) Membrane is elevated to completely expose anterior part of sinus, (H) Second window is made as far posterior to include most distal implant. (I–K) Second part of sinus is elevated, (L–M) The posterior wall does not need to be exposed unless most distal implant encroaches upon it. (N) Clinical image depicting two sinus windows.

Middle.

When the septum is located in the middle region of the sinus, it is more difficult to make two separate access windows within the direct vision of the surgeon. As a result, one access window is made in front of the septum. The sinus curette then proceeds up the anterior aspect of the web, toward its apex. The curette then slides toward the lateral wall and above the septum's apex. The curette may then slide over the crest of the septum approximately 1 to 2 mm. A firm, pulling action fractures the apex of the septum. Repeated similar curette actions can fracture the web off the floor. Once the septum is separated off the floor, the curette may proceed more distal along the floor and walls (Fig. 13.39).

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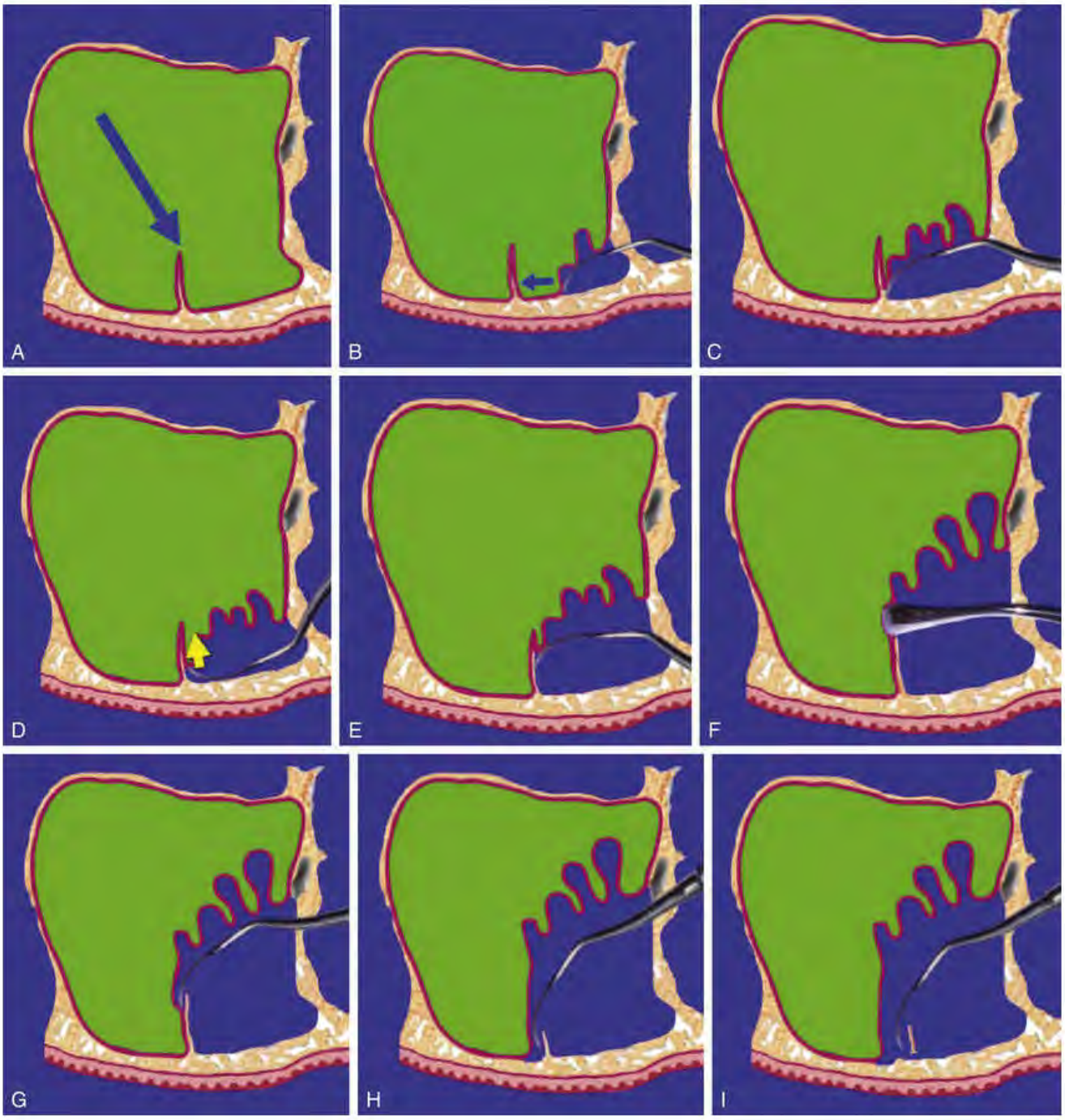

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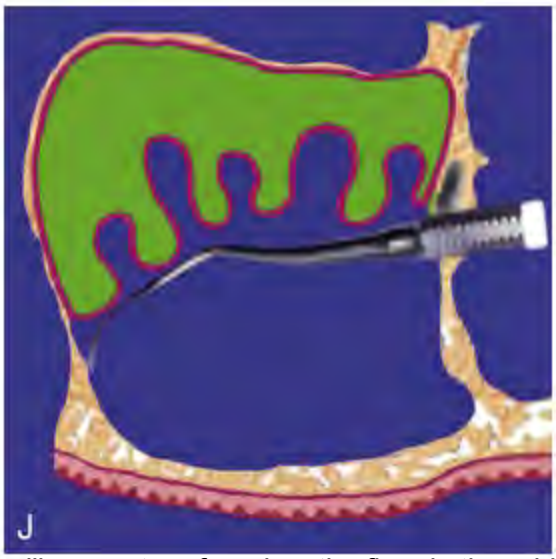

FIG 13.39 (A) A maxillary septum found on the floor in the middle of the sinus. (B–E) An access window and curette elevates the mucosa anterior to the septum. (F) The curette slides over the top of the septum and pulls it off by greenstick fracture. (G) Once the septum is removed, the rest of the sinus mucosa may be elevated. (J) The posterior wall does not need to be exposed unless the most distal implant encroaches upon it.

Posterior.

When the septum is in the posterior compartment of the sinus, it is often distal to the last implant site. When this occurs, the posterior septum is treated as the posterior wall of the sinus, containing the graft material. The sinus membrane manipulation and sinus graft is placed up against and anterior to the posterior septum (Fig. 13.40).

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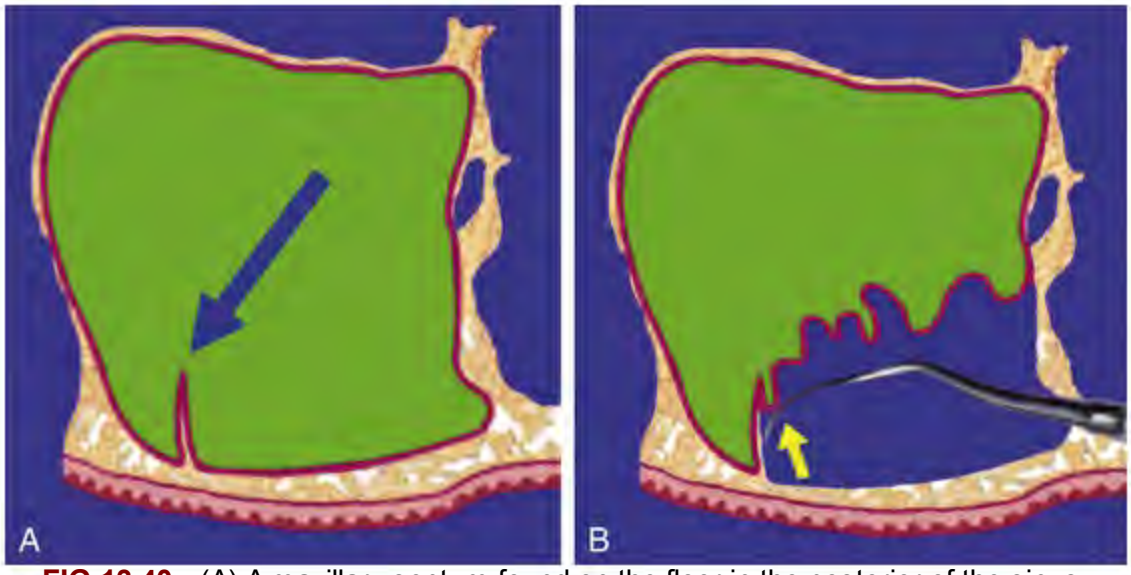

FIG 13.40 (A) A maxillary septum found on the floor in the posterior of the sinus. (B) An access window and curette elevates the mucosa anterior to the septum. The posterior septa is used as a posterior wall to contain the graft material.

Bleeding

Bleeding from the lateral-approach sinus elevation surgery has the potential to be problematic. Three main arterial vessels should be of concern with the lateral-approach sinus augmentation. During this surgery, there exist multiple arteries which may cause an increase in bleeding issues (see Chapter 7).

Extraosseous Anastomosis

The soft tissue vertical-release incisions of the facial flap in a resorbed maxilla may sever the extraosseous anastomoses. The extraosseous anastomosis on average is located 23 mm from the crest of the dentate ridge. However, in the resorbed maxilla, it may be within 10 mm of the crest. When this anastomosis is severed, significant bleeding has been observed. These vessels originate from the maxillary artery and have no bony landmark to compress the vessel. Vertical release incisions in the soft tissue should be kept to a minimum height with delicate reflection of the periosteum.

Intraosseous Anastomosis

The vertical component of the lateral-access wall osteotomy for the sinus graft often severs the intraosseous anastomoses of the posterior alveolar artery and infraorbital artery, which is on average approximately 15 to 20 mm

from the crest of a dentate ridge. Because of the intra- and extraosseous anastomoses that are formed by the infraorbital and posterior superior alveolar arteries, intraoperative bleeding complications of the lateral wall may occur.

Management

If intraosseous bleeding becomes problematic, a high-speed diamond used to score the window may be utilized without irrigation to polish the bleeding site, which cauterizes the vessel from the heat on the bony wall. Electrocautery may also be used on these vessels if necessary. It also has been reported that the use of a sterile cotton applicator soaked with epinephrine (1 : 100,000) can also be used to control bleeding. A hemostat to crush the artery may be less effective because it may fracture the lateral wall and/or perforate the sinus mucosa. Elevating the head may help reduce bleeding, as studies have shown that blood flow may be reduced by 38%.[55] If the excessive bleeding occurs while the medial wall is elevated, the sinus may be packed with gauze or a hemostatic agent such as BloodSTOP or HemCon.

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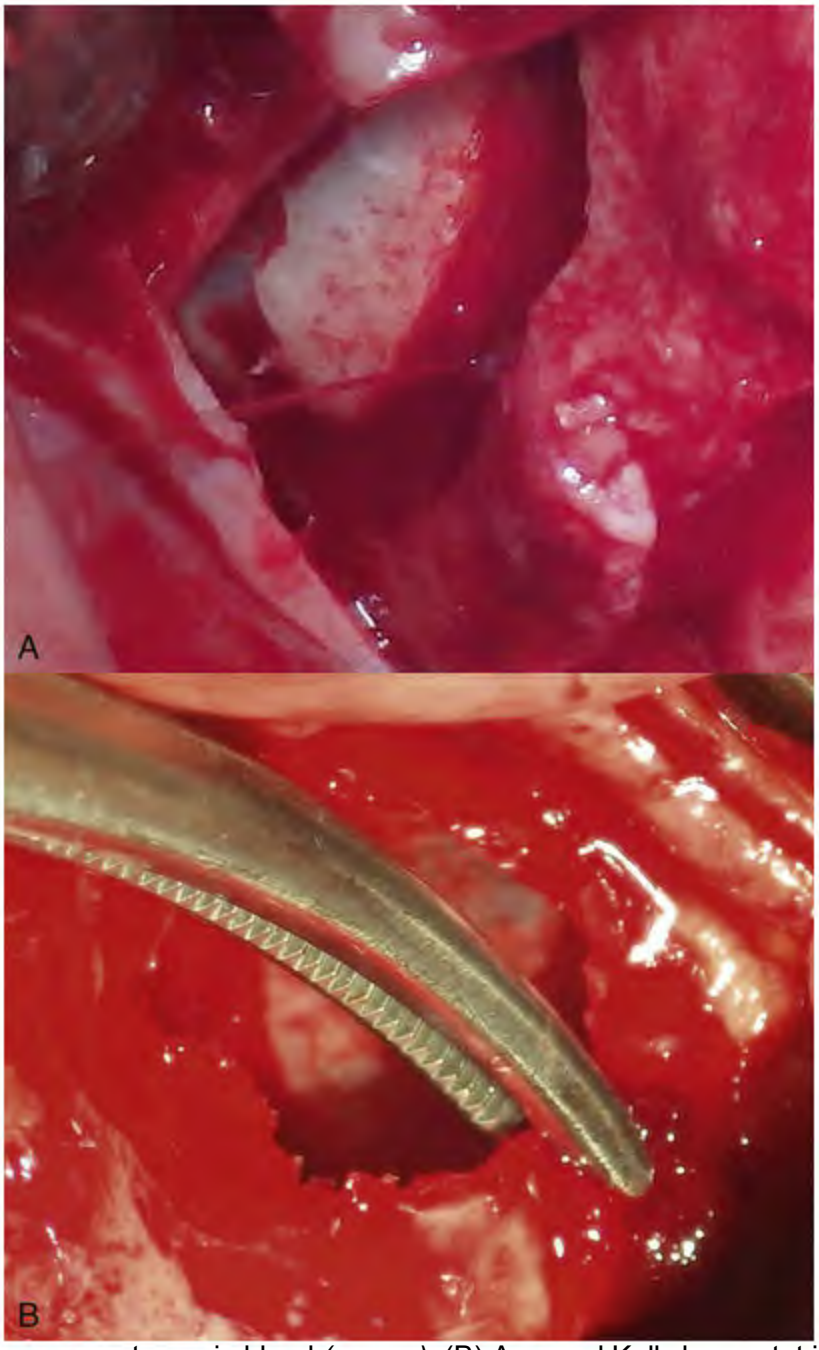

(A) Intrassous anastamosis bleed *(arrows)*. (B) A curved Kelly hemostat is used to clamp the bleeding vessels.

Posterior Lateral Nasal Artery

The third artery of which the implant clinician should be cautious is the posterior lateral nasal artery. This artery is a branch of the sphenopalatine artery that is located within the medial wall of the antrum. As it courses anteriorly, it anastomoses with terminal branches of the facial artery and ethmoidal arteries. A significant bleeding complication may arise if this

vessel is severed during elevation of the membrane off the thin medial wall. The most common site (90%) of nasal bleeding is from a plexus of vessels at the anteroinferior aspect of the nasal septum and the anterior nasal cavity (which is anterior to the sinus cavity and within the anterior projection of the nose). The posterior nasal cavity accounts for 5% to 10% of epistaxis events and is in the region of the sinus graft. If the medial wall of the sinus is perforated, a curette may enter the nares and cause bleeding.

Excess Pressure on Graft Site

The stabilization of the sinus graft material is paramount to predictable bone growth because it ensures blood clot adhesion and the associated growth factors for predictable healing. Graft immobility is vital to capillary ingrowth and graft revascularization. The implant clinician must take great care in preventing any excess pressure over the graft site.

Complication

One of the most common and challenging roadblocks to implant treatment acceptance is the patient's perception of the temporization (provisionalization) of the edentulous areas after bone grafting. In most cases, pressure directly or indirectly on the surgical site can lead to bone loss and increased morbidity of the graft site.

Prevention

Ideally, no provisionalization after surgery is the best treatment. However, if the patient is going to wear a removable prosthesis (flipper), the prosthesis must be modified and relieved in the area of the graft. The flange of the prosthesis along with the ridge area should be hollowed out so no pressure from occlusal forces will result in trauma to the graft. The primary stress-bearing area of the maxilla (horizontal palate) must not be modified. It is imperative that all forces are concentrated on this area when the patient is masticating on the prosthesis (Fig. 13.41).

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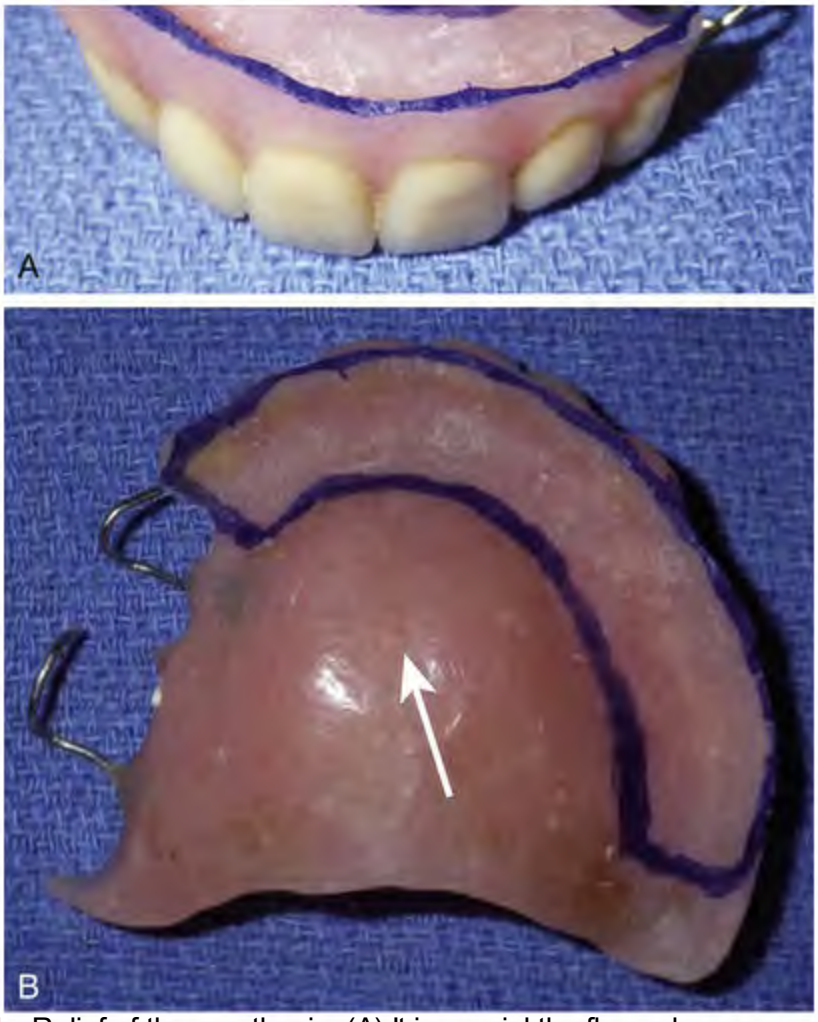

FIG 13.41 Relief of the prosthesis. (A) It is crucial the flange be removed from the prosthesis and (B) the ridge area be hollowed out so the primary stress-bearing area (horizontal palate—*arrow*) takes the majority of the occlusal load upon mastication.

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Postoperative Complications

Nerve Impairment

The infraorbital nerve is of concern in sinus elevation surgery because of its anatomic position. This nerve enters the orbit via the inferior orbital fissure and continues anteriorly. It lies in a groove in the orbital floor (which is also the maxillary sinus superior wall) before exiting the infraorbital foramen. The infraorbital nerve exits the foramen approximately 6.1 to 7.2 mm from the orbital rim.

It is of note that anatomic variants have been reported to include dehiscence and malpositioned infraorbital foramina, along with the nerve transversing the lumen of the maxillary sinus rather than coursing through the bone within the sinus ceiling (orbital floor). Malpositioned nerves have been reported as far as 14 mm from the orbital rim in some individuals. In the severely atrophic maxilla, the infraorbital neurovascular structures exiting the foramen may be close to the intraoral residual ridge and should be avoided when performing sinus graft procedures to minimize possible nerve impairment. This is of particular concern on soft tissue reflection and the bone preparation of the superior aspect of the window. Special considerations should be taken during reflection of the superior flap and sharp-ended retractors should be avoided. Usually, those most at risk have a small cranial base (i.e., elderly females).

Complication

Because the infraorbital nerve is responsible for sensory innervations to the skin of the molar region between the inferior border of the orbit and the upper lip, iatrogenic injury to this vital structure can result in significant neurosensory deficits of this anatomic area. Most often the nerve is not severed, and a neuropraxia results. Even though this injury is sensory and there is no motor deficit, patients usually have a difficult time adapting to this neurosensory impairment (Fig. 13.42).

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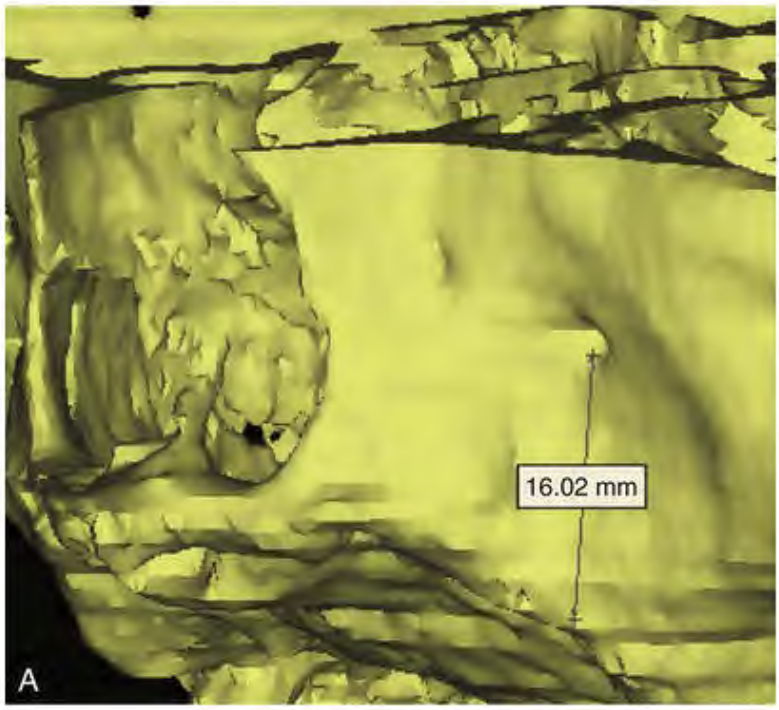

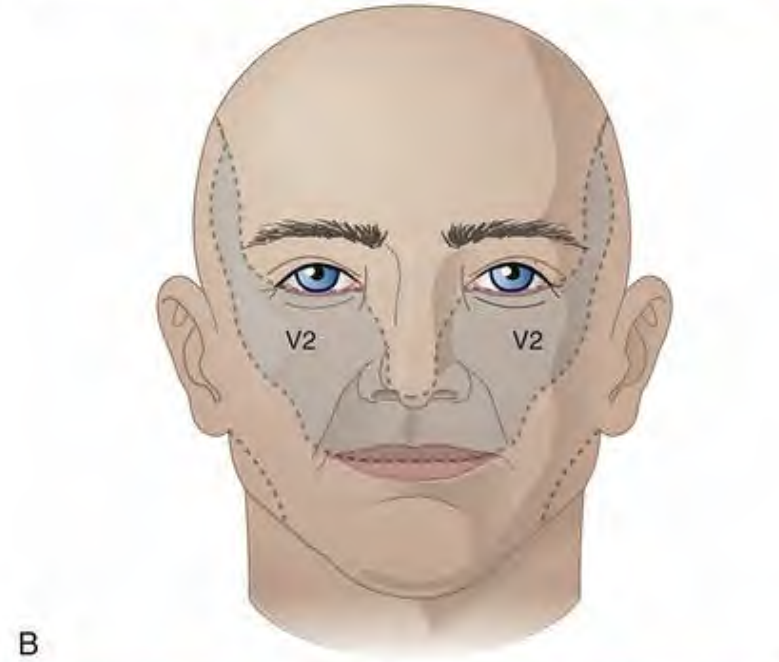

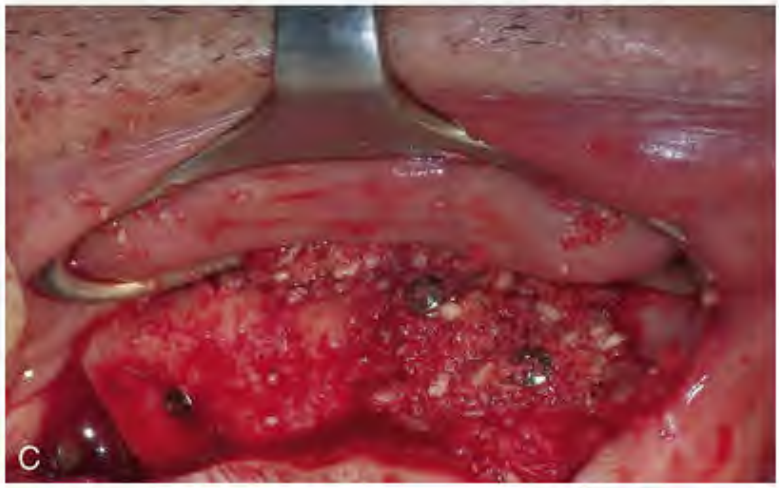

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FIG 13.42 Nerve impairment. (A) Infraorbital foramen anatomic variants that are close to the residual ridge. (B) V2 sensory impairment. (C) Broad-based retractor to avoid nerve trauma.

Management

If an infraorbital nerve impairment occurs, the implant clincian should immediately follow the clincial and pharmacologic neurosensory impairment protocol (i.e., outlined in Chapter 9).

Revision Surgery

When failure or compromise of the sinus graft occurs, reentry procedures are sometimes required to correct deficits. Failed or compromised sinus grafts result in altered soft and hard tissue characteristics, mainly the formation of adhesions of the Schneiderian membrane to the buccal flap. This results in difficulty with reflecting the buccal flap during the reentry procedure. Studies have shown that separation of the adhesions from the sinus mucosa led to a 47% perforation rate.

In addition, it has been shown that altered characteristics of the Schneiderian membrane result in a nonflexible thick fibrotic membrane. In some cases, where voids are present but have difficult access, regrafting procedures may need to be accomplished via a closed approach through the osteotomy site.[56]

Treatment Implications

Because of access issues, along with the higher perforation rate and fibrotic changes in the Schneiderian membrane, patients need to be informed of a higher postoperative complication rate involving questionable reentry bone growth and implant success. If reentry is necessary, usually bony adhesions and bony fenestrations of the lateral walls will be present.

The combination of fibrotic changes of the Schneiderian membrane, increased chance of perforation, and altered sinus physiology lead to a high complication rate. The continuation of the sinus mucosa and oral mucosa make reentry revision surgery problematic and difficult (Fig. 13.43). This will require the separation of the oral and sinus mucosa to gain access to the sinus proper.

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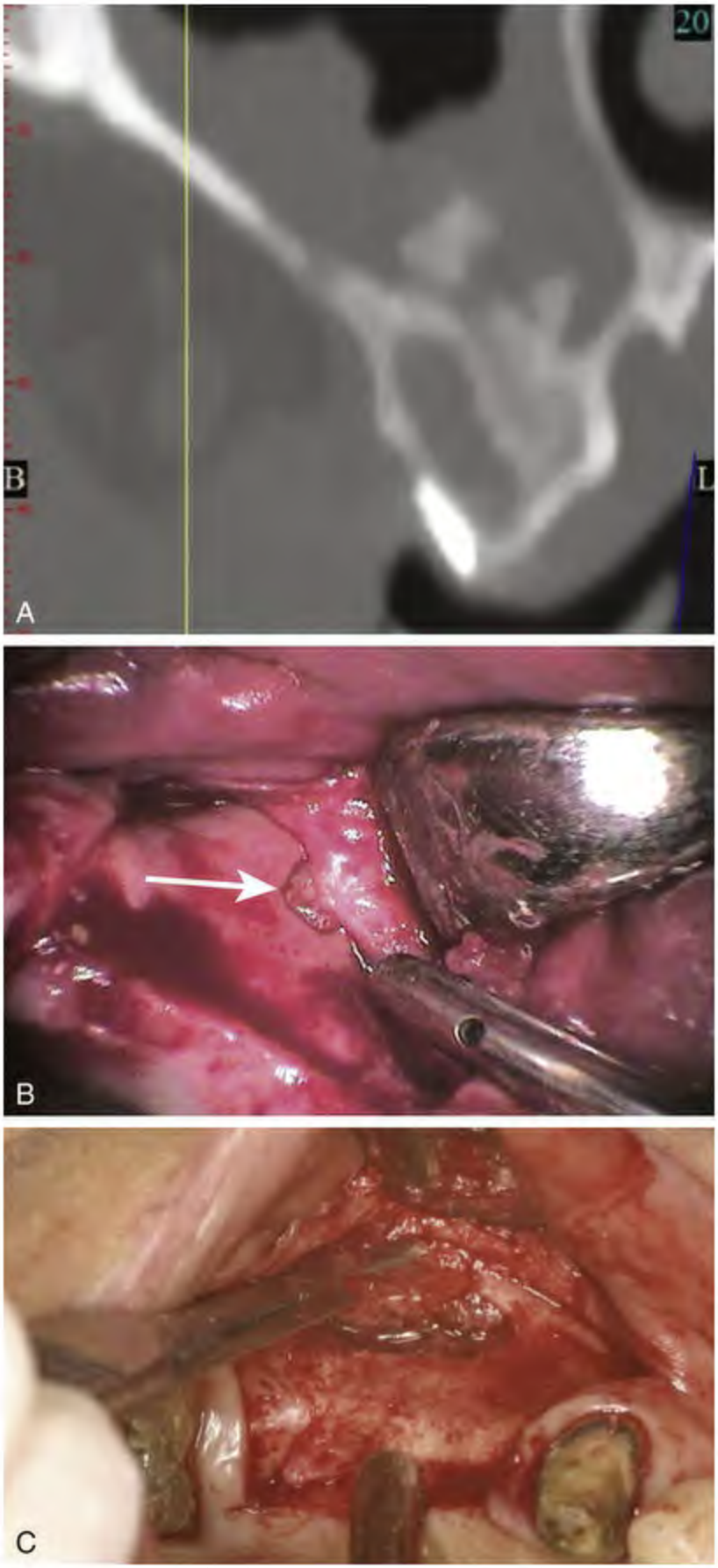

FIG 13.43 Post–sinus graft infections. (A) Post-sinus infection resulting in fibrous tissue growth and migration of graft material, (B) Post-op infection with the sinus and

vestibular mucosa being continuous, (C) To gain access to the sinus cavity, separation of the two tissues is accomplished with a 15 blade.

Edema

Because of the extent of tissue reflection and manipulation, sinus graft surgery often results in significant edema. The resultant postoperative swelling can adversely affect the incision line, leading to greater morbidity.

Prevention

The use of good surgical technique that involves careful reflection and retraction will decrease the amount of postoperative edema.

Minimize Surgical Duration.

The greater the surgery duration, the greater the chance of edema. Caution should be noted to decrease the amount of surgical duration and should not exceed the patient's tolerance.

Corticosteroid Treatment.

To minimize edema, corticosteroid use is utilized 1 day prior to and 2 days after surgery. This short-term prophylactic steroid use will allow for adequate blood levels to combat edema, which usually will peak at 48 to 72 hours. Dexamethasone is the ideal drug of choice because of its high antiinflammatory potency.

Cryotherapy.

Application of an ice pack, along with elevation of the head and limited activity for 2 to 3 days, will help minimize the postoperative swelling. This cryotherapy will cause vasoconstriction of the capillary vessels, reducing the flow of blood and lymph and resulting in a lower degree of swelling. Ice or cold dressings should only be used for the first 24 to 48 hours. After 2 to 3 days, heat (moist) may be applied to the region to increase blood and lymph flow to help clear the area of the inflammatory consequences. This will also help reduce the possibility of ecchymosis that may result.

Ecchymosis

Sinus graft surgery also increases the possibility of bruising or ecchymosis. Because of the extent of reflection, bone preparation, and the highly vascular surgical area, ecchymosis will occur more often with this procedure in comparison to other implant related surgeries.

Etiology

The etiology of ecchymosis includes the following: blood vessels rupture → red blood cells die and release hemoglobin → macrophages degrade hemoglobin via phagocytosis → production of bilirubin (bluish-red) → bilirubin is broken down to hemosiderin (golden-brown).

Prevention

In most cases, ecchymosis will not be able to be completely prevented; however, the goal should be to minimize the extent of bruising. Additionally, good surgical technique, shorter surgical duration, the avoidance of anticoagulant analgesics, and postoperative cryotherapy all aid in the control of this phenomenon (Fig. 13.44). Patients should always be informed of the possibility of ecchymosis. This is easily accomplished by having it be part of the postoperative instructions.

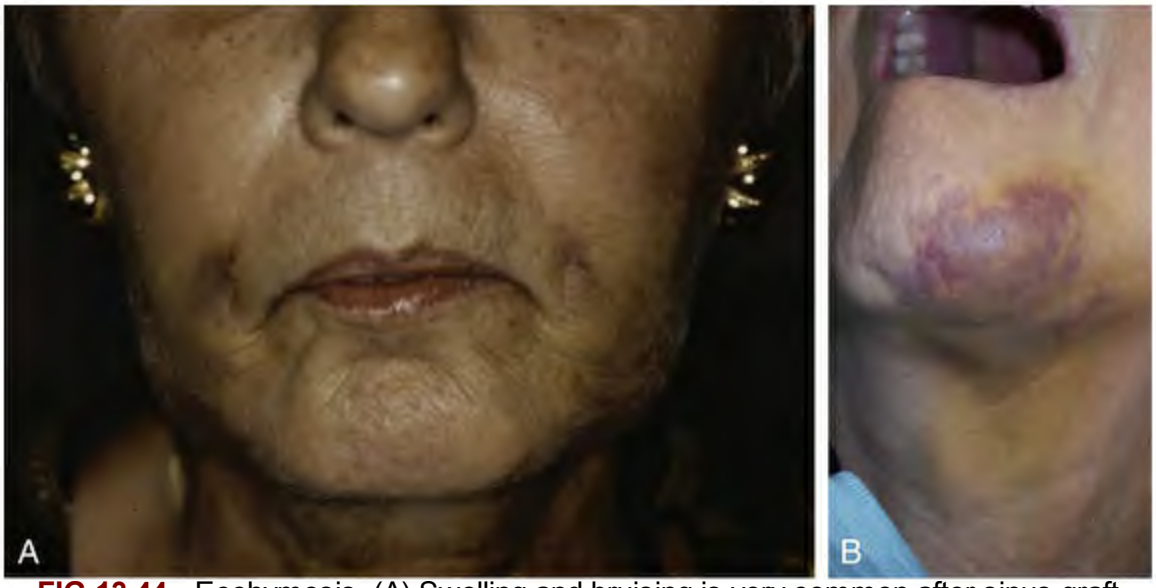

FIG 13.44 Ecchymosis. (A) Swelling and bruising is very common after sinus graft procedures because of the amount of tissue stretching and reflection. (B) It will most likely extend into the neck because of gravity.

Pain

Minimal discomfort and pain is usually associated with sinus graft surgery. However, if narcotics are indicated, any analgesic combination containing codeine, such as Tylenol 3, is prescribed postoperatively because codeine is a potent antitussive, and coughing may place additional pressure on the sinus membrane and introduce bacteria into the graft. The patient is instructed to cough (if necessary) with the mouth open to minimize possible air pressure changes within the sinus cavity.

Nasal Bleeding

Epistaxis (active bleeding from the nose) is a common complication following sinus elevation surgery, especially when a membrane perforation has been noted. Usually, this occurs within the first 24 hours after surgery.

Treatment

Treatment options to treat epistaxis include nasal packing, electrocautery, and the use of vasoconstrictive drugs. Placing a cotton roll (coated with petroleum jelly with dental floss tied to one end) into the nares may obtund nose bleeding after the surgery. After 5 minutes the dental floss is gently pulled to remove the cotton roll. The head is also elevated, and ice is applied to the bridge of the nose. If bleeding cannot be controlled, reentry into the graft site and endoscopic ligation by an ENT surgeon may be required.

Incision Line Opening

Incision line opening is uncommon for this procedure because the crestal incision is most likely in attached gingiva and is usually at least 5 mm away from the lateral-access window. Routinely, the soft tissue requires release before primary approximation and suturing. Incision line opening occurs more commonly when lateral-ridge augmentation is performed at the same time as sinus graft surgery or when implants are placed above the residual crest and covered with the soft tissue. It may also occur when a soft tissue–supported prosthesis compresses the surgical area during function before suture removal.

Complication

The consequences of incision line opening are delayed healing, contamination of the graft, and increased risk of infection. However, if the incision line failure is not related to a lateral augmentation graft and is only on the crest of the ridge and away from the sinus access window, the posterior crestal area is allowed to heal by secondary intention.

Prevention

Usually, when a collagen membrane is placed over the window, the soft tissue will not approximate without tension release with the surgeon expanding the facial flap by releasing the periosteum above the mucogingival junction (where the tissue becomes thicker). It is imperative that tension-free closure be completed.

Management

If incision line opening occurs, the soft tissue–borne restoration should be aggressively relieved, with no reline material in contact with the ridge. If incision line opening includes a portion of a nonresorbable membrane (e.g., for lateral-ridge augmentation), the membrane should be cleaned at least twice daily with an abrasive device and oral rinses of chlorhexidine. If the incision line is not closed after 2 months, a surgical procedure should reenter the site, expand the tissues, remove the bone regeneration membrane, and reapproximate the tissue.

Oroantral Fistulae

Oroantral fistulae may develop postoperatively, especially if the patient has a history of past sinus pathology or infection. Small oroantral fistulae (<5 mm) usually will close spontaneously after treatment with systemic antibiotic drugs and daily rinses with chlorhexidine. However, larger fistulae (>5 mm) will normally require additional surgical intervention (Fig. 13.45). Larger fistulae are associated with an epithelialized tract, which is the result of the fusion of the sinus membrane mucosa to the oral epithelium. When this occurs, patients will most likely complain of fluids entering the nasal cavity upon eating or drinking. Caution should be exercised in using the nose blowing test to confirm the presence of a oral-antral fistula. The patient is asked to pinch their nostrils together to occlude the nose. The patient blows gently to see if air escapes into the oral cavity via the sinus. This is not recommended as this test may create an opening or make a small opening

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larger.

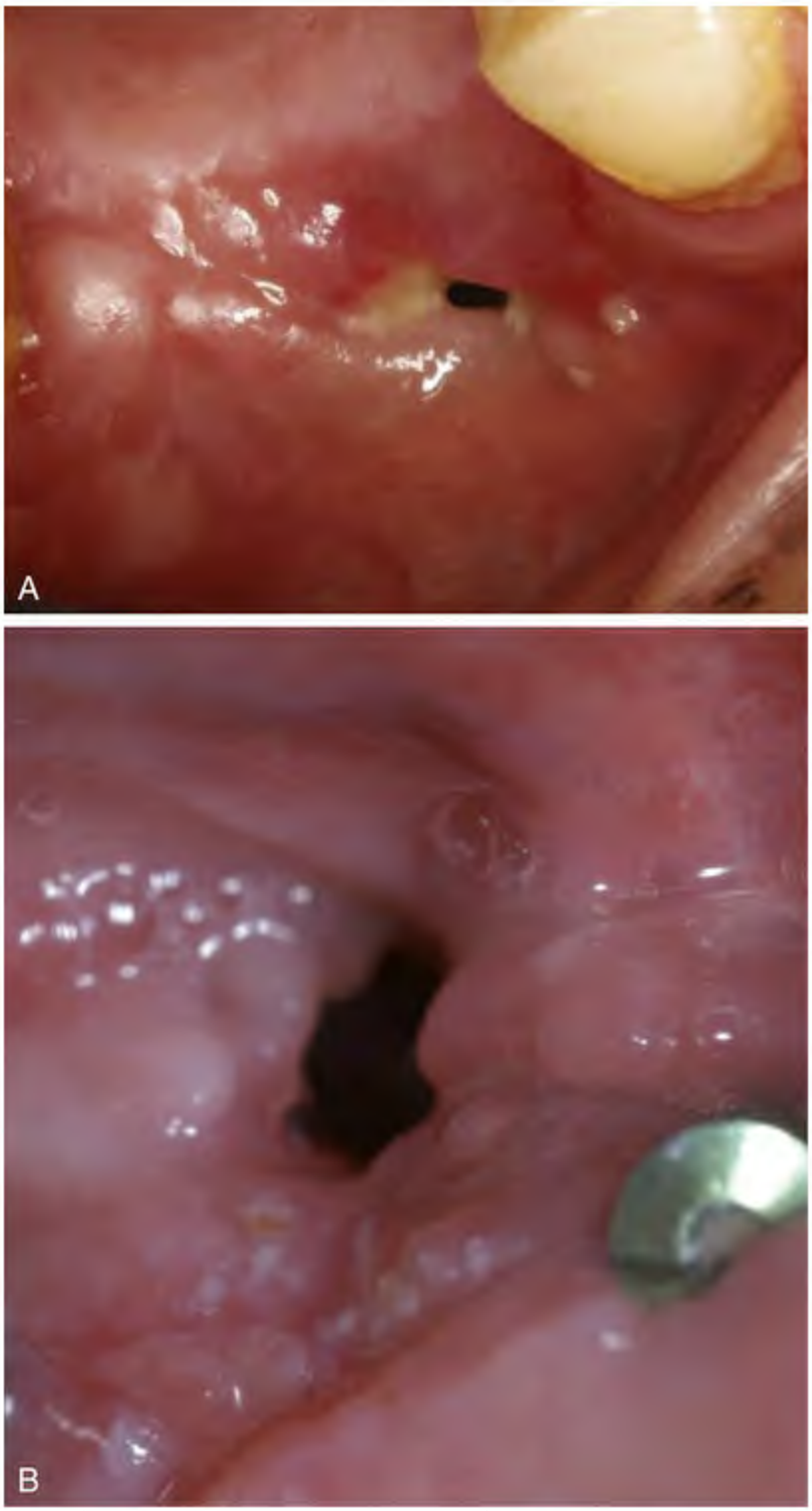

FIG 13.45 Oroantral communications. (A) Small communication. (B) Large communication.

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Management

Closure of oroantral fistulae can be accomplished by using broad-based lingual or facially rotated flaps (Figs. 13.46 and 13.47). Buccal flaps to close the fistula may be more difficult after a sinus graft because of the location of the graft site. In addition, the buccal tissue is very thin, and rotated or expanded buccal flaps usually result in loss of vestibular depth. Before the initiation of the flap design, the soft tissue around the fistula is excised and the sinus floor curetted to ensure direct bone contact. A tension-free rotated flap is then made for complete covering of the communication. For oroantral closure after sinus graft procedures, a lingual flap is recommended because of the abundance of keratinized mucosa with an adequate blood supply. Flap designs include island flaps, “tongue-shaped” flaps, or rotational and advanced flaps, depending on the size of the exposure.

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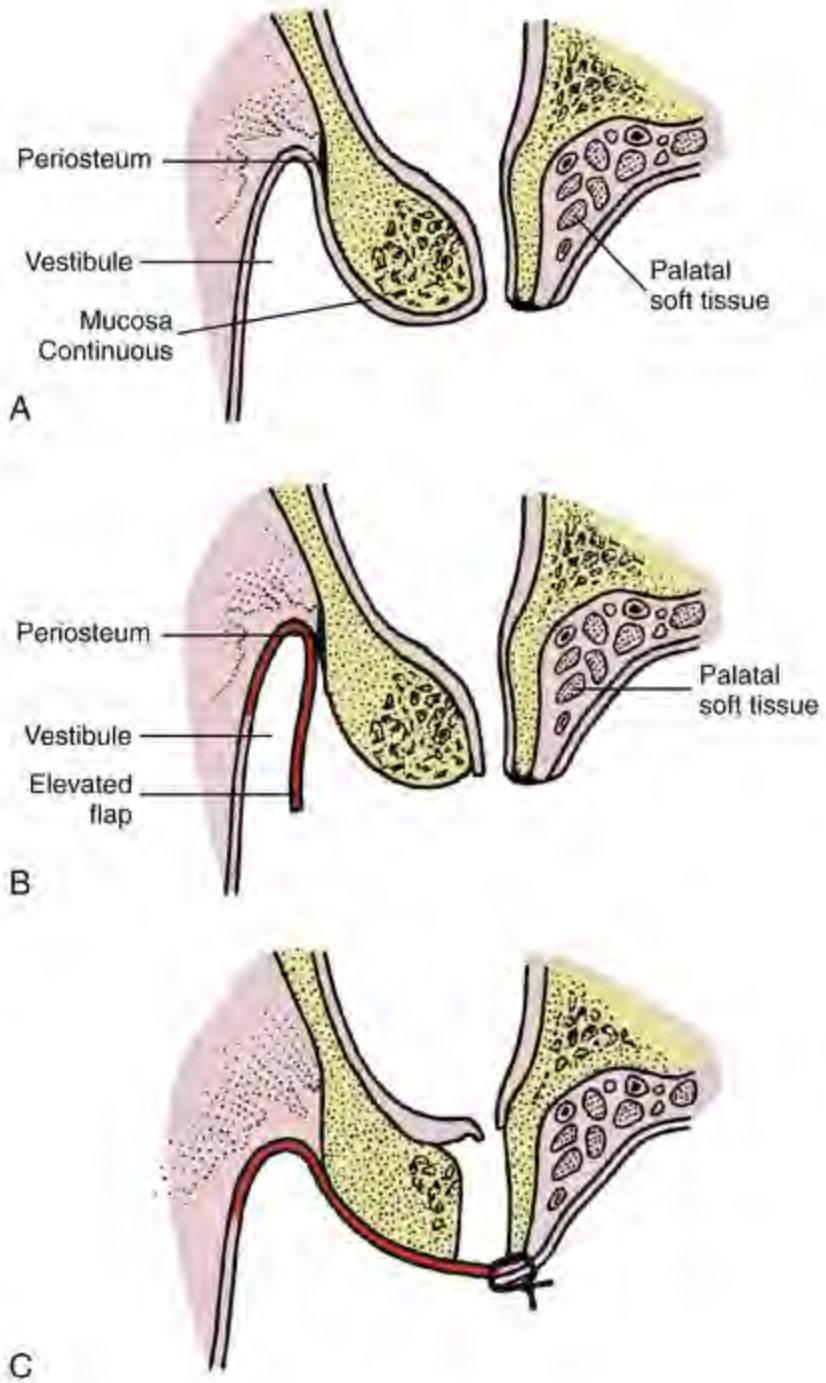

FIG 13.46 Buccal flap closure of oroantral fistula. (A) Cross-section of oroantral fistula in the molar region. (B) The buccal flap has been elevated. (C) The epithelium lining the fistula has been excised, the periosteum has been released at the vestibular height of the dissection, and the tension-free flap has been closed across the defect, with the margins of the flap resting over bone. (From Hupp JR, et al: *Contemporary oral and maxillofactal surgery*, 5 ed, St. Louis, 2009, Elsevier.)

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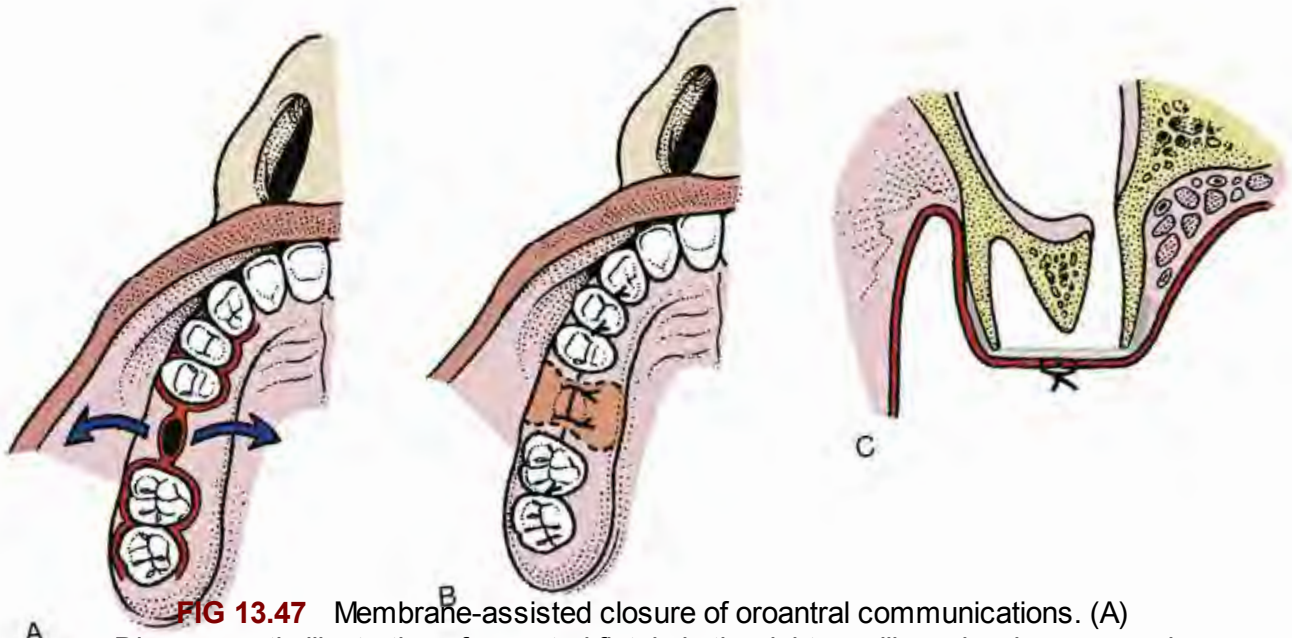

FIG 13.47 Membrane-assisted closure of oroantral communications. (A) Diagrammatic illustration of oroantral fistula in the right maxillary alveolar process in the region of the missing first molar, which is to be closed with subperiosteal placement of alloplastic material such as gold or titanium foil or a resorbable collagen membrane. Facial and palatal mucoperiosteal flaps are developed. Extension of the flaps along the gingival sulcus one or two teeth anterior and posterior allows some stretching of the flap to facilitate advancement for closure over the defect. The fistulous tract is excised. Osseous margins must be exposed 360 degrees around the bony defect to allow placement of the membrane beneath the mucoperiosteal flaps. The flap is supported on all sides by underlying bone. (B) Diagram of closure. Ideally, the flaps can be approximated over the defect. In some cases, a small gap between the flaps will heal over the membrane by secondary intention. Even if the intraoral mucosa does not heal primarily, the sinus lining usually heals and closes, and the membrane is then exfoliated or resorbed, and mucosal healing progresses. (C) Cross-sectional diagram of membrane closure technique. Buccal and palatal mucoperiosteal flaps are elevated to expose osseous defect and large area of underlying alveolar bone around the oroantral communication. The membrane overlaps all the margins of the defect, and the facial and palatal flaps are sutured over the membrane. (From Hupp JR, et al: *Contemporary oral and maxillofactal surgery*, 5 ed, St. Louis, 2009, Elsevier.)

A key to closing the oroantral opening is the dissection of the buccal flap lateral to the fistula. An incision that extends 15 mm anterior and posterior to the fistula is of benefit. The fistula then has an elliptical incision on each side of the opening. The core of tissue and the fistulous tract are excised. The facial flap is undermined and expanded well into the tissues of the cheek. The palatal aspect of the incision is adjacent to the tongue-shaped flap. Placement of the incision for the pedicle flap should be split thickness and take into account the location and depth of the greater palatine artery. Once the attached palatal pedicle graft is rotated to the lateral and attached to the facial flap, horizontal mattress sutures are placed to invert the flap to achieve

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a watertight seal. Sutures with high tensile strength (Vicryl) should be used and allowed to remain in place for at least 2 weeks (Fig. 13.48).

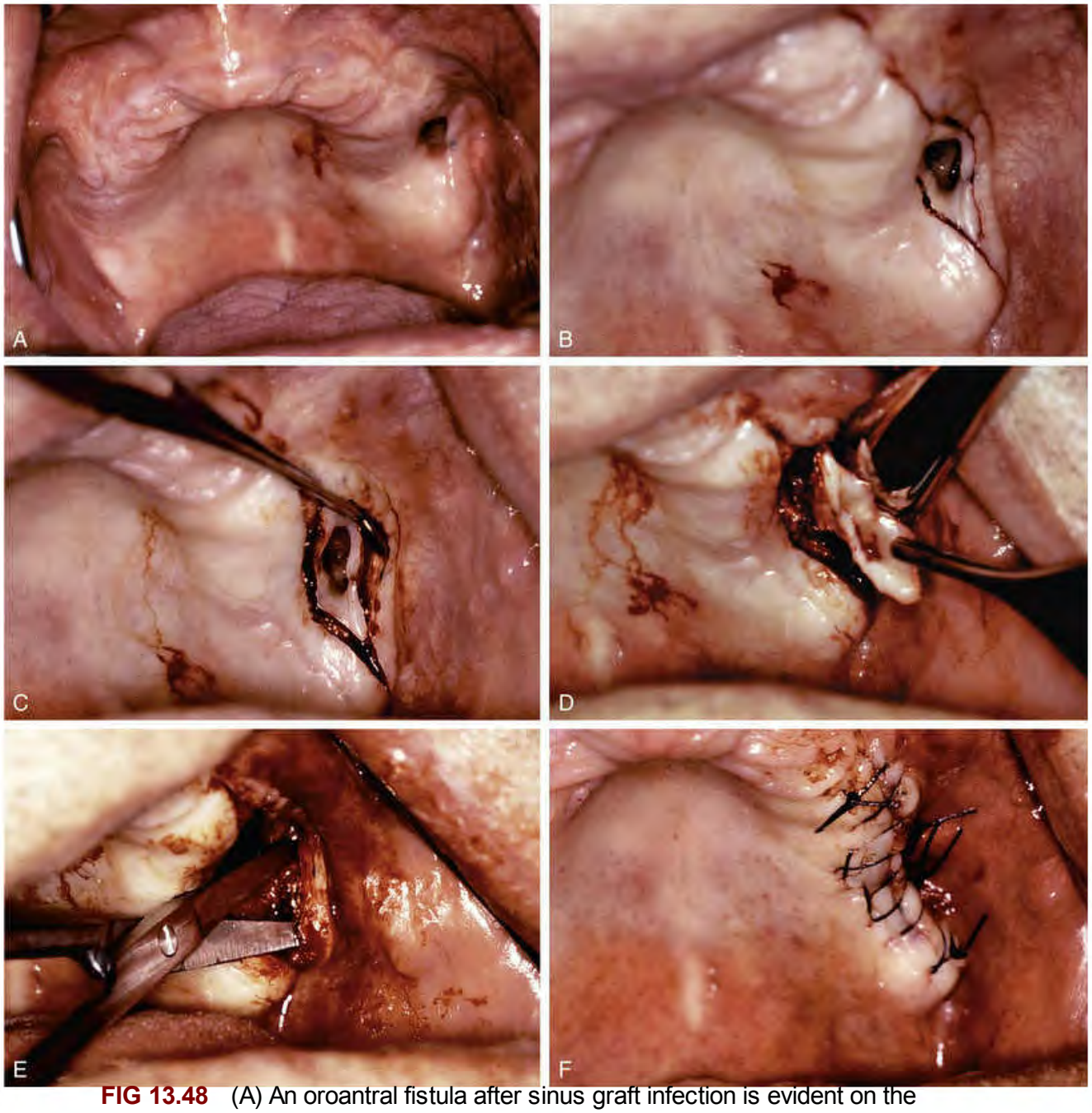

FIG 13.48 (A) An oroantral fistula after sinus graft infection is evident on the patient's left side. (B) An elliptical incision is made around the fistula and extends both anterior and posterior to the site. (C) The tissues are reflected. (D) The fistulous tract is removed, complete with the epithelial lining. (E) The facial flap is undermined, and a submucosal space is created. (F) Horizontal mattress sutures are used for the watertight closure.

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Infections

When evaluating postsurgical infectious complications after sinus graft procedures, the implant clinician must differentiate the type, location, and etiology of the infectious episode. The infection may originate within the graft site or may originate in the maxillary sinus proper. It could also be a combination of both (Table 13.1). Very few studies have evaluated these different processes. Postsurgically, there exist many reports with varying results (~0%–27%) on the incidence of infection leading to acute rhinosinusitis.[56a] Postoperative infections after sinus graft surgery may result from the following:

- Acute rhinosinusitis: infection within the sinus proper
- Graft site: infection within the graft area (Fig. 13.49)
- Combination infection: from acute rhinosinusitis or graft site

Fig. 13.50 shows preoperative and postoperative infection rates, and infection rates after 4 weeks.

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TABLE 13.1
Postoperative Infections

	Acute Rhinosinusitis	Graft Site Infection	Combination
Etiology	Preexisting pathology Nonpatent ostium Anatomic variants Graft overfill Postsurgery physiologic alteration Spread of infection from graft site History of chronic rhinosinusitis Preexisting odontogenic or allergic rhinosinusitis	Pre-existing pathology Oral pathogens contamination Untreated periodontitis Perforation Lack of asepsis Long duration surgery Simultaneous ridge augmentation Simultaneous implant placement Lack of prophylactic medication Lack of local graft antibiotics Systemic diseases, smoking/alcohol	Primary site could be sinus proper or graft site
Bacteria	Aerobic gram-positive cocci *(Streptococcus pneumoniae)* Aerobic gram-negative rods *(Haemophilus influenzae)* *(Staphylococcus epidermidis, Streptococcus viridans, B catarrhalis)*	Aerobic gram-positive cocci *(Streptococcus viridans)* Aerobic gram-positive cocci *(Staphylococcus aureus)* Aerobic gram-negative rods *(Bacteroides)* Aerobic gram-positive cocci (peptostreptococcus)	Any combination of pathogens
Prevention	CBCT: Confirmation of ostium patency Confirmation of no pathology or anatomic variants Prophylactic medications	Prophylactic medication Good surgical technique Aseptic technique Short surgical duration No membrane perforation	Any combination of preventive measures
Symptoms	**Mild** Facial pain/edema Congestion Nasal drip/blockage Cough **Severe** Significant facial pain/edema Fever Headache Proptosis/diplopia Malaise	Site pain/edema Incision line opening Exudate Bad taste Bleeding Intra-oral swelling	Any combination of symptoms
Ideal Antibiotic	Beta-lactam Quinolone	Beta-lactam Lincosamide	Beta-lactam Quinolone
Initial Treatment	Antibiotic: 1. Augmentin 2. Levaquin Nasal saline	Antibiotic: 1. Augmentin 2. Clindamycin Chlorhexidine	Antibiotic: 1. Augmentin 2. Levaquin Nasal saline/rinse
Secondary Treatment	Referral, especially if cerebral/ocular symptoms	Debridement/irrigation Possible culture	Debridement Possible culture Referral, especially if cerebral/ocular symptoms

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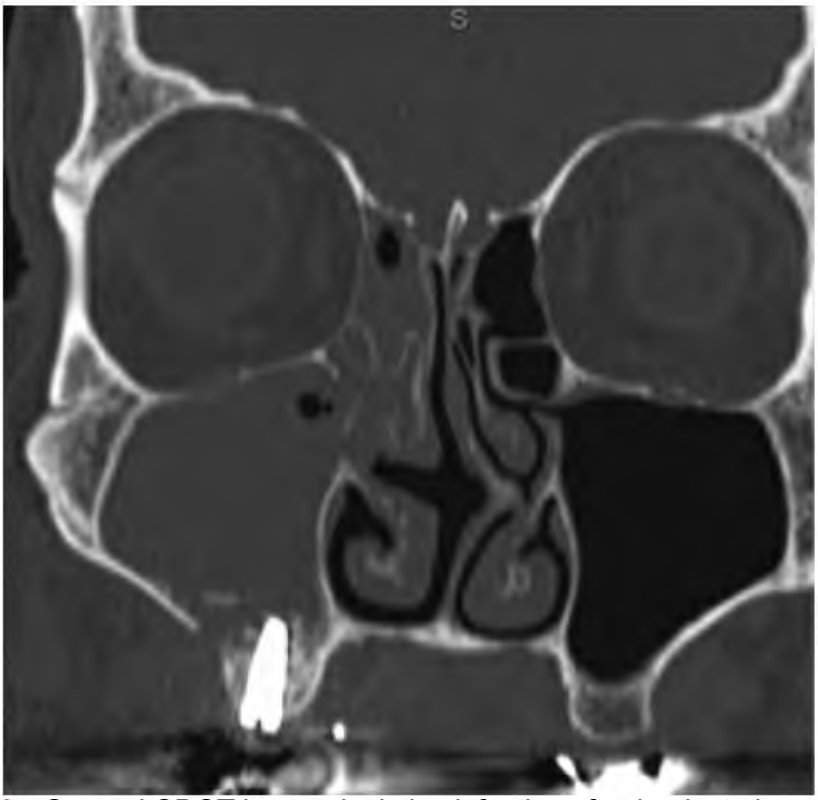

FIG 13.49 Coronal CBCT image depicting infection after implant placement and sinus graft (SA-3 Immediate).

FIG 13.50 Post–sinus graft infection. (A) Preoperative. (B) Postoperative graft. (C) Infection 4 weeks after graft showing sinus radiopacity and nonpatent ostium.

Graft Site Infections

Etiology of Graft Site Infection

The graft site may become infected from many sources: (1) preexisting site bacteria, (2) bacterial contamination of the surgical site, (3) graft material, (4) surgical technique, (5) bacterial contamination from acute rhinosinusitis, (6)

lack of systemic and local prophylactic antibiotics, and (7) systemic, mediation, or lifestyle factors.

Additionally, studies have shown a direct correlation between an increased infection rate with simultaneous implant placement as well as with simultaneous ridge augmentation. One such study showed that simultaneous ridge grafting increased the infection rate significantly (15.3%) vs. sinus grafting alone (3%).[57] Most often, the infection begins more than 1 week after surgery, although it may begin as soon as 3 days later.

Diagnosis

The most common sign of graft site infection is swelling, pain, dehiscence, or exudate near or including the grafting surgical site. Patients may complain of poor taste and loss of graft particles in their mouth. Incision line opening is a common sequalae with exudate discharge. Graft site infections usually occur within days to weeks of the surgery and are less common as a late infection. Initially, the infection may start as a graft site infection (localized to the graft), which then leads to an acute maxillary rhinosinusitis.

Prevention

The prevention of graft site infection includes:

Good Surgical Technique.

Good surgical technique involves the use of a true aseptic technique consisting of sterile drapes and gowning. A clean surgery will decrease the possibility of contamination of the graft site from many of the pathogens that predispose to this type of infection. Additionally, aseptic care in the handling of graft materials is crucial. As such, a surgical environment that includes intraoral and extraoral scrubbing with chlorhexidine, scrubbing and draping the patient, as well as gowning the doctor and assistant should be considered in addition to sterile gloves and sterile instruments. The risk of postoperative sinus infection is generally less than 5% when these procedures, combined with a preoperative and postoperative pharmacologic regimen, are used.[57]

Prophylactic Medications.

The risk of bacterial contamination during and after sinus graft procedures is much different than regular implant surgical procedures. The pharmacologic protocol should be effective against the organisms in this surgical site. The

pharmacologic regimen includes an antibiotic drug, antiinflammatory medications, antimicrobial rinse, and analgesic medications.

Antibiotics.

Following the principles of prophylactic antibiotic administration, the antibiotic should be effective against the bacteria most likely to cause infection. The most likely contaminating organisms after transoral surgery are primarily streptococci, anaerobic gram-positive cocci, and anaerobic gram-negative rods. *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis* are the three most common pathogens found with acute sinus infections.[58] *Staphylococcus aureus* along with anaerobic bacteria have a significant role in causing chronic rhinosinusitis disease. The organisms associated with infection of allografts such as demineralized bone in oral surgery include alpha-hemolytic streptococci and S. *viridans*.[59] *S. aureus*, *Bacteroides* spp, and endogenous bacteria cause the vast majority of postoperative infections. A pharmacologic protocol effective against these organisms is appropriate.

Bacterial resistance.

When evaluating various classes of antibiotic medications used for treatment of maxillary sinus infections, the antibiotic class of choice is beta-lactam antibiotic drugs. However, bacterial resistance has become a significant problem in the treatment of these pathogens. With the wide range of possible routes of bacterial invasion and types of bacteria, the antibiotic drug must be broad spectrum to account for all these possibilities. Bacterial resistance is initiated by two common mechanisms: (1) production of antibiotic-inactivating enzymes *(S. aureus, H. influenzae,* and *M. catarrhalis)* and (2) alteration in target site *(S. pneumoniae).* Studies have shown the following resistance results[60]:

H. influenzae: 36.8%

M. catarrhalis: 98%

S. pneumoniae: 28.6%

Ideal antibiotic.

Because of the high rate of bacterial resistance, amoxicillin (the drug of

choice for many years) is no longer used for antibiotic prophylaxis for the sinus graft surgery. Instead, amoxicillin-clavulanate (Augmentin) is recommended because of the addition of clavulanic acid, which enhances amoxicillin's activity against the beta-lactamase–producing strains of bacteria. The clavulanate acid, which is also an antibiotic, has an affinity to the beta-lactamase. Because of this interaction, the beta-lactamase is inactivated. Additionally, Augmentin has a very good, broad spectrum of bacteria that may cause oral infections.

Alternative antibiotics.

The patient with a history of nonanaphylactic allergic reaction to penicillin may take cefuroxime axetil (Ceftin), which is a second-generation cephalosporin, as an alternative.[61] Ceftin possesses good potency, efficiency, and strong activity against resistant *S. pneumoniae* and *H. influenzae* bacteria.

If a patient has a history of an anaphylactic reaction to penicillin, recurrent sinus infections, or a recent history of antibiotic use, levofloxacin (Levaquin) may be indicated. This newer type of quinolone antibiotic exhibits superior activity against most types of involved bacteria, along with resistant strains.

Early administration.

Maximum effectiveness of prophylactic antibiotic drugs occurs when the antibiotic is in adequate concentrations in the tissue prior to bacterial invasion. Because the sinus mucosa has limited blood supply to combat possible bacterial invasion from the sinus surgery, along with a high incidence of tissue inflammation, antibiotic medications should be administered at least 1 full day before surgery and extended for 5 days after surgery.

Local antibiotic medications.

The antibiotic concentration within a blood clot of the sinus graft depends on the systemic blood titer. After the clot stabilizes, further antibiotic drugs do not enter the area until revascularization.[62] The bone graft is a dead space with minimum blood supply and the absence of protection by the host's cellular defense mechanisms. This leaves the graft prone to infections that would normally be eliminated by either the host defenses or the antibiotic. The osteogenic induction of autografts and allografts is greatly retarded when contaminated with infectious bacteria.[63] To ensure adequate antibiotic levels in a SA graft, it is recommended to add antibiotic (e.g., pure form) to

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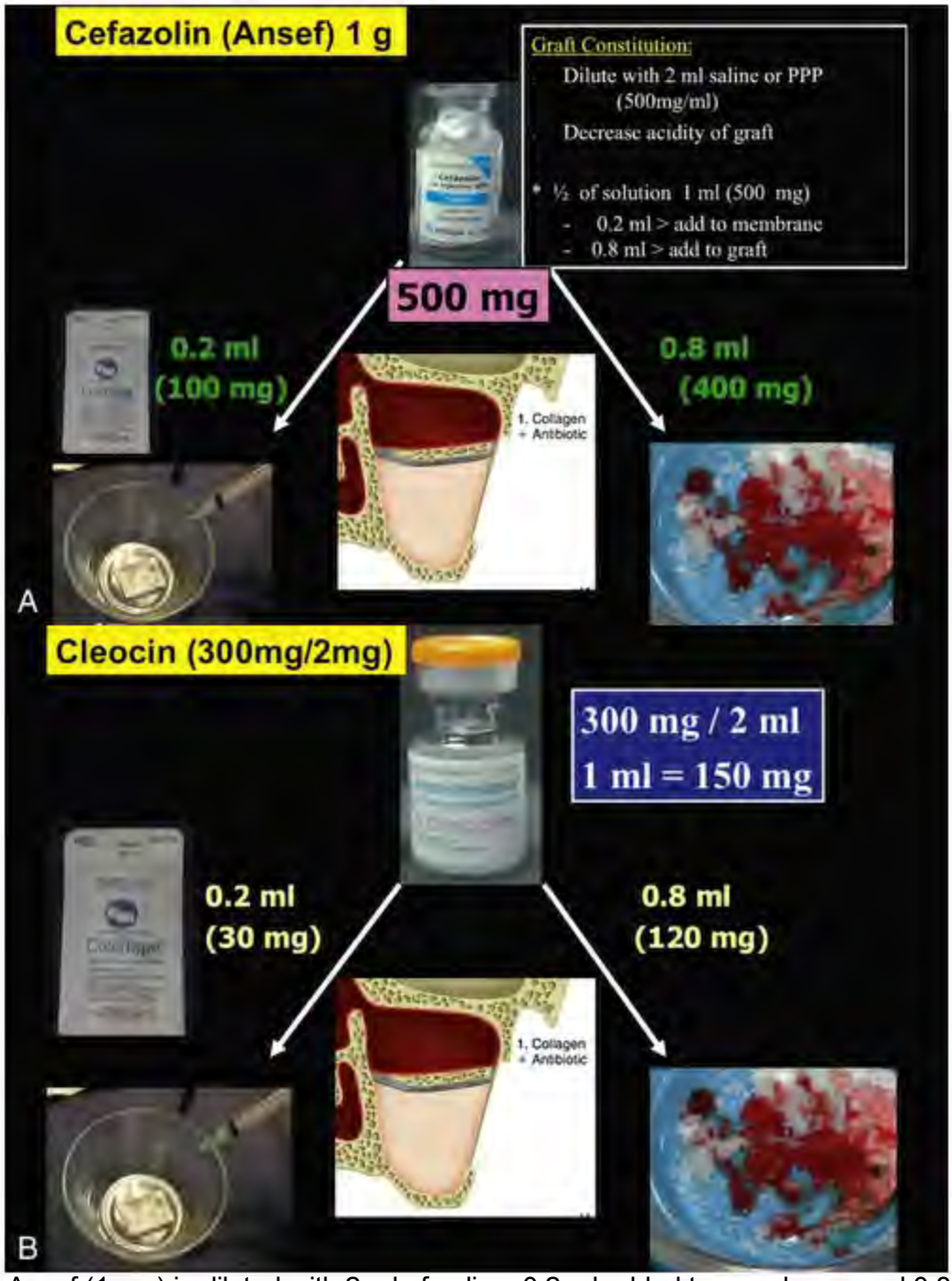
the graft mixture.[64] The local antibiotic may protect the graft from early contamination and infection. Numerous studies have shown that an antibiotic added to graft material has no deleterious effects on bone growth. Antibiotic drugs such as penicillin, cephalosporin, and clindamycin, even in high concentrations, have not been found to be destructive to bone-inductive proteins.[65]

The locally delivered antibiotic should have efficacy against the most likely organisms encountered. Because the incidence of allergy is so high with beta-lactam antibiotic drugs, the parenteral form of cefazolin (Ancef) or clindamycin is selected. Orally administered capsules and tablets should not be used within the graft because they contain fillers that are not conducive to osteogenesis. When the parenteral form of antibiotic is a liquid, the volume of liquid added to the graft should be minimized to allow adequate handling of the graft mixture.



(A) Ansef (1 gm) is diluted with 2 ml of saline, 0.2 ml added to membrane and 0.8 ml added to the graft. (B) Cleocin (300 mg/2 mg), 0.2 ml added to membrane and 0.8 ml added to the graft.

Clinical experience indicates that less risk of infection exists when preoperative and postoperative antibiotic drugs are used both orally and in the graft. Because infection considerably impairs bone formation for patients undergoing sinus graft procedures, oral antibiotic coverage is continued for 5 days after the surgery.

Oral antimicrobial rinse.

An additional antimicrobial medication that is recommended is chlorhexidine gluconate. This category of mouth rinse has been shown to successfully decrease infectious episodes and minimizes postoperative complications from the incision line. Gentle oral rinses of chlorhexidine gluconate 0.12% should be used twice daily for 2 weeks after surgery.

Glucocorticoid medications.

The decrease in inflammation of the soft tissue decreases postoperative pain, swelling, and incision line opening. In addition, the clinical manifestations of surgery on the sinus mucosa can also be decreased by use of a steroid.[66] The usual surgical protocol for most implant surgeries, including sinus grafts, includes a short-term dose of dexamethasone (Decadron). To ensure patency of the ostium and minimize inflammation in the sinus before surgery, steroid medications are initiated 1 full day before surgery. This medication should also be extended 2 days postoperatively because edema peaks at 48 to 72 hours.

Decongestant medications.

Sympathomimetic drugs that influence alpha-adrenergic receptors have been used as therapeutic agents for the decongestion of mucous membranes. Both systemic and topical decongestant medications have been used in reversing a nonpatent ostium. However, recent recommendations from the otolaryngology literature discourage the use of these medications. Topical decongestant drugs can cause a rebound phenomenon and the development of rhinitis medicamentosa if used more than 3 to 4 days. It should also be noted that the pulse amplitude and blood flow in the sinus mucosa is reduced with decongestant drugs such as oxymetazoline. This may, in turn, decrease the defense mechanism of the tissues.[67] Oxymetazoline 0.05% (Afrin or Vicks Nasal Spray) and phenylephrine 1% should not be used prophylactically or for therapeutic purposes.

Treatment

Although the incidence of infection after the procedure is usually low, the damaging consequences on osteogenesis and the possibility of serious complications require that any infection be aggressively treated. In case of postoperative infection, it is recommended that the clinician perform a thorough examination of the area by palpation, percussion, and visual inspection to identify the area primarily affected. Infection will usually follow

the path of least resistance and is observed by changes in specific anatomic sites to which it spreads.[68]

Early, aggressive treatment is crucial for graft site infections to prevent the loss of graft or extension of the infection into the sinus proper causing an acute rhinosinusitis or spread of infection to other vital areas. Initially, systemic antibiotics along with antimicrobial rinses should be used. If infection persists, debridement and drainage should be completed along with the use of sterile saline and chlorhexidine. A Penrose drain may also be used in cases that do not respond to systemic antibiotics. In some instances, oroantral fistulas result after infection cessation (see the section on oroantral fistula).

Antibiotic treatment in the maxillary sinus, both prophylactically and therapeutically, is much different than for most oral surgical procedures. When selecting antibiotic medications for sinus infections, a variety of factors must be evaluated. These include the most common type of pathogens involved, antimicrobial resistance, pharmacokinetic and pharmacodynamic properties, and the tissue (sinus) penetration of the various antibiotic drugs. The antibiotic medication of choice should be effective against respiratory and oral pathogens while exhibiting known activity against resistant strains of the common pathogens. Two such factors are used when evaluating sinus antibiotic medications: (1) the minimum inhibitory concentration (MIC) and (2) the concentration of antibiotic drugs penetrating inflamed diseased sinus tissue. The MIC is the lowest concentration of the antimicrobial agent that results in the inhibition of growth of a microorganism. The MIC is usually expressed by MIC 50 or MIC 90, meaning that 50% or 90% of the microbial isolates are inhibited, respectively.

Previous studies and treatment modalities used amoxicillin as the first drug of choice. However, with the increasing prevalence of penicillinase- and beta-lactamase–producing strains of *Haemophilus influenzae* and *Moraxella catarrhalis*, along with penicillin-resistant strains of *Streptococcus pneumoniae*, other alternative antibiotic drugs should be selected.

Beta-Lactam Medications.

The most common beta-lactam antibiotic drugs used in the treatment of rhinosinusitis and graft site infections are penicillin (amoxicillin, Augmentin) and cephalosporin (Ceftin, Vantin). Amoxicillin has been the drug of choice for years to combat the bacterial strains associated with

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rhinosinusitis and infections in the oral cavity. However, its effectiveness has been questioned recently because of the high percentage of beta-lactamase–producing bacteria and penicillin-resistant *S. pneumoniae*. Augmentin (amoxicillin-clavulanate) has the added advantage of activity against beta-lactamase bacteria. It has been associated with a high incidence of gastrointestinal side effects. However, with the dosing regimen (twice a day [bid]), these complications have been significantly decreased.

Two recommended cephalosporin medications have also been suggested to treat rhinosinusitis: cefuroxime axetil (Ceftin) and cefpodoxime proxetil (Vantin). Other cephalosporin drugs fail to achieve adequate sinus fluid levels against the causative pathogens. Ceftin and Vantin have good potency and efficacy while exhibiting strong activity against resistant *S. pneumoniae* and *H. influenzae*.

Fluoroquinolone Medications.

Fluoroquinolone drugs are bactericidal antibiotic medications that are classified into four different generations. The third-generation quinolone drugs are well-suited, broad-spectrum antibiotic medications and have been labeled by the US Food and Drug Administration (FDA) for use against sinus and oral pathogens. They exhibit excellent absorption and achieve very significant sinus blood levels, even in pathologic conditions. Quinolone drugs are distributed extensively throughout the sinus, with high levels being found in inflamed tissue and maxillary sinus cysts. The tissue/blood ratio is approximately 4 : 1, making it extremely potent within the diseased sinus. The three most common quinolone medications used for sinus treatment include levofloxacin (Levaquin), gatifloxacin (Tequin), and moxifloxacin (Avelox).

Macrolide Medications.

Macrolide drugs are bacteriostatic agents that include erythromycin, clarithromycin (Biaxin), and azithromycin (Zithromax). Macrolide medications have good activity against susceptible pneumococci; however, with the increasing rate of macrolide resistance, their use in combating sinus pathogens is becoming associated with a high likelihood of clinical failure. These antibiotic drugs are very active against *M. catarrhalis,* although their activity on *H. influenzae* is questionable. These antibiotic medications are not suggested to treat postoperative sinus infections.

Lincosamide Medications.

Clindamycin (Cleocin) is the primary lincosamide drug used in clinical practice today that is considered to be bacteriostatic. However, in high concentrations, bactericidal activity may be present. Clindamycin is mainly used for the treatment of gram-positive aerobes and anaerobes. With acute sinus disease, clindamycin is usually not indicated because it exhibits no activity against *H. influenzae* and *M. catarrhalis*. This drug may be used in chronic sinus conditions because anaerobic organisms play a much larger role in the disease process.

Tetracycline Derived Medications.

Doxycycline (Vibramycin) is a bacteriostatic agent with adequate activity against penicillin-susceptible pneumococci and *M. catarrhalis*. This drug does not exhibit any activity against penicillin-resistant bacteria and is not effective against *H. influenzae*. However, doxycline may be used as an alternative antibiotic for the treatment of acute rhinosinusitis infections.

Sulfonamide Medications.

The most common sulfonamide drug, trimethoprim-sulfamethoxazole (Bactrim) is bacteriostatic. Recently, a high rate of resistance to these drugs has been seen with *S. pneumoniae, H. influenzae, M. catarrhalis,* and other sinus pathogens. This drug should not be considered to treat postoperative infections, unless a culture and sensitivity test has been performed and susceptibility is shown.

Metronidazole Medications.

Metronidazole is the most important member of the nitroimidazole group. It is bactericidal and is effective against gram-positive and gram-negative anaerobic bacteria. Its main use would be in the treatment of chronic sinus (not acute) conditions. The medication should be used with another antibiotic drug to be effective against aerobic bacteria.

Antibiotic Conclusion

In the evaluation of different antibiotic drugs used for the treatment of pathologic conditions of the sinus, meticulous analysis of the activity against the most common pathogens must be evaluated. With all of the antibiotic medications evaluated, amoxicillin-clavulanate, cefuroxime axetil,

levofloxacin, and moxifloxacin showed significant sinonasal and MIC 90 blood levels against the most common pathogens associated with sinus infections. Moxifloxacin, a third-generation fluoroquinolone drug, has been shown to have superior qualities compared with many other antibiotic medications. It shows extensive distribution throughout the sinuses in both inflamed and noninflamed sinus tissue, with significantly high concentration within maxillary sinus cysts. The tissue/blood ratio is 4 : 1, with blood levels occurring 3 to 4 hours after administration. Because of the potency and expense of this medication, it is used only in the treatment of severe infections.

Decongestant Medications.

Recent recommendations in the medical literature state that nasal decongestants (sympathomimetic drugs) should not be used except in severe cases of congestion and infection. Nasal decongestants have been shown to impair blood flow, thus decreasing antibiotic levels to the site. Additionally, it may cause a rebound phenomenon and the development of rhinitis medicamentosa. This rebound phenomenon has been theorized to occur as a negative feedback vasodilation after repeated introductions of the sympathomimetic (vasoconstricting) drug.

Saline Rinses.

An important treatment for the patient with the presence of acute rhinosinusitis and graft infections is the use of saline rinses with a bulb syringe or a squeeze bottle in the nostril used to lavage the sinus through the ostium. The nasal saline rinse has a long history for treatment of sinonasal disease. Hypertonic and isotonic saline rinses have proven to be effective against chronic rhinosinusitis. These techniques of nasal irrigation have been evaluated, with the best option of a positive-pressure irrigation using a squeeze bottle that delivers a gentle stream of saline to the nasal cavity (NeilMed's Sinus Rinse [NeilMed Pharmaceuticals Inc.]). The syringe or squeeze bottle should not seal the nasal opening because this may force bacteria up toward the ethmoidal sinus. Instead, a gentle lavage with sterile saline rinses the sinus and flushes out the mucus and exudate. Ideally, the head is placed down and forward so that the saline can reach the ostium in the superior and anterior portion of the sinus. The course of therapy should continue for at least 7 days.[69] Another option is for the use of a Neti-Pot,

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which is very common amongst chronic rhinosinusitis patients (Fig. 13.51).

FIG 13.51 (A) Saline rinse should be directed toward the ostium *(arrow)*. (B) Neti-Pot used to clear nasal passages. (B, From GettyImages.com.)

Acute Rhinosinusitis Infections

Etiology of Acute Rhinosinusitis

There are two causes of acute maxillary rhinosinusitis after sinus graft surgery: (1) preexisting maxillary sinus pathology, or (2) progression of sinus graft surgery to involve the maxillary sinus proper.

Diagnosis

Maxillary rhinosinusitis is a complication that arises when the patient postoperatively complains of any of the following symptoms: (mild) headache, pain, or tenderness in the area of the maxillary sinus, rhinorrhea, or (severe) fever, headache, or ocular symptoms. Studies have supported the fact that patients who had predisposing factors for rhinosinusitis were more at risk of developing postoperative transient rhinosinusitis. The wide range of reported percentages (3% to 20%) may be the result of different methods used for diagnosis (i.e., clinical, radiographic, endoscopic).

Cases of maxillary sinusitis after dental implant surgery have rarely been reported in the dental literature. However, recently in the medical literature, numerous cases of minor to severe complications after sinus surgery have been documented. Although very infrequent, severe infections may lead to more severe complications, such as orbital cellulitis, optic neuritis, cavernous sinus thrombosis, epidural and subdural infection, meningitis, cerebritis, blindness, osteomyelitis, and, although rare, brain abscess and death.[70]

Prevention

The prevention of acute rhinosinusitis after sinus graft surgery includes:

CBCT Examination.

The paranasal sinus area must be determined to be void of preexisting pathology, anatomic variants, and a patent ostium. The superior limits of the CBCT survey must include the maxillary ostium. Evaluation of this anatomic area is most important in preventing postoperative sequelae. Additionally, evaluation of the paranasal sinus anatomy for anatomic variants, pathology, or any preexisting condition that would lead to clearance morbidity issues must be determined prior to surgery.

Prophylactic Antibiotics.

Prophylactic antibiotic medications and sound surgical principles minimize postoperative infections and complications. The resistance of the sinus to

contamination is low, and the chances of this happening are easily increased with contamination by intraoral or sinus pathogens. The use of systemic antibiotics, antimicrobial mouth rinses, and corticosteroids will help maintain the patency of the ostium.

Treatment

If infection occurs postoperatively, treatment must be aggressive because of the possible complications that may arise to close anatomic structures. Systemic antibiotic therapy is the first line of treatment along with close observation of symptoms. Recent medical literature discourages the use of systemic decongestants and highly recommends the use of saline lavage and rinses. Systemic decongestants have been shown to impair site antibiotic delivery and also have a high degree of rebound effect (rhinitis medicamentosa).

If symptoms are not alleviated with antibiotic and decongestant medications, possible referral to the patient's physician or otolaryngologist is warranted. Emergency consultation should be considered if the patient complains of a severe headache that is not relieved by mild analgesics, as well as persistent or high fever, lethargy, visual impairment, or orbital swelling.

The authors highly recommend that a professional association with an otolaryngologist be obtained. Because the possible morbidity of these infections and causative pathogen is not easily determined, referral is sometimes needed. Additionally, if mild sinus symptoms persist or signs of severe infection are present, immediate referral is recommended. Resolution of these conditions has been accomplished with the use of antibiotic drugs, endoscopic treatment, or Caldwell-Luc procedures.

Combination (Graft Site Infections/Acute Rhinosinusitis)

Etiology

The etiology of a combination infection can either be initiated from the graft site or the sinus proper.

Diagnosis

The diagnosis for a combination type infection can parallel a combination of

graft site symptoms and/or acute rhinosinusitis.

Prevention

Same preventive techniques discussed previously for graft site infections and acute rhinosinusitis.

Treatment

The treatment of a combination type infection should include the use of a beta-lactam antibiotic (e.g., Augmentin) followed by the use of debridement and nasal saline rinses. If ocular or cerebral symptoms persist, or the patient does not respond to antibiotic treatment, referral is recommended.

Postoperative CBCT Mucosal Thickening (False-Positive for Infection)

Immediate postoperative radiographs may reveal significant mucosal thickening within the sinus. The clinician should not determine this to be infection unless the above signs of infection are noted. Normally, elevation of the sinus mucosa and bone grafting does alter the overall maxillary sinus environment by reducing the size of the sinus and repositioning the mucociliary transport system. In spite of this, only short-term clearance impairment exists, resulting in only subclinical effects on the sinus physiology. However, in cases of preoperative sinusitis histories, elevation surgery may predispose a patient to sinus-related complications. It has been shown that these procedures do alter the microbial environment. Studies reveal at 3 months after surgery, positive sinus cultures were present compared with cultures taken for the same patients preoperatively. However, after 9 months the cultures were similar to the preelevation results. The key is maintenance of the osteomeatal opening between the maxillary sinus and the nasal cavity.

Migration/Displacement of Implant

In 1995 the first case of a displaced (migrated) implant into the maxillary sinus was documented. Since then, an increased number of reports are coming to light, documenting an ever-increasing problem. Reports have shown that implants migrating from the maxillary sinus have been found in

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the sphenoid sinus, ethmoid sinus, orbit, nasal cavity, and anterior cranial base.

Etiology

The etiology of implant displacement or migration from the maxillary sinus includes many possibilities. The timing of implants ending up in the maxillary sinus proper varies from intraoperative displacement to migration years later. Many etiologic factors have been suggested according to the timing (early vs. late) (Table 13.2).

TABLE 13.2

Migration/Displacement of Implants

Early	Late
• Poor initial stability • Overpreparation of osteotomy site • Poor quality of bone • No crestal cortical bone • Implant placement into sinus without bone graft • Incorrect treatment planning • Surgical inexperience • Untreated antral preparation • Postoperative sinus infection • Immediate placement implants	• Too early loading • Changes in intranasal or intrasinus pressure • Peri-implantitis • Autoimmune reaction

Prevention

For early migration/displacement complications, most likely the cause is surgical error or incorrect treatment planning. When evaluating late migration/placement complications, the majority of issues are a direct result of postoperative prosthetic errors (too early loading) or factors that are precipitated by lack of integration or minimal bone at the implant interface.

Management

The management of displaced or migrated implants into the maxillary sinus should be treated with urgency. Leaving implants in the maxillary sinus may lead to acute rhinosinusitis complications. Additionally, implants left in the maxillary may become calcified (antrolith) or become displaced into other anatomic areas (e.g., sinuses, orbit, nasal cavity, brain). The patients should be referred as soon as possible for removal via a Caldwell-Luc approach or endoscopy (FESS) (Fig. 13.52).

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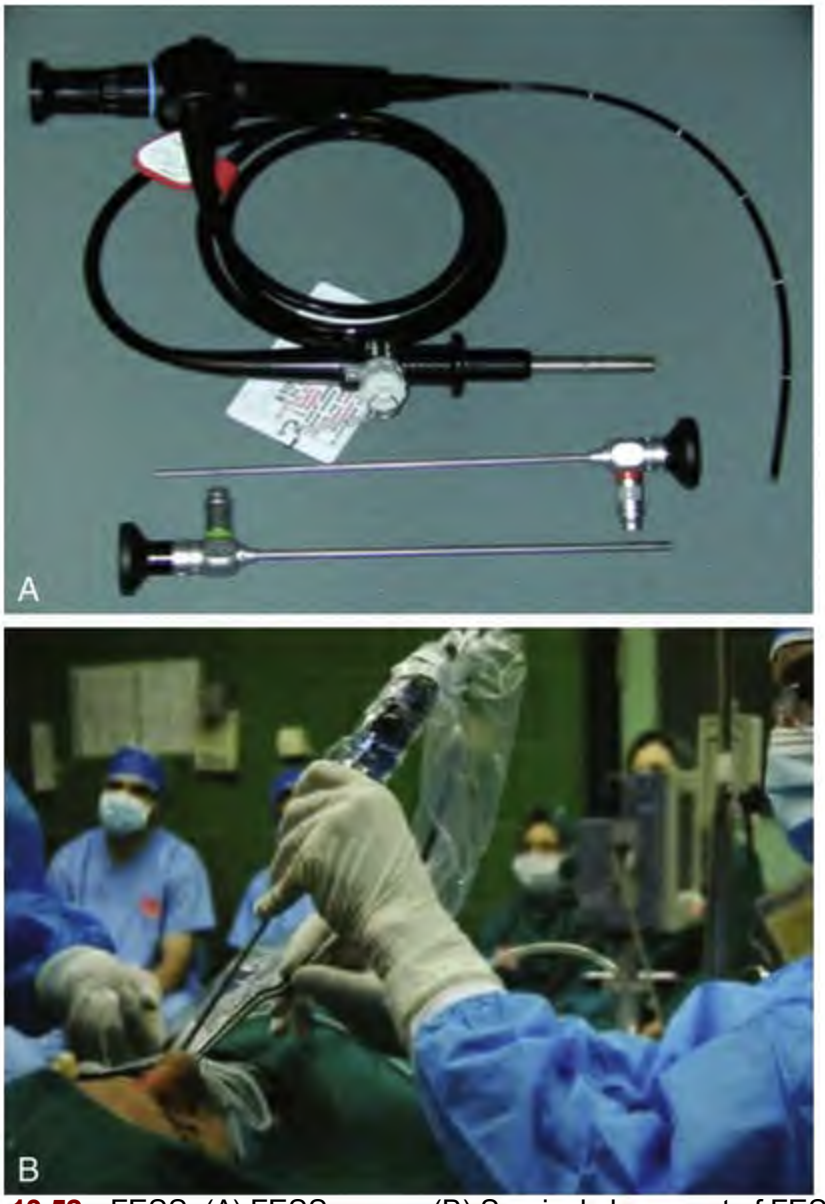

FIG 13.52 FESS. (A) FESS scope. (B) Surgical placement of FESS.

Postoperative Fungal Infection

Fungal infection after sinus bone grafting is rarely reported; however, with the increased number of sinus graft procedures being performed, inevitably more will be reported in the literature. Fungal sinusitis is a destructive, invasive disease which is mostly caused by *Aspergillus*. *Aspergillus* spp is a fungus of the Ascomycetes class, which is one of the most commonly encountered in the human environment.

In the diagnosis of fungal sinusitis, there exist two forms: noninvasive and invasive. The invasive form is rare and is almost always associated with immunocompromised patients. Erosion and osseous destruction occurs that

may be fatal. However, this form has not been associated with dental implants or sinus graft surgery.

Case studies have shown postoperative complications after sinus graft surgery[71] and overextension of root canal filling involving the noninvasive form.[72] This type of fungus growth is also termed fungus balls or asperilloma and is associated with immunocompetent patients.

Diagnosis

Usually, the patient will present with clinical symptoms of frontal headache, orbicular pain, nasal congestion, and bleeding with signs of chronic rhinosinusitis. Radiographically, a distinctly increased soft tissue density mass (radiopacity) is seen on CBCT scans.

Management

Referral to an ENT for evaluation and confirmation of diagnosis. Usually, treatment involves surgical removal via Caldwell-Luc or FESS techniques because systemic antimycotic drugs are ineffective.

Postoperative Maxillary Surgical Cysts

Postoperative maxillary surgical cysts have been reported in the literature after sinus graft surgery. However, they are extremely rare. In 1927, Kubo reported a postoperative maxillary cyst arising in the maxilla as a delayed complication of radical surgical intervention in the maxillary sinus.[36] In 1992, Misch et al reported one incidence of a maxillary surgical cyst associated with a past sinus graft and blade implant. Complete enucleation was accomplished, and healing was uneventful.[37] Incidence reports are more common in Japan, where sinus disease is often treated aggressively with surgery, but are rare in other parts of the world.[73]

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Complications Associated With Immediate Implant Placement

Glenn J. Jividen, Carl E. Misch

The placement of endosseous implants at the time of tooth extraction has been shown to be a viable protocol.[1-5] The objectives of immediate implant placement are the same as for staged treatment: achievement of implant primary stability, sufficient rigid fixation after healing, proper prosthetic location, and an esthetic result. Immediate implant placement has the potential to accomplish these objectives with fewer procedures, less treatment time, and less cost. Although complications can occur with any particular technique or protocol, this technique adds multiple variables that cumulatively place the clinician more at risk of having an adverse result (Table 14.1). Extraction and immediate implant placement may also be combined with immediate provisionalization (either nonfunctional or loaded). This chapter will address complications specifically related to immediate implant placement at the time of extraction.

TABLE 14.1

Implant Placement in Extraction Site

Immediate	Delayed
Advantages	
↑ Surgery ↑ Time ↓ Maintenance of soft tissue Intraosseous bone graft	↑ Surgical control, position, angulation ↑ Hard tissue quality ↑ Success, less risk of infection
Disadvantages	
↑ Facial bone loss after loading or during healing Implant too facial and/or angled abutment	Extended time for transitional Onlay graft may be needed at surgery

(From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.)

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General Considerations

Immediate implant placement after tooth extraction has the potential to decrease the number of appointments as well as treatment time. Patient acceptance of this technique is high. Optimal esthetics in many cases is possible along with hard and soft tissue preservation (Figs. 14.1, 14.2, and 14.3). The caveat relates to case selection and changing medicolegal standards. Before discussing immediate placement complications, a review of alternative (staged) placement is presented, with contrasts to immediate placement where applicable.

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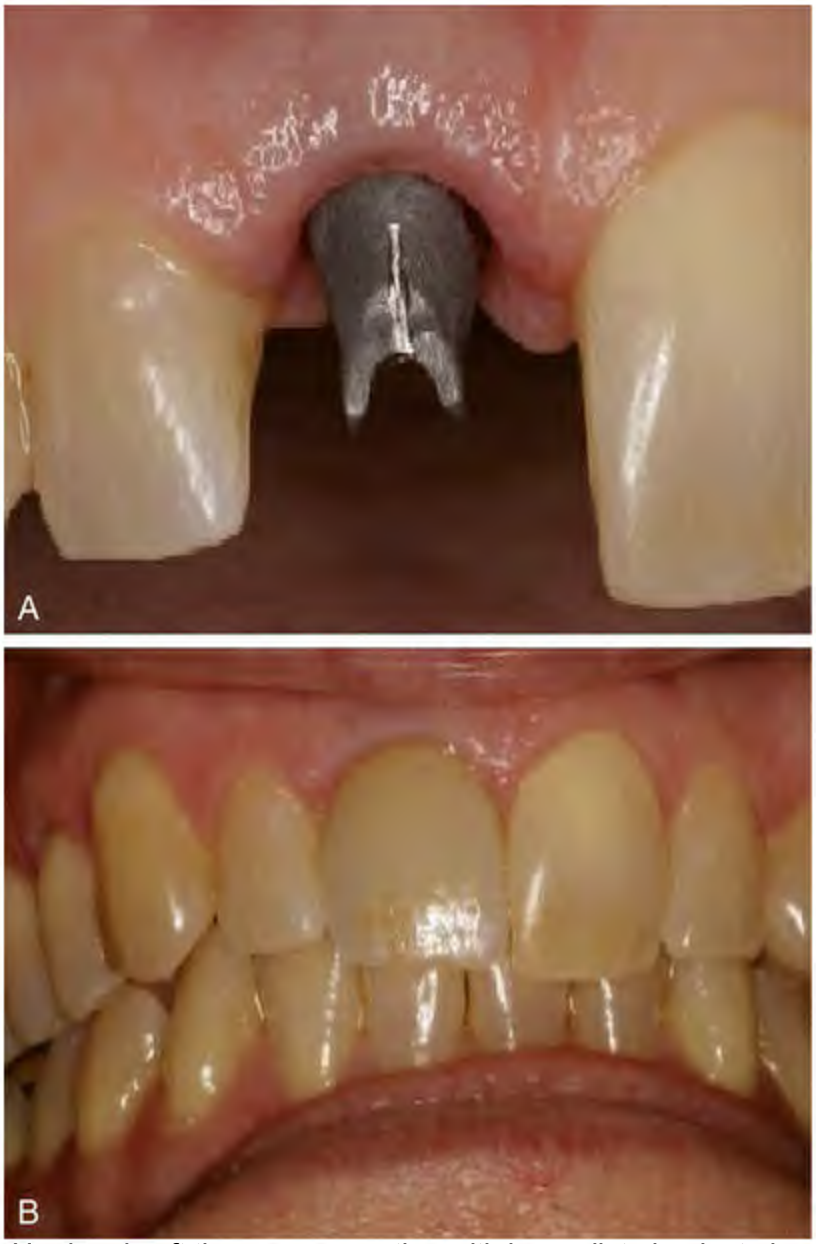

FIG 14.1 Hard and soft tissue preservation with immediate implant placement can result in optimum esthetic outcomes.

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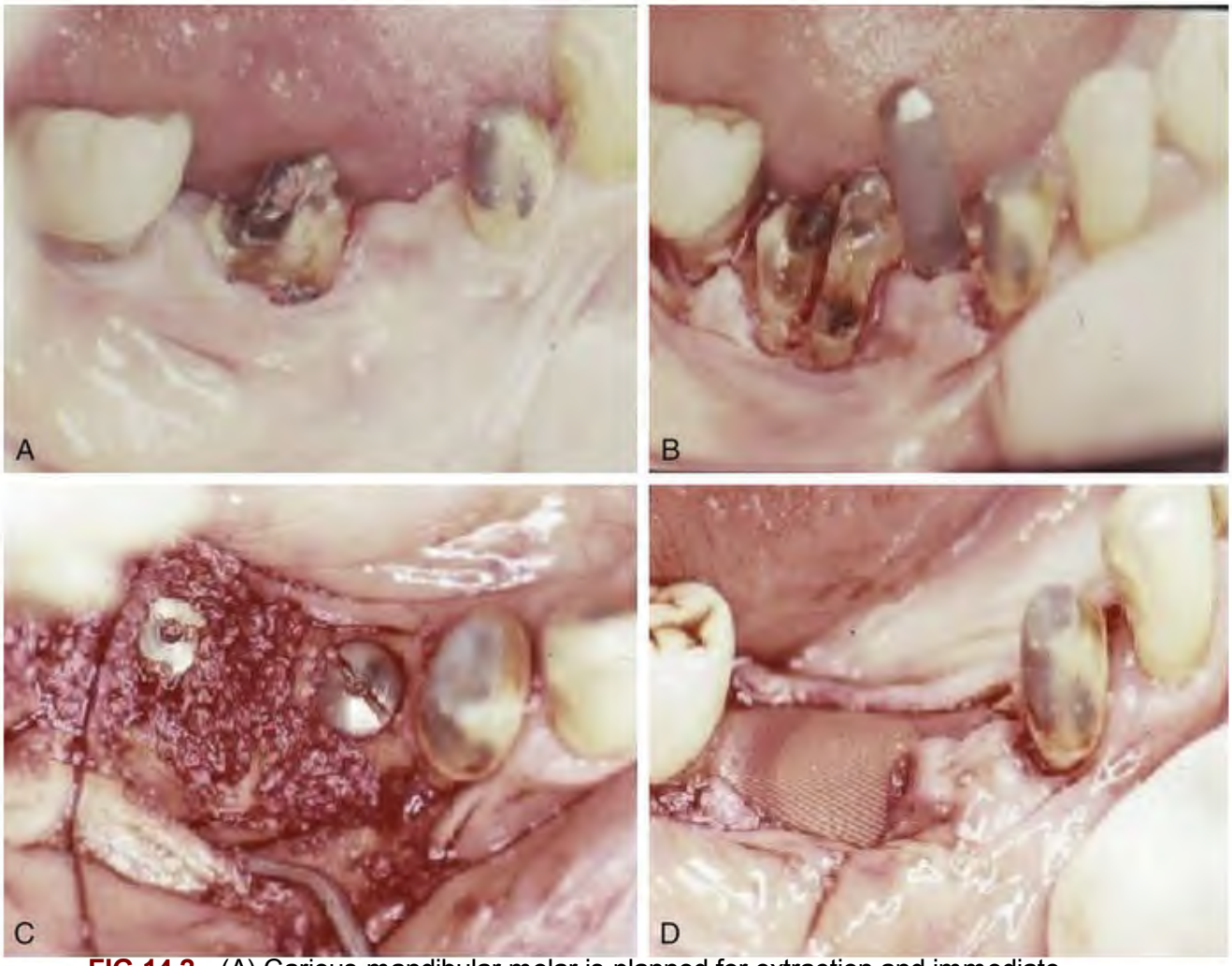

FIG 14.2 (A) Carious mandibular molar is planned for extraction and immediate implant placement. (B) Molar is sectioned to minimize extraction-related bone loss. Premolar implant has been placed in healed site with force direction indicator in place. (C) Bone allograft used to fill in voids. (D) Vicryl mesh used as GBR membrane.

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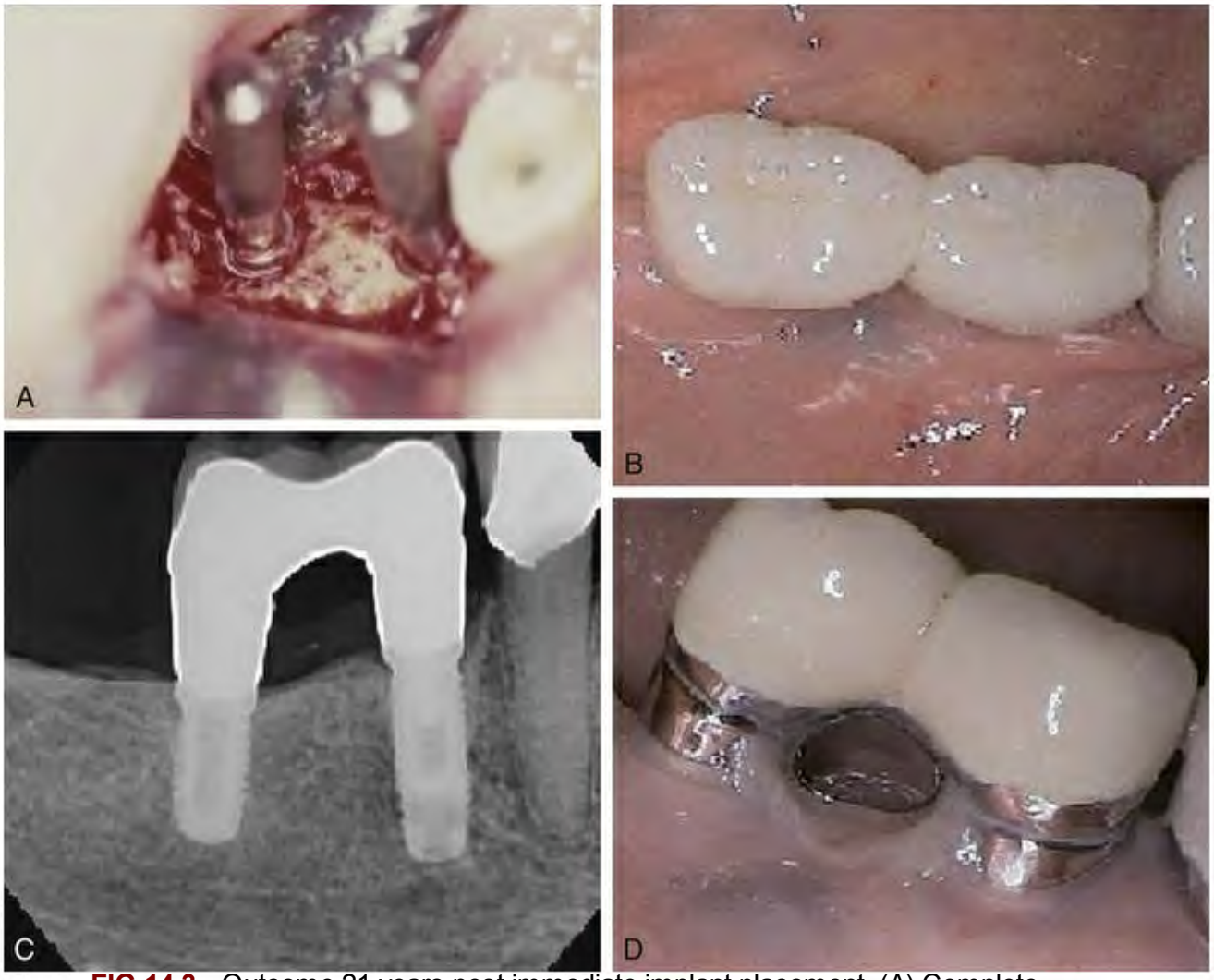

FIG 14.3 Outcome 21 years post immediate implant placement. (A) Complete bone fill around immediately placed implant. (B) Occlusal view of final restoration. (C) Radiograph of splinted prosthesis. (D) Buccal view of splinted prosthesis.

Available Bone

Available bone describes the amount of bone in the edentulous extraction site considered for implantation. It is measured in width, height, length, angulation, and crown height space (Fig. 14.4). As a general guideline, 1.5 to 2 mm of surgical error is maintained between the implant and any adjacent landmark. This is especially critical when the opposing landmark is the mandibular inferior alveolar nerve. However, the implant may be placed without complication through the cortical plate of the maxillary sinus or inferior border of the mandible. The implant may also be positioned closer to the cribriform plate of a natural tooth.[6] When placing an implant in an immediate-extraction site, the surgeon needs to consider the socket

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dimension and the defect between the labial plate of bone and the implant. The faciopalatal dimension of an anterior tooth, for example, is often greater than its mesiodistal dimension. When an anterior tooth requires extraction, during the extraction process the thin facial cortex often becomes compromised or lost. As a result, it is most always several millimeters apical to the palatal cortical plate, and frequently bone grafting and/or membrane placement in conjunction with the implant insertion are needed. Immediate implant placement in the anterior region using a round implant often requires that the osteotomy and implant insertion engage the lingual wall of the alveolus and penetrate halfway to two thirds of the way down the extraction site into the remaining lingual apical bone for rigid fixation (Fig. 14.5). This surgical approach is more challenging than preparing the osteotomy in a homogenous bone density. The best implant size is often 4 to 5 mm in diameter for a central incisor because the associated extraction socket is often greater than 6 mm (especially in the faciopalatal dimension), so a surgical defect as large as 2 mm remains around the implant. More or less broad, oval, or kidney-shaped spaces have been described to run coronoapically along the entire surface of the socket next to the implant.[7] The natural resorption of the facial plate may not be halted by implant insertion, and bone implant contact may be reduced when the facial plate resorbs.[8]

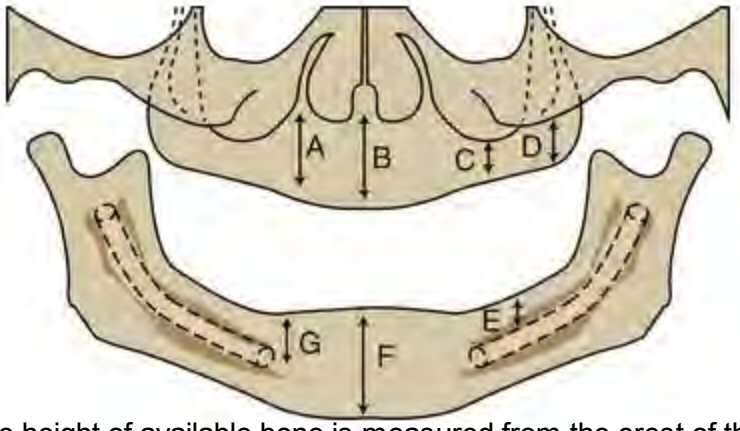

FIG 14.4 The height of available bone is measured from the crest of the edentulous ridge to the opposing landmark. The opposing landmark may be in the maxillary canine region (A), floor of the nares (B), maxillary sinus (C), tuberosity (D), mandibular canine region (G), anterior mandible (F), or bone above the inferior mandibular canal (E). (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

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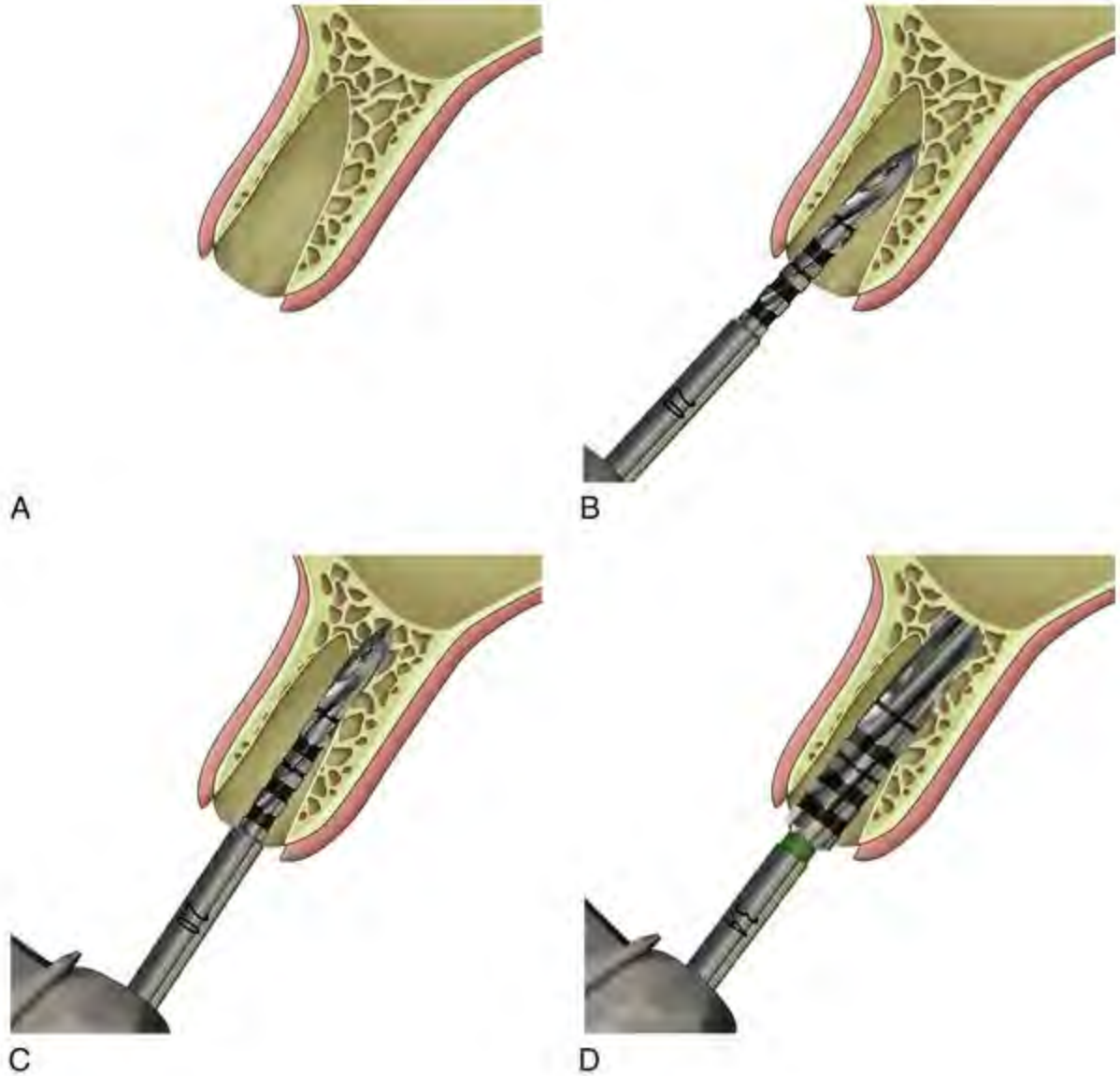

FIG 14.5 Multiplanar drilling technique. (A) Extraction socket whose walls have been evaluated and confirmed to be intact and free from infection. (B) 2-mm pilot drill first prepares the initial osteotomy two thirds of the way down from the crest and through the thick palatal cribriform plate. (C) The implant site prepared to the opposing landmark or preplanned length. (D) The osteotomy is kept in an angulation aligned with the incisal edge of the adjacent teeth. (From Misch CE: *Contemporary implant dentistry*, ed 3, St Louis, 2008, Mosby.)

Available Bone Height

The height of available bone is measured from the crest of the edentulous ridge to the opposing landmark. The anterior regions are limited by the maxillary nares or the inferior border of the mandible. The anterior regions of the jaws have the greatest height because the maxillary sinus and inferior alveolar nerve limit this dimension in the posterior regions. The maxillary canine eminence region often offers the greatest height of available bone in

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the maxillary anterior.[9] In the posterior jaw region, there is usually greater bone height in the maxillary first premolar than in the second premolar, which has greater height than the molar sites because of the concave morphology of the maxillary sinus floor. Likewise, the mandibular first premolar region is usually anterior to the mental foramen and provides the most vertical column of bone in the posterior mandible. However, on occasion, this premolar site may present a reduced height compared with the anterior region because of the presence of an anterior loop of the mandibular canal. The nerve courses anteriorly below the foramen and proceeds superiorly, then distally, before its exit through the mental foramen. Posterior nerve anatomy has particular significance with regard to immediate implant placement. Primary stability for immediately placed implants is frequently achieved using bone apical to the extraction site. In the posterior mandible, the course of the inferior alveolar nerve can vary from Type 1 to Type 3 with associated available apical bone ranging from nonexistent to sufficient and surgical risk varying accordingly. In addition, variants of the mental foramen exist that can increase the possibility of injury to the inferior alveolar nerve during immediate implant placement in the region (Fig. 14.6). The available bone height in an edentulous site is the most important dimension for implant consideration because it affects both implant length and crown height. Crown height affects force factors and esthetics. In addition, vertical bone augmentation, if needed, is less predictable then width augmentation.

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FIG 14.6 Variation of mental foramen positions. (A) 3-D image depicting premolar root located in mental foramen. (B) In 25% to 38% of patients, the mental foramen is superior to the root apex of the premolar. (C) Proximity of mandibular canal to the premolar apex.

Available Bone Width

The width of available bone is measured between the facial and lingual plates at the crest of the potential implant site. It is the next most significant criterion affecting long-term survival of endosteal implants. The crestal aspect of the residual ridge is often cortical in nature and exhibits greater density than the underlying trabecular bone regions, especially in the mandible.

Accordingly, the lack of crestal bone at an extraction site makes the achievement of primary stability more challenging for immediate implant placement. Facial dehiscence defects commonly found after tooth extraction and immediate implant placement have been shown to have more compromised healing as compared to infrabony defects.[10]

Available Bone Length

Bone length is defined as the mesiodistal length of bone in a postextraction area. It is most often limited by adjacent teeth or implants. As a general rule the implant should be at least 1.5 mm from an adjacent tooth and 3 mm from an adjacent implant. This dimension not only allows surgical error but also compensates for the width of an implant or tooth crestal defect, which is usually less than 1.4 mm and may vary with implant diameter and thread design. As a result, if bone loss occurs around the crest module of an implant or around a tooth with periodontal disease, the associated vertical bone

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defect will not typically expand into horizontal defect and thereby cause bone loss on the adjacent structure.

Bone Angulation

Bone angulation is an additional determinant for available bone. The initial alveolar bone angulation represents the natural tooth root trajectory in relation to the occlusal plane. Ideally, it is perpendicular to the plane of occlusion, which is aligned with the forces of occlusion and is parallel to the long axis of the prosthodontic restoration. The incisal and occlusal surfaces of the teeth follow the curve of Wilson and curve of Spee. As such, the roots of the maxillary teeth are angled toward a common point approximately 4 inches away. The mandibular roots flare, so the anatomic crowns are more lingually inclined in the posterior regions and labially inclined in the anterior area compared with the underlying roots. The mandibular first premolar cusp tip is usually vertical to its root apex. The maxillary anterior teeth are the only segment in either arch that does not receive a long axis load to the tooth roots but instead are usually loaded at a 12-degree angle. As such, their root diameter is greater than the mandibular anterior teeth. In all other regions the teeth are loaded perpendicular to the curves of Wilson or Spee. The anterior sextants may have labial undercuts that often mandate greater angulation of the implants or concurrent grafting of the site after insertion. The narrower width ridge often requires a root form implant design that is likewise narrower. Compared with larger diameters, smaller-diameter designs cause greater crestal stress and may not offer the same range of custom abutments. In addition, the narrower width of bone does not permit as much latitude in placement regarding angulation within the bone. This limits the acceptable angulation of bone in the narrow ridge to 20 degrees from the axis of the adjacent clinical crowns ora line perpendicular to the occlusal plane.[6] The angulation of available bone in the maxillary first premolar region may place the adjacent cuspid at risk during implant placement (Fig. 14.7).

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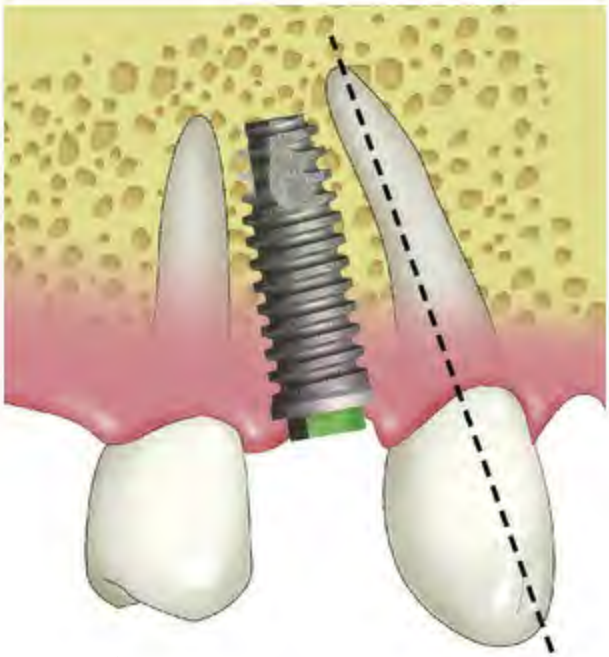

FIG 14.7 Angulation of available bone adjacent to maxillary canine possess increase risk for tooth injury. The maxillary first premolar is often angled distally to remain parallel to the canine root. A shorter implant or tapered implant may be of benefit. This limitation of bone-implant contact could compromise primary stability for immediate implant placement. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Type of Prosthesis

The clinician must always be aware of the anticipated final prosthesis and its associated dimensions of crown-height space, whether for a single tooth crown or full arch prosthesis. In cases where tooth extraction will result in an edentulous arch, the frequent need for alveoloplasty may result in almost complete elimination of the residual socket, thus making it comparable to an implant placement protocol for a healed site.

When considering immediate implant placement for partially edentulous patients, the dimension of the tooth space(s) being replaced, in the context of the desired final tooth positioning within and between the arches, may require orthodontic evaluation and treatment. Typical examples would be extruded and tipped teeth.

Bone Density

Bone quality or density refers to the internal structure of bone and reflects a number of its biomechanical properties, such as strength and modulus of

elasticity. The density of available bone in a potential implant site is a determining factor in treatment planning, implant design, surgical approach, healing time, and initial progressive bone loading during prosthetic reconstruction. The quality of bone is often dependent upon the arch position. The most dense bone is usually observed in the anterior mandible, with less dense bone in the anterior maxilla and posterior mandible, and the least dense bone typically found in the posterior maxilla. In addition to arch location, several independent groups have reported different failure rates related to the quality of the bone. Johns et al reported 3% failure of implants in moderate bone densities, but a 28% implant failure in the poorest bone type.[11] Smedberg et al reported a 36% failure rate in the poorest bone density.[12] The reduced implant survival most often is more related to bone density than arch location. In a 15-year follow-up study, Snauwaert et al reported early annual and late failures were more frequently found in the maxilla.[13] Hermann et al[14] found implant failures were strongly correlated to patient factors, including bone quality, especially when coupled with poor bone volume. Bone quality is directly related to the ability to achieve an acceptable level of primary fixation for immediate implant placement as well as long-term success for all placement protocols.

Anatomic Location

For immediate implant placement, an awareness of the bone characteristics of the proposed anatomic location will help dictate the appropriate treatment plan modifications for short- and long-term success. Regional variations in both available bone and bone density have already been described. The initial treatment plan prior to surgery suggests the anterior maxilla be treated as D3 bone, the posterior maxilla as D4 bone, the anterior mandible as D2 bone, and the posterior mandible as D3 bone. Bone remodeling, including loss of bone density, is primarily related to the length of time the region has been edentulous and therefore not loaded, the initial density of the bone, and mandibular flexure and torsion. Immediate implant placement can take advantage of the fact that implant placement can be performed before the bone density in the jaws begins its usual decline after tooth loss.

Presence of Bacteria/Existing Pathology

Immediate implant placement is generally recognized as a more complex

procedure in contrast to implant placement in a healed ridge of adequate bone quality. The presence of infection adds an additional variable to this complexity. A site can be classified as having either periapical, endodontic, perioendodontic, or periodontal infection. Multiple studies have found the survival rates for implants immediately placed in infected sockets similar to those placed in noninfected sockets or healed ridges.[15-17] These reviews, however, should be interpreted taking into account the classification of infection was often vague and varied among the studies.

Biomechanical Overload Issues

Immediate occlusal loading on temporary crowns positioned immediately on implants placed in fresh extraction sockets have been shown to reduce treatment time. A number of different immediate load protocols have been described in the literature (Schnitman, Tarnow, Misch).[18-20] An acknowledged common concern, however, is the risk of occlusal overload. Often the risks of this procedure are perceived to be highest during the first week after the implant insertion surgery. In reality, the bone interface is stronger on the day of implant placement than it is 3 months later.[21] As a result of the surgical placement, organized, mineralized lamellar bone in the preparation site becomes unorganized, less mineralized, woven bone of repair next to the implant.[22] The implant-bone interface is weakest and most at risk of overload at 3 to 6 weeks after surgical insertion because the surgical trauma causes bone remodeling at the interface that is least mineralized and unorganized during this time frame. A clinical report by Buchs et al[23] found immediately loaded implant failure occurred primarily between 3 and 5 weeks after implant insertion from mobility without infection. In addition to procedures and techniques needed to manage the immediate implant placement, the desire to add immediate load requires the clinician to address and control the issues of occlusal overload and bone remodeling.

Learning Curve

Clinical experience has been shown to affect the outcomes of dental implant treatment. Lambert reported surgical experience may influence the success or failure of dental implants from initial placement to second-stage surgery.[24] Preiskel et al concluded that a 2-year differential of surgical experience can have a major impact on the failure probability of unloaded implants.[25] Geckili

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noted a decrease in failure rate from 4.6% to 1.6% owing to the presumptive improvement in the skill of the surgeon over a 5-year period.[26] The added variable of perioperative bone grafting, frequently performed during immediate implant placement, was thought to negatively affect implant success rates in a 6-year study by Smith. That study reported an overall 1-year survival of 94% and a 5-year survival of 92.8%. In addition, there were a relatively high proportion of technical failures due to errors in treatment planning or surgical technique, which accounted for the intraoperative failures (33%) and late failures (14%) that were attributed to the experience levels of the surgical trainees.[27]

Implant Size

Length Relative to Tooth or Teeth Being Replaced

Prosthesis type, bone density, and anticipated load factors are treatment plan modifiers affecting implant size, design, number, surface condition, and the need/method of progressive loading.

The implant dimension of width is often limited by adjacent teeth or implants. As a general rule the implant should be at least 1.5 mm from an adjacent tooth and 3 mm from an adjacent implant. This dimension not only allows for surgical error but also compensates for the width of an implant or tooth crestal defect, which is usually less than 1.4 mm. As a result, if bone loss occurs at the crest module of an implant or from periodontal disease with a tooth, the vertical bone defect will not spread horizontally and cause bone loss on the adjacent structure.[28] The ideal implant width for single-tooth replacement or multiple adjacent implants is often related to the natural tooth that is being replaced in the site. The tooth has its greatest width at the interproximal contacts, is narrower at the cement-enamel junction (CEJ), and is even narrower at the initial crestal bone contact, which is 2 mm below the CEJ. The ideal implant diameter corresponds to the width of the natural tooth 2 mm below the CEJ, if it also is 1.5 mm from the adjacent tooth. In this way the implant crown emergence through the soft tissue may be similar to that of a natural tooth (Table 14.2).[6] The ability to select the most ideal implant size based on these parameters is much less difficult in a healed site as compared to an extraction site. An ideal treatment plan would include implant length of 12 mm or greater with a 4-mm diameter for most anterior implant sites and 5 mm or greater in the molar regions.[29] When the ideal implant size cannot be inserted because of

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inadequate bone, an alternative to bone augmentation may be to increase the surface area of the implant by modifying the implant body design.[6]

TABLE 14.2

Maxillary Anterior Teeth Dimension

Type and Number of Teeth	Mesiodistal Crown (mm)	Mesiodistal Cervix (mm)	Mesiodistal Cementoenamel Junction (−2 mm)	Faciolingual Crown (mm)	Faciolingual Cervix (mm)
Central	8.6	6.4	5.5	7.1	6.4
Lateral	6.6	4.7	4.3	6.2	5.8
Cuspid	7.6	5.6	4.6	8.1	7.6

(From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Implant Design

The most predictable aspect of implant dentistry appears to be the surgical success rate from implant insertion to uncovery; it is usually higher than 98% regardless of implant design or size.[30-36] Implant design considerations, however, should be made with intent of successful long-term outcomes, not just short-term surgical success; designing an implant for surgical ease does not appear to be the most important aspect of the long-term overall implant prosthodontic-related process to reduce the incidence of complications. Given the desire for long-term implant survival and health, careful selection of implant design should include the features of titanium alloy material, roughened surface treatment, tapered crest module, and square thread design.[37,38]

Many biocompatible materials are unable to withstand the type and magnitude of loads that may be imposed on dental implants. Titanium and titanium alloys have a long history of successful use in dental and orthopedic applications. The excellent biocompatibility of titanium and its alloy has been well documented. Titanium-aluminum-vanadium alloy (Ti-6Al-4V) has been shown to exhibit the most attractive combination of mechanical and physical properties, corrosion resistance, and general biocompatibility of all metallic biomaterials.[39,40] The primary advantage of titanium alloy as compared with other grades of titanium is its strength. Ultimate strength and fatigue strength are primary considerations given the ramifications of the loading profiles to which dental implant bodies are subjected and that can still place an alloy at fracture risk (Fig. 14.8).

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FIG 14.8 Fractured 5.0-mm ext hex implant. (BioHorizons IPH, Inc.)

Crest module design has a significant influence in regard to overall implant body design. There are at least six causes of marginal bone loss at the crestal bone region of implants, including the formation of a "biologic width" and occlusal overload after the implant is in function.[6] Ultimate strength and fatigue strength are primary considerations given the ramifications of the loading profiles to which dental implant bodies are subjected and that still can place an implant of ideal dimensions at fracture risk. The crest module of an implant should be slightly larger than the outer thread diameter of the implant body (Fig. 14.9). In this way the crest module may completely seal the osteotomy, providing a barrier and deterrent for the ingress of bacteria or fibrous tissue during initial healing after insertion in a healed site. The contact created by the larger crest module may also provide for greater initial stability of the implant following placement, especially in softer unprepared bone, because it compresses the crestal bone region. In the case of immediate implant placement, the crestal bone contact, if any, will usually be on the lingual or palatal aspect and can contribute to initial stabilization. The next consideration of the crest module is related to occlusal loading. Most of the occlusal stress occurs at the crestal region of an implant design (Fig. 14.10). A smooth, parallel-sided crest module will increase the risk of bone loss after loading, whereas any crest module design that incorporates an angled geometry or grooves to the crest module, coupled with a surface texture that increases bone contact, will impose a beneficial compressive component to the contiguous bone and decrease the risk of bone loss (Fig. 14.11).

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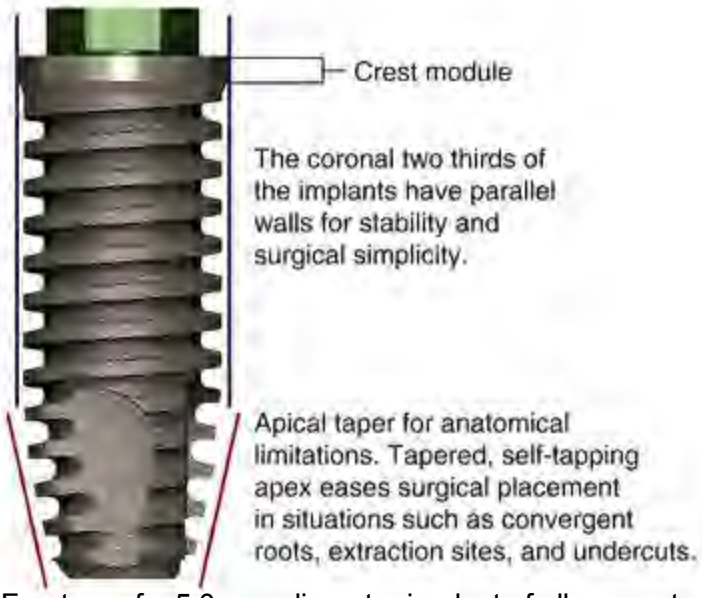

FIG 14.9 Fracture of a 5.0-mm diameter implant of alloy construction. This complication can be minimized with a less complicated selection of ideal implant dimension possible in a healed or augmented site. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

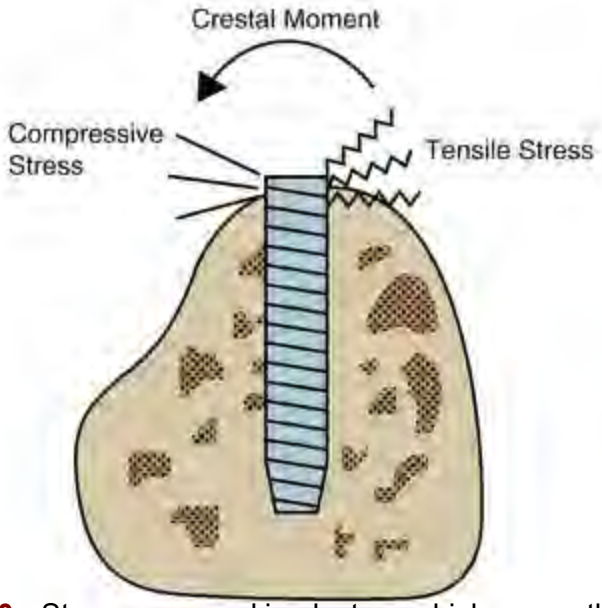

FIG 14.10 Stresses around implants are higher near the crest.

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FIG 14.11 The crest module with a cylinder metal collar transfers primarily shear forces to the bone *(left).* (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

The surface condition of the implant is particularly important for healing of immediately placed implants. The bone-implant contact (BIC) of roughened implants has been shown to be increased during initial healing as compared to smooth metal.[41] Lastly, although selection of thread shape should be optimized for long-term load function, thread shape may have an influence on the initial healing phase of osseointegration. An animal study by Steigenga et al compared three thread shapes with identical implant width, length, thread number, thread depth, and surface condition. The V-shaped and reverse buttress thread shapes had similar BIC percent and similar reverse torque values to remove the implant after initial healing. The square thread design (Fig. 14.12) had a higher BIC percent and a greater reverse torque test value.[38]

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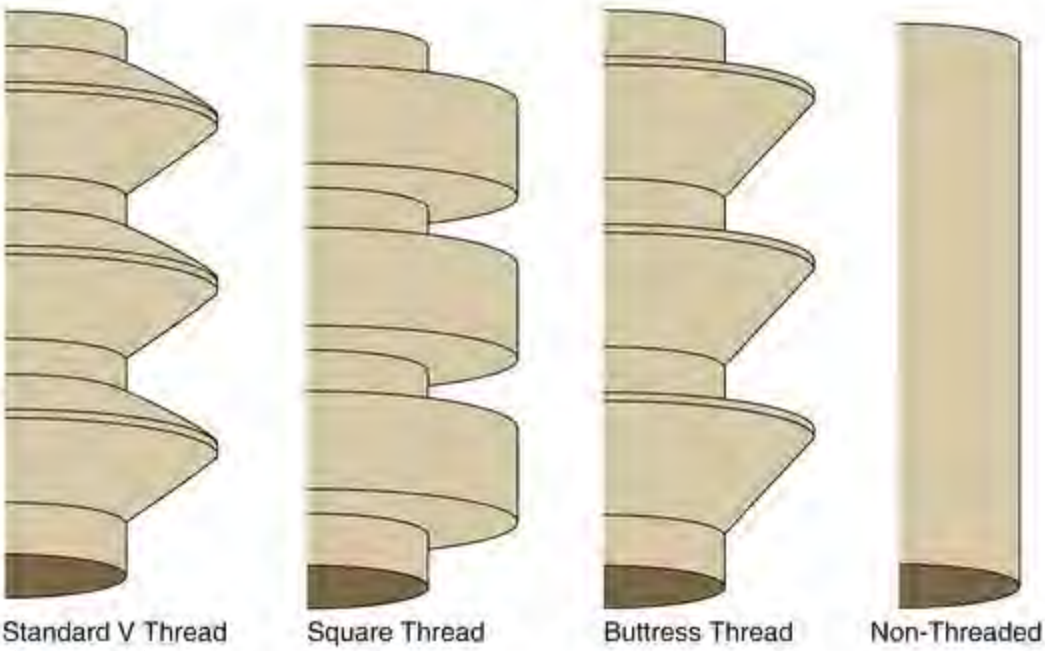

FIG 14.12 Standard thread shapes in dental implant design. The V, square, reverse buttress threads, and non-threaded. (From Steigenga J, et al: *J Periodontol* 75(9):1233–1241, 2004.)

Potential Complications Related to Immediate Placement Protocol

In cases where the facial bone is missing, the bone regenerated over the facial aspect of the implant with guided bone regeneration (GBR) is often immature woven bone, which is more prone to resorption because of occlusal overload. To improve GBR success, techniques for immediate implant placement after extraction typically include countersinking the implant 2 mm or more below the facial plate (which is already more apical than the palatal plate) and placing a biomaterial such as deproteinized bovine bone, calcium phosphate ($CaPO_4$), resorbable hydroxyapatite (HA), allograft, and/or autologous bone to fill the labial defect, with or without the addition of connective tissue grafts and/or membranes. Many classifications and protocols have been published with regard to immediate implant placement. The implant will obtain rigid fixation with nearly all of these techniques. However, the goal of implant therapy is not limited solely to rigid fixation. The inability to achieve proper esthetic and health parameters constitutes a compromised result and increased risk of esthetic or implant failure.[42] When the implant is countersunk below the facial bone, the implant platform may be as much as 4 mm apical to the CEJ of the adjacent teeth, which increases the anatomic crown height and the pocket depth, especially after crestal bone

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loss during the first year. In addition, synthetic grafts, if used, placed around the titanium implant grow less dense quality bone that is also limited in implant contact. The capacity of this less dense bone promoted by barrier membranes around implants to withstand loading seems to be limited, and animal studies indicate as much as 85% may be lost after loading.[43] An explanation may be that no blood vessels arise from the implant; to the contrary, it reduces the number of bony walls of the defect and limits blood supply to the facial bone graft. As a result, bone is less likely to form, and when it forms it is less dense and more at risk of resorption once the implant is loaded. Although primary closure of the soft tissue provides a more predictable result when bone grafting is performed, it may be more difficult with an immediate extraction technique. Although not advocated, the labial tissue is often reflected to approximate the tissue over the socket defect. This technique further compromises the blood supply to the labial cortical bone and also decreases the amount of facial keratinized gingiva because the facial tissues are placed over the extraction socket. As a consequence, some type of mucogingival corrective surgery may be indicated after stage I healing to restore the facial attached and keratinized tissue. The labial bone usually remodels to 0.5 mm below the abutment-implant connection (which was, in most cases, already countersunk below the facial bone and several millimeters below the palatal bone). Bone loss may continue in the region to the first thread (as a result of the implant crest module design), then stabilize in a region of greater bone density. As a consequence, reports often illustrate soft tissue pocket depths greater than 7 to 8 mm at the midfacial tooth position. The presence of anaerobic microorganisms in soft tissue pockets of 5 mm or more has been documented. With good hygiene the soft tissue often recedes, with a resulting lengthened clinical crown and “black triangles” in the interproximal areas caused by the absence of properly developed interdental papillae, which compromises long-term esthetics and/or contributes to soft tissue complications. When judicious case selection has not been exercised and thorough debridement has not been performed, an increased risk of postoperative infection exists around the implant with an immediate insertion owing to the presence of bacteria that were part of the cause of tooth loss. The presence of exudate lowers the pH, which causes a solution-mediated resorption of the grafted bone and contaminates the implant body with a bacterial smear layer, which in turn reduces bone contact. An improved bone interface may be obtained if the large-diameter extraction site is grafted before implant placement. If the

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labial plate is compromised, additional intraorally harvested bone and/or GBR are indicated. The delayed implant insertion method appears to enhance capillary propagation and trabecular formation before implant placement, facilitating the formation of an implant-bone interface.[44] A staged protocol allows the soft tissue to granulate over the augmented extraction site, creating an increased zone of attached gingiva. The result of the augmentation can be evaluated before implant placement, rather than dealing with compromises after implant integration. In this way the implant may be placed in an ideal position in relation to the crestal bone and the adjacent teeth and within the exact contours of the final restoration.[6]

Intraoperative Complications

Prevention Related to an Immediate Placement Protocol

Presence of Nonintact Alveolar Socket

Bone fill around an implant in an extraction site is most favorable when an intact socket is present. A nonintact socket may be encountered, either related to a preexisting condition or the tooth extraction process. This unanticipated loss of bone may have an extent and anatomy that the clinician may be unprepared to address if expectations were only of an intact socket.

Prevention

Thorough Pretreatment Evaluation.

The type of extraction defect (e.g., walls of bone present) can be anticipated with careful preoperative clinical exam that includes periodontal probing along with two- and three-dimensional radiographs. This clinical data, including attachment levels, is useful in accessing the periodontium for bone defects such as dehiscences.

Atraumatic Tooth Extraction.

Once the extraction of a natural tooth is indicated, methods to maintain or obtain the needed surrounding hard and soft tissues are indicated. Avoiding soft tissue injury reduces dimensional loss of the underlying bone because the periosteum supplies more than 80% of the blood supply to cortical bone.[45] The extraction of a natural tooth begins with an incision within the sulcus, preferably with a thin scalpel blade rather than a blunt periotome, 360 degrees around the tooth, to cut the connective tissue attachment fibers above the bone. The next step in an atraumatic extraction process is to observe the crown and root anatomy, especially in multirooted teeth. Proximal reduction may be indicated to prevent damage to adjacent teeth and provide space for bone expansion around the root(s). If the roots of the tooth to be extracted are divergent, they should be sectioned and removed as individual units, rather than risking fracture of the roots or surrounding bone. Periotomes and dental elevators, which both use the mechanical advantage of a wedge, can then be used to initiate the luxation of teeth for

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their removal. A traditional dental forceps can then be used to grasp the tooth for any needed additional luxation prior to tooth removal. Alternatively, a biomechanically based forceps (physics forceps) can be used. Its increased mechanical advantage may allow for tooth removal without application of rotational forces, minimizing potential fracture of the facial plate of bone.[46]

Treatment Options

Abort Procedure.

Depending on the extent of the residual socket defect, the clinician may consider aborting the procedure if there is concern or doubt regarding the skill set needed for bone grafting.

Bone Grafting.

The grafting materials and techniques are based on the number of bony walls that remain after the tooth is removed (Fig. 14.13).[47]

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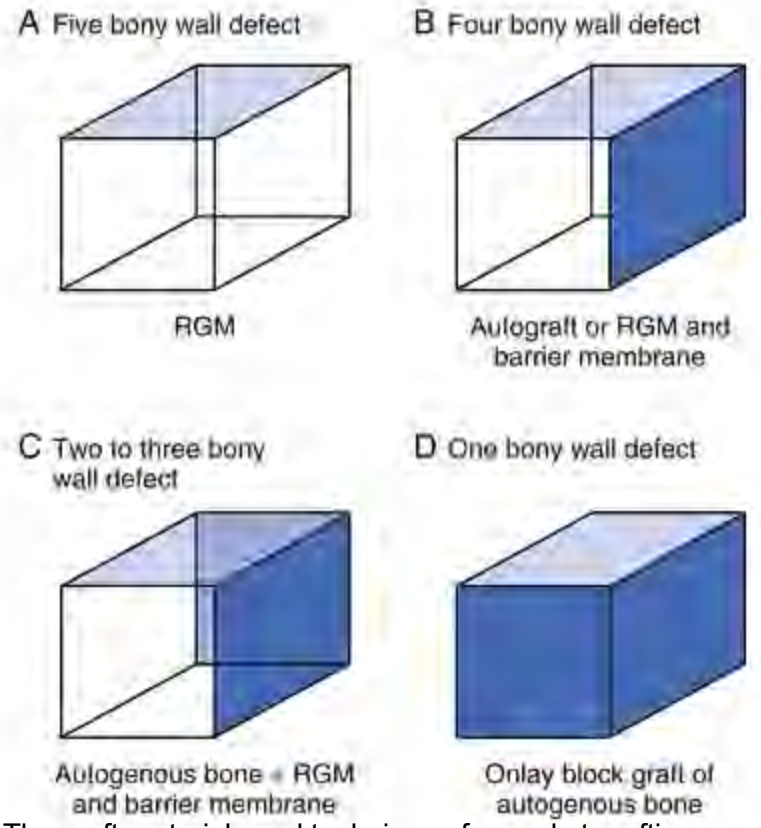

FIG 14.13 The graft materials and techniques for socket grafting are related to the remaining number of bony walls. (A) A thick five-wall bony defect may use any resorbable graft material (RGM). (B) Four-wall defects require an autograft or mineralized alloplast, allograft, and barrier membrane. (C) A two- or three-wall bony defect may use some alloplast/mineralized allograft but should use autograft and a barrier membrane as well. (D) A one-wall bony defect is most predictable with a cortical autograft fixated to the host bone. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

Thick five bony wall defect.

Regeneration restores complete morphology and bone volume to the residual ridge. This most often occurs when there are five thick, bony walls around the extraction site. Most of the keys for predictable bone formation are present under these conditions, and the socket often forms bone in the extraction socket without loss of width or height. The atraumatic extraction of a tooth without pathology provides many of the keys necessary for predictable bone regeneration. The soft tissue around the extraction site begins to grow over the clot and granulation tissue of the socket and within 2 to 3 weeks covers the site.

Four- to five-wall bony socket.

When a labial plate around a socket is missing, the absence of the wall

prevents space maintenance, reduces host bone vascularization, and replaces it with soft tissue vascularization. The facial bone level will never grow above the height of bone on the facial cortical plate of the tooth. Bone augmentation procedures must be used to obtain an ideal volume and contour of bone. Sockets with a missing lateral wall are significantly compromised and heal by repair rather than regeneration. The first determination after the tooth extraction is complete is the assessment of the thickness of labial and palatal plates of bone and their relative height to the ideal volume desired. When one of the lateral plates of bone is thinner than 1.5 mm or when height is desired, a socket graft is indicated, even in the presence of five bony walls. A similar socket augmentation procedure also may be used when the labial plate of bone is missing. The two techniques of choice are a barrier membrane (BM) with a mineralized alloplast/freeze-dried bone (FDB) socket fill or a modified socket seal surgery.

Barrier membrane with alloplast/freeze-dried bone.

An acellular dermal matrix is selected for a BM when soft tissue augmentation is also desired, or a collagen membrane is used when the soft tissue drape is not an issue. A periotome or thin periosteal elevator is used to tunnel under the final bone periosteum and lift the soft tissue off the bone over the thin bony wall. This tunnel should extend several millimeters beyond the desired augmentation site. A BM is then slid into the "pocket" created under the tissue and extends apical, mesial, and distal beyond the extraction site. Approximately 6 to 8 mm of the BM should extend above the marginal tissue. When the facial plate is thin, the socket may be filled with FDB (e.g., MinerOss, Puros) or a mineralized HA source (e.g., BioOss, Osteograf-N). When the labial plate is missing, the FDB may be placed in the apical portion, but particulate autologous bone should be placed in the crestal half of the socket. The walls of bone on the mesial, distal, and palatal provide bone blood vessels to this autograft. The extension of collagen or AlloDerm then covers the top of the socket and is tucked below the palatal tissue. Sutures are then placed over the top of the BM. Primary closure of the soft tissues is not obtained because the tissues would need to be reflected and advanced over the socket, which would affect the soft tissue drape. The extraction site may be reentered after 4 to 6 months. The clinical time for reentry is determined by the absence of the cortical lining of the socket (cribriform plate) on a periapical radiograph. Once this has occurred, the implant may be inserted and followed by a regular healing and restoration

protocol.

Socket seal surgery.

A composite graft socket seal surgery has been developed by Misch et al[48,49] composed of connective tissue, periosteum, and trabecular bone used to seal a fresh extraction socket. A connective tissue graft has the advantage over a keratinized graft of blending into the surrounding attached gingival regions, offering similar color and texture of the epithelium. This is most advantageous in the maxillary anterior region and other aesthetic areas. The composite graft also contains autogenous bone. The major advantage of autologous bone is a more rapid and predictable bone formation via osteogenesis. This technique may be used any time a tooth is extracted and an implant is planned as replacement. It employs the use of a 6- to 10-mm trephine burr (corresponding to the extraction site diameter) in a slow-speed, high-torque handpiece to harvest a gingival graft with underlying bone. The most common site for the intraoral composite graft harvest is the maxillary tuberosity region. The bone core (usually 5 to 10 mm in height) and the attached soft tissue (about 3 mm in height) are trimmed of their epithelium with a tissue scissors, leaving 3 to 6 mm of connective tissue attached to the bone core. A mallet and blunt instrument should be used to tap it into place and compress the bony core to conform to the crestal contour of the socket. The connective tissue portion of the graft is then sutured to the surrounding gingival tissue with facial and palatal interrupted 4-0 Vicryl sutures. A removable transitional prosthesis should not be permitted to load the tissue during the first few weeks after extraction; otherwise, the composite graft may become mobile and sequestrate. The transfer of the bone graft with an intact periosteal layer expedites revascularization and may decrease the healing time.[50,51] As a result, reentry may be in 4 to 5 months, and placement of an ideal implant diameter is often made possible.

Two to Three Bony Wall Defects.

A two to three bony wall defect is treated very similarly to a four bony wall defect. However, because the defect size is larger, more autograft is required in the bone graft. Rather than using the autograft primarily in the crestal region, it is of benefit that the entire first layer of the resorbable graft materials be an autograft. As a consequence, more often a donor site from the mandible is required. The most common two to three bony wall defects are extraction sites missing more than the labial bony wall. Because the

mesial distal bony walls are usually present, the host site is more predictable than a one bony wall defect. Incision line opening is less of a complication because the residual ridge form has soft tissue support around the defect.

One Bony Wall Defects.

Bone augmentation for these types of defects typically uses GBR or block graft techniques. Several methods have already been discussed regarding edentulous site augmentation. There are advantages and disadvantages to each of the bone regeneration techniques. Although this discussion will focus on particulate grafting techniques, the clinician needs to carefully discern the scope and objectives of an augmentation case in the context of defect size, anticipated soft tissue contours, healing time, and skill/experience level.

Barrier membranes and guided bone regeneration.

There are disadvantages to using GBR procedures for all host defects or deficiencies. Bone height and width augmentation with BM are usually limited to less than 3 to 4 mm. Soft tissue contours are more difficult to predict. Extended healing times are necessary. The bone quality is often less than ideal. The concept for GBR is to place a BM directly over a bone defect and under the soft tissue (including the periosteum) before primary closure. It has been accepted that the periosteum is a source of osteoblasts for bone formation and takes part in the bone augmentation process. However, this apparently is incorrect. When the periosteum is placed directly over a particulate bone graft, bone does not form under the periosteum. Instead, fibrous tissue is observed on the surface. When a barrier membrane is placed over the particulate graft, bone is found. The new bone forms from the surrounding walls of host bone and follows the invading blood vessels from the host bone, which grows into the space provided by the membrane or particulate graft. A wide range of BM exists for GBR. There are three primary categories of absorbable BM for GBR: collagen membranes, polylactic/polyglycolic acid membranes, and acellular dermal matrix. The ideal BM should be absorbable (but last long enough for predictable bone formation), decrease tissue movement and, when necessary, increase the tissue thickness over the bone graft. Clinical studies of GBR with different resorption rates, from 6 weeks to 6 months, often demonstrate similar bone augmentation results. This includes Biomend, which absorbs over 4 to 8 weeks. Bio-Guide is a bilayer collagen membrane from types I and III porcine

collagen and absorbs over a 2- to 4-week period. Ossix is a porcine barrier membrane that may take more than 6 months to absorb. It appears that once the blood vessels from host bone invade the bone graft space, the other key factors are more relevant (e.g., graft immobilization). Another type of barrier membrane is AlloDerm (LifeCell Corporation). This dermal allograft is deepithelialized skin tissue processed to remove all cells, leaving an acellular dermal matrix. The collagen, elastin, and proteoglycans are still present and allow for an inert avascular connective tissue to be obtained.[52] As a result, the acellular allograft tissue material may become completely and permanently incorporated into the soft tissue after 6 weeks rather than resorbing as a collagen BM; thus it may increase tissue thickness over the graft site. This is beneficial in esthetic zones when the soft tissue drape needs to be developed. Because it binds to the overlying soft tissue, it may create a zone of immobile tissue. This is a benefit for particulate graft immobilization and for implant soft tissue maintenance after the prosthesis delivery.

Implant insertion and guided bone regeneration.

Guided bone regeneration has been successfully reported at the time of implant insertion in both animal and human trials.[43,53] In most of these reports, the threads of the implant were exposed on only one side. The procedure is less at risk when the GBR is for width only, not for both width and height. The technique is very similar to that already presented. The osteotomy of the implant site is prepared to the opposing landmark (when possible), and the bone debris is harvested from the drills. The implant length does not need to be as deep as the osteotomy, but the extra depth allows more bone to be harvested. Holes in the cortical bone distal to the implant (not directly over the intact lateral bone), tent screws, autograft, the second layer of demineralized freeze dried bone (DFDB) (30%), freeze dried bone (FDB) (70%), platelet rich plasma (PRP), and the top of the graft are covered with a barrier membrane with primary closure of the soft tissue. The most difficult part of GBR at the time of implant insertion is to ensure that the implant is positioned for the prosthesis without compromise, rather than positioned more palatal (lingual) or angled to engage more host bone. The position of the implant should not be compromised so as to improve the success of the bone graft or to improve the osteointegration rate. The implants are useful for the prosthesis, not the bone graft. When the implant cannot be inserted in the correct position (in all three planes) because of the inadequate host bone, only the bone graft should be performed. Only after

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graft maturity can the implant be inserted. It should be noted that in the anterior regions of the mouth the GBR procedure (with acellular dermal matrix) is used over the labial plate whenever it is less than 1.5 mm thick. This reduces the risk of marginal bone loss on the facial, which would result in shrinkage or recessing of the soft tissue at the cervical of the implant crown (Fig. 14.14).

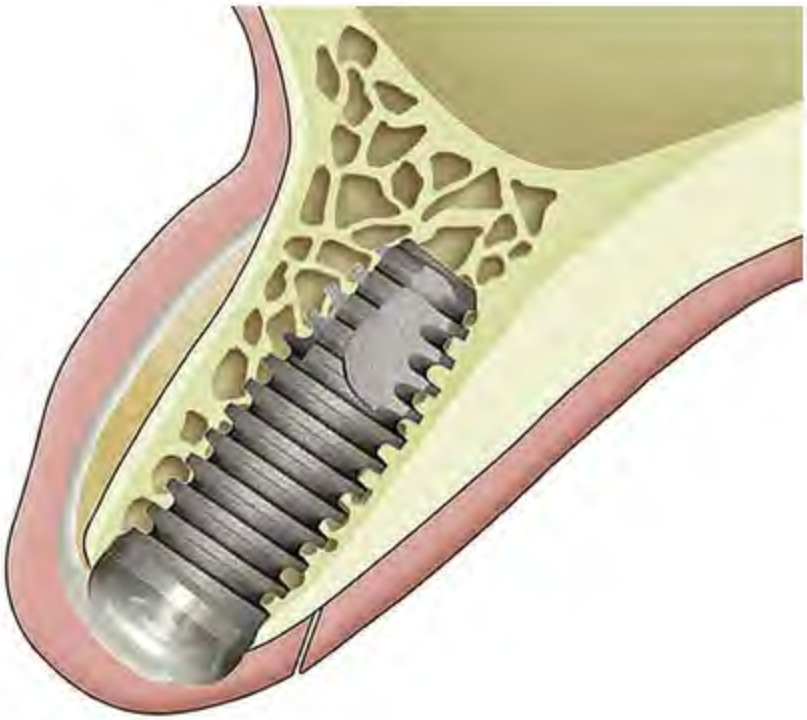

FIG 14.14 An implant may be inserted in the correct position, but the labial plate is less than 1.5 mm thick. A graft and a barrier membrane on the facial of an implant are indicated when the facial plate is thin and bone loss increases the risk of an esthetic compromise. (From Misch CE: *Contemporary implant dentistry,* ed 3, St Louis, 2008, Mosby.)

The GBR procedure may be used when an implant is immediately placed after a tooth extraction when conditions permit the implant to be positioned without compromise to the prosthesis. The osteotomy for the implant is made to the opposing landmark. The autograft is positioned over the implant and completely fills the extraction defect. The second layer of graft material is placed over the facial thin or missing bone. The barrier membrane is placed over the missing (or thin) bony wall, usually the facial. When a facial plate of the bone is missing, primary closure of the soft tissue is preferred (Fig. 14.15). Inability to maintain primary closure will directly influence the success of the bone graft (Figs. 14.16 and 14.17).

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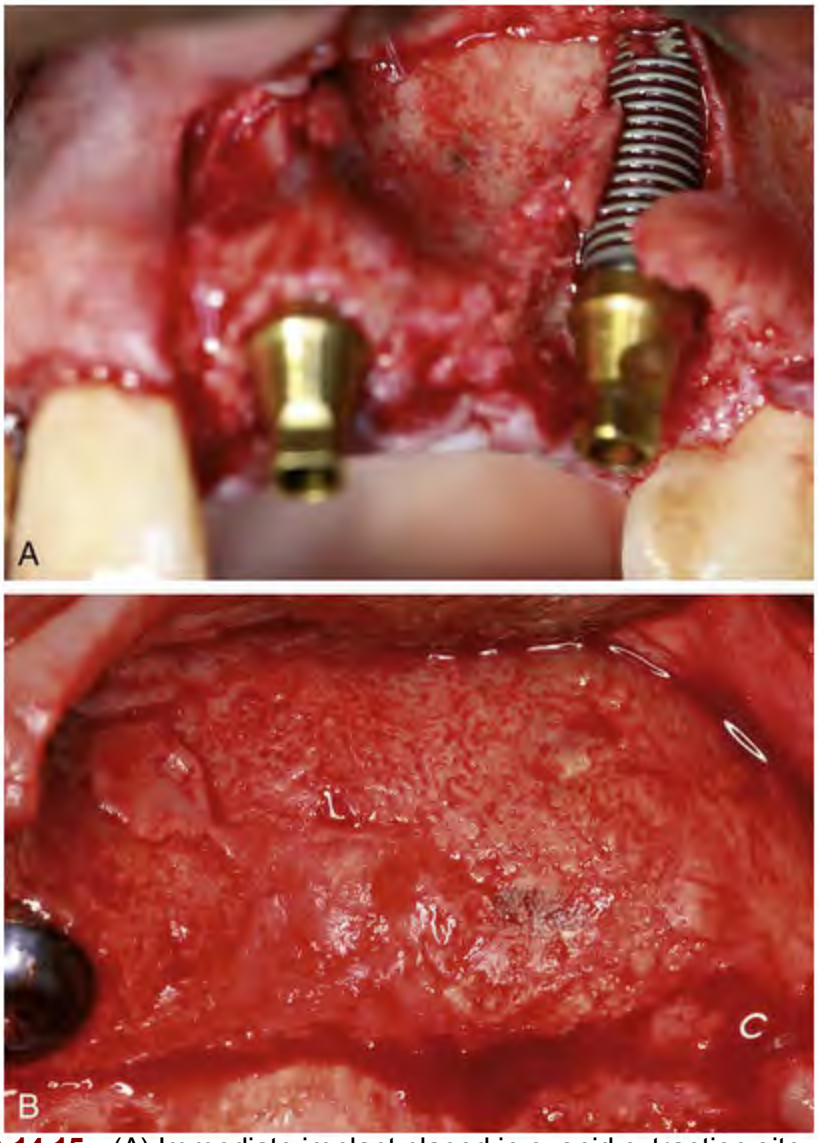

FIG 14.15 (A) Immediate implant placed in cuspid extraction site with compromised facial plate. (B) Six-month regenerative result with primary closure maintained.

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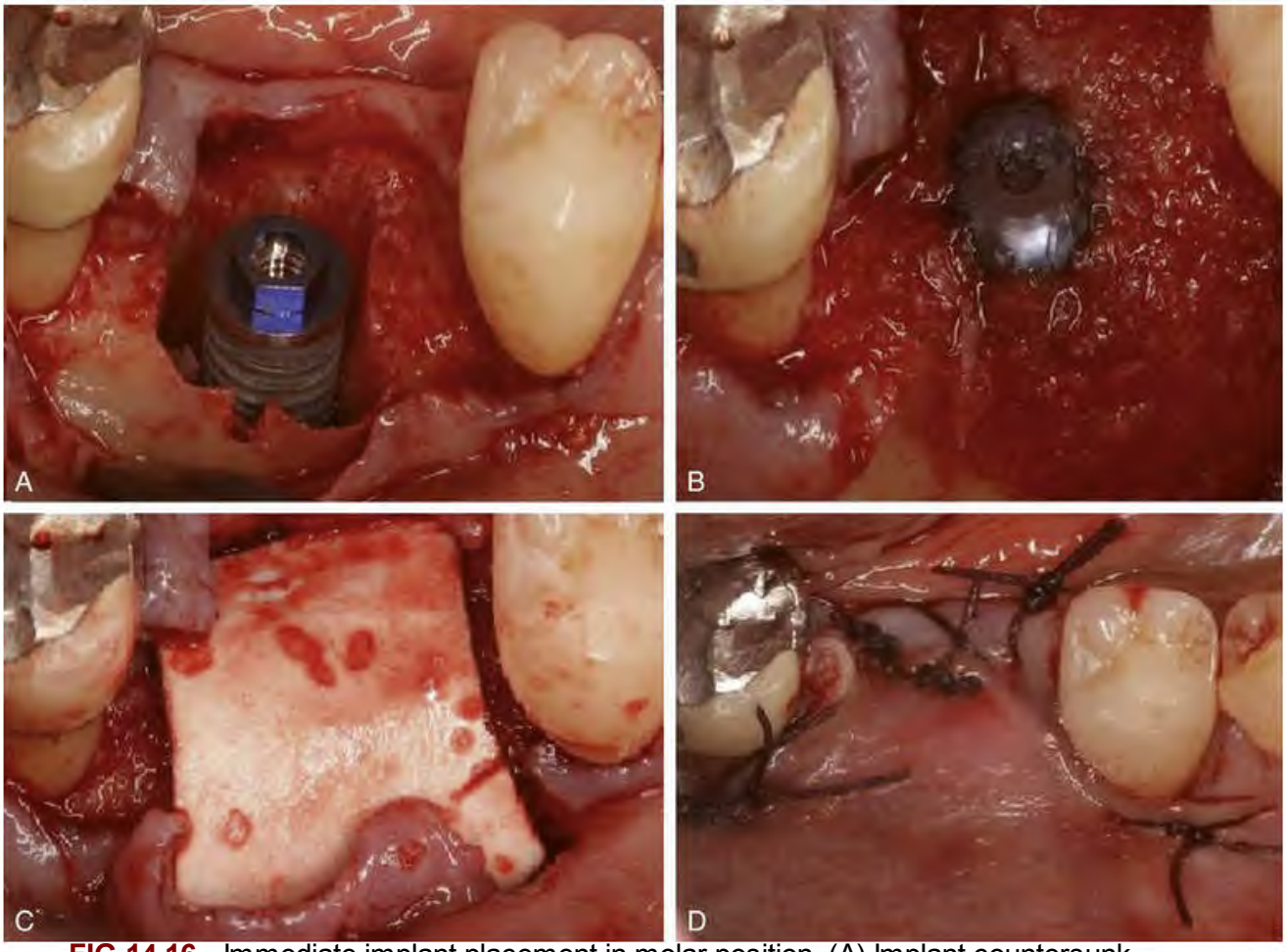

FIG 14.16 Immediate implant placement in molar position. (A) Implant countersunk with no encroachment on buccal plate. (B) Mineralized allograft used to fill voids. (C) Guided bone regeneration membrane in place. (D) Initial primary closure.

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FIG 14.17 (A) Incision line opening with complete exposure of cover screw after 6 months. (B) Resultant partial absence/loss of crestal bone.

Inability to Achieve Primary Stability

Implant stability plays an important role in determining treatment outcome.[54] Primary stability is the absence of mobility in the bone after the implant has been placed. The phenomenon behind this is the same as that applied for reduction of fractured long bones; that there should be absolutely no movement between the fragments when the ends of a fractured long bone are reduced to enable fracture healing.[55] This is because movements even in the micrometer range can induce a stress or strain that may hinder the

formation of new cells in the gap. Likewise, during implant healing a micromotion between 50 and 150 μm may negatively influence osseointegration and bone remodeling by forming fibrous tissues at the bone-to-implant interface thereby inducing bone resorption.[55]

Primary implant stability may be difficult to achieve in extraction sites where the trabecular bone density is less than ideal. Even for healed sites, there are examples of implant displacement into or excessively close to vital structures such as the mandibular nerve canal[56] or the maxillary sinus.[57] The displacement or migration of dental implants into the ethmoid sinus, nasal floor, or anterior cranial fossa has also been reported.[58-60]

Unlike a healed ridge of desirable bone volume, primary stability in fresh extraction sites is more difficult to achieve in general due the lesser quantity of native bone present as well as the fact that the anatomic challenge of the coronal aspect of the extraction site is often wider than the implant being placed. Potential variations in bone density may necessitate multiple modifications to osteotomy preparation and implant placement protocols as compared to procedures performed in homogeneous bone density. As a result, after attempted implantation, the clinician may be faced with a mobile implant with a questionable level of primary stability.

Prevention

Complete Osteotomy Preparation in Appropriate Location and Sequence.

Depending on the size of the extracted tooth and the implant to be placed, somewhere along the surface of the original tooth socket the implant will extend past the original dimensions of the root and provide mechanical retention of the implant.[61] As described in the general considerations section, immediate implant placement in the anterior region often requires that the osteotomy and implant insertion engage the lingual wall of the alveolus and penetrate halfway to two thirds of the way down the extraction site into the remaining lingual apical bone for rigid fixation. For maxillary posterior teeth the initial bur should be positioned off center toward the lingual side of the interradicular septum. For mandibular posterior teeth initial bur should be positioned on the mesial aspect of the interradicular septum. A Lindemann bur is very useful for initiating and modifying osteotomies. The objective of this multiplane preparation process is to create an osteotomy in a

prosthetically correct position without compromising the buccal wall of bone.

Underprepare Osteotomy Width and Over Prepare Osteotomy Length.

Misch initially outlined a protocol that adapts the treatment plan, implant selection, surgical approach, healing regimen, and initial prosthetic loading to all bone densities and all arch positions and that resulted in similar implant success for all bone densities.[6] To assist in bone quality evaluation, Cavallero advises clinicians to determine the degree of osseous density with a 2-millimeter twist drill and describes ways in which they can use this information to alter osteotomy development and subsequent prosthetic design.[62] These concepts can also be applied to immediate implant placement.

The density of the residual native bone can influence the ability to achieve adequate primary fixation. With anterior single-rooted teeth, using bone beyond the apex and the lateral engagement of the some or all of the tooth socket walls is instrumental in obtaining sufficient primary stability. With posterior implants, vital structures such as the inferior alveolar nerve and the maxillary sinus limit stability derived from bone beyond the tooth apices. Furthermore, the limited native bone present undergoes remodeling after the surgical trauma of osteotomy preparation and implant insertion. This trauma leads to a weakening of the bone-implant interface and may have an adverse effect on implant stability. Often, inadequate primary stability may only manifest itself after 4 to 6 weeks; the bone interface is stronger on the day of implant placement compared with 3 months later. The surgical process of the implant osteotomy preparation and implant insertion cause a regional acceleratory phenomenon of bone repair around the implant interface. As a result of the surgical placement, organized, mineralized lamellar bone in the preparation site becomes unorganized, less mineralized, woven bone of repair next to the implant. The implant-bone interface is weakest and most at risk of overload at 3 to 6 weeks after surgical insertion because the surgical trauma causes bone remodeling at the interface that is least mineralized and unorganized during this time frame. A clinical report by Buchs et al[23] found immediately loaded implant failure occurred primarily between 3 and 5 weeks after implant insertion from mobility without infection. At 4 months the bone is still only 60% mineralized, organized lamellar bone. With time, bone formation and mineralization will lead to increased interlocking with the implant surface and a stronger implant/bone interface. However, this has

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proved to be sufficient in most bone types and clinical situations for two-stage healing and delayed implant loading. The relative lack of native bone (compared to a healed site) suggests the osteotomy should frequently be undersized in width, the degree of which is dependent on bone density. In addition, for less dense bone, immediate implant fixation can be facilitated if the clinician can use osteotomes for radial compaction.

Dependent on tooth socket size and anatomy, sufficient implant stability can sometimes be achieved by lateral wall engagement only. Extending the osteotomy 3 to 5 mm past the socket apex (without encroaching on vital structures) is more commonly done for primary stability.[61]

Clinically Confirm Primary Stability.

Accurate assessment of primary stability is crucial in the immediate placement protocol. Methods of measuring implant stability include the percussion testing, insertion torque (IT), percussion testing, reverse torque testing, resonance frequency analysis (RFA), and surgical experience. Instrumented percussion testing has utilized the Periotest system. Periotest evaluations have been useful to gauge primary stability.[55,63,64] It is composed of a metallic tapping rod in a handpiece, which is electromagnetically driven and electronically controlled. Signals produced by tapping are converted to unique values called *Periotest values*. These results are expressed in arbitrary units with acceptable Periotest values in the ranges of −4 to −2 and −4 to +2.[55] This device has been supplanted by RFA due to the lack of reproducibility of results derived from Periotest measurements. These measurements are subject to a number of factors such as the vertical position of the measuring point on the abutment, angulation of the handpiece, and horizontal distance of the handpiece from the abutment.[65]

Reverse torque testing (RTT) has been said to be beneficial at stage II surgery as a definitive clinical verification of initial integration[66] or "adequacy" of the implant-bone interface.[67] Given the potential for early crestal bone loss and early implant failure as a result of this test, especially in less dense bone types, RTT is not advisable for evaluating healed bone-implant interfaces.[68] This author has found a variation of RTT useful in the determination of sufficient primary fixation. Some implant systems are sold with preaffixed abutments, with the abutment screw tightened as per manufacturer's specifications (e.g., BioHorizons external hex system abutment screw is pretightened to 6–10 N/cm). The ability to untighten the abutment screw without countertorque and without any associated implant

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movement has been found by these authors to be an additional affirmation of sufficient primary stability.

More commonly used methodologies for primary stability assessment are IT measurement and RFA. Interestingly, IT and RFA appear as two independent features of primary stability. Data in a study by Degidi showed that IT is only influenced by bone density and that RFA is only correlated to the length of implants used.[69] Insertion torque values also have shown good correlation with calibrated bone mineral density values as assessed through CT scans[70] and may be considered as a valid measure for determining bone quality at an implant site. Some studies have determined that implant stability associated with torque values of 32, 35, 40 N/cm and higher are preferred thresholds for immediate loading.[55,71,72]

Resonance Frequency Analysis (RFA) (Fig. 14.18) is a testing method that provides objective and reliable measurements of lateral micromobility at various stages of the implant treatment process. The method analyzes the first resonance frequency of a small transducer attached to an implant or abutment. It can be used to monitor the changes in stiffness and stability at the implant-tissue interface and to discriminate between successful implants and clinical failures. Integration diagnostics developed the Implant Stability Quotient (ISQ) as a scale of measurement for use with the RFA method. This more objective assessment of stability may help improve a clinician's learning curve and is useful for future comparison. Multiple studies[73,74] have determined that an acceptable stability range lies between 55 and 85 ISQ, with an average ISQ level of 70.[75]

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FIG 14.18 Radiofrequency analysis testing. (A) Osstell transducer. (B) Transducer placed into immediately placed implant. (C–D) Implant Stability Quotient (ISQ) readings on various surfaces of the transducer. (E) ISQ reading of 70, which relates to high stability for an immediate implant.

The information provided by RFA is useful; however, the clinician should be wary of relying completely on a general standardized range of ISQ readings due to variations that may exist for different implant designs and surface conditions as well as the inability to correlate RFA with histomorphometric data of bone anchorage or with the torque required to tap the bone for implant placement. The study concluded that validity of the individual measurement of implant stability using RFA should be considered with caution because the boundary height, width, and density factors can influence the resonance frequency of dental implants. However, there is no clinical study today that proves the RFA level for implants surviving long-term and the necessary minimum RFA threshold needed for the success of immediate loaded (IL) implants. These data seem to confirm that RFA and IT represent two different features of primary stability, with the first indicating the resistance to bending load and the latter indicating the resistance to shear forces.[76]

Degiti conducted a clinical study to (1) evaluate the Osstell as a diagnostic tool capable of discriminating between stable and mobile ITI (Straumann) implants, (2) to evaluate a threshold ISQ value obtained at implant placement (ISQitv) that might be predictive of osseointegration when assessed after 1 year of loading, and (3) to compare the predictive ISQitv of IL and DL implants. Degidi's study in 2006 demonstrated a surgeon's capability to predict IT but at the same time have poor accuracy in prediction of RFA values. Despite these findings, an experienced surgeon's perception of primary stability under no circumstances should be discounted.[75]

Implant design and initial stability.

The clinical perception of primary implant stability is frequently based on the cutting resistance of the implant during its insertion. The feeling of "good" stability may be accentuated if there is the sense of an abrupt stop at the seating of the implant. Although root form tapered implants often have a geometry that will provide a firm stop, the resultant stability may be a false perception.[77] In addition, in a tapered, threaded implant, threads at the apical half are often less deep because the outer diameter of the implant body continues to decrease. This limits the initial fixation of the implant and further reduces the functional surface area. For immediate implant placement, the tapered/conical body design may be of benefit during initial insertion because it is positioned within the osteotomy halfway before engaging bone.[36] The choice of implant body with regard to primary stabilization is equivocal and may be more influenced by osteotomy preparation than implant body design. A study by Sakoh concluded the combination of both conical implant design and the procedure of underdimensioned drilling appeared to be associated with increased primary stability.[78]

Treatment Options

Bone Density.

Dependent on bone density, the implant can sometimes be redirected into more dense bone; the redirection may be needed in more than one plane and kept within the needed three-dimensional boundaries for prosthetic reconstruction. Often a subtle tap of the (threaded) implant in an axial direction will gain the needed initial primary stability without putting the implant at risk from excessive apical positioning relative to the osseous crest

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and any adjacent teeth. A straight or offset osteotome can be utilized (Fig. 14.19).

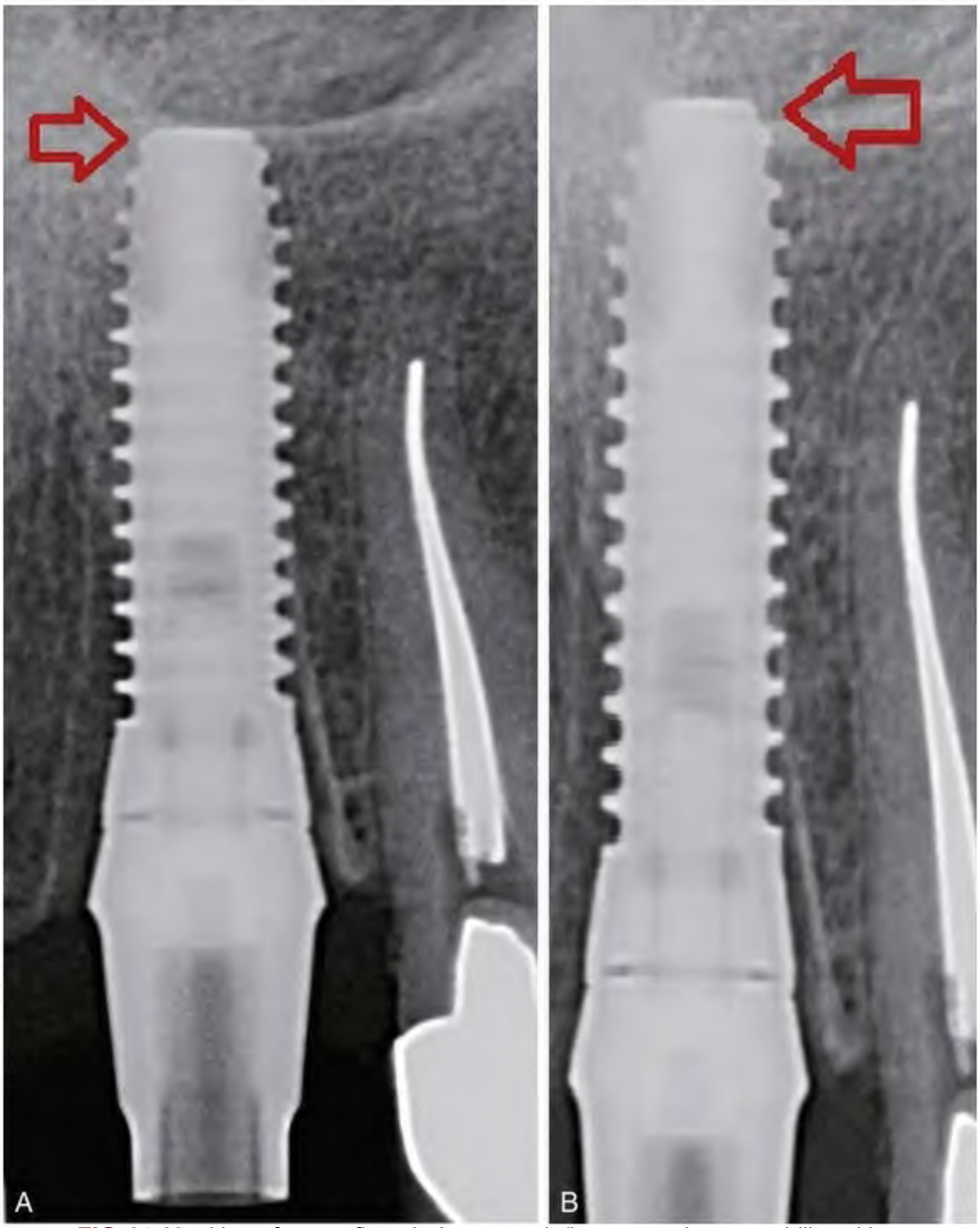

FIG 14.19 Use of press fit technique to gain/improve primary stability with a threaded implant. (A) Prior to osteotome use. (B) After osteotome use.

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Use of Larger Implant.

The dimensions, longer and/or wider, of the "rescue" implant may allow for satisfactory primary fixation; however, it must still be in an acceptable position in relation to the crestal bone, adjacent teeth, and planned final prosthesis.[79] This may be placed in a redirected manner described above. An increased implant surface area can engage more cortical bone. It has also been shown in an experimental study in rabbit tibia that wider implant diameters resulted in increased removal torque values.[80] Matsushita et al[81] employed a two-dimensional finite element method to analyze the effect of different implant diameters on stress distribution within the alveolar bone using HA-coated implants. They found that stress in cortical bone decreased with increased implant diameter. Ivanhoff, however, reported a lower survival rate and a tendency for higher bone loss for 5.0-mm diameter implants, as compared to 3.75-mm- or 4.0-mm diameter implants.[82] Resultant decreased facial bone dimensions associated with wider implant dimensions increase the probability of soft tissue recession.

Leave Implant in Place.

An implant with loss of rotational stability (spinner) and minimal, if any, surrounding ridge deficiencies may be left in place. If replacement is not possible (for example, in cases of inadequate bone dimensions or where a larger implant is unavailable), the surgeon must then decide whether to leave the implant in place or remove it and reevaluate the site for further implant therapy after healing is complete. Some studies have found that primary stability, while desirable, may not be an absolute requirement to achieve and maintain osseointegration.[83]

Ivanhoff reported osseointegrated implants that have been mobilized due to a traumatic disruption of the bone-implant interface may reintegrate if allowed to heal for an additional period of time.[84] Orenstein reported a 79.8% survival rate after 3 years of implants that were mobile at placement. A significant factor for most of these implants was the presence of a HA coating. Almost one half of the noncoated, initially mobile, implants failed by 3 years postplacement. Even if initially mobile implants are found to integrate, precautions are advised to avoid implant overload. Clinicians may want to employ strategies such as long-term temporization to promote bone maturation and evaluate the viability of initially mobile implants in function prior to inserting the definitive prosthesis.[83]

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Abort the Procedure.

The clinician may consider aborting the procedure and proceeding only with the bone graft.

Implant Malposition.

Often there are visual cues for immediate implant placement, such as adjacent and opposing teeth and tooth sockets. Deviations from normal anatomy and cases of multiple implant placement, however, can be deceptive and lead to implant malpositioning (Fig. 14.20). Dependent on the experience level of the clinician, a surgical template can help facilitate more precise placement in the buccolingual, mesiodistal, and apicocoronal directions.[85] Intraoperative imaging with force direction indictors in place is beneficial in evaluating current osteotomy development vs. planned locations. The combined use of intraoperative radiographs and surgical template (clinical visualization) maximizes feedback to the implant surgeon and allows for corrective measures to be undertaken prior to osteotomy completion and implant placement.

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FIG 14.20 Implant malposition following immediate implant placement for a first molar. (A–B) Mandibular implant placement too far distal. (C–D) Maxillary implant placement too far distal. (C) Preoperative of non-restorable molar, (D) Implant improper placement resulting in placement too far posterior.

Postoperative Complications

Transitional Prosthesis Impingement

The transitional prosthesis over a particulate graft or healing implant should not rest on the soft tissue over the site. Although the tent screws provide some protection to a graft site, a fixed transitional prosthesis is more predictable for the process. Particulate grafts are more prone to movement during healing, which prevents blood vessels from entering and forming bone in the site. Patient compliance is improved with fixed provisionals.

Neurosensory Impairment

The close proximity of inferior alveolar nerve to the apices of the mandibular posterior teeth poses the possibility of neurosensory impairment when preparing osteotomies and during implant insertion. Not infrequently, the immediate implant gains its primary stability from the bone beyond the root apices. This risk is higher in the posterior mandible extraction site than in a healed site with its increased volume of bone and associated likelihood of the more abundant bone achieving primary stability without nerve encroachment. If the surgeon suspects a nerve injury, the algorithms outlined in the Chapter 9: Neurosensory Deficit Complications in Implant Dentistry should be followed. Preventive strategies include preoperative three-dimensional imaging, guided surgery, and having a heightened awareness of local anatomy.

Excessive Postoperative Pain

If a clinician's patient base has an otherwise unremarkable history of postoperative discomfort with two-stage implant procedures, an increase in postoperative symptoms such as discomfort and edema with immediate placement techniques may be reflective of increased surgical time and additional gingival flap manipulation of a less experienced operator. Preoperative communication with the patient regarding posttreatment expectations, treatment phasing, and appropriate choice of pharmacologic agents can help minimize or eliminate this sequela. Not infrequently, removal of a tooth as part of treatment may place some of the remaining teeth in traumatic occlusion. Occlusal adjustment via selective grinding frequently results in rapid resolution of this problem. Although not a

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frequent occurrence, the clinician should always be aware of patients whose histories suggest they may present with atypical facial pain.[86]

Patient Management: Medicolegal Considerations

When anticipating immediate implant placement, the patient should be informed that the procedure may need to be aborted with only a bone graft placed. The surgeon does not want to compromise a 30-year prosthesis simply to avoid waiting an additional 3 to 6 months.[6]

Incision Line Opening

Primary closure is typically desired when attempting regeneration in other than simple three-wall defects (with or without the presence of an implant). Incision line opening (ILO) following implant placement and simultaneous complex augmentation can have a devastating outcome, whereas, in other cases, primary closure is not necessary dependent on the defect size and anatomy (see Fig. 14.14). Strategies for ILO management are discussed in Chapter 11: Wound Dehiscence: Incision Line Opening. Although some authors describe the need for primary flap closure, survival of implants is not dependent on primary closure in all cases.[87,88]

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Complications Following First Stage

Bone Healing

Compromised Implant Position

This common complication of immediate implant placement may not be readily apparent until the restorative process has been initiated (Fig. 14.21). For this discussion, care must be taken to distinguish between a compromise(s) that could be present following a delayed/two-staged procedure (e.g., increased final crown height) vs. a compromise that could be solely attributed to implant placement at the time of extraction. Examples of the later are characterized by excessive positions in one or more of the potential three reference planes. Nonideal positioning can also result after multistage procedures; however, the need for native bone for primary stability in immediate placement cases increases the likelihood of positioning error. Management of cases with resultant excessive mesial-distal space/length can be frequently treated by placement of additional (usually narrower-diameter) implants. Use of surgical templates or guided surgery are recommended for clinicians desiring physical reference points during surgery.

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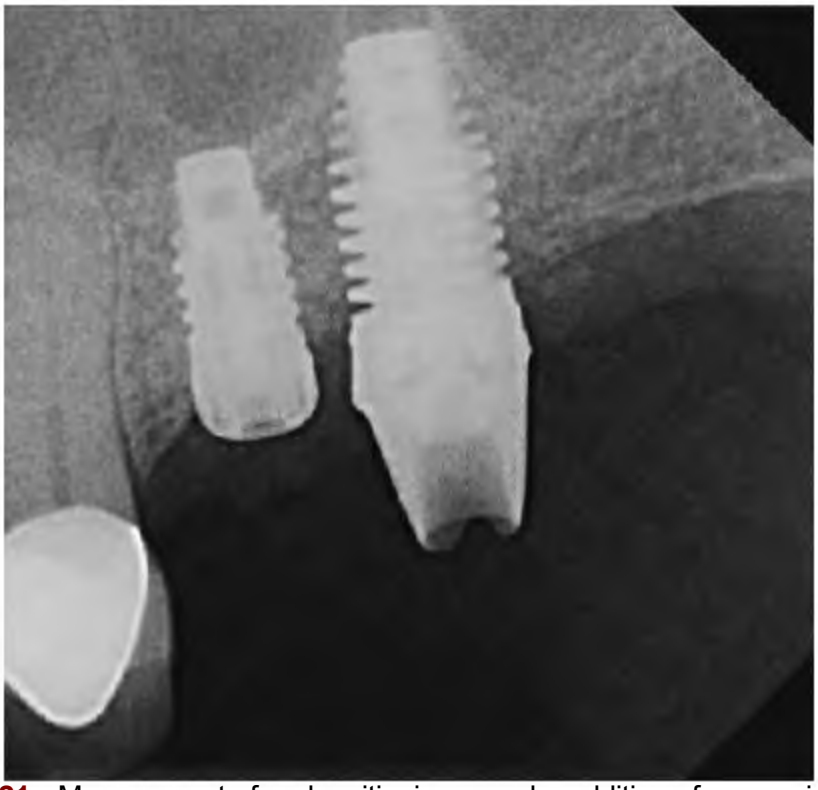

FIG 14.21 Management of malpositioning error by addition of narrow implant.

Long-Term Results

The success rate and radiographic results of immediate restorations of dental implants placed in fresh extraction sockets were comparable to those obtained in delayed loading group.[89]

A prospective cohort study by Rodrigo with a 5-year follow-up has shown that, in the same patients, implants placed immediately upon tooth extraction behave similarly to implants placed with a delayed protocol. Both showed similar clinical characteristics, although the implants placed with the immediate protocol demonstrated a higher tendency for crestal bone loss and incidence of peri-implantitis.[90]

Lang found a high survival rate although soft tissue issues were apparent.[5] In particular, soft tissue recession was found to be associated with thin tissue biotype, facial malpositioning, and/or a thin or damaged buccal bone plate (Figs. 14.22 and 14.23). About 20% of patients who underwent immediate implant placement and delayed restorations suffered from suboptimal aesthetic outcomes due to buccal soft tissue recession in studies with observation period of 3 years or more.

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FIG 14.22 Immediate maxillary anterior implants. (A) Compromised facial bone. (B) Rigidly fixated implants with excellent zone of attached tissue. (C) Provisionalization of implants. (D) Radiographs of implants during provisionalization stage. (E) Radiographs after 7 years in function. (F) Facial soft tissue recession after 7 years in function.

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FIG 14.23 Staged maxillary anterior implants. (A) Healed ridge with no facial defects. (B) Implant placement in intact ridge. (C) Radiograph of implants at time of placement. (D) Final prosthesis shortly after delivery. (E) Radiograph of splinted implants after 10 years in function. (F) Final prosthesis after 10 years in function.

Summary

Implant placement in general involves multiple steps and decision points. As a distinct procedure, the technique of immediate implant placement adds multiple additional decision points, making it a technique-sensitive modality. It can have equivalent success rates to staged implant placement if the implant surgeon has an awareness of the potential pitfalls and the ability to deal with its unique complications.

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Removable Implant Complications

Randolph R. Resnik

The rate and pattern of edentulism in the United States has certainly shifted over the years. There is a distinct overall trend toward a decrease in edentulism; however, the group in need of this rehabilitation is rapidly growing. It has been estimated over the past 30 years there has been a 10% decrease in edentulism. However, this has been offset by an increase of 79% in the adult population over 55 years of age.[1] According to the literature, age is directly related to tooth loss.[2] This aging population is an important factor when evaluating the need for removable implant-retained prostheses. With tooth loss in this age group, many negative consequences related to conventional dentures such as decreased masticatory function, systemic consequences, patient dissatisfaction, and speech and psychologic effects may result (Box 15.1).

Box 15.1

Negative Effects of Complete Dentures

- Bite force is decreased from 200 psi for dentate patients to 50 psi for edentulous patients
- 15-year denture wearers have reduced bite force to 6 psi
- Masticatory efficiency is decreased
- More drugs are necessary to treat gastrointestinal disorders
- Food selection is limited
- Healthy food intake is decreased
- The life span may be decreased
- Reduced prosthesis satisfaction

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- Speech difficulty
- Psychologic effects

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

With the growing number of implants being placed, even with the advances that have been seen in implant dentistry, complications do occur with implant-retained removable prostheses. The complications may arise from the treatment planning phase, implant positioning, implant number, selection of attachments, and the insertion of the prosthesis. This chapter discusses various complications that may arise with implant-retained removable prostheses and various techniques to prevent and treat the complications if they occur (Fig. 15.1 and Fig. 15.2).

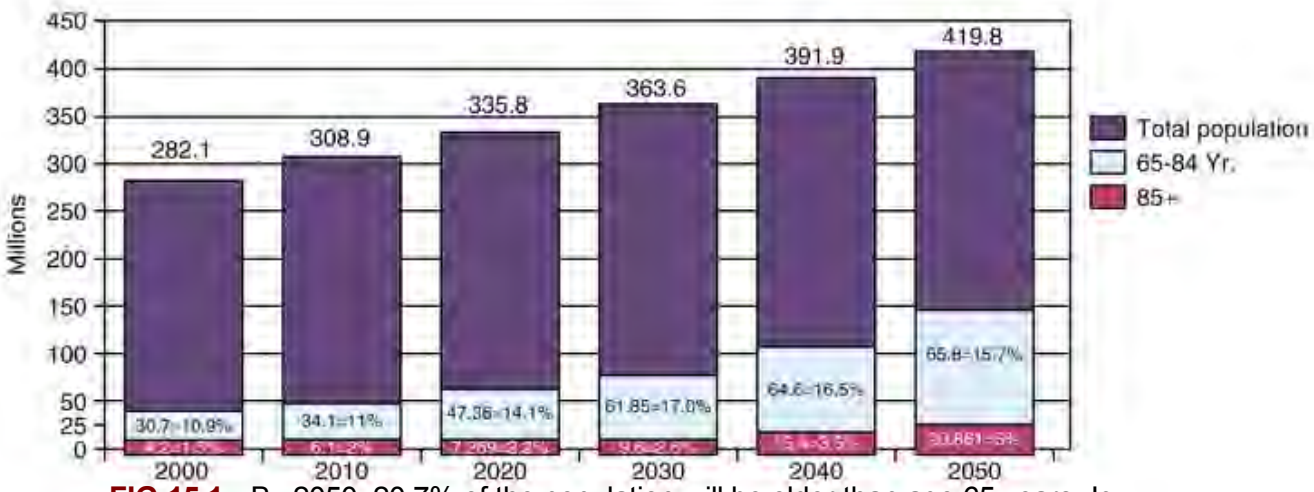

FIG 15.1 By 2050, 20.7% of the population will be older than age 65 years. In addition to the increasing percentage of 65-year-old adults, the population is also increasing. As a result, 34.9 million people were older than 65 years in 2000, and 86.6 million people will reach this milestone by 2050. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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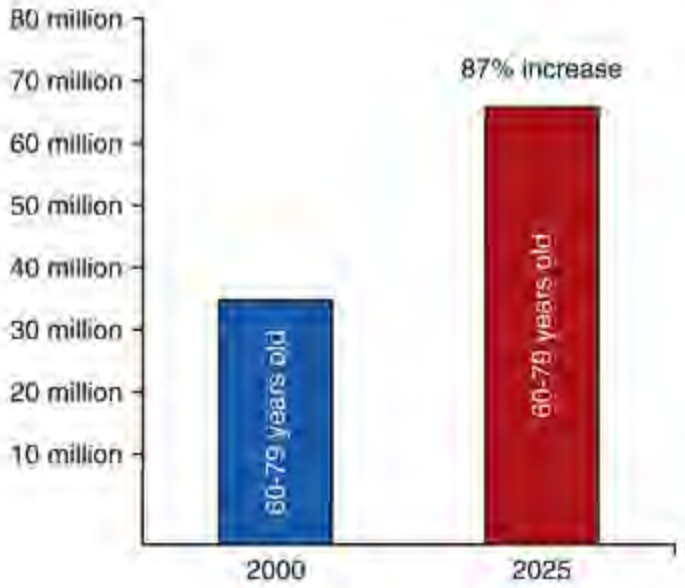

FIG 15.2 The adult population older than the age of 60 years old will increase by 87% from the year 2000 to the year 2025. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Complications of Overdentures for the Edentulous Patient

Not Understanding the Disadvantages of Edentulism

When evaluating an edentulous patient, it is the clinician's responsibility to explain to the patient the disadvantages that may result from edentulism. The following are consequences of edentulism that play a significant role in treatment planning (Box 15.2).

Box 15.2

Disadvantages of Edentulism

- Continued bone loss
- Decreased occlusal biting force
- Decreased masticatory function
- Increased soft tissue discomfort
- Systemic consequences
- Lack of prosthesis satisfaction
- Speech difficulty
- Psychologic

Continued Bone Loss

One of the most common issues of edentulism that is not commonly explained to patients is the continued loss of bone. Alveolar bone requires constant stimulation to maintain its form, strength and density. Roberts et al reported that a 4% strain to the skeletal system maintains bone and helps balance the resorption and formation phenomena.[3] The forces applied to teeth transmit compressive and tensile forces to the surrounding bone.

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However, when a tooth is lost, the lack of stimulation to the residual bone causes a decrease in trabeculae and bone density in the area, with loss in external width, then height of the bone volume.[4] Studies have shown a 25% decrease in width of bone during the first year after tooth loss and an overall 4-mm decrease in height during the first year after extractions for an immediate denture.[5] In a longitudinal 25-year study of edentulous patients, Tallgren demonstrated continued bone loss during this time span, with a fourfold greater loss observed in the mandible.[6] In 1963 Atwood introduced five different stages of bone loss in an anterior mandible after tooth loss showing the resorptive process over time.[7] Even though the mandibular bone resorbs faster than the maxillary bone, the mandible has almost twice the bone initially available.

When patients wear a removable prosthesis, the bone is not stimulated in the same fashion that a tooth does. The load placed on the removable prosthesis is transferred to the bone surface, not the internal structure of the bone. This causes the blood supply to be reduced to the bone resulting in total bone volume being lost.[8] The bone loss accelerates when the patient wears a poorly fitting soft tissue–borne prosthesis. The average denture wearer sees a dental professional approximately every 14.8 years after having a complete denture. Ideally, edentulous patients should be seen every 1 to 2 years and should be informed that every 3 to 5 years a reline or new denture is suggested to replace the additional bone loss by atrophy that naturally will occur.

The rate and amount of bone loss may be influenced by many factors such as gender, hormones, metabolism, parafunction, and ill-fitting dentures. Studies have shown almost 40% of denture wearers have been wearing an ill-fitting prosthesis for more than 10 years.[9] Patients wearing dentures day and night place greater forces on the hard and soft tissues, which accelerates bone loss. Nonetheless, 80% of dentures are worn both day and night.[9] Loss of bone in the maxilla or mandible is not limited to alveolar bone; portions of the basal bone may also be resorbed, especially in the posterior aspect of the mandible, where severe resorption may result in the mental foramen or mandibular canal becoming dehiscent. This may result in significant pain and discomfort, leading to the inability to wear a removable prosthesis. In the maxilla, the complete anterior ridge and nasal spine may be resorbed, causing pain and an increase in maxillary denture movement during function (Fig. 15.3 and Box 15.3).[10]

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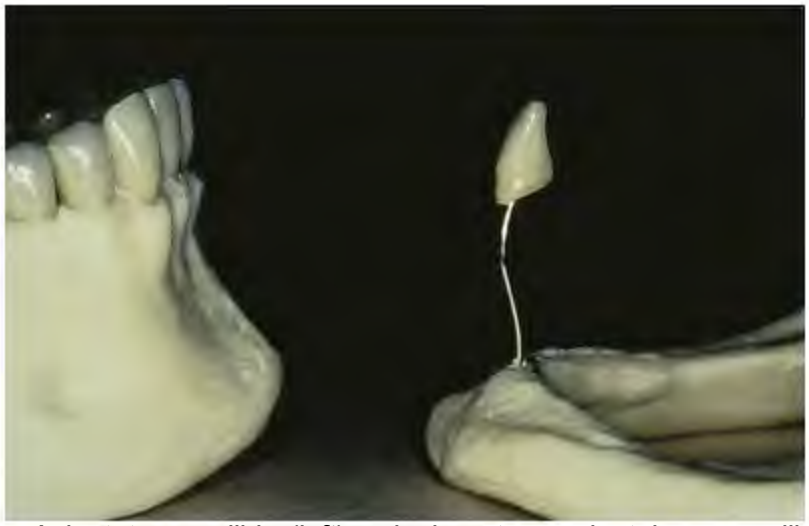

FIG 15.3 A dentate mandible *(left)* and a long-term edentulous mandible on the *(right)*. Note the amount of bone loss in height. Loss of bone height in the mandible may be measured by the centimeter and often is ignored. Such bone loss is often more significant than the bone loss (in millimeters) from periodontal disease. The patient should understand that a denture often replaces more bone than teeth to restore the proper dimensions of the face. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Box 15.3

Anatomic Consequences of Edentulism

- Decreased width of denture-supporting bone
- Decreased height of denture-supporting bone
- Prominent mylohyoid and internal oblique ridges with increase in denture sore spots
- Progressive decrease in keratinized attached mucosa
- Prominent superior genial tubercles with increased denture movement
- Muscle attachments near crest of edentulous ridge
- Posterior elevation of prosthesis with contraction of mylohyoid and buccinator muscles during function
- Forward movement of prosthesis from anatomic inclination with moderate

to advanced bone loss

- Thinning of surface mucosa with increased sensitivity to abrasion
- Loss of basal bone
- Paresthesia from dehiscent mental foramen and neurovascular canal
- Increased risk of mandibular body fracture from advanced bone loss

Decreased Occlusal Biting Force

The biting force of edentulous patients is a significant factor that patients must be educated about concerning various treatment plans. The difference in maximum occlusal forces recorded in a patient with natural teeth and one who is completely edentulous is dramatic. In the first molar region of a dentate person, the average force has been measured to be approximately 150 to 250 psi.[11] A parafunction patient who grinds or clenches their teeth may exert a force that approaches 1000 psi. In edentulous patients the maximum occlusal force approaches less than 50 psi. This is very important when explaining various treatment plans to patients, especially with expectations. The longer patients are edentulous, the less occlusal force they are able to generate. Studies have shown that patients wearing complete dentures for more than 15 years have been shown to exhibit a maximum occlusal force of less than 6 psi.[12] This is a significant disadvantage that patients need to be educated about, especially when patients decline implant treatment plans in favor of conventional removable dentures. In comparison, the maximum occlusal force may improve upwards of 300% with an implant-supported prosthesis.[13]

Decreased Masticatory Efficiency

As a result of decreased occlusal force and the instability of the complete denture, masticatory efficiency will decrease with tooth loss. Rissen et al showed that 90% of food chewed with natural teeth fits through a no. 12 sieve; this is reduced to 58% in the patient wearing complete dentures.[12] A study of 367 denture wearers (158 men and 209 women) found that 47% exhibited a low masticatory performance.[14] In patients with dentures, 29% are able to eat only soft or mashed foods, 50% avoid many foods, and 17% claim they eat more efficiently without the prosthesis.[15] Lower intakes of fruits,

vegetables, and vitamin A by women were noted in this group. Denture patients also take significantly more drugs (37%) compared with those with superior masticatory ability (20%), and 28% take medications for gastrointestinal disorders. The reduced consumption of high-fiber foods could induce gastrointestinal problems in edentulous patients with deficient masticatory performance. In addition, the coarser bolus may impair proper digestive and nutrient extraction functions.[16]

Increased Soft Tissue Discomfort

Mandibular discomfort was listed in a study by Misch and Misch with equal frequency as movement (63.5%), and, surprisingly, 16.5% of the patients stated they never wear the mandibular denture. In comparison, the maxillary denture was uncomfortable half as often (32.6%), and only 0.9% were seldom able to wear the prosthesis. Function was the fourth most common problem reported by these 104 denture wearers. Half of the patients avoided many foods, and 17% claimed they were able to masticate more effectively without the prostheses. The psychologic effects of the inability to eat in public can be correlated with these findings. Other reports agree that the major motivating factors for patients to undergo implant-related treatment were related to the difficulties with eating, denture fit, and discomfort.[15]

Systemic Consequences

The literature includes several reports suggesting that compromised dental function causes poor masticatory performance and swallowing poorly chewed food, which in turn may influence systemic changes favoring illness, debilitation, and shortened life expectancy.[17,18] In a study evaluating the ability to eat fruit, vegetables, and other dietary fiber in edentulous subjects, 10% claimed difficulty, and blood tests demonstrated reduced levels of plasma ascorbate and plasma retinol compared with dentate subjects. These two blood tests are correlated to an increased risk of dermatologic and visual problems in aging adults. In another study the masticatory performance and efficiency in denture wearers were compared with those of dentate individuals. This report noted that, when appropriate corrections were made for different performance norms and levels, the chewing efficiency of a denture wearer was less than one sixth of a person with teeth.[19]

Several reports in the literature correlate a patient's health and life span to dental health. Poor chewing ability may be a cause of involuntary weight loss

in the elderly population, with an increase in mortality rate.[20] In contrast, persons with a substantial number of missing teeth were more likely to be obese. After conventional risk factors for strokes and heart attacks were accounted for, there was a significant relationship between dental disease and cardiovascular disease, the latter still remaining as the major cause of death.[21] It is logical to assume that restoring the stomatognathic system of these patients to a more normal function may indeed enhance the quality and length of their lives.

Lack of Prosthesis Satisfaction

A dental survey of edentulous patients found that 66% were dissatisfied with their mandibular complete dentures. Primary reasons were discomfort and lack of retention causing pain and discomfort. Past dental health surveys indicate that only 80% of the edentulous population are able to wear both removable prostheses all the time. Some patients wear only one prosthesis, usually the maxillary; others are only able to wear their dentures for short periods. In addition, approximately 7% of patients are not able to wear their dentures at all and become “dental cripples” or “oral invalids.” They rarely leave their home environment, and when they feel forced to venture out, the thought of meeting and talking to people when not wearing their teeth is unsettling.[22]

Speech Difficulty

A report of 104 completely edentulous patients seeking treatment was performed by Misch and Misch. Of the patients studied, 88% claimed difficulty with speech, with one fourth having great difficulty. The lower prosthesis rests upon the buccinator muscle and mylohyoid muscle when the posterior mandible resorbs. When the patient opens their mouth, the contraction of these muscles acts like a trampoline and propels the lower denture off the ridge. As a result, the teeth often click when the patient talks, not from too much of the vertical dimension restored but from the lack of stability and retention of the prosthesis. Speech problems may be associated with a concern for social activities. Awareness of movement of the mandibular denture was cited by 62.5% of these patients, although the maxillary prosthesis stayed in place most of the time at almost the same percentage.

Psychologic Impact of Edentulism

The psychologic effects of total edentulism are complex and varied and range from very minimal to a state of neuroticism. Although complete dentures are able to satisfy the esthetic needs of many patients, some believe their social lives are significantly affected. They are concerned with kissing and romantic situations, especially if a new partner in a relationship is unaware of their oral handicap. Fiske et al, in a study of interviews with edentulous subjects, found tooth loss was comparable to the death of a friend or loss of other important parts of a body in causing a reduction of self-confidence ending in a feeling of shame or bereavement.[23]

The psychologic needs of edentulous patients are expressed in many forms. For example, in 1970, Britons used approximately 88 tons of denture adhesive.[24] In 1982, more than 5 million Americans used denture adhesives (Ruskin Denture Research Associates: AIM study, unpublished data, 1982), and a report shows that in the United States, more than $200 million is spent each year on denture adhesives, representing 55 million units sold.[27] Patients are willing to accept the unpleasant taste, need for recurring application, inconsistent denture fit, embarrassing circumstances, and continued expense for the sole benefit of increased retention of the prosthesis. Clearly, the lack of retention and psychologic risk of embarrassment in the denture wearer with removable prostheses is a concern the dental profession must address.

Advantages of an Implant-Supported Prosthesis (Box 15.4)

Maintenance of Existing Bone

The use of dental implants to provide support for prostheses offers many advantages compared with the use of removable soft tissue–borne restorations. A primary reason to consider dental implants to replace missing teeth is the maintenance of alveolar bone. It is well accepted that dental implants placed in the anterior mandible help retain a lower denture and are a benefit over a complete denture. However, the posterior bone loss will continue and may eventually lead to significant complications. Instead, when sufficient implants are inserted, the restoration is not only retained but it also is completely supported and stabilized off the tissue and bone. The implants also stimulate and maintain the bone of the mandible as well as serve as an anchor for the prosthetic device. As a result, dental implants are

one of the better preventive maintenance procedures available in dentistry.

Box 15.4

Advantages of an Implant-Supported Prosthesis

- Maintenance of existing bone
- More ideal occlusion
- Increased masticatory function
- Less morbidity in comparison to teeth
- Increased biting force
- Increased retention and stability
- Enhanced phonetics
- Improved psychologic health

More Ideal Occlusion

One of the main complications of wearing a lower removable denture is the associated movement and lack of security. A mandibular denture often moves when the mylohyoid and buccinator muscles contract during speech or mastication. Occlusion is difficult to establish and stabilize with a completely soft tissue–supported prosthesis. Because the mandibular prosthesis may move as much as 10 mm or more during function, proper occlusal contacts occur by chance, not by design. In comparison, an implant-supported restoration is much more stable.[25] The patient can more consistently return to centric relation occlusion rather than adopt variable positions dictated by the prosthesis' instability. Proprioception is awareness of a structure in time and place. The receptors in the periodontal membrane of the natural tooth help determine its occlusal position. Although endosteal implants do not have a periodontal membrane, they provide greater occlusal awareness than complete dentures. Whereas patients with natural teeth can perceive a

difference of 20 μm between the teeth, implant patients can determine a 50-μm difference with rigid implant bridges compared with 100 μm in those with complete dentures (either one or two).[26] As a result of improved occlusal awareness, the patient functions in a more consistent range of occlusion. With an implant-supported prosthesis, the direction of the occlusal loads is controlled by the restoring dentist. Horizontal forces on removable prostheses accelerate bone loss, decrease prosthesis stability, and increase soft tissue abrasions. The decrease in horizontal forces that are applied to implant restorations improves the local parameters and helps preserve the underlying soft and hard tissues.

Increased Masticatory Function

In a randomized clinical trial comparing conventional vs. implant-supported prostheses by Kapur et al, the implant group of patients demonstrated a higher level of eating enjoyment and improvement of speech, chewing ability, comfort, denture security, and overall satisfaction.[27] The ability to eat several different foods among complete denture vs. mandibular overdenture patients was evaluated by Awad and Feine. The implant overdenture was superior for eating not only harder foods, such as carrots and apples, but also softer foods, such as bread and cheese. Geertman et al evaluated complete denture wearers with severely resorbed mandibles before and after mandibular implant overdentures. The ability to eat hard or tough foods significantly improved.[28]

Researchers at McGill University evaluated blood levels of patients who had complete dentures and 30 maxillary dentures and mandibular implant prostheses 6 months after treatment. Within this rather short period, implant patients had higher vitamin B_{12} hemoglobin (related to iron increase) and albumin levels (related to nutrition). These patients also had greater body fat in their shoulders and arms, with decreased body fat in their waists.[29]

Less Morbidity in Comparison to Teeth

The success rate of implant prostheses varies depending on a host of factors that change for each patient. However, compared with traditional methods of tooth replacement, the implant prosthesis offers increased longevity, improved function, bone preservation, and better psychologic results. According to 10-year survival surveys of fixed prostheses on natural teeth, decay is indicated as the most frequent reason for replacement; and survival

rates are approximately 75%.[30] In a partially edentulous patient, independent tooth replacement with implants may preserve intact adjacent natural teeth as abutments, further limiting complications such as decay or endodontic therapy, which are the most common causes of fixed prosthesis failure. A major advantage of the implant-supported prosthesis is that the abutments cannot decay and never will require endodontics. The implant and related prosthesis have been shown to attain a 10-year survival rate of more than 90%.

Increased Biting Force

Patients with an implant-supported fixed prosthesis may increase their maximum bite force by 85% within 2 months after the completion of treatment. After 3 years the mean force may reach more than 300% compared with pretreatment values. As a result, an implant prosthesis wearer may demonstrate a force similar to that of a patient with a fixed restoration supported by natural teeth. Chewing efficiency with an implant prosthesis is greatly improved compared with that of a soft tissue–borne restoration. The masticatory performance of dentures, overdentures, and natural dentition were evaluated by Rissin et al. The traditional denture showed a 30% decrease in chewing efficiency; other reports indicate a denture wearer has less than 60% of the function of people with natural teeth. The tooth-supported overdenture loses only 10% of chewing efficiency compared with natural teeth. These findings are similar with implant-supported overdentures. In addition, rigid, implant-supported fixed bridges may function the same as natural teeth.[31]

Improvement of Retention and Stability

Stability and retention of an implant-supported prosthesis are great improvements over soft tissue–borne dentures. Mechanical means of implant retention are far superior to the soft tissue retention provided by dentures or adhesives and cause fewer associated problems. The implant support of the final prosthesis is variable, depending on the number and position of implants, yet all treatment options demonstrate significant improvement over conventional prosthesis treatment options.

Enhanced Phonetics

Phonetics may be impaired by the instability of a conventional denture. The

buccinator and mylohyoid muscles may flex and propel the posterior portion of the denture upward, causing clicking, regardless of the vertical dimension. As a result, a patient in whom the vertical dimension already has collapsed 10 to 20 mm may still produce clicking sounds during speech. Often the tongue of the denture wearer is flattened in the posterior areas to hold the denture in position. The anterior mandibular muscles of facial expression may be tightened to prevent the mandibular prosthesis from sliding forward. The implant prosthesis is stable and retentive and does not require these oral manipulations. The implant restoration allows reduced flanges or palates of the prostheses. This is of special benefit to new denture wearers, who often report discomfort with the bulk of the restoration. The extended soft tissue coverage also affects the taste of food, and the soft tissue may be tender in the extended regions. The palate of a maxillary prosthesis may cause gagging in some patients, which can be eliminated in an implant-supported overdenture.

Improved Psychologic Health

Patients treated with implant-supported prostheses judge their overall psychologic health as improved by 80% compared with their previous state while wearing traditional, removable prosthodontic devices. They perceived the implant-supported prosthesis as an integral part of their body.[32] For example, Raghoebar et al evaluated 90 edentulous patients in a randomized multicenter study. Five years after treatment, a validated questionnaire targeted patient esthetic satisfaction, retention, comfort, and the ability to speak and eat with either a complete mandibular denture, complete mandibular denture with vestibuloplasty, or mandibular two-implant overdenture. Implant overdentures had significantly higher ratings, but no significant difference was found between the two complete-denture groups.[33] Geertman et al reported similar results comparing chewing ability of conventional complete dentures with mandibular implant overdentures.[34]

Not Understanding the Disadvantages of a Removable Implant Prosthesis (Overdenture)

Although dental implant overdentures are successful in many situations, patients should be informed of the inherent disadvantages and complications that may occur. Many studies have shown a rather high

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incidence of complications. Goodacre et al have shown overdenture complications to include clip/attachment loosening (30%), clip/attachment fracture (17%), and overdenture fracture (12%). In a study by Bilhan et al on 59 patients, two thirds of implant-supported overdenture (IOD) patients had prosthetic-related complications the first year. For example, relines were necessary in 16%, loss of retention in 10.2%, fracture of the IOD in 8.5%, pressure spots in 8.5%, dislodged attachment in 6.8%, and screw loosening in 3.4%.[35] Other studies have shown up to 18% of overdentures requiring a reline of the prosthesis within the first year.[36] It is imperative that patients understand fully the basis and long-term issues that may be associated with implant-retained overdentures.

Not a Fixed Prosthesis

Many patients are not educated in the inherent mechanics of overdentures and the various levels of support that exist, which are dependent on the position, number, and types of retentive mechanisms. The most common misconception that may lead to patient disapproval is an overdenture is not a "fixed prosthesis." With that, the patient must understand the decreased occlusal force in comparison to fixed prosthesis. An overdenture is considered a prosthesis, whereas a fixed prosthesis is considered a body part. Fixed implant prostheses are often considered by patients to be similar to their natural teeth in esthetics and function. With an overdenture, movement of the prosthesis is usually noted by the patient along with decreased masticatory function (Fig. 15.4).

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FIG 15.4 (A) Fixed prosthesis, which exhibits greater masticatory efficiency. (B) Removable implant prosthesis, which has many disadvantages in comparison to a fixed prosthesis.

Need of Adequate Crown Height Space (CHS)

A greater crown height space (CHS) is required for an implant-retained overdenture in comparison to other types of implant prostheses. With an overdenture prosthesis, there is often a lack of space that results in a prosthesis fracture or loss of denture teeth. When space is compromised, inadequate room results in modification of the materials (reduction of acrylic from denture base or hollowing out of denture teeth) to obtain room for attachment mechanisms. In these situations, the appropriate attachment (e.g., Locator 6–low profile) must be selected to minimize these complications. When abundant bone is present and implants are already inserted, a compromised CHS may indicate a change in treatment planning to a fixed prosthesis if adequate number and position of implants are present (Fig. 15.5).

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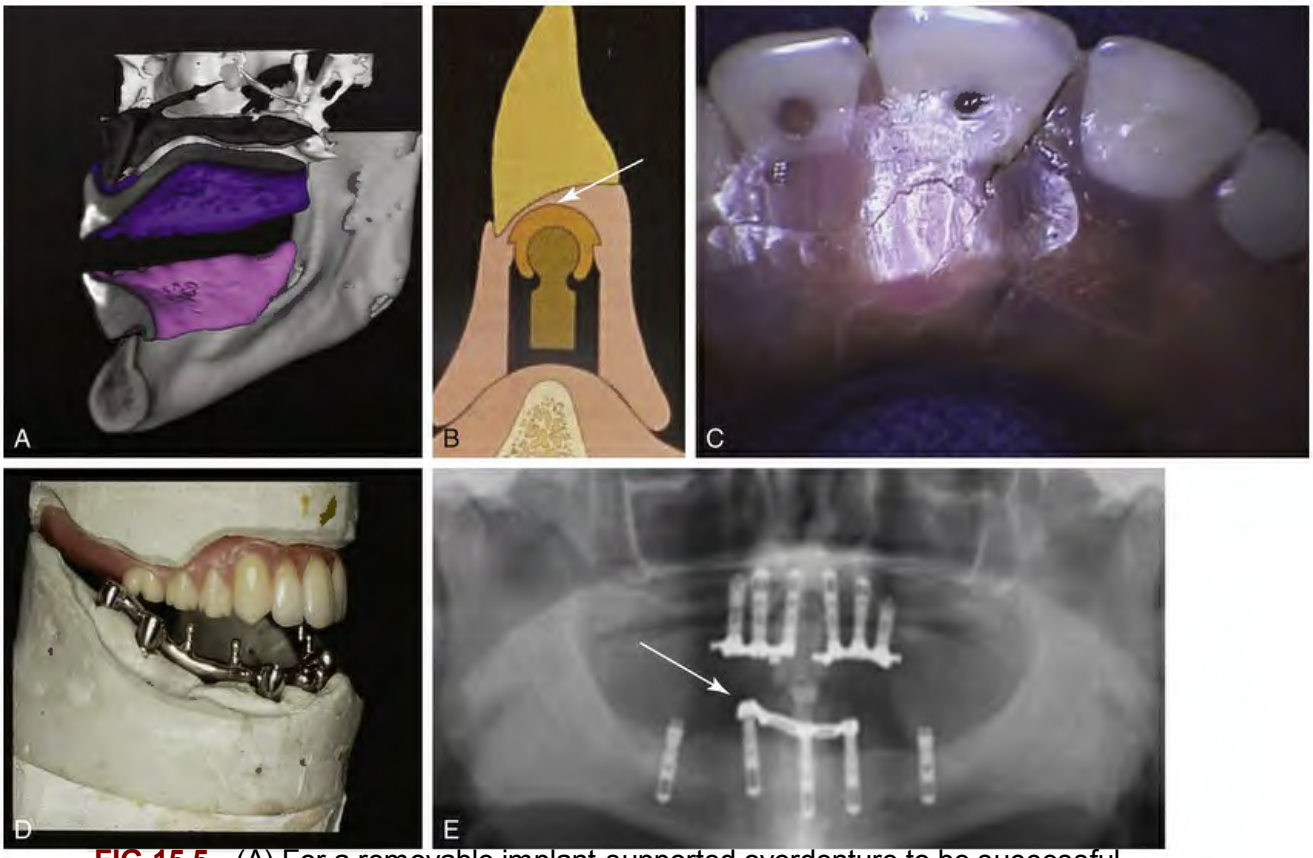

FIG 15.5 (A) For a removable implant-supported overdenture to be successful, adequate space is needed for the attachments and denture teeth. Sagittal CBCT view depicting the available space between the bone level and incisal edge. (B) When inadequate space is available *(arrow)*, the denture base or denture is weakened (i.e., inadequate acrylic thickness) leading to possible fracture. (C) Fractured denture base due to lack of acrylic bulk. (D) Articulated setup of overdenture case exhibiting lack of interocclusal space with bar contacting maxillary posterior teeth. (E) Panorex showing lack of prosthetic space due to inadequate amount of osteoplasty *(arrow)*.

Maintenance

An increased maintenance protocol is often required for an overdenture. Denture teeth wear more rapidly on an IOD in comparison to a denture (i.e., increased occlusal force). As a result, a new IOD may need to be fabricated on a more continuous basis depending on the amount of wear. The patient should be informed at the beginning of treatment of the need for maintenance to avoid patient complications. Although the initial cost of treatment may be less for an IOD, overdenture wearers often incur greater long-term expenses than those with fixed restorations. Attachments (i.e., O-rings or clips) regularly wear and must be replaced, which in some cases is very time consuming. Walton and McEntee noted there were three times more maintenance and adjustments issues for overdentures compared with

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fixed restorations.[37]

Food Impaction

A common complaint with IODs is food impaction under the prosthesis. When the denture is fabricated, border molding captures the muscles in their contracted position. In the relaxed muscle state, food will sometimes become displaced under the denture border. For example, when the patient swallows, the food is pushed under the denture. Because the IOD moves less than a denture, the food remains under the IOD and becomes lodged, usually requiring the patient to physically remove the irritants (Fig. 15.6).

FIG 15.6 A removable implant prosthesis tends to impact food more than a conventional removable prosthesis. An RP-4, totally implant-supported prosthesis, will tend to accumulate food more than an RP-5 (soft tissue support with secondary implant support).

Loss of Posterior Bone

Most mandibular IODs used by the profession are supported by implants anterior to the mental foramina and soft tissue support in the posterior regions. The anterior implants allow improved anterior bone maintenance, and the prosthesis benefits from improved function, retention, and stability. Dental implants placed in the anterior mandible help retain a lower denture and are certainly a benefit over a complete denture. The posterior bone loss will continue and may eventually lead to significant complications with respect to lack of soft tissue support (i.e., RP-5 prosthesis). Studies have

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shown posterior bone loss to occur four times faster than anterior bone loss.[38] The lack of posterior support in two- and three-implant overdentures allows continued posterior bone loss. A primary concern for RP-5 overdentures (soft tissue support in the posterior regions) compared with RP-4 or fixed restorations (restorations completely supported, retained, and stabilized) should be the continued bone loss in the posterior regions.

Wright et al evaluated the change in the posterior mandibular residual ridge over time comparing patients wearing mandibular IOD with bar attachments or mandibular fixed cantilever prostheses stabilized on five or six implants. Bone measurements were made by digitizing tracings of panoramic radiographs. The mandibular fixed cantilever prostheses demonstrated bone growth in the posterior mandibular residual ridge while IOD showed bone resorption in the same area (Fig. 15.7).[39]

FIG 15.7 Posterior ridge resorption. Anterior bone is retained due to the presence of implants; however, posterior ridge resorption will occur.

Reddy et al also confirmed this finding with the measurement of bone height under a fixed detachable cantilever restoration supported by five or six endosseous implants. A computer-enhanced method was used to measure mandibular height distal to the last implant, which showed a significant bone growth in the mandible the first year of function.[40]

Not Understanding the Wide Range of Overdenture Retention

Etiology

A common complication that arises with overdenture treatment planning is utilizing the same or “favorite” treatment plan (i.e., implant number and position) for all patients. The clinician must understand there exists a significant difference between overdenture treatment plans including number of implants, implant positioning, opposing dentition, and patient expectations.

Prevention

Understand Overdenture Mechanics.

To develop a mandibular IOD with reduced complications, the final prosthesis should be predetermined and related to three factors:

1. *Retention:* retention is related to the vertical force necessary to dislodge the prosthesis. The amount of overdenture retention is dictated by the number, location, and type of attachments.

2. *Support:* the support of a prosthesis is related to the amount of vertical movement of the prosthesis toward the tissue. This will vary greatly depending upon the patient's ridge form. Support is primarily related to implant number, independent attachments or presence of a bar design in the posterior region.

3. *Stability:* stability of a prosthesis is evaluated with horizontal or cantilevered forces applied to the restoration. The stability of the IOD is more related to implant (attachment and bar) position. This is often a misconception of patients because they believe there should exist no movement of the prosthesis.

Treat According to Patient's Desires.

The patient's initial complaints, hard and soft tissue anatomy, prosthetic desires, and financial commitment determine the amount of implant support, retention, and stability. Because different anatomic conditions and patient force factors influence these factors for an IOD, not all prostheses

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should be treated in the same manner. In other words, the two-implant overdenture should not be the only treatment plan offered to a patient. One should emphasize that most mandibular overdentures should be designed to eventually result in a RP-4 prosthesis (e.g., totally implant supported). If the patient wishes for a less retentive prosthesis, a prosthesis with less support, and with minimal stability, the patient needs to understand the inherent disadvantages. It is highly recommended that the clinician furnish all patients with ALL possible overdenture treatment plans. This is important for two reasons. First, the patient will be well aware of the type of prosthesis they have selected, and, secondly, this allows for the patient to understand they can "upgrade" to a prosthesis at a later time that will have increased retention, support, and stability. This will prevent unacceptable expectations from the patient following the insertion of the prosthesis.

Understand Prosthesis Movement.

The most common complications found with mandibular IODs are related to the prosthetics and a misunderstanding of retention, support, and stability of the prosthesis. When a fixed restoration is fabricated on implants, it is rigid, and cantilevers or offset loads are clearly identified. For example, rarely will a practitioner place a full-arch fixed restoration on three implants, especially with excessive cantilevers because of implant positioning. However, three anterior implants with a connecting bar may support a completely fixed overdenture, solely because of attachment design or placement. The restoring clinician believes the three-implant overdenture has less prosthetic occlusal load but does not realize that a three-implant overdenture may become "fixed" just by the design of the attachments. A complete understanding of the concept of prosthesis movement (PM) is needed by the clinician (Fig. 15.8).

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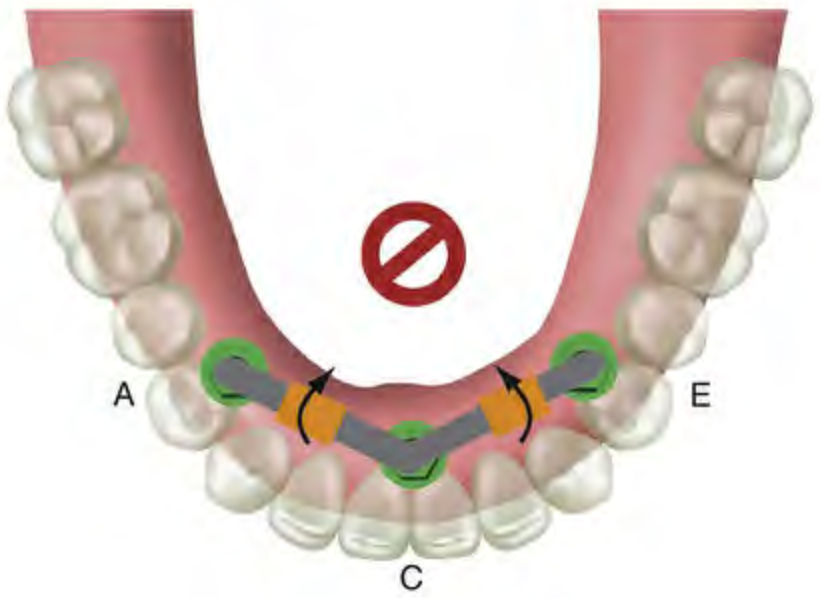

FIG 15.8 Example of improper use of the bar/attachment system. Because the attachments are not in the same plane, the prosthesis will become fixed instead of allowing for rotational movement *(arrows)*.

Not Understanding the Concept of Prosthesis Movement

An overdenture is by definition a removable prosthesis; however, in function or parafunction the prosthesis may not move (e.g., because of the retentive mechanism, it may become fixed). Clinicians need to understand that an attachment may be classified as having movement in all directions; however, using it incorrectly or in combination with other attachments may actually change the range of motion. This may result in damaging forces to the implant or the prosthesis.

Prosthesis Movement

Many precision attachments with varying ranges of motion are used in IODs. The motion may occur in zero (rigid) to six directions or planes: occlusal, gingival, facial, lingual, mesial, and distal.[41] For example, a type 2 attachment moves in two planes and a type 4 attachment in four planes. Attachment and the prosthesis movement are independent from each other and should be evaluated as such. An important item for the IOD treatment plan is to consider how much prosthesis movement the patient can adapt to or tolerate with the final restoration. It was to address this need that Misch has formulated the concept of prosthesis movement instead of the classification

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of the individual attachment. The PM classification encompasses movement from PM-0 to PM-6 (Fig. 15.9).

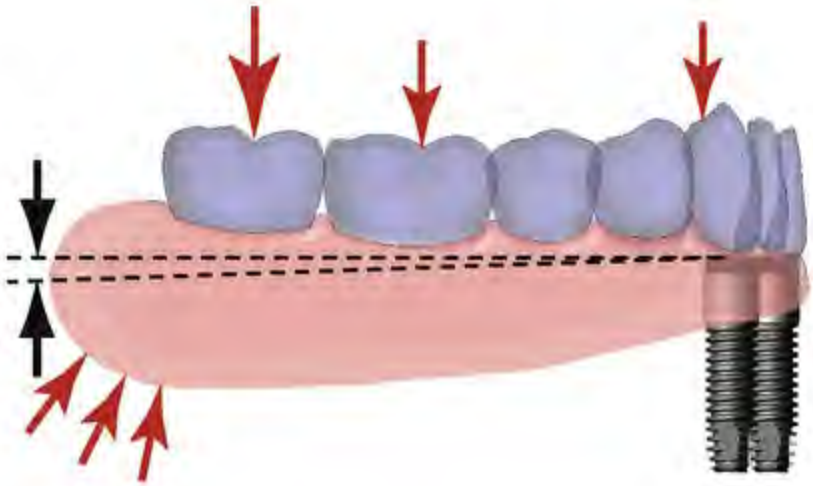

FIG 15.9 Prosthesis movement. Hinging action of the prosthesis resulting from anterior implants and lack of posterior soft tissue support (i.e., primary stress bearing area – buccal shelf). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

PM-0.

A PM-0 attachment exhibits no movement in any direction. For example, if the prosthesis is rigid (i.e., movement in no direction) when in place but can be removed, the PM is labeled PM-0 regardless of the attachments used. If an O-ring is used individually, they may provide motion in six different directions. However, if four O-rings are placed along a complete arch bar, the prosthesis rests directly on the bar and result in a PM-0 restoration. Because of the design of the attachments and prosthesis, the end result would be a fixed prosthesis (Fig. 15.10).

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FIG 15.10 Prosthesis movement PM-0.

PM-2.

A hingelike PM permits movement in two planes (PM-2) and most often uses attachments that have the capability to hinge. The most common examples of PM-2 attachments are the Dolder bar and clip without a spacer or Hader bar and clip. A Dolder bar is egg shaped in cross section, and a Hader bar is round. A clip attachment may rotate directly on the Dolder bar. A Hader bar is more flexible because round bars flex (x^4) related to the distance between the abutments and other bar shapes flex (x^3). As a result, an apron often is added to the tissue side of the Hader bar to limit metal flexure, which might contribute to unretained abutments or bar fracture.[42] A cross section of the Hader bar and clip system reveals that the apron, by which the system gains strength compared with a round bar design, also limits the amplitude of rotation of the clip (and prosthesis) around the fulcrum to 20 degrees, transforming the prosthesis and bar into a more rigid assembly. The Hader bar and clip system may be used for a PM-2 when posterior ridge shapes are favorable and soft tissue is stable enough to limit prosthesis rotation (Fig. 15.11).

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FIG 15.11 Prosthesis movement PM-2, 3, or 4 depending on the number and types of attachments placed.

It should be noted that for these systems to function as designed, the hinge attachment needs to be perpendicular to the axis of prosthesis rotation so the PM also will be in two planes (i.e., PM-2). If the Hader or Dolder bar is at an angle or parallel to the direction of desired rotation, the prosthesis is more rigid and may resemble a PM-0 system. As a consequence, the implant system may be overloaded and cause complications such as prosthetic screw loosening or fracture, implant crestal bone loss, and even implant failure. A Hader bar-clip system is an ideal low-profile attachment for a RP-4 prosthesis with PM-0. Usually, these clips are placed on the bar in different planes of rotation around the arch.

PM-3.

A prosthesis with an apical and hinge motion is defined as a PM-3. An example is a Dolder bar with a space provided over the bar. As a result, the prosthesis moves toward the tissue and then rotates.

PM-4.

PM-4 allows movement in four directions.

PM-6.

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PM-6 has a range of PM in all six directions. The most common overdenture attachments for a PM-6 are independent O-rings or Locator attachments (Fig. 15.12).

FIG 15.12 Prosthesis movement PM-6. O-Ring with a single implant may move in all six directions.

Height of the Attachment

An important aspect of overdenture PM is also related to the height of the attachment connection. There are two crown height dimensions for overdentures: (1) the occlusal plane to the height of the attachment rotation and (2) the height of the attachment to the level of the bone. The occlusal plane to attachment height is a force magnifier to the overdenture with any lateral or cantilevered force. When an attachment is connected to an implant directly, the crown height above the attachment is greater than when the attachment is placed on a bar. If you double the crown height, the force is increased 200%. Hence, the individual implant attachment has a greater crown height above the attachment and greater lateral force to the prosthesis. Therefore, the overdenture is less stable (Fig. 15.13).

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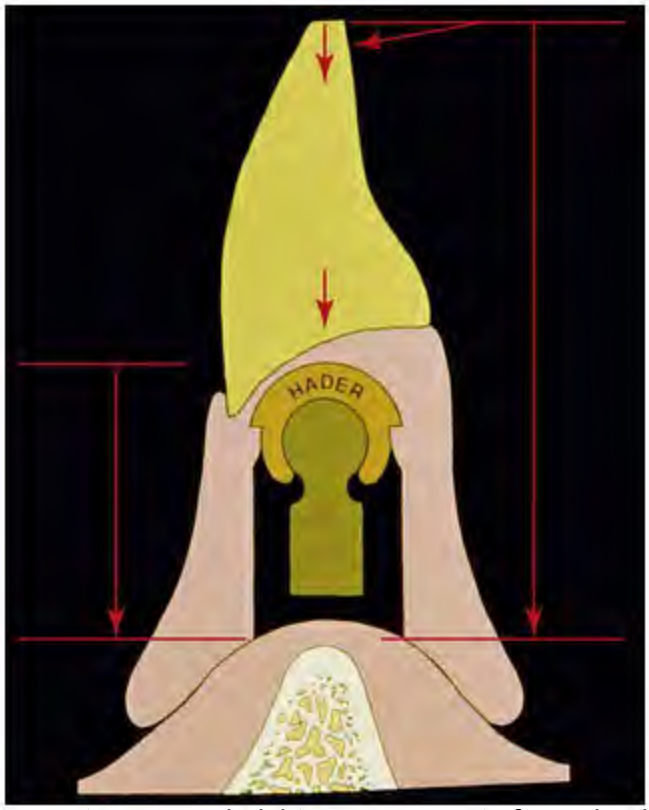

FIG 15.13 There are two crown height space aspects for an implant overdenture. The occlusal plane to the attachment is a crown height force magnifier to the overdenture. Any lateral or offset load will be magnified in relation to the crown height above the attachment.

When the attachment is placed on a bar, the stability of the prosthesis is improved because less lateral force is applied to it (i.e., the crown height above the attachment is reduced). Whenever possible, the implant should be connected with a bar and an attachment placed on top of the bar. Rotation of the prosthesis should be as far off the bone as practical. However, there should be a minimum of 2 mm or more of acrylic space between the attachment and the denture teeth. This allows adequate bulk of material to decrease prosthesis fracture or dislodgement of teeth.

The second CHS is the height of the attachment to the bone level. The greater the attachment-to-bone level, the greater the force placed on the implant abutment screw, marginal bone, and implant-bone interface with any lateral load. When the attachment-to–bone height distance is greater than 7 mm, the implants should be splinted together to decrease the risk of complication of the implant system.

Too Large of a Cantilever (“Hidden Cantilever”)

The hidden cantilever was postulated by Misch in 1993 and describes the

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portion of the removable prosthesis that extends beyond the last implant or connecting bar.[43] When hidden cantilevers exist, they may result in lack of support for the prosthesis, excessive wearing of attachments, increased stress to the bar-implant interface, and possible fracture of the prosthesis. In many of these cases, the attachment system does not wear because the removable prosthesis is PM-0 (i.e., no prosthesis movement); however, the excessive resultant forces place the prosthesis, abutment screws, and marginal bone at risk.

Etiology

If the bar/attachment is not designed correctly, the removable prosthesis does not rotate at the end of the implant or bar to load the soft tissue. This results in a "hidden cantilever." For example, if a cantilevered bar extends to the second premolar but forces on the second molar of the restoration do not result in movement of the restoration (i.e., posterior-inferior movement, anterior-superior movement), the cantilever extends to the second molar position. The cantilever length is measured to the point of PM, not to the end of the bar and attachment system.

Prevention

With most overdentures, the final restoration should not include extension beyond the first molar. This will minimize the hidden cantilever and will decrease the possibility of excessive force. The design of the overdenture system should have the proper movement, and care should be exercised to not induce a PM movement, especially when minimal number of implants exist. (Fig. 15.14).

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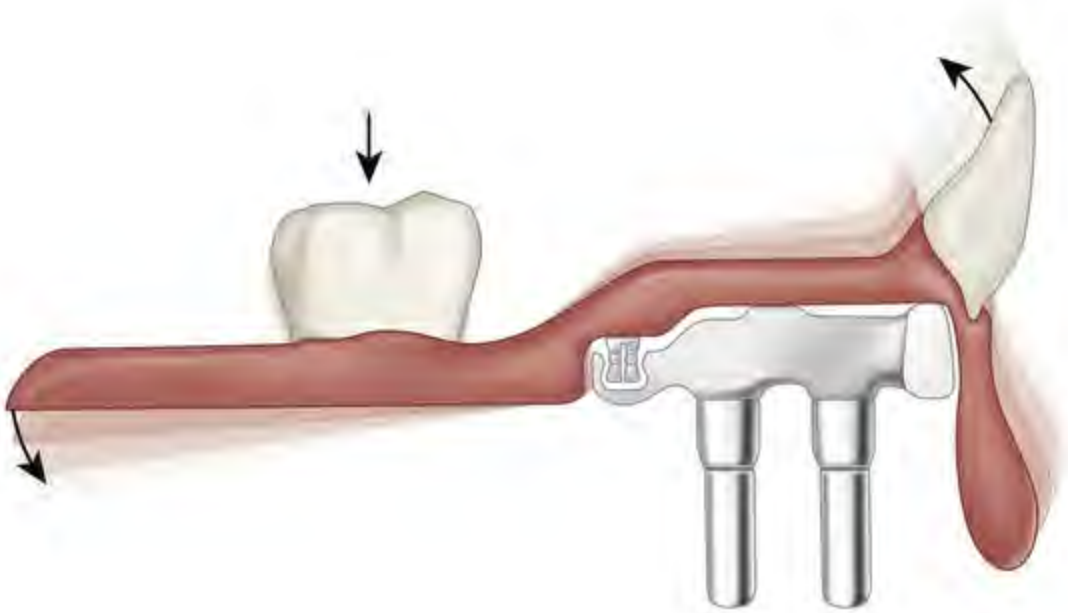

FIG 15.14 The hidden cantilever is that portion of the removable prosthesis that extends beyond the connecting bar, which does not rotate. If the prosthesis rotates at the first molar position and the bar extends to the premolar, the true cantilever length is the first molar position. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Mandibuar Overdenture Complications

In 1985 Misch presented five organized treatment options for implant-supported mandibular overdentures in completely edentulous patients. With these mandibular overdenture treatment options, studies have shown less than 1% implant failure and no prosthesis failure over a 7-year period with 147 mandibular overdentures (IOD) when using the organized treatment options and prosthetic guidelines presented in this chapter.[43] Kline et al reported on 266 implants for mandibular splinted implant-supported overdentures for 51 patients with the Misch protocol. An implant survival rate of 99.6% and a prosthesis survival rate of 100% were reported.[44]

When evaluating a patient for a mandibular overdenture, ideal treatment planning and overdenture mechanics must be considered. A determination of the final prosthesis being totally implant supported or soft tissue supported must be ascertained. Misch has determined the IOD treatment options to range from primarily soft tissue support and secondary implant retention (RP-5) to a completely implant-supported prosthesis (RP-4) with rigid stability and retention gained primarily from overdenture attachments (no soft tissue support). The prostheses are usually supported by two to five anterior implants for these five treatment options between the mental foraminal area. There are four RP-5 options that have a range of retention, support, and stability. The RP-4 restoration is defined as a rigid cantilevered bar that completely supports, stabilizes, and retains the restoration (Fig. 15.15).

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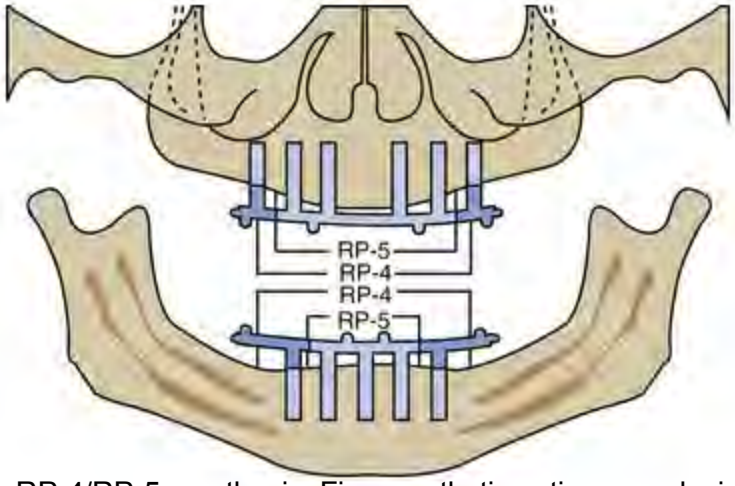

FIG 15.15 RP-4/RP-5 prosthesis. Five prosthetic options are designed for the mandibular overdentures. Four options are RP-5 (posterior soft tissue support) and one option is RP-4 (prosthesis completely supported by implants and connective bar). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Complications arise when patients are treated with the same protocol without regard to the patient's needs and expectations. For example, a two-implant overdenture may work very well with some patients; however, for others it tends to work very poorly. There are many factors that need to be evaluated prior to implementing an overdenture treatment plan. A thorough understanding of the positioning, number, and type of implants along with patient expectations should be ascertained according to various treatment plans. In addition, reports indicate that RP-5 mandibular IODs may cause a combination-like syndrome, with increased looseness, subjective loss of fit, and midline fracture of the upper denture.[45]

Inadequate Crown Height Space

Etiology

Implant overdentures may exhibit significant complications when reduced CHS (i.e., interocclusal space) exists. When sufficient CHS is lacking, the prosthesis is more prone to component fatigue and fracture and has more complications in comparison to porcelain-to-metal fixed prostheses.[1]

Prevention

Removable prostheses have space requirements for elements such as a connecting bar, type, and position of attachments and restorative material (metal vs. resin). According to English, the minimum CHS for individual attachments is 10 mm of CHS for Locator-type attachments and between 12

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and 15 mm for a bar and O-rings.[14] The ideal CHS for removable prostheses is greater than 14 mm, and the minimum height is 10.5 mm.[46] The lowest possible profile attachment should be used in situations of reduced CHS to fit within the contours of the restoration, provide greater bulk of acrylic resin to decrease fracture, and allow proper denture tooth position without the need to weaken the retention and strength of the resin base.[16]

The minimum CHS provides adequate bulk of acrylic to resist fracture; space to set denture teeth without modification; and room for attachments, bars, soft tissue, and hygiene. In the mandible the soft tissue is often 1 to 3 mm thick above the bone, so the occlusal plane to soft tissue should be at least 12 mm in height (Fig. 15.16).

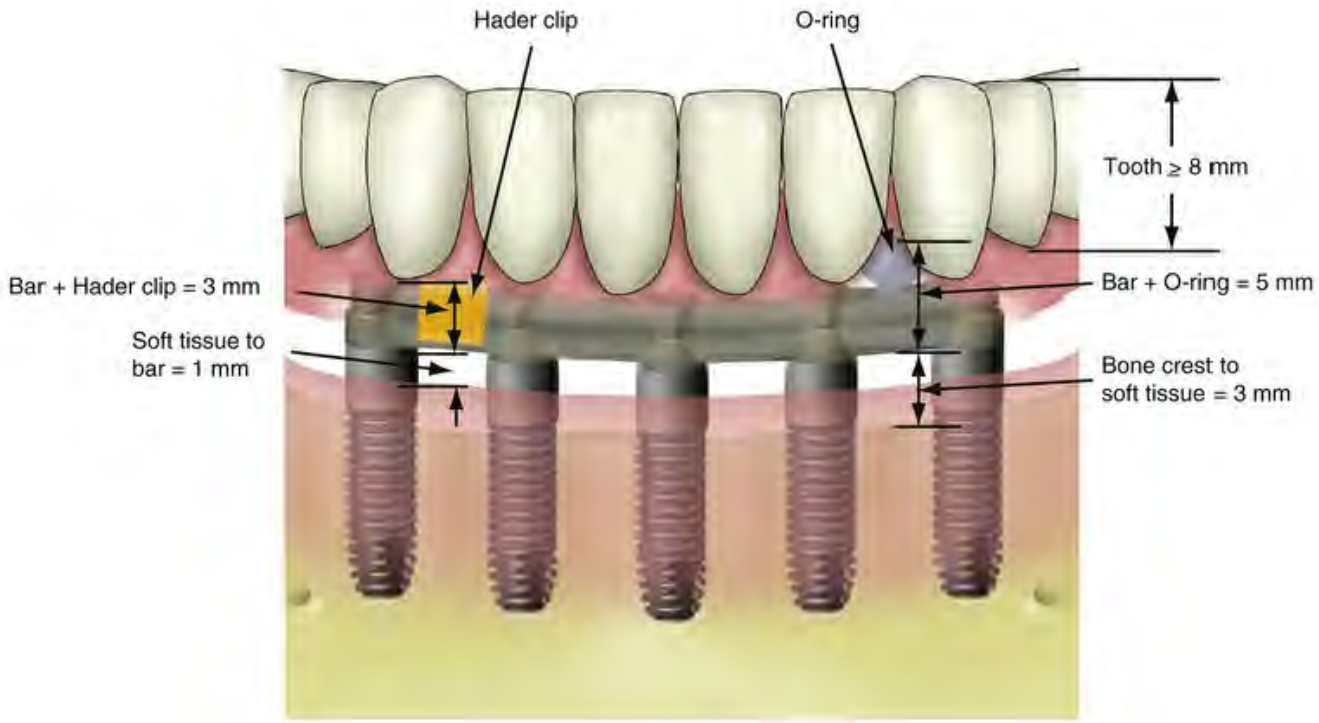

FIG 15.16 The mandibular overdenture requires at least 12 mm between the soft tissue and the occlusal plane to provide sufficient space (15 mm from bone level to occlusal plane) for the bar, attachments, and teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

An osteoplastic procedure to increase CHS before implant placement is often indicated, especially when abundant bone height and width are present. The crown height space should be evaluated and properly treatment planned prior to implant placement. Otherwise, a fixed porcelain-metal restoration should be considered (Fig. 15.17).

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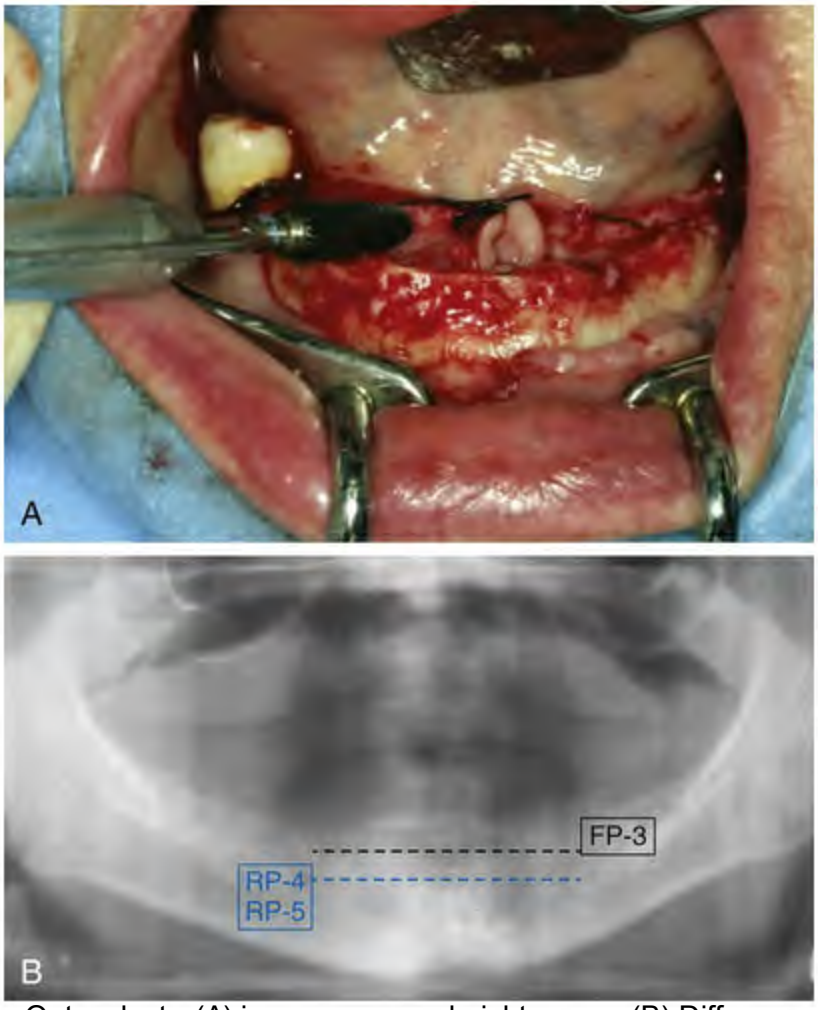

FIG 15.17 Osteoplasty. (A) increase crown height space. (B) Difference in amount of osteoplasty for a FP-3 vs. RP-4/5 prosthesis.

The most common method of bar retention by almost the same percentage for overdentures is screw retention. In minimum CHS situations, the screw-retained bar has a clear advantage, but in ideal to excessive CHS situations, the cemented bar may be considered. A combination of screw retention on some abutments and cement retention on others offers an advantage for many RP-4 prostheses, especially when implants are placed in the posterior region.

Poor Osseous Angulation (C-A)

Etiology

With increased bone resorption, the mandible resorbs from a division A to division C, eventually being compromised in angulation (division C–a). The division C–a is defined as an anterior mandible that is angled more than 30 degrees. If the clinician is unaware of this angulation, the implants may

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perforate the lingual plate and irritate the tissues of the floor of the mouth. If the implants are within the confines of the bone, they may enter the crest of the ridge at the floor of the mouth and make it almost impossible to restore (Fig. 15.18). In a study by Quirynen et al of 210 computer tomogram images, 28% of the anterior mandibles were lingually tilted −67.6 degrees ± 5.5 degrees.[47] The mandibles with less than −60 degree tilt represent about 5% of the cases (Fig. 15.19).

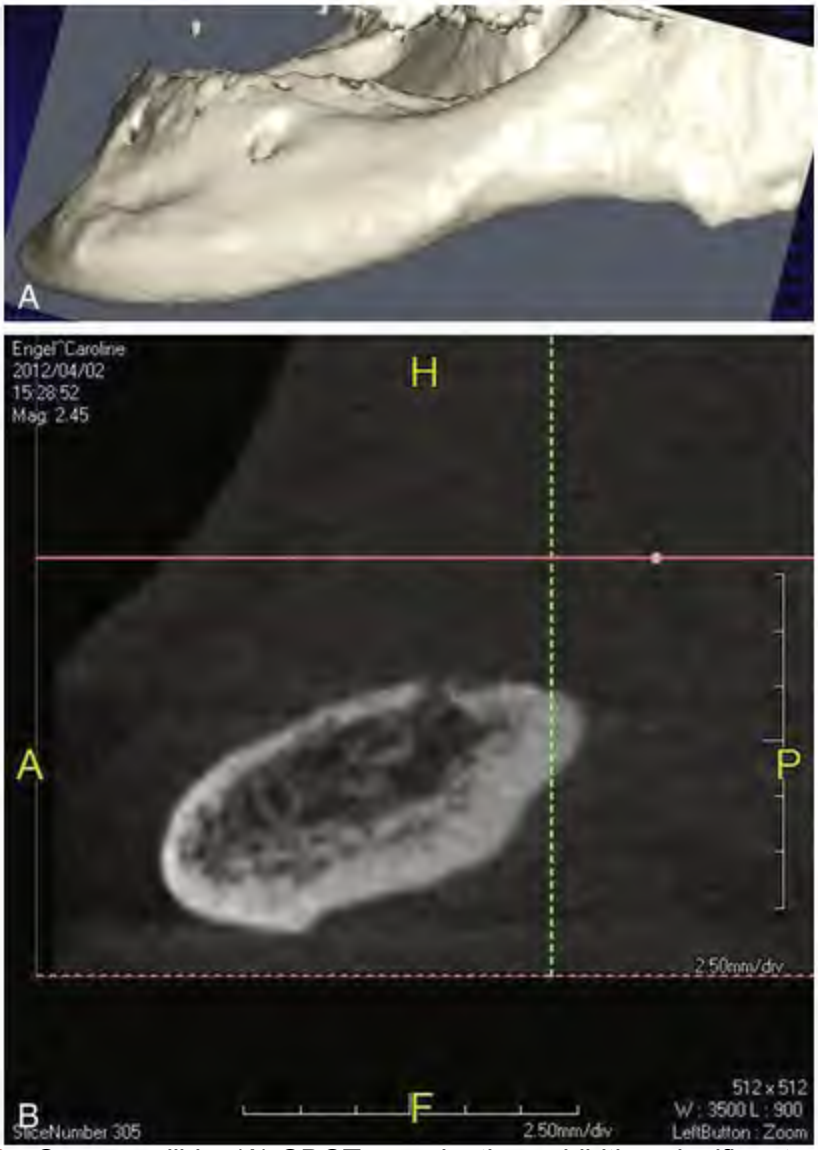

FIG 15.18 C−a mandible. (A) CBCT examination exhibiting significant angulation. (B) Cross-section CBCT exhibiting angulation from extensive buccal bone resorption.

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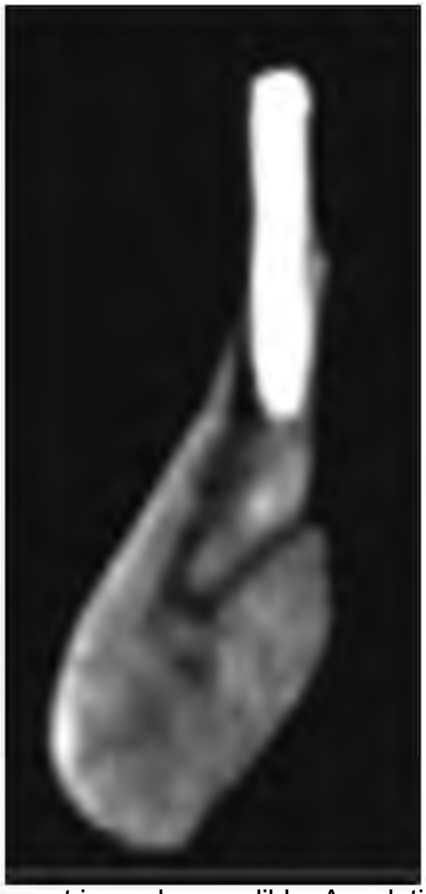

FIG 15.19 Implant placement in angle mandible. Angulation overcorrection leading to possible perforation of lingual plate.

Almost 10% of patients may have a greater than 30-degree angle to the occlusal plane. When present, this condition is most often found in the anterior mandible. Root form implants placed in this bone category (i.e., within the cortical plates) may have the abutments positioned within the floor of the mouth and compromise prosthetic reconstruction, speech, and comfort.

Prevention

In patients with division C–a, implants may be contraindicated to prevent surgical and prosthetic complications. In some cases, conventional removable prosthetics may be indicated or extensive bone grafting may be warranted to transform the division C–a into a division A.

Treatment

If implants have been placed prior to restoration, it may be the implants are nonrestorable. If the implants are nonrestorable, treatment options include:

1. Removal of the implants followed by bone grafting, placement of new implants in a more ideal position.

2. Surgical cover screws are placed in the implants, thus “sleeping” the implants followed by fabrication of a conventional prosthesis.

Nonideal Implant Positioning

Etiology

Usually, the greatest available bone height in an edentulous mandible is located in the anterior region between the mental foraminae. This location most likely exhibits optimal density of bone for implant support and ease of implant placement. The implant overdenture treatment options presented are designed for anterior implant placement between the mental foramina because the prostheses movement will be more limited and available bone volume and density is more favorable than posterior implants.

Nonideal implant positioning leads to many complications, which include hard and soft tissue complications, prosthesis dissatisfaction or fracture, and questionable long-term implant health.

Prevention

The available bone in the anterior mandible (between the mental foramen) is divided into five equal columns of bone serving as potential implant sites, labeled A, B, C, D, and E, starting from the patient's right side (Fig. 15.20).[48] The mean interforaminal distance has been shown to be approximately 53 mm.[49] Five implants of 4 to 5 mm diameter can usually be placed with general placement guidelines of 3 mm between implants and 2 to 3 mm from the mental foramen.

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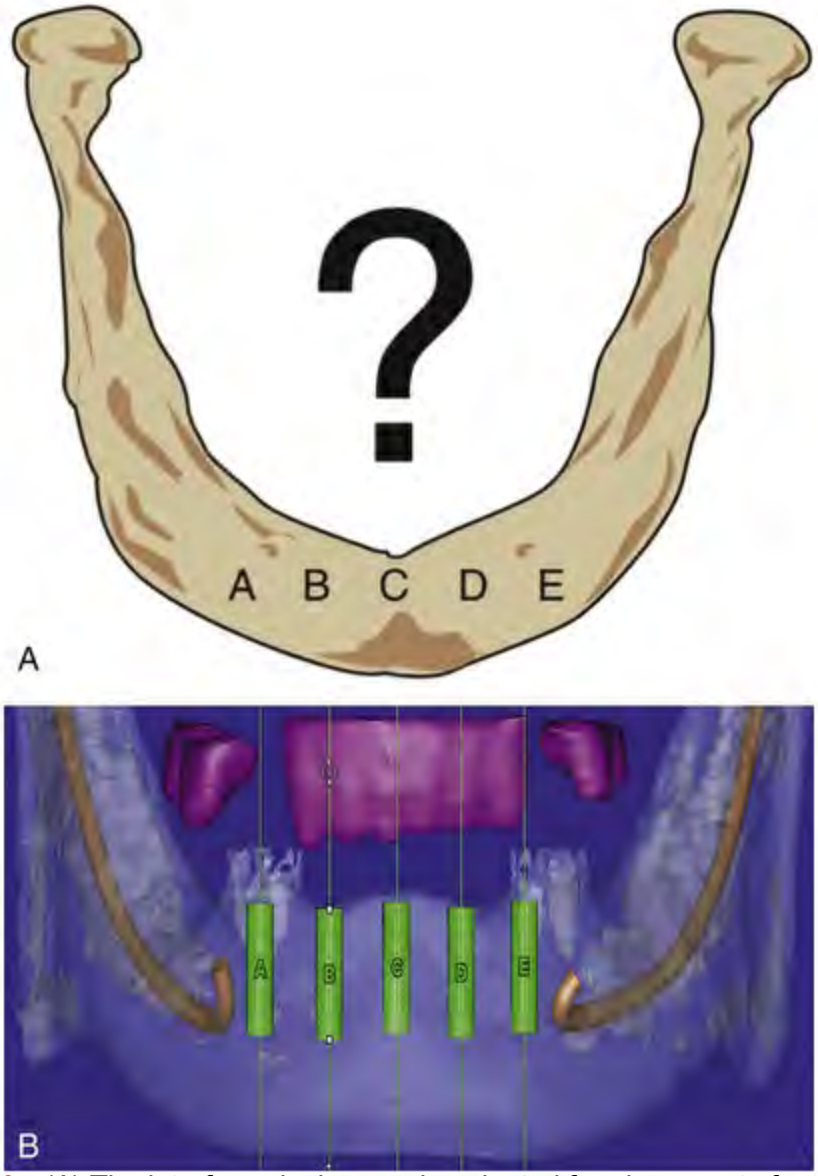

FIG 15.20 (A) The interforaminal space is selected for placement of mandibular implants for overdentures. (B) Five implants sites are easily selected labeled *A*, *B*, *C*, *D*, *E* starting from the right side.

When placing implants, regardless of the treatment option being executed, all five implant sites should be ideally located at the time of treatment planning and surgery. There are three reasons for this treatment approach:

1. The patient always has the option to obtain additional implants and prosthesis support and stability in the future if all five sites were not initially used for implant support. For example, a patient may receive adequate retention, stability, and support for an IOD with four implants. However, if the patient desires a fixed prosthesis in the future, the four implants most likely will be inadequate for the new prosthetic requirements. If the clinician does not plan an additional implant site during the initial surgery, but

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instead placed the four implants an equal distance apart, the additional interimplant space may not be available without removing one of the preexisting implants.

2. A patient may desire a completely implant-supported restoration (e.g., RP-4 implant supported overdenture or FP-3—fixed prosthesis), but for financial reasons may not able to enter into the treatment at that time. Three implants in the A, C, and E positions and an IOD may be provided first. This is the initial or first phase of the treatment, which has many advantages over a conventional complete denture. Two more implants may be added in the B and D locations at a later date, and a completely implant-supported overdenture or fixed restoration may then be fabricated (Fig. 15.21).

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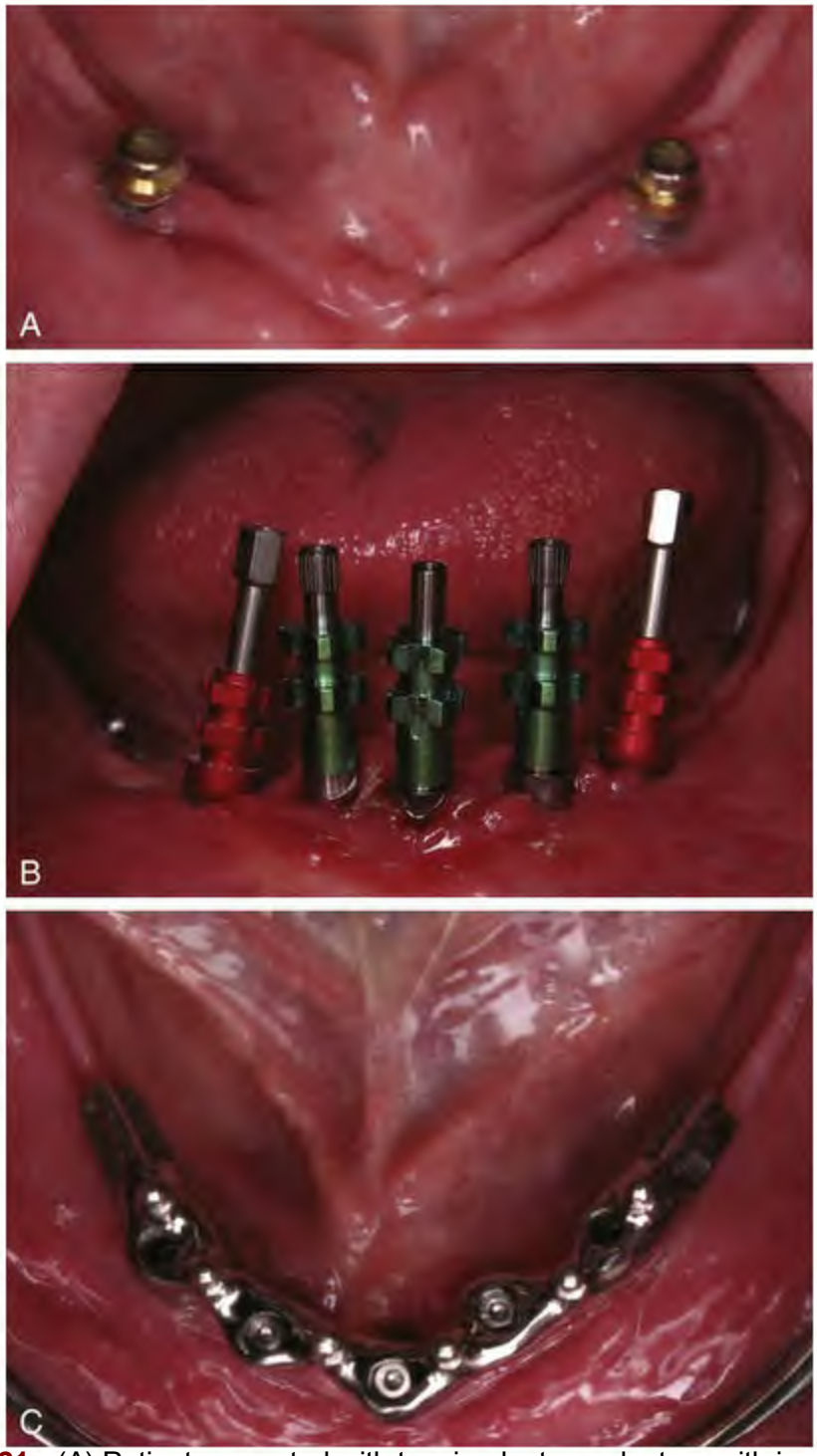

FIG 15.21 (A) Patient presented with two-implant overdenture with inadequate retention. (B) Three additional implants placed in the B, C, D positions. (C) Final RP-4 prosthesis.

3. If an implant complication occurs, the preselected option sites permit repeatable corrective procedures. For example, if implants were placed in the A, B, D, and E positions and an implant fails to achieve rigid fixation, the failed implant may be removed and an additional implant placed in the C

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position at the same time. This saves an additional surgery and eliminates the time required for bone grafting and healing before another implant could be reinserted.

Not Understanding Mandibular Overdenture Treatment Plans

The five treatment options proposed for mandibular implant–supported overdentures provide an organized approach to solving a patient's complaints that takes into consideration various anatomic limitations. The treatment options initially proposed are designed for completely edentulous patients with division A or B anterior bone who desire an overdenture. These options are modified when the CHS is excessive (as when the anterior bone is division C–h) and eliminated for division D. The implants are placed between the foramens in the A through E positions (Fig. 15.22).

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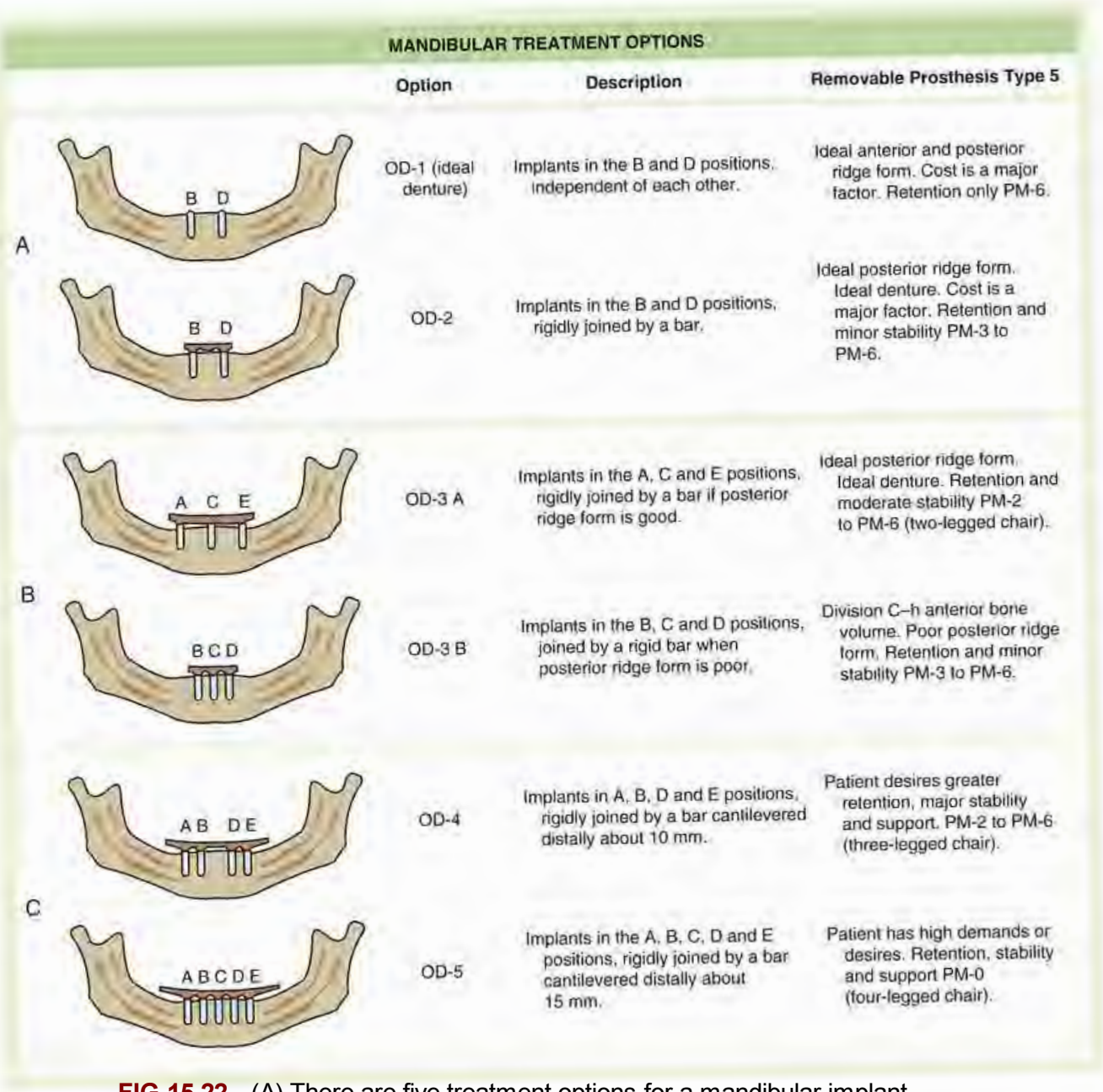

FIG 15.22 (A) There are five treatment options for a mandibular implant overdenture. Two implants in the B, D position may be independent (OD-1) or splinted together (OD-2). (B) Three implants may be used, splinted together with a bar (OD-3). (C) Four implants with a cantilevered bar (OD-4) or five implants and a cantilevered bar (OD-5) may have a RP-5 or RP-4 restoration. *C–h,* division C minus height bone class; *OD,* overdenture option; *PM,* prosthesis movement class. (From Misch CE: *Misch Implant Institute manual,* Dearborn, MI, 1984, Misch Implant Institute.)

Overdenture Option 1 (OD-1)

The overdenture option 1 (OD-1) must be a RP-5 (soft tissue supported with secondary implant support), which means it must be able to rotate and load the posterior soft tissue regions of the mandible. The stability and support of

the prosthesis are gained primarily from the anatomy of the mandible and prosthesis design, which is similar to a complete denture.

Advantages.

The primary advantage with treatment option OD-1 is reduced cost to the patient. The two implants are usually the fewest implant number, and no connecting bar reduces the prosthetic appointments and the laboratory costs.

Indications.

The first treatment option for mandibular overdentures (OD-1) is indicated primarily when cost is the most significant patient factor. However, it is important to note the patient's desires should also be minimal (i.e., patient must understand the limitations of the treatment plan), and the bone volume in both the anterior and posterior regions should be abundant (division A or B). The posterior ridge form should be an inverted U shape, with high parallel walls for good to excellent anatomic conditions for conventional denture support and stability. The problem associated with the existing denture should relate primarily to the amount of retention, not stability or support. In addition, the opposing arch should ideally be completely edentulous and restored with a traditional complete denture (Box 15.5).

Box 15.5

Patient Selection Criteria: OD-1

- Opposing a maxillary full denture
- Anatomic conditions are good to excellent (division A or B anterior and posterior bone)
- Posterior ridge form is an inverted U shape
- Patient's needs and desires are minimal, primarily related to lack of prosthesis retention
- Edentulous ridge not square with a tapered dentate arch form
- Cost is the primary factor

- Additional implants will be inserted within 3 years

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Anatomic Position.

Usually, two implants are placed in the B and D positions. The implants remain independent of each other and are not connected with a superstructure. The overdenture attachment primarily improves retention and gives little additional support or stability to the prosthesis. The stability of the restoration is slightly improved in the anterior section by the implants, and the posterior inverted U shape regions from the ridge form are required to improve this factor (Fig. 15.23).

FIG 15.23 Overdenture option 1 consists of two independent implants. These are best inserted in the B and D positions to limit the forward rocking of the restoration during function. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In the past, most two-implant overdentures positioned the implants immediately anterior to the mental foramen in the A and E positions. Positioning of the implants in the B and D position is a much better prosthetic option in OD-1 than positioning in the A and E regions. Independent implants in the A and E positions are usually implant locations in the first premolar region, which is more posterior to the anterior fulcrum line of the anterior teeth and allows a greater amplitude of rocking of the restoration. When using B and D implants (with positions similar to the natural canines), the anterior movement of the prosthesis is reduced (Fig.

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15.24).

FIG 15.24 Care should be exercised to not prevent rotational movement of an RP5 prosthesis. In this example, two implants in the B and D position are accurately placed, however because the attachments are in different planes, the prosthesis becomes a fixed prosthesis.

Support.

The support of the OD-1 restoration is provided primarily from the buccal shelf in the posterior and the ridge in the anterior, similar to a traditional denture. The IOD must be RP-5 with preferably a PM-3 or more, which allows for rotation and loading of the posterior soft tissue regions of the mandible (Fig. 15.25).

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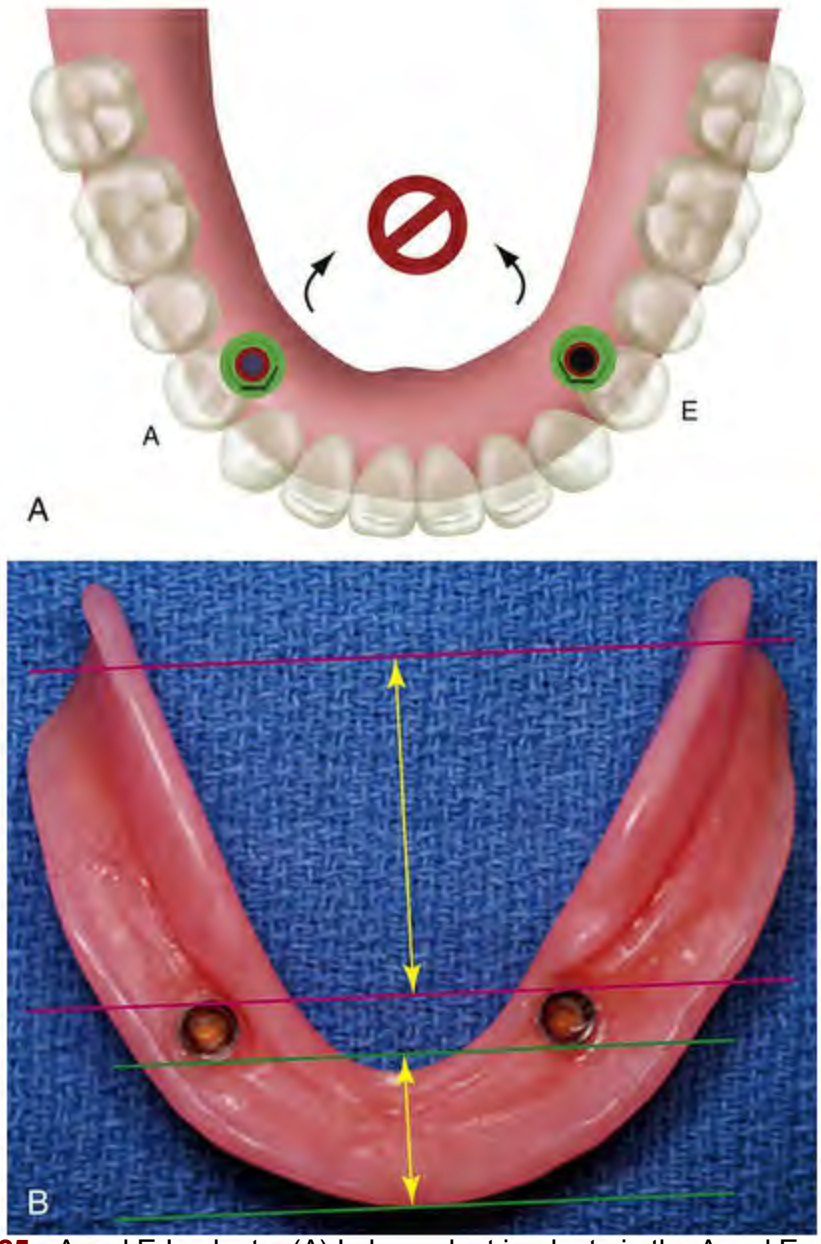

FIG 15.25 A and E Implants. (A) Independent implants in the A and E positions allow a greater anterior rocking of the restoration and place greater leverage forces against the implants *(arrows)*. (B) Resultant prosthesis will have an associated anterior and posterior cantilever *(arrows)*.

Attachment.

The most common type of attachment used in OD-1 is an O-ring or Locator design. The implant support mechanism is poor because stress relief of the attachment is permitted in any plane. In other words, the stability and support of the prosthesis are gained primarily from the anatomy of the mandible and prosthesis design, which is similar to a complete denture.

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Complications of OD-1

Lack of posterior support.

If the posterior area is not supported (buccal shelf) adequately, the prosthesis will be loaded mainly from the implants. This will lead to excessive forces being applied to the implants, which may result in bone loss. As the posterior ridge resorbs, the patient will gradually lose posterior occlusion, leading to a posterior open bite.

Positioning.

The two independent implant retention systems often have more prosthetic-related complications in comparison to other treatment plans. There are several reasons the complication risk is increased (Fig. 15.26A).

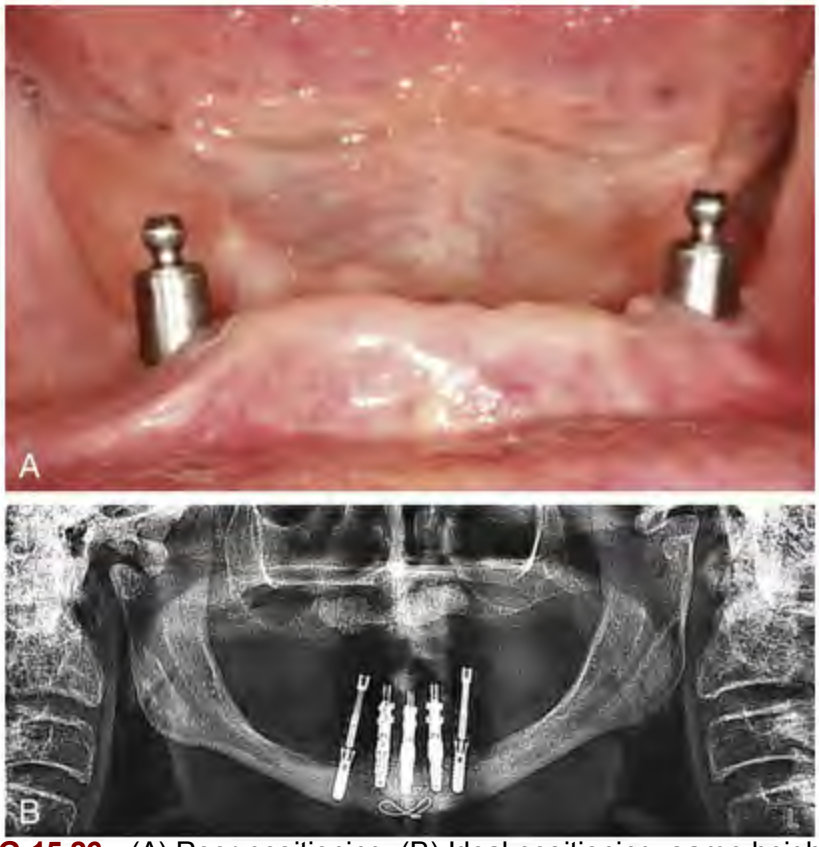

FIG 15.26 (A) Poor positioning. (B) Ideal positioning, same height.

Perpendicular to occlusal plane.

The two implants should be perpendicular to the occlusal plane to allow the

posterior regions of the overdenture to move downward and load the soft tissue over the mandibular buccal shelves for support. The hinge rotation should be at 90 degrees to the rotation path; otherwise, one side is loaded in a different manner than the other. In addition, because only two implants sustain the occlusal load during function or parafunction, minimization of the forces to the implant components and crestal bone is achieved by placing the implants in the long axis of the implant body and perpendicular to the occlusal plane (Fig. 15.26B).

Height parallel to occlusal plane.

The two independent implants should be positioned at the same occlusal height parallel to the occlusal plane. If one implant is higher than the other, the prosthesis will disengage from the lower implant during function and rotate primarily on the higher implant. This situation will accelerate the wear of the O-rings or Locator attachments. In addition, because the higher-positioned implant receives the majority of the occlusal load, an increased risk of complications may occur, including abutment screw loosening, marginal bone loss around the implant, and implant failure (Fig. 15.27). If the implant bodies are positioned at different heights, the use of different size abutments should be used to make them as level as possible.

FIG 15.27 Implants placed in ideal position with abutments at the same height.

Distance from midline.

The implants should be equal distance off the midline. If one implant is

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more distal (farther from the midline), it will serve as the primary rotation point or fulcrum when the patient occludes in the posterior segments. In such a case, the more medial implant attachment will wear faster, and the more distal implant will receive a greater occlusal load when the patient occludes in the anterior region (Fig. 15.27).

Implant parallelism.

The two implants in this treatment option should be parallel to each other. The path of insertion of the prosthesis should also be similar to the path of insertion of the attachments. When the implants are not parallel, the first attachment to engage wears less, and the second attachment rubs along the side of the male and increases the wear rate. When the path of insertion of the restoration is different than the attachments (as when a facial undercut below the crest exists), the attachments will wear prematurely (Fig. 15.27).

Angulation.

If a facial undercut exists, the path of insertion of the restoration may not coincide because of the implant position. This may lead to chronic sore spots and the need for multiple adjustments. This most often occurs when there has been extensive atrophy (buccal resorption) from a division A to a division B or C (Fig. 15.28).

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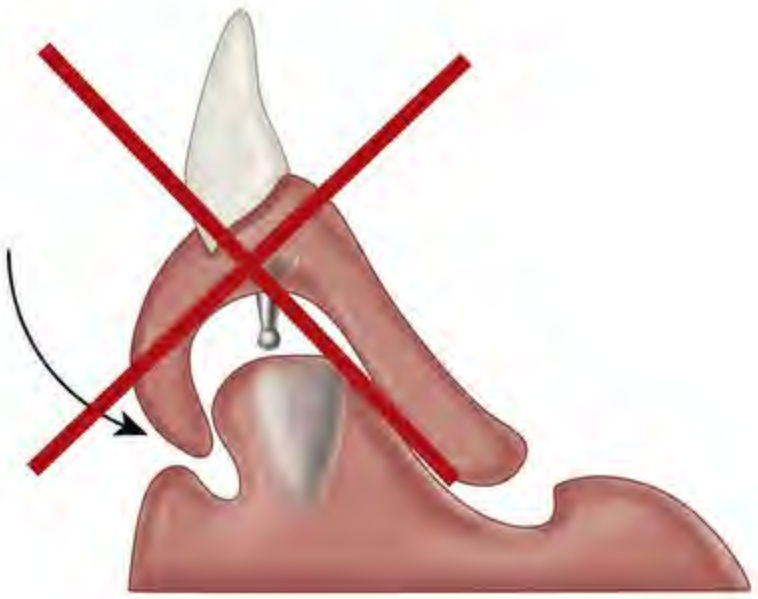

FIG 15.28 When an anterior undercut is present it determines the pathway of insertion of the restoration and should be similar to the pathway of the insertion into the attachment. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Arch form.

There are two types of arch forms: the tooth position arch form and the edentulous ridge arch form. It should be noted that the edentulous residual ridge may be square, ovoid, or tapering. The dentate arch form is also divided into square, ovoid, and tapering categories and may be different than the ridge form. When a tapered tooth position arch form is supported by two independent implants in a square residual ridge form, the anterior teeth are cantilevered anteriorly from the implant retentive system. More implants are required in this type of tooth-supported ridge form combination to help stabilize the prosthesis, and the OD-1 option will have a considerable disadvantage.

Decreased support.

Individual implants have more prosthetic complications than when the implants are joined by a bar. When implants are supported by a bar, the individual implants have less force and stress applied to the system. Attachments are easily made parallel with a bar-fabricated prosthesis by the laboratory in similar horizontal, vertical, and axial planes. This is much easier and more predictable than relying on the surgical placement making the implants completely parallel in all planes.

The opposing arch for an OD-1 mandibular treatment option should be a

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traditional complete denture. The bite forces are reduced when the patient is completely edentulous. The maxillary denture has some movement during function and acts as a stress reliever. The instability of the maxillary denture and mandibular OD-1 overdenture is shared. The support requirements of the posterior regions of the mandible are reduced when opposing a complete denture. Ideally, the opposing arch should be a complete denture when OD-1 is the treatment option.

Patient misconceptions.

The OD-1 is used as a treatment option when patients understand that a connecting bar or additional implants are beneficial but financial constraints require a transition period. However, many patients do not realize the lack of support that is associated with two implants. The ultimate long-range goal in the treatment plan is to convert OD-1 patients to a RP-4 or FP with more implant support and stability before the loss of the posterior bone in the mandible occurs posterior to the foramina. Future modification of the treatment plan results in implant placement in the A and E positions. This will allow the four implants (A, B, D, E positions) to be connected with a bar that may be cantilevered to the posterior. Additionally, an increased surface area for support helps reduce the posterior bone loss.

Abutment height.

The two independent implants most often use a Locator system or O-ring attachment. After healing, the permucosal extensions and premanufactured titanium alloy Locator or O-ring abutments are inserted into the implant bodies. The abutment for attachment replaces the permucosal extension. The attachments should be parallel to each other and at the same occlusal height. The higher the abutment, the more the lateral stability of the prosthesis. However, at least 2 mm of acrylic should be present between the teeth and borders of the denture around the encapsulator of the attachment (Fig. 15.29).

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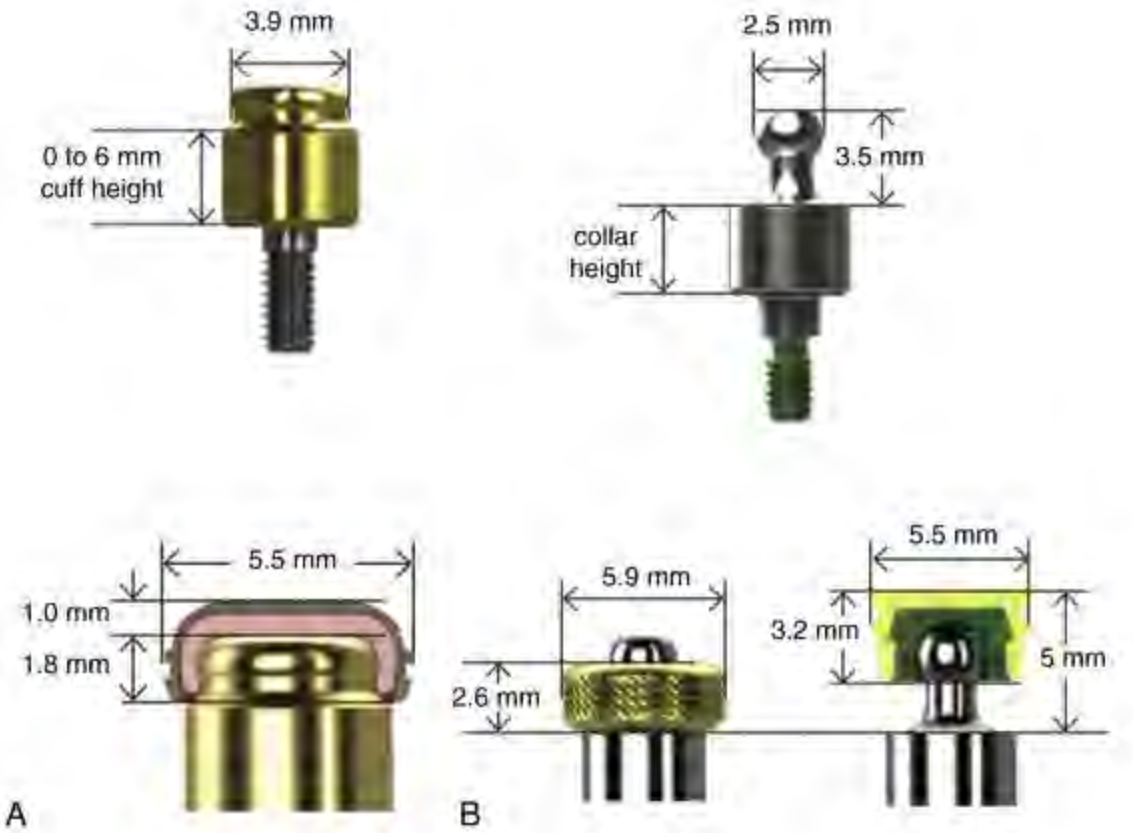

FIG 15.29 Attachment heights. (A) Locator attachment. (B) O-ring attachment.

The abutments for attachments are provided in different heights. The abutment should be ideally 2 mm above the tissue and 2 mm below the denture teeth so adequate thickness of acrylic is present. The attachment and encapsulator are placed into the implants. The abutments are then tightened with a torque wrench at 20 to 35 N/cm (depending on the manufacturer). Too high of an abutment placement will lead to increased torqueing forces and instability.

Overdenture Option 2 (OD-2)

Indications.

The second treatment option for a mandibular overdenture (OD-2) is selected when more support is indicated in comparison to OD-1 (Box 15.6). The anatomic needs and patient desires are similar to the first option, OD-1. A bar is designed to position the attachments for added retention at an equal distance off the midline parallel to each other at the same occlusal height and in a similar angulation. The ideal distance between the implants is in the 14- to 16-mm range or B and D positions.

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Box 15.6

Patient Selection Criteria: OD-2

- Opposing arch is a maxillary denture
- Anatomic conditions are good to excellent (division A or B bone in anterior and posterior regions)
- Posterior ridge forms an inverted U shape
- Patient's needs and desires are minimal, primarily related to lack of retention
- Patient can afford a new prosthesis and connecting bar
- Additional implants will not be inserted for more than 3 years
- Low patient force factors (e.g., parafunction)
- The mandibular residual ridge form is square to ovoid, and the dentate arch form is square to ovoid

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Anatomic Position.

The implants in OD-2 are also positioned in locations B and D, but with this option, they are splinted together with a superstructure bar without any distal cantilever. Reduced loading forces are exerted on two anterior implants when splinted with a bar compared with individual implants.[50,51] The implants should not be positioned in the A, E position even when connected with a bar. The A, E position is most often the first premolar and may even be in the second premolar position (depending on sex and race). When the implants are joined with a straight bar, the connecting bar is lingual to the anterior ridge. The overdenture flange is often too bulky and may impinge on the sublingual area and affect speech. The denture teeth are anterior to the residual ridge and act as a lever on the bar, and the prosthesis is not stable (i.e., anterior cantilever). The connecting bar between A and E implants flexes five times more than when the bar connects B and D implants; therefore

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screw loosening is more of a risk. When a curved bar is used to position it more anterior, the prosthesis often rides along the sides of the bar and limits PM. If the prosthesis rests against the sides of the curved bar, the PM may even be reduced to PM-0. This places a much greater vertical and lateral load on the implant system. There are greater lateral forces on the A, E implant position, which may increase screw loosening. If the patient has implants already inserted into the A and E positions, the best treatment option is to insert another implant in the C position and connect the three implants with a bar (Figs. 15.30 and 15.31).

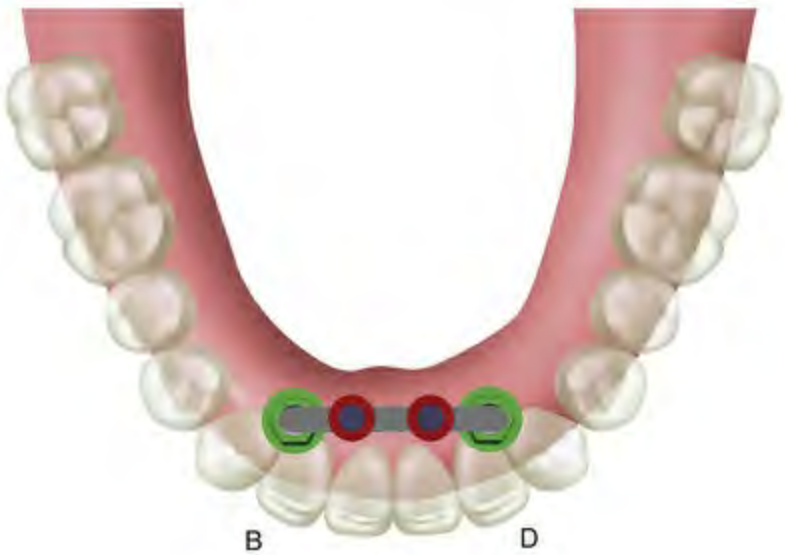

FIG 15.30 Treatment option 2 has implants in the B and D positions, and a bar joins the implants. Attachments such as an O-ring or a Hader clip, which allow movement of the prosthesis, can be added to the bar. The attachments are placed at the same height at equal distances off the midline and parallel to each other. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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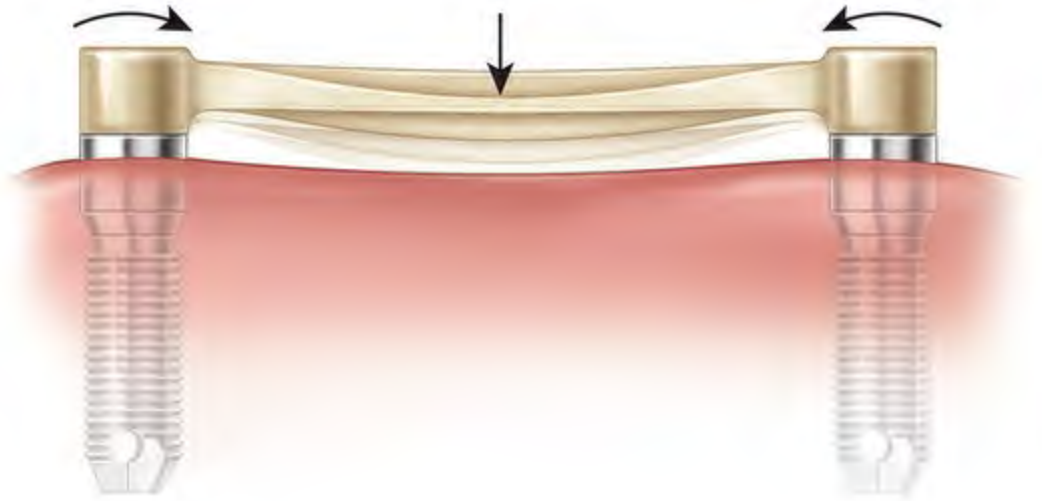

FIG 15.31 A bar splinting the A and E positions will flex five times more than a bar connecting implants in the B and D positions. As a consequence, screw loosening risk is increased. Implants in positions A and E should not be splinted together. Instead, an implant in the C position should first be inserted. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

Bar/Attachment.

When attaching two implants together, reduced loading forces are exerted on the two anterior implants when splinted together with a bar. This may result in less screw loosening and crestal bone loss than OD-1. Secondly, the laboratory may position the attachments parallel to each other at the same height and equal distance from the midline regardless of the corresponding implant positions, thus reducing prosthetic complications. The retentive element on the splinted bar may be an O-ring or clip design depending on the crown height distance available. The bar can be similar to those designed by Dolder or Hader. The bar cross section is ideally ovoid (Dolder) or round with an apron so as to increase the strength of the bar and reduce its flexibility. Ideally, the bar should be a minimum of 1 mm away from the soft tissue to provide easy access for hygiene aids.

Complications of OD-2

Compromised bone.

Two implants often work well in cases when there is abundant bone. However, two implants are not indicated in division C–h bone, division D bone, or when there is parafunction and opposing anterior or posterior natural teeth. The resulting increase in crown height, poor posterior ridge

form, and masticatory forces, as well as the natural opposing arch, place additional stresses on the implant system and will most likely increase complications. When these situations are present, additional implants should be used to decrease the possible prosthetic risks.

Connecting bar complications.

One of the most common complications with an implant connecting bar is insufficient space between the bar and the soft tissue. This will most likely impair oral hygiene procedures and may also be the cause of food debris impaction and soft tissue inflammation. The success of the bar may be achieved more easily by the selection of the proper height implant abutments and an accurate master cast. The abutment height should be a minimum of 1 mm above the tissue and no greater than 2 mm. Too high of an abutment will increase force and stress on the prosthesis components. The prosthesis attachment system to the superstructure bar is closely scrutinized when Hader and Dolder clips are used for retention. The connecting bar and clips should be perpendicular to the path of rotation and parallel to the occlusal plane. This usually requires a straight bar perpendicular to the midline. A curved bar often places the clips closer to the implants and prevents rotation of the prosthesis, therefore becoming more of a fixed prosthesis (Fig. 15.32).

FIG 15.32 Two-implant bar with implants too close together.

The connecting bar of the restoration should always be fabricated after the final contours and teeth position are ascertained for the overdenture. Otherwise, compromises of inadequate room for denture teeth or overcontoured restorations (most often on the lingual surface) result. The bar may be connected on the facial aspect of each implant coping. In this way the

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lingual flange of the prosthesis remains within the contour of a traditional denture.

Positioning.

It should be noted implants placed closer than the B, D position will result in reduced prosthesis stability during function, whether they are connected or independent units. When a bar is going to be fabricated, implants positioned too close together will impede the use of an attachment. Additionally, the nonideal positioning may lead to future issues if additional implants are treatment planned. By placing implants in a differing position than B and D will result in future inability to place implants in the A, B, or C position.

Lever arm.

The higher the attachment position, the more stable the overdenture will be. However, CHS above the attachment will act as a lever arm. The greater the occlusal height, the greater the force and the less stable the overdenture to any lateral force. However, the height of the attachments on the connecting bar should allow a minimum of 2 mm of acrylic space between the denture teeth and attachment to permit adequate dimension for strength. The internal aspect of a bar-retained overdenture should not be processed against the sides of the abutment or bar because this will limit rotation and increase the possibility of fractures (Fig. 15.33).

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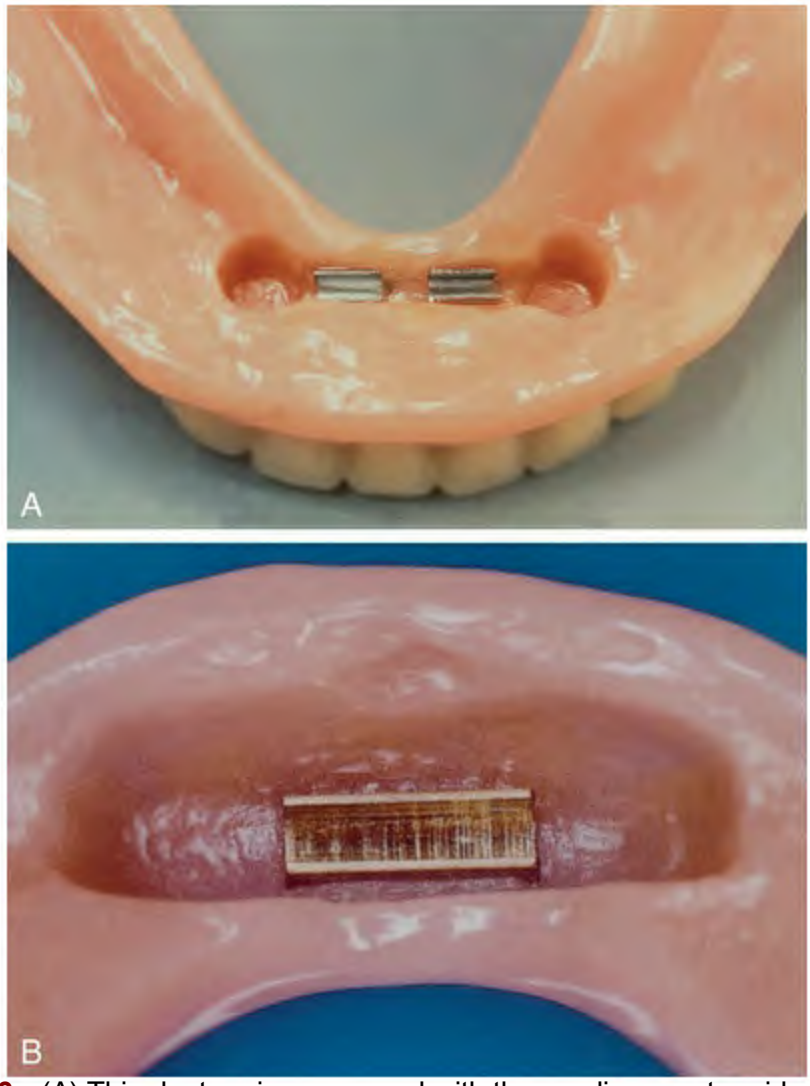

FIG 15.33 (A) This denture is processed with the acrylic receptor sides over the copings and bar too close and will limit (or prevent) rotation of the implant overdenture during function. (B) The clip should engage the bar, and the denture should not rest on the sides of the implant abutments or bar. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Cantilever.

The connecting bar should not be cantilevered to the distal when only two implants are placed. When a bar is cantilevered from anterior implants, there is insufficient anteroposterior (A-P) distance between the two implants to counter the effect of the cantilever. An increased risk of prosthetic and abutment screw loosening exists with the cantilever (Fig. 15.34).

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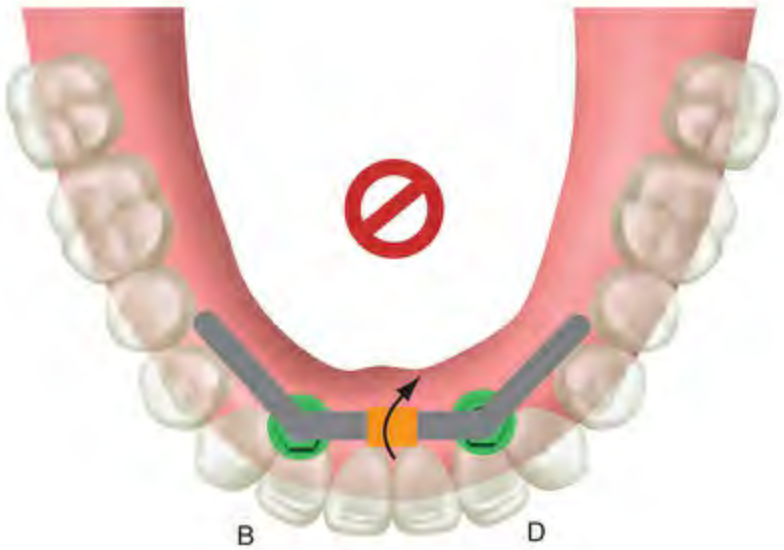

FIG 15.34 The connecting bar between implants B and D should not be cantilevered to the distal *(arrow)*. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Increased fee.

Because a bar is indicated in OD-2, the clinician must take into consideration the increased associated expense. A laboratory fabricated bar/attachment can be costly. The patient should be well aware of this prior to the initiation of treatment.

Overdenture Option 3 (OD-3)

Indications.

The third treatment option may be used when the opposing arch is a denture and the patient has moderate to low retention, support, and stability needs. With an opposing complete denture, the amount of force on the prosthesis is minimized. When the posterior ridge form is poor (division C–h or D bone), the OD-3 is the lowest treatment option suggested.

The OD-3 treatment option is usually the first option presented to a patient with minimal complaints and is concerned primarily with retention and anterior stability of the IOD when cost is a moderate factor. The posterior ridge form should be evaluated because it determines the posterior lingual flange extension of the denture (buccal shelf), which limits lateral movement of the restoration in this treatment option (Box 15.7).

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Box 15.7

Patient Selection Criteria: OD-3

- Opposing arch is a maxillary denture
- Anatomic conditions are moderate to excellent
- Posterior ridge forms an inverted U shape
- The patient's needs and desires require improved retention, support, and stability
- Cost a moderate factor
- The patient may have moderate force factors (e.g., parafunction)

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Position.

Three root form implants are placed in the A, C, and E positions for OD-3. A superstructure bar connects the implants but with no distal cantilever. A PM-2 or greater can be designed with three A, C, and E anterior implants. In the future, when more retention, support, and stability is warranted, additional implants may be placed in the B and D positions. If the posterior ridge form is poor (division C–h), the lack of lateral stability places additional forces on the anterior implants. Implants then are best placed in the B-C-D position to allow greater freedom of movement of the prosthesis. The greater the stress to the system, the greater prosthesis movement/stress relief indicated. This increases the posterior movement of the restoration, but decreases the amount of stress placed on the implants and screw-retained bar (Fig. 15.35).

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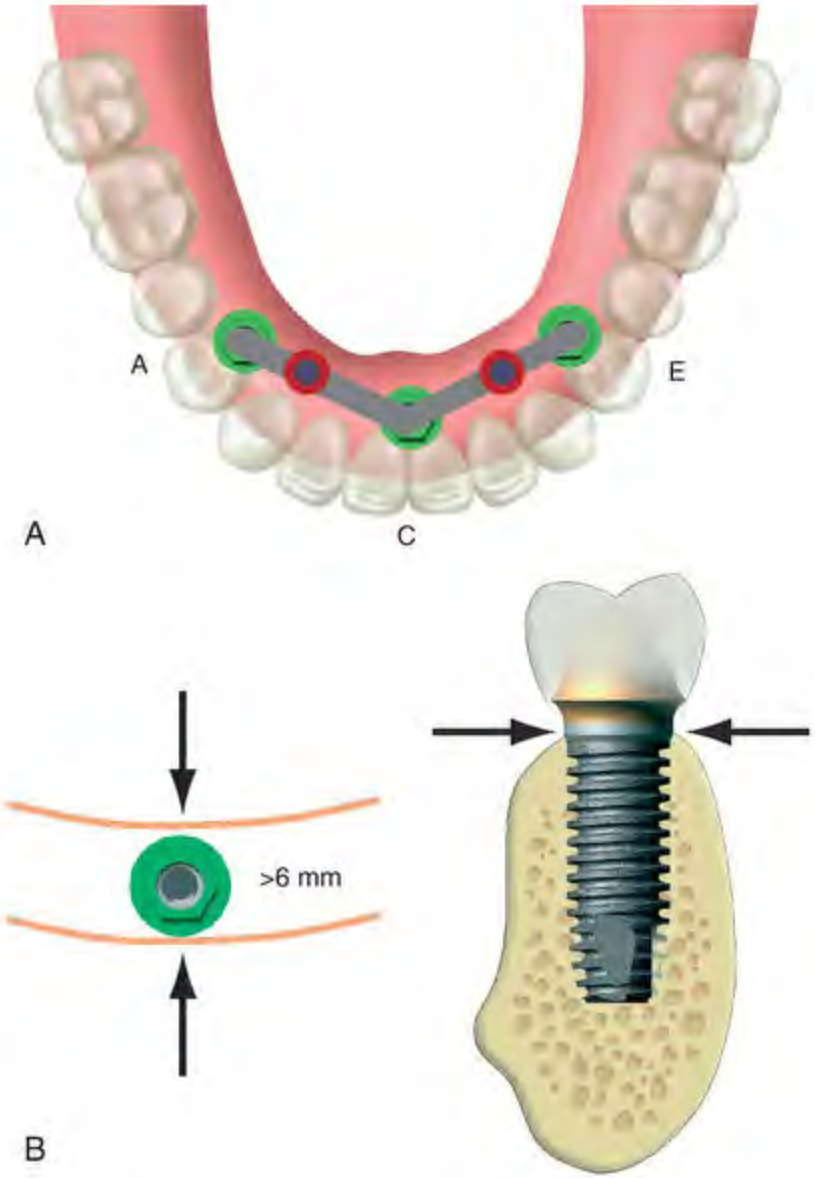

FIG 15.35 (A) Overdenture option 3 corresponds to implants in the A, C, and E positions connected with a bar. The attachments should be positioned to allow movement of the distal section of the prosthesis. (B) Minimum bone width for a 4-mm-diameter root form is 6 mm in the midfacial and lingual regions because the round implant design results in more bone in all other dimensions (width and height). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Advantages.

There are many advantages of splinting A, C, and E implants compared with implants in the B and D positions. The implants splinted in the A, C, and E positions usually do not form a straight line. The C implant is most often anterior to the more distal A and E implants (in the premolar regions) and ideally directly under the cingulum position of the anterior incisor denture teeth (increased A-P spread). The restoration benefits from direct occlusal

load to the implant support in the anterior arch, which reduces tipping and improves stability. As a consequence, when more than two implants are placed in the anterior mandible, a tripod support system may be established. To determine the amount of benefit of an A-P distance, the distal of the most posterior implants on each side are connected with a straight line. The distance from this line to the perpendicular position of the center implant is termed the *A-P spread*. The greater the A-P spread of the A, C, and E implants, the greater the biomechanical advantage of the bar to reduce stress on the implants because they are splinted together. The splinted A-C-E implant and bar position is more stable than the B-D position for the prosthesis. The lateral stability of the overdenture system is improved because the implants are in the A and E positions and the attachments are in the B and D positions and more distal than OD-2. In addition, the connecting bar can be higher off the tissue when the interocclusal space permits, and the attachment-to–bone height dimension can be greater. As a result, rotation of the prosthesis is more limited compared with OD-1 and OD-2. Therefore, the third implant for OD-3 for a division C–h mandibular edentulous patient is a considerable advantage because of the compromised height.

Bar/Attachment System.

O-rings/Locators attached to the connecting superstructure offer greater leeway in bar design and position. An O-ring is often used when CHS permits to increase the crown height attachment–to-bone dimension and decrease the occlusal plane–to-attachment dimension. The smaller the occlusal plane–to-attachment distance, the more stable the overdenture is to lateral forces. The intaglio surface of the prosthesis should not contact the sides of the connecting bar because this would result in too rigid a system, placing too much force on the bar system.

The connecting bar should be parallel to the plane of occlusion, and the attachments should be placed at the same height along the bar. Such placement is needed for the prosthesis to rotate effectively during function. No cantilever of the bar should be designed within this three-implant system. However, the attachments may be placed on the distal of the A and E abutments, similar to a Kennedy class 1 partial denture design (if positive force factors).

Complications of OD-3

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Improper attachment design.

The IOD option 3 usually does not use two Hader clips for the attachment. Because the two clips do not rotate in the same plane, the prosthesis is usually too rigid, and the clips do not rotate unless they expand, making wearing of the clip and bar a common complication. If a clip attachment is designed for the prosthesis, the bar may connect the facial of the A and E implant copings and the lingual of the C coping. As a result, a straight bar may be fabricated perpendicular to the path of rotation (Fig. 15.36).

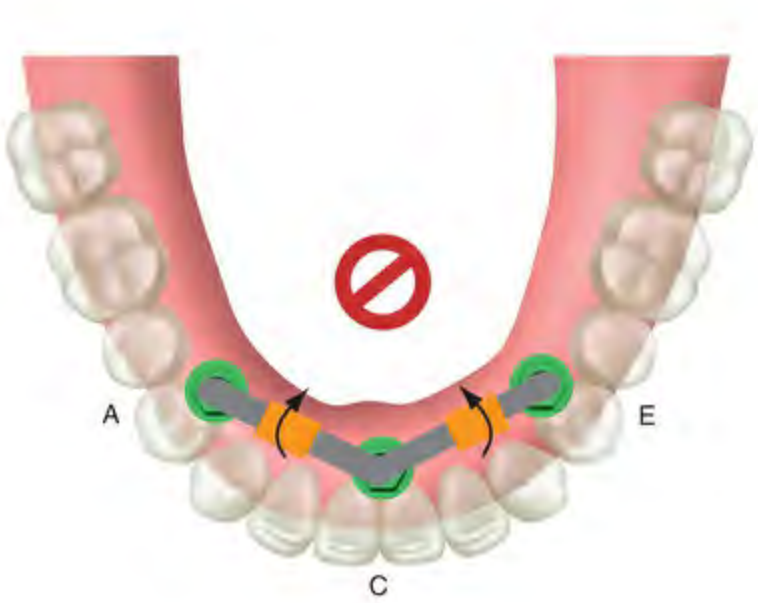

FIG 15.36 An implant overdenture option 3 should rarely use a Hader clip for the attachment system. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Fabricating a RP-4 prosthesis.

With a three-implant overdenture, an RP-5 prosthesis should always be fabricated because of the need for soft tissue support. Often an RP-4 prosthesis is fabricated with a three-implant treatment plan, leading to overloading the implants. This may result in excessive attachment wear or an accelerating wear of attachments.

Overdenture Option 4 (OD-4)

Indications.

The patient's indications for the OD-4 treatment option as a minimum requirement include moderate to poor posterior anatomy that causes a lack

of retention and stability of the IOD, history of recurrent soft tissue soreness, or difficulty with speech. The clinician must understand the edentulous posterior mandible resorbs four times faster than the anterior mandible. In the C–h posterior mandibles, the external oblique and mylohyoid ridges are high (in relation to the residual ridge) and often correspond to the crest of the residual ridge. The muscle attachments are at or near the crest of the posterior ridge. Another condition that indicates an OD-4 as a minimum treatment option is when the patient's complaints and desires are more demanding than for the previous treatment options (Box 15.8).

Box 15.8

Patient Selection Criteria: OD-4

- Moderate to severe problems with traditional dentures
- Needs or desires are demanding
- Need to decrease bulk of prosthesis
- Inability to wear traditional prostheses
- Desire to abate posterior bone loss
- Unfavorable anatomy for complete dentures
- Problems with function and stability
- Posterior sore spots
- Opposing natural teeth
- C–h bone volume
- Unfavorable force factors (parafunction, age, size six, crown height space >15 mm)

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Positions.

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With the fourth mandibular overdenture option (OD-4), four implants are placed in the A, B, D, and E positions. This is often the minimum number of implants when the patient has opposing maxillary natural teeth, or C–h anterior bone volume with CHS greater than 15 mm. The implants usually will provide sufficient support to include a distal cantilever up to 10 mm on each side if the stress factors are intermediate to low (i.e., parafunction, CHS, masticatory dynamics, and opposing dentition) (Fig. 15.37).

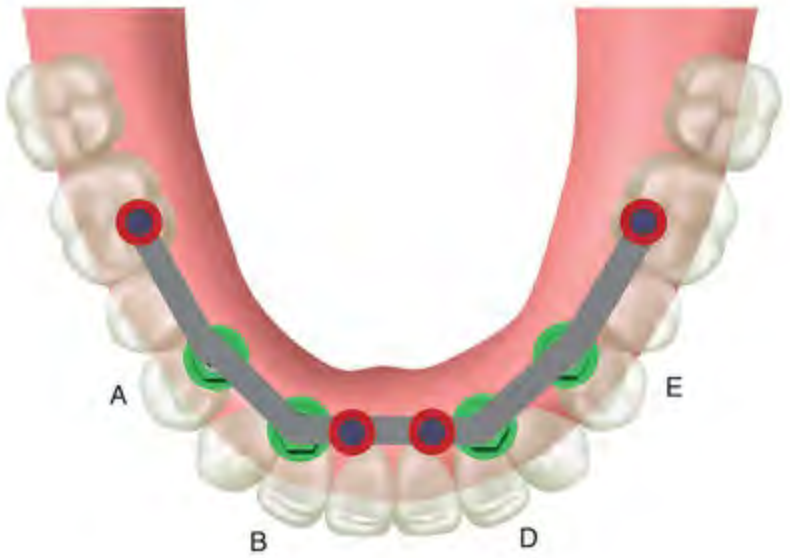

FIG 15.37 In overdenture option 4, four implants are placed in the A, B, D, and E positions. The implants usually provide sufficient support for a distal cantilever up to 10 mm. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Cantilever.

The cantilevered superstructure (bar) is a feature of the four or more implant treatment options in a completely edentulous arch for three reasons:

1. Increase in implant support compared with OD-1 to OD-3.

2. Biomechanical position of the splinted implants is improved in an ovoid or tapering arch form compared with OD-1 or OD-2.

3. Additional retention is provided by the fourth implant for the superstructure bar, which limits the risk of prosthetic screw loosening and other related complications of cantilevered restorations.

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In considering a distal cantilever for a mandibular overdenture bar, the implant position is the primary local determinant. Cantilevers may be compared to a class 1 lever in mechanics. The distalmost implant on each side acts as a fulcrum when occlusal forces are applied to the distal cantilever. The amount of the occlusal force is magnified by the length of the cantilever, which acts as a lever. For example, a 25-lb load to a 10-mm cantilever results in a 250-lb mm force.

This moment force is resisted by the length of the bar anterior to the fulcrum. If the two anterior implants (B and D) are 5 mm from the fulcrum (distal implants A and E), the effect of the posterior cantilever is reduced. If the implants are 5 mm apart, the mechanical advantage of the lever is the 10-mm cantilever divided by the 5-mm A-P spread, which equals 2. Because the implants are splinted, a 25-lb distal force is magnified to 50 lb to the anterior implant and 75 lb (50 + 25 = 75) to the distal (fulcrum) implant.

Arch form.

As a general rule the posterior cantilever from anterior implants may be equal to the A-P distance when other stress factors are low to moderate. The mandibular residual ridge arch form may be square, tapering, or ovoid. The arch form relates to the A-P distance of A-E and B-D implants. Square arch forms limit the A-P spread between implants and may not be able to counteract the effect of a distal cantilever.

A square arch form often results in an A-P distance of 4 mm or less. Under these conditions a minimum cantilever should be designed, and a PM-3 to PM-6 restoration is indicated. The distal cantilevers are significantly reduced for square arch forms. In a mandibular ovoid to tapering arch form, the A-P spread between implants in the A, E and D, B positions is greater and permits a longer distal cantilever. This A-P spread is usually 8 to 10 mm in these arch forms and often permits a cantilever up to 10 mm from the A and E positions.

It should be emphasized that the A-P spread is only one factor to determine the length of the cantilever. When stress factors such as occluding forces are greater, the cantilever is decreased. Parafunction, opposing arch, masticatory dynamics, and CHS affect the amount of force on the cantilever. For example, when the crown height is doubled, the moment forces are doubled. Under ideal, low-force conditions (crown height less than 15 mm, no parafunction, older female patient, opposing a maxillary denture), the cantilever may be up to 1.5 times the A-P spread for OD-4 overdentures.

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When the force factors are moderate, the cantilever should be reduced to 1 times the A-P spread. The amount of distal cantilever is related primarily to the force factors and to the arch form, which corresponds to the A-P spread (Fig. 15.38).

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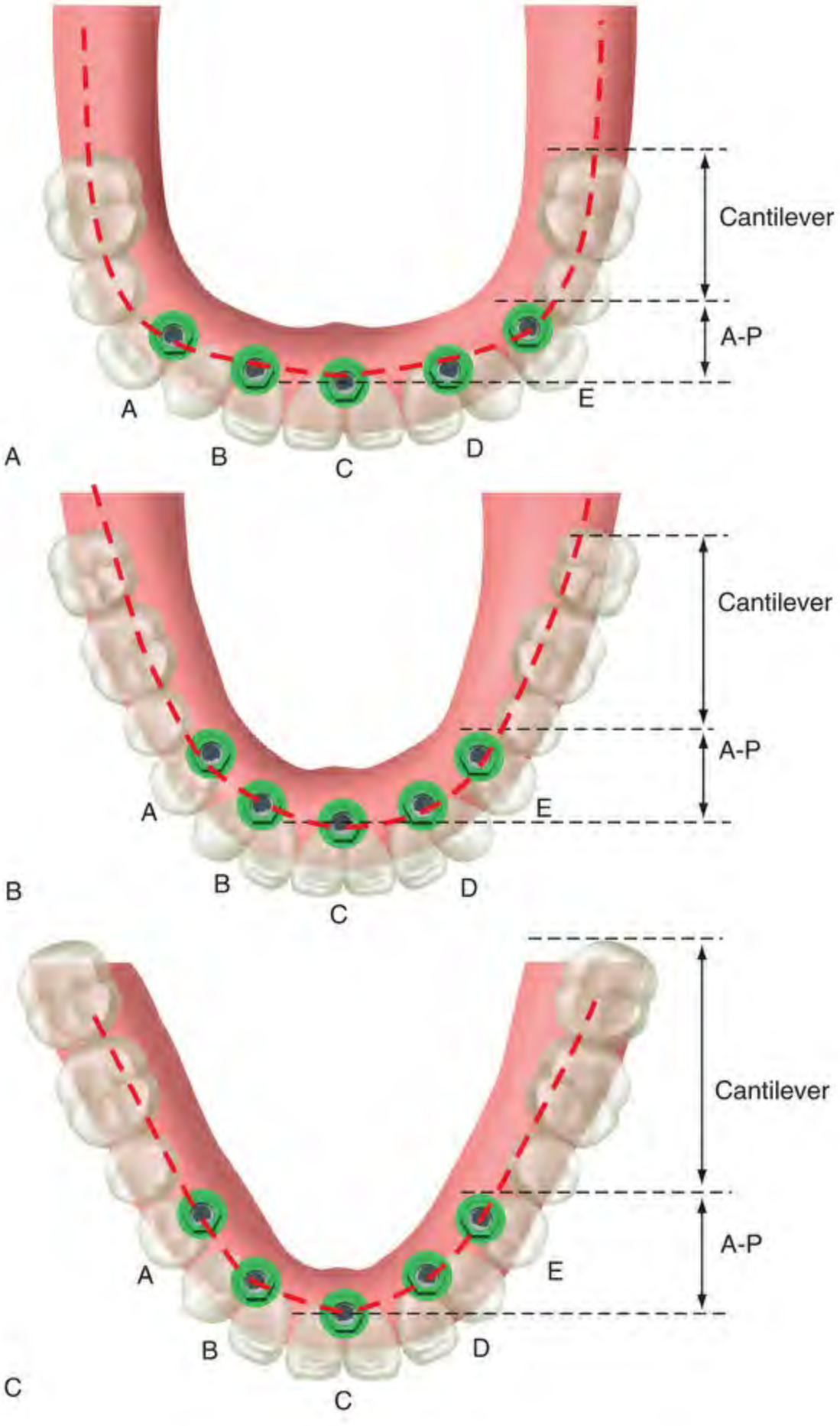

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FIG 15.38 (A) Arch shape affects the anteroposterior (A-P) distance. The square arch form is less than 5 mm. (B) The ovoid arch form often has an A-P distance of 5 to 8 mm. (C) A tapered arch form has the greatest A-P distance, larger than 8 mm. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Attachments.

The most common attachment type is an O-ring or Locator because its position allows the most freedom. The usual O-ring positions are on the distal aspect of each bar and in between the A-B and D-E positions. An alternative is to position one O-ring in the C implant position (because no implant is at this site). The two distal O-rings permit rotation of the restoration toward the buccal shelf, and the anterior O-rings permit the restoration to rotate up toward the incisal. The connecting bar gives implant support from the premolar region forward and lateral stability. The O-rings provide adequate retention. A smaller-size O-ring or less retentive material usually is positioned in the anterior, especially when two anterior O-rings are used.

Advantages.

The patient benefits from the four-implant option because of greater occlusal load support, lateral prosthesis stability, and improved retention. The prosthesis loads the soft tissue over the buccal shelf and the first and second molars and retromolar pad regions. The amount of occlusal force on the implant system is reduced (compared with a fixed restoration or RP-4 prosthesis) because the bar does not extend to the molar position, where the forces are greater.

The OD-4 treatment option is usually the lowest treatment rendered when the patient has maxillary teeth. The greater vertical and horizontal forces to the mandibular IOD require anterior disclusion in excursions to decrease the bite force. As such, more anterior implants are required under these conditions.

Complications/Disadvantages of OD-4

Hidden cantilever.

To reduce the hidden cantilever effect, the second molar is not restored in the mandibular overdenture. In addition, the overdenture must contain movement when loads are placed in the molar region. The position and type

of attachments on the connecting bar are important. The OD-4 prosthesis is indicated to obtain greater stability and a more limited range of prosthesis motion. The overdenture attachments often are placed in the distal cantilevers with an O-ring attachment in the midline. The prosthesis is still RP-5 but with the least soft tissue support of all RP-5 designs. The anterior attachment must allow vertical movement for the distal aspect of the prosthesis to rotate toward the tissue.

Hader bar/clip positioning.

The use of Hader bar/clips, which permit rotation, are difficult to use on cantilevered superstructures. To allow movement, the clip must be placed perpendicular to the path of rotation, not along the cantilevered bar where its only function then is retention (and limits rotation). When Hader bar/clips are made nonperpendicular to the path of insertion, the prosthesis becomes fixed, which results in increased force to the bar/attachment system.

Overdenture Option 5 (OD-5)

Indications.

The fifth mandibular overdenture option (OD-5) is designed for two types of patients. Most important, this is a minimum treatment option for patients with moderate to severe problems related to a traditional mandibular denture. The needs and desires of the patient are often most demanding and may include limiting the bulk or amount of the prosthesis, major concerns regarding function (mastication and speech) or stability, posterior sore spots, or the inability to wear a mandibular denture. This option is often indicated when maxillary teeth or a fixed implant restoration is in the opposing arch (especially with parafunction) (Box 15.9).

Box 15.9

Patient Selection Criteria: OD-5

- Moderate to severe problems with traditional dentures
- Needs or desires are demanding
- Need to decrease bulk of prosthesis

- Inability to wear a traditional prosthesis
- Desire to abate posterior bone loss
- Unfavorable anatomy for complete dentures
- Problems with function and stability
- Posterior sore spots
- Moderate to poor posterior anatomy
- Lack of retention and stability
- Soft tissue abrasion
- Speech difficulties
- More demanding patient type
- Maxillary teeth or fixed implant prostheses
- Angle's class II division I mandible restored to class I

(From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The second patient condition that determines this option is for the treatment to stop the continued bone loss in the posterior mandible. If no prosthetic load is on the posterior bone, the resorption process is delayed considerably and often reversed. Even when no posterior implants are inserted, the cantilevered bar and overdenture avoid load to the posterior residual ridge and often halt its resorption process. Recent studies show that completely implant-supported prostheses often increase the amount of posterior bone height even when no posterior implants are inserted.[52] However, it should be noted that a better option to prevent this posterior bone loss and increase the A-P spread is the insertion of one or more posterior implants before the bone atrophy has occurred. The OD-5 treatment option is also indicated when the patient desires a RP-4 or fixed restoration, the arch form is square for a RP-5 prosthesis, or the maxillary arch has natural teeth (especially in a young patient or male).

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Position.

In the OD-5 treatment option, five implants are inserted in the A, B, C, D, and E positions. The superstructure is usually cantilevered distally up to two times the A-P spread (when favorable force factors) and averages 15 mm, which places it under the first molar area (Fig. 15.39).

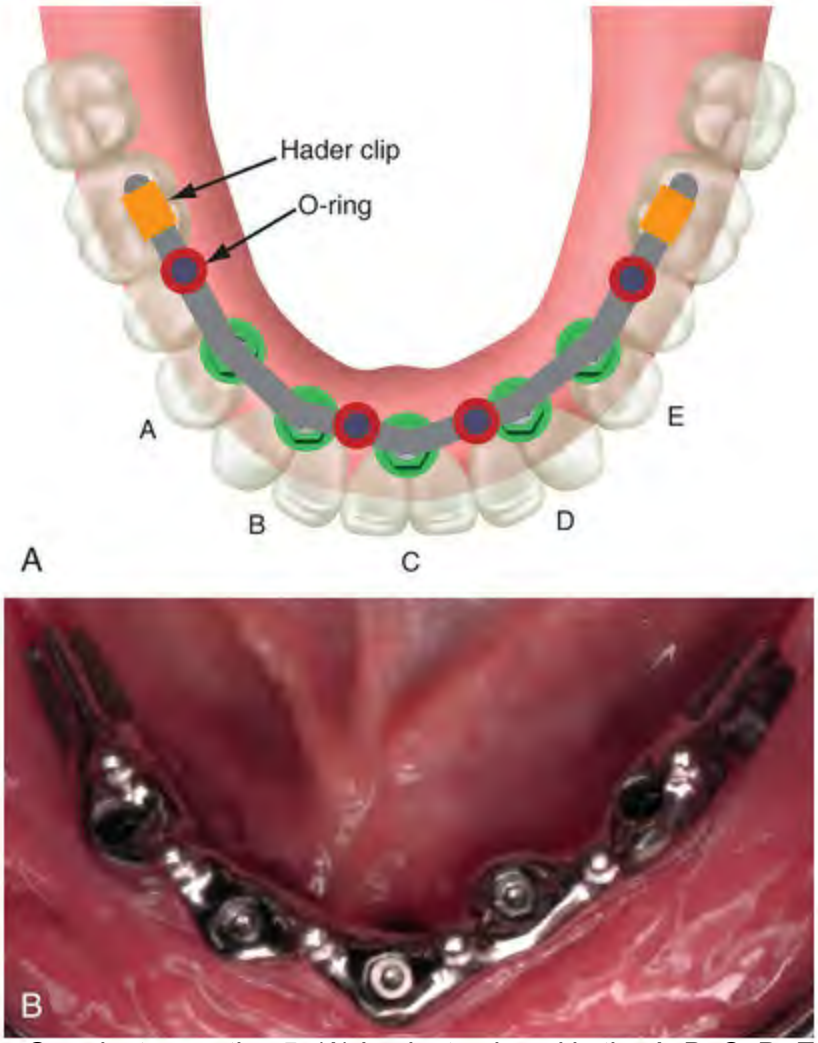

FIG 15.39 Overdenture option 5. (A) Implants placed in the A, B, C, D, E positions, which are splinted together with a distal cantilever. The size of the cantilever is based on many factors including size of implants, position, A-P spread, bone density, parafunction, and opposing occlusion. (B) Clinical image of five implant splinted bar.

Forces/A-P Spread.

The amount of the distal bar cantilever is related (in part) to the A-P distance. The forces exerted on cantilevered bar designs and implants have been

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studied by several authors. A constant finding is that the most distal implants receive stresses two to three times greater than the other implants. The highest concentration of stresses is at the level of the crest distal to the most distal implant on the loaded side. No statistical differences were found between different implant lengths. The stresses increase with the length of the cantilever. Stress factors need to be evaluated carefully and pondered before an extended cantilever is designed.

Stresses are magnified in direct proportion to the length of cantilever and should be planned carefully based on the patient's force factors and the existing anatomy. The A-P distance is greater than in OD-4 because the C implant is often more anterior than the B and D implant sites. A square ridge form usually has an A-P spread of less than 5 mm and should have a minimum cantilever even with five implants joined together. An ovoid arch has an A-P spread from 5 to 8 mm and a tapered arch form more than 8 mm. In these situations a cantilever of two times this distance is indicated when force factors are not excessive (see Fig. 15.39).

If any major stress factors (e.g., parafunction, opposing arch) are not favorable, the cantilever should be reduced. The patient force factors are as important as the A-P spread. In a study in which the failure criterion was the failure of the screw joint with arrangements of three, four, five, and six implants with a similar A-P spread submitted to forces from 143 to 400 N, the greater transmitted forces to the prosthetic connection always exceeded the yield strength of the system. This study emphasizes the fact that the amount and duration of occlusal load is even more important than the A-P spread to be considered for cantilever length determination.[53]

The superstructure bar may be cantilevered up to two times the A-P distance with low stress factors for three reasons. The additional C implant increases the implant–bone surface area of the system, adds another retentive element to the bar to reduce screw loosening, and increases the A-P dimension. This helps counter act the class 1 lever action created by the distal cantilever.

Five implants also allow the superstructure and prosthesis to be cantilevered forward from the anterior ridge. This is of particular benefit for Angle's skeletal class II patients. The lower lip is supported by the maxillary teeth when the jaw is at rest. Traditional mandibular dentures reconstruct the original horizontal overjet, so the lower anterior teeth position does not infringe on the neutral zone during rest or function. However, in an RP-4 restoration, the teeth may be set in a skeletal class I pattern, where they

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provide the best esthetic result. This also increases the amount of function in the anterior region. Because these patients are skeletal class II, the forward anterior tooth position also places the molars forward, reducing the need for a more distal cantilever. The distal cantilever reduction also decreases the posterior lever force.

Attachments.

Usually four to six retentive attachments are included in the cantilevered bar design. The attachments are typically O-rings, Locators, or Hader clips. Because of their number and distribution, the attachments provide retention and oppose PM. Typically, four O-rings are distributed evenly (two anterior and two posterior to the distal implants). If the OVD is limited or parafunction is present, the IOD may use a metal framework within the prosthesis (similar to a partial denture). This design reduces the risk of IOD fracture.

A Hader bar clip may be placed distal to the last O-rings on each cantilevered section. At delivery, the O-rings may be the only attachments used. The Hader clip may be added as a backup system for additional retention in case an O-ring stud breaks or when the vertical dimension of occlusion does not permit the use of high-profile retentive O-rings and causes repeated fracture of the overlying acrylic denture. It can also provide additional retention to prevent sticky food from lifting the posterior aspect of the denture.

The six-attachment bar design also permits a method to decrease stress to the bar and implants if screw loosening or bone loss around the implants is noticed. The Hader clip and bar may be sectioned off the connecting bar. The RP-4 prosthesis then is converted to a RP-5 restoration because it may rotate on the two O-rings placed just distal to the posterior implants.

Maxillary Overdenture Complications

The maxillary overdenture concept is much different in comparison to mandibular overdentures in many aspects. Fewer reports have been published for maxillary IOD compared with mandibular overdentures. According to Goodacre et al, mandibular overdentures have one of the highest implant success rates, and the restoration with the highest implant failure rate is a maxillary overdenture (19% failure rate).[54] A prospective study by Johns et al reported on maxillary IODs at 1 year, 3 years, and 5 years.[55] Sixteen patients were followed throughout the study with a cumulative success rate of 78% for prostheses and 72% for implants.

Not Understanding the Advantages Associated With a Maxillary Overdenture

Facial Esthetics May Be Enhanced

The loss of facial esthetics often occurs first in the maxillary arch, with the loss of vermilion border of the lip, increased length of the maxilla lip, and lack of facial bone support. However, patients may not realize these changes are related and are accelerated because of the loss of teeth and bone. The use of implant-retained prosthesis has the advantage of decreasing the continued bone loss and prevent the later complications found in the maxillary arch. Although difficult because of the premaxillary bone loss, a maxillary overdenture may eliminate the complications.

Less Soft Tissue (Palatal) Coverage

The extended soft tissue coverage of a maxillary denture negatively affects the taste of food and acts as an insulator to temperature. The soft tissue may become tender in the extended vestibular borders as the crest of the ridge resorbs. The palate of a maxillary prosthesis may cause gagging in some patients. Most of these disadvantages of a complete maxillary denture may be eliminated in an implant-supported overdenture, especially with an RP-4 horseshoe overdenture. Reducing the bulk of the prosthesis, especially when the palate is eliminated from the overdenture, is more of a patient benefit in comparison to the mandibular overdenture. Eliminating the palate reduces the gagging effect from some patients and improves the taste of food in some individuals. In some patients, an anatomic variant is present that includes

taste factors from the 11th nerve that innervate taste buds in the palate. Although unusual, these patients benefit from the reduction of the palate of their overdenture.

Decreases Premaxillary Resorption

When the resorption of the premaxilla increases, the maxillary denture will become unstable. The maxillary anterior teeth will become positioned more facially with respect to the residual bone. As a result, the denture will rotate up in the anterior, resulting in rotation in a downward direction in the posterior. The denture will lose the posterior valve seal as a consequence. In the maxillary arch an implant-retained overdenture should be considered before significant bone is lost in the premaxilla. The complete anterior ridge and even the nasal spine may be resorbed in the maxilla, causing pain and an increase in maxillary denture movement during function.[56]

Several factors affect the condition of the premaxilla and may result in a decrease in implant survival or an increase in prosthetic complications. The completely edentulous anterior bony ridge is often inadequate for endosteal implants. The facial cortical plate may be resorbed from periodontal disease or often is lost during the extraction of teeth. In addition, the facial cortical plate resorbs during initial bone remodeling, and the anterior ridge loses 25% of its width within the first year after tooth loss and 40% to 60% over 3 years, mostly at the expense of the labial plate. As a result, the maxillary denture migrates to a more palatal position.[57]

In the maxilla, horizontal and vertical loss of bone results in a more palatal ridge position. As a consequence, implants are often inserted more palatally than the natural tooth position. With overdentures, this is an advantage. Removable restorations have several advantages under these clinical circumstances. The removable prosthesis does not require embrasures for hygiene. The facial cantilevered fixed prosthesis may make it impossible to perform sulcular hygiene. The removable restoration may be removed during sleep to decrease the effects of an increase in CHS on nocturnal parafunction. The removable restoration may improve the lip and facial support, which is deficient because of the advanced bone loss. The overdenture may have sufficient bulk of acrylic resin to decrease the risk of prosthesis fracture. The increase in CHS permits denture tooth placement without infringement of the implant-prosthetic substructure.

Ability to Increase Soft Tissue Support

The primary advantages of a maxillary IOD compared with a fixed prosthesis is the ability to provide a flange for maxillary lip support, the improved sulcular hygiene, and the reduced laboratory fee compared with a fixed restoration. As a consequence, before the selection of a specific prosthesis type and to facilitate the diagnosis, the labial flange above the maxillary teeth of the existing denture (or wax try-in of a new prosthesis) may be removed and the facial appearance of the maxillary lip without labial support assessed. A common complication after the placement of a fixed prosthesis in the maxillary arch is to have insufficient soft tissue support leading to dissatisfaction from patients. If labial lip support is not satisfactory, two options are available:

1. A bone or soft tissue graft to the premaxilla is performed before or in conjunction with implant insertion or at uncovery for a fixed implant prosthesis.

2. A maxillary IOD is fabricated with a labial flange on the prosthesis.

Possible Maxillary Overdenture Complications

Compromised Crown Height Space

Removable prostheses often require a CHS greater than 12 mm for denture teeth and acrylic resin base strength, attachments, bars, and oral hygiene considerations.[58] The amount of CHS in an edentulous region greatly varies. The larger CHS may facilitate the fabrication process of removable overdentures because it is easier for denture tooth setup and greater bulk of acrylic can be used to strengthen the prosthesis. The inadequate CHS may make an overdenture contraindicated. In these situations the denture tooth position may be affected, the prosthesis may repeatedly fracture, and the attachments may be compromised. This often occurs in the maxilla because of the available bone and trajectory. When less than 12 mm of CHS is present, an osteoplasty is considered before implant insertion. However, rarely can an osteoplasty be completed because insufficient bone will be available for implant placement (Fig. 15.40).

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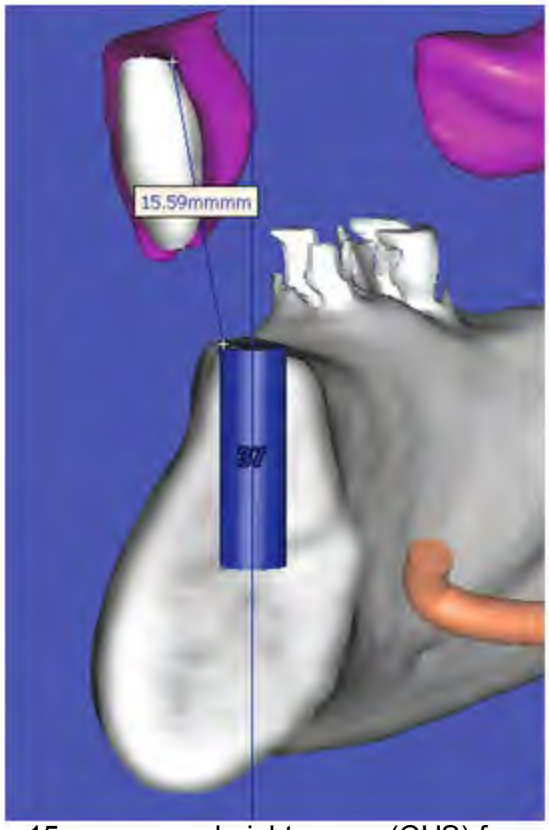

FIG 15.40 Less than 15 mm crown height space (CHS) for an implant overdenture may compromise the position of the overdenture teeth and increase the risk of prosthesis fracture. An insufficient CHS is a major problem for the fabrication of a prosthesis (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Hidden Cantilever

A rigid overdenture (RP-4) has identical requirements for implant support in position and number as a fixed prosthesis because it is rigid during function. Soft tissue support in addition to implant-supported removable implant restorations with an excessive CHS are recommended when it is not possible to adequately engineer the implant support system. Misch has described the "hidden cantilever" beyond the cantilevered bar with a rigid IOD.[59] When the overdenture has no movement during function, the cantilever does not stop at the end of the cantilevered substructure but ends at the last occlusal contact position on the prosthesis, often the distal of a second molar. This can lead to occlusal overload and overstress to the implant system.

Poor Treatment Planning Options

When the premaxilla is compromised with regards to available bone, some clinicians will treatment plan posterior implants (premolar and molar)

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without implant support in the canine regions. The prosthetic design is to connect the implants with a full-arch bar for a maxillary overdenture. This is not indicated when a bar extends from premolar to premolar around an arch because the overdenture prosthesis is completely implant supported (RP-4) and will not move (PM-0) during function or parafunction. As such, the overdenture acts as a fixed restoration with less support and without implants in the key implant positions.

Another poor treatment option for fully edentulous maxillae is the placement of implants in each posterior quadrant (no canine position) with independent bar segments and an overdenture (Fig. 15.41). This treatment option is prone to failure for the following reasons:

1. If the IOD in the maxilla has only posterior implants and is not rigid, the prosthesis rocks forward and up every time the patient bites into food or the mandible moves into excursions. The rigid, posterior implants act as fulcrums, and the restoration is not stable.

2. The implants in the premolar regions act as the fulcrum, and the incisal edge of the prosthesis is cantilevered from this position. As a result, the attachment system repeatedly fails. This type of prosthesis resembles a Kennedy class IV partial denture and is the least stable restoration in prosthetics. In fact, it is usually less stable than a conventional denture.

3. The posterior implants in this type of restoration are in a straight line and do not resist the lateral forces as well. Often the attachments repeatedly need replacement, and all the implants on one side of the arch may fail.

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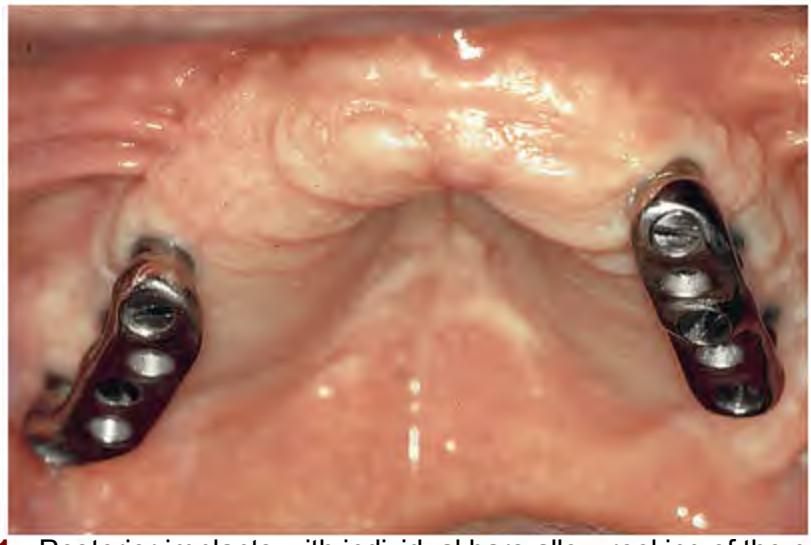

FIG 15.41 Posterior implants with individual bars allow rocking of the prosthesis, which accelerated attachment wear and prosthetic screw loosening. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Not Taking Into Consideration Treatment Planning Factors.

To increase implant and prosthesis survival rates, treatment for maxillary overdentures with division A bone is planned similarly to treatment for mandibles with C minus height (C–h) bone and greater factors of forces. In other words, four or more implants are inserted from first premolar to first premolar. In addition, subantral augmentation often is performed to place more distal implants and dramatically improve the A-P distance when the anterior and posterior implants are splinted with a bar. This treatment approach has proved successful in yielding success rates similar to those for mandibular overdentures.

From a biomechanical perspective the implant-restored anterior maxilla is often the weakest section compared with other regions of the mouth. Compromised anatomic conditions and their consequences include the following factors.

Poorer bone quality.

In the majority of patients with available bone in the maxilla, the bone is less dense in the anterior maxilla than in the anterior mandible. In the mandible a dense cortical layer is coupled with coarse trabecular bone strength and permits implants to be supported by a denser bone quality. The maxilla presents thin, porous bone on the labial aspect, very thin, porous cortical bone in the floor of the nasal region, and denser cortical bone on the palatal

aspect. The trabecular bone is usually fine and is also less dense than the anterior region of the mandible.

Force issues.

In the premaxilla, esthetics and phonetics dictate that the replacement teeth be placed at or near their original position, often cantilevered off the residual ridge, which usually is resorbed palatally and superiorly. Crown height as a force magnifier is of paramount importance in the anterior maxilla, where the natural crown height is already greater than in any other region even under ideal conditions. The arc of closure is anterior to the residual ridge; as a consequence, the moment force is greatest against the maxillary anterior crowns supported by implants and directed against the thinner facial bone. All mandibular excursions place lateral forces on the maxillary anterior teeth, with resulting increased stress on the crestal bone, especially on the labial aspect of the implant.

Available bone.

The narrow ridge of a premaxilla has parallel walls of bone, so an osteoplasty to increase width is less effective. Because of the compromised bone width, smaller-diameter implants will result in increased stress concentrations in the implant and contiguous interfacial tissues, particularly at the crestal region.

Cantilevers.

The use of facial cantilevers result in increased moment loads at the implant crest, often leading to localized crestal remodeling and implant or abutment fracture.

Occlusion.

Oblique centric contacts result in potentially harmful, off-axis load components, and lateral forces in excursion resulting in greater moment loads applied to the implant.

Buccal plate thickness.

The premaxilla has inherently minimal buccal plate thickness. Absence of thick cortical plate at the crest results in the loss of high-strength implant support and less resistance to angled loads, which increase stress.

Bone loss.

After loss of teeth in the premaxilla, bone volume loss in the incisor region accelerates, often resulting in the inability to place central and lateral incisor implants without substantial augmentation procedures. In the posterior maxilla, compromised bone quantity is also an issue resulting in the need for subantral augmentation.

Maxillary Overdenture Treatment Options

Whereas there are five overdenture treatment plans for the mandible, there are only two options for the maxilla (Box 15.10). The difference is primarily due to biomechanical disadvantages of the maxilla compared with the mandible. Independent implants are unpredictable with a higher incidence of morbidity and are completed with caution. In addition, the attachment is closer to the tissue, and the CHS from the attachment is greater, so the prosthesis has more movement. As such, the two treatment options are limited to a removable prosthesis RP-5 restoration with 4 to 6 implants with some posterior soft tissue support, or an RP-4 restoration with 6 to 10 implants (which is completely supported, retained, and stabilized by implants).

Box 15.10

Maxillary Implant Overdenture Options

1. RP-5 prosthesis: four to six implants in three to five arch positions

2. RP-4 prosthesis: 6 to 10 implants in all five key implant arch positions

Option 1: Maxillary RP-5 Implant Overdenture

Indications.

The first treatment option with a maxillary implant-retained overdenture is an RP-5 prosthesis. This option is not as beneficial to the patient compared with mandibular RP-5 restorations. A RP-5 maxillary IOD may have associated movement and may even rock more than a denture because the anterior implants act as a fulcrum under the prosthesis. The major advantages of an RP-5 maxillary IOD is the maintenance of the anterior bone

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and the cost (a less expensive treatment option than an RP-4 or fixed prosthesis). The RP-5 overdenture treatment is less expensive than an RP-4 overdenture because fewer implants are required and bilateral sinus grafts and ridge augmentation are not required to support molar implants. The RP-5 treatment plan is often used as a transition to an RP-4 prosthesis when financial considerations of the patient require a staged treatment.

Implant Number/Position.

The maxillary OD-1 treatment plan for a completely edentulous maxilla uses four to six implants supporting an RP-5 prosthesis, of which three are usually positioned in the premaxilla. Based on the poor success rates reported in the literature, specific biomechanical requirements, and poor bone quality, the fewest number of implants for a RP-5 maxillary overdenture should be four, with a wide A-P spread (Fig. 15.42). Implant number and location are more important than implant size, but the implants should ideally be a minimum of 9 mm in length and 3.5 mm in body diameter. An improved and more predictable number of implants for an RP-5 prosthesis is five. The key implants are positioned in the bilateral canine regions and at least one central incisor position. Other secondary implants may be placed in the first or second premolar region (five-sided arch of treatment planning).

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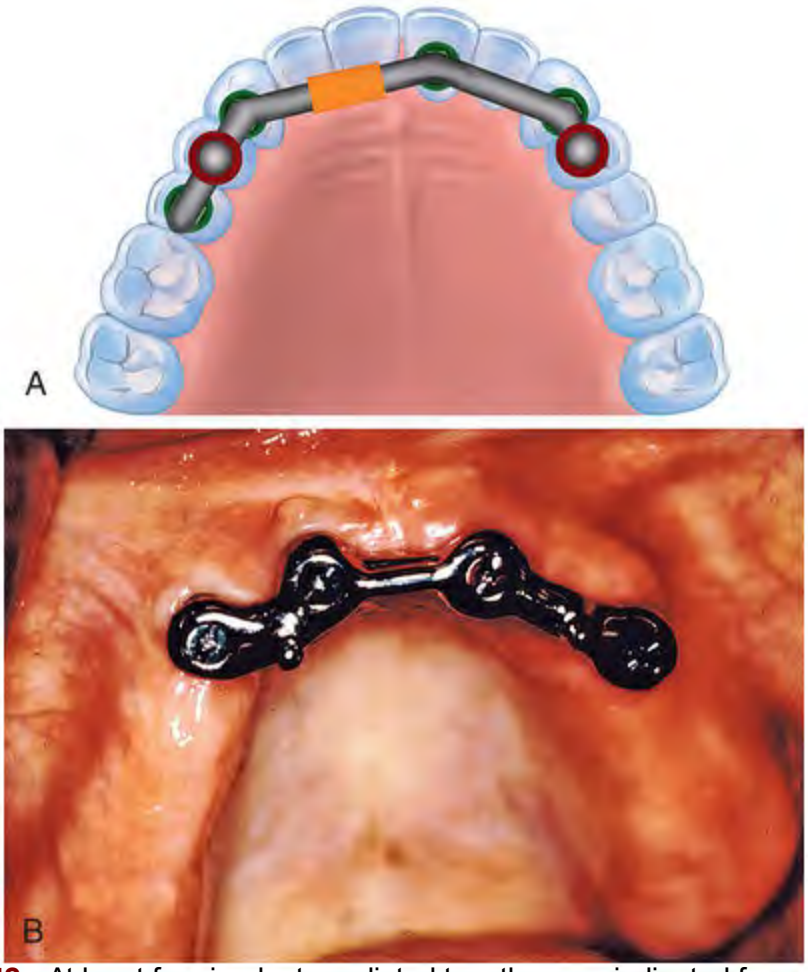

FIG 15.42 At least four implants, splinted together, are indicated for a maxillary implant overdenture, at least three of which are placed in the premaxilla. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Alternative positioning includes placing an implant in the incisive foramen or lateral incisor area. When an implant cannot be placed in at least one central incisal position, the incisive foramen may be considered for implant insertion. Another alternative is the use of a lateral incisor implant. In such cases, owing to the reduced A-P spread of the lateral incisor in the anterior most implant site, the second premolar position also should be used on the contralateral side (along with the canine) to improve the A-P spread. Six implants are often indicated for an RP-5 prosthesis when force factors are greater (Fig. 15.43).

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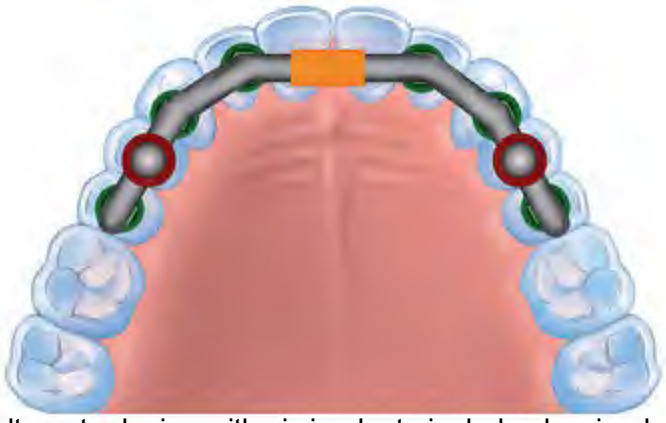

FIG 15.43 An alternate design with six implants includes key implants in the canine regions, implants in the lateral incisor regions, and secondary implants in the second premolar regions to improve the anterior-posterior spread. Dolder clips or O-rings can be used in such a way as to allow two directions of prosthesis movement. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prosthetic Design.

The implants are always ideally splinted together with a rigid bar. There is no distal cantilever, and the bar design should follow the dental arch form but slightly lingual to the maxillary anterior teeth. This will allow for more room of acrylic for strength and retention. The prosthesis should have at least two directions of movement; however, three or more are preferred. A Dolder clip or O-ring may be used if it is placed in the center of the arch and perpendicular to the midline. A Dolder clip has a spacer over the clip to allow some vertical movement before rotation. When O-rings are used to retain the restoration, they may be positioned more distal than a center Dolder clip, often immediately distal to the canine position. O-rings may also be used just distal to the last abutment on each side or between the implants. When intermediate O-rings are used, relief is provided distal to the bar to allow prosthesis movement toward the tissue under posterior occlusal forces.

Support.

The maxillary RP-5 IOD is designed exactly as a complete denture with fully extended palate and flanges. The restoration should be allowed to move slightly in the incisal region during function so that the restoration may rotate toward the posterior soft tissue around a fulcrum located in the canine or premolar position. The prosthesis is soft tissue–supported with secondary retention from the implants. Ideal support on the primary stress-bearing area of the maxilla must be utilized (horizontal palate).

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Advantages.

The benefits of a RP-5 maxillary overdenture are retention and stability from the implants. Posterior support is obtained from the soft tissue. The other primary benefit is the maintenance of the premaxillary bone because of implant force stimulation to the bone. There is also a reduced fee compared with a RP-4 prosthesis because bilateral sinus grafts are not required for molar implants, and the number of implants may be as few as four.

Option 2: Maxillary RP-4 Implant Overdenture

Indications.

The second option for a maxillary IOD is a RP-4 prosthesis with 6 to 10 implants that is rigid during function (Fig. 15.44). This option is the preferred IOD design because it maintains greater bone volume and provides improved security and confidence to the patient compared with a denture or RP-5 prosthesis. The loss of bone width in the premaxilla does not require a bone graft or hydroxyapatite graft for lip support as for a fixed prosthesis. However, the cost of treatment parallels that of a fixed hybrid prosthesis. The RP-4 restoration most often still requires sinus grafts and posterior implants. In some instances, extensive bone grafting may be indicated for the entire premaxilla for a fixed prosthesis. The RP-4 restoration may be required for facial esthetics if augmentation procedures are not performed.

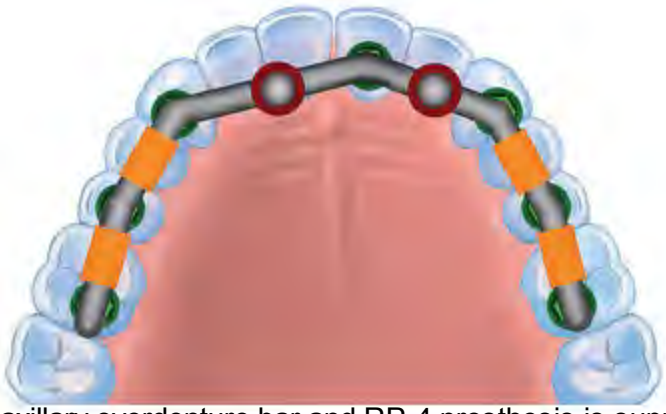

FIG 15.44 A maxillary overdenture bar and RP-4 prosthesis is supported by 7 to 10 implants and is rigid during function. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Unfortunately, many practitioners believe that the RP-4 overdenture

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requires fewer implants and less attention to the biomechanics of occlusal load compared with a fixed restoration just because the restoration is removable. This is a primary cause of implant failure in maxillary IODs. When the IOD is completely supported, retained, and stabilized by the implant support, it acts as a fixed prosthesis. The number of implants is similar to that of a fixed prosthesis.

Implant Number/Positions.

Treatment planning for RP-4 maxillary overdentures is very similar to fixed prosthesis because the IOD is fixed during function. Two of the key implant positions for the RP-4 maxillary IOD are in the bilateral canines and distal half of the first molar positions. These positions usually require sinus grafts in the molar position. Additional posterior implants are located bilaterally in the premolar position, preferably the second premolar site (greater force than first premolar). In addition, at least one anterior implant between the canines often is required. The anterior implant often may be placed in the incisive canal when inadequate bone width is present (Fig. 15.45). Six implants is the minimum suggested number for a RP-4 treatment option, and seven implants are used more often. When force factors are greater, the next most important sites are the second molar positions (bilaterally) to increase the A-P spread and improve the biomechanics of the system. A 10th implant may be placed in the premaxilla for a tapered arch form.

FIG 15.45 Incisive canal implant.

Prosthesis Design.

The 6 to 10 implants are splinted together around the arch with a rigid bar (five-sided arch in treatment planning). Four or more attachments are usually positioned around the arch. This provides a retentive, stable overdenture prosthesis. Usually palatal coverage is maintained with a horseshoe design. This helps prevent speech problems and allows for greater patient comfort.

Occlusal Scheme.

The occlusal scheme for this RP-4 restoration is similar to that for a fixed prosthesis: centric occlusion around the arch and only anterior contact during mandibular excursions (unless opposing a mandibular complete denture). The maxillary overdenture should be removed during sleep to prevent nocturnal parafunction. If the patient wears maxillary and mandibular overdentures, only the mandibular restoration needs to be removed. However, the maxillary overdenture should be removed for a short interval during the day.

Attachments.

The position and type of overdenture attachments may render an overdenture rigid during function even in the absence of distal cantilevers on the bar. For example, when three anterior implants are splinted together and a Hader clip is used to retain the prosthesis, if the Hader clips are placed at angles to the midline, the attachments have limited movement and result in a rigid overdenture during function.

Advantages.

The main advantage of an RP-4 maxillary prosthesis is the minimal palatal coverage. Because the prosthesis is horseshoe shaped, patient satisfaction is much higher, especially if the patient has a gagging habit.

Understanding Maxillary Arch Forms

When evaluating arch forms for implant prostheses, the clinician should evaluate two distinct forms: the edentulous and dentate. The residual edentulous bone determines the A-P distance for implant support. The dentate arch form will determine the arch form for the final prosthesis. Both arch forms may be described as ovoid, tapering, or square.

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Types of Arch Forms

Ovoid.

The ovoid arch form is the most common followed by the square and then the tapered form. The ovoid arch form has qualities of both tapered and square arches.

Square.

The square arch form may result from the residual formation of the basal skeletal bone. However, the presence of a square arch form is more common in maxillary implant patients as a result of labial bone resorption of the premaxilla region when anterior teeth are lost earlier than the canine. The square dental arch form is preferred when canine and posterior implants are used to support anterior teeth in either arch.

Tapering.

The tapering arch form is often found in skeletal class II patients as a result of parafunctional habits during growth and development. It is not uncommon to find different arch forms in the upper and the lower arches. The tapering residual ridge arch form is favorable for anterior implants supporting posterior cantilevers.

Importance of Arch Form

The dentate and edentulous arch forms are not necessarily related, and the worst situation in the maxilla corresponds to a square residual arch form that supports a tapered dental restoration. The prosthesis cantilever off the anterior available bone is greatest in this combination (Fig. 15.46).

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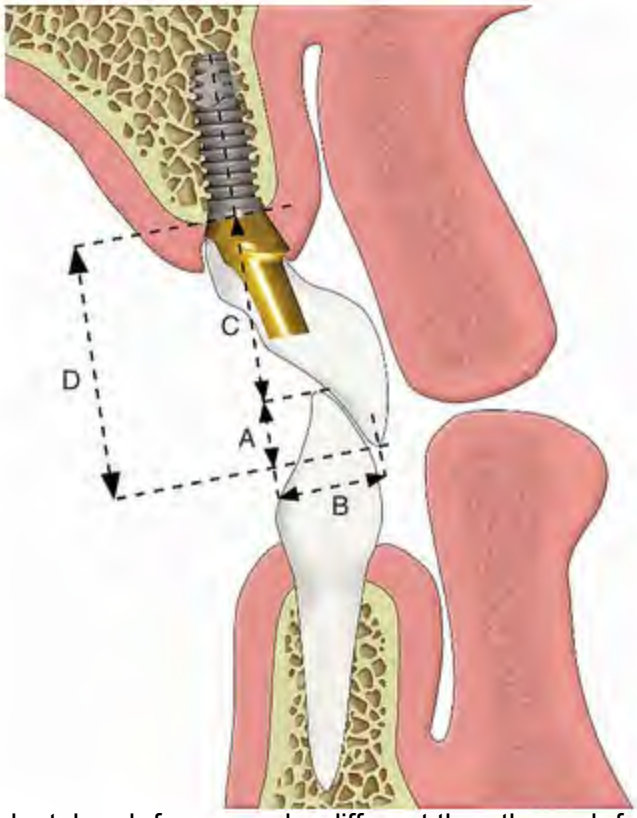

FIG 15.46 The dental arch form may be different than the arch form of the residual arch. A tapered dentate arch form on a square residual bone form is the worst combination because the anterior teeth are cantilevered from the implant abutments. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The arch form is a critical element when anterior implants are splinted together and support a posterior cantilever restoration. For these conditions, a square arch form provides a poorer prognosis than a tapered arch form. The A-P distance or A-P spread is the distance from the center of the most anterior implant to a line joining the distal aspect of the two most distal implants.[60] It provides an indication as to the amount of cantilever that can be reasonably planned. When five anterior implants in the mandible are used for prosthesis support, the cantilevered posterior section of the restoration should not exceed two times the A-P spread when all patient force and stress factors are low and bone density is favorable. The actual length of the cantilever depends not only on implant position but also on other stress factors, including parafunction, crown height, implant width, and number.

The predominant factors to determine the cantilever length are related to stress, not only the A-P distance. For example, the distance between two implants supporting a cantilever (C) forms a class I lever. For implants 10 mm apart and a 10-mm posterior cantilever, the following forces are applied:

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a 25-lb force on cantilever C results in a 25-lb force on the most anterior implant from the cantilever (A) and 50 lb for the nearest implant to the cantilever (B), which acts as a fulcrum. An interimplant distance of 5 mm with the same 10-mm cantilever and a 25-lb force applied on C results in a 50-lb force on A and a 75-lb force on B. The distance between implants significantly increases the forces to both implants. But in the first example, if a patient with parafunction bites with a 250-lb force on C, the force on implant A is 250 lb, and the force on implant B is 500 lb. In other words, parafunction is much more meaningful in terms of force than the interimplant distance (A-P distance) when designing a cantilever. A-P distance is only one stress factor to evaluate for cantilever length. Parafunction, crown height, masticatory dynamics, arch position, opposing arch, direction of force, bone density, implant number, implant width, implant design, and A-P distance are all factors to be considered. When the force factors are low and the area factors (implant number, width, and design) are high, the cantilever length may be as much as two times the A-P distance in good-quality bone.

As mentioned previously, anterior endosteal implants often may not be inserted in their ideal location in the maxilla as a result of labial plate resorption and inadequate bone width at the implant site. This not only requires implant placement more palatally compared with the original natural teeth, but it may also negate the lateral and central positions and require the use of the canine regions in more advanced atrophic arches. The resulting restoration is a fixed, anteriorly cantilevered prosthesis to restore the original arch form. Under these conditions, greater stresses are placed on the dentate-tapered arch forms compared with dentate square arch forms, all other factors being identical.[60]

The maxillary anterior cantilever to replace teeth in a dentate-tapered arch form requires the support of additional implants of greater width and number to counteract the increase in lateral load and moment force. For example, not only are the canine implants necessary, but two more additional anterior implants are also suggested even if bone grafting is required before their placement. In addition, additional posterior implants in the first to second molar region splinted to the most anterior implants are highly suggested. If a maxillary tapered arch form requires this treatment approach, at least eight implants (four on each side) and an increased A-P distance from molar implants splinted to incisor implants is suggested. In addition, second molar implants should be splinted to the anterior implants to

increase the A-P distance. In the maxilla the recommended anterior cantilever dimension is less than for the posterior cantilever in the mandible because of poor bone density and forces directed outside the arch during excursions.

Overdenture Attachment Complications

The selection of the overdenture attachment system is often a confusing part of the prosthetic rehabilitation of the patient. Clinical studies concerning the attachments are scarce and difficult to evaluate. Usually, attachment selection is based on the clinician's personal preference, laboratory preference, expert opinion, or empirical information. An ideal overdenture attachment should have basic features to minimize and decrease clinical complications. An overdenture attachment main goal is to retain the prosthesis and allow movement during function or removal of the prosthesis. As a consequence of forces applied to the prosthesis, all overdenture attachments wear and become less retentive over time. The clinician should understand the positive and negative inherent factors associated with attachments.

Ideal Attachment

Ease of Replacement.

Ideally, the attachment selected should allow ease of replacement. A chair side, cold-cure acrylic procedure should not have to be used every time the attachment needs replaced. This leads to nonproductive time for the clinician and also places the prosthesis at risk of being altered. Additionally, this will result in considerable time, risk, and frustration every time the attachment is changed. To prevent this issue, an attachment should be selected that allows for easy replacement and long-term use.

Ability to Control Retention.

The ideal overdenture attachment should also offer many options to control the degree of retention. A mobile or minimally retentive attachment at the initial delivery ensures improper fit leading to prosthesis movement and possible screw loosening. Adequate retention should be ascertained prior to the final insertion of the prosthesis. A gradual increase in retentive capability may be achieved later by replacing the component within the encapsulator by a more retentive attachment. Likewise, if more retention is required in the

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future, a stiffer element, which is held by the same encapsulator, easily solves the problem (Fig. 15.47).

FIG 15.47 Control of retention. (A) Locator: various colored inserts with varying degrees of retention. (B) O-rings: retention varies with the type of material.

Male Attached to Implant/Female in Prosthesis.

Most attachments used in implant dentistry today have the male component in the oral cavity and the female in the prosthesis. The male can be more easily cleaned while in the mouth, and the more difficult component (i.e., female) may be cleaned with direct vision via access outside of the mouth (i.e., within the prosthesis). When the female component is part of the implant or connecting bar, if any plaque or food accumulates within the component, the overdenture will not seat completely. This will lead to patient frustration because of occlusal disharmonies, lack of retention, and possible tissue impingement (Fig. 15.48).

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FIG 15.48 Female attachment in prosthesis. When the female attachment is in the prosthesis, it is easier to clean. When female attachments are placed intraorally, food impaction is common, which prevents complete seating of the prosthesis.

Adequate Retention for the Prosthesis.

The retention and stability are significant factors that affect the type of attachment system. For a single unsplinted attachment, 4 N has been suggested as the minimum retentive force.[61] Other studies have shown a cumulative force of 20 N of retentive force needed for a two-implant mandibular overdenture.[62] When evaluating the retentive capabilities of attachment systems, the term *peak load* is used to define the maximum force that is developed before complete separation of the attachment components from the implant abutments. When evaluating peak load, various attachment systems have been classified as: (1) high (e.g., ERA gray), (2) medium (e.g., Locator LR white, Spheroflex ball, Hader bar and metal clip, ERA white), (3) low (e.g., Locator LR pink), and (4) very low (e.g., Shiner magnet, Maxi magnet, Magnedisc magnet) retention groups.[63]

Alsabeeha et al showed that Locator attachments white, pink, and blue connectors have demonstrated higher retentive forces than either a 7.9-mm prototype ball attachment design or the standard 2.25-mm ball attachment.[64] Other studies have shown the attachment with the highest peak load was the Zest Anchor Advanced Generation (ZAAG) attachment (Zest Dental Solutions), in comparison to the Nobel Biocare ball, the Zest Anchor, and the Sterngold ERA (Sterngold Dental, LLC).[65] The ZAAG attachment showed significantly the highest retentive vertical and oblique forces under dislodging tensile forces applied to the housings in the vertical and oblique

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directions.

Ideal Attachment Summary.

In implant dentistry today the two most common attachment systems to use are the Locator system and the O-ring attachment system. They have the universal advantage of different retention strengths, utilize metal encapsulators, are easy to change and replace, and have the male component in the oral cavity. The Locator and O-ring have been shown to be long lasting through numerous clinical studies. And lastly, both of these attachments can be used independently or attached and incorporated into a bar via cast-to or cemented protocols (Fig. 15.49).

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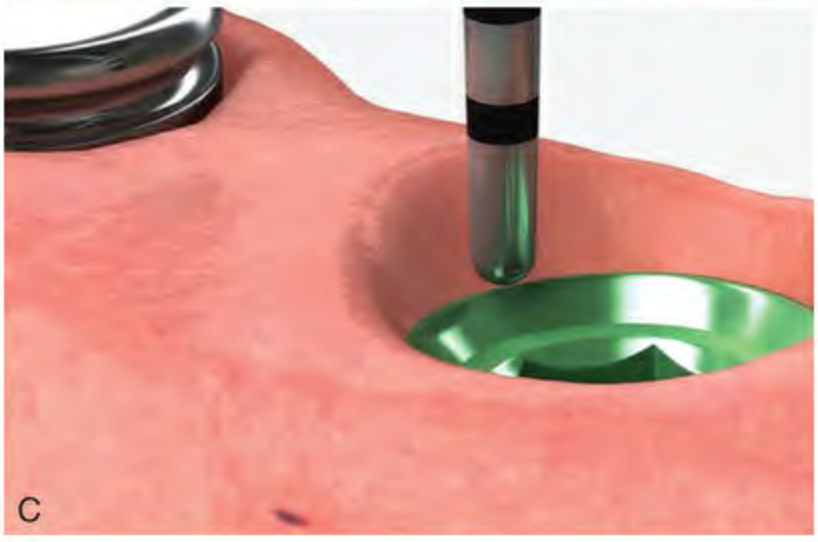

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FIG 15.49 Attachment location. (A) Independent attachments. (B) Incorporated into a bar. (C) The abutment height is dictated on the tissue depth. The attachment needs to be slightly above the highest area of tissue depth.

Complications of Dental Implant Attachments

Retention Loss Over Time.

The main complication over time with dental implant attachments is the loss of retention. Depending on the situation, this is highly variable and dependent on many factors. Retention loss over time studies show the wear-induced structural changes inherent with every attachment system will inevitably lead to a reduction or total loss of retention. Mechanical action alone or a combination of chemical and mechanical actions will induce loss of material from the surface, which is defined as wear. Wear has been shown to decrease the attachment's retention, lead to deterioration and deformation, work hardening, and can also lead to attachment fracture.[66] Factors that predispose to loss of retention and wear include the following:

Mastication wear.

The attachment wear from occlusal forces is much different from insertion-removal cycles. In most overdentures (RP-5), the amount of occlusal load applied to the attachment is dictated by the resiliency of the tissue. The amount of mucosa displacement will reduce the denture movement and less force on the attachment. Studies showing simulated masticated Locator attachment retention to be reduced by 40% with a nonlinear descending curve. This correlates with maintenance issues being directly related to masticatory forces. In this study, only minor changes were found for ball type attachments.[67]

Insertion-removal wear.

Mechanical fatigue has been shown to reduce retention on almost all attachment systems after 15,000 fatigue cycles.[62] Studies have shown approximately 800 cycles are needed to attain relatively stable retention of overdenture attachments.[68] The Locator pink attachment remained the most retentive after fatigue, compared to the ERA orange and white. However, researchers concluded that implant parallelism has more impact on complications that occur than the choice or type of attachments.[69] When

directly picking up the attachment, care should be exercised not to place too much force on the denture (i.e., displacement force). Any installation load greater than 0 N will have a resultant force acting on the prosthesis/implant.

Other studies have evaluated the force-related issues with the insertion and removal consequences of attachment systems. Alsabeeha et al submitted various attachment systems to either axial or paraxial forces in the range of 540 to 10,000 cycles from repeated insertion and removal of the prosthesis. This would represent 6 months to 9 years of clinical function, on the basis of three daily overdenture removals and insertions for hygienic purposes. A common trend toward reduction or total loss in retentive force was found across the majority of the attachment systems.[70] Rutkunas et al concluded that ball-socket attachments have a gradual and continuous loss of retention after repeated insertion-removal cycles. This loss can be abrupt after approximately 500 cycles and may reach 80% of the initial value after 2000 cycles.[68]

Types of Attachment Systems

O-Ring Attachment System

The O-ring attachment system is composed of an elastic O-ring, a metal encapsulator, and a metal post. It may be used as an independent unit or part of a connecting bar that joins the implants together (Fig. 15.50). O-rings are doughnut-shaped, synthetic polymer gaskets that possess the ability to bend with resistance and then return to their approximate original shape. In part, this feature results from a three-dimensional network of flexible elastomeric chains. The O-ring attaches to a post with a groove or undercut area within the O-ring. The O-ring is compressed radially between two mating surfaces consisting of a post and a metal encapsulator into which the O-ring is installed. The O-ring has been used primarily in removable prosthetics as a retentive device and has seen a resurgence in popularity with overdentures supported by endosteal implants and is widely available in a variety of implant systems.[71] The advantages of O-rings are ease in changing the attachment, the wide range of movement, low cost, different degrees of retention, and possible elimination of the time and cost of a superstructure for the prosthesis.

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FIG 15.50 An O-ring attachment has a resilient O-ring gasket *(top right)*, a metal encapsulator *(top left)*, and a male post *(middle)*. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

Range of Motion.

All O-ring applications are categorized in terms of relative motion. In situations that require few or no moving parts or movement, the O-ring is classified as static (e.g., gasket or washer). In situations involving reciprocation, rotation, or oscillating motion relative to the O-ring, it is classified as dynamic. The dynamic movement of the O-ring allows it to be one of the most resilient or mobile types of attachments.

O-rings may allow motion in six different directions. However, if a superstructure connects the implants, the range of motion decreases. If the O-ring is placed on a complete arch bar in four different sites and the prosthesis rests on the superstructure bar, the restoration may have PM of 0 (PM-0). Two O-rings placed on a bar perpendicular to the midline may have two to six directions of PM, depending on the resilient depression of the O-rings, whether a spacer is over the post head, or space is over the connecting bar.

Encapsulator.

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A metal or plastic encapsulator permits the easy replacement of the O-ring after wearing or damage. This eliminates the need for chairside cold curing of a new attachment in place. Virtually every O-ring encapsulator has an undercut region that houses the O-ring, called the internal cavity. The O-ring volume must be larger than the internal cavity. As a result, the O-ring is compressed into position in the encapsulator and prevents the ring from moving or rolling while in place, which prematurely damages and wears the ring. The overall size of the encapsulator is larger than the O-ring and should be placed with the O-ring on the O-ring post during fabrication of the prosthesis to ensure adequate space (>2 mm of acrylic) (Fig. 15.51).

FIG 15.51 The metal encapsulator of the O-ring should fit within the contours of the implant overdenture, so at least 2 mm of acrylic exists around this structure. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

O-Ring Post.

The O-ring post usually is made of machined titanium alloy when used as an independent attachment or a Delrin post that is waxed and cast in metal alloy along with the connecting superstructure bar joining root forms. The three

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components of the post are a head, neck, and body. The head is wider than the neck, and the O-ring is compressed over the head during insertion. Under the head of the post there is an undercut region called the neck or groove that the ring engages after it stretches over the head. The body of the post is connected to the implant abutment or superstructure bar.

Complication.

Overpolishing of a cast post head or neck region may unwittingly cause a decrease in retention of the system. When the attachment is fabricated and cast within the bar system, care should be exercised to not overpolish when finishing.

O-Ring Size.

The inside surface of the O-ring slides over the post neck or groove. The internal diameter (hole diameter) of the O-ring must be smaller than the post neck and fit snugly in the groove diameter. The O-ring inside diameter will be stretched to 1% to 2% (not to exceed 5%) when in place against the post neck.[72] If not, the O-ring will roll or wobble over the post and increase wear and tear of the attachment. O-rings and posts may come in a variety of diameters depending on the space available within the volume of the prosthesis. The larger the diameter of the O-ring system, the easier it is to place the O-ring within the encapsulator. Troubleshooting retention complications is also easier, and greater retention is possible with a larger-diameter system. Typically, three sizes of O-rings are used in implant prostheses (small, medium, and large) (Fig. 15.52).

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FIG 15.52 O-ring size identification. Red line: the height of contour of the ball attachment. Usually the ring selection will be approximately 0.5 mm larger than the measurement. Blue line: the diameter of the retentive zone, which correlates to the size of the O-Ring. (Courtesy Preat Corporation, Grover Beach, CA.)

Complication.

The manufacturer's size protocol should be adhered to for all O-ring systems. Too large of an O-ring size will result in compromised retention and too small of an O-ring will prevent full seating of the prosthesis. Most O-rings are specifically made (e.g., size, retention) for the specific implant and abutment system.

O-Ring Height.

The O-ring attachment system needs a minimum of 5 mm or more height, which is the greatest of any attachments for overdentures. In addition, a space of 1 to 2 mm above the O-ring post is suggested to ensure the ring seats completely over the head of the post. This space also prevents the post from penetrating or fracturing the prosthesis over the head and allows apical movement for a partial soft tissue–supported removable prosthesis (RP-5).

Complications.

The height requirements of the O-ring attachment present several disadvantages. A decreased CHS, which is often present in overdenture cases, may require a lower-profile attachment. A denture tooth, O-ring, post, bar, and hygiene clearance often require at least 12 to 15 mm of CHS to allow sufficient room for the acrylic base of the restoration to resist fracture. In addition, the higher the freedom of movement of a stress-relief attachment

(required for all partial soft tissue–supported prostheses), the greater the moment of force on the attachment. Because the rotation point of O-rings is at the neck of the O-ring post, the point of rotation is not as high as first perceived. However, if the prosthesis is made incorrectly and places lateral forces on the post, the lever arm of the post height can increase the force to the bar, screws, implants, and bone.

O-Ring Hardness.

O-ring hardness can be measured with a durometer, which measures surface resistance to the penetration of an indentation point. The resultant numerical rating of hardness ranges from 0 to 100. The softest O-rings will range from 30 to 40, and the hardest are 80 to 90. Color is not indicative of hardness as this is dependent on the manufacturer.[72]

O-Ring Materials.

The US Food and Drug Administration has issued guidelines for O-rings used in medicine. The elastomeric materials meeting these requirements include silicone, nitrile, fluorocarbon, and ethylene-propylene. The materials are available from a variety of industrial manufacturers.[72]

Complications.

The clinician should be aware of the type of O-ring material used. Silicone is composed of a group of elastomers made from silicone, oxygen, hydrogen, and carbon. Silicones are known for their retention of flexibility and low-compression set characteristics. Silicones are also fungus resistant, odorless, tasteless, and nontoxic. However, poor tensile and tear strength, low abrasion resistance, and high friction characteristics preclude silicones from effective O-ring use in most implant dynamic situations. In addition, silicone is not compatible with petroleum-based products such as petroleum jelly.[73] Ethylene-propylene is a copolymer of ethylene and propylene, sometimes combined with a third comonomer. Similar to silicone, this elastomer performs poorly when exposed to petroleum-based products.

Nitrile is one of the more widely used elastomers for implant O-ring use. Nitrile combines excellent resistance to petroleum-based products, silicone greases, water, and alcohols, with a good balance of desirable properties such as high tensile strength and high abrasion resistance. Fluorocarbon also combines excellent resistance to petroleum products with outstanding

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chemical resistance. Fluorocarbon-based compounds approach the ideal for a universal O-ring material.[74]

Surface treatment of O-rings with lubricants helps protect them from abrasion, pinching, and cutting during performance. External lubrication also helps seat the O-rings easily into the metal encapsulator with minimal twisting or damage and maximal assembly speed. In all cases requiring O-ring lubrication, a lubricant should be selected that is compatible with the O-ring compound and the oral environment. Nitrile O-rings may be lubricated with petroleum jelly or petroleum-based ointments. Petroleum-based products will damage silicone O-rings, so a water-based lubricant (e.g., KY-Jelly [Johnson & Johnson]) that has a glycerin component should be used.

O-Ring Failure.

O-rings typically fail in their application because of the combined adverse effects of stress and environmental elements (i.e., friction, heat, and swelling).[75] Such environmental factors may be compounded by incorrect O-ring size, improper laboratory technique, installation damage during final component assembly, and failure to properly maintain or lubricate the O-ring.

Extrusion and nibbling.

Extrusion and nibbling occur with forced extension of part of the O-ring into the clearance gap of the metal encapsulator. The problem is identified by O-ring diameter enlargement or many small bites (nibbles) taken from the internal diameter of the O-ring. This results when O-ring materials are too soft, oral fluids degrade the O-ring, or the O-ring is too large for the metal encapsulator. The clinical solution for this problem is to use a harder O-ring material or install a properly sized O-ring.

Spiral failure.

A spiral failure results when certain segments of the O-ring slide while other segments simultaneously roll (Fig. 15.53). At a single point on its periphery, the O-ring gets caught on an eccentric component or against the metal encapsulator wall, causing twisting, spiraling, or surface cuts. Problem sources include an uneven surface or finish of the post by the laboratory, inadequate lubrication, or excessive O-ring material softness. The suggested solutions are evaluation of the post to ensure that it is not out of round, increasing O-ring hardness, and making sure the patient uses a lubricant

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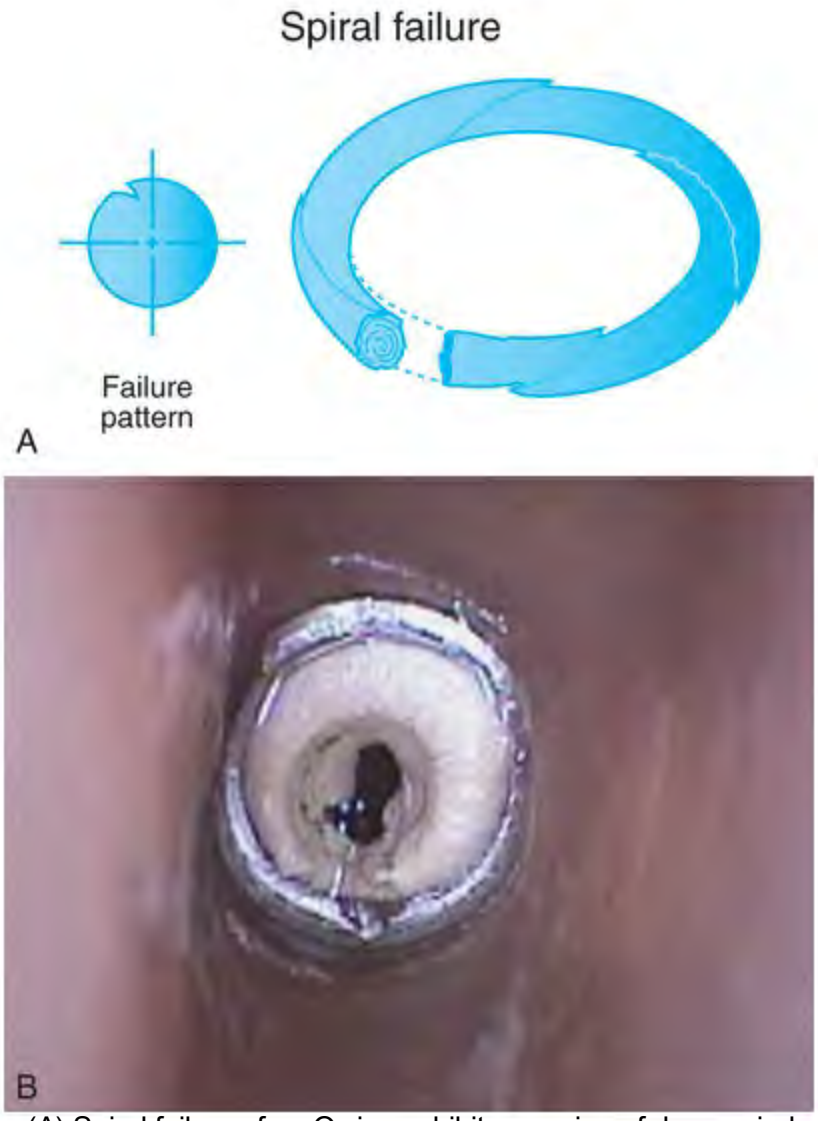

FIG 15.53 (A) Spiral failure of an O-ring exhibits a series of deep spiral cuts on the surface. (B) Clinical image of O-ring failure. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Abrasion.

Abrasion may occur in dynamic O-rings involved in reciprocating, oscillating, or rotary motion. This failure pattern can be identified by a flattened, worn surface on the inner diameter of a cross section of the O-ring. The most common cause is bruxism by the patient or lifting and seating of the overdenture as a nervous habit. Another source of the problem includes a rough metal surface on the post (acting as an abrasive). The suggested

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recommendations are to use metal finishes; change to a more abrasion-resistant O-ring material (nitrile); or eliminate abrasive contamination, which may be found in the diet (e.g., the abrasive particles found in chewing tobacco).[76]

Compression set.

Compression set failure produces flat surfaces on both sides of the cross section of the O-ring (Fig. 15.54). The most common cause of this type of failure is parafunctional clenching on the prosthesis. Other problem sources include selection of an elastomer with poor compression set properties or excessive “squeezing” or biting of the prosthesis into place to seat the restoration. The suggested solution is to make sure the prosthesis is removed at night or to reduce the O-ring hardness, which reduces the compression required to insert the prosthesis.

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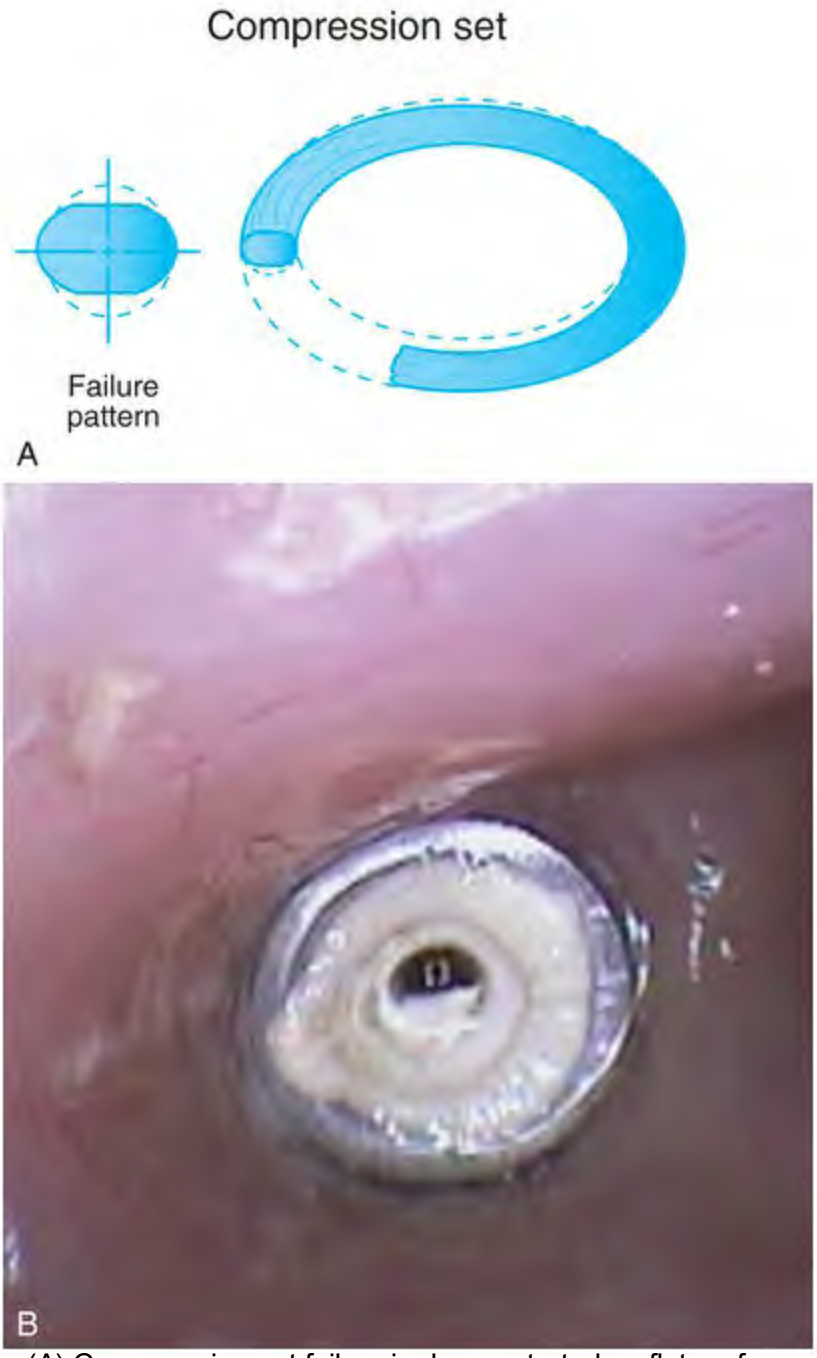

FIG 15.54 (A) Compression set failure is demonstrated as flat surfaces on the top and bottom of the O-ring. (B) Clinical image of O-ring failure. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Installation damage.

Installation damage is one of the most common types of O-ring complications. This failure mode is marked by short cuts, notches, or a skinned or peripherally peeled surface. The problem sources include sharp edges on the encapsulator from poor laboratory technique, sharp edges on the O-ring post head, too large an O-ring for the encapsulator, twisting or

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pinching of the O-ring into the encapsulator, attempting to insert the O-ring with a sharp instrument, too small an O-ring for the post, or lack of O-ring lubrication during installation. The suggested solutions include installing properly sized O-rings, using a blunted insertion instrument, and using lubrication during assembly (Fig. 15.55).

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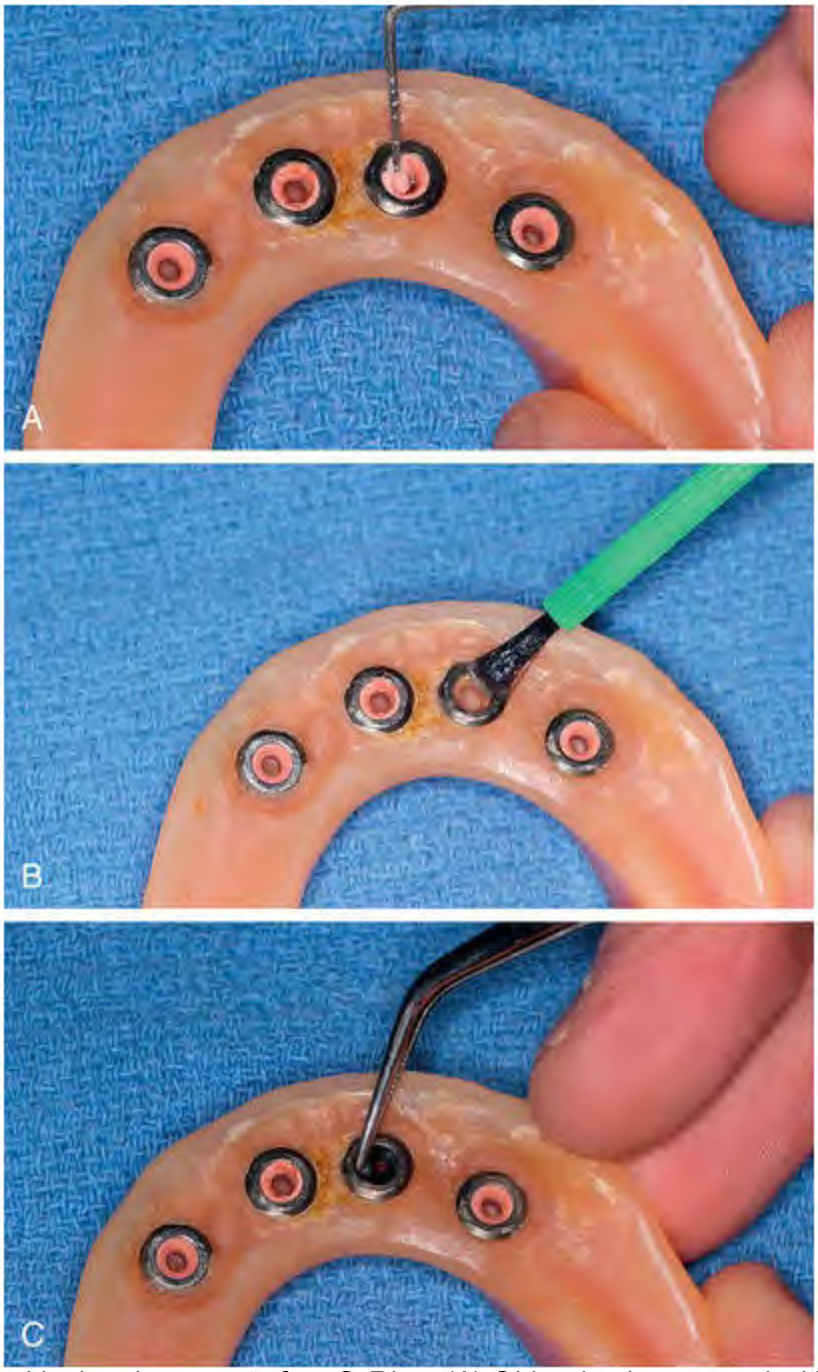

FIG 15.55 Ideal replacement of an O-Ring. (A) Old o-ring is removed with explorer, (B) Water soluble lubricant is added to metal encapsulator, (C) O-ring is squeezed and easily slips into encapsulator.

Locator Attachment

The Locator attachment system (Zest Anchors) has been available in implant dentistry since 2000. The Locator attachment has become one of the most popular attachments in implant dentistry today. The advantages of the Locator include the ease of insertion and removal, dual retention capabilities,

low vertical profile, ability to pivot, toleration of implant divergence, and increased resiliency. Although this attachment system is associated with a similar incidence of prosthodontic complications as other attachment systems, these problems seem to be simpler and easier to resolve. Studies have shown the most common issues that dentists report concerning the maintenance and repair of Locator attachments were inadequate remuneration, lack of training, experience, and equipment.[77] The inherent advantages of the Locator attachment include:

Self-Alignment.

One of the most common complications of Locator implant attachments involves distortion of the overdenture attachments from malalignment of the male and female components. Many patients prefer to "bite" the overdenture into place, causing damage to the attachments. To avoid this complication, the locator was designed to be self-aligning. This is accomplished by the rounded contours of the female attachment (in the mouth) and the nylon male (in the overdenture). The skirt of the male attachment is guided into position, similar to guide planes on a partial denture.

Dual Retention.

Another important quality of the Locator attachment is the "dual retention" of the attachment. The nylon male attachment engages both the inside and outside of the female attachment. The retentive surface area is doubled with respect to other types of attachments. This feature allows for greater longevity of retention (Fig. 15.56).

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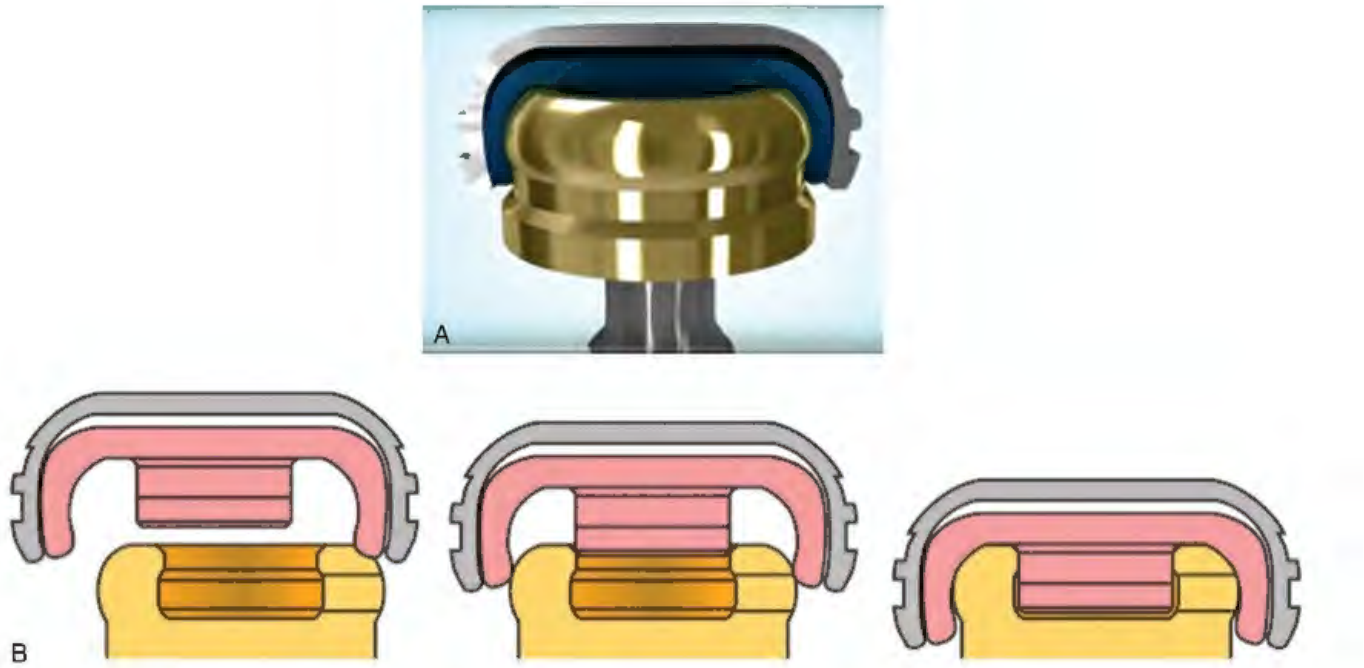

FIG 15.56 (A) Dual retention of the Locator attachment. (B) Self-aligning advantage of Locator.

Attachment Divergence.

A common complication of overdenture attachments is a divergence between implants that prevent the prosthesis from seating completely. With the Locator attachment, the nylon male insert is allowed to pivot within the metal housing. The pivotal advantage allows the standard male to accommodate 10 degrees each, for a total of 20 degrees between implants. In cases with extended divergence, there are extended range male attachments that allow for divergence of 20 degrees each or a total of 40 degrees. Studies have shown with this tolerance for divergence, retention may reach up to 60,000 insertion/removals.[78]

Resilient Function.

The locator is one of the most resilient attachments used in implant dentistry. The resiliency allows movement between the prosthesis and the implant, allowing and transferring stress from the implants to the tissue bearing areas. The male remains in static contact with the female socket while the metal housing has a full range of rotational movement over the male.

Use in Cases With Lack of Interocclusal Space.

A common problem that leads to prosthesis fracture is the lack of

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interocclusal space. If insufficient space is available, increased complications will result. This occurs because of inadequate acrylic thickness, overcontoured prosthesis, and increased susceptibility to breakage. The Locator metal housing with nylon male inset requires approximately 2.27 mm above the tissue, and the female abutment needs to extend only 1.5 mm above the tissue for the male element to seat without impinging on the tissue. With external hex implants a minimum of 3.2 mm is required; 2.5 mm is required for internal hex implants. Locator female abutments are also available in 0 mm connections for flat-top connection implants.[79] With a total attachment height of only 3.17 mm (male plus 1-mm collar abutment) for an externally hexed implant, the Locator attachment has been shown to save a minimum of 1.68 mm to 3.05 mm of interocclusal space compared to other implant overdenture attachments (Fig. 15.57).

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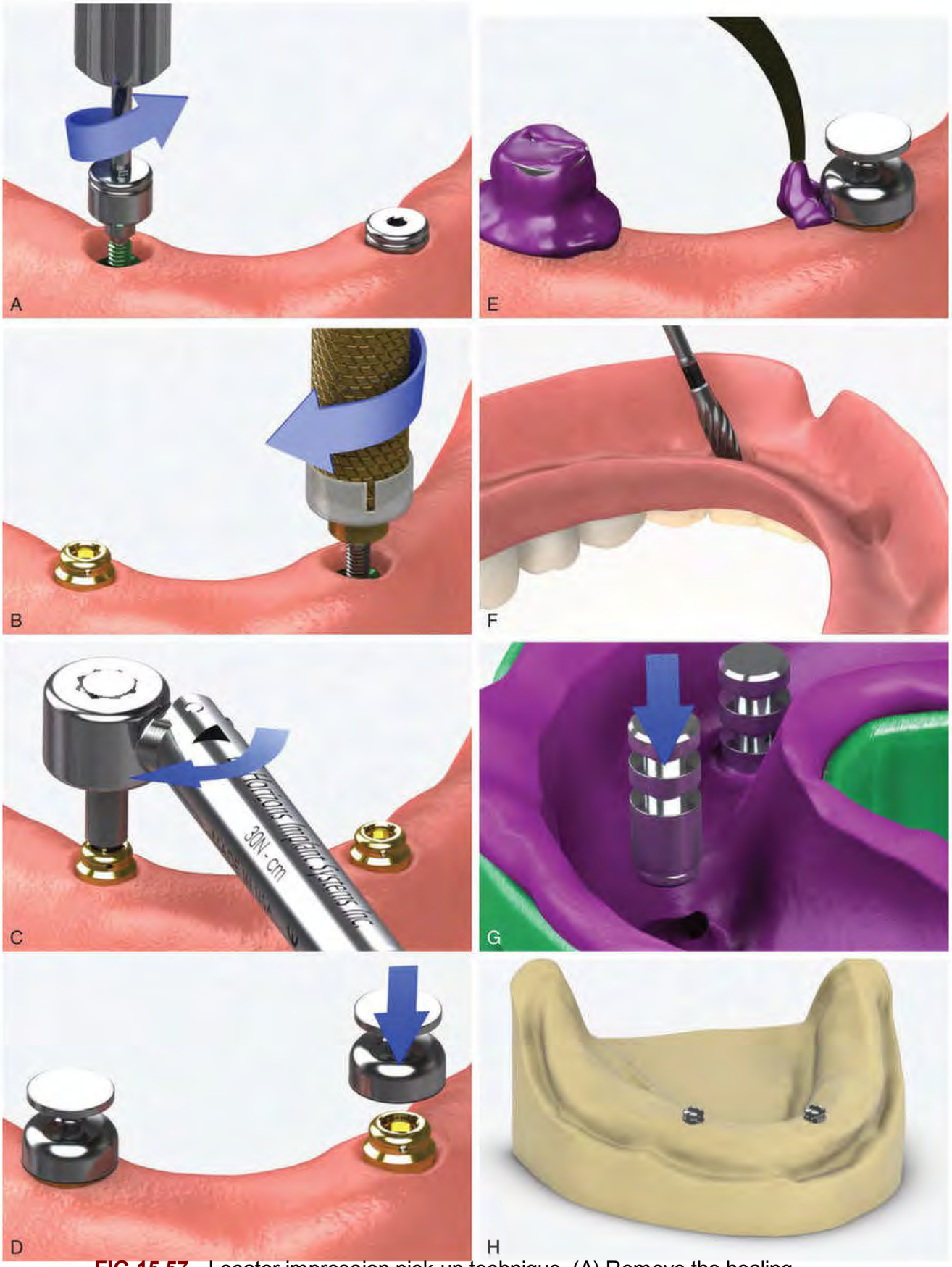

FIG 15.57 Locator impression pick-up technique. (A) Remove the healing abutments and confirm that the prosthetic platforms are free of any bone debris or soft tissue. (B) Place Locator abutment onto each implant using the Locator hand

driver with a Locator abutment holder. Hand tighten. (C) Each Locator abutment is torqued to 30 Ncm using a calibrated torque wrench and a Locator square drive tool. (D) Impression coping snapped onto each Locator abutment. (E) Impression is made to pick up the impression copings and to record all soft tissue contours for the new denture fabrication. The impression copings will remain in the impression when it is removed. (F) Denture base is relieved, must have verification that abutment has no contact with denture base. (G) The Locator female analogs are placed into the impression. (H) Final master cast.

Available in Multiple Abutment Heights.

The abutment should be selected that results in a minimum of 1.5 mm above the tissue. If less height is available, the male attachment will not be able to seat completely. The clinician should measure the deepest portion of the implant to tissue crest in determining the height selection. The Locator attachment is available for use with most implant systems. The abutments are available in numerous tissue heights ranging from 0 to 6 mm in 1-mm increments. Ideally, 1.5 mm of the abutment should be above the tissue. The tissue cuff height measurement must be taken at each implant site using the deepest side of the tissue for measuring from the apical shoulder of the implant to the crest of the tissue. The working portion of the Locator abutment is at or slightly above the gingival level.

Locator Core Tool.

When replacing Locator attachments, care should be exercised to use the Locator tool. Use of any other type of placement tool will lead to damage to the attachments. The Locator Core Tool may be utilized for three different purposes:

1. Insertion the female abutments: The abutment retention sleeve is used to secure the female abutment during insertion. The sleeve is placed over the end of the abutment driver and the Locator female is then placed through the sleeve.

2. Removal of processing males (used during the retrofitting step to lock the position of the metal housing inside a denture base): To remove processing or worn nylon males, the male removal tool is slightly unscrewed from the middle section of the male removal tool.

3. Removal of worn males and insertion of new male attachments: The

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inverted conical tip is inserted into the worn male and pulled straight back for removal. The male removal tool is then screwed completely into the middle section to protrude the plunger and kick off the male insert. A new nylon male is placed on the middle male seating section and inserted into the metal housing (Fig. 15.58).[79]

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FIG 15.58 Chairside pick-up of locator attachment. (A) Locator abutment placed onto each implant using the Locator hand driver with a Locator abutment holder. Hand tighten. (B) A white block-out spacer is placed over the head of each Locator abutment. This blocks out the area immediately surrounding the abutment allowing

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the full resilient function of the pivoting metal denture cap over the Locator male. A Locator cap with a black processing insert is placed on each Locator abutment. (C) Denture base is hollowed out to accommodate the protruding Locator males. There must be no contact between the denture and the titanium caps. If the denture rests on the metal cap, excess pressure on the implant will result and the prosthesis will be ill-fitting. Lingual vent holes should be made for excess acrylic to escape. (D) A chairside light cure acrylic resin or a permanent self-curing acrylic is used to bond the denture caps to the denture. A small amount of a material of choice is placed into the recessed area of the denture and around the denture caps. Seat the prosthesis, verify occlusion. (E) After the acrylic has cured, the denture is removed and the white spacer is discarded. Voids are filled with acrylic and the excess is removed. (F) The black processing male is removed from the denture cap with the use of the Locator male removal tool. (G) The Locator core tool is used to firmly push a Locator male retention insert into the denture cap. The retention insert must seat securely into place, level with the rim of the cap. (H) Removal of the prosthesis, verify occlusion, and polish.

Hader Bar and Clip

Helmut Hader, a master dental technician, developed the Hader bar and rider system in the late 1960s, and this system was unchanged for almost 30 years. English, Donnel, and Staubli modified the system in 1992 to form the Hader EDS system.[80] The Hader bar system involves a semiprecision bar attachment that provides hinge movement. The function of the bar is based on the principle of mechanical snap-retention technology (Fig. 15.59).

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FIG 15.59 (A) Hader Bar. RP-4 bar with posterior cantilever Hader bars. (B) Hader clips. (B, Courtesy Preat Corporation, Grover Beach, CA.)

Complications

Bar position.

A common complication arises when two implants are positioned in the A and E positions and connected with a bar. Because the implants are placed farther distally than the ideal B and D position, the bar will need to be placed lingually and possibly would interfere in the tongue space. This may create problems with speech and possible fracture of the prosthesis. If implants are placed in a diagonal position (A → D or B→ E), friction-free movement will not be possible, which will result in excessive pressure and force on the implants. Ideally, the bar should be perpendicular to the line that bisects the angle formed by the most distal implants.

Clip assembly.

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The ideal length for a clip bar is 20–24 mm to accommodate two clips and housings. If less space is available, inadequate retention will result. The clips have three different retention strengths and a 20-degree clip rotation, which greatly improves the flexibility of the system for a range of patient needs or desires. In addition, a gold-plated stainless steel housing maintains the clip, which reduces the need to cold cure new attachments in place. This is a significant advantage because the gold plating minimizes the color bleeding through the prosthesis. The Hader bar and clip is a type 2 attachment and may be used for PM-0 or PM-2 treatment plans.

The standard or EDS Hader bar has a round superior aspect and an apron toward the tissue below. The apron acts as a stiffener to improve the strength of the bar and limit its flexibility. Round bar designs flex in relation to x^4 (x to the 4th power). In other words, a bar twice as long flexes $2 \times 2 \times 2 \times 2 = 16$ times more. Other bar shapes flex to x^3 or $2 \times 2 \times 2 = 8$ times more. This is a considerable improvement. The height of the apron or stiffener is related to the amount of clearance between the bar and gingiva.

There are three color-coded clips/riders with three retentive strengths. In order, from lightest to strongest, they are white, yellow, and red. The use of metal housings with Hader plastic clips/riders is recommended. In addition to plastic clips/riders, the adjustable gold alloy clips/riders are an available option.

Design/movement.

Because of poor design, Hader clips may wear prematurely. The clip rotation compensates for the resilience of the posterior soft tissue, which is usually 0.5 to 1 mm in the mandible. Highly mobile tissue, more often seen in the maxilla, requires a greater range of clip movement. For a bar and clip to rotate, several important design features must be considered. For example, the bar should be aligned perpendicular to a line bisecting the angle between the posterior arches and should be parallel to the plane of occlusion.[81]

Interocclusal space.

Whereas the EDS bar is only 3 mm high, the original was 8.3 mm in height. The total height of the Hader bar and clip assembly may be as low as 4 mm rather than the 5 to 7 mm required for an O-ring system. A greater moment of force is placed on the bar during rotation, and clearance is required under the denture base. However, the increase in CHS above the attachment may make the prosthesis less stable to lateral loads for PM-2–type prostheses (Fig.

15.60).

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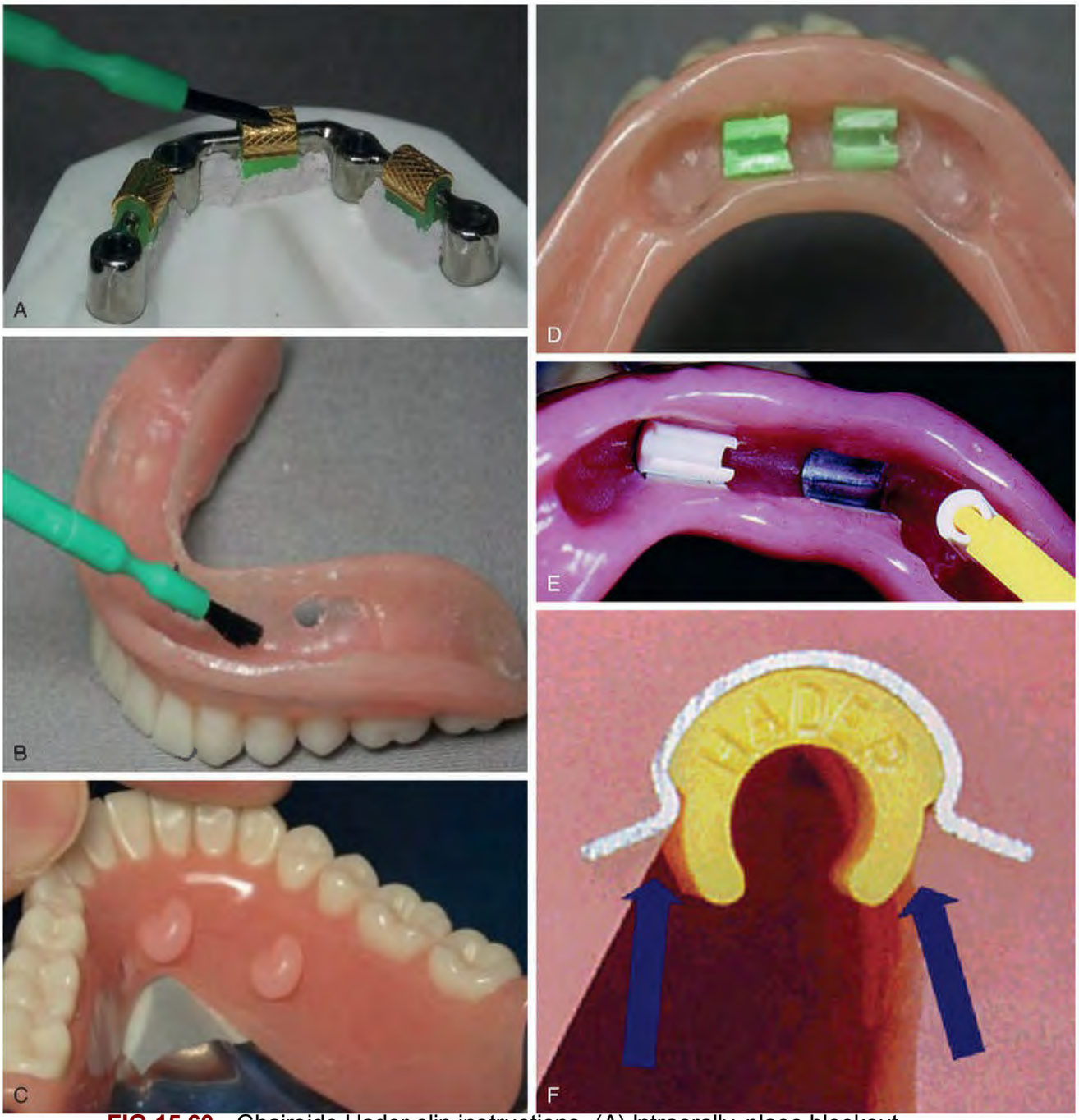

FIG 15.60 Chairside Hader clip instructions. (A) Intraorally, place blockout compound and the green processing spacers. (B) Relieve denture and prepare a lingual escape vent. (C) Place self-cure acrylic in the prosthesis (only about 1/4 of the relief area should be filled) and on the housings. Seat the prosthesis. Do **NOT** have the patient bite the prosthesis into place as this may displace tissue and distort attachment alignment. (D) Prosthesis with cured green processing spacers. (E) Remove green spacers and place clip into metal housing. (F) *Note:* right side has room for clip to flex (green spacer used) and left side does not allow clip to flex, which will prevent proper seating (no green space used).

Dolder Bar

The Dolder bar is a prefabricated precision bar attachment developed by Dr Eugen Dolder in Switzerland. This bar system comes in two different forms: (1) rigid: a U-shaped bar with parallel walls; and (2) resilient: egg-shaped form in cross section, which provides vertical and hinge resiliency.

The Dolder bar and its metal sleeve are made of gold alloy (Elitor) and is adjustable so the clinician can control the amount of retention provided by the bar. The Dolder bar is usually soldered to the abutments, and the sleeve should be secured in the denture base with self-cure acrylic.

The Dolder bar is usually used in patients who have increased crown height space and when a minimum resiliency and maximum retention is indicated. There are various sizes ranging in height from 2.3 to 3.0 mm and in width from 1.6 to 2.2 mm (Fig. 15.61).

FIG 15.61 Dolder bar. Multiple Dolder bars turning prosthesis into a PM-0.

Complications.

The complications associated with a dolderbar/clip are similar to the Hader bar/clip.

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Miscellaneous Removable Complications

Bar Try-in Resulting in Pain

In certain clinical situations, when trying in the bar, the patient may experience pain. The pain may originate from many different areas (Fig. 15.62).

FIG 15.62 Bar try-in may cause pain upon insertion.

Etiology

Nonpassive Prosthesis.

Nonpassive prosthesis (i.e., ill-fitting) can be due to poor impression technique, laboratory error, or milling or casting discrepancy.

Incorrect Placement.

Incorrect insertion placement can occur, especially when placing the bar where there is deep sulcular tissue present. This will result in the bar not being able to be seated fully.

Loose Abutment.

If the abutment is loose or not fully seated, trying-in the bar may result in pain.

Poor Bone-Implant Interface.

Although there is no innervation to the implant, if the implant is failing, pain may result from the infected or inflamed fibrous tissue interface.

Impingement on Tissue.

Trying-in a bar with tissue collapse (i.e., soft tissue impeding the seating) will result in pain from the tissue (Fig. 15.63).

FIG 15.63 Bar insertion. Screws should be initially inserted ½ the length of the screw in the following order: # 1, center; # 2 and # 3, terminal abutments; # 4 and # 5, in between the center and terminal abutments.

Prevention

Always tighten abutments prior to try-in, making sure no tissue collapse is present that would impede placement.

The bar should be tried-in in the following sequence:

1. Place bar over abutments or implant bodies and evaluate for stability

2. With insertion driver, hand tighten center screw (½ screw length)

3. Hand tighten terminal screws (½ screw length)

4. Place and hand tighten the remainder of screws (½ screw length)

5. Evaluate margins between bar/abutment

6. All screws should then be sequentially tightened and torqued to manufacturer's recommendations (Fig. 15.64)

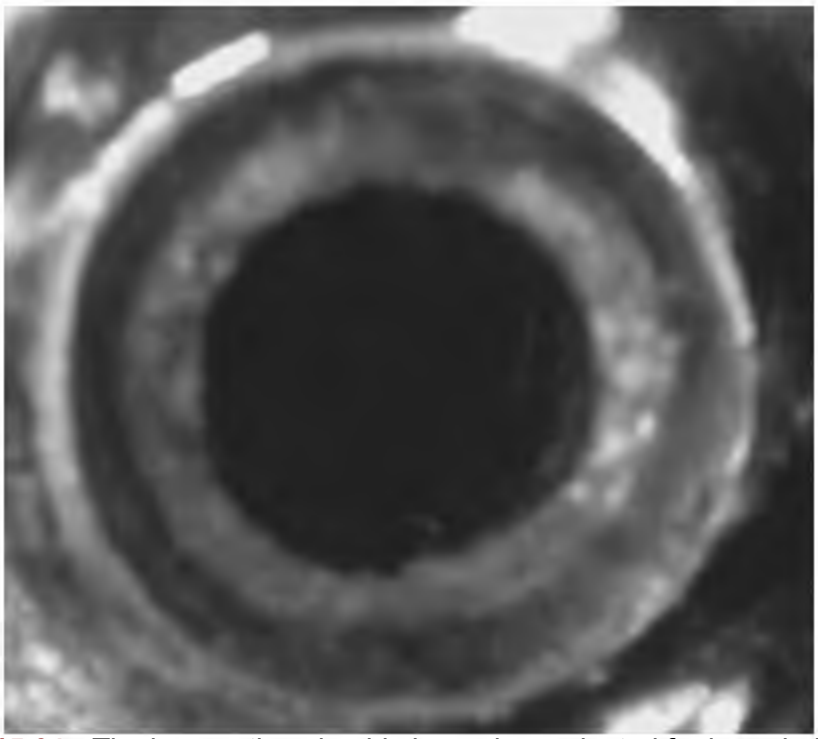

FIG 15.64 The bar casting should always be evaluated for irregularities.

Note: If there is any rocking present or open margins, the bar is nonpassive and should be sectioned /soldered or redone.

Treatment

Nonpassive Bar.

Fabricate new bar or solder (e.g., bar is sectioned, all screws fixated, luted together with GC Pattern Resin or impression plaster, pick-up impression).

Incorrect Placement.

Reinsert with ideal path of insertion.

Loose Abutment.

Tighten abutments prior to bar try-in; verify with radiographs to ensure complete seating.

Poor Bone-Implant Interface.

Evaluate implants for possible failure (i.e., radiographic evaluation).

Impingement on Tissue.

Remove tissue with tissue punch bur.

Gingival Inflammation Around Bar

When a bar is fabricated and placed too close to the tissue, gingival hyperplasia may result. This will lead to a chronic inflammatory complication that may be painful and result in bleeding with possible bone loss (Fig. 15.65).

FIG 15.65 Hyperplastic tissue. Excessive tissue growth due to lack of space between bar and tissue.

Etiology

Ideally, there should exist 1 to 2 mm or more of space between the bar and the tissue surface. This will allow for adequate space for hygiene. Less than 1

to 2 mm of space results in plaque and calculus accumulation and will complicate oral hygiene maintenance. If the bar is fabricated to be in direct contact with the tissue, compression of the mucosa will initiate a hyperplastic response.

Prevention

To prevent this complication, a minimum of 1 to 2 mm is needed between the bar and soft tissue. This will allow for self-cleansing of the area along with decreasing the possibility of tissue inflammation and discomfort.

The ideal spatial relationship of the bar should be over the crest of the ridge. If the bar is positioned facial, this will result in possible prosthesis fracture. Bulk acrylic (2 mm) is required for minimal strength. Additionally, if the implants are positioned too far labial, there will be lack of attached tissue, which may result in chronic tissue soreness. A lingual positioned prosthesis will result in interference with the tongue space leading to speech and mastication complications.

Treatment

The hyperplastic tissue should be removed with a scalpel (gingivectomy) or laser. Care should be exercised to not use an electrosurgery unit because this will result in sparking and resultant hard and soft tissue damage. Additionally, iatrogenic damage of the implant titanium surface should be avoided because it could harbor plaque and enhance gingival tissue inflammation.

Prosthesis With Lack of Soft Tissue Support for RP-5

The clinician must understand the inherent differences between a RP-4 and an RP-5. Because the RP-5 is soft tissue–supported (buccal shelf), it is mandatory the prosthesis have adequate flange support, mainly in the primary stress bearing area (maxilla: horizontal palate; mandible: buccal shelf). If the primary stress-bearing area is not utilized, the prosthesis will be loaded as an RP-4, completely soft tissue–supported (Fig. 15.66).

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FIG 15.66 RP-5 lack of tissue support. No buccal shelf support increases movement and rocking of the prosthesis.

Etiology

If extension is not utilized in the prosthesis to encompass the primary stress-bearing areas, the implants will be overloaded. A common error is an RP-5 mandibular treatment plan (two or three implants) that has insufficient soft tissue support. This will result in overstressing the implants, leading to increased morbidity and/or bone loss.

Prevention

Maxillary.

For RP-5 prostheses the horizontal palate should have ideal primary stress-bearing coverage. An RP-5 must be a full-coverage prosthesis (no horseshoe design) (Fig. 15.67). A RP-4 (i.e., more implants) would be indicated if a horseshoe palate is required.

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FIG 15.67 Maxillary RP-5 should always have full palatal support.

Mandibular.

For mandibular RP-5 prostheses, the buccal shelf should have adequate coverage because this is the primary stress-bearing area. The buccal shelf is a flat area in the mandible bounded by the crest of the ridge (medially), external oblique ridge (laterally), and retromolar pad (distally; Fig. 15.68). This area has a thick submucosa and lies perpendicular to the occlusal plane.

FIG 15.68 Mandibular RP-5 should have peripheral extensions similar to a complete denture.

Denture Teeth Fractures/Debonding

With overdentures, if insufficient space exists, the prosthesis is more prone to fracture. Denture or composite teeth may "pop-off" for a number or reasons (i.e., most common is the lack of sufficient acrylic). Repairing a fracture or adding a denture tooth is often a time-consuming and difficult procedure.

Etiology

When insufficient space is available for acrylic (<2 mm), this will result in denture base fracture or teeth debonding. It is common for laboratory technicians to hollow out denture teeth to gain additional space. However, this results in the possibility of the denture teeth fracturing or debonding from the prosthesis. Denture teeth may become debonded from lack of mechanical retention (Fig. 15.69).

FIG 15.69 Denture teeth debonding. When there is a lack of acrylic, denture teeth may fracture or become unbounded from prosthesis.

Prevention

Bulk of Acrylic.

Acrylic is always stronger in bulk. A minimum of 2 mm of acrylic should be maintained. In some situations a different attachment system may need to be

removed. Approximately 15 mm of space is needed for an implant bar overdenture with Hader bar or O-Rings.

Verify Occlusion.

The occlusion should always be verified to maintain an even distribution of masticatory force. Any prematurities should be eliminated and frequent recall examinations should be part of the postoperative care.

Increase Mechanical Retention.

Usually, it is difficult to add mechanical retention into a denture tooth as this will lead to stress fractures. Diatoric retention may be utilized with PERMA RET system, which involves placing a metal wire into the denture tooth for mechanical retention (Fig. 15.70).

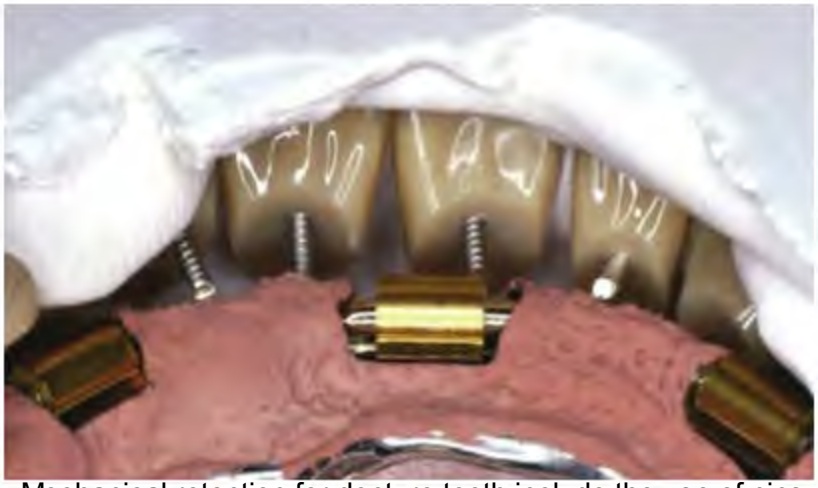

FIG 15.70 Mechanical retention for denture teeth include the use of pins placed into the lingual aspect of the teeth. (Courtesy Preat Corporation, Grover Beach, CA.)

Overdenture Fractures

A significant and often embarrassing complication that may occur is the fracture of an overdenture base. This often will result in loss of confidence in the doctor by the patient.

Etiology

Occlusal Force.

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Excessive occlusal force may result in fracture of the denture base. Ideal occlusion and even distribution of force is mandatory. If warranted, an occlusal guard should be fabricated.

Thin Acrylic Base.

When compromised acrylic thickness is present, this will most likely result in microfractures and resultant denture base fracture.

Prevention

Strengthen the Denture Base.

The denture base may be strengthened with the use of acrylic or meshwork. This will result in fewer fractures to the denture base (Fig. 15.71).

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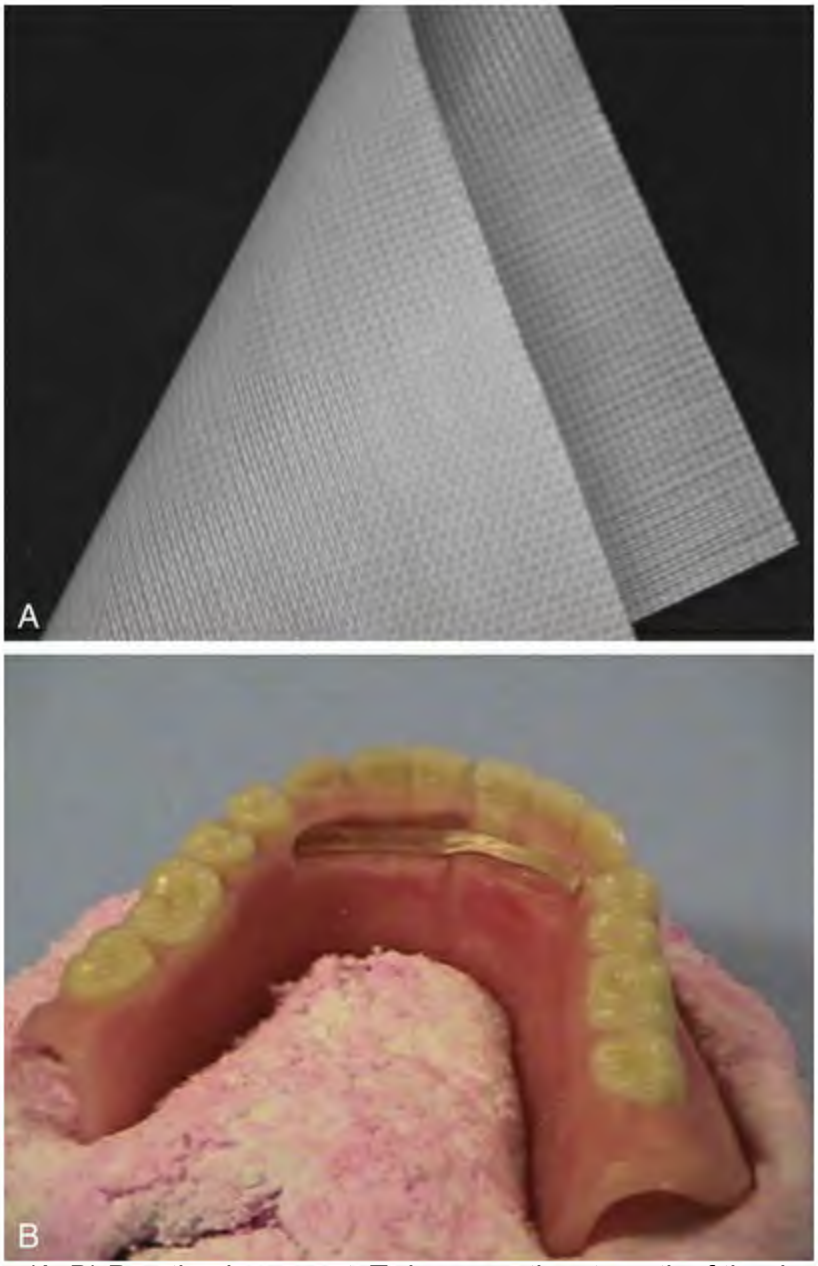

FIG 15.71 (A–B) Prosthesis support. To increase the strength of the denture base, fiber mesh or rods may be processed inside the prosthesis. (Courtesy Preat Corporation, Grover Beach, CA.)

Treatment Planning.

For an overdenture, always make sure there is sufficient room for attachment or bar with adequate acrylic thickness (Fig. 15.72).

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FIG 15.72 Overdenture fracture due to lack of acrylic support.

"Locking" Denture Under Bar Locking Prosthesis in

When picking up attachments (i.e., cold or light cure) for an overdenture, sometimes locking the prosthesis under the bar will occur. This may lead to significant complications and morbidity.

Prevention

A block-out material should always be used. It is recommended to use a cellulose-based caulking and block-out material that is syringe delivered (e.g., Perma Block [Preat Corporation]). These materials will adhere to wet surfaces such as gingival and mucosal tissues.

This material will block-out the undercuts during attachment pick-up or impression procedures. Its heavy body will prevent displacement, which may allow encroachment of the autopolymerizing material into the sulcus. An air-water syringe along with a brush will assist in removal (Fig. 15.73).

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FIG 15.73 Block-out compound should be used anytime attachments are cold cured within the mouth. The compound works very well in moist conditions.

Treatment

If the denture is locked under the bar/attachment, careful access to the undercut can be obtained via the use of a diamond bur with excess irrigation. This is most likely in the lingual aspect of the flange, directly over the attachment in question.

Food Impaction

Etiology

A common compliant of mandibular overdentures is food impaction. Because the flanges of the prosthesis do not extend to the floor of the mouth in the rest position (to eliminate sore spots caused by elevation of the floor of the mouth during swallowing), openings allow for food accumulation under the prosthesis. During mastication, food debris migrates and become impacted under the prosthesis during swallowing. A similar condition is found with a traditional denture. When a lower denture "floats" during function, the food more readily goes under and then through the prosthesis; however, the IOD will trap the food debris against the implants, bars, and attachments.

Prevention/Treatment

Highly polished borders of the prosthesis should be completed because less food will tend to accumulate. The patient should be informed of food impaction prior to implant placement. An RP-4 will tend to accumulate more food impaction because of more implants, larger space at the tissue level, and the ease of food accumulating around the bar (Fig. 15.74).

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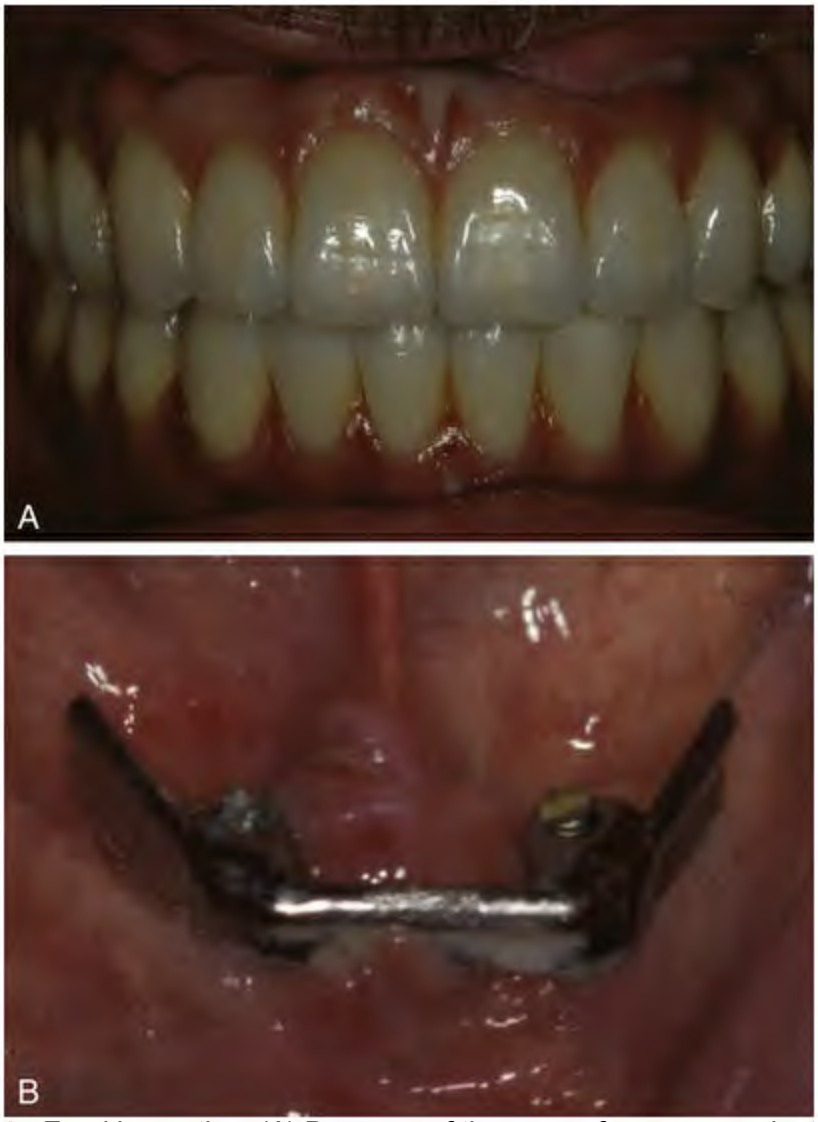

FIG 15.74 Food impaction. (A) Because of the space from an overdenture, food may easily accumulate underneath. (B) Food debris is difficult to remove from under the bar.

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Fixed Prosthodontics Complications

Randolph R. Resnik

Dental implants have been shown to have excellent clinical survival; however, many longitudinal studies have shown an increased incidence of biologic and technical complications when compared with tooth-borne full coverage restorations.[1] As dental implants are becoming more and more popular, the implant clinician must be cognizant of potential prosthetic complications that may ensue. In this chapter, a wide range of fixed prosthetic complications will be discussed. These include biomechanical force–related complications, prosthesis complications, intraoperative complications, esthetic complications, and postoperative complications. By having an understanding of the guidelines established to prevent, identify, and treat these numerous fixed prosthetic complications, an implant dentist can significantly improve clinical outcomes while reducing the overall stresses of daily practice life.

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Biomechanics: Force-Related Issues

Biomechanical stress, which is responsible for a majority of dental implant complications, most commonly occurs from occlusal function. Most biomechanical complications do not occur as a result of a single force event because they typically develop over time. This repetitive force, which is applied to the various dental materials that make up the prosthesis, follows a fatigue curve. The fatigue curve is directly related to the number of cycles and the intensity of the force.[2] When lower-force magnitudes repeatedly contact an object, the force can eventually exceed the endurance limit and fracture of the material will result (Fig. 16.1). For example, a wire coat hanger that is bent does not break the first time, but repeated bends will fracture the material—not because the last bend was more forceful but because of the resultant fatigue. This same principle applies to dental implants and is why the most common cause of implant and prosthesis component complications are related to biomechanical conditions that give rise to fatigue.[3]

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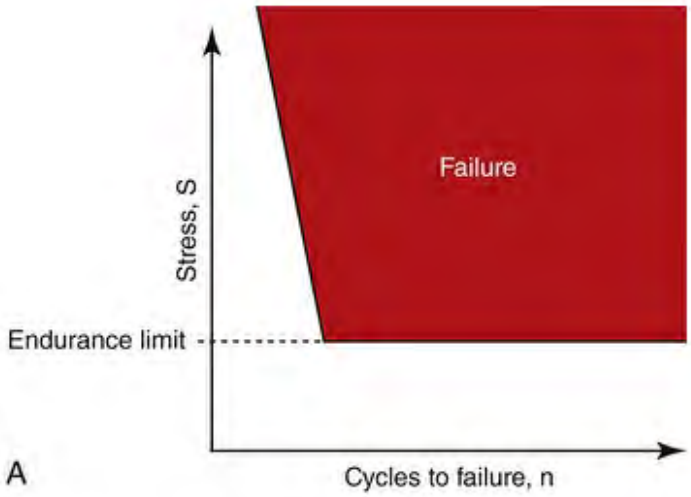

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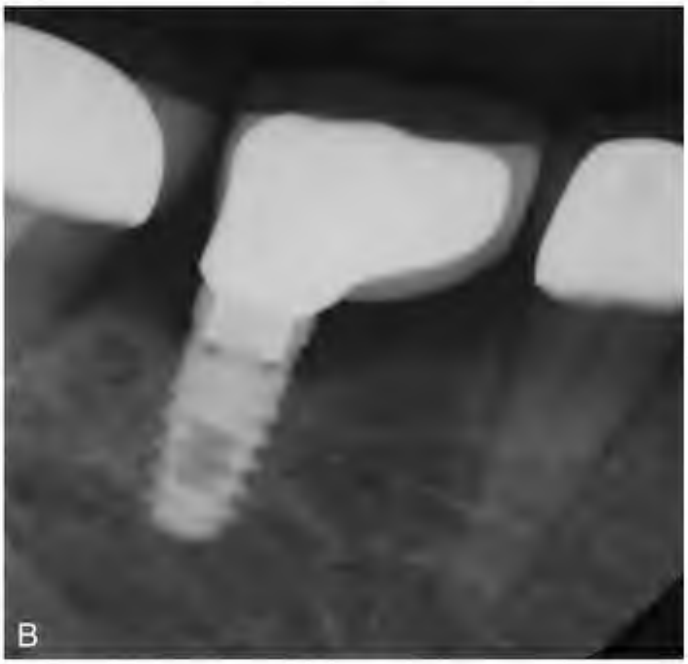

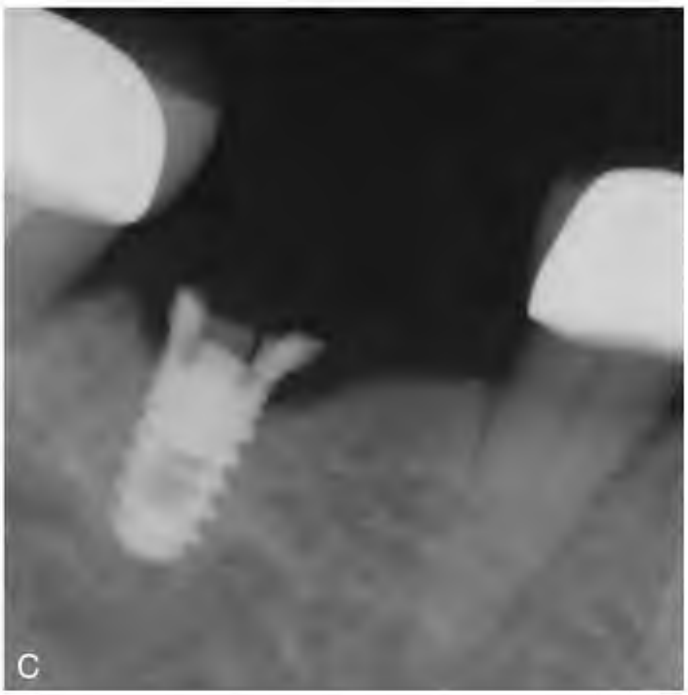

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FIG 16.1 (A) When stress is plotted on the y-axis and cycles to failure are plotted on the x-axis, the fatigue curve of a material may be established. Any stress condition above the endurance limit will eventually cause fracture when enough cycles are applied. (B–C) Force-related fractured implant (i.e., cantilevered prosthesis and small diameter implant).

Screw Loosening

Abutment screw loosening has been shown to be associated with an overall average of 6% of implant prostheses fabricated.[3] Screw loosening is the most common implant prosthetic complication, accounting for approximately 33% of all postimplant prosthodontic complications.[4] More recent studies indicate this complication occurs in approximately 8% of single crowns, 5% of multiple-unit fixed prostheses, and 3% of implant overdentures. De Boever has shown that 12% of prostheses exhibit loosening within 3 years,[5] while Chaar has shown an incidence of 4.3% within 5 years and approximately 10% long term (5–10 years).[6]

Screw loosening may cause considerable complications. A loose screw may contribute to crestal bone loss because bacteria are able to colonize and harbor in the open interface. When an abutment screw becomes loose on a cemented crown, the crown may need to be cut off the abutment to gain access to the abutment screw, which results in patient disappointment and unproductive clinician time. If a loose abutment screw is not treated appropriately, fracture of the prosthesis, implant components, or the implant body may occur.

Etiology

External Force Factors (Box 16.1).

External forces that act on a screw joint greatly increase the risk of screw loosening. These forces may be called joint-separating forces when related to screw loosening; however, they are the same forces that are risk factors for implant failure, crestal bone loss, and component fracture. When the external joint-separating forces are greater than the force holding the screws together (called *clamping forces*), the screw will become loose. The external forces from parafunction, crown height, masticatory dynamics, position in the dental arch, and opposing dentition are factors that can dramatically increase the stress to the implant and the screw joint. In addition, conditions that

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magnify or increase these factors are cantilevers, angled loads, and poor occlusal designs.

Box 16.1

External Forces That Increase Screw Loosening

1. Parafunction

2. Crown height space

3. Masticatory musculature dynamics

4. Arch position (anterior, middle, posterior)

5. Opposing arch

6. Cantilevers

7. Angled loads

8. Poor occlusal designs

9. Lack of key implant positions

a. Canine

b. First molar

. Inadequate implant number

a. No three adjacent pontics

. Nonpassive prostheses

. Inadequate Screw Torque

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. Excessive Screw Torque

. Improper Prosthesis Insertion Technique

External forces applied to the joint system are important to account for when the aim is to decrease the incidence of screw loosening. The *endurance limit* of a material is the amount of force required to fracture the object when enough cycles are applied. The greater the force, the fewer cycles required before fracture occurs. It is the combination and relationship of both the amount of force and the number of cycles that is the cause of the screw loosening complication.

Cantilevers/Increased Crown Height Space.

One of the most common etiologic factors that results in screw loosening is excessive continuous occlusal forces. The most common example occurs in prostheses with improper occlusal contacts. The greater the stress applied to the prostheses, the greater the risk of abutment screw loosening. A nonideal prosthetic design may potentiate the force applied. Cantilevers increase the risk of screw loosening because they increase the magnitude of forces to the implant system: there is a direct relationship between the length of the cantilever and force applied to the prosthesis.[7] Any of these external forces applied to a cantilever will further magnify the joint-separating forces. For example, cantilevers on prostheses lead to uneven occlusal loads. Uneven occlusal loads cause repeated cycles of compression and then tension and shear of implant components. Screws are especially vulnerable to tensile and shear forces. Both of these are dramatically increased with cantilever forces or angled loads. Because the screw is an inclined plane, the continued vibration causes it to unthread. The greater the range of external forces, the fewer the number of cycles necessary before screw loosening.

When an increased crown height space exists (poor crown-implant ratio), there is a resultant greater force applied to the screw. This usually results in a greater risk of screw loosening (or fracture). Boggan et al demonstrated that the force that is applied to the screw is directly related to the crown height. The crown height acts as a vertical cantilever, which magnifies the force on the abutment screw (Fig. 16.2).[8]

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FIG 16.2 (A) Excessive crown height space comparing an FP-3 to a FP-1, which leads to a vertical cantilever to any angle load. (B) Apical placement of implant results in greater force to the prosthesis and abutment screw leading to an increased incidence of screw loosening. (C) Poor implant positioning (e.g., implant placement too far posterior) leading to excessive resultant force from cantilever effect and greater stress on the screw system. Note the significant cusp height and opposing cusp concavity, which increases the shear component of force on the implant system. ([A] From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Parafunction.

Of all the external forces that cause screw loosening, the primary factor is parafunction related. A horizontal bruxing patient loads the implant crown with an angled force repeatedly. This increases the magnitude of force, cycles to fatigue failure, and the angle of the force that places shear on the interface. Abutment screw loosening can be expected in a patient with a severe bruxing habit. A parafunction patient increases the amount of force to the system while also increasing the number of cycles to the system. Hence, fractures of porcelain and cement seals and screw loosening or fracture are inevitable. When the adjacent natural teeth are mobile to lateral or angled forces, the rigid implant and implant crown may be overloaded. A heavy bite force occlusal adjustment, which allows the adjacent teeth to move before implant crown contact, is recommended to reduce the risk of overload.

Continuous occlusal loads can have a cumulative effect on the preload, and the screw material may undergo deformation.[9] When the force exceeds the yield strength, plastic deformation occurs, and the screw begins to deform. This material deformation causes the screw to loosen and leads to potential failure of the prosthesis.

Screw loosening is also affected by the amount of the force and the number of cycles and is similar to fatigue. External methods to limit screw loosening include factors that reduce the biomechanical stress. These include

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key implant positions (i.e., to distribute forces evenly), sufficient number of implants (i.e., adequate surface area), passive frameworks, and adequate occlusal schemes.[10]

Splinted vs. Nonsplinted Crowns.

Screw loosening of abutment or prosthetic screws occurs more often on individual implant crowns than on crowns that are splinted together. For example, in a report for single molar replacement, the abutment screw-loosening rate was 40% during a 3-year period. When two splinted implants were used to replace the molar space, the screw loosening was reduced to 8%.[11] The stress distribution of splinted prosthetic units results in less force applied to the screw system. Studies have shown splinted implant-retained overdentures have far less screw loosening in comparison to fixed prostheses.[12]

Crown/Abutment Not Fully Seated.

If the abutment is not fully seated because of improper abutment placement, tissue impingement, or bone impingement, a poor distribution of force in the screw system will result, which leads to increased screw loosening. When the abutment is not seated fully and completely tightened, the prosthetic screw will be distorted, which leads to inadequate preload and subsequent screw loosening or fracture (Fig. 16.3).

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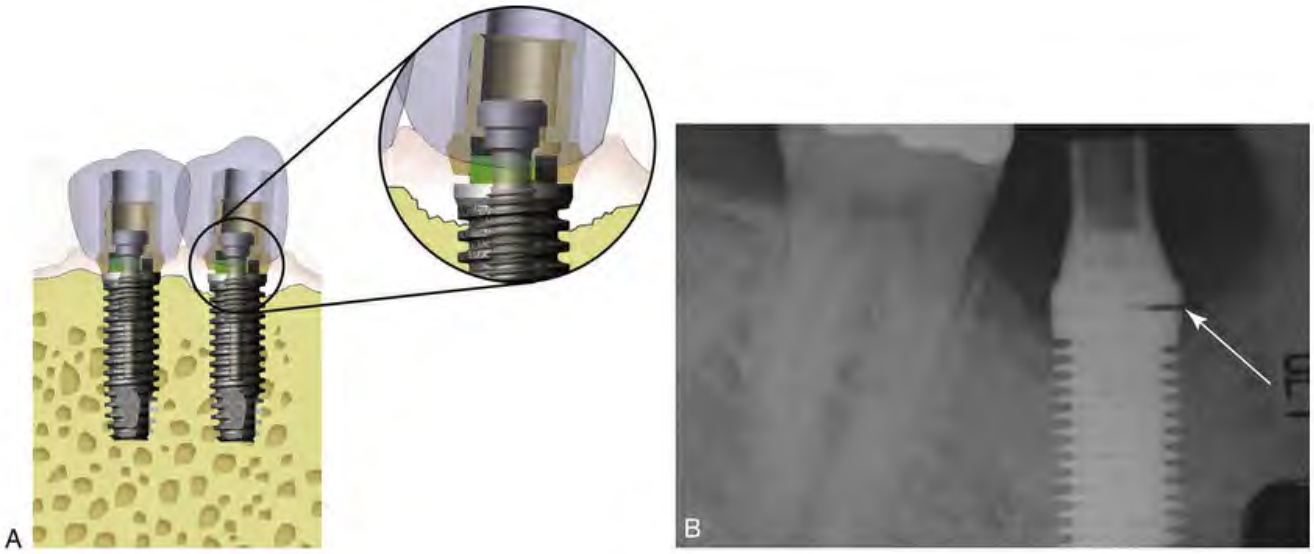

FIG 16.3 (A) Nonpassive or improperly seated screw-retained restorations may be distorted when seated into position when the prosthetic screw is threaded. The distortion of the superstructure causes stresses that are concentrated at the crestal bone level and may result in bone loss. (B) Radiographic image depicting incomplete seating of abutment, which predisposes prosthesis to screw loosening. ([A] From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Insufficient/Excessive Torqueing.

When improper preload via the torqueing process is applied to the abutment screw, screw loosening will often occur. This may be caused by either excessive or insufficient tightening of the abutment screw. An implant screw is similar to a bolt joint in engineering. There is a preload (tightening force) placed on the screw, which develops a force within the screw. As the screw is tightened, it elongates, producing tension, which results in the implant screw acting like a spring. The preload stretch of the screw is maintained by frictional force, and the tension between the screw and the implant/abutment is termed a *clamping force.* When insufficient preload is applied to the screw, there is insufficient clamping force, which ultimately leads to screw loosening, especially under occlusal loading. When excessive force is applied, the clamping force is easily released, and screw loosening will occur (Fig. 16.4).

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FIG 16.4 (A) Insufficient torque applied to the screw leads to a greater incidence of screw loosening. If the screw is not torqued sufficiently or overtorque occurs, insufficient preload will result, which will most likely result in screw loosening. (B) The proper torque wrench and technique should be used according to the manufacturers' specifications as implant systems have various recommended torque values. ([A] From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby. [B] Courtesy BioHorizons Implant Systems, Inc.)

Screw Diameter.

The diameter of the abutment screw may have a significant effect on the amount of preload applied to the system before deformation occurs. The greater the screw diameter, the higher the preload that may be applied, which results in a greater clamping force on the screw joint. However, the coping and prosthetic screws vary greatly according to the type, size, and material. The strength of the material increases by a power of four when the diameter of the screw doubles (a screw with twice the diameter is 16 times stronger). As a result, abutment screws loosen less often because they can take a higher preload compared with coping and prosthetic screws. Some companies offer similar diameters for abutment and prosthetic screws. As a result, a similar clamping force may be used for either component (Fig. 16.5).

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FIG 16.5 Screw sizes vary according to manufacturers. In general, the larger the screw diameter, the greater preload that may be applied. Care should be exercised to not place too high of a torque as this will lead to screw deformation and screw loosening.

Screw Material.

The composition of the screw is another factor that modifies its performance. The composition of the metal may influence the amount of strain in the screw from preload and the point of fracture, directly affecting the amount of preload that can be safely applied. Screw material and yield strength vary greatly when all other factors are similar (e.g., 12.4 N for a gold screw to 83.8 N for a titanium alloy screw fixation).[13]

The deformation or permanent distortion of the screw is the end point of the elastic modulus. Titanium alloy has four times the bending fracture resistance of grade 1 titanium. Abutment screws made of grade 1 titanium deform and fracture more easily than the alloy. Titanium alloy is 2.4 times stronger than grade 4 titanium. As such, a higher torque magnitude can be used on the titanium alloy abutment screw and female component (found within the implant body), less on grade 4 titanium, less on grade 1 titanium, and the least on gold screws.

The elongation of metal is related to the modulus of elasticity, which depends on the type of material, width, design, and the amount of stress applied. The material of which the screw is made (e.g., titanium alloy, titanium, or gold) has a specific modulus of elasticity. A prosthetic gold screw

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exhibits greater elongation than a screw made of titanium alloy but has a lower yield strength.

Although the strengths of titanium grades are dramatically different, the modulus of elasticity is similar for grade 1 to 4 titanium. Hence, the strain of the abutment screw is similar with each grade of titanium, but the safety load relative to fracture is different. Titanium alloy (grade 5) has a slightly higher modulus of elasticity. Although not clinically relevant to metal-bone osseointegration, the titanium alloy screw should have a slightly higher preload value. This is not a consequence relative to permanent deformation or fracture because it is more than twice as strong as the other grades of titanium.

The metal for the screwdriver used in the torque wrench is also important to consider. Stripping of the screw head prevents the clinician from tightening or removing the screw. Some manufacturers make the torque wrench driver out of titanium alloy, and the screw is made of gold or titanium. The concept is that the torque wrench will not deform the hexagon and will not strip, so the device lasts longer. However, this is not ideal. It is easier to replace the torque wrench driver than the abutment or prosthetic screw. Because of this, the torque wrench should be made of titanium and the screw of titanium alloy.

From a clinical standpoint the receptor site for the torque wrench is also a feature of the screw head to consider. The screw head has a rotation feature, most commonly a hexagonal design. The more sides to the rotation feature, the more often the head will strip. A slot or triangular feature will strip less than a hexagon (Fig. 16.6).

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FIG 16.6 Variation of abutment screw threads. (A) The more threads present on an abutment screw the less chance of screw loosening. (B) Material. Ideally, screw material should be titanium alloy, as gold alloy screws have a higher incidence of loosening and fracturing. (Courtesy BioHorizons Implant Systems, Inc.)

Component Fit.

In the science of machining metal components, there is a range of dimensions that manufacturers use. For instance, an implant 4 mm in diameter may actually range from 3.99 mm to 4.01 mm. Likewise, the abutment and prosthetic coping connection also has a range. As a result, if a smaller implant body hex dimension is mated with a larger abutment connection, the components may not ideally fit together. Most implant manufacturers allow for a misfit range that results in the abutment or coping being able to rotate ±10 degrees on the implant body. Components between the abutment and implant body may have a misfit of 10 degrees in a rotational dimension, and horizontal discrepancies have been reported up to 99 μm.[14,15] These ranges are different with respect to each implant system. The more accurate the component fit, the less force applied to the abutment or prosthetic screw (Fig. 16.7).

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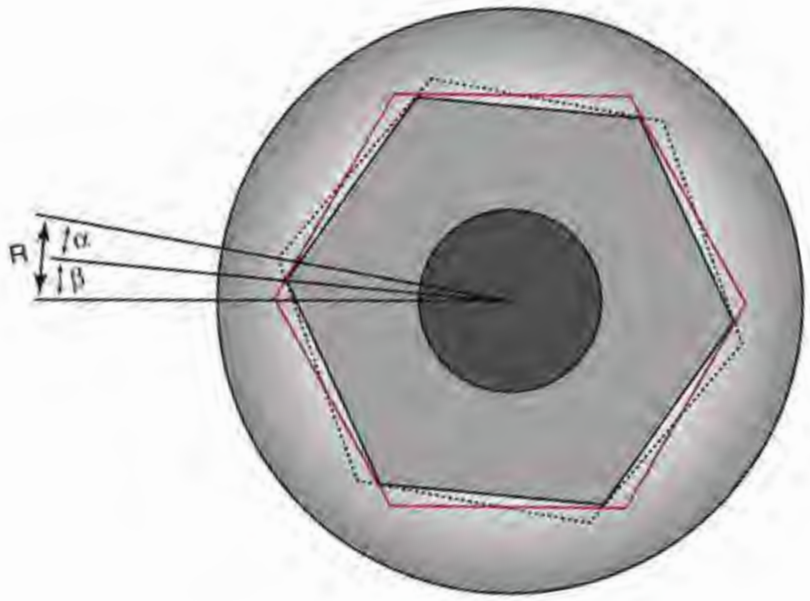

FIG 16.7 The rotational fit of the abutment-to-implant body is variable from one manufacturer to another. The greater the rotational misfit *(red line* and *dotted line),* the more force is applied to the abutment screw. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The incidence of screw loosening is also a function of the accuracy of fit of the flat-to-flat connection of the implant and abutment or prosthetic component. Implant abutment connections or prosthetic connections with an unstable mating interface place undue stress on the screw that connects the components. Mechanical testing has demonstrated a direct correlation between the tolerance of the flat-to-flat dimension of the external hexagon and the stability of the abutment or prosthetic screw. Binon showed that a mean flat-to-flat range of less than 0.005 mm exists on the hexagon, and a flat-to-flat range of less than 0.05 mm for the entire sample would result in a more stable screw joint.[16] Studies have shown plastic castable patterns, which can be highly inaccurate, to have a vertical misfit as high as 66 μm.[17]

The same manufacturing conditions apply to impression transfer copings and analogs. Many manufacturers have a wider machining range (+ or − variance) for the prosthetic components to reduce the cost of manufacturing. When transfer copings and analogs are used in impressions and then to fabricate the prosthesis in the laboratory and the implants are splinted together, the prosthesis may not passively seat.

Many manufacturers recommend the use of plastic (non-metal) burn-out posts. Plastic burnout prosthetic copings cost less, but they exhibit much greater laboratory variance and poor fit because of irregularities and settling of the superstructure. Besides cost, another advantage of a plastic burnout pattern for a coping is that one type of metal is used for the coping and

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superstructure, lessening the risk of metal corrosion or separation between the coping and superstructure.

To reduce settling a machined coping may be used to fit the implant abutment more accurately. Some manufacturers suggest a titanium coping to reduce the risk of misfit. However, oxides form on the titanium-machined coping surface and impair metal adherence when the prosthesis or abutment metal work is cast to the coping. Mechanical retentive features on the coping improve this metal-to-metal attachment.

Laboratory studies demonstrate that an alloy-cylinder compatibility exists when noble metal alloys are used rather than titanium for a superior metal-to-metal connection. A machine coping connection is still present, so it is superior to the plastic components used to cast one metal.[18] The risk of oxides forming between the coping and metal of the prosthesis is also reduced (Fig. 16.8).

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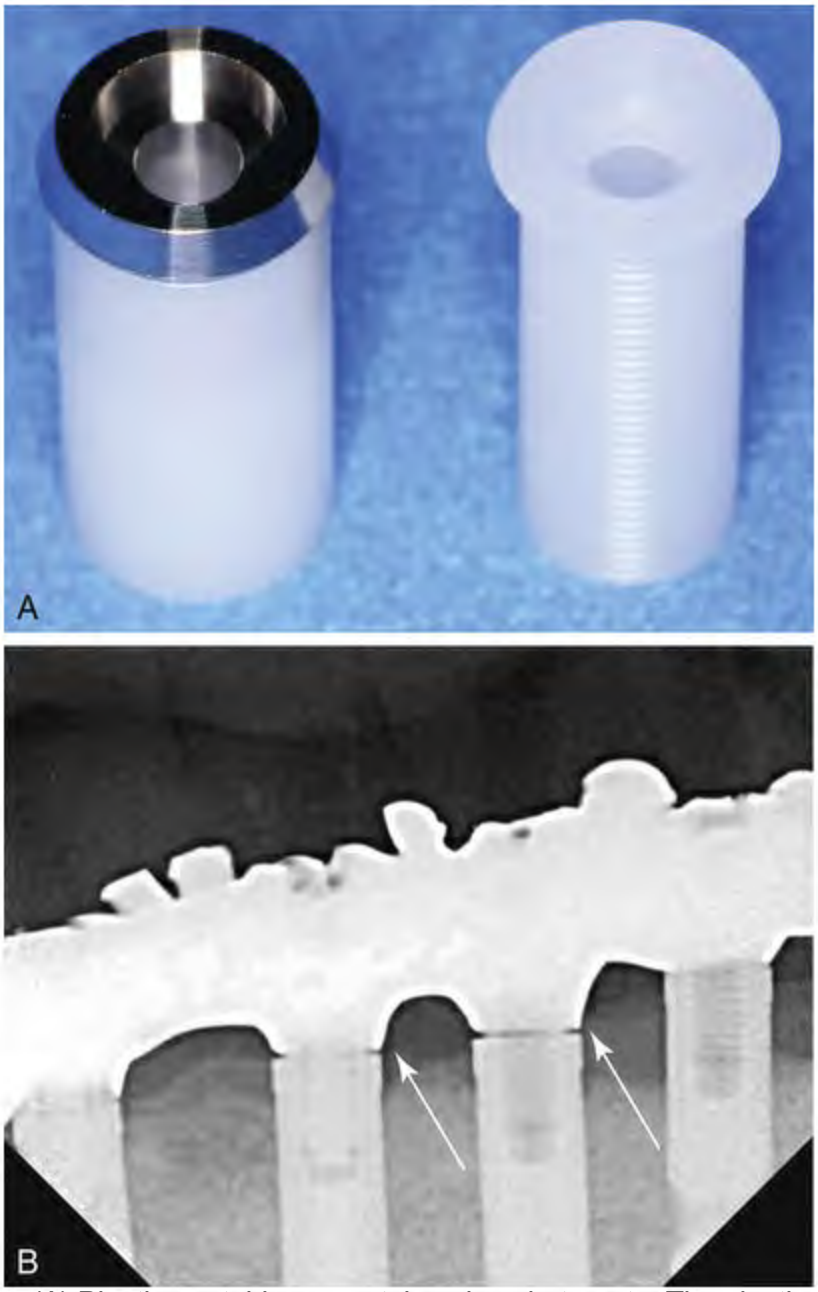

FIG 16.8 (A) Plastic castable vs. metal coping abutments. The plastic castable abutments often lead to significant discrepancies in fit after casting. (B) Nonpassive casting resulting from incomplete seating of prosthesis.

Implant Design.

The type and design of the dental implant has a significant impact on screw loosening. As a general rule, most implant bodies have an antirotational feature for the abutment connection. The most common designs are an external hexagon, an internal hexagon, a Morse taper, and a Morse taper with threads.

Factors that affect the abutment screw connection and screw loosening

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include the height (or depth) of the hexagon and the platform diameter. Boggan et al studied the influence of design factors on the mechanical strength and quality of fit of the implant abutment interface. Whereas failure mode for static test samples was bending or deformation of the abutment screw, fracture of the abutment screw was the common failure mode for the fatigue test samples. The static failure load was greater for the external hex implants of 1 mm in height compared with implants with an internal hexagon of 1.7 mm. The larger-diameter implant had the greatest static load before failure (Table 16.1).[8] As the hexagon height (or depth) increases, the load on the abutment screw decreases. Likewise, as the diameter of the implant platform increases, the force on the abutment screw decreases. Reduction of the lateral load (P) on the abutment screw is crucial to prevent the load on the screw to be beyond the yield strength of the material.

TABLE 16.1

Failure Loads of Various Implant Types

Implant Type	Static Failure Load (N)
1.0 mm external hexagon, 4 mm	966
1.0 mm external hexagon, 5 mm	1955
0.7 mm external hexagon	756
0.6 mm internal octagon	587
1.7 mm internal hexagon	814

From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.

The height (or depth) of the antirotational hexagon is directly related to the force applied to the abutment screw with any lateral load. Because the crown is connected to the abutment and the abutment rests on the implant platform, a lateral force on the crown creates a tipping force on the abutment. This tipping force is resisted by the hexagon height or depth, the platform, and the abutment screw. When the arc of rotation is above the hexagon height, all of the force is applied to the abutment screw. For the hexagon height to be above the arc of tipping forces, the hexagon height must be at least 1 mm for a 4-mm-diameter implant. Yet many implant manufacturers feature a hexagon height of only 0.7 mm, so almost all of the force is directed to the abutment screw, increasing the occurrence of screw loosening and fracture (Fig. 16.9).

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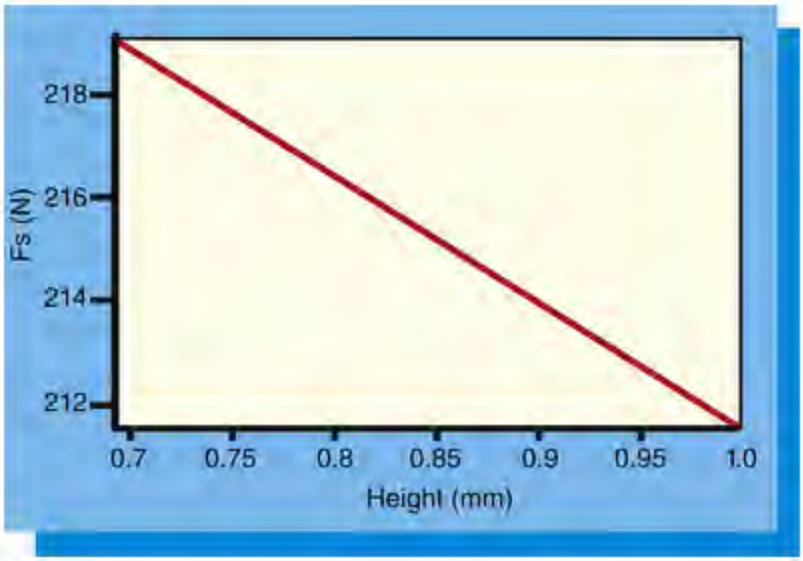

FIG 16.9 The higher (or deeper) the antirotational hexagon component (x component on the graph), the less the force applied to the abutment screw (Fs) on the y-axis. A 0.7-mm hexagon height is standard in the industry and was used first by Nobel Biocare. A 1-mm hexagon height has less risk of screw loosening because the force on the screw is decreased. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The difference between external vs. internal connections has been well documented. Studies have shown the incidence associated with external-connection (EC) implants was 18.3% at a mean of 5.3 years (217 of 1183 restorations; maximum, 59.9%).[19,20] The complication rate with internal-connection (IC) implants was 2.7% at a mean of 4.5 years (142 of 5235 restorations; maximum, 31.6%).[21,22] Other studies have shown the external hex to have a significantly higher incidence of screw loosening than internal hex (MA-EC, 15.1%; Zr-EC, 6.8%; MA-IC, 1.5%; Zr-IC, 0.9%).[23]

The platform dimension upon which the abutment is seated is also an important factor in screw loosening. Larger-diameter implants, with associated larger platform dimensions, reduce the forces applied to an abutment screw and change the arc of displacement of the abutment on the crest module. For example, in a report by Cho et al, abutment screw loosening over a 3-year period was almost 15% for a 4-mm implant diameter but less than 6% for the 5-mm implant diameter (Fig. 16.10).[24]

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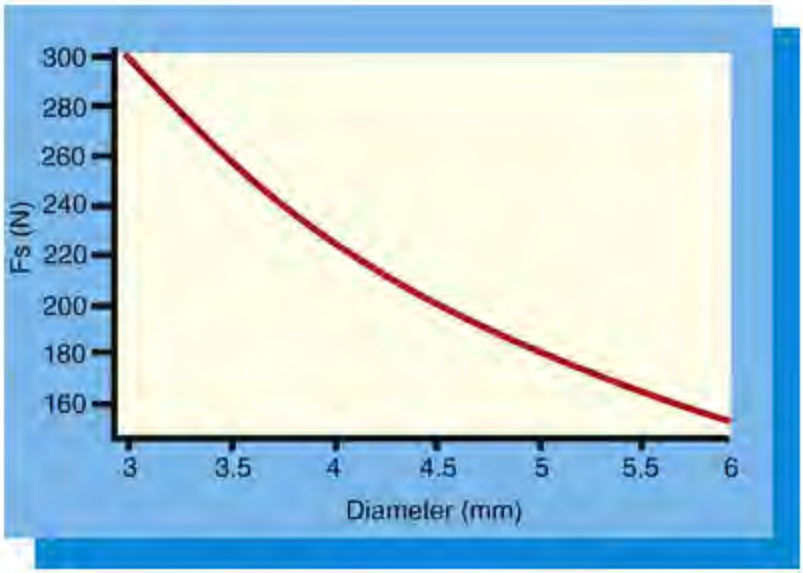

FIG 16.10 To reduce forces on the abutment screw, the platform diameter of the implant is more important than the hexagon height. The larger the diameter (x-axis), the less the force applied to the screw (y-axis). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Screw vs. Cement Retained.

When evaluating the prosthesis type (cement vs. screw), studies have shown screw-retained (8.5%) had a much higher incidence of screw loosening in comparison to cement retained (3.1%). These complications have a greater incidence with screw-retained restorations compared with cement-retained restorations because cement-retained restorations are more passive and have less strain on the implant system.[25] Although a cement-retained restoration is more common, screw-retained restorations are indicated when low-profile retention is necessary on a short abutment or when the implant bodies are more than 30 degrees from each other and splinting is required to restore the patient. Additionally, a screw-retained prosthesis has the advantage of less chance of tissue irritation because of the high incidence of retained cement with a cement retained prosthesis.

Screw loosening and partially unretained restorations are common complications of nonpassive castings. The more passive the fit on the implant abutment for screw retention and the more controlled the occlusal forces, and the more secure the prosthesis. The repeated compressive and tensile forces from nonpassive castings under occlusal loads cause vibration and loosening of the screw components. Accuracy in design and fabrication of the metal superstructure are determining factors for the reduction of forces at the implant abutment and implant-bone interface.

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Passive screw-retained restorations are more difficult to fabricate than passive cement-retained restorations. When the screw is threaded into position, the superstructure may distort, the implant may move within the bone, or the abutment screw may distort. The distortion of the superstructure and implant system may reach a level such that a 500-µm original gap may not be detectable.[26] As a result, the casting may appear to fit the implant abutment for screw retention. However, the superstructure, bone, and components do not bend beyond their elastic limit, and compression, tensile, and shear forces are placed on the bone-implant interface.[27] The bone must remodel to eliminate these forces. If the forces are beyond physiologic or ultimate strength limits, resorption of the bone-implant interface occurs. As a result, greater crestal bone loss has been associated with nonpassive castings. Creep (a constant force applied over time on a material) or fatigue also can contribute to fracture of the components over time because of a constant load or cyclic load frequency (Figs. 16.11 to 16.13).

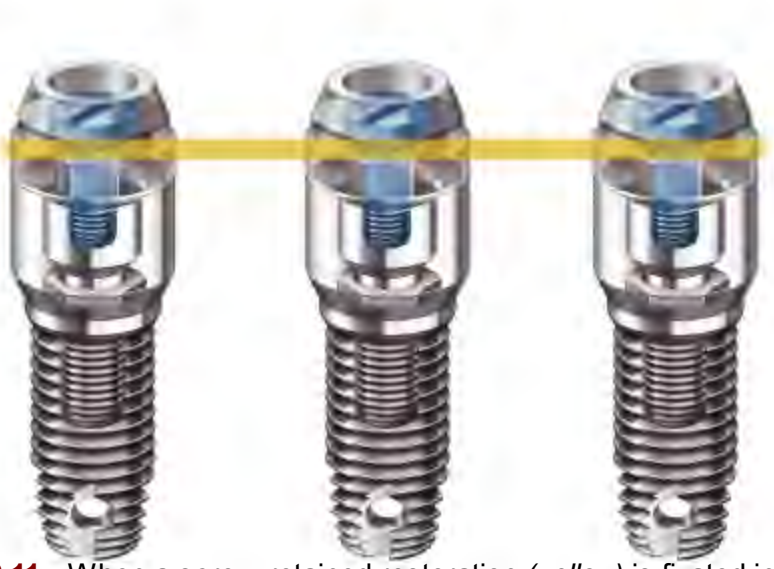

FIG 16.11 When a screw-retained restoration *(yellow)* is fixated in place, compressive, tensile, and shear forces are present with the screw components *(blue)*. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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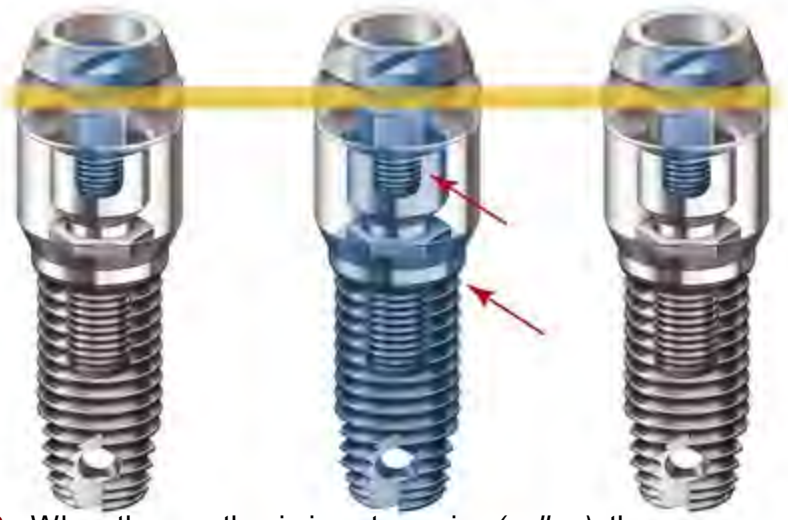

FIG 16.12 When the prosthesis is not passive *(yellow),* the compressive tensile and shear forces are directly applied to the implant system (i.e., *Red Arrows:* abutment, implant body, abutment screw, marginal bone, implant-bone interface). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 16.13 An improper fit between the abutment and the implant will lead to stresses that are applied throughout the implant concentrated at the crestal bone level, which may cause bone loss. In this example, a 50-µm misfit may force the implant body to move approximately 200 µm at the apex. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Anatomic Location.

The location of the prosthesis in the oral cavity is also a significant factor in the incidence of screw loosening. Sadid-Zadeh showed a significant incidence difference with respect to anatomic locations; anterior (12.8%; 51 of 398 restorations) and posterior positioning (4.8%; 144 of 2972 restorations). However, when evaluating internal connection implants, they had an associated higher incidence of screw loosening in the posterior region (4.3%) than the anterior region (0.7%).[28]

Prevention

Decreased Force.

Because of the directional relationship between force and screw loosening, the evaluation, diagnosis, and modification of treatment plans related to stress conditions are of considerable importance. After the clinician has identified the source of excessive force on the implant system, the treatment plan is altered in an attempt to minimize the negative impact on the longevity of the implant, bone, and final restoration.

Prosthetic Design.

The prosthetic design may be altered to minimize the possibility of screw loosening. Ideal implant placement in the key implant positions should be adhered to. Cantilevers should be eliminated or reduced, especially when high occlusal forces are present. Additionally, implant protection principles should be adhered to including reduction of cuspal inclines of the prosthesis (decreased cusp height), decreased occlusal table, and no lateral contacts, especially in the posterior.

Ideal Preload.

The ideal torque force on an abutment screw varies by manufacturer and may range from 10–35 N/cm. This preload is determined by many variables including the screw material, screw head design, abutment material, abutment surface, and possible lubricant. To reduce the incidence of screw loosening, the abutment screw should be torqued by the following protocol:

1. Light finger tighten with driver (~10 N/cm)

2. Maximum finger tighten with driver (~20 N/cm)

3. Implant screw should be torqued to the manufacturer specifications

4. After 5–10 minutes, the screw should be retorqued to the same manufacturer specifications.

Note: For cases of expected increased force, the implant screw may be retorqued a third time after 30–60 days.

Screw Tightening Sequence.

When screw tightening a multi-unit fixed implant prostheses, a proper sequence and technique is crucial to obtain the correct torque. The torque should be applied incrementally amongst all screws so that not one screw is tightened fully. This is based on the fact that a multi-unit prosthesis is unlikely to be "completely" passive. A nonideal tightening sequence will lead to either an insufficient or excessive amount of torque placed onto a specific screw thread. Undertorque will lead to insufficient clamping force and lack of ideal stretching of the screw. This will most often lead to screw loosening. Overtorque will lead to permanent deformation of the screw which may lead to screw fracture (Fig. 16.14).

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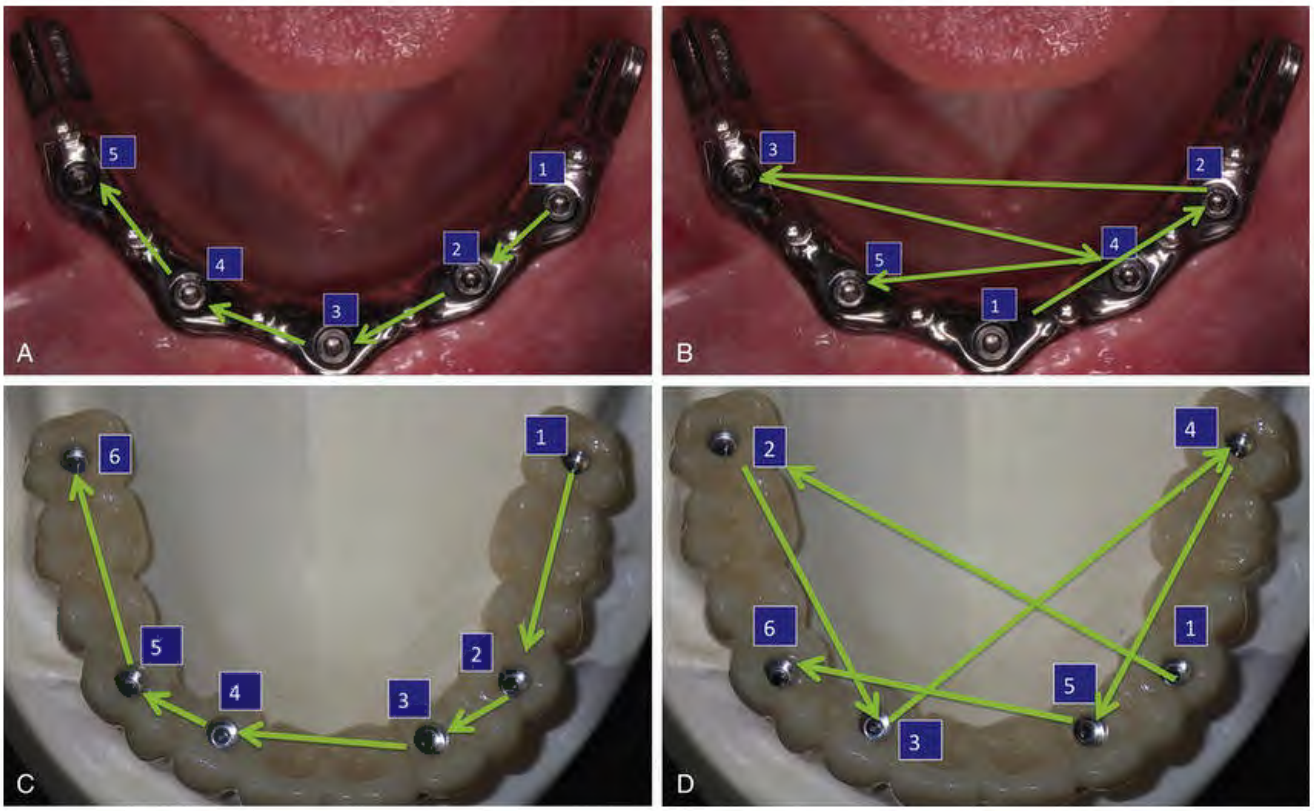

FIG 16.14 Screw tightening sequence. (A) Incorrect tightening sequence for bar, leading to uneven distribution of stress to the screw system. (B) Correct sequence, which should be completed with light finger tightening, then maximum finger tightening, and lastly final torque wrench. (C) Incorrect tightening sequence for a fixed prosthesis. (D) Correct sequence, which should be completed with light finger tightening, then maximum finger tightening, and lastly final torque wrench.

Settling Effect.

Settling is a term used to describe the effect of various implant parts wearing and fitting closer together. Minor irregularities on or within a casting that incorporates the top of an abutment or screw can cause slight elevation of the casting or the screw head. Over time, micromovement wears down the irregularities, and the parts fit closer together. However, this settling relaxes the preload force on the prosthetic screw and is more likely to cause screw loosening. This embedment relaxation or loss of preload has been shown to be approximately 2% to 10 % of the initial preload within the first few seconds or minutes after tightening. This is the reasoning for the above protocol to include a second retorque after 5–10 min to regain the lost preload due to settling (Fig. 16.15).[29]

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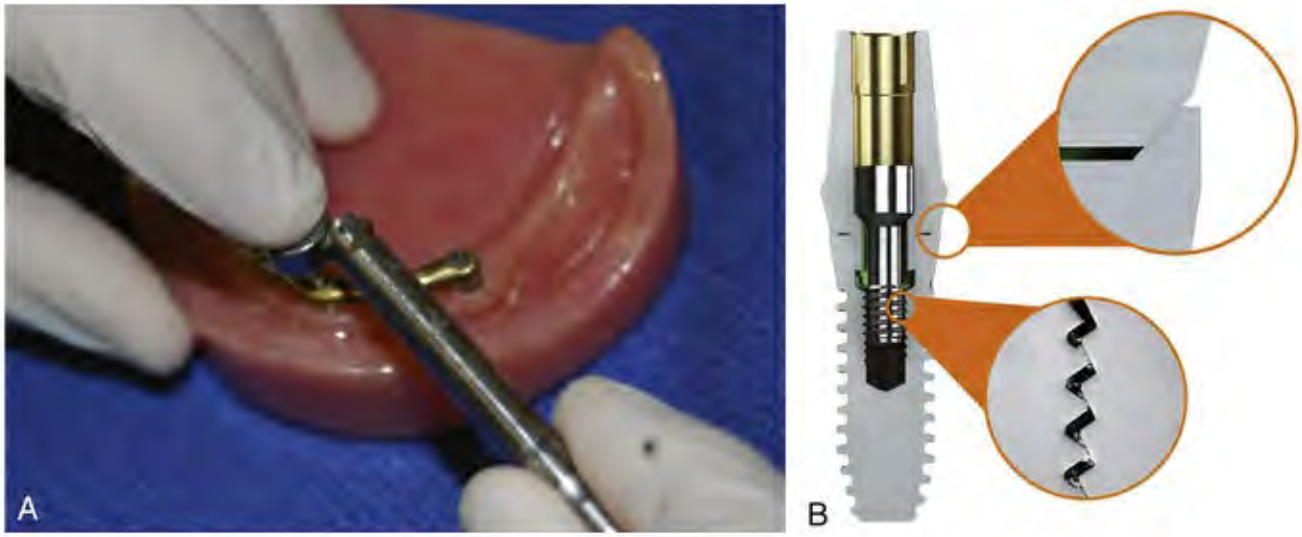

FIG 16.15 (A) Final ideal torque technique (after hand tightening). Phase 1 final torque, then, after 5–10 minutes, phase 2 final torque. (B) Settling effect of the abutment screw occurs after the initial preload. A final torque is needed to maintain the initial preload. (Courtesy BioHorizons Implant Systems, Inc.)

Torque Under Moist Conditions.

Studies have shown when placing and torqueing abutment screws, more accurate torque values result under wet conditions vs. dry.[30] Saline may be used to lubricate the screw prior to placement of preload to maximize the accuracy of the preload.

Wider Implant Bodies.

The use of wider implant bodies results in decreased force on the screw. Graves has shown increasing implant size from 3.75 mm to 5.0 mm results in 20% greater strength, while increasing implant size from 3.75 mm to 6.0 mm to increases the strength by 33%.[31]

Treatment

When confronted with a mobile prosthesis, it is important to determine if the mobility is a result of screw loosening or the actual implant being mobile (implant failure). Box 16.2 shows a technique to determine the etiology of the prosthesis movement (Fig. 16.16).

Box 16.2

Technique to Determine the Etiology of the

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Prosthesis Movement (see Fig. 16.16)

Step 1: Movement of crown. With the use of two mirror handles placed on the buccal and lingual aspect of the crown, a buccal-lingual force is applied to evaluate the mobility of the prosthesis. This will result in a subjective response from the patient experiencing either pain or no pain.

No pain: if no pain is present, then it is most likely the abutment screw is loose.

Pain: if pain is present, it may be the result of either the abutment loosening or implant failure. With respect to the abutment screw, the pain will originate from the movement of the crown, most likely resulting from tissue impingement. In some situations, this can be verified by a radiograph showing incomplete seating of the prosthesis with the abutment. If the pain originates from the implant, this will usually indicate failure of the implant.

Step 2: Palpation of buccal/lingual cortical plates. A second test is to palpate the buccal and lingual cortical plates over the implant body. If no pain is present, then it is most likely the abutment. If pain is present, it is usually a sign the implant has failed.

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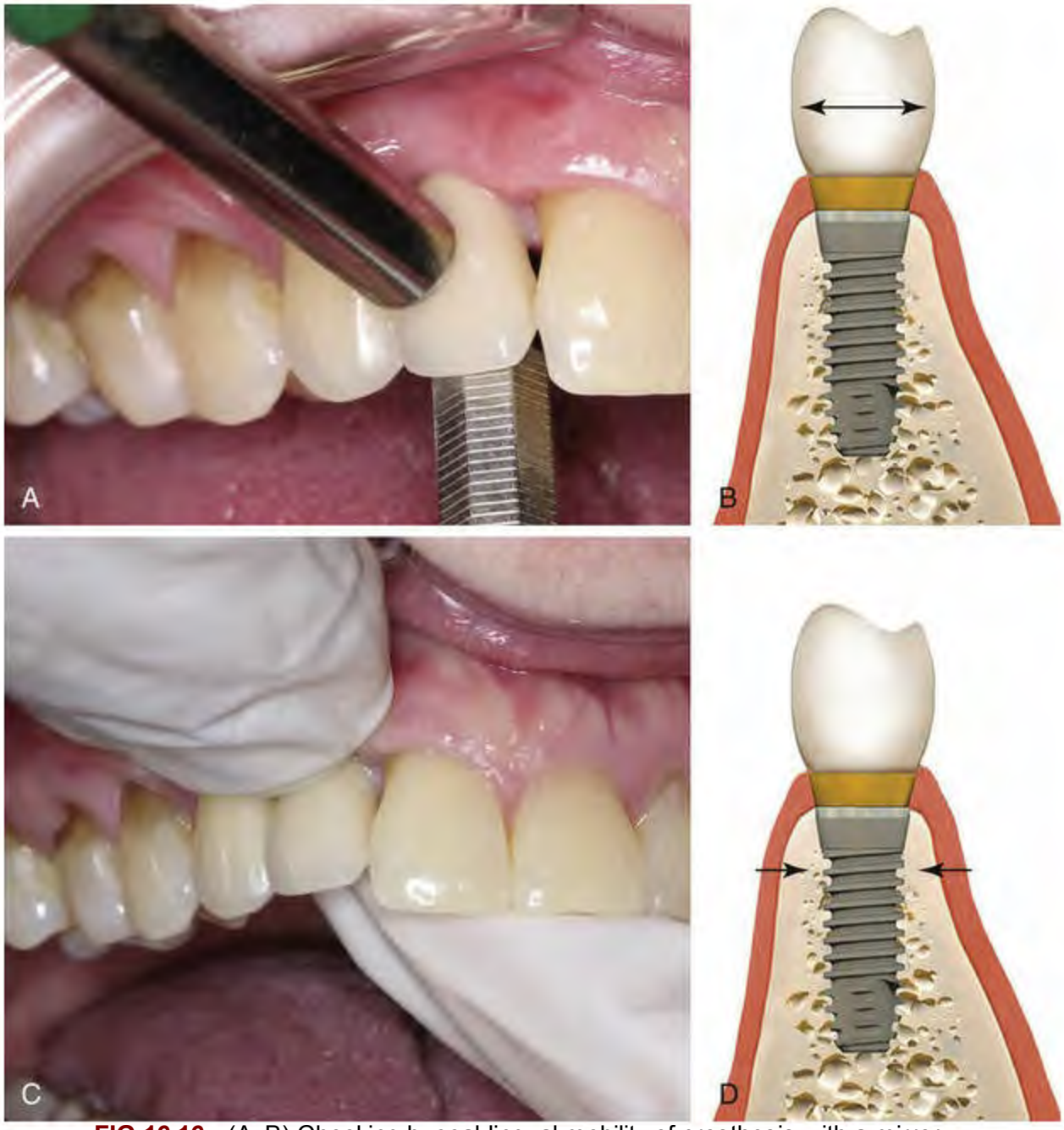

FIG 16.16 (A–B) Checking buccal-lingual mobility of prosthesis with a mirror handle. (C–D) Palpation of buccal and lingual cortical plates to assess the presence of pain.

Implant Movement.

Mobility of the implant indicates failure of the implant and necessitates immediate removal. A radiograph may reveal a circumferential radiolucency. The site should then be reevaluated after adequate healing for the need of bone grafting, implant placement, or change in prosthetic treatment planning (Fig. 16.17).

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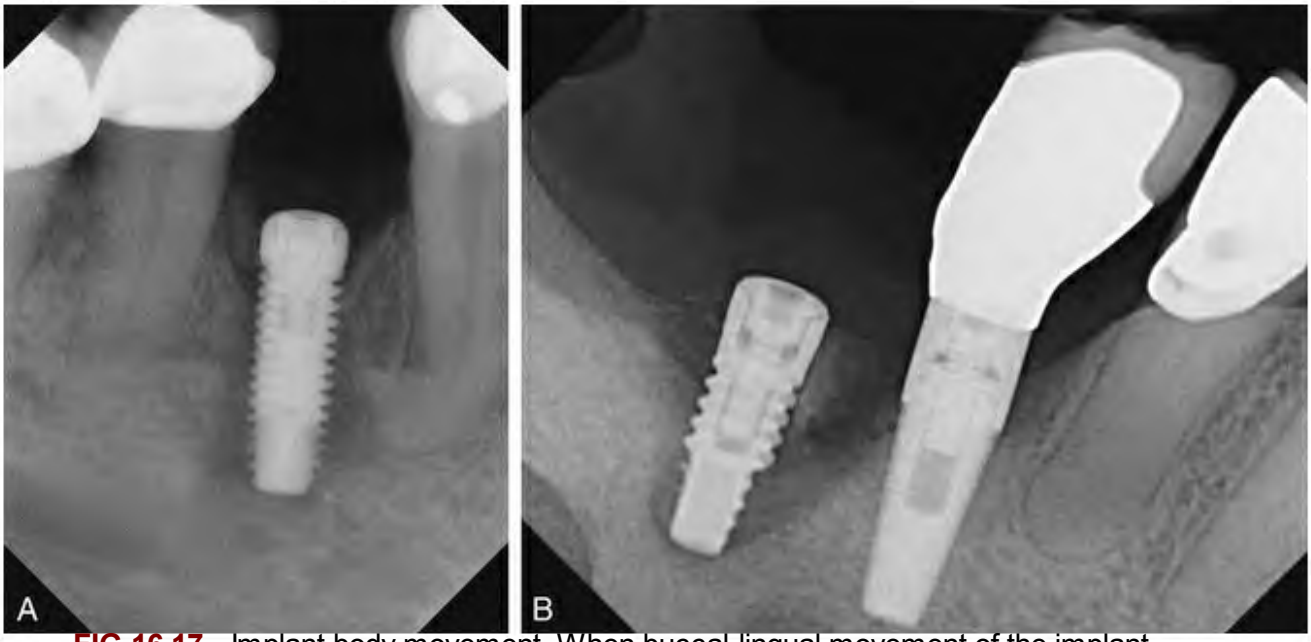

FIG 16.17 Implant body movement. When buccal-lingual movement of the implant body is present, usually radiographic signs will be present confirming implant failure (i.e., circumferential radiolucency).

Abutment Screw Movement

Option 1.

Removing a cemented crown from a mobile abutment is very challenging with crown removal techniques (e.g., crown bumper). The impact force that is applied to the mobile crown is dissipated because of the loose screw. This may result in damage to the internal threads of the implant body. In addition, when an implant crown margin is subgingival, it is often difficult to obtain access for the crown remover. In poorer bone densities, overzealous use of a crown remover may result in loss of bone-implant interface.

Option 2.

The safest and most predictable treatment option to treat abutment movement is accomplished with making an occlusal access, and turning the cement-retained crown into a screw-retained crown (Fig. 16.18).

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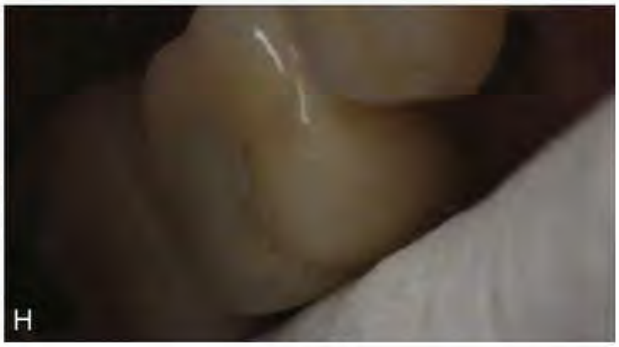
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FIG 16.18 Technique for removing a screw. (A) Occlusal opening to obtain access to abutment screw with #8 diamond round bur. (B) Hex driver engages abutment screw. (C) Reverse torque removes the screw. (D) Implant-retained crown is removed along with screw. (E) Implant crown with abutment retained within the crown. (F) A new screw should always replace the old screw. The old screw is most likely deformed and will have a high incidence of chronic loosening. Screw is discarded; new screw is used to fixate implant crown. (G) PTFE tape is used to protect the screw head. (H) Opaque composite used to occlude access hole.

The following are the steps for completing this procedure:

1. Evaluate and determine the location and angulation of the implant abutment screw (buccal-lingually and mesial-distally). An intraoral radiograph is often helpful.

2. With a round diamond bur (≈#8 round), access is made through the occlusal surface to remove the abutment screw (i.e., central fossa: posterior teeth and lingual aspect of crown in anterior teeth).

3. After the screw is located, the screw is engaged with the appropriate hex driver, reverse-torqued, and the screw is removed.

4. Discard old screw and place new screw.

5. Torque to the manufacturer specifications with ideal protocol.

6. Cover access hole with filler (polytetrafluoroethylene [PTFE]) and opaque composite.

In situations where the access hole is through the facial aspect of the prosthesis (i.e., anterior crowns), the crown will need to be removed and a new crown fabricated. Care should be exercised when cutting the crown off because in most cases it is difficult to determine the cement location (Fig. 16.19). This may result in sectioning the crown too deep causing damage to the abutment, abutment screw, or implant body (Fig. 16.20). A safer method includes the above technique (access with screw removal) with fabrication of a new prosthesis. If the abutment remains fixated to the prosthesis, the prosthesis can be easily removed by gently heating the prosthesis with a Bunsen burner.

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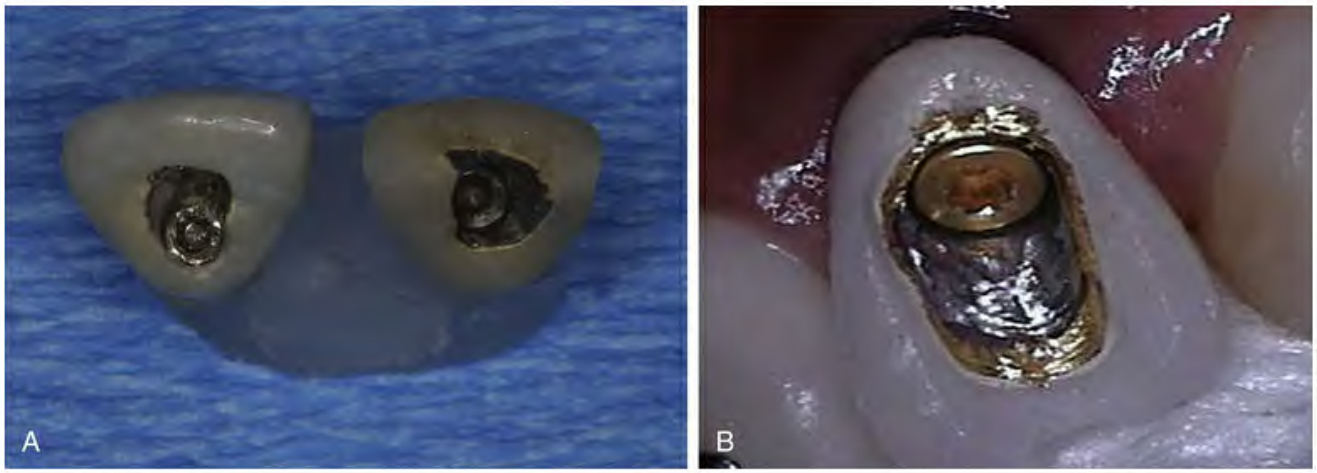

FIG 16.19 Screw access. (A) Ideally, the screw will be able to be removed without compromising esthetics (i.e., anterior teeth—lingual, posterior teeth—central fossa). (B) Anterior crown where screw has to be removed via the facial surface, resulting in the need to remake crown.

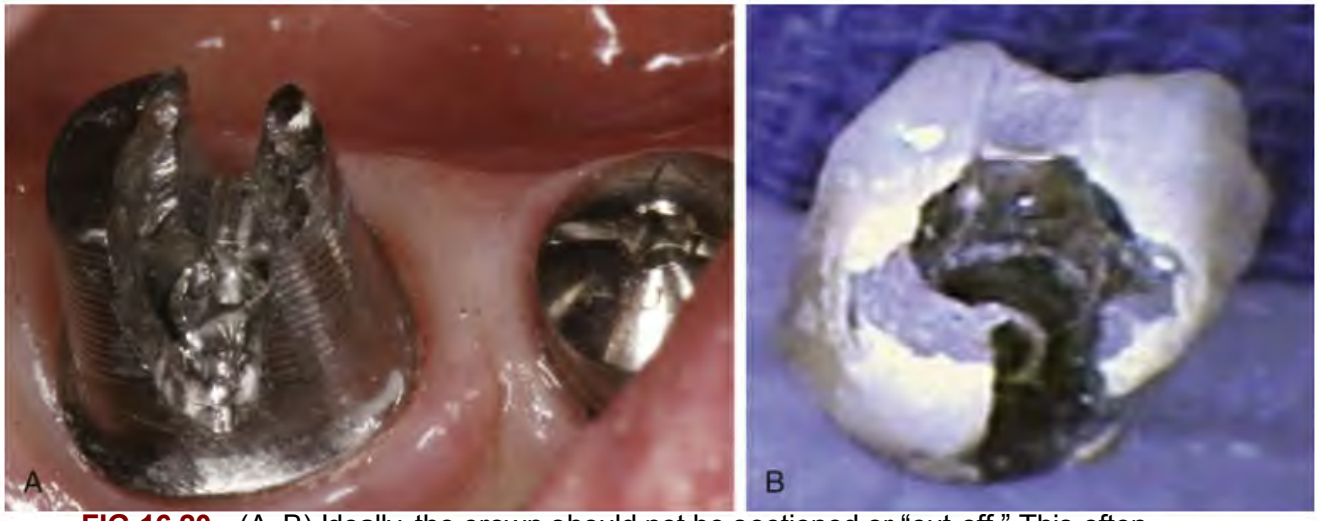

FIG 16.20 (A–B) Ideally, the crown should not be sectioned or "cut-off." This often leads to trauma to the abutment screw because of the very thin cement margin.

Screw Fracture

Etiology

The etiologic factor most likely to cause screw fractures is biomechanical stress to the implant system. The biomechanical stress leads to partially unretained restorations or fatigue, which is directly related to an increased amount of force. Prosthesis screw fracture has been shown to occur with a mean incidence of 4% with a range of 0% to 19%. Abutment screw fracture is

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directly related to the screw diameter, with larger-diameter screws fracturing less often, with a mean incidence of 2% and a range of 0.2% to 8%[3] (Fig. 16.21).

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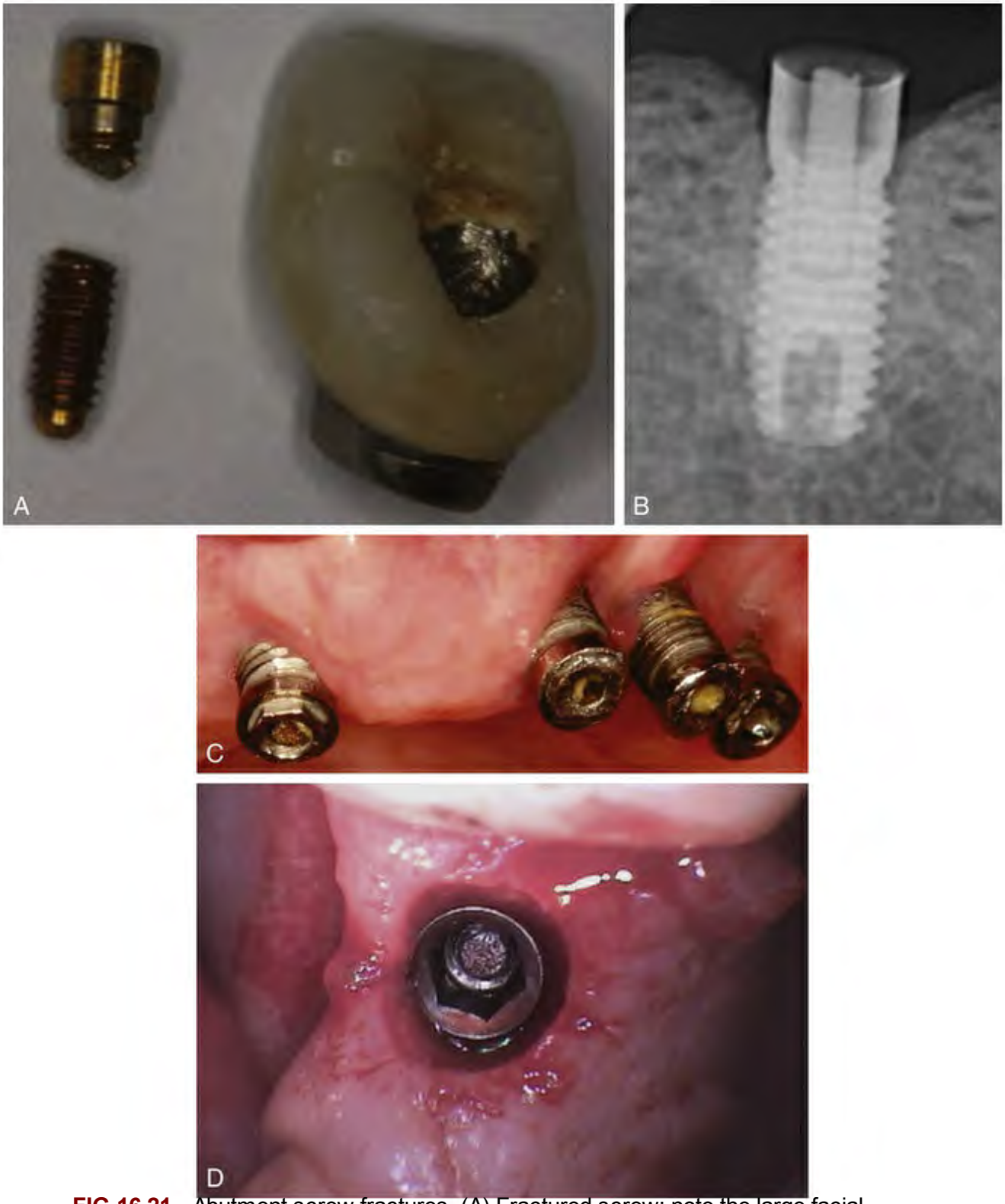

FIG 16.21 Abutment screw fractures. (A) Fractured screw; note the large facial overcontouring resulting in a shear load to the screw. (B) Implant with screw fractured; space can be identified between the screw and the threads of the implant body, which result from loss of preload. (C) Prosthesis fracture leading to multiple fractured screws. (D) In some instances, the screw will fracture with the retained preload, which makes removal very difficult.

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The etiology of abutment screw fracture is the same for screw loosening (see above).

Prevention

Immediate Treatment of Loose Screw.

If an abutment screw is determined to be mobile, immediate treatment is recommended. The longer the time period that force is applied to a mobile prosthesis, the greater the chance the abutment screw will be deformed and possibly fracture. The loose screw follows a fatigue curve that is related to the number of cycles and the intensity of the repeated forces.

Treatment

Explorer.

The easiest method to remove a screw is to rotate the screw counterclockwise with a sharp explorer tip. Because a loose screw has no preload, the fractured component remains passive in the implant body. If the screw has been deformed or debris has been introduced between the screw and implant body, this technique may not be successful (Fig. 16.22).

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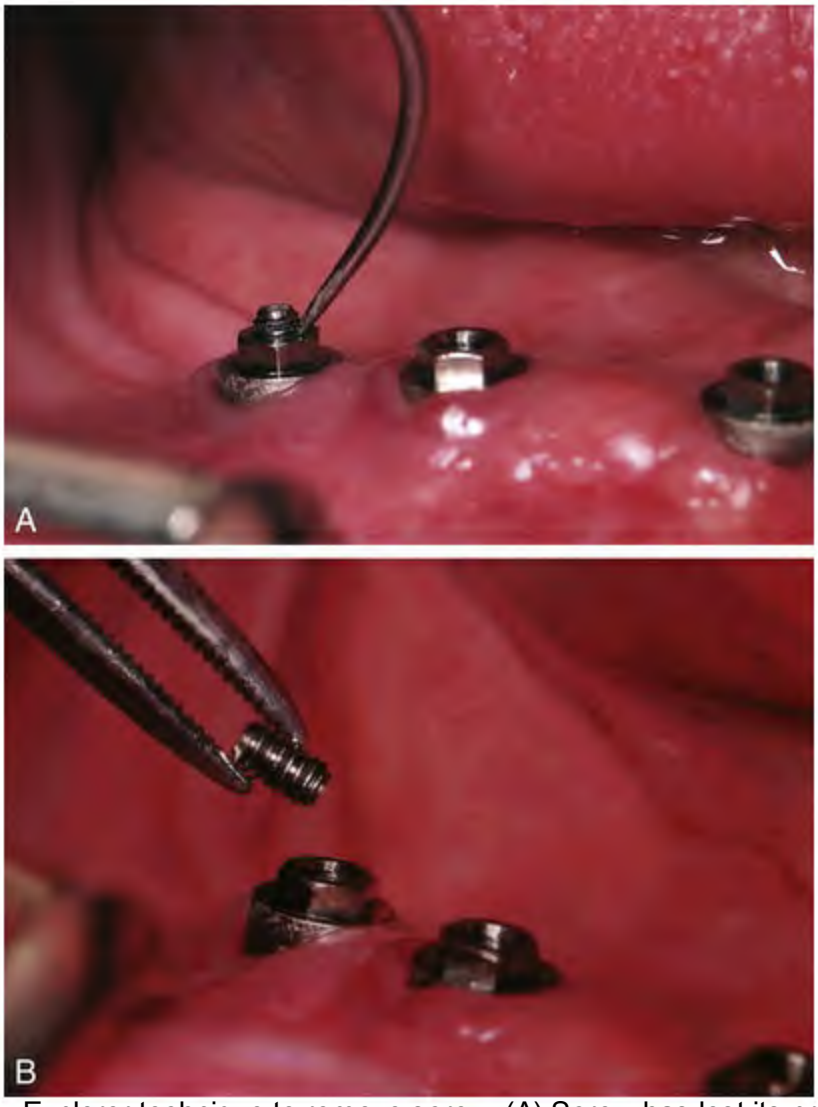

FIG 16.22 Explorer technique to remove screw. (A) Screw has lost its preload, can easily be unscrewed (counterclockwise). (B) Screw removal.

Ultrasonic/cavitron Device.

If debris is present between the threads, an ultrasonic or cavitron device may be used. The vibration (≈20,000–30,000 rpm) will usually dislodge the debris, and the screw can then be removed via the explorer method.

Round Bur (205LN).

A very small round bur or 205LN can be used in a slow-speed handpiece or AS123 screwdriver. The tip of the bur is placed at the seam of the fractured screw and abutment (implant). As the bur spins clockwise, the friction placed on the screw makes it turn counterclockwise, and the screw unthreads (Fig. 16.23).

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FIG 16.23 Round bur (205LN). (A) A fractured abutment screw in a bruxing patient. (B) A very small round bur is used in a slow handpiece. (C) The bur is positioned in the seam of the screw and implant and as it rotates clockwise, friction unthreads the screw. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Inverted Cone Bur (≈33½ Bur).

With an inverted cone bur in a high-speed handpiece (ideally electric handpiece in reverse), gently touch the top of the screw. This will usually result in the screw being extruded from the implant body. Care should be exercised to not touch the implant body with the bur because this will result in damage to the implant body threads. With this technique, always use a throat pack to prevent loss (Fig. 16.24).

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FIG 16.24 Inverted cone ($33\frac{1}{2}$ carbide bur) with handpiece. (A) Screw fractures off within the abutment for screw. (B) $33\frac{1}{2}$ inverted cone. (C) The fractured screw is lightly tapped in the center of the screw, care must be exercised to not touch the internal walls/threads of the implant.

Slot the Top of Screw.

A slot 1 mm deep is made through the center of the screw with a high-speed handpiece and a very narrow fissure bur (or $33\frac{1}{2}$ bur). A small screwdriver is

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then used to unthread the screw. Be careful using this technique because the bur may inadvertently perforate the side of the implant body. There is no predictable method to repair the implant body if this occurs. The patient should be informed that implant failure may result as a consequence of this technique (Fig. 16.25).

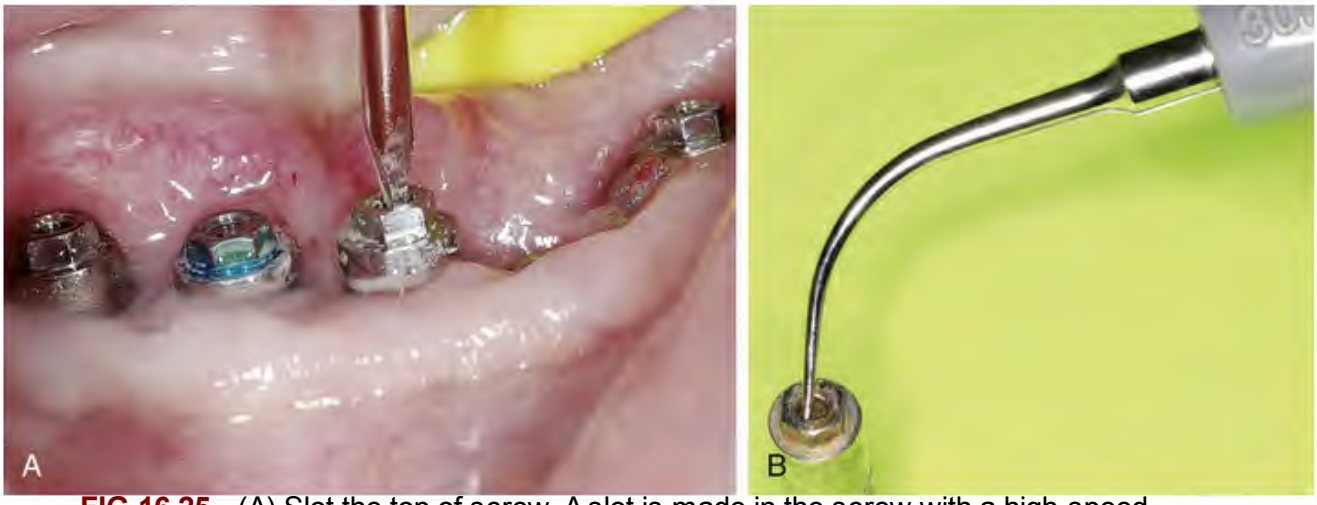

FIG 16.25 (A) Slot the top of screw. A slot is made in the screw with a high-speed handpiece and narrow fissure bar. A screwdriver is then used to unthread the screw. (B) Use of an ultrasonic scaler to loosen debris between the screw and the internal threads of the implant. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Manufactured Retrieval Instruments.

There are multiple retrieval kits on the market that are used to remove fractured screws. These are usually specific for the type of implant body type (internal, external, trilobe, etc.) (Fig. 16.26).

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FIG 16.26 Salvin Implant Rescue Kit. (A) Place guide on implant and hold with stabilizing handle. Insert drill into implant handpiece. Set motor to REVERSE at 1000–1250RPM and 50–70 N-cm torque. (B) Drill in REVERSE using "up and down" motion to prepare 1- to 2-mm deep dimple into top of broken screw. (C) Insert tap into implant handpiece set motor to REVERSE at 70–80 rpm and 50–70 N-cm torque. (D) Insert tap into the 1- to 2-mm dimple in the top of the broken screw. Use the tap in REVERSE to remove broken screw. (E) Screw removed. (Courtesy Salvin Dental Specialties, Inc., Charlotte, NC.)

Excessive Torque Applied to the Abutment Screw/Prosthesis

Etiology

The amount of force applied to tighten a screw joint is related to the success and technique in placement of the screw preload. Torque rotational forces on a screw may be measured in newton-centimeters (N-cm). Too large of a torque (exceeding manufacturers' recommendations) leads to a low clamping force, which increases the risk of loosening. The clamping forces on a metal-to-metal screw component are one of the more important considerations for long-term screw fixation. The joint strength is improved the most by achieving ideal clamping forces. The clamp force is directly proportional to

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the force used to tighten the screw or the preload.

The torque applied to a screw component affects both the compressive forces in the threads and the compressive force applied to the head of the screw on the recipient component. The torque applied to the screw will also result in tensile forces within the male component of the screw. The compressive and tensile forces from the torque forces are magnified because they are applied to the inclined plane of the screw components. The tensile forces attempt to lengthen (strain) the screw when adequate torque is applied. The strain (change in length divided by original length) of the screw is also related directly to the amount of torque force. The higher the force, the greater the strain. Too great a torque force causes plastic or permanent deformation or a permanent change in the material, at which point the screw is no longer retrievable and additional force causes fracture of the screw. Too large a torque results in fracture of the screw or stripping of the thread components (Fig. 16.27).

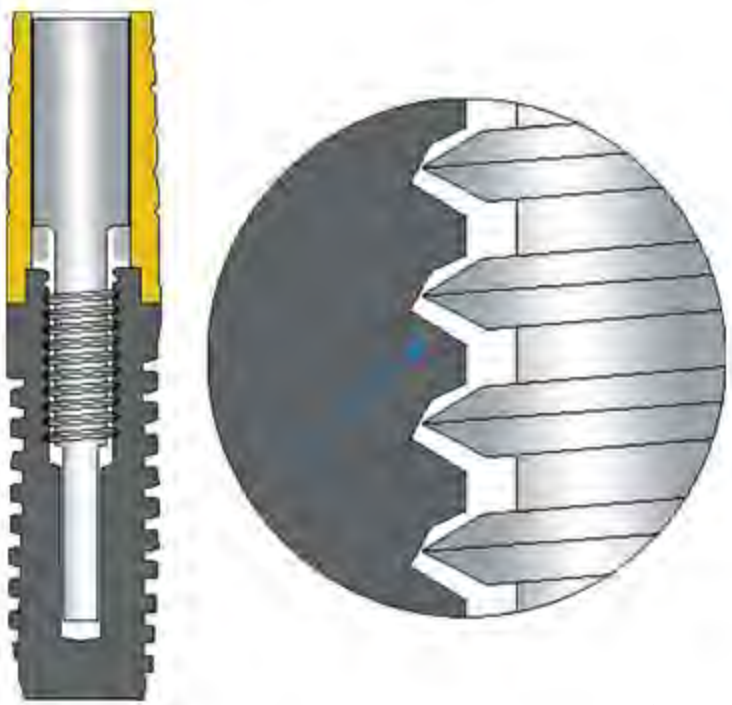

FIG 16.27 The abutment screw male *(light gray)* engages the female receptor site *(blue arrow),* and as it rotates in position, the male component is stretched (strain) in relation to the preload force. If too large force is applied, the screw will be deformed leading to fracture or screw loosening. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prevention

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Ideal Torque.

The suggested amount of the torque for a preload should be 75% of the value to reach permanent deformation of the screw material.[32] The amount of preload applied to a screw joint should be consistent and adequate enough to cause deformation (strain) within the screw thread. In the original screw retention system of Nobelpharma from 1980 to 1990, only finger pressure from a handheld screwdriver was used to tighten screws. However, a hand screwdriver has been shown to produce an inconsistent torque value. In a study by Misch with 136 dentists, the average torque placed on a screw joint with a hand screwdriver was 11 N-cm and ranged from 5 to 21 N-cm. As a consequence, abutment and screw loosening during that era was observed in almost 50% of the restorations.

Consistent Torque.

A torque wrench is required to obtain a consistent value of torque. However, several reports have shown that most torque wrenches are not completely accurate and components may corrode after autoclaving many times, which may increase the torque applied to the system.[33,34] There exist two types of torque wrenches, friction and spring. Studies have shown that spring-type wrenches are more accurate and have less chance of over-torquing the abutment screw.

Autoclaving hand torque wrenches in the open position and the clinician testing the torque wrench before use are suggested to make sure the components are not frozen in place, which will increase overtorque. Periodically, the torque wrench should be recalibrated or replaced (≈ after 100 autoclave cycles) by the implant company or manufacturer (Fig. 16.28).

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FIG 16.28 Torque wrenches. (A) Various types of torque wrenches, friction wrenches, and spring wrenches. (B) If the torque wrench is a preset release type, make sure it is autoclaved in the open position *(arrow)*. (C) A torque wrench, which has significant debris and corrosion *(arrow)*. This can lead to incorrect torque values.

Prostheses Fractures/Occlusal Material Fracture

In a retrospective analysis by Kinsel and Lin, porcelain failures of metal ceramic crowns and fixed partial dentures supported by implants ranged from 0% to 53% of patients and were directly related to force factors.[35] For example, whereas 35% of patients with bruxism (and 19% of the implant crowns) experienced porcelain fracture with implant-supported prostheses, 17% of patients without bruxism had at least one of the porcelain units fractured. When implant prostheses opposed a denture, no fracture was observed. When implant prostheses opposed each other, 16% of the dental units experienced a fracture of porcelain. The higher forces in the implant system (including the occlusal porcelain) were related to a dramatic increase

in biomechanical complications. The fracture rate was greatest for bruxism patients or group function occlusal patients with 34.9% and 51.9% of patients, respectively, affected. The percentage of porcelain units that fractured in these two conditions were 18.9% and 16.1%, respectively. Note that the incidence of porcelain fracture, even in patients without higher force conditions, is greater than observed with natural teeth.

Etiology

The second most common complication for fixed prostheses on natural teeth is porcelain fracture. Occlusal material fracture is more common with implants than natural teeth because of the lack of periodontal stress relief with implants and a resultant higher impact force to the occlusal material.[36]

Material.

Porcelain, acrylic, and composite fractures may occur under excessive loads or even with a lesser load of longer duration, angulation, or frequency. Acrylic or composite materials fracture more easily than porcelain, metal, or enamel. The compressive strength of acrylic resin is 11,000 psi compared with 40,000 psi for enamel.[37] Composite resin is three times stronger than acrylic. Acrylic fractures more often occur when used as a crown and bridge occlusal veneer than does porcelain fused to gold.

Acrylic fracture is a much more common complication for fixed reconstructions than for removable prostheses. Acrylic denture teeth on traditional dentures do not sustain the forces developed in implant-supported restorations. In addition, unlike porcelain, acrylic obtains its strength by bulk. Mechanical retention must be incorporated in the metal superstructure with proper resistance to the forces of occlusion. Posterior acrylic or composite facings often fracture because of the inadequate bulk and inadequate yield and fatigue strengths compared with the bite force developed under parafunction or on cantilevers for fixed restorations (Figs. 16.29 to 16.31).

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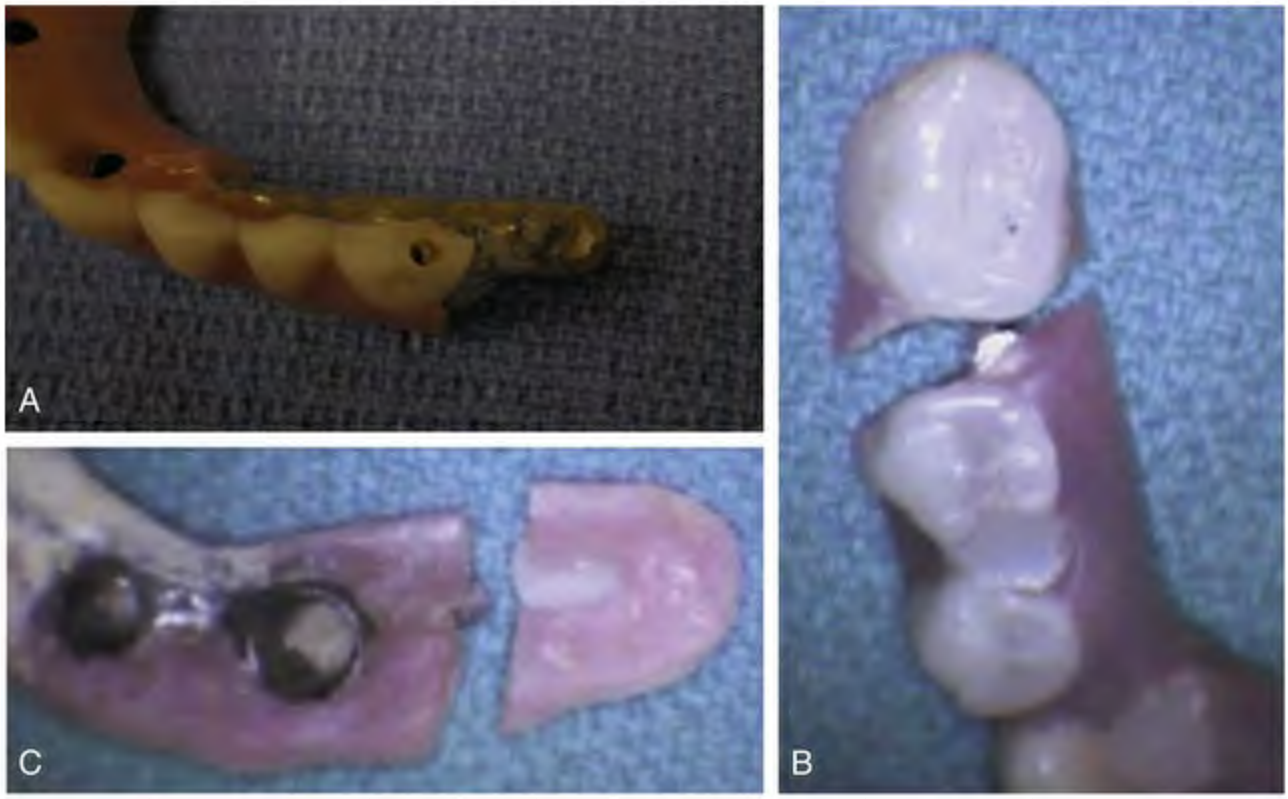

FIG 16.29 Acrylic fracture. (A) Cantilevered acrylic FP-3 fracture. (B–C) The etiology of fracture is lack of metal extension leading to unsupported acrylic.

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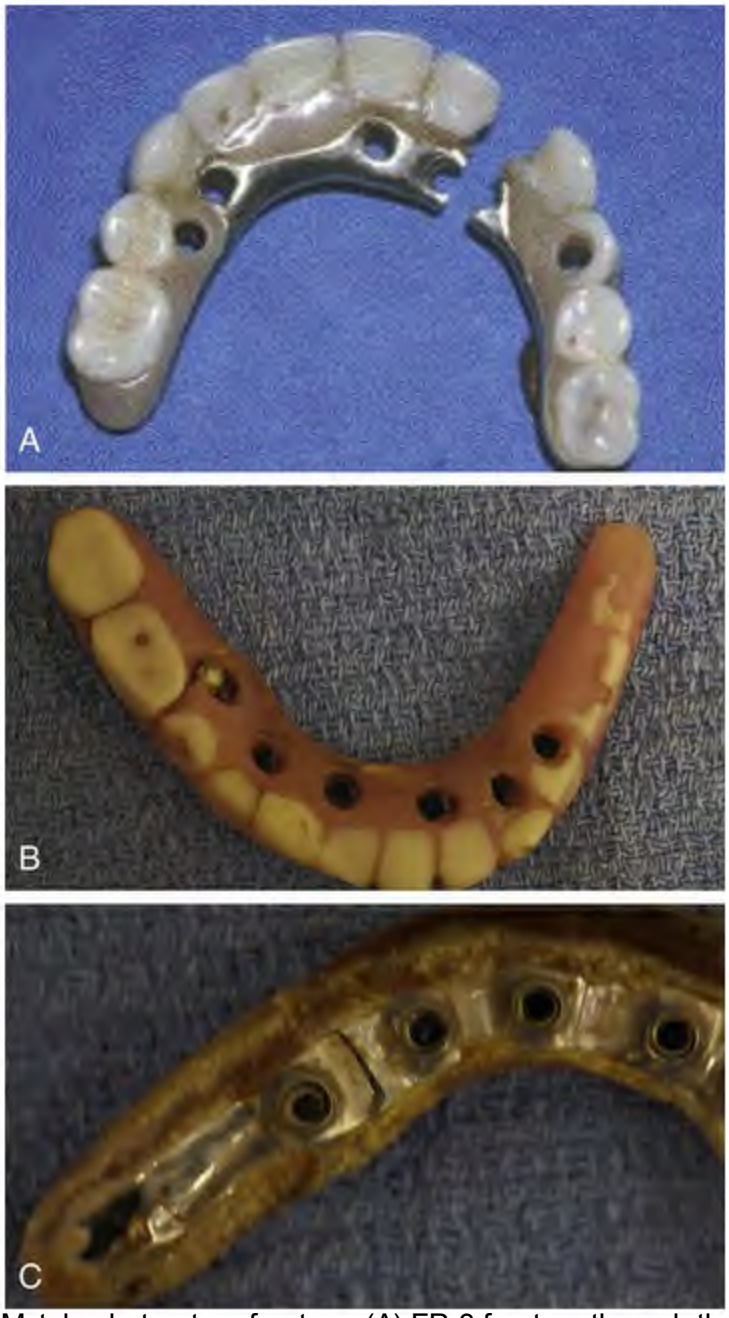

FIG 16.30 Metal substructure fracture. (A) FP-3 fracture through the most distal abutment. (B) FP-3 cantilever fracture. Note the attrition of the acrylic from excessive, repeated forces. (C) Resultant metal substructure fracture.

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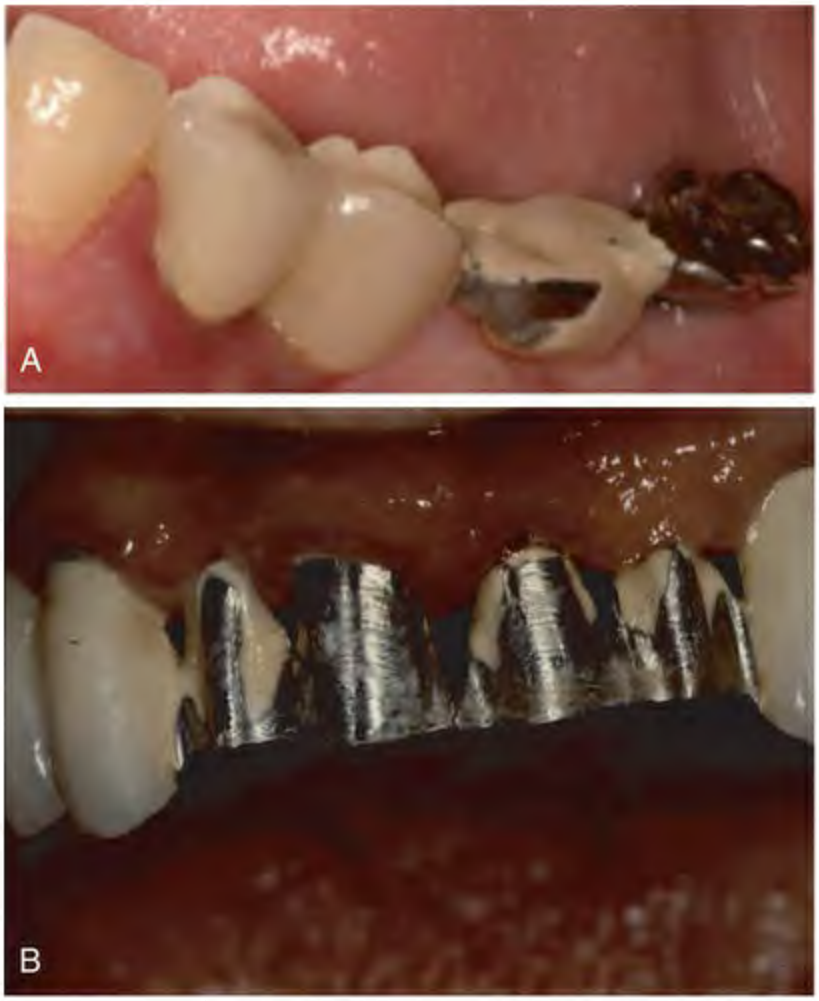

FIG 16.31 (A) Porcelain fracture on posterior implant. (B) Anterior porcelain implant prosthesis fracture.

Monolithic zirconia is a relatively new restorative material with exceptional mechanical properties in comparison to ceramics available today in dentistry. Zirconia exhibits very high flexural strength (i.e. 900–1200 MPa) and fracture resistance and toughness (i.e. 9–10 MPa). Additionally, monolithic zirconia has solved many of the chipping problems associated with zirconia veneer ceramics as studies have show a complication rate of for single crowns after 2–3 years and 3%–36% for fixed prostheses after 1–5 years.[37a] (Fig. 16.32).

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FIG 16.32 (A) Zirconia Veneer—common complication is chpping and fracture, (B) Monolithic Zirconia—material has been shown to be superior to other implant restorative materials as it exhibits high fracture resistance and exceptional flexural strength.

Cement vs. Screw.

A decreased incidence of porcelain or acrylic fracture of the prosthesis has been observed with cement-retained restorations when compared with screw-retained prostheses. The screw hole may increase stress concentration to the restoring material and more often leads to unsupported porcelain. For example, a study presented by Nissan et al examined the porcelain fracture incidence of screw-retained restorations compared with cemented prostheses. The study used a split-mouth evaluation for bilateral edentulous sites in partially edentulous patients. Ceramic fracture was 38% for screw-retained vs. 4% for cemented prostheses. The mean loading period for these restorations was 5 years (Table 16.2).[38]

TABLE 16.2
Occlusal Material Characteristics

	Porcelain	Gold	Resin	Zirconia
Esthetics	+	−	+	+/−
Impact force	−	+	+	+
Static load	+	+	+	+
Chewing efficiency	+	+	−	+
Fracture	−	+	−	+
Wear	+	+	−	+
Interarch space	−	+	−	+
Accuracy	−	+	−	+

+, Favorable; −, unfavorable.

Prevention/Treatment

Reduce Force.

Implants, components, and the prosthesis are subjected to loads with a broad range of magnitude, duration, direction, and frequency. As a result, permanent deformation may result, and fatigue fracture and creep are expected conclusions after years of function. These effects relate to factors of force. Force-related issues need to be addressed. A common treatment that is most widely underutilized is the use of occlusal guards. It is highly recommended to treat all patients with an occlusal guard who exhibit symptoms of parafunction and prosthesis situations that are prone to fracture (implant prosthesis against implant prosthesis).

Ideal Porcelain Thickness.

The ideal thickness of porcelain to minimize the possibility of breakage is approximately 2 mm.[39] When the metal superstructure is not designed properly, unsupported areas of porcelain may occur. This is especially true with FP-2 or FP-3 prostheses due to their large volume of metal and porcelain. Many dental laboratories fabricate thin metal copings over the implants and teeth and then add porcelain to the final contour and occlusal table. As a result, FP-2 or FP-3 restorations may have significantly more unsupported porcelain (>2 mm). To limit the amount of unsupported porcelain, the incisal edge and occlusal table position of the prosthesis must be planned before fabrication of the metal superstructure. The technician then may fabricate a full-contour wax-up of the final prosthesis and afterward reduce the contour by 2 mm in the regions where porcelain is to be added. A

common error is to fabricate the metal framework, then determine the incisal position (Fig. 16.32).

Uncemented Prosthesis

Uncemented prostheses are the third most common cause of fixed prostheses failure on natural teeth.[40] This complication is even more common with implant abutments because they are more rigid and higher forces are transmitted to the cement interface. Kourtis has reported an uncemented prosthesis to be the second most common implant prosthetic complication, which compose 25% of the documented complications.[4]

Etiology

Implant Abutment.

An implant prosthesis is most often susceptible to loss of cementation when chronic loads or shear forces are applied to the prosthesis, which eventually weakens the cement interface. With dental implants an uncemented restoration is more common because of the inherent qualities that an implant abutment exhibits. The implant abutment is usually made of titanium alloy, which predisposes the restoration to inferior cement adherence in comparison to a natural tooth. In dentistry today, most cements are made to adhere to the interface with the dentin of a natural tooth. The porosity of a natural tooth is far greater than most machined and lab-fabricated abutments. Additionally, an implant abutment is usually smaller in diameter than a natural tooth, resulting in less surface area. With less surface area, a greater possibility of loss of retention may result. To complicate the situation further, many clinicians often desire to make implant restorations retrievable to more easily handle future complications. A softer cement (temporary implant cement) is often used for implant crowns, which additionally predisposes to uncemented restorations (Fig. 16.33).

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FIG 16.33 (A) Implant abutment often has decreased surface area and nonideal taper. (B) Most stock abutments have a smooth surface leading to possible uncemented restoration. (C) Ideal preparation of the abutment leads to roughened surface and increased cement retention.

Prevention

Retention/Resistance Form.

The tenets of retention and resistance of fixed prosthodontics are directly applicable to implant abutments and include taper, surface area, height, the geometry of the abutment preparation, surface roughness, and luting agents (Box 16.3).

Box 16.3

Properties of Various Restorative Materials

Material	Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	Elastic Modulus (N/mm^2)	Shear Modulus (N/mm^2)
Titanium Alloy (TI-6AL-4V)	827	1050	1.048×10^6	4.428×10^3
Denture (Acrylic)	45	73	3000	1.2×10^3
Monolithic Zirconia	1000	1300	2.1×10^5	6.06×10^3

Bullis G, Jokada M: Finite element analysis of the BruxZir full-arch implant prosthesis vs. the titanium-bar-supported acrylic denture, *Inclusive Magazine-Glidewell Laboratories*, 6(1):42–47.

Abutment Taper.

The retention of a crown has been shown to rapidly decrease as the taper is increased from 6 to 25 degrees.[41] Taper degree is defined as the sum of both sides of the preparation. A typical tapered diamond bur is ideally fabricated to exhibit a taper of about 3 degrees on each side, or a 6-degree total taper.

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The parallelism of the axial walls has been recognized to be the single most effective factor for retention.[42] The ideal taper originally was recommended to be within 2 to 5 degrees of parallelism of the path of insertion, which also places minimal stress concentrations on prepared abutments.[43]

Unfortunately, most manufactured stock implant abutments for cement exhibit total tapers ranging from 10 to over 30 degrees. As a result, the retentive surfaces of the more tapered, unprepared implant abutments provide less retention than natural abutments. The preparation in the cervical third of the abutment near the crown margins may be indicated in the more tapered implant abutments to reduce the taper even when the path of insertion is satisfactory (Fig. 16.34).

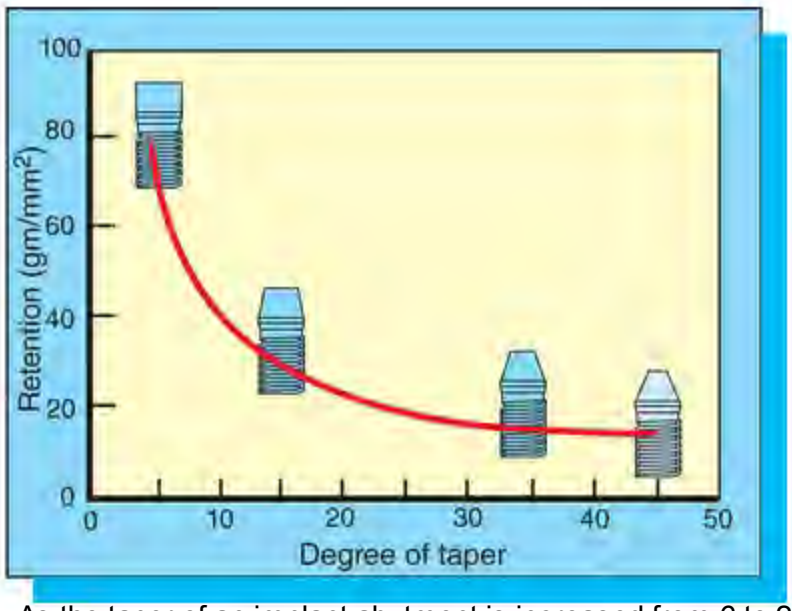

FIG 16.34 As the taper of an implant abutment is increased from 6 to 25 degrees, the retention of the crown is rapidly decreased. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Abutment Surface Area.

The surface area of an implant abutment influences the amount of retention. The parameters of retention are similar for a tooth or implant and mainly are influenced by the diameter and height of the abutment. Studies have shown a linear increase in retention occurs as the diameter increases for preparations with identical height, and a wider abutment offers greater retention than a narrower abutment.[44]

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The diameter of an implant abutment for cement retention is often less than 5 mm (posterior region), which is comparable to that of a prepared lateral incisor. The decreased surface area results in poorer retention than most natural abutments. Wider implant abutments usually have more retention than standard-size abutments. A wider abutment can be obtained by two methods. First, a wider implant body has a corresponding wider abutment for cement than a smaller-diameter implant. Second, the abutment may have a wider emergence design than the implant body (or abutment flare). The greater-diameter abutment has many advantages including providing a greater taper, a thicker outer body wall, and more surface area for retention (Fig. 16.35).

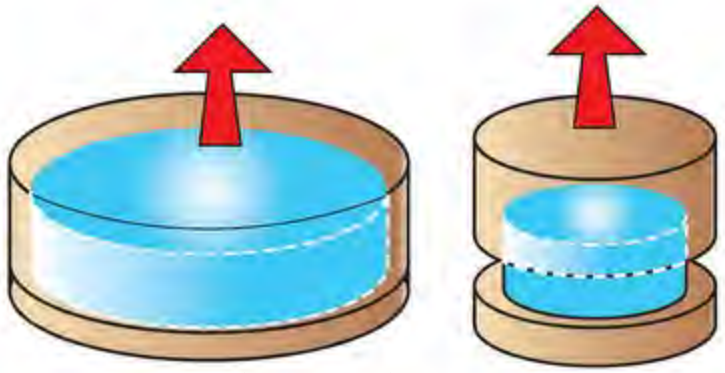

FIG 16.35 The greater the surface area of an abutment, the greater the retention. Wider implant abutments *(left)* have greater retention than narrow-diameter implant abutments *(right).* (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Additionally, preparing or roughening the abutment surface will result an increased surface area. The surface of stock or premanufactured abutments should be modified with a diamond bur, cross-cut fissure carbide, or a heatless stone. This will also increase mechanical retention for cementation (Fig. 16.36).

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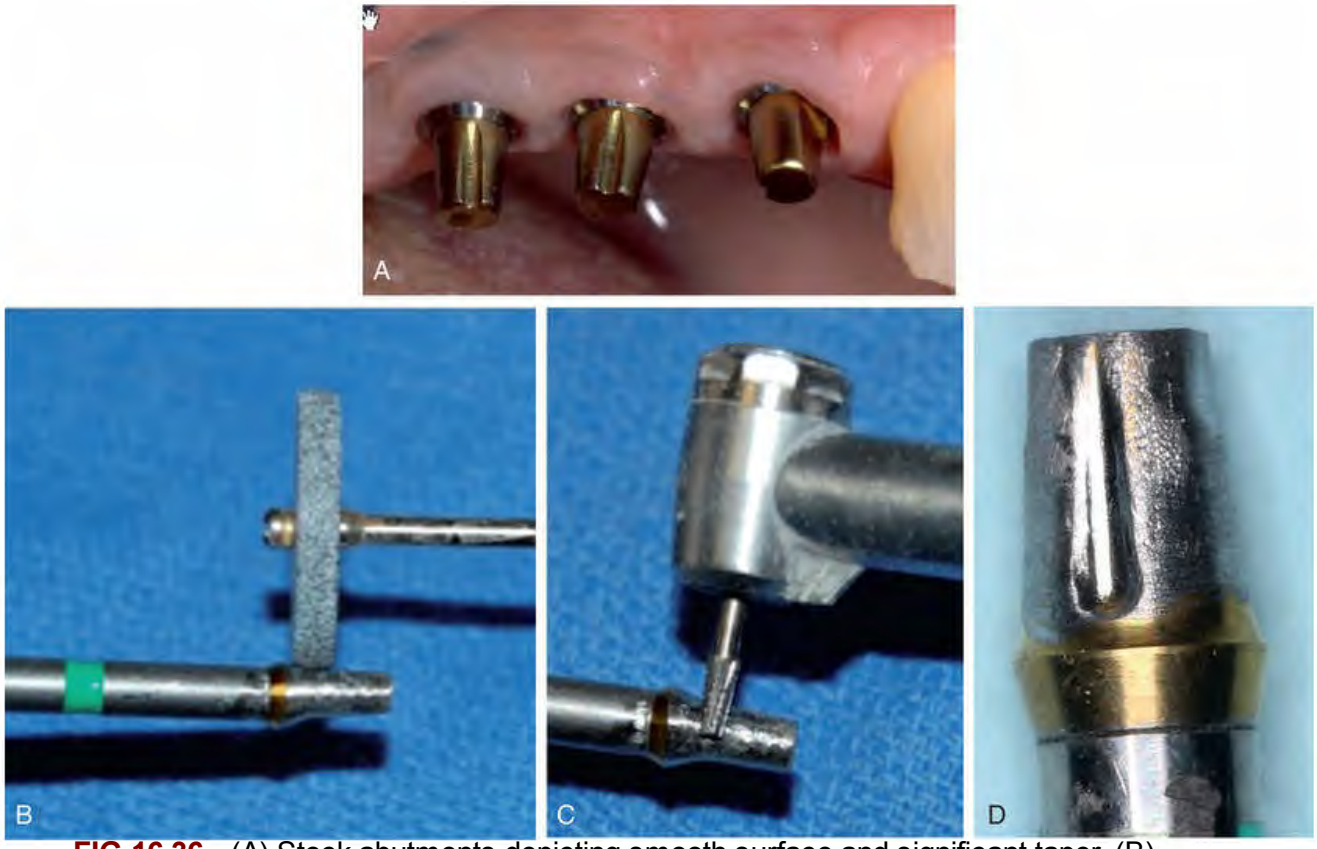

FIG 16.36 (A) Stock abutments depicting smooth surface and significant taper. (B) To increase surface area, abutments are roughened with heatless stone. (C) Abutments roughened with cross-cut fissure bur. (D) Grooves may be placed within the abutment, which increases retention and resistance form.

Abutment Height.

With dental implant abutments, the longer (increased height) the abutment, the greater the retention, which results in fewer uncemented restorations. The increase in height and the height-to-width ratio are determinants for retention. Studies have shown a 2-mm increase in height will increase retention up to 40%, especially when the abutment is only 4 mm in diameter. An increase in height from 4 to 7 mm results in a 67% increase in retention.[45] When the height of the implant abutment is less than 5 mm, the diameter of the implant abutment is more critical to improve cement retention or resistance. A customized abutment, larger in diameter than the stock abutment, may be necessary to retain the restoration. In these instances, additional abutment height not only increases the surface area but also results in increased retention and resistance form. The longer axial walls allow for more compressive and tensile force, rather than damaging shear stress.

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Geometry of Abutment.

Manufactured implant abutments for cement are usually circular in cross section, providing little resistance to shear forces, especially on individual, unsplinted crowns. The surface area of an abutment exposed to shear forces is more critical than the total surface area under tensile force.[46] The strength of the cement interface is weakest under the shear component of a force. A flat side on the implant abutment preparation decreases shear forces on the cement interface. Whenever possible, a preparation with one or two flat sides should be made on circular abutments for cemented prostheses (Fig. 16.37).

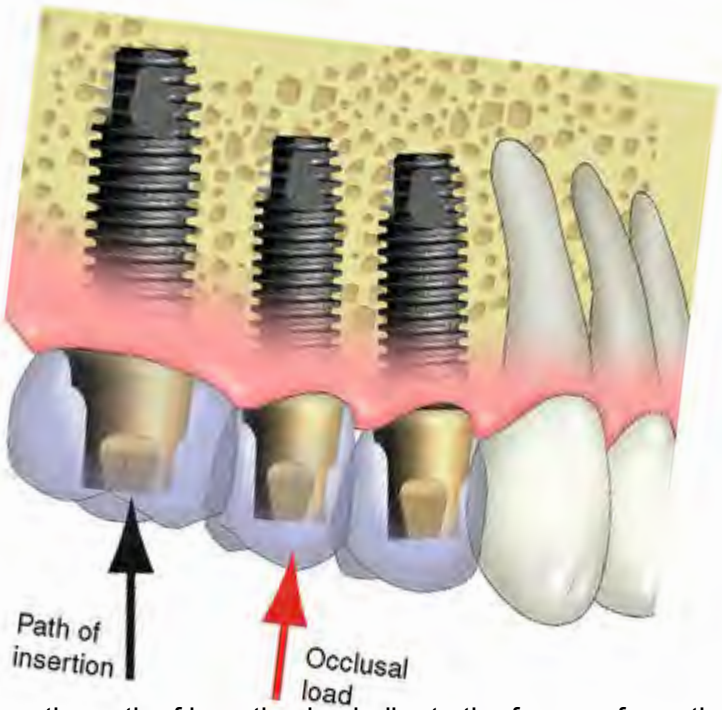

FIG 16.37 When the path of insertion is similar to the forces of mastication, sticky food may place shear and tensile forces on the restoration and contribute to uncemented prostheses. The implant body should receive a long-axis load to reduce crestal stress. A path of insertion different from the occlusal force direction is selected to decrease the shear loads to the cement seal from the sticky foods. A path angle to the mesial facilitates preparation of the abutment and seating of the restoration. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A tapered implant abutment post may provide multiple paths of insertion or removal. The addition of one or more parallel-sided grooves to an abutment limits the path of withdrawal of the crown to one direction.[47] Whenever possible, retentive elements such as grooves parallel to the path of insertion should be added to a short or excessively tapered implant abutment for cement. Additional grooves parallel to the path of insertion mechanically

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resist rotational forces, place compressive forces on the cement in these regions, and dramatically improve cementation.[48] However, caution should be exercised on the outer walls of two-piece abutments. These abutments most likely have thin walls, and a groove may perforate or weaken the abutment (Figs. 16.38 and 16.39).

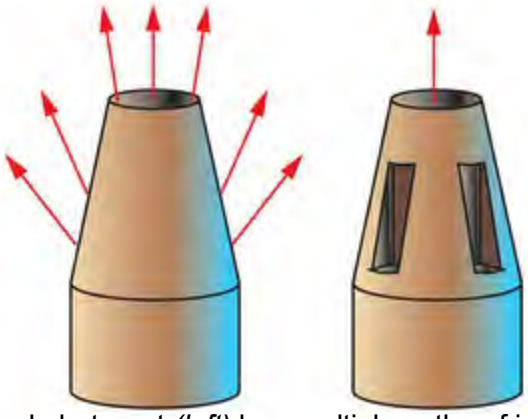

FIG 16.38 A tapered abutment *(left)* has multiple paths of insertion or removal. Grooves in the axial walls of the abutment limit the path of removal and decrease uncemented restorations. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 16.39 Short abutments may increase retention and resistance by preparing parallel grooves in the axial walls and by having a subgingival margin that increases abutment height. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Abutment Surface Texture.

The surface texture of the abutment increases the retention of a restoration

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by creating microretentive irregularities into which the luting agent projects. The surface retention depends on the surface texture, the type of burs used for the preparation, and the type and thickness of the luting agent.[49] The clinician may use a coarse diamond over the surface of the implant abutment to increase the amount and depth of microscopic scratches on the surface to more than 40 μm. The internal aspect of the casting can also be air abraded with 50 μm of alumina to enhance its retention for cementation by as much as 64%.[50]

Abutment Resistance Form.

The resistance form of an abutment opposes the uncementation of the prosthesis against forces directed in apical, oblique, or horizontal directions.[46] Forces most likely to cause uncemented restorations related to resistance are associated with parafunction, long spans, cantilevers, mobile natural abutment teeth joined to implants, offset loading, and horizontal loads from occlusal contacts.

When a force is directed within the margins of the abutment crowns, leverage or tipping forces are limited. However, for implant-supported prostheses, forces often are projected away from the abutment, usually facially. In addition, excursive movements generate a leverage force, especially on maxillary anterior abutments. The forces affect not only the bone-implant interface but also the cemented abutment crown. The arc of rotation of the crown influences the dislodging forces and is affected by the direction of forces. The surface design and conditions of the preparation farthest from the fulcrum or rotation point provide the resistance to uncementation. The greatest resistance factors of the abutment for cement retention to a moment force are a minimum abutment taper and maximum abutment height. The higher the abutment, the greater its resistance to lateral forces. The height of the abutment should ideally be greater than the arc formed by the crown rotating about a fulcrum at the margin of the opposite side of the restoration (Fig. 16.40).[43]

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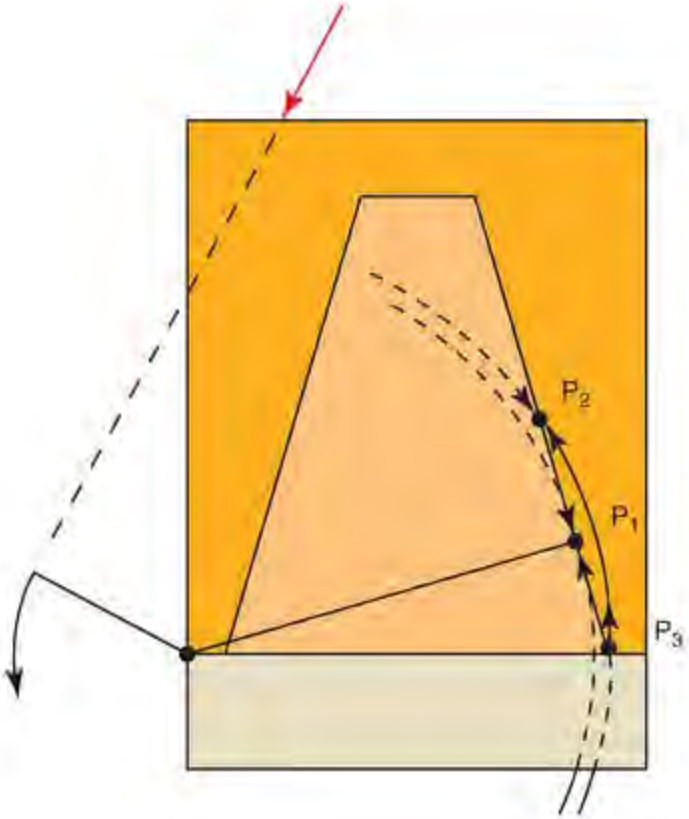

FIG 16.40 The dislodging force to a crown is related to the arc of rotation and is a radius of a circle determined by the edge of the crown margin to the base of the abutment (P_3). The taller the abutment, the more resistance to the lateral force. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Most implant abutment heights range from 4 to 10 mm. Some manufacturers only supply ≈5-mm abutments to save the clinician preparation time. Although this may be adequate in some situations, a cantilever or fixed prosthesis with a large crown height often may require longer implant abutments to resist the arc of removal or to resist lateral forces in the anterior regions of the mouth. In cases with insufficient height, ideally a custom abutment should be fabricated to increase retention and resistance form (Fig. 16.41).

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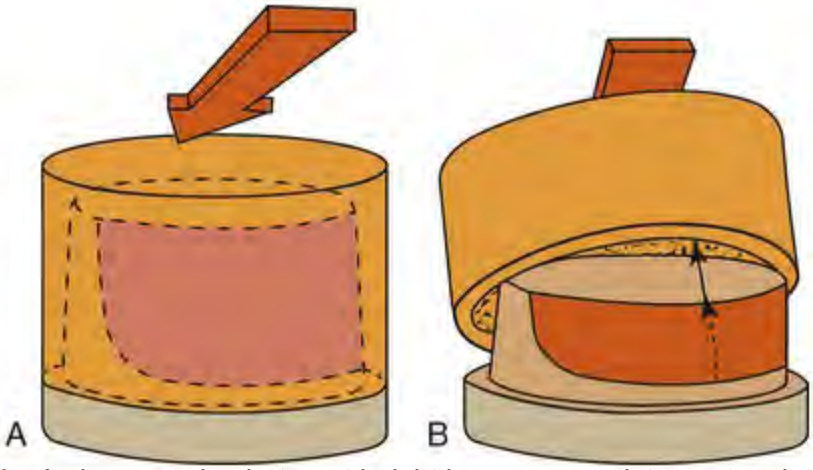

FIG 16.41 An increase in abutment height increases resistance to a lateral force because more of the axial walls are placed under compressive forces (A). A short abutment height has less resistance to a lateral force or cantilever force (B). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A wider-diameter implant abutment provides greater retention but may offer less resistance to moment forces than a narrow abutment for a similar height and degree of taper. The wider abutment for cement has a longer axis of rotation and provides a reduced area of resistance at the opposite side of the preparation. The worst resistance form is with a short, wide abutment, for example, in a molar region (Fig. 16.42).

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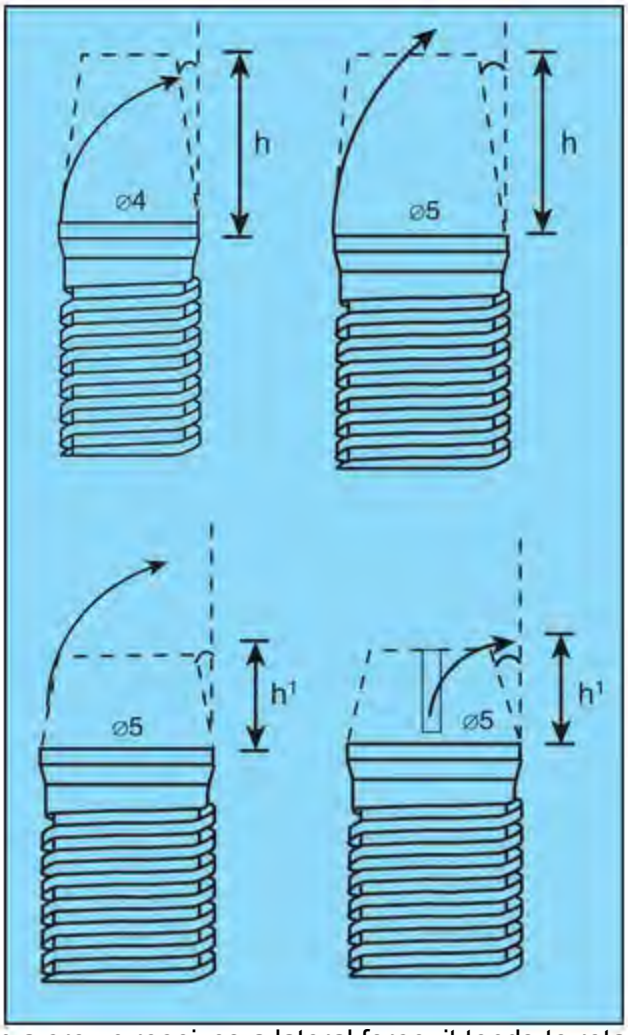

FIG 16.42 When a crown receives a lateral force, it tends to rotate upward on one side of the implant. The arc of rotation is related to the diameter of the implant. The greater the width, the greater height the arc of rotation. The abutment should be higher than the arc of rotation. A wider implant requires a taller abutment than a smaller-diameter implant *(top).* The arc of rotation is decreased when directional grooves are prepared into the abutment *(bottom).* When abutment height is questionable, directional grooves decrease the risk of uncementation *(bottom right).* (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Since the introduction of implant-supported cantilevered prostheses for completely edentulous arches (i.e., Brånemark approach), the cantilever has gained acceptance in implant dentistry. A cantilevered restoration also forms an arc of removal when force is applied on the cantilevered portion. The radius of the arc of displacement is equal to the anterior to posterior contacts, not the A-P distance of the implants. The height of the implant abutment farthest from the fulcrum or cantilever is the primary element for resistance (Fig. 16.43).[43]

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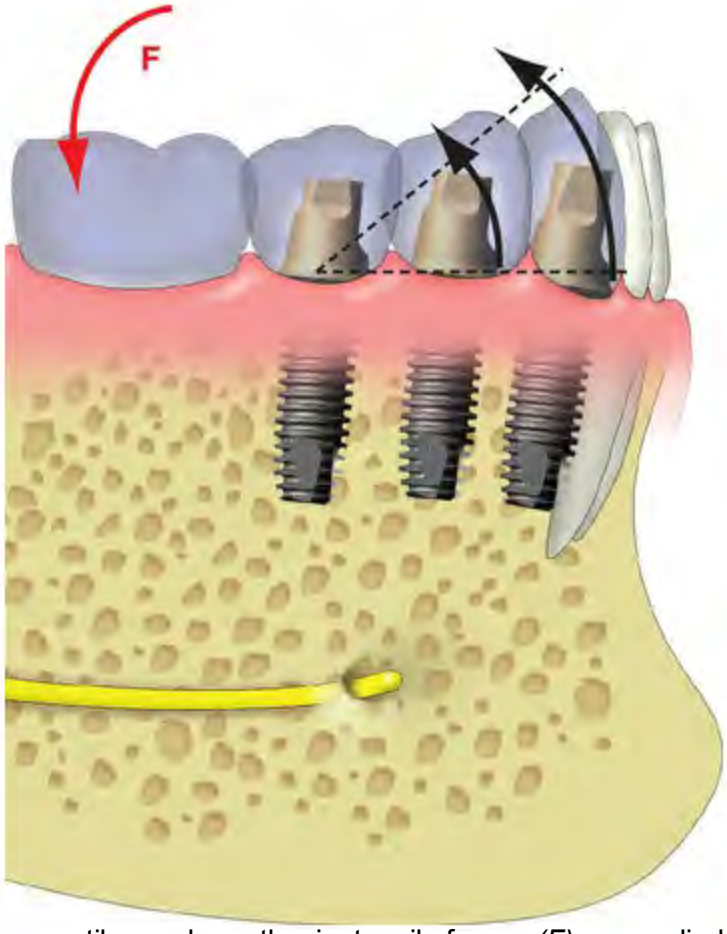

FIG 16.43 In a cantilevered prosthesis, tensile forces *(F)* are applied on the crown farthest from the cantilever. The height of the implant abutment should be greater than the arc of displacement of the prosthesis to increase the amount of resistance and compressive forces to the cement seal below the arc of displacement. The abutment farthest from the cantilever has the greatest height requirement. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Torque or bending moments placed on implants as a result of, for example, cantilever bridges or bar sections may result in interface breakdown, bone resorption, prosthetic screw loosening, and fracture of the implant, components, or prostheses. However, one of the most common complications of cantilevers is an uncemented restoration, which may occur as often as 60% of the time in three-unit restorations. Proper restorative designs must include features to resist such forces. The tensile and shear forces on the abutment for cement retention from the posterior cantilever bar or pontics may be reduced by vertical grooves on the buccal and lingual aspects of the posterior abutments. As a result, the arc of displacement and the moment force on the restoration are mechanically reduced (Fig. 16.44). Implants often are placed more medial than the occlusal or incisal contacts of the overlying prostheses. Both of these conditions create offset loads on the implant

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abutments and greater tensile and shear forces on cement or screw fixation devices. Buccolingual offset loads place the cement under tension, which may increase uncementation. When the implant crown has an offset load to the facial or lingual, the radius of rotation for dislodging forces is increased. Additional resistance features are indicated on the mesial or distal of the abutment (Fig. 16.45). These loads may be reduced on a cement-retained prosthesis by placing vertical grooves on the mesial and distal aspects of the restoration (Fig. 16.46). The same features are beneficial when horizontal forces are introduced from a mutually protected occlusion or bruxism.

FIG 16.44 Buccal or lingual vertical directional grooves (or both) may be used with a mesial or distal cantilever to modify the arc of displacement and decrease the risk of uncementation. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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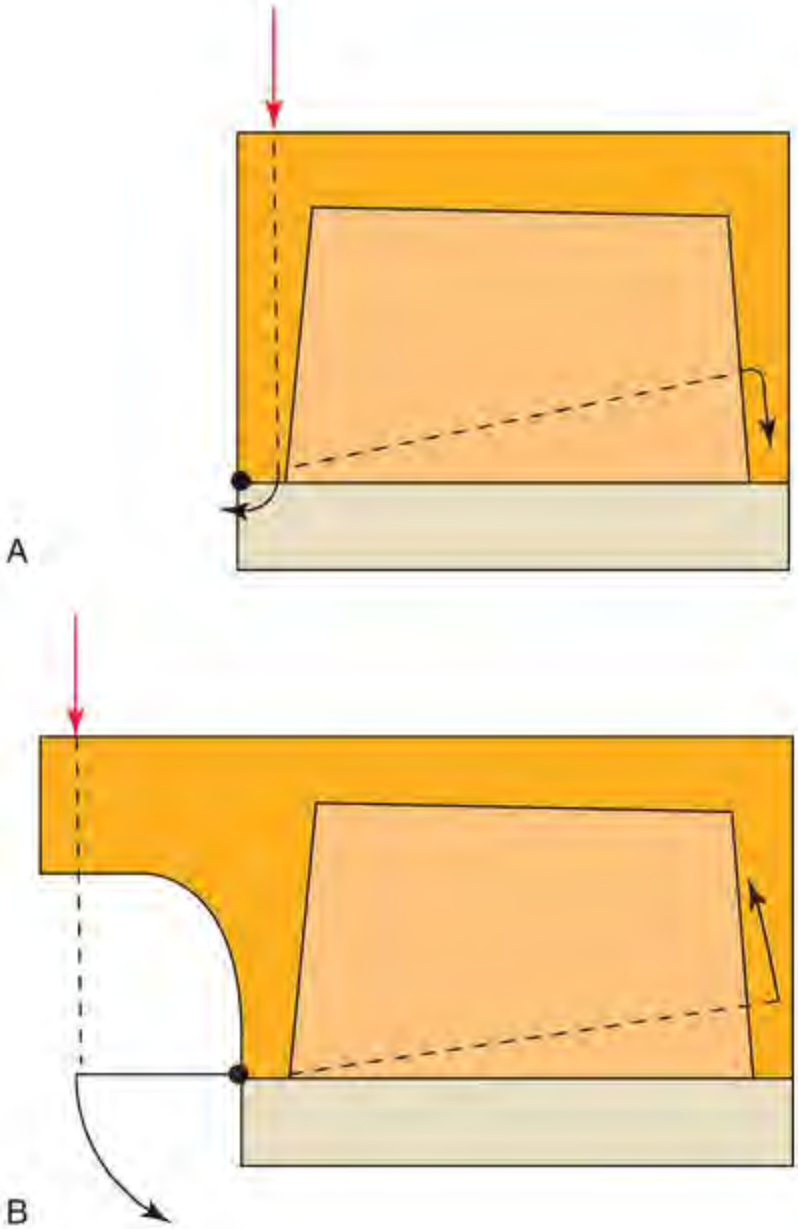

FIG 16.45 (A) An offset load is often placed on an implant crown. (B) This load acts as a cantilever force and increases the radius of the arc of rotation for dislodging forces. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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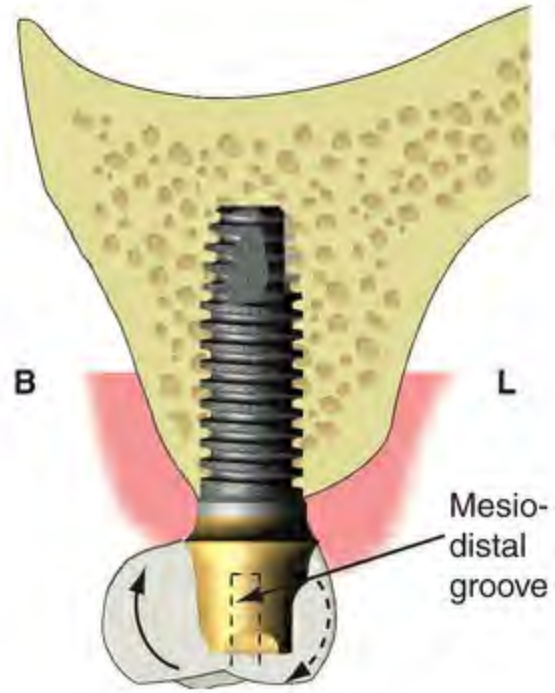

FIG 16.46 Mesial and distal vertical directional grooves decrease tensile and shear forces on a prosthesis subjected to buccal or lingual offset loads. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In summary, when the cantilever is to the mesial or distal, the grooves or boxes in the abutment preparation should be on the facial or lingual of the preparation. When the cantilever is to the facial or lingual, the groove or box should be placed on the mesial or distal of the abutment.

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Prosthesis Complications

Improper Crown Margin

Etiology

Position.

The indications for subgingival margins described for teeth may be adapted to implants and are only indicated for two reasons: increased retention and esthetics. The advantages of supragingival margins suggest their use on implants in the majority of situations that are out of the esthetic zones. Often clinicians use the prefabricated abutments with a built-in flare. This is most likely 1 mm above the implant body connection, which is often near the crest of the bone, resulting in a deep subgingival margin.

Margin type.

Implant abutments are a common indication for minimum abutment margin reduction because they are usually smaller in diameter than a prepared natural tooth for a crown (5 mm or less). Reduction of the abutment diameter to achieve room for porcelain or a beveled margin further decreases the surface area for retention. Additional space for metal and porcelain in the region of the margins typically is not required because the implant is already smaller in diameter than the cervical aspect of the tooth and sufficient volume is available for the restorative materials (Fig. 16.47).

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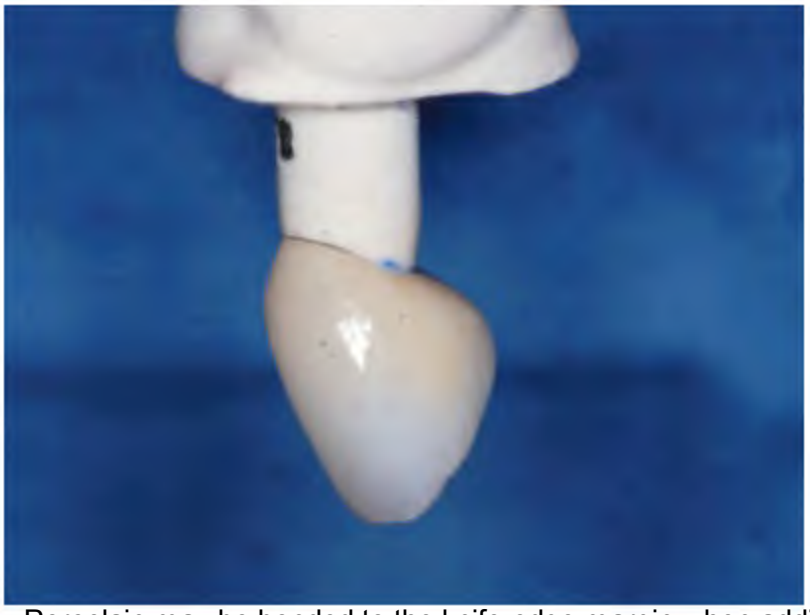

FIG 16.47 Porcelain may be bonded to the knife-edge margin when additional bulk and contour are necessary to develop the emergence of the crown. The porcelain applied to the knife-edge margin may extend from the metal coping to any emergence contour desired. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prevention/Treatment

Position.

The subgingival margin for teeth or implants should not proceed further than 1.5 mm below the free gingival margin even in the interproximal region. It is important to note that the implant abutment flare is often 1 mm above the implant body connection, which is often at the crest of the bone. When the tissues are 2.5 mm thick (or more), the abutment flare is apical to the crown margin location.

Margin Type.

Traditional preparations on teeth usually restrict the use of knife-edge margins (minimum tooth preparation) to avoid overcontouring of the final restoration. No scientific studies have stated that chamfers or chamfer and aprons are superior to other finish lines, but the ease of preparation has made them desirable and avoids excessive bulk of restorations. However, whenever minimum implant abutment or tooth preparation is indicated, a knife-edge finish line should be considered (Box 16.4).

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Box 16.4

Indications for a Knife-Edge Margin

1. Implant abutments
2. Furcation regions
3. Interproximal region mandibular incisors
4. Lingual surface of mandibular posterior teeth
5. Convex axial surfaces
6. Abutment tilted more than 15 degrees

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

A knife-edge finish line also is indicated on the side of the implant or natural abutment tilted more than 15 degrees. The amount of abutment material removed for parallelism jeopardizes the width of the implant abutment. Minimum structure removal of the implant or natural tooth on the side toward the angulation is suggested to reduce these complications.

An exception to a knife-edge abutment margin is when the implant is too facial or too close to an adjacent tooth and a porcelain crown margin is desired. Crown margin designs such as a shoulder or chamfer can be selected in cases in which the implants are placed too facially so as to create sufficient space for the restoration and avoid overcontouring (Fig. 16.48). Another indication for greater reduction is to allow for sufficient space in a mesiodistal dimension for the prosthesis when two implants are too close to each other. Preparation will need to be made to allow for ideal hygiene practices.

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FIG 16.48 The facial position of two of these implant abutments requires a chamfer preparation to provide greater room for porcelain. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Nonpassive Prosthesis

The passive fit of a prosthesis was first described by Brånemark to be approximately 10 μm between the prosthesis and the implant or abutment.[51] Other authors have shown marginal fits up to 100 μm are clinically acceptable, with larger gaps having a greater chance of bacterial colonization and increasing inflammation around the implants.[52] The definition of passive fit has evolved to be a clinical "acceptable fit in which the stress/strain conditions are within the physiologic range that enables immature bone to mature and remodel in response to occlusal loads following physiologic connection."[53] A horizontal fit discrepancy leads to binding of the screws and bending stresses in the implant system. A vertical fit discrepancy results in the preload bringing the mating surfaces together, which predisposes the screw to fatigue fractures and loosening.[54]

Ideally, when a prosthesis is retained by prosthetic (coping) screws, the restoration passively sits on top of the abutments, and the prosthetic screws fixate the two components together. When the prosthesis fits passively, the screws place a compressive or tensile force on the abutments, but no force is transmitted to the implant bodies (Fig. 16.49). If, however, the casting of the prosthesis does not sit passively on the abutments for screws, the force of the prosthetic screws is then transmitted to the implant bodies (Fig. 16.50).

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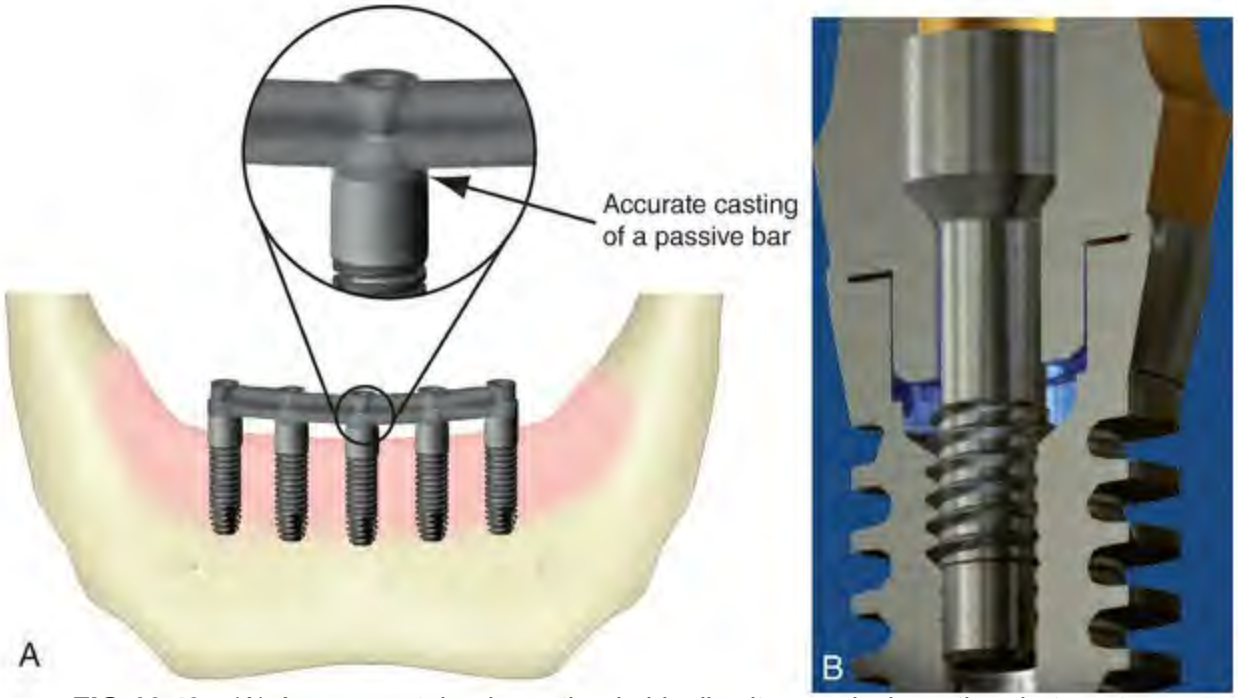

FIG 16.49 (A) A screw-retained prosthesis ideally sits passively on the abutments, and the prosthetic screws are held in place by compressive, tensile, and shear forces. (B) Passive fit of the prosthesis occurs when no microgap is present and the abutment is fully seated. ([A] from Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 16.50 If the prosthesis is not passive, the torque force placed on the prosthetic screw is transferred to the implant body. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A screw is a combination of inclined planes and wedges and is one of the most efficient machine designs. A torque force of 20 N-cm applied on a screw can move two railroad cars. This same force applied to a nonpassive casting tends to distort the superstructure, underlying bone, and implant components (Fig. 16.51). Because the force is constant, it can introduce biomechanical creep into the system, which can fatigue materials and bone. An implant does not predictably move within bone, yet retained stresses from nonpassive castings must be accommodated through a bone remodeling process.

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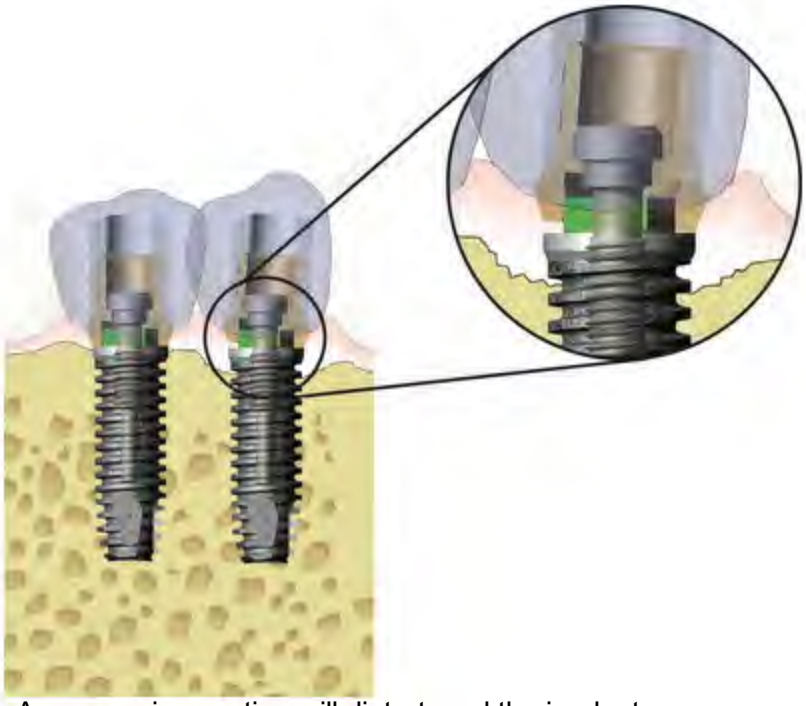

FIG 16.51 A nonpassive casting will distort, and the implant may move or strain the bone when the screw is torqued into position. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

As a result of all these variables, implant prosthesis distortions ranging from 291 to 357 μm may be observed during the fabrication of the restoration.[55] Passive final restorations are highly unlikely when more than two implants are splinted together and support a prosthesis with screw retention as the method of fixation. If a casting has a 50-μm misfit, the casting and implant may have to move 200 μm before the system is completely passive (Fig. 16.52). This is a considerable risk to create crestal bone loss, loose prosthetic screws, and implant failure.

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FIG 16.52 A misfit of 50 µm of casting may require the prosthesis and implant to move 200 µm before becoming passive. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Etiology

When the screw-retained prosthesis is attached to the abutment for screw retention of the implant, no space exists between the crown and abutment. Instead, a metal-to-metal system with zero tolerance for error is created. Nonpassive screw-retained restorations may create permanent strain conditions on the implant system that can be many times greater than that of cemented prostheses. The microstrain applied to the bone may fall beyond the overload zone and into the pathologic zone in which bone remodeling occurs with crestal bone loss or even implant failure.

Nonpassive prostheses have been shown to be a primary cause of unretained restorations, crestal bone loss, implant component fracture, and implant mobility. A truly passive screw-retained dental restoration is virtually impossible to fabricate on multiple splinted implants.[56] There are too many variables that are out of the clinician's control when attempting to fabricate a prosthesis. Unfortunately, this process allows for zero tolerance for error, and laboratory procedures may lack the precision needed for such an exact result.

Full-arch restorations more often are not passive despite an acceptable metal try-in because the volume of porcelain or acrylic shrinkage may have caused material distortion. Porcelain and acrylic shrinkage also is related directly to material volume and may distort the superstructure even though

the superstructure was initially passive.

The "clamping down" while tightening the prosthetic screws of an inaccurate structure may lead to screw loosening and fracture. After prosthesis delivery, an abutment for screw retention or prosthesis screw may loosen between appointments. This usually indicates that the casting is not seated passively, yet the cause often is overlooked. Instead, the screws are tightened again (often with more torque), and the bone must remodel to release the strain in the implant system. This strain may lead to crestal bone loss and possibly even implant failure.

Indirect Transfer Copings.

The use of indirect transfer copings on multiunit implant cases is a significant source of nonpassive restoration. An *indirect-transfer coping* utilizes the elastomeric properties of impression material. The indirect-transfer coping is screwed into the abutment or implant body and remains in place when a traditional "closed-tray" impression is set and removed from the mouth. The indirect-transfer coping is removed from the implant body/abutment in the mouth, connected to an implant body analog, and then reinserted into the closed-tray impression. The copings usually have undercuts that engage the elastic impression material when reinserted, are slightly tapered to allow ease in removal from the impression, and often have flat sides or smooth undercuts to facilitate reorientation in the impression after it is removed.

The disadvantages of this technique include inaccuracies within the elastomeric impression material, inability to insert the implant into the correct position, and micromovement of the implant components. The indirect impression transfer copings remain in the mouth when the impression is removed and are replaced into the impression before pouring the working or master cast. The greater the permanent deformation, the less retentive the impression pin and the more variable its position in the distorted receptor site. As stone is vibrated around the indirect transfer, the attached abutment analog may move, and the final position may not be accurate relative to the intraoral abutment position.

Another source of impression transfer error may occur when the impression is made. An air bubble inadvertently may be present on the top of the transfer coping; as a result, the transfer may be reinserted into this void beyond its initial position. Some manufacturers have incorporated a screw hole or slot in the top of the transfer coping, which should be blocked

out before making the impression. Otherwise, the positive replica in the impression may prevent the indirect transfer from seating completely in the impression before the pouring of the master model. This will result in definite inaccuracies of the true position of the implant bodies.

Prevention

Impression Material.

Clinicians must understand the advantages and disadvantages of impression materials. The dimensional change of the impression material from 2 minutes after it leaves the mouth to 24 hours later is an important property. The amount of change can be used as a gauge to evaluate other properties of the material. All elastic impression materials shrink after they are removed from the mouth.[57] The rate of shrinkage is not uniform. In general, about half of the shrinkage occurs during the first hour after removal from the mouth. The greatest accuracy occurs if impressions are poured soon after they are made. Polyethers absorb water, which increases dimensional change, and should not be stored in this medium. In addition, most impression materials continue to change after the 24-hour period. The exception to this rule is addition silicones, which are stable and may not change for many days. The greatest dimensional change occurs with condensation silicones (Table 16.3), which exhibit more than a 0.5% dimensional change. This change is clinically relevant. Superstructures fabricated from these models will be less precise. The use of condensation silicone should be avoided. Polysulfide has about half the amount of shrinkage as the condensation silicones (0.2%). This also may be clinically relevant. Polysulfide continues to shrink dramatically after 24 hours.[58] Pouring of the impression as early as possible is strongly advised. In a study comparing tray and impression material performance over time, addition silicone impression materials exhibited the longest stability, with up to 720 hours.[59] Although varied results have been published, the vast majority of studies appear to conclude that the least amount of dimensional change occurs with addition silicones (0.06%) and polyethers (0.1%). The use of these materials to make the final impression for a screw-retained restoration is strongly suggested (Fig. 16.53).

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TABLE 16.3
Setting Properties of Elastic Impression Materials

	Permanent Deformation (%)	Dimensional Change at 24 Hours (%)
Polysulfide	3.0	0.22
Silicone Condensation Addition	0.4 0.07	0.58 0.06
Polyether	1.1	0.10

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

FIG 16.53 Impression materials. All impression materials shrink after setting. This results in the implant analogs being in a different position than in the mouth. Silicones and polyethers are the most dimensionally stable materials for final impressions.

Laboratory Process/Materials.

Almost all laboratory materials will have associated inaccuracies. Dental stone has been shown to expand 0.01% to 0.1% and does not correlate to the dimensional changes of impression materials.[60] In addition, the wax patterns distort while setting or spruing, and the investment material expands a variable amount.[61] The metal castings shrink when cooled, and the shrinkage does not permit an accurate metal-to-metal connection.[55] The metal superstructures are often thicker and larger in implant prostheses than in traditional prostheses because the implant abutment is of reduced diameter,

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and bone loss volume often is replaced by the final prosthesis. Dimensional changes during metalwork fabrication are correlated directly with the size of the casting. The marginal fit and tolerance between the implant analog and implant abutment are often different from actual implant and abutment components.[62] Implant components are not all fabricated to exact dimensions, and each transfer of an implant component has a slightly different size, which leads to misfit and is magnified by the number of different pieces used during the fabrication steps.

As a result of all these variables, implant prosthesis distortions ranging from 291 to 357 μm may be observed during the fabrication of the restoration.[55] Passive final restorations are highly unlikely when more than two implants are splinted together and support a prosthesis with screw retention as the method of fixation. If a casting has a 50-μm misfit, the casting and implant may have to move 200 μm before the system is completely passive. This is a considerable risk to create crestal bone loss, loose prosthetic screws, and implant failure (Fig. 16.54).

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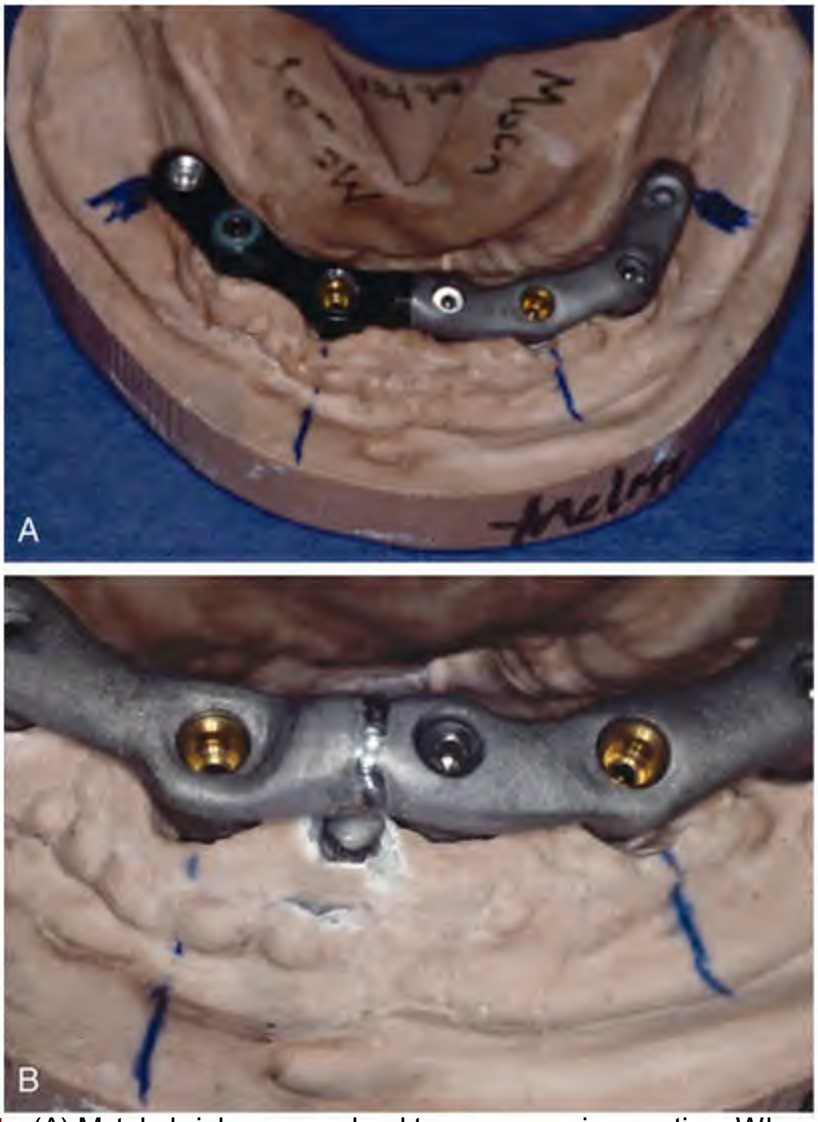

FIG 16.54 (A) Metal shrinkage may lead to a nonpassive casting. When the bar is fabricated in two or more sections, the volume of metal is reduced, and the amount of shrinkage is minimized. (B) When the casting is made in sections, it then may be laser soldered together. The two-step cross section results in a stronger union than when the sections are split in one dimension. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Impression Technique.

Various techniques have been suggested to achieve an accurate master cast. The precise transfer of the spatial relationships of implants from the mouth to the master cast with an impression is the first and critical step to ensure passive fit of implant framework. To maximize the accuracy of the impression process, an understanding of direct vs. indirect and open vs. closed impression technique must be understood. A direct-transfer impression coping consists of two components, a hollow transfer coping (often square)

and a long central screw to secure it to the abutment or implant body. An "open-tray" impression tray is used to permit direct access to the long central screw securing the direct-transfer coping. After the impression material is set in the mouth, the direct-transfer coping screw is unthreaded to allow removal of the impression from the mouth. The square coping remains in the impression, seated on the implant without fixation. This technique utilizes the advantages of impression material with rigid properties and eliminates the error of permanent deformation because the transfer coping remains within the impression until the master model is poured and separated. They are also less likely to be rotated or moved during the model fabrication compared with the indirect techniques.

Impression Recommendation.

Square impression coping with a direct open-tray technique has been shown to be much more accurate than a tapered impression coping and stock tray.[63,64]

When evaluating the splinting of impression copings as per the Brånemark et al recommendation, there have been many controversies.[65] The basis of joining transfer copings together with acrylic resin is to stabilize and prevent any micromovement of the copings during the impression process. The problem in the past with autopolymerizing resin is the inherent shrinkage of the material. Acrylic resin has been shown to have a total shrinkage of acrylic resin between 6.5% and 7.9% in the first 24 hours, with 80% of shrinkage occurring in the first 17 minutes after mixing.[66] Another material that has been shown to be superior is impression plaster, which has a setting expansion of 0.01% and 0.12%.[67] Impression plaster is quick setting, very rigid with no distortion, easy to manipulate, and inexpensive. If acrylic resin is used, a resin scaffold should be fabricated 24 hours in advance and then separated and fused together with a low shrinkage resin (e.g., Pattern Resin [GC America Inc.]).

Treatment

Modification.

If a cemented prosthesis is not passive, the casting or abutment may be modified slightly at the same try-in appointment. High-speed carbides with copious amounts of water may be used to modify the abutment, adjust the

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internal aspect of the casting, or both, and may provide an immediate solution. The internal aspect of the casting should always be evaluated for any distortions.

Soldering.

A screw-in prosthesis that is not clinically passive requires casting separation and soldering of the casting or a new impression. The separation of the metal superstructure must respect specific dimensions to ensure the precision of the soldering (0.008 inch). Too much space causes solder shrinkage and a weak joint; too little space may cause distortion from expansion during heating of the casting.[68] Indexing the separate pieces also requires greater time, and the patient must return for another appointment after the laboratory process of soldering, which includes an additional laboratory fee (Figs. 16.55 to 16.57).

FIG 16.55 Long screws from the impression transfers are used to secure the sectioned bar. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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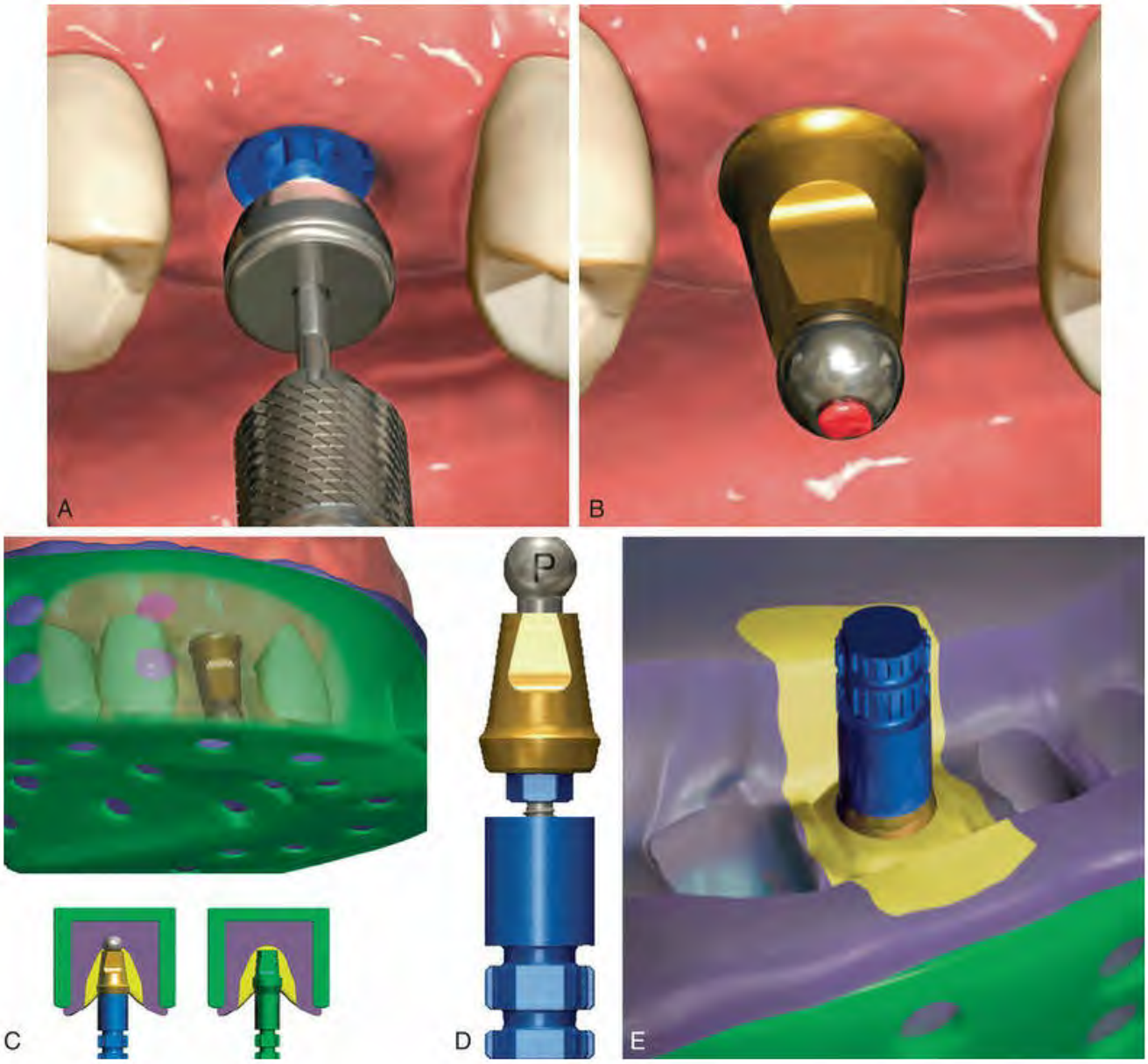

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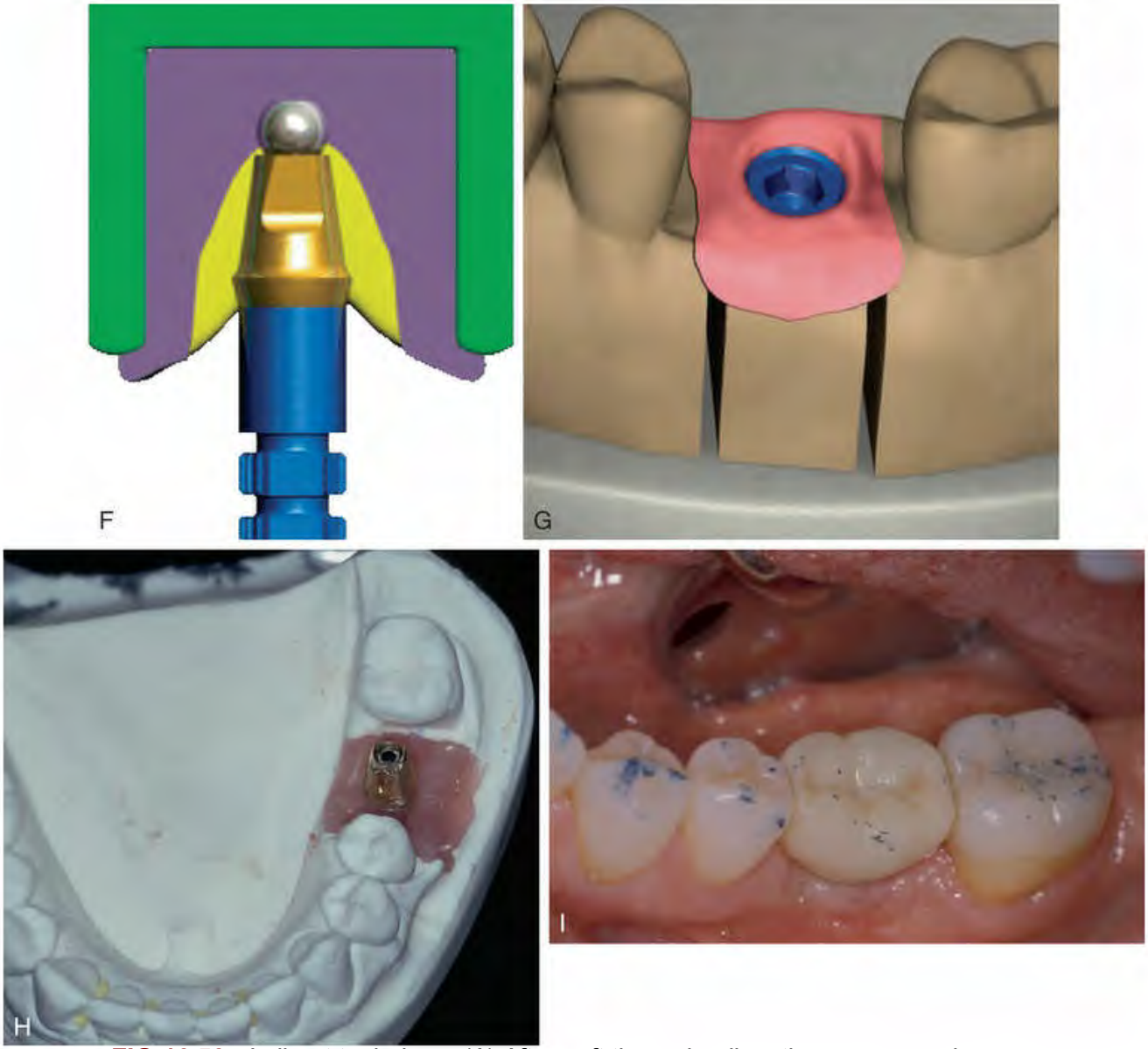

FIG 16.56 Indirect technique. (A) After soft tissue healing, the permucosal extension is removed from the implant body. (B) An "indirect" impression transfer coping is inserted into the implant body. (C) A "closed-tray" impression is made of the indirect impression transfer coping. (D) The indirect impression transfer coping is removed from the mouth and attached to the implant body analog. (Two-piece transfer and ball-top screw allow the hex of the implant module to be transferred to the analog.) (E) The implant body analog and indirect impression transfer is reinstated into the impression. (F) The indirect impression transfer is reinserted into the impression. (G) A working model is made with dental stone. A soft tissue replica may be used around the implant body. (H) A patient model with implant abutment inserted into the implant analog replacing the first molar. (I) The prosthesis is made and inserted into the mouth. ([A–G] Courtesy BioHorizons Implant Systems, Inc.; [H–I] From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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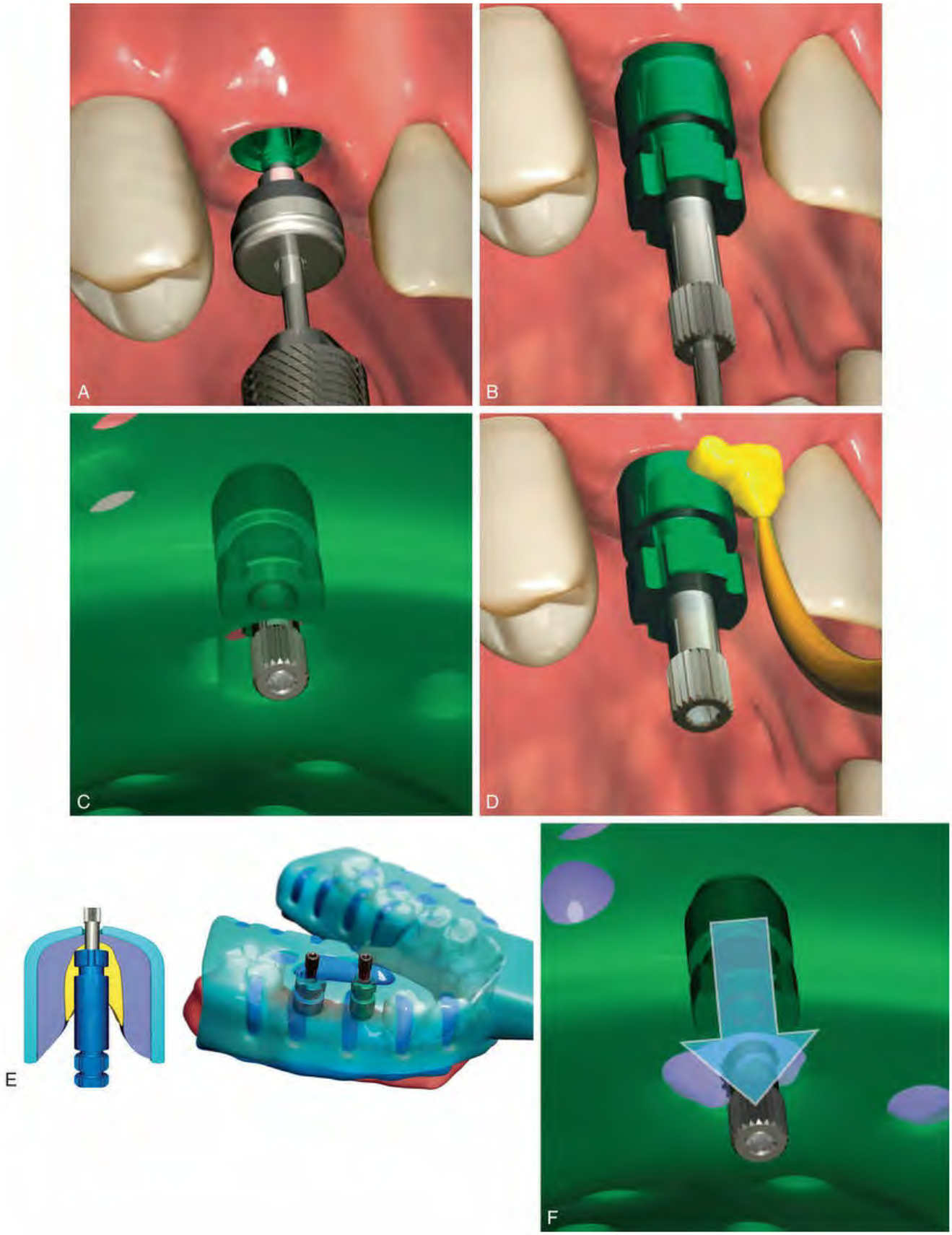

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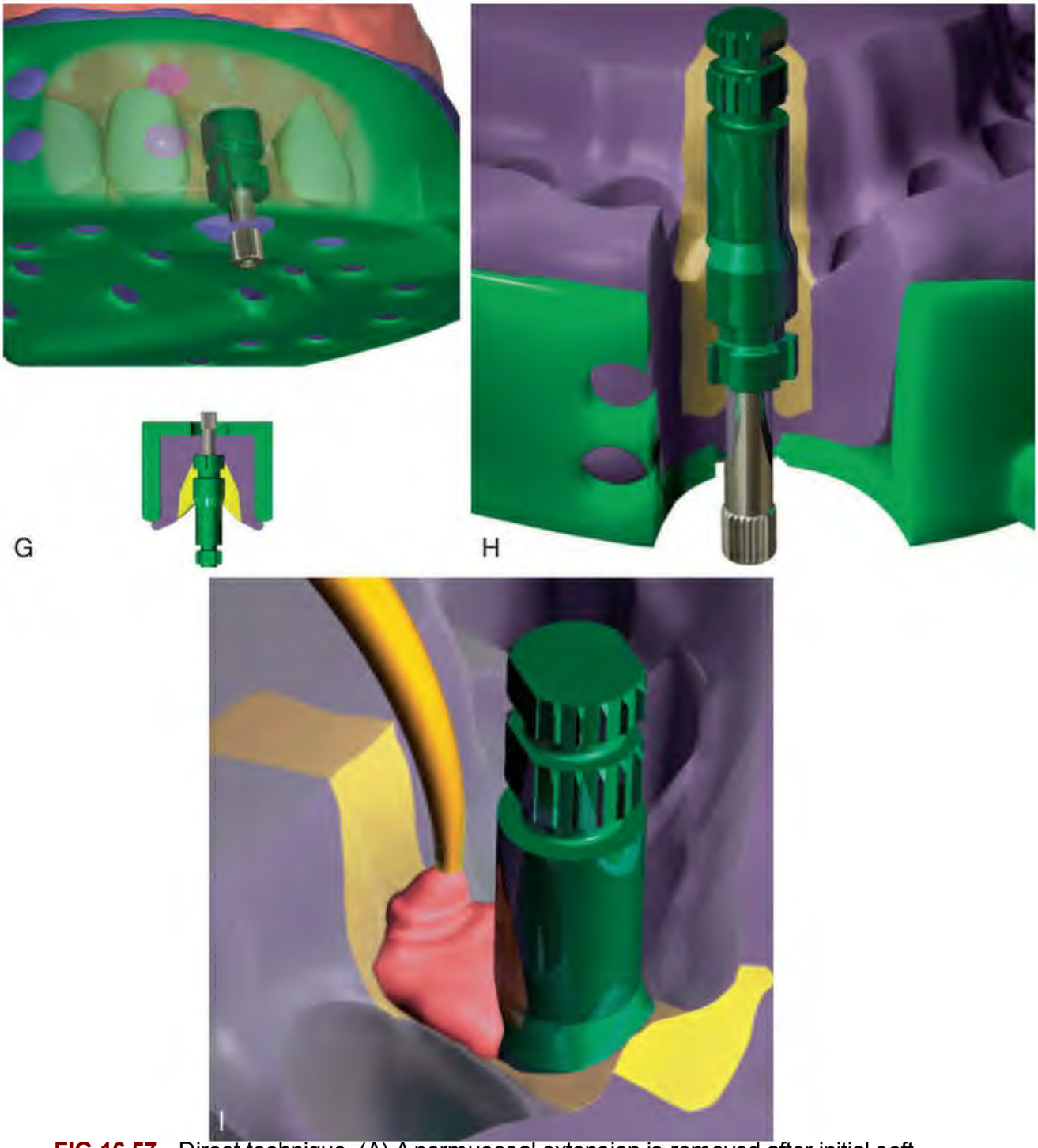

FIG 16.57 Direct technique. (A) A permucosal extension is removed after initial soft tissue healing. (B) A "direct" impression transfer coping is inserted into the implant body. (C) An "open" impression tray with an opening over the impression transfer is positioned over the implant to verify its position. (D) An impression is made of the impression transfer coping and (E) allowed to set. (F) After the impression sets, the screw is unthreaded and removed from the transfer coping. (G) An implant analog is attached to the transfer coping while it remains in the impression. (H) The implant body analog is a direct transfer because the transfer coping is never removed from the impression. (I) A soft tissue replica material is often used around the implant transfer before the stone model is poured. (Courtesy BioHorizons Implant Systems, Inc.)

Splinted vs. Independent Implant Crowns

Etiology

In implant dentistry today, many clinicians use the same concepts and protocols for implant prosthetics that they do with prosthetics on natural teeth. However, there are many misconceptions concerning splinting vs. nonsplinting of implants. The clinician must have a complete and comprehensive understanding of the differences and misconceptions between prosthetic rehabilitation of implants vs. natural teeth.

Independent Crowns (Natural vs. Implants).

The primary advantages for independent crowns are related to biologic complications on natural teeth. A single crown has a caries risk of less than 1% within 10 years. However, when natural teeth are splinted together, decay at the interproximal margin often occurs at a rate of more than 20%.[69] In addition, the endodontic risk is increased when crowns are splinted. Whereas a single crown has an endodontic risk of 3% to 5.6%, splinted teeth have an endodontic risk of 18%. Independent units reduce the incidence of complications and allow the practitioner to more readily treat these complications. However, implants do not decay or need endodontic therapy. As a result, independent units on implants would not be required to address these complications.

Splinted Crowns (Natural vs. Implants).

The primary perceived advantage of restoring implants as independent units is interproximal hygiene. When natural teeth crowns are splinted, interproximal aids are difficult to use. This is because the roots of the teeth are often less than 1½ mm apart. However, in ideal placement of implants, there will be a ≈3 mm separation. Most interproximal aids (e.g., floss threader, proxy brush) can easily reach and clean an intraimplant region. Unfortunately, fewer than 8% of our patients floss daily, and an even lower percent use any interproximal aid when their natural teeth are splinted together.[70] Because more than 90% of patients do not floss and those who do can more easily use an interproximal device between implants, the perceived advantage of improved hygiene is not a relative concept for most implant prostheses. Additionally, implants do not have the inherent disadvantages of natural teeth, in that they do not decay and are less prone to bone loss from

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bacterial plaque than natural teeth (Fig. 16.58).

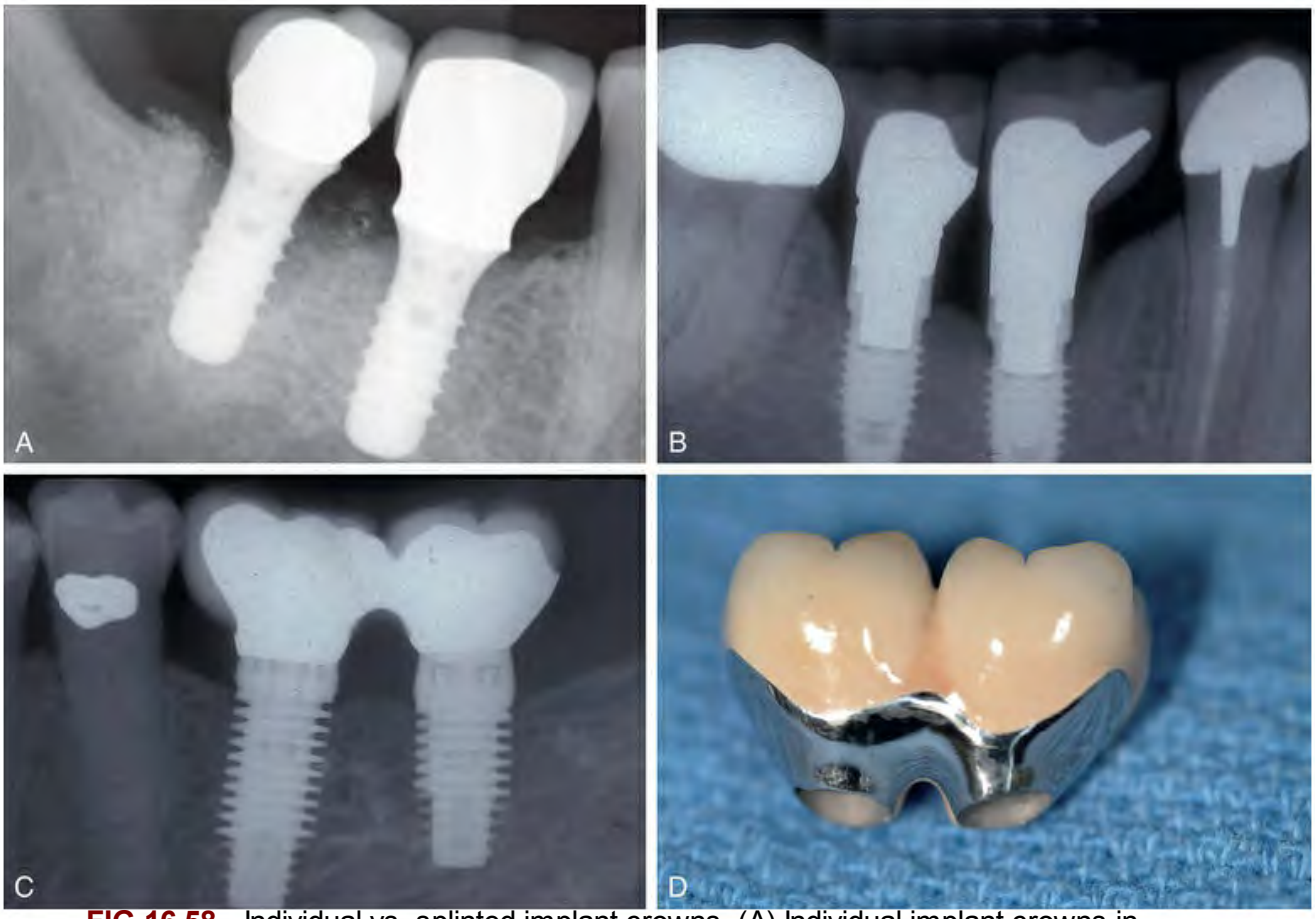

FIG 16.58 Individual vs. splinted implant crowns. (A) Individual implant crowns in the posterior mandible with associated crestal bone loss. (B) Individual implant crowns further compromised by an increased crown-implant ratio, large cusp height, and anterior cantilever. (C–D) Ideally splinted crowns, which are significantly stronger and distribute force much better than individual crowns.

Porcelain Repair.

Many clinicians will recommend the use of independent crowns on dental implants so they may repair porcelain fracture if it occurs. An evaluation of the forces on the porcelain of splinted vs. nonsplinted implants must be understood. When implants are independent, the margins of porcelain-to-metal crowns are most often placed over unsupported porcelain with shear loads, which increases the risk of porcelain fracture (interproximal). When dental implants are splinted together, the implants are supported by metal, which results in the porcelain being placed under compressive forces.

Splinting Is More Difficult.

Another perceived reason for independent implant crowns is the belief that splinting makes the case more technically challenging. As individual units, the interproximal contacts can be modified to seat the individual crowns. Fully seating all the implant crowns, although more time consuming, is supposedly a more accurate technique. The authors disagree with this thought process. The cause of casting misfit is related to impression material shrinkage, stone expansion, and analog variance of the abutment or implant body. Although this may have been an issue in the past, advancements with dental materials and techniques have led to the ability to obtain an accurate prosthesis.

Planning for Failure.

Another perceived advantage of independent implant units is if one implant fails, the clinician needs to replace only one implant and crown. However, the implant failure often causes bone loss, which then requires bone augmentation, implant reinsertion, and crown refabrication. These procedures are usually more difficult to perform around existing teeth and implants than the original implants.

Advantages of Splinted Implant Crowns.

There are many advantages to splinting dental implants together. To maximally benefit from an increased number of implants, the implants should be splinted together. Splinted implants have the following advantages over independent units:

Increase the functional surface area of prosthesis support.

Splinted implants increase the functional surface area to the support system. When implants are independent, they cannot share the occlusal load from one implant to another.[71] As a consequence, with splinted implant crowns, the risks associated with the biomechanical overload to the implant system are reduced (occlusal porcelain, cement, screw, marginal bone loss, implant-bone interface stress, and implant components failure). If a maxillary second molar implant is connected to a maxillary first molar implant, it can share an occlusal load to the first molar even when the second molar has no direct occlusal load. As a consequence of splinting, implant survival may be greater. For example, Quiryman et al[72] reported success rates of 90% for single

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implants, 97% for two splinted implants, and 98% for three splinted implants.

Increase the A-P distance (A-P spread) to resist lateral loads.

An anteroposterior (A-P) distance between two or more implants is a benefit for any angled load or cantilever, especially when three or more implants are not in a straight line. The biomechanics of an arch is of most benefit because there are five different planes connected together (bilateral molar, bilateral premolar, bilateral canines, and an anterior implant). Rotational forces, angled forces, and cantilevers to the facial or lingual (offset loads) are all reduced when splinted implants are not in the same plane and receive a load comparable to individual units (Fig. 16.59).[73]

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FIG 16.59 A-P splint. (A–C) The mandible may have a square, ovoid, or tapering shape. The anteroposterior distance between the most distal implant on each side and most anterior implant is variable and directly related to the shape of the arch. (D) The anteroposterior (A-P) distance is determined by a line drawn from the distal portion of the distalmost implant on each side of the arch and another parallel line drawn through the center of the anteriomost implant from the cantilever. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Increased retention and resistance form of the prosthesis.

Splinted implant crowns provide greater abutment surface area and resistance form; thus the prosthesis has more retention. For a cementable prosthesis, there is less force transferred to the cement interface, which results in less likelihood of uncementation. This is especially significant when the abutments are short or lateral forces are present. Both cement retention and resistance form are increased with splinted crowns. The prosthesis is less likely to become uncemented, so less hard cements or temporary cements may be used, which allows the restoration to be more easily removed when necessary (Fig. 16.60).

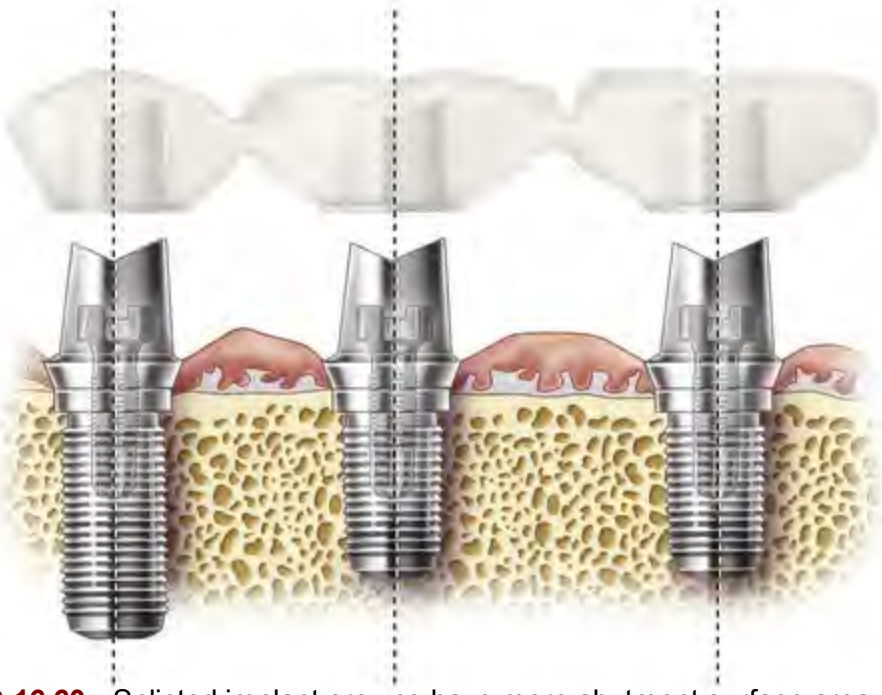

FIG 16.60 Splinted implant crowns have more abutment surface area and improved retention and resistance form. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Ease of removing the prosthesis for abutment screw loosening.

If a prosthesis does become partially retained or an abutment screw becomes loose, a splinted restoration is much easier to remove than individual nonsplinted units. The impact removal force to an individual crown is decreased by the loose abutment screw. This results in difficulty in removing the crown and possible damage to the internal threads of the implant body. In addition, attempting to engage a single crown margin is often difficult for

the crown remover, especially when a subgingival margin is present. As a consequence, the crown may need to be cut off and destroyed to gain access to the loose abutment screw. With a splinted prosthesis, a crown remover is easily engaged into the interproximal space of the prosthesis.

Decrease the risk of marginal bone loss because of better force distribution.[74]

Splinted implants have less stress transmitted to the crestal marginal bone. Force distribution is more beneficial with a splinted prosthesis; thus less force is transmitted to the osseous tissue. Increased stress to the prosthesis is related to marginal bone loss around an implant.

Decrease the risk of porcelain fracture.

Splinted crowns have less risk of porcelain fracture. The marginal ridges (and often buccal mandibular cusps) of implant crowns are usually unsupported by the metal work. As a consequence, the load on a marginal ridge is a shear load, with porcelain weakest to shear loads. In a report by Kinsel and Lin, porcelain fractures occurred in 35% of patients with implant crowns, especially when bruxing patients were restored in group function. Splinted implant crowns have the metal connectors of the casting below the marginal ridges. The interproximal porcelain has a compressive force on the porcelain, and porcelain is strongest to compressive loads.[75]

Decrease the risk of abutment screw loosening.

Splinted implants reduce the risk of screw loosening. One of the highest prosthetic complications with single tooth or independent implant crowns is abutment screw loosening. In a review of the literature by Goodacre et al, independent crowns had a screw loosening rate of 8%, with a range as high as 22%.[3] In a report by Balshi and Wolfinger, single-tooth implants replacing a molar had 48% screw loosening over a 3-year period. When two implants were splinted together to replace a molar, the incidence of screw loosening was reduced to 8% over the same time period.[76]

Decrease the risk of implant component fracture.

Splinted implants distribute less force to the implant bodies, which decreases the risk of implant body fracture. In a report by Sullivan and Siddiqui, a 4-mm single implant replacing a molar had implant body fracture in 14% of the cases. In comparison, multiple implants splinted together

report a 1% implant body fracture rate.[3,77]

Easier to treat upon implant failure.

When an independent implant fails, the implant most likely will need to be removed, which usually indicates bone grafting prior to the reimplantation. This may require multiple surgeries over a long time period with great expense to the clinician. In contrast, when multiple crowns are splinted and an implant fails, the affected implant may often be removed and the implant crown converted to a pontic using the same prosthesis. As a result, rather than several surgical and prosthetic procedures over an extended period when independent units are restored, the problem may be solved in one relatively short appointment.

Mandibular Full-Arch Splinting—Flexure

In the mandible, full-arch splinting with implants distal to the mental foramen may lead to significant complications with the patient. Patients may exhibit myofascial pain complications along with limited opening from a full-arch splint.

Etiology

Medial Movement.

The body of the mandible flexes distal to the foramen upon opening and has torsion during heavy biting with potential clinical significance for full-arch implant prostheses. Many reports have addressed the dimensional changes of the mandible during jaw activity as a result of masticatory muscle action. Five different movements have been postulated. Medial convergence is the one most commonly addressed.[78] The mandible between the mental foramina is stable relative to flexure and torsion. However, distal to the foramina, the mandible exhibits considerable movement toward the midline on opening.[79] This movement is caused primarily by the attachment of internal pterygoid muscles on the medial ramus of the mandible. The distortion of the mandible occurs early in the opening cycle, and the maximum changes may occur with as little as 28% opening (or about 12 mm). This flexure has also been observed during protrusive jaw movements.[80] The greater the active opening and protrusive movements, the greater the amplitude of mandibular flexion. The amount of movement varies among

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individuals and depends on the density and volume of bone and the location of the site in question. In general, the more distal the sites, the more medial flexure. The amplitude of the mandibular body flexure toward the midline has been measured to be as much as 800 μm in the first molar–to–first molar region to as much as 1500 μm in the ramus-to-ramus sites (Fig. 16.61A).

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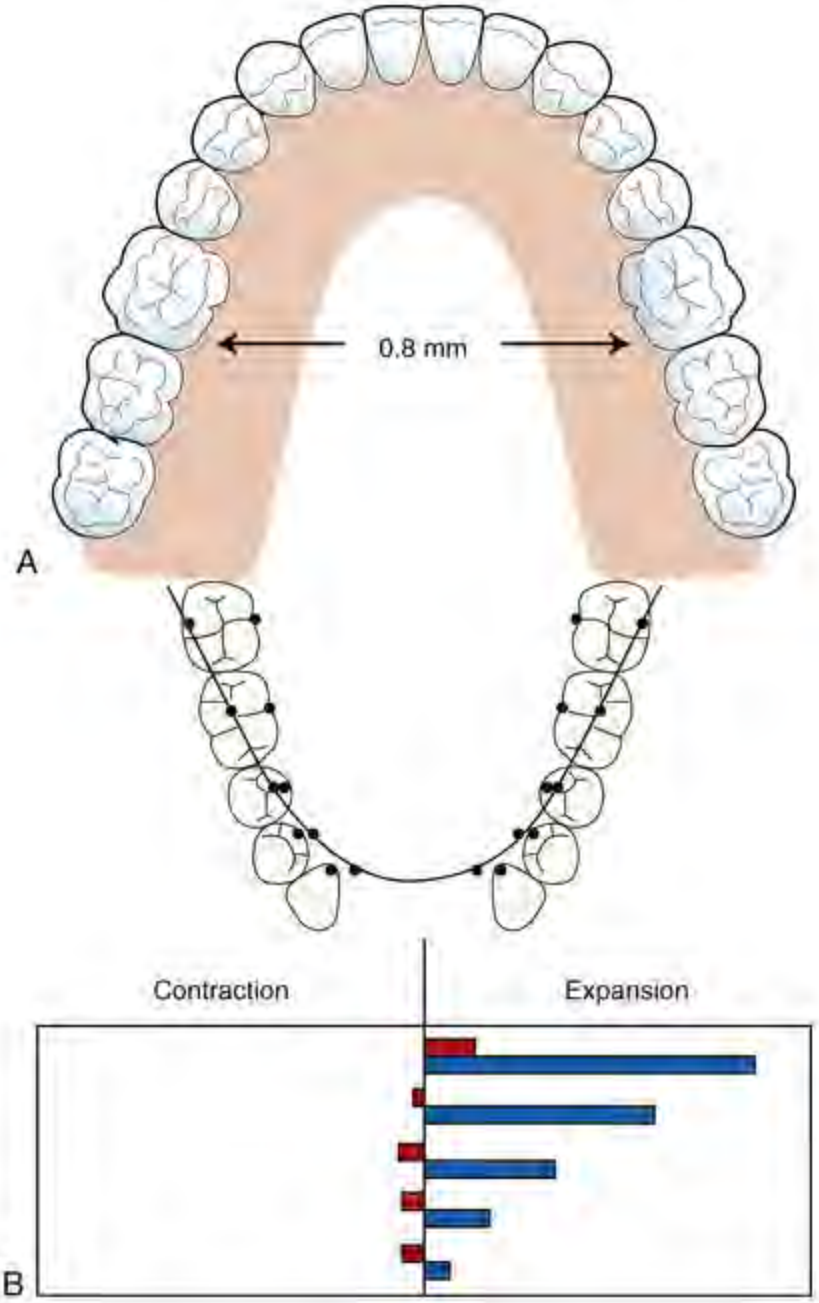

FIG 16.61 Flexure of mandible. (A) The flexure of the mandible during opening and protrusive movements occurs distal to the mental foramina. The amount of flexure depends on the amount of the bone volume and the sites in question. The medial movement from the first molar to the first molar region may be 800 μm. (B) Unilateral molar biting causes the mandible to undergo torsion with the bottom of the mandible expanding outward and the crest of the mandible rotating medially. (Adapted from Hylander WL: Mandibular function in Galago crassicaudatus and Macaca fascicularis: an in vivo approach to stress analysis of the mandible, *J Morphol* 159:253–296, 1979.)

Torsion.

Torsion of the mandibular body distal to the foramina has also been documented in both animal and human studies. Hylander evaluated larger

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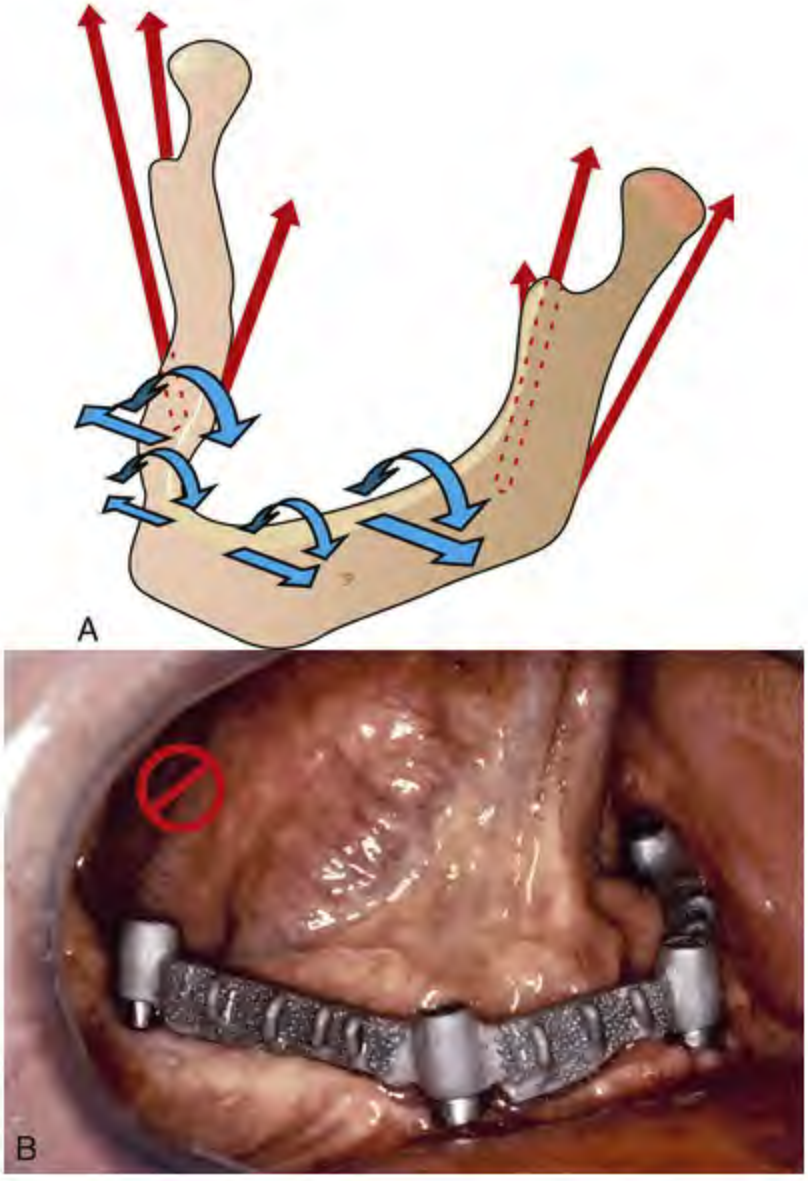
members of the rhesus monkey family (macaque) and found the mandible twisted on the working side and bent in the parasagittal plane on the balancing side during the power stroke of mastication and unilateral molar biting (Fig. 16.61B).[81] Parasagittal bending of the human jaw during unilateral biting was confirmed by Abdel-Latif et al, who showed patients with implant prostheses measured up to 19 degrees of dorsoventral shear.[82] The torsion during parafunction is caused primarily by forceful contraction of the masseter muscle attachments (Fig. 16.62A). Parafunctional bruxism and clenching may cause torsion-related problems in the implant support system and prosthesis when the mandibular teeth are splinted from the molar-to-molar regions.



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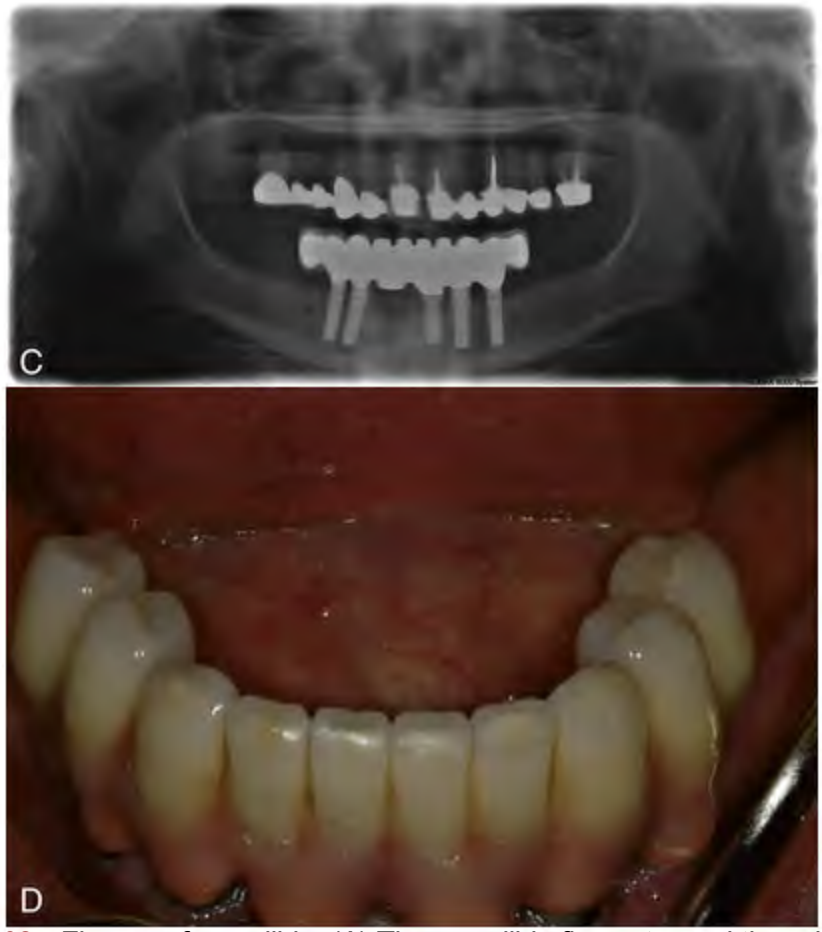

FIG 16.62 Flexure of mandible. (A) The mandible flexes toward the midline on opening or during protrusive movements as a result of the internal pterygoid muscle attachments on the ramus. The mandible also torques, with the inferior border rotating out and up and the crestal region rotating lingually. The movement is caused by the masseter muscles during forceful biting or parafunction. (B) Some authors propose that the ideal implant positions to support a mandibular full-arch prosthesis are the bilateral molars and bilateral canines splinted together with a rigid structure. These positions are not ideal because of the mandibular dynamics during opening and function. (C) Panorex showing ideal treatment planning with implants between the foramen. (D) Prosthesis. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Implants placed in front of the foramina and splinted together or implants in one posterior quadrant joined to anterior implants have not shown these complications related to the flexure or torsion of the mandible. Complete implant-supported fixed restorations can halt the posterior bone loss associated with edentulism, improve psychologic health, and produce fewer prosthetic complications than removable restorations. All edentulous mandibular patients should be given the option of having a fixed prosthesis. However, the increase in forces of mastication, increase in force with patients of greater force factors (e.g., parafunction, crown height space, opposing arch type), or reduced bone density in the implant sites warrants an increase in

implant number or implant position in anterior and posterior implant sites.

Prevention

The concept of flexure and torsion does not affect the maxilla, where all implants are often splinted together, regardless of their positions in the arch. Prevention of mandibular flexure should include the following treatment plans:

Bilateral Posterior Implants: If implants are positioned bilaterally in the premolar/molar regions of the mandible, the final prosthesis should be splinted with two sections. This will minimize the possibility of flexure/torsion issues.

Anterior Implants with Unilateral Implants Posterior: Full-arch splinted prostheses may be fabricated without concern regarding flexure/torsion problems.

Anterior Implants with No Posterior Implants: Full-arch splinted prostheses may be fabricated without concern regarding flexure/torsion problems.

Treatment

If a full-arch splinted prosthesis is fabricated and the patient exhibits complications related to the flexure/torsion of the mandible, the prosthesis needs to be remade or modified so that it is not fabricated in one piece (Fig. 16.62B).

Connecting Implants to Teeth

Prior to 1988, many practitioners connected an implant to one or two natural teeth. These implants were designed to have either a fibrous tissue or a direct bone interface. When the root form osseointegration concept of Brånemark for full-arch edentulous fixed prostheses became more dominant in the mid-1980s, these implants came to be used in partially edentulous arches. It was hypothesized at the time that joining a rigid implant to a natural tooth would cause biomechanical complications on the implant, implant prosthesis, or both. Since that time, several reports have indicated that a rigid implant may be joined to a natural tooth in the same prosthesis.[83,84] In fact, implant-cantilevered prostheses in partial edentulous patients have more reported

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complications than when implants are joined to teeth.

There are more partially edentulous patients missing posterior teeth than anterior teeth. As a result, the most common scenario for which a root form implant may be joined to a natural tooth is in the posterior regions. Of these cases, the most common scenario is as a terminal abutment in a patient missing the molars. For example, if a patient is missing the first and second molars in a quadrant (with no third molar present), the segment requires at least two implants of proper size and design to independently restore these two teeth. If adequate bone exists in the second molar and distal half of the first molar but inadequate bone exists in the mesial half of the first molar, a premolar-size pontic is required. The pontic may be cantilevered from the anterior natural teeth or the posterior implants. Either of these options may result in complications because of tensile forces on the cement seal of the abutment farthest from the pontic.

The connection of natural teeth and osseointegrated implants within a single rigid prosthesis has generated concern in publications, with studies and guidelines for both extremes. In other words, some articles report complications, but others state that no problem exists. To be more applicable to a particular situation, more information is required to design a successful treatment plan. Two prosthetic designs are available for the connection of implants and teeth within the same prosthesis: a conventional fixed partial denture (FPD) or an FPD with a nonrigid connector. To address this issue, the mobility of the natural abutment should be assessed (Fig. 16.63).

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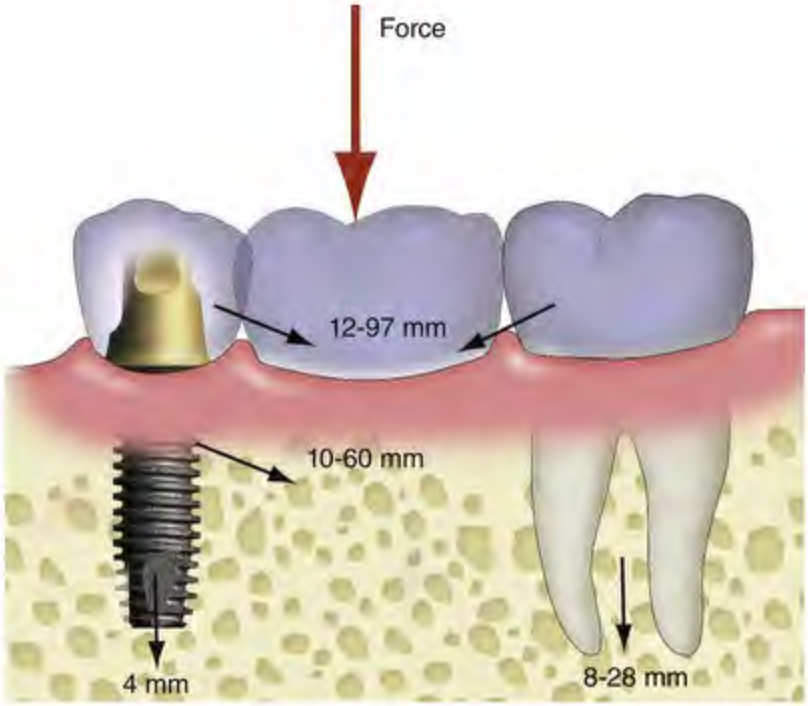

FIG 16.63 A three- or four-unit precious metal prosthesis with an implant and a posterior tooth rigidly splinted has some inherent movement. The implant moves apically 0 to 5 mm, and the tooth moves apically 8 to 28 mm but can rotate up to 75 mm toward the implant because of a moment force. The metal in the prosthesis can flex from 12 to 97 mm, depending on the length of the span and the width of the connecting joints. The abutment-to-implant component movement may be up to 60 µm because of abutment prosthetic screw flexure. As a result, a vertical load on the prosthesis creates little biomechanical risk when joined to a nonmobile tooth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Etiology

The mobility of potential natural abutments influences the decision to join implants and teeth more than any other factor. In the implant-tooth rigid fixed prosthesis, five components may contribute movement to the system: the implant, the bone, the tooth, the prosthesis, and implant and prosthetic components.

Existing Tooth Mobility.

The tooth exhibits normal physiologic movements in vertical, horizontal, and rotational directions. The amount of movement of a natural tooth is related to its surface area and root design. The number and length of the roots; their diameter, shape, and positions; and the health of the periodontal ligament primarily influence tooth mobility. A healthy tooth exhibits no clinical mobility in a vertical direction. Actual initial vertical tooth movement is

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about 28 µm and is the same for anterior and posterior teeth.[85] The immediate rebound of the tooth is about 7 µm and requires almost 4 hours for full recovery, so additional forces applied within 4 hours depress the tooth less than the original force.[86] The vertical movement of a rigid implant has been measured as 2 to 5 µm under a 10-lb force and is mostly attributable to the viscoelastic properties of the underlying bone (Fig. 16.64).[87] The implant movement is not as rapid as the tooth movement because the tooth movement is a consequence of the periodontal ligament, not the surrounding bone elasticity.

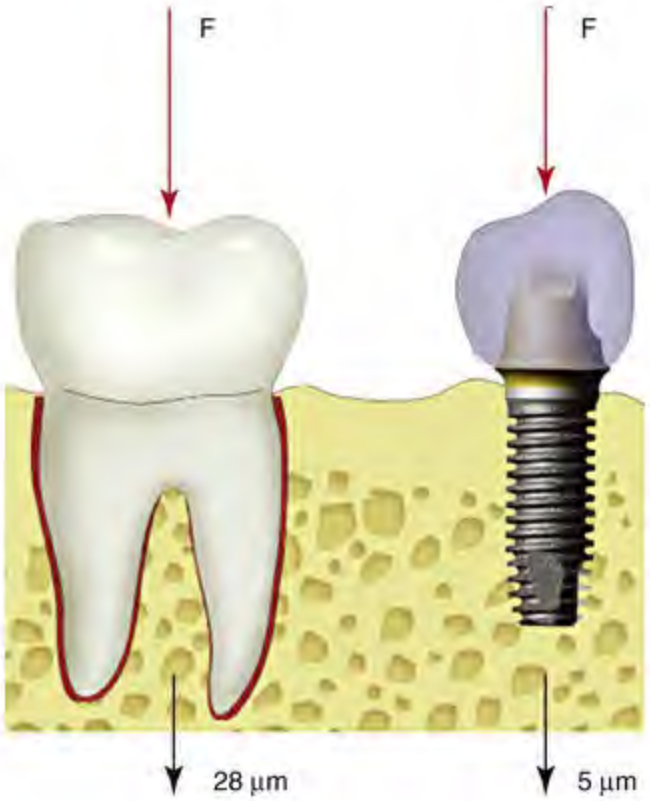

FIG 16.64 Whereas a vertical force on a tooth results with 28-µm movement, an implant moves only 2 to 5 µm. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Horizontal tooth mobility is greater than vertical movement. A very light force (500 g) moves the tooth horizontally 56 to 108 µm (Fig. 16.65). The initial horizontal mobility of a healthy, nonmobile posterior tooth is less than that of an anterior tooth and ranges from 56 to 75 µm, which is two to nine times the vertical movement of the tooth.[88] Initial horizontal mobility is even greater in anterior teeth and ranges from 90 to 108 µm in healthy teeth.[88]

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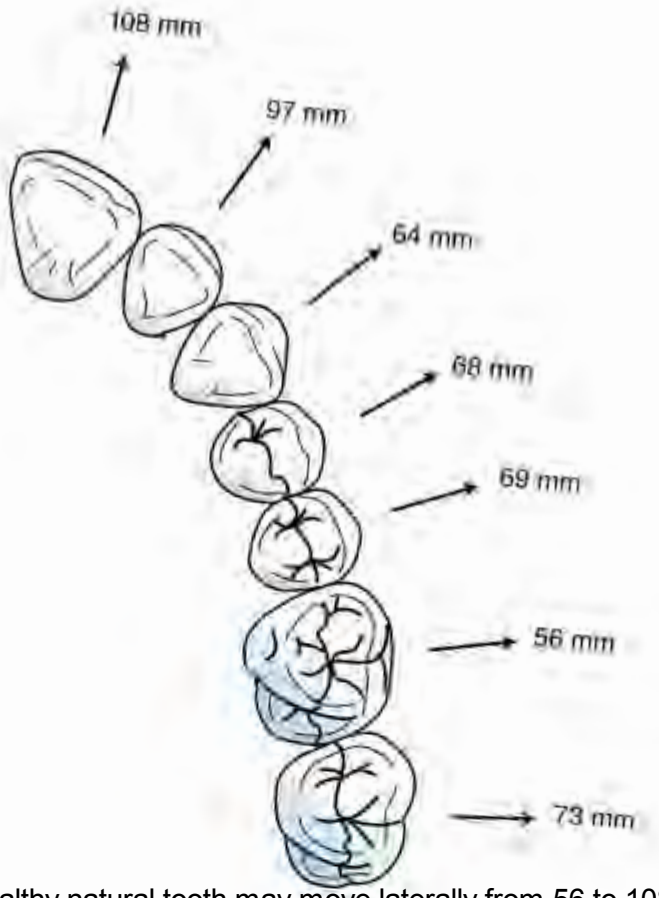

FIG 16.65 A healthy natural tooth may move laterally from 56 to 108 µm, with anterior teeth moving more than posterior teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Muhlemann found that tooth movement may be divided into initial mobility and secondary movement.[88] The initial mobility is observed with a light force, occurs immediately, and is a consequence of the periodontal ligament. If an additional force is applied to the tooth, a secondary movement is observed, which is related directly to the amount of force. The secondary tooth movement is related to the viscoelasticity of the bone and measures up to 40 µm under considerably greater force (Fig. 16.66). The secondary tooth movement is similar to implant movement.

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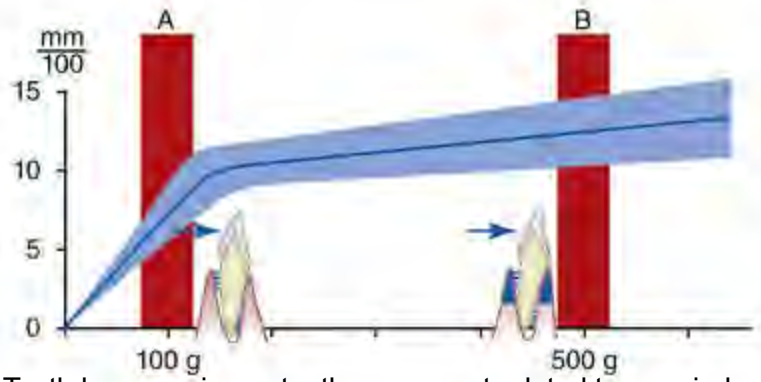

FIG 16.66 Teeth have a primary tooth movement related to a periodontal ligament. This accounts for the 28-µm apical and 56- to 108-µm lateral movement. They also have a delayed secondary mobility related to the viscoelastic nature of bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prosthesis Movement.

A fixed prosthesis that connects a tooth and implant also illustrates movement. Studies have shown that with a 25-lb vertical force, a prosthesis with a 2-mm connector fabricated in noble metal results in a 12-µm movement for one pontic and 97-µm movement for a two-pontic span (Fig. 16.67).[89] The FPD movement helps compensate for some difference in vertical mobility of a healthy tooth and implant.

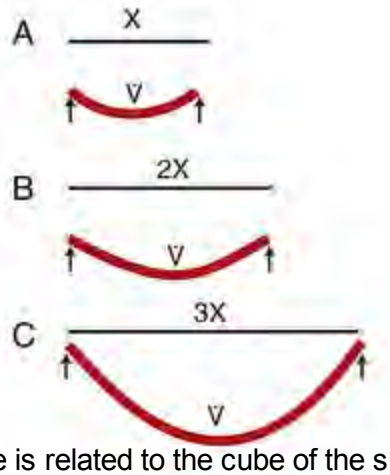

FIG 16.67 Bridge flexure is related to the cube of the span between abutments. Whereas a one-pontic prosthesis may flex 12 µm, a two-pontic prosthesis flexes up to 97 µm. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Rangert et al reported an in vitro study of a fixed prosthesis supported by one implant and one natural tooth and showed that the abutment or gold cylinder screw joint of the system also acts as a flexible element. The inherent

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flexibility matched the vertical mobility of the natural tooth. The minimal movement of the tooth and the fact that implant, prosthesis, and abutment components have some mobility indicate that the risk is small in the vertical direction with the biomechanical difference of an implant and a tooth in the same prosthesis when one or two pontics separate these units.[90]

Implant Mobility.

The implant-bone interface also exhibits lateral movement. Sekine et al evaluated the movement of endosteal implants with rigid fixation and found a range of 12 to 66 μm of movement in the labiolingual direction.[87] Komiyama measured 40 to 115 μm of implant movement in the mesiodistal direction under a force of 2000 g (≈4.5 psi) and a labiolingual range of 11 to 66 mm (Fig. 16.68).[91] The greater implant movement in the mesiodistal dimension corresponds to the lack of cortical bone around the implants in this direction compared with the thicker lateral cortical plates present in the labiolingual dimension. The mobility of implants varies in direct proportion to the load applied and the bone density, which reflects the elastic deformation of bone tissue.

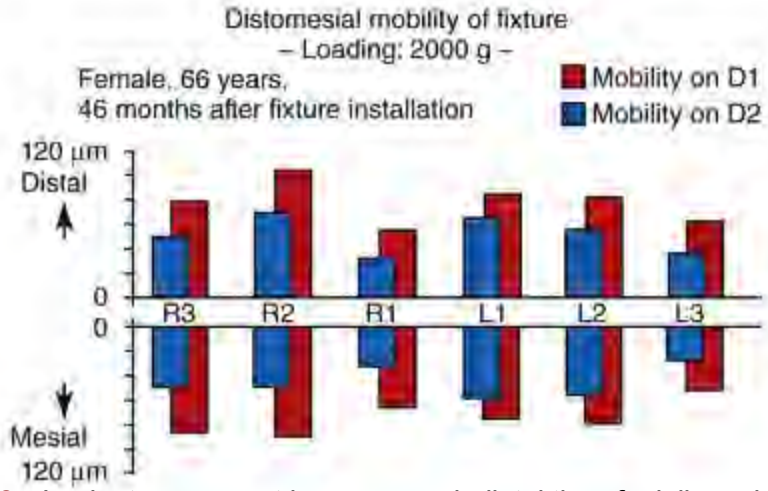

FIG 16.68 Implant movement is more mesiodistal than faciolingual, reaching values between 40 and 115 μm. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Although the implant has a range of mobility, the mobility is related to the viscoelastic component of bone, not the physiologic aspect of a periodontal membrane. As such, when the implant and tooth are loaded in the same prosthesis, the tooth immediately moves (primary tooth movement), and

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then the tooth and implant move together. In other words, secondary tooth movement is similar to implant movement because they both depend on the viscoelasticity of the bone. In a study by Sekine et al, when a tooth was gradually loaded over a 2-second period, the tooth immediately moved 36 μm and then gradually moved an additional 6 μm. The implant gradually loaded had movement directly related to the amount of load and eventually moved as much as 22 μm. The secondary tooth movement was similar to the implant movement (Fig. 16.69).[87]

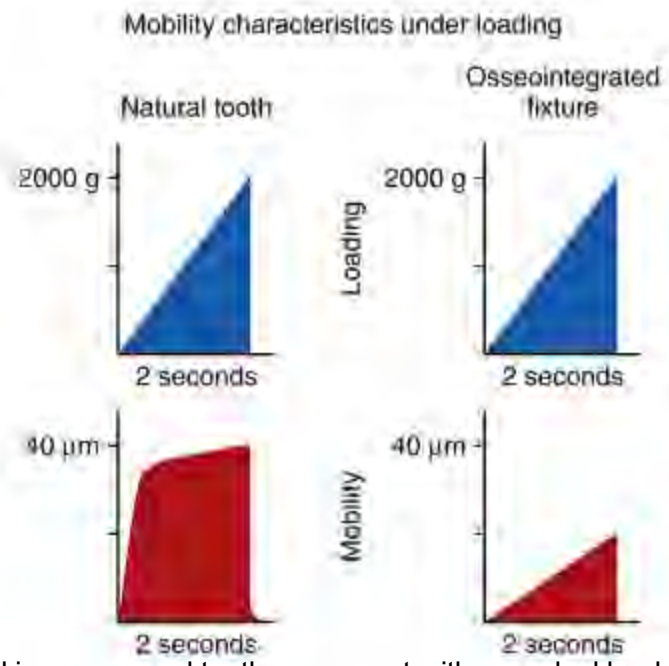

FIG 16.69 Sekine compared tooth movement with a gradual load over 2 seconds *(left)* with implant movement. The secondary tooth movement was similar to implant movement. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In summary, when all factors are considered, an implant moves vertically and horizontally, the abutments and prosthesis flex, and the tooth has apical and lateral movements. However, the major difference in movement between implants and teeth is more related to the direction of movement (the horizontal dimension is more compared to much less difference in the vertical dimension).

Prevention/Treatment

Guidelines for Joining Implants to Teeth

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No lateral force on prosthesis.

To decrease biomechanical conditions, which increase the risk of complications, a requisite to join an implant to a natural tooth is that no lateral force should be designed on a unilateral prosthesis. Lateral forces increase the amount of tooth movement and decrease the amount of implant movement (faciolingual vs. mesiodistal). Horizontal forces placed on an implant also magnify the amount of stress at the crestal bone region.

Natural tooth with no clinical mobility.

A vertical movement or force placed on a posterior implant joined to a healthy posterior tooth causes mesial tension on the implant. The implant can move vertically 3 to 5 μm and mesially 40 to 115 μm, and a noble metal–fixed prosthesis with one pontic allows mesiodistal movement of 6 μm (Fig. 16.70). A natural tooth with no clinical mobility could be connected rigidly to an osseointegrated implant with no lateral forces because the implant, bone, and prosthesis compensate for the slight tooth movement. Finite element, photoelastic, and clinical documentation confirm that implants can be connected rigidly to stable teeth.[92] However, the occlusion should be modified to allow the initial occlusal contacts on the natural tooth so that the implant does not bear the major portion of the initial load.[93]

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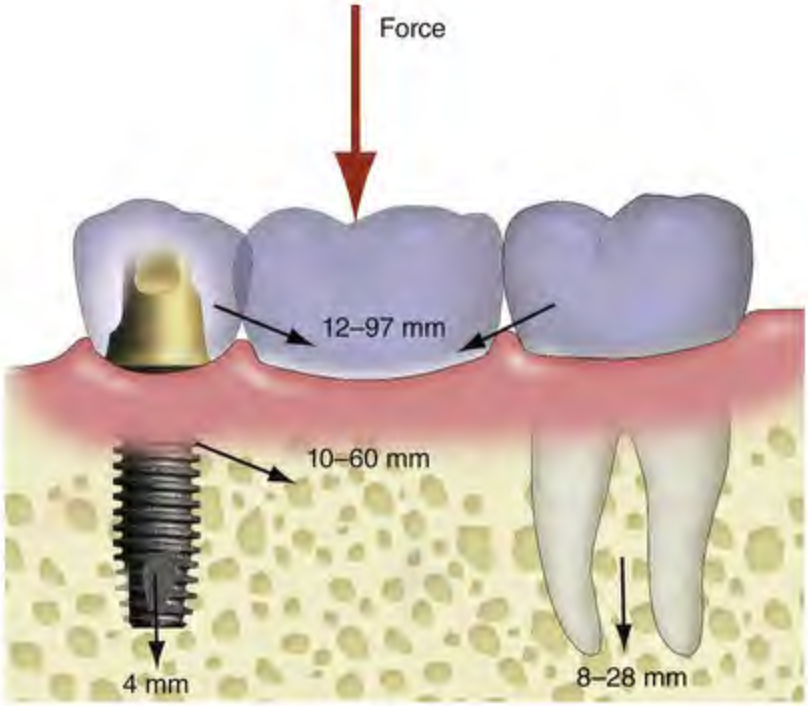

FIG 16.70 A three- or four-unit precious metal prosthesis with an implant and a posterior tooth rigidly splinted has some inherent movement. The implant moves apically 0 to 5 mm, and the tooth moves apically 8 to 28 mm but can rotate up to 75 mm toward the implant because of a moment force. The metal in the prosthesis can flex from 12 to 97 mm, depending on the length of the span and the width of the connecting joints. The abutment-to-implant component movement may be up to 60 μm because of abutment prosthetic screw flexure. As a result, a vertical load on the prosthesis creates little biomechanical risk when joined to a nonmobile tooth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The lateral mobility of healthy anterior incisor teeth often is recorded as (+) with a range of movement from 90 to 108 μm. Visual clinical evaluation by the human eye can detect movement greater than 90 μm. When the horizontal mobility of a natural tooth (anterior or posterior) can be observed, mobility is greater than 90 μm and too great to be compensated by the implant, bone, and prosthesis movement. When the vertical posterior tooth movement, vertical implant movement, mesiodistal implant movement, and prosthesis movement are compared with the same conditions of a "mobile" tooth with lateral loads, the biomechanical risk factors are not the same. One of the primary conditions for joining an implant to natural teeth is the lack of observable clinical movement of the natural abutment during functional movement. Nonmobile posterior teeth with no lateral forces on the prosthesis may join rigid implants. However, implants rarely should be connected to an individual anterior tooth because (1) anterior teeth exhibit more than tenfold greater clinical mobility than the implant, and (2) the lateral forces applied to the restoration during mandibular excursions are

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transmitted to the natural tooth and implant abutments.

When the natural abutment exhibits clinical horizontal movement or conditions promote horizontal forces against the abutment tooth, two options can be selected for the final prosthesis. The first, and the option of choice, is to place additional implants and to avoid the inclusion of natural abutments in the final prosthesis. This may include the extraction of the mobile tooth and replacement with an implant. The other option is to improve stress distribution by splinting additional natural abutments until no clinical mobility of the splinted units is observed.

Rigid connectors are contraindicated.

Implants should not be joined to mobile teeth with rigid attachments, which basically adds a cantilever on the implant (the tooth acting as a living pontic). If the natural teeth are too mobile in relation to the implant in the same prosthesis, several complications may occur that may be detrimental to the tooth and implant. If the prosthesis is cemented, movement may break the cement–implant abutment seal. Cement does not adhere as well to titanium as to dentin. In addition, the mobile tooth will move (which decreases the impact force) rather than break the cement seal on the tooth. However, the rigid implant will have greater stresses applied to the cement (or screw) retained crown. After the prosthesis is loose from the implant, greater stress is applied to the natural mobile tooth. The tooth may increase in mobility as a result or fracture as a consequence (especially when endodontic procedures were performed) (Fig. 16.71).

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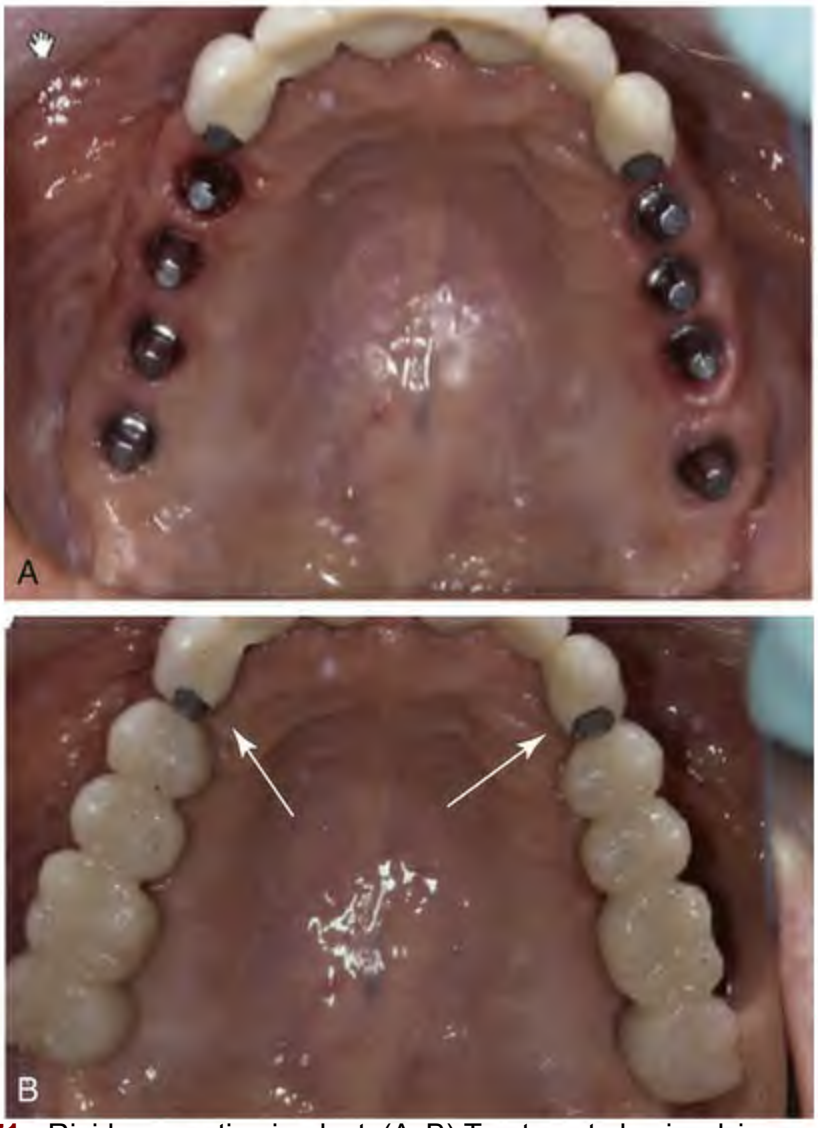

FIG 16.71 Rigid connection implant. (A–B) Treatment plan involving connecting posterior implant-supported crowns to natural teeth.

Nonrigid connectors are contraindicated.

A mobile attachment between the implant and natural tooth is usually not a benefit. A mobile attachment moves more than an implant or a tooth. Therefore, it is not an "attachment." The pontic is cantilevered from the implant with little to no support from the tooth. It is usually better to have a rigid connector between implants and teeth than a mobile attachment.

Although nonrigid connectors have been advocated in the literature, a nonrigid connector in a unilateral prosthesis rarely is indicated for implant-fixed prostheses and may be detrimental.[94] Nonrigid connection does not improve the stress distribution between the different abutments and has been reported to have caused migration of the natural teeth.[95,96]

If the nonrigid connector exhibits any clinically observed mobility, it moves more than the implant. As such, the implant-supported part of the restoration is cantilevered to the attachment. In addition, the nonrigid (or mobile) attachment adds cost, creates overcontoured abutments, impairs daily hygiene, and does not decrease the clinical tooth movement.

Prevent Tooth Intrusion.

When implants are joined to teeth that act as a terminal abutment, a definitive cement should be used for the natural tooth. The tooth cannot intrude unless it becomes unretained from the abutment (or has a nonrigid connector between the units).

Reports of intrusion of the natural tooth connected to an implant usually include the use of temporary cement to lute a coping to the natural abutment, leaving the final restoration uncemented on the coping, or the use of a nonrigid connector.[97]

A possible explanation for tooth intrusion may be that the tooth is pushed vertically 28 μm but wants to rebound only 8 μm. The fixed prosthesis rebounds immediately and pulls on the tooth. The cement seal eventually breaks, causing a space to develop, which is first occupied by air. The prosthesis then acts as an orthodontic appliance and continually pushes the tooth in a vertical direction. Eventually, the space is occupied by saliva, and hydraulics continue the downward force during mastication. The tooth eventually submerges or intrudes from the prosthesis.

Ideal, Favorable Conditions.

An alternative may be to join the implant(s) to a natural tooth if all other factors are favorable. This treatment option is more likely in the presence of a division C–h ridge in the pontic region when inadequate bone height adjacent to the natural tooth decreases the prognosis of a vertical bone graft. This option is also available when a posterior implant is positioned too distal to restore with a single crown. It is almost always better to splint the implant to the adjacent tooth rather than fabricating a cantilevered crown from one implant, especially when parafunction is present.

Narrow-Diameter Implants.

Another scenario in favor of this treatment plan is when the posterior implants are of a narrower diameter than usual. When two division B root

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forms are used in the posterior mandible to replace molars, there should be no cantilever to magnify the force on the implants. Posterior pontics should not be cantilevered from even two splinted division B root form implants because they will have a greater biomechanical risk. An additional root form implant or a natural tooth is usually required as an abutment for the fixed prosthesis. When an additional implant insertion is not an option, the posterior implants may be joined by a rigid connector (e.g., a solder joint) to a natural tooth or teeth within the prosthesis, provided all dental factors are favorable.

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Intraoperative Prosthodontic Complications

Abutment Not Seated

If an abutment is not fully seated within the implant, the preload placed on the screw will be insufficient. This will lead to an increased possibility of screw loosening and prosthesis mobility. An opening or microgap will lead to bacterial accumulation, which will result in soft tissue infection and irritation. If left untreated, fracture of the screw or implant may occur (Fig. 16.72).

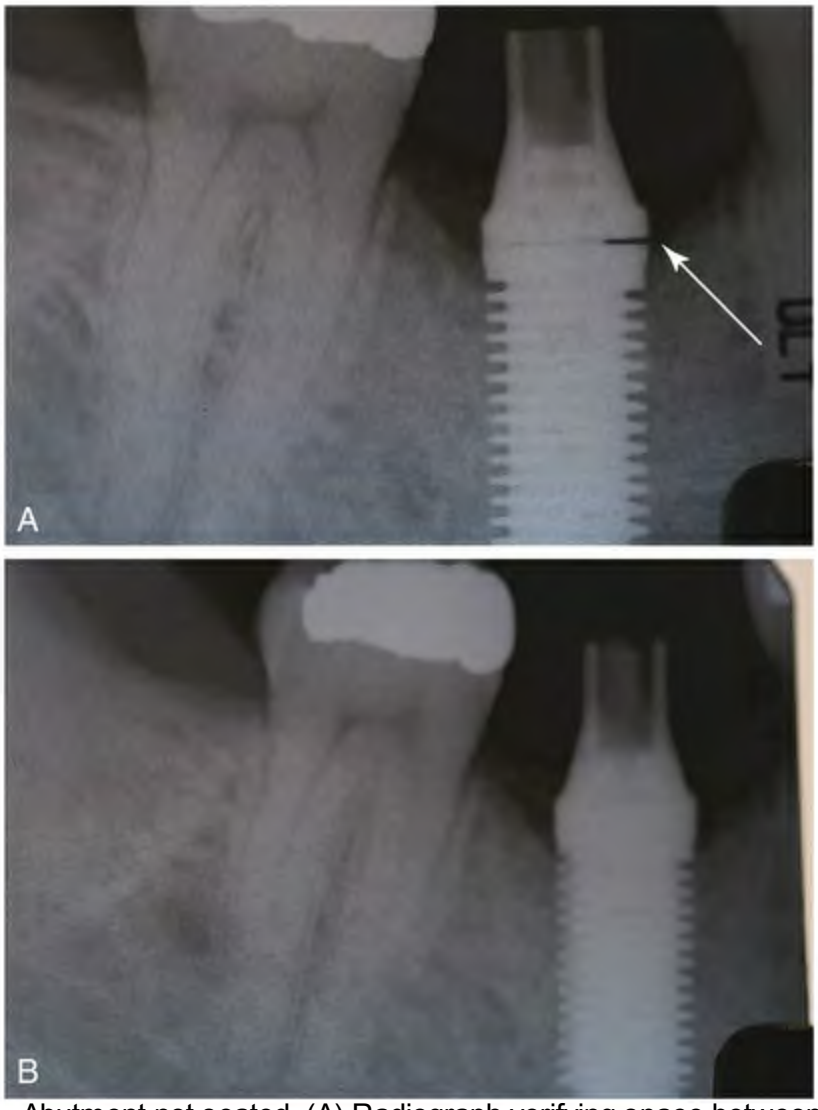

FIG 16.72 Abutment not seated. (A) Radiograph verifying space between abutment and implant. (B) After correction, no space present between abutment and implant.

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Etiology

When an abutment is torqued into an implant, care must be noted to fully seat the abutment into the hex of the implant. In some situations, tissue or bone may impede the full seating of the prosthesis, causing a microgap to exist, which may lead to complications.

Prevention

When placing the abutment, insert the abutment into the implant until it is fully seated. When the implant is significantly subgingival, this may be difficult to determine. A radiograph should always be taken to confirm complete seating.

Treatment

If the abutment is not seated via the radiograph, it should be treated in the following ways:

Improper Placement.

Remove abutment, replace, then verify seating with a new radiograph.

Tissue Impingement.

Remove tissue with a tissue punch bur or scalpel, then verify seating with a new radiograph (Fig. 16.73).

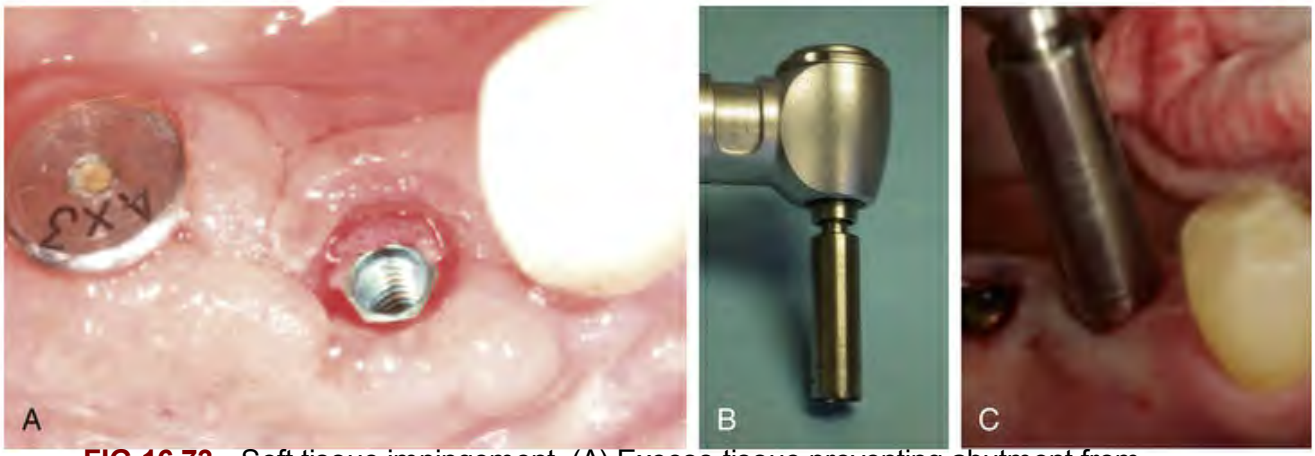

FIG 16.73 Soft tissue impingement. (A) Excess tissue preventing abutment from complete seating. (B) Tissue punch bur used in latch handpiece. (C) Removal of soft tissue impingement.

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Bone Impingement.

Remove bone that is preventing the abutment from fully seating. A curette or a profiling bur may be used. Verify seating with a new radiograph (Fig. 16.74).

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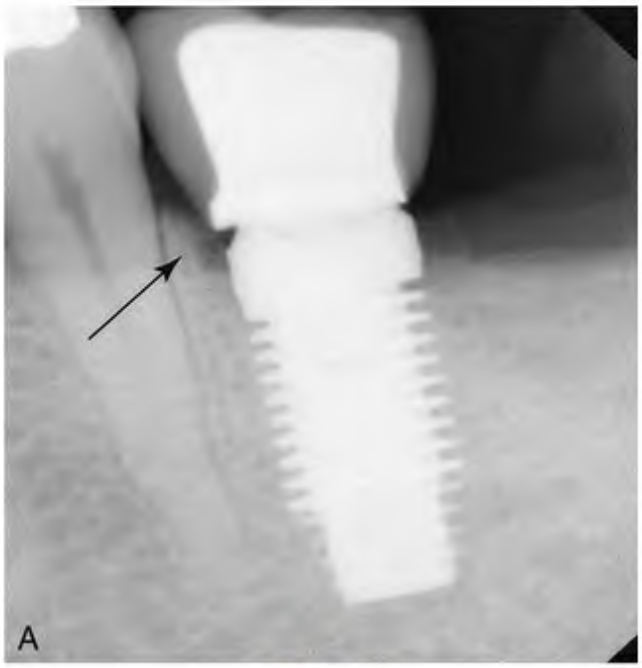

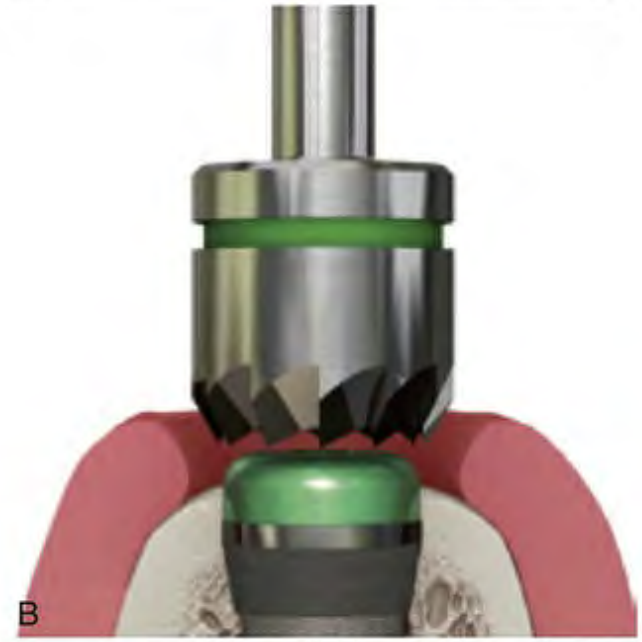

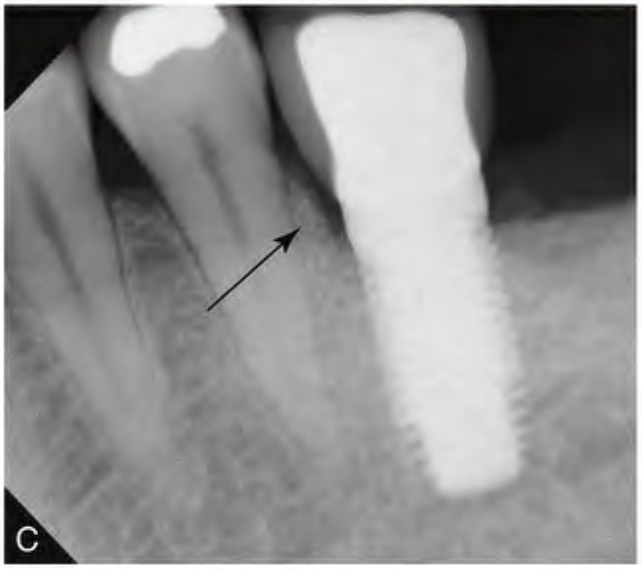

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FIG 16.74 Bone impingement. (A) Radiograph depicting mesial bone preventing proper seating of abutment *(arrow)*. (B) Profiling bur to remove bone. (C) Final radiograph showing complete seating *(arrow)*.

Pain on Abutment Placement

When placing the abutment into the implant body, sometimes pain will result. This may be due to many reasons.

Etiology

Pain may occur from many possibilities.

Tissue Impingement.

Because of the lack of circular fibers, tissue collapse is very common after permucosal extension removal. When placing the abutment, the tissue will become pinched resulting in pain.

Implant Failure.

If the implant becomes infected or loses integration, in some instances when pressure is placed on the implant, pain will result.

Prevention

Tissue Impingement.

To decrease the possibility of tissue collapse, abutment placement should be completed without delay after the permucosal extension. The greater the time period the abutment is out, the greater the chance of tissue impingement.

Implant Failure.

Prior to abutment placement, clinical and radiographic evaluation of the integration of the implant should be completed.

Treatment

Tissue Impingement.

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Remove excess tissue with a tissue punch bur or a scalpel (see Fig. 16.73).

Implant Failure.

If the implant has mobility or circumferential radiolucency is present, the implant should be removed (Fig. 16.75).

FIG 16.75 Pathology associated with a failed dental implant. Note the circumferential radiolucency.

Pain on Application of Torque to Abutment

When applying torque to an implant, on rare occasions, the patient will complain of pain.

Etiology

Tissue Impingement.

Because of the lack of circular fibers, tissue collapse is very common after permucosal extension removal. If tissue impinges between the abutment and the implant, a painful response may occur.

Implant Failure.

If the implant becomes infected or loses integration, in some instances when pressure is placed on the implant, pain will result.

Poor Bone Quality.

If an abutment screw is torqued into place in poor quality of bone, an unsupported force may be applied that may eliminate the osseous integration of the implant.

Prevention/Treatment

Tissue Impingement.

Remove any excess tissue prior to abutment placement.

Implant Failure.

If the implant becomes infected or loses integration, removal of the implant is indicated.

Poor Bone Quality.

When placing torque on an implant, always hold abutment with curved hemostats or the use of an acrylic verification jig. This will help stabilize the abutment (Fig. 16.76).

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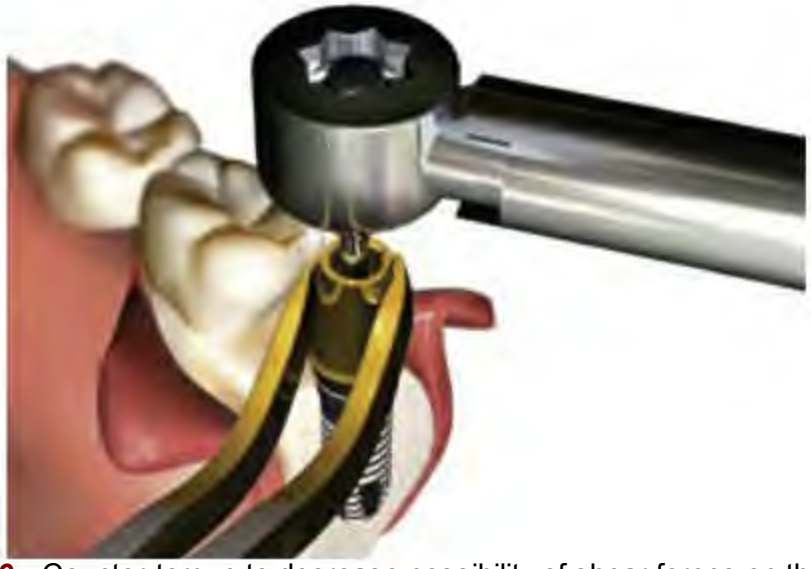

FIG 16.76 Counter-torque to decrease possibility of shear forces on the implant body. (Courtesy BioHorizons Implant Systems, Inc.)

Abutment Will Not Tighten

In some situations the abutment is tightened onto the implant; however, the abutment will move in a vertical direction. This is the direct result of the abutment screw not being fully seated, which may lead to screw loosening or component fracture.

Etiology

The most common cause of inadequate abutment tightness is debris inside the base of the implant. It is not uncommon for blood coagulants or excess debris to accumulate in the base of the implant. Because many implant systems are designed with minimal space between the end of the screw and the base of the implant, the screw will be prevented from being fully seated. This will result in the screw being tight; however, the implant abutment will move vertically.

Prevention/Treatment

This can be easily prevented by irrigation with saline or 0.12% chlorhexidine with a small tuberculin syringe (Fig. 16.77).

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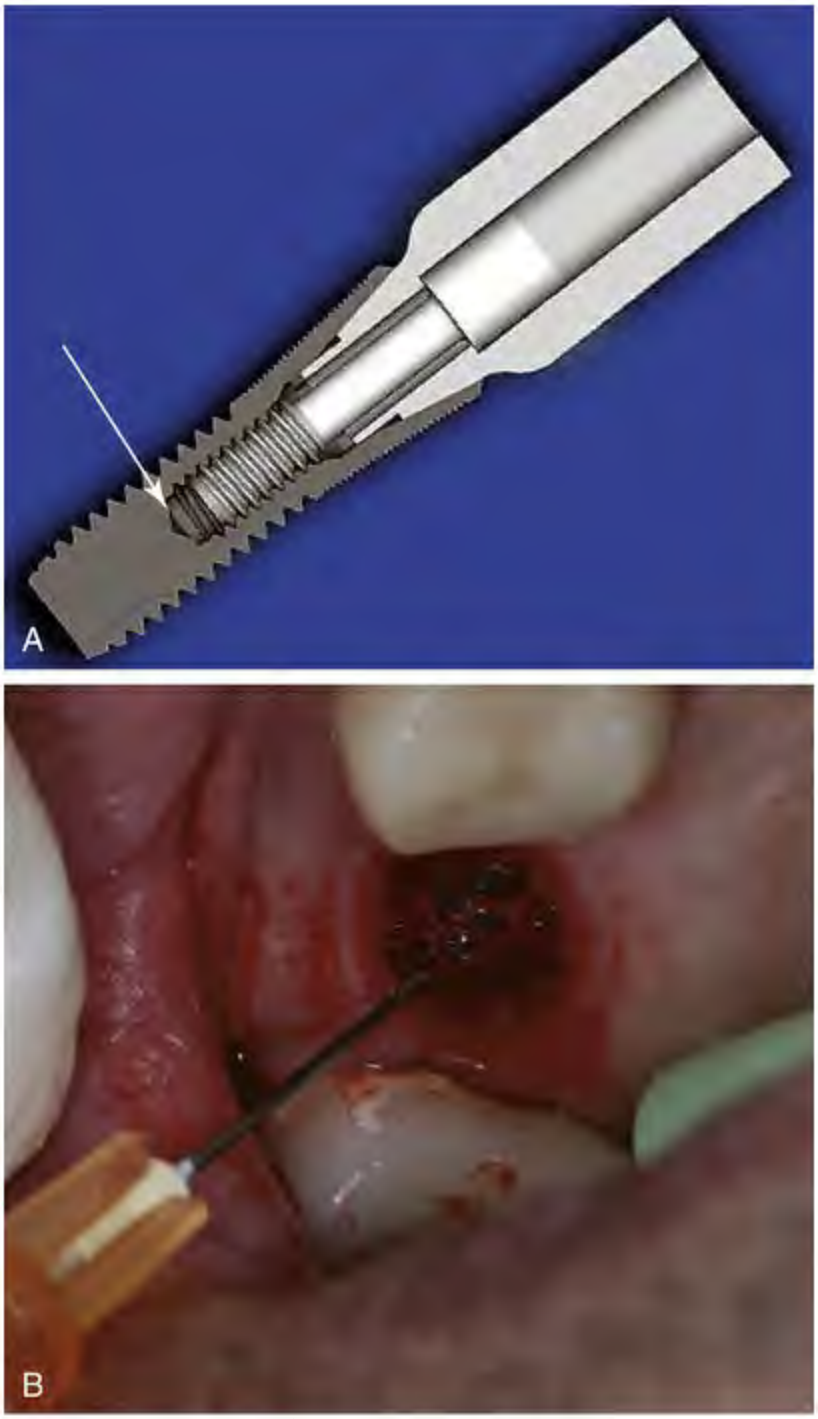

FIG 16.77 (A) Abutment screw fully seated showing minimal space between end of screw and implant body. (B) Irrigating debris out of implant body with chlorhexidine.

Hex on Abutment Screw Is Stripped

The most common hex insertion tool used in implant dentistry today is the 0.05 (1.25-mm) hex. After extended use, the hex will become stripped, which will prevent final torque to be applied to the abutment screw (Fig. 16.78).

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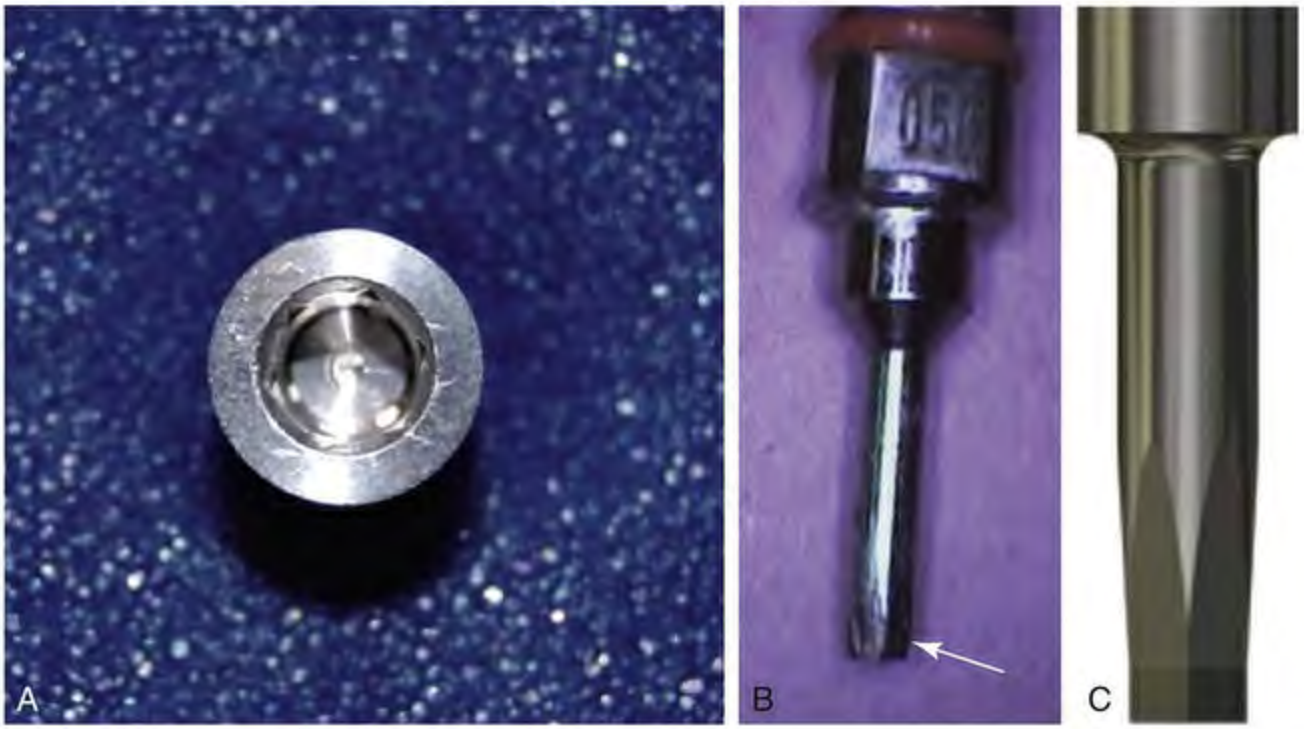

FIG 16.78 (A) Stripped hex. The more sides a screw has, the greater chance of stripping. (B) One of the most common causes is the use of a stripped hex driver *(arrow)*. (C) Hex driver should have a clear delineated hex, not rounded.

Etiology

The most common cause of a stripped hex screw is the placement of the final torque with the torque wrench not completely seated in the hex screw head or the use a hex driver that is worn.

Prevention

Always seat the hex driver completely into the hex screw head. This will minimize the possibility of stripping the hex screw or dulling the hex driver. When placing torque on the screw, insert the hex driver first, then attach the torque driver to the hex driver. This will minimize the possibility of not having the hex driver fully seated.

Treatment

There are three possible treatment options to remove a stripped hex screw.

1. Place and fully seat the hex driver into the hex screw head. With an osteotome or mirror handle, lightly tap the hex drive to fully seat the driver into the hex. Ideally, a new hex driver should be used.

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2. Add a small amount of autopolymerizing acrylic (GC Pattern Resin) onto the tip of the hex driver. Seat the hex driver into the hex screw head. Place constant pressure to hold the hex driver into the fully seated position. After final curing, with good apical pressure, reverse torque the screw (Fig. 16.79).

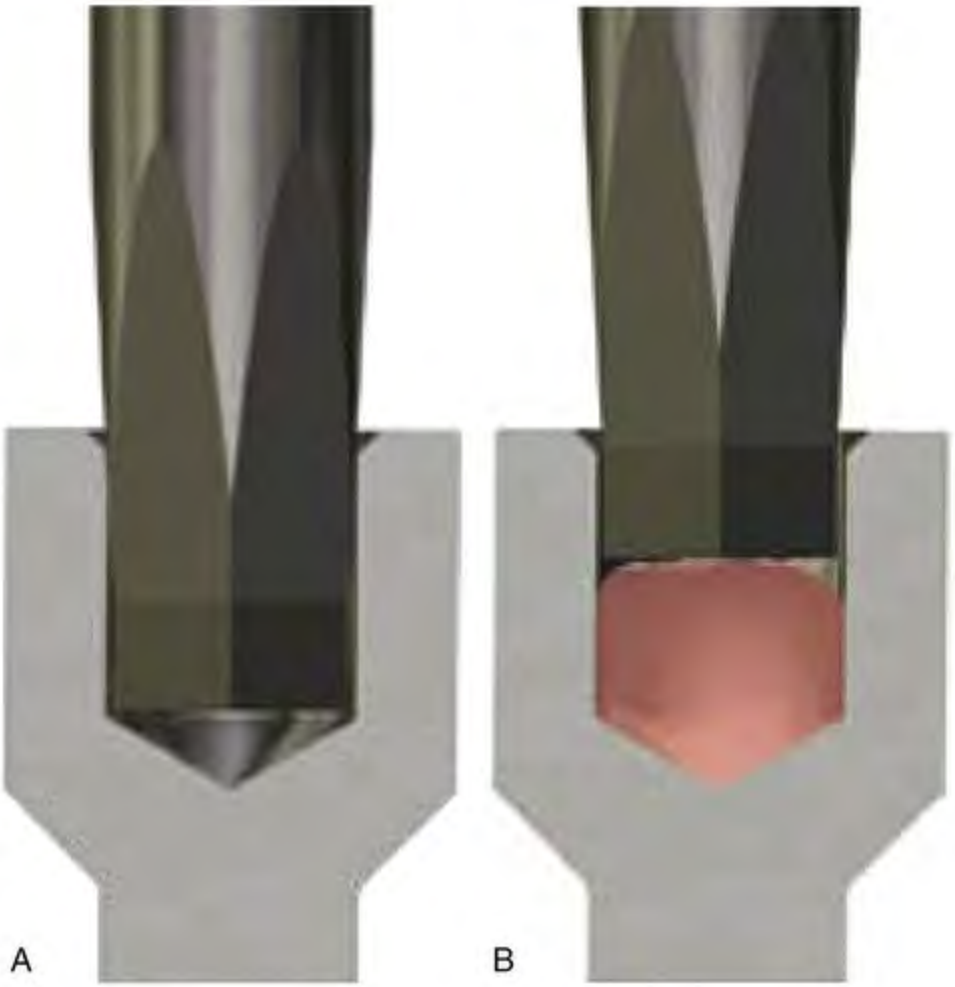

FIG 16.79 Treatment of a stripped screw abutment. (A) Insert hex driver, lightly tap to engage hex fully. (B) Another option includes placing a small amount of acrylic (Pattern Resin [GC America Inc.]) and hold in place until fully cured, reverse torque.

3. The last option should only be used if #1 and #2 are unsuccessful. The abutment is sectioned, the screw exposed, and the screw is slotted and reverse torqued to remove.

Improper Torqueing Technique

The use of a torque wrench improperly may lead to inadequate torque

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application, stripping of the hex screw head, and/or dulling of the hex driver.

Etiology

There are numerous errors when using a torque wrench. The first is not placing apical pressure on the top of the torque wrench. Failure to keep good apical pressure will lead to a shear force applied to the screw and/or stripping of the screw. Secondly, the torque wrench can be a significant lever arm. Thus, the torque wrench should be used with short strokes. And lastly, the torque wrench should be replaced on a regular basis and maintained in a good working condition. When autoclaving the torque wrench, make sure the wrench is in the open position. This will reduce the possibility of excess residue forming within the torque wrench assembly. Studies have shown that, on average, clinicians use torque wrenches with deviations of 10% or greater. Regular recalibration with a torque tester restores the required torque values.[98]

Prevention

Finger tighten the hex screw to approximately 10–15 N/cm. Place good apical pressure with your index finger when torqueing the abutment. Hold the torque wrench stable to minimize lateral forces. An abutment clamp may be used to apply countertorque, which is held against the rotation of the wrench to protect the bone interface from excess lateral stress. Wet torques (implant screws lubricated with saliva) have a higher mean torque than dry torques (unlubricated).[99] Because of the settling effect, abutment screws should be retorqued after 10–15 minutes to minimize screw loosening (Figs. 16.80 and 16.81).

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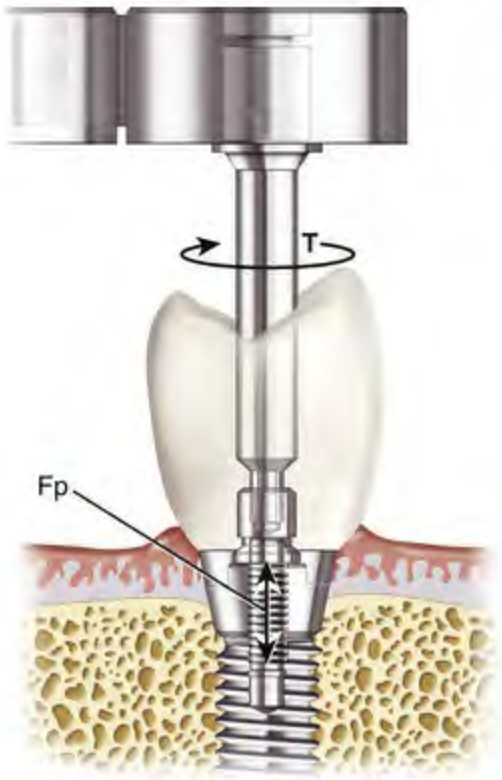

FIG 16.80 The torque *(T)* applied to an abutment screw (which strains the screw *[Fp]*) is also applied to the implant-bone interface. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 16.81 A counter-torque technique (which stops the abutment from rotating) is used when possible to resist the rotational force applied to the screw being applied to the implant-bone interface. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Damaging Implant Body

Most implants today are fabricated from grade 5 titanium or Ti6Al4V. This metal does have the disadvantage of easily being altered or damaged. If an implant is traumatized with a handpiece and bur, or a sharp instrument, irreversible damage may be done to the implant (Fig. 16.82).

FIG 16.82 High-speed handpieces may easily damage a titanium alloy implant.

Etiology

When removing tissue or bone around an implant, care should be exercised to not damage the implant. No high-speed handpiece should be used around an implant. Another common situation that may damage the implant is the removal of a fractured screw. Attempting to slot the screw may lead to damaging the internal threads or walls of the implant.

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Prevention/Treatment

To prevent damage to the implant, a tissue punch bur or profiling bur should be used. Alternative techniques to remove a fractured screw should be used to minimize the possibility of implant damage.

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Fixed Occlusal Complications

When two bodies collide in a small interval of time (fractions of a second), large reaction forces develop. Such a collision is described as *impact*. In dental implant systems subjected to occlusal implant loads, deformation may occur in the prosthodontic restoration, in the implant itself, and in the contiguous interfacial tissues. The nature of the relative stiffness of these components in the overall implant system largely controls the response of the system to impact load. The higher the impact load, the greater the risk of implant and bridge failure and bone fracture.

Rigidly fixed implants generate a higher interfacial impact force with occlusion compared with natural teeth, which possess a periodontal ligament. Soft tissue–borne prostheses have the least impact force because the gingival tissues are resilient.

The manner in which forces are applied to implant restorations within the oral environment dictates the likelihood of system failure. The duration of a force may affect the ultimate outcome of an implant system. Relatively low-magnitude forces, applied repetitively over a long time, may result in fatigue failure of an implant or prosthesis. Stress concentrations and, ultimately, failure may develop if insufficient cross-sectional area is present to dissipate high-magnitude forces adequately. If a force is applied some distance away from a weak link in an implant or prosthesis, then bending or torsional failure may result from moment loads. An understanding of force delivery and failure mechanisms is critically important to the implant practitioner to avoid costly and painful complications.

Moment Loads

The moment of a force about a point tends to produce rotation or bending about that point. A moment force is defined as a vector *(M)* (vectors are described in terms of magnitude and direction) the magnitude of which equals the product of the force magnitude multiplied by the perpendicular distance (also called the *moment arm*) from the point of interest to the line of action of the force. This imposed moment load also is referred to as a *torque* or *torsional load* and may be destructive to the implant system (Fig. 16.83).

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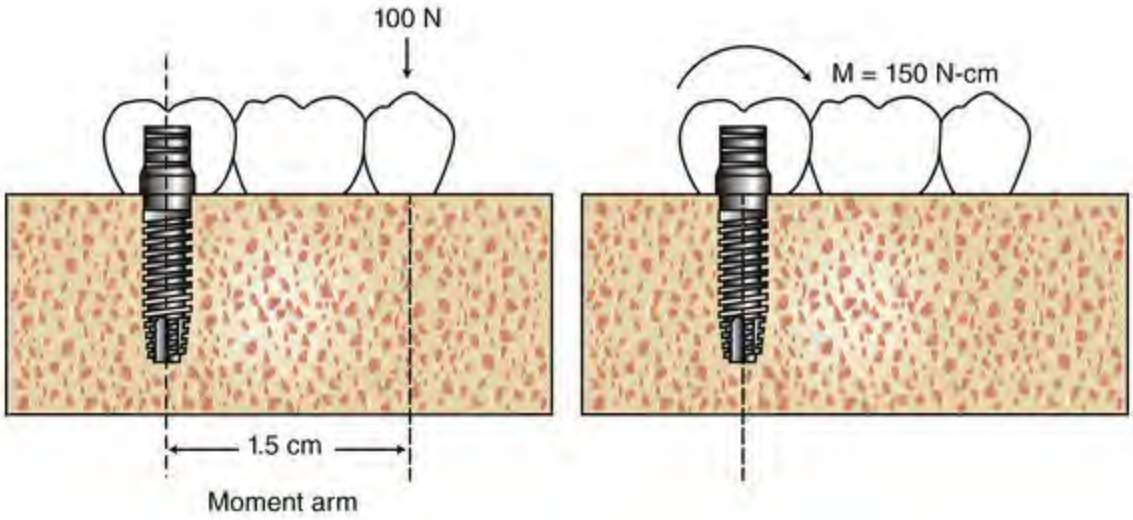

FIG 16.83 The moment of a force is defined as a vector *(M)*, the magnitude of which equals the product of the force magnitude multiplied by the perpendicular distance (moment arm) from the point of interest to the line of action of the force. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A total of six moments (rotations) may develop about the three clinical coordinate axes previously described (occlusoapical, faciolingual, and mesiodistal axes). Such moment loads induce microrotations and stress concentrations at the crest of the alveolar ridge at the implant-tissue interface, which lead inevitably to crestal bone loss (Fig. 16.84).

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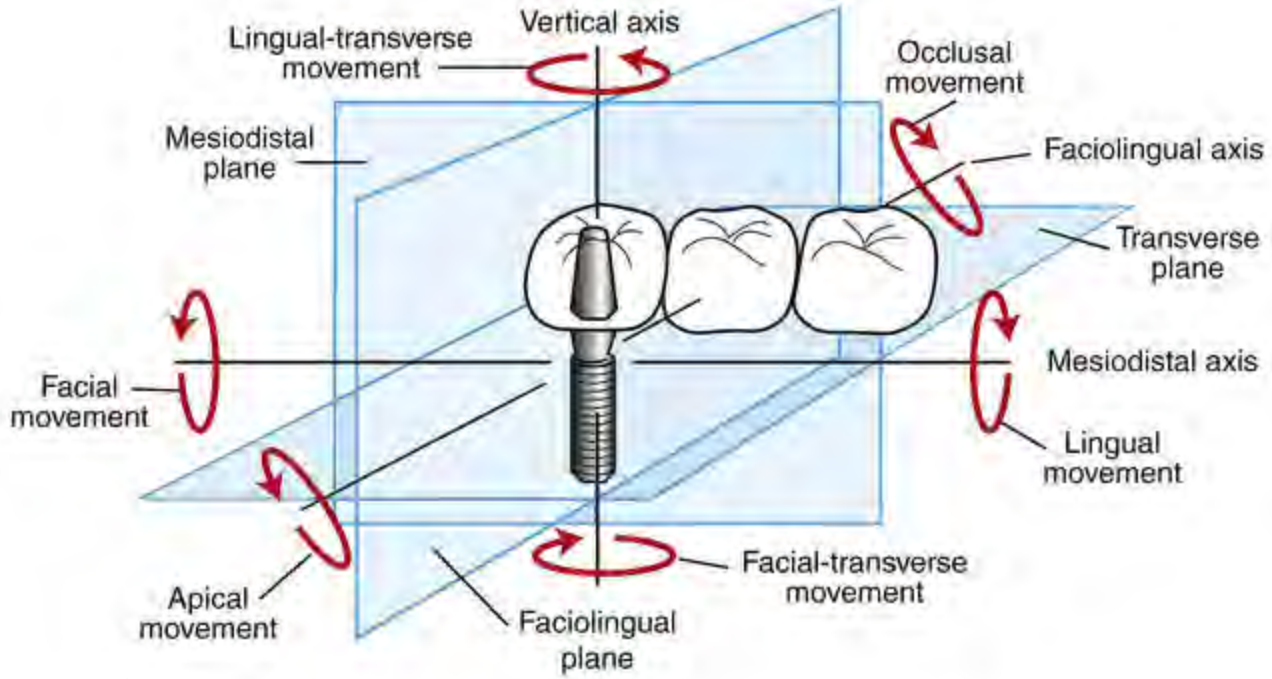

FIG 16.84 Moment loads tend to induce rotations in three planes. Clockwise and counterclockwise rotations in these three planes result in six moments: lingual-transverse, occlusal, apical, facial, and lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Three clinical moment arms exist in implant dentistry: (1) occlusal height, (2) cantilever length, and (3) occlusal width. Minimization of each of these moment arms is necessary to prevent unretained restorations, fracture of components, crestal bone loss, and complete implant system failure.

Occlusal Height

The occlusal height serves as the moment arm for force components directed along the faciolingual axis working or balancing occlusal contacts, tongue thrusts, or in passive loading by cheek and oral musculature, as well as force components directed along the mesiodistal axis.

In division A bone, initial moment load at the crest is less than in division C or D bone because the crown height is greater in division C and D bone. Treatment planning must take into account this initially compromised biomechanical environment (Table 16.4). The moment contribution of a force component directed along the vertical axis is not affected by the occlusal height because no effective moment arm exists. Offset occlusal contacts or lateral loads, however, introduce significant moment arms.

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TABLE 16.4

Moment Load at Crest When Subjected to Cantilever Forces in Relation to Crown Height

INFLUENCES ON MOMENT		IMPOSED MOMENTS (N/mm) AT IMPLANT CROWN–CREST INTERFACE					
Occlusal Height	Cantilever Length	Lingual	Facial	Apical	Occlusal	Facial-Transverse (mm)	Lingual-Transverse (mm)
10	10	100	0	50	200	0	100
10	20	100	0	50	400	0	200
10	30	100	0	50	600	0	300
20	10	200	0	100	200	0	100
20	20	200	0	100	400	0	200
20	30	200	0	100	600	0	300

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

Cantilever Length

Large moments may develop from vertical axis force components in prosthetic environments designed with cantilever extensions or offset loads from rigidly fixed implants. A lingual force component also may induce a twisting moment about the implant neck axis if applied through a cantilever length.

An implant with a cantilevered mesobar extending 1, 2, and 3 cm has significant ranges of moment loads. A 100-N force applied directly over the implant does not induce a moment load or torque because no rotational forces are applied through an offset distance. This same 100-N force applied 1 cm from the implant results in a 100 N-cm moment load. Similarly, if the load is applied 2 cm from the implant, a 200 N-cm torque is applied to the implant-bone region, and at 3 cm, a 300 N-cm moment load results. For comparison, recall that implant abutments typically are tightened with 30 N-cm of torque.

Occlusal Width

Wide occlusal tables increase the moment arm for any offset occlusal loads. Faciolingual tipping (rotation) can be reduced significantly by narrowing the occlusal tables or adjusting the occlusion to provide more centric contacts.

In summary, a vicious, destructive cycle can develop with moment loads and result in crestal bone loss. As crestal bone loss develops, occlusal height automatically increases. With an increased occlusal height moment arm, the faciolingual microrotation and rocking increase and cause even more stress to the crestal bone. Unless the bone increases in density and strength, the

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cycle continues to spiral toward implant failure if the biomechanical environment is not corrected (Fig. 16.85).

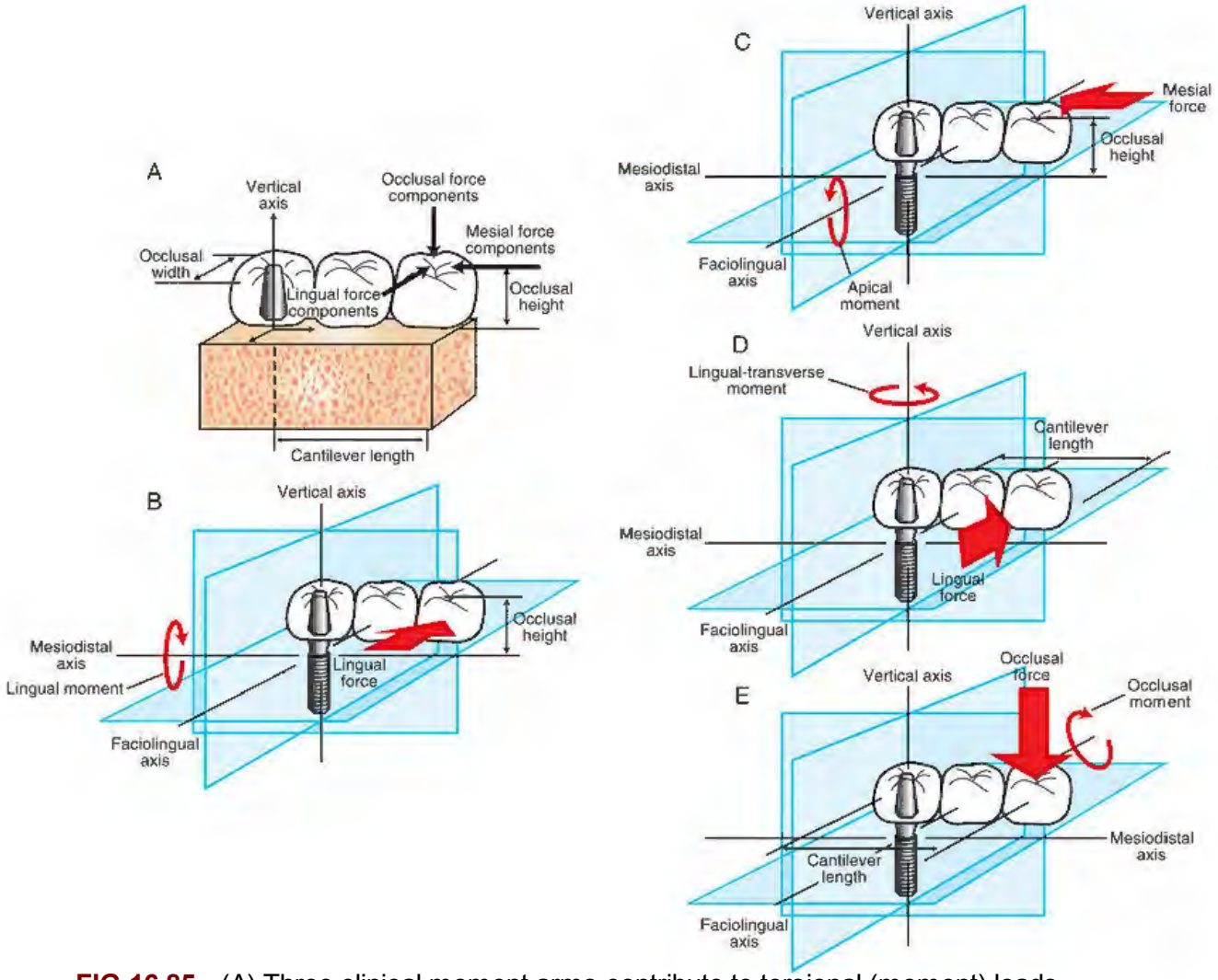

FIG 16.85 (A) Three clinical moment arms contribute to torsional (moment) loads on dental implants: occlusal height, occlusal width, and cantilever length. (B) Occlusal height serves as moment arm for force components directed along faciolingual axis and force components directed along mesiodistal axis (C). D, Lingual force component also may induce twisting moment about the implant neck if applied through the cantilever length. E, Moment of force along the vertical axis is not affected by occlusal height because its effective moment arm is zero if positioned centrically. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Not Utilizing Implant-Protected Occlusion

Etiology

A proper occlusal scheme is a primary requisite for long-term implant

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prosthetic survival, especially when parafunction or a marginal foundation is present. A poor occlusal scheme increases the magnitude of loads and intensifies mechanical stresses (and strain) to the implant system. These factors increase the frequency of complications of the prosthesis and bone support. Crestal bone loss may lead to anaerobic sulcus depths and peri-implant disease states. These conditions may also cause tissue shrinkage and loss of interdental papillae and poor esthetic conditions. All of these complications may be caused by biomechanical stress as a result of occlusal loads (functional or parafunctional).

Prevention

The implant-protective occlusion (IPO) concept refers to an occlusal plan specifically designed for the restoration of endosteal implants, providing an environment for reduced biomechanical complications and improved clinical longevity of both the implant and prosthesis.[93] The biomechanical rationale for this concept was published by the author after long-term clinical evaluation and biomechanical studies (and was originally called medial-positioned, lingualized occlusion). This concept was specifically designed for fixed prostheses in either partial or complete edentulous patients. Clinical considerations for this concept are drawn from basic prosthetic concepts, bone biomechanical principles, and finite element analyses to reduce noxious occlusal loads and establish a consistent occlusal philosophy.

A primary goal of an occlusal scheme is to maintain the occlusal load that has been transferred to the implant system within the physiologic and biomechanical limits of each patient. These limits are not identical for all patients or restorations. The forces generated by a patient are influenced by ranges of parafunction, masticatory dynamics, implant arch position and location, arch form, and crown height. The treatment plan philosophy for dental implants varies greatly and depends on these several parameters. The clinician can address these force factors best by selecting the proper position, number, and implant size, increasing bone density when necessary by progressive bone loading and selecting the appropriate occlusal scheme using stress-relieving design elements.

The IPO principles for fixed prostheses address several conditions to decrease stress to the implant system, including existing occlusion, implant body angle to occlusal load, cusp angle of implant crowns, mutually protected articulation, cantilever or offset loads, crown height, crown contour, occlusal contact position, timing of occlusal contacts, and protection

of the weakest component (Box 16.5).

Box 16.5

Implant-Protective Occlusion Principles

- No premature occlusal contacts or interferences
- Mutually protected articulation
- Implant body positioned perpendicular to occlusal load
- Narrow cusp angle of crowns (cuspal inclination)
- Minimize cantilever or offset loads
- Minimize crown height (vertical offset)
- Ideal implant crown contour
- Ideal occlusal contact positions
- Ideal timing of occlusal contacts
- Protect the weakest component (i.e arch)
- Long, wide contact area

Occlusal Considerations for Fixed Implant Prostheses

Initial Evaluation

Many clinicians begin to evaluate the occlusion of the patient when the final implant prosthesis is delivered to the patient. However, this time frame is often too late to properly restore the patient. The underlying question that helps determine the need for occlusal correction before restoration of the implant patient is the observation of negative symptoms related to the existing condition. This may include temporomandibular joint (TMJ) conditions, tooth sensitivity, mobility, wear, tooth fractures, cervical

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abfraction, or porcelain fracture. The fewer and less significant the findings, the less likely an overall occlusal modification is required before restoration of the patient. However, to properly assess these conditions, the clinician must not ignore them before treatment.

Existing Occlusion

Maximal intercuspation (MI) is defined as the complete intercuspation of the opposing teeth independent of condylar position, sometimes described as the best fit of teeth regardless of the condylar position. Centric occlusion (CO) is defined as the occlusion of opposing teeth when the mandible is in centric relation (CR).[100] This may or may not coincide with the tooth position of MI. Its relationship to CR (a neuromuscular position independent of tooth contact with the condyles in an anterior, superior position) is noteworthy to the restoring dentist. The potential need for occlusal adjustments to eliminate deflective tooth contacts as the mandible closes in CR and the evaluation of their potential noxious effects on the existing dentition and the planned restoration is important to evaluate.

Correction of the deflective contacts before treatment presents many advantages and may follow a variety of approaches depending on the severity of the incorrect tooth position: selective odontoplasty (a subtractive technique), restoration with a crown (with or without endodontic therapy), or extraction of the offending tooth. The existing occlusion is best evaluated with facebow-mounted diagnostic casts on an articulator mounted with an open-mouth bite registration in CR.

Controversy exists as to the necessity to have MI harmonious with CO (CR occlusion). A vast majority of patients do not have such a relationship, yet they do not exhibit clinical pathology or accelerated tooth loss. It is difficult to state that these two positions must be similar. However, it is important to evaluate the existing occlusion and the mandibular excursions to decide whether the existing situation should be modified or be maintained. In other words, clinicians should determine whether they are going to ignore or control the occlusion of the patient.

As a general rule, the more teeth replaced or restored, the more likely the patient is restored to CO. For example, if a completely edentulous mandible is to be restored with an implant-supported fixed prosthesis, CO provides consistency and reproducibility between the articulator and the intraoral condition. The slight changes in occlusal vertical dimension (OVD) and its relationship to the position of anterior implant abutments to the direction of

force may be studied and implemented on the articulator without the need to record a new occlusal vertical position on the patient. On the other hand, when one anterior tooth is being replaced, the existing MI position is often satisfactory to restore the patient even though a posterior interference and anterior slide into full interdigitation may be present (with little clinical variance from the ideal conditions). However, in a partially edentulous patient, the existing occlusion should be evaluated to determine if noxious conditions are present.

Premature Occlusal Contacts

A fundamental biomechanical formula is stress equals force divided by the area over which the force is applied (S = F/A). During either maximum intercuspation or CO, no occlusal contacts should be premature, especially on an implant-supported crown. Premature occlusal contacts often result in localized lateral loading of the opposing contacting crowns.[101] Because the surface area of a premature contact is small, the magnitude of stress in the bone increases proportionately (i.e., S = F/A). All of the occlusal force is applied to one region rather than being shared by several abutments and teeth. In addition, because the premature contact is most often on an inclined plane, the horizontal component of the load increases the shear crestal stresses and the overall amount of stress to the entire implant system. The occlusal porcelain, the abutment screw, and the cement retaining the crown are all at increased risk because shear loads render more complications.

This is a general criterion for natural teeth, but the concept is much more important on implant prostheses with their higher impact force and less occlusal awareness for the several reasons previously addressed. Myata et al evaluated premature contacts on implant crowns in monkeys *(Macaca fascicularis)*. The crestal bone was histologically evaluated on implant crowns with 100 μm, 180 μm, and 250 μm of premature contacts for 4 weeks. The crowns with 100-μm premature contacts had little bone changes. The 180-μm group demonstrated a V-shaped pattern of bone loss for several millimeters. The 250-μm implant crowns for 4 weeks had a large V-shaped defect around the implants that extended for more than two thirds of the implant body. The implant is rigid, and the premature implant load cannot be released by increased mobility or occlusal material wear as with a natural tooth.[102] The premature contact on an implant system contributes to a higher risk of early abutment screw loosening, porcelain fracture, early loading failure, and

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crestal bone loss.

The elimination of premature occlusal contacts is especially important when habitual parafunction is present because the duration and magnitude of occlusal forces are increased. The elimination of premature contacts is more critical than in natural teeth because of the lack of proprioception and the implant's inability to move and dissipate the forces. Because of increased proprioception, an initial premature occlusal contact on a tooth often affects the closure of the mandible to result in an MI position different from CO. A premature contact on an implant crown does not benefit from such protective features. As a result, the implant system is at increased risk. Therefore, occlusal evaluation in CO and MI and adjustment as necessary in partially edentulous implant patients is more critical than in natural dentition because the premature contacts can result in more damaging consequences on implants compared with teeth (Fig. 16.86).[33]

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FIG 16.86 Premature occlusal contacts (i.e. implant prosthesis occluding prior to natural teeth) are detrimental to the implant leading to possible bone loss or implant fracture.

Implant Body Orientation

Forces acting on teeth and dental implants are referred to as vectors (defined in magnitude and direction). Occlusal forces are typically three dimensional, with components directed along one or more of the clinical coordinate axes. The primary forces of occlusion can be resolved into a combination of components in any given plane. The same magnitude of force can have dramatically different effects on the implant system solely because of the direction of the applied load. This is especially noted on implant support systems because they are more rigid. Teeth are naturally designed primarily for long-axis loads. The natural tooth roots in the majority of the mouth are perpendicular to the curves of Wilson and Spee. Although chewing is in an elliptical "tear drop" pattern, when the teeth finally contact, the forces are in the long axis of the roots, especially during power biting (Fig. 16.87). The apical movement of teeth is minimal compared with their lateral movement.

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The maxillary anterior teeth receive a lateral load. The consequences of a lateral force to a tooth are reduced because of the increased tooth mobility, which decreases the effects of the lateral force component of a load.

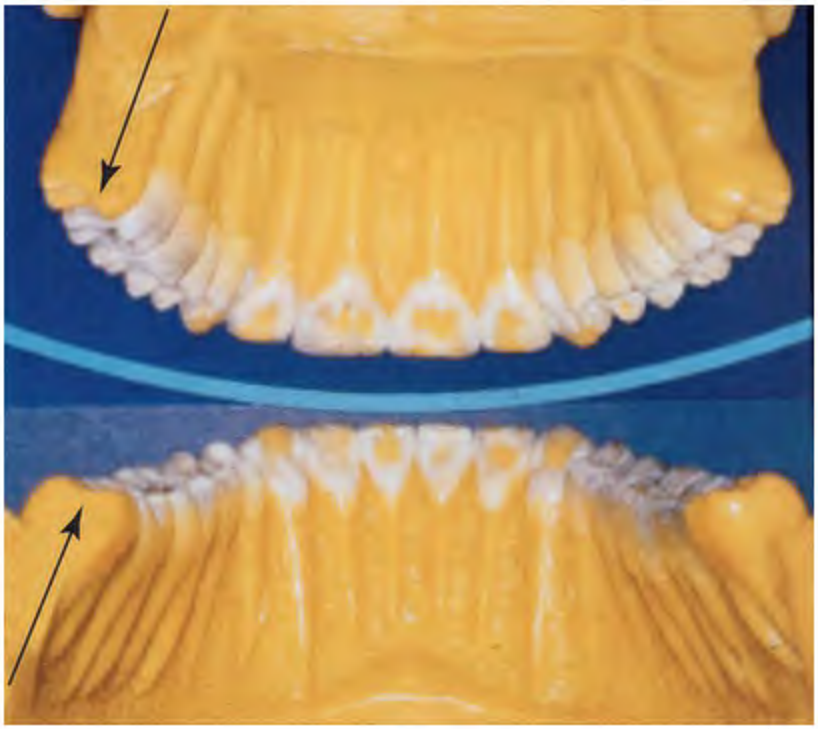

FIG 16.87 The natural teeth occlude perpendicular to the curves of Wilson and Spee *(arrows)*. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

An axial load over the long axis of an implant body generates less overall stress and a greater proportion of compressive stress compared with an angled force to the implant body. When an implant body is loaded along its long axis, a 100-N force results with an axial force component of 100 N, and no lateral force component is observed. The implant body should be positioned perpendicular to the curves of Wilson and Spee, just as with natural teeth.

Most anatomic variations of the bone (e.g., bony concavities) are located on the facial aspect and influence implant body inclination. An implant body may be positioned with a 15-degree angle to avoid the facial concavity and, therefore, is positioned at 15 degrees to the occlusal load. This angled implant may be restored during prosthetic reconstruction with a 15-degree angle abutment. From the level of the crest of the ridge to the occlusal plane, the implant abutment looks similar to one in an axial implant body. The laboratory technician and restoring dentist often treat the angled implant

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and axial implant in similar fashion. However, in the 15-degree angled implant body, the load to the facial bone increases by 25.9% compared with an axial load (Fig. 16.88). If the implant surgeon places the implant body with a 30-degree angulation, the buccal force component of any occlusal load will result in a 50% increase of the load applied to the facial bone.[93]

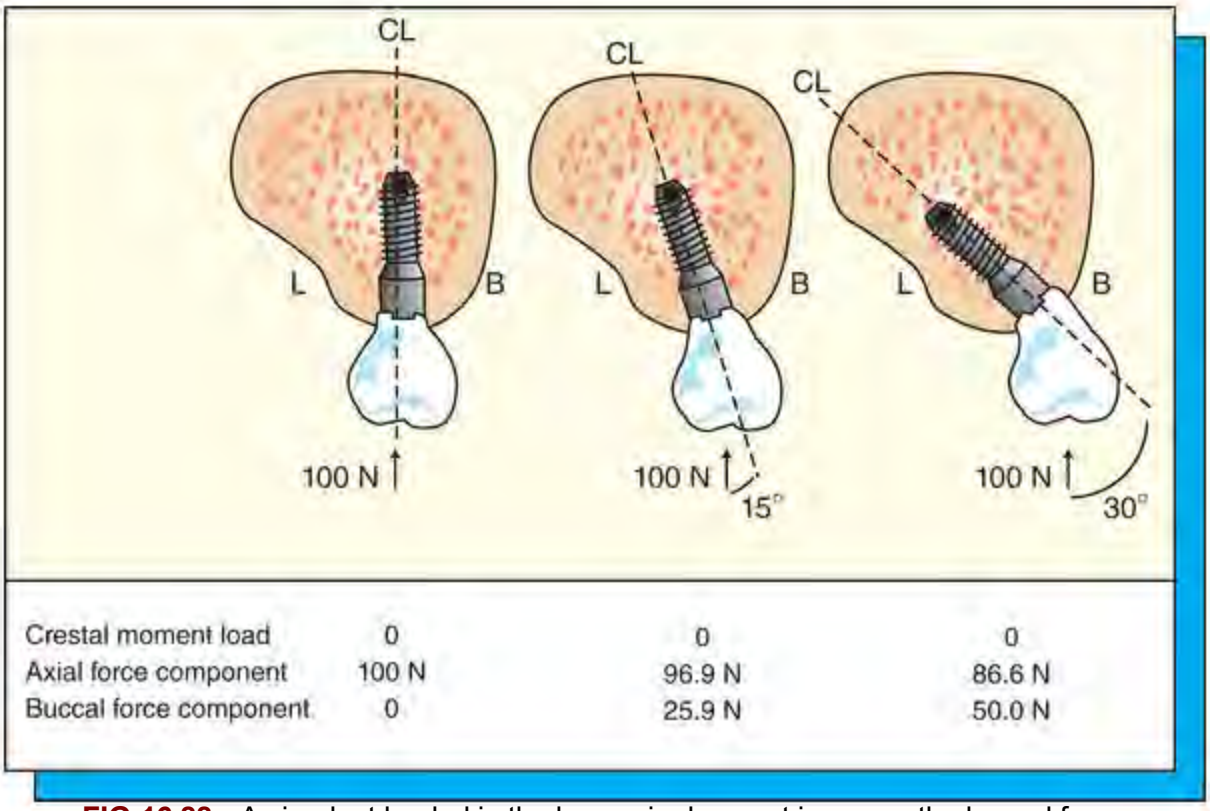

FIG 16.88 An implant loaded in the long axis does not increase the buccal force component of the load *(far left)*. A 15-degree angle increases the buccal force component by 25.9% *(middle)*. A 30-degree angle load increases the force by 50%. When the forces are applied along the long axis of an implant body, stresses are concentrated on the crestal region *(far left)*. The intensity of the stress is not increased as a result of the position of the implant. The implant body in the center is 15 degrees off the long axis. With an angled abutment of 15 degrees, the implant restoration is similar to the previous situation. However, now 25.9% greater stress is on the crestal bone; all other factors are similar. The implant body on the far right is 30 degrees off the long-axis load. With a 30-degree angled abutment, the crown may appear similar. However, the abutment screw, abutment-implant connection, and implant-bone interface are subject to a 50% increase in stress on the facial aspect of the system. (From Misch CE: *Contemporary implant dentistry,* ed 2, St Louis, 1999, Mosby.)

The risk of crestal bone loss is increased with an angled implant. In addition, the greater force is applied to most of the implant system. The occlusal porcelain may be loaded in the long axis with the angled abutment, but the abutment screw loosening and implant component fracture risks

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increase in direct comparison to the load applied to the bone. Although the restoring dentist may place a 30-degree angled abutment and restore the case similar to the axial implant, the conditions and risks of early loading failure, crestal bone loss, and loose abutment screws are dramatically different (Fig. 16.89).

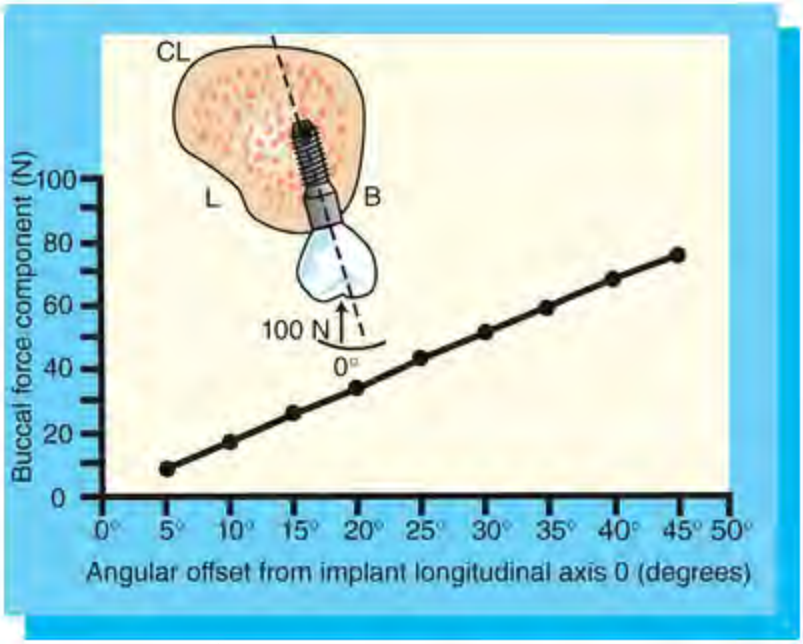

FIG 16.89 As the angle of the implant body load direction increases, the stresses to the entire crown implant-bone system increase. *B,* buccal; *L,* lingual. (From Misch CE: *Contemporary implant dentistry,* ed 2, St Louis, 1999, Mosby.)

Force Direction and Bone Mechanics

The noxious effect of offset or angled loads to bone is exacerbated further because of the anisotropy of bone. Anisotropy refers to the character of bone whereby its mechanical properties, including ultimate strength, depend on the direction in which the bone is loaded and the type of force applied. For example, cortical bone of human long bones has been reported as strongest in compression, 30% weaker in tension, and 65% weaker in shear.[103] Porcelain, titanium components, and cements are also weakest to shear components of a load. IPO attempts to eliminate or reduce all shear loads to the implant system because the bone, porcelain, titanium components, and cement are weakest to shear loads.

Any occlusal load applied at an angle to the implant body may be separated into normal (compressive and tensile) and shear forces. As the

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angle of load to an implant body increases, the amount of compressive and tensile forces is modified by the cosine of the angle. Hence, the force is slightly reduced. However, the angled component of force is a shear force, and the shear force is the amount of force times the sine of the load, which considerably increases the load. The force the bone observes is the sum of the compressive, tensile, and shear forces. For example, a 100-N force applied at 12 degrees off-axis will increase the total force to the bone by 100 N × cosine 12 degrees = 97.81 N + 100 N × sine 12 degrees = 20.79 N. The total force is 97.81 N + 20.79 N = 118.60 N (or almost a 20% increase in total force). The greater the angle of load to the implant long axis, the greater the compressive, tensile, and shear stresses (Fig. 16.90).

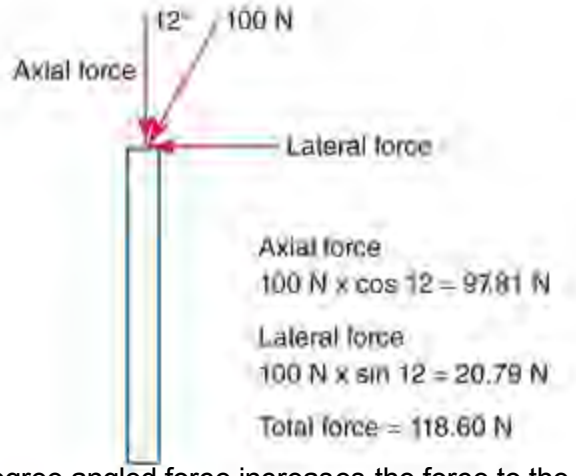

FIG 16.90 A 12-degree angled force increases the force to the implant system by 18.6%. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

In finite element analysis, when the direction of the force changes to a more angled or horizontal load, the magnitude of the stress is increased by three times or more.[104] In addition, rather than a primarily compressive type of force, tensile and shear components are increased more than tenfold compared with the axial force. In a photoelastic block with implants inserted, the strain contours in the bone may be observed (Fig. 16.91). The axial-loaded implants have less strain in the system (*left side* and *lower right* of figure). The angled implant has more strain lines indicating greater loads *(right upper implant)*.

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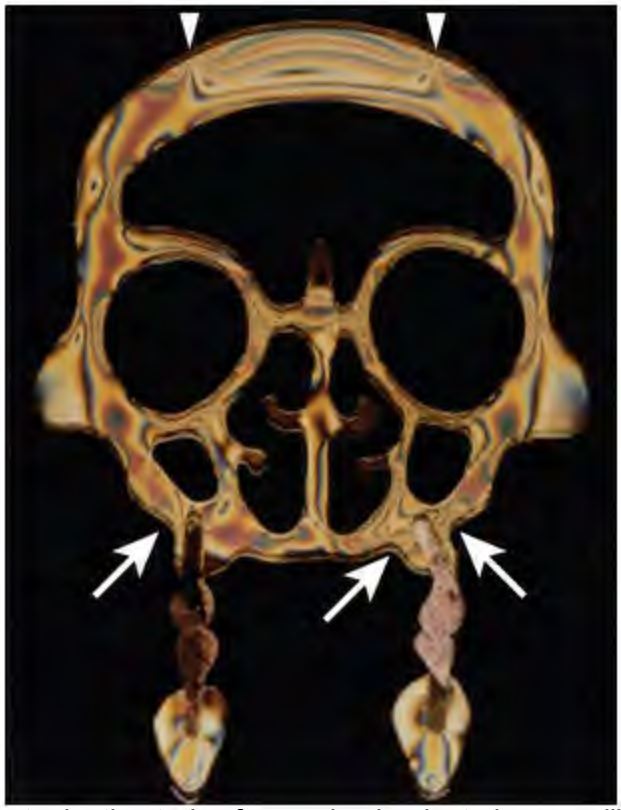

FIG 16.91 A photoelastic study of opposing implants in a maxilla and mandible. One of the maxillary implant bodies is angled in relation to the direction of load. The number of stress contour lines in the material is similar for the three implants with a long-axis load. The stress contour lines are increased for the angled implant body. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

An angled load to the implant long axis increases the compressive forces at the crest of the ridge on the opposite side of the implant, increasing the tension component of force along the same side as the load. The greater the angle of force to the long axis of the implant body, the greater the potentially damaging load at the crest of the bone. For example, three-dimensional finite element analysis demonstrates that a vertical load on an implant with 100% bone contact may have compressive stress of 4000 psi (27.6 MPa) and almost no tensile stress at the bone-implant crest interface. With a load at a 45-degree angle on the same implant design, the compressive stress may increase to 14,000 psi (96.6 MPa), and on the opposite side, tensile stress may increase to 4000 psi (27.6 MPa). The compressive stresses are tripled, and the tensile stress increases 1000-fold with a load from a 45-degree angle.

The stress contours in the bone simulant of the three-dimensional studies resemble the clinical pattern of early crestal bone loss on implants. Not only does the magnitude of stress increase under angled loads, but it also evolves into a more noxious shear component, which is more conducive to bone loss and screw loosening.[105] The greater the angle of the force, the greater the

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shear component. Bone is 65% weaker to shear load. The amount of the force increases, and the strength of the bone decreases. It has been reported that angled occlusal forces decrease the ability of successful bone repair on natural teeth. It may also impair successful bone remodeling around an implant.

Not only is the bone weakest to shear loads but forces applied at an angle to the bone also further affect the physiologic limit of compressive and tensile strengths of bone. A force applied at a 30-degree angle may decrease the bone strength limits by 10% under compression and 25% with tension (Table 16.5). A 60-degree force angle reduces the strength 30% under compression and 55% under tension. Not only does the crestal bone load increase around the implant with angled forces but also the amount of stress the bone may withstand (i.e., the ultimate strength) decreases in shear, tension, and compression. The greater the angle of load, the lower the ultimate strength of bone. IPO attempts to eliminate lateral or angled loads to an implant-supported prosthesis because the magnitude of the force increases and the strength of the bone decreases.

TABLE 16.5

Cortical Bone Strength Related to Angle of Load

Type	Strength (MPa)	Direction of Load
Compression	193	Longitudinal
	173	30 degrees off axis
	133	60 degrees off axis
	133	Transverse
Tension	133	Longitudinal
	100	30 degrees off axis
	60.5	60 degrees off axis
	51	Transverse

From Reilly DT, Burstein AH: The elastic and ultimate properties of compact bone tissue, *J Biomech* 80:393–405, 1975.

In conclusion, the microstrain of the crestal bone is increased with an angled load and may shift from an axial load within physiologic limits to an angled load in the pathologic overload zone and, as a consequence, result in bone loss. The greater force, especially in shear, is generated to the entire implant system. The occlusal porcelain is weaker to shear and may fracture, the cement that retains the prosthesis is weakest to shear and may become unretained, the abutment screw more likely becomes loose with shear loads, the crestal bone region may resorb, and implant components fracture more often with higher shear loads. When shear forces are increased with an

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angled load to the implant system, an attempt should be made to reduce the negative effect of angled loads.[106]

The primary component of the occlusal force should be directed along the long axis of the implant body, not at an angle or following an angled abutment post. Angled abutments should be used only to improve the path of insertion of the prosthesis or improve the final esthetic result. The angled abutment, which is loaded along the abutment axis, transmits a significant moment load (i.e., tending to rotate or rock the implant) to the entire implant system.

Prosthetic Angled Loads

Greater crestal bone strains with angled forces have been confirmed with photoelastic and three-dimensional finite element analysis methods. Whether the occlusal load is applied to an angled implant body or an angled load (e.g., premature contact on an angled cusp) is applied to an implant body perpendicular to the occlusal plane, the results are similar (Fig. 16.92). A biomechanical risk to the implant system increases.

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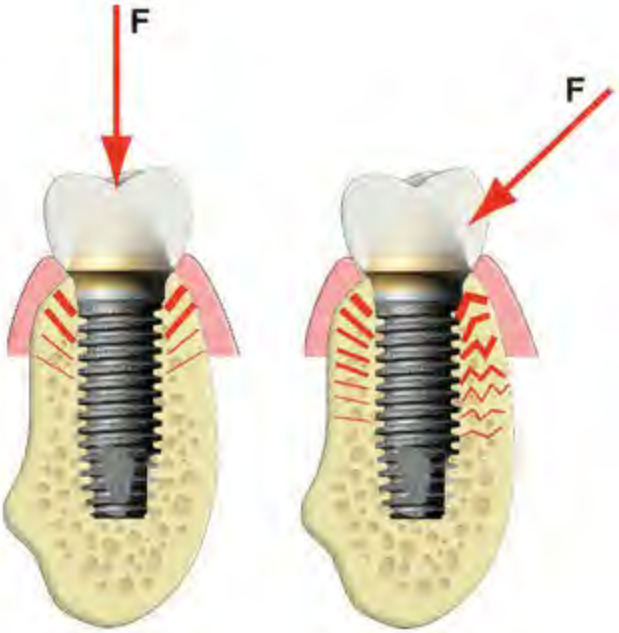

FIG 16.92 When an angled load is placed on an implant body, the compressive stresses on the opposite side of the implant increase and the tensile and shear loads on the same side of the implant increase. Because bone is weaker to tensile and shear forces, the risks to the bone are increased for two reasons: (1) the amount of the stress increases, and (2) the type of stress is changed to more tensile and shear conditions. *F,* force. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The implant surgeon may place the implant body ideally, perpendicular to the occlusal plane, yet the restoring dentist then may load the implant crown at an angle. Similar noxious forces are increased in shear, and a decrease in bone strength occurs to the crestal bone, as well as an increase of shear loads on implant components and the abutment screws. An angled implant body or an angled load on the implant crown increases the amount of crestal stresses on the implant system, transforms a greater percentage of the force to shear force, and reduces bone, porcelain, and cement strength. In contrast, the surrounding implant system stress magnitude is least, and the strength of bone, porcelain, and cement is greatest under a load axial to the implant body and perpendicular to the occlusal plane. All of these factors mandate the reduction of angled forces to the implant system (Fig. 16.93).

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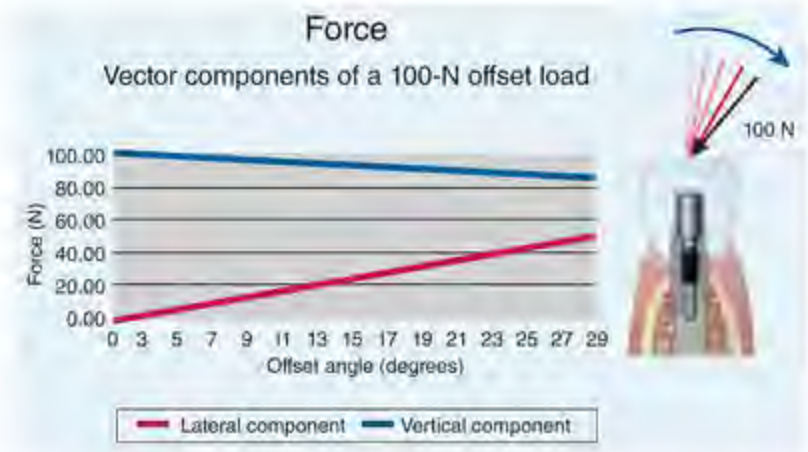

FIG 16.93 The force applied to an implant body with an angled load or angled direction of force is increased in direct relation to the force angle. The major increase of force is a result of the offset angle of the load. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Most implant bodies inserted at an angle of greater than 12 degrees to the occlusal plane require an angled abutment. The surgeon and restoring dentist should understand that angled abutments are fabricated in two pieces and are weaker in design than a two-piece straight abutment without an angle. Because less metal flanks the abutment screw on one side of an angled abutment, it is at more risk of fracture or is less able to be reduced in width for ideal crown contours. Furthermore, a larger transverse load component develops at the abutment screw and crest of the ridge as a result of angled loads and increases the risk of abutment screw loosening. In a study by Ha et al, the angled abutment was compared with a straight abutment for screw loosening in the anterior maxilla. The angled abutments showed more screw loosening with cyclic loading than the straight abutments.[107]

Solutions to Angled Loads

When lateral or angled loads cannot be eliminated, a reduction in the force magnitude or additional surface area of implant support is indicated to reduce the risk of biomechanical complications to the implant system. For example, if three adjacent implants are inserted with the first in the long axis to the load, the second at 15 degrees, and the third implant at 30 degrees, the surgeon may decrease the overall risk by (1) adding an additional implant in the edentulous space next to the most angled implant, (2) increasing the diameter of the angled implants, or (3) selecting an implant design with greater surface area. Of the three options, increasing the implant number is

most effective to reduce overall stress to the system.[108] In addition, a greater number of implants also has more retention for the restoration.

The restoring dentist may reduce the overload risk by (1) splinting the implants together, (2) reducing the occlusal load on the second implant and further reducing the load on the third implant, and (3) eliminating all lateral or horizontal loads from the most angled implant and completely eliminating them in all posterior regions.

The anterior mandible (with a force magnitude similar to the anterior maxilla) often has the implant body positioned perpendicular to the occlusal plane and restored with a straight abutment. In the anterior maxilla, even under ideal conditions, the implant should be angled away from the labial bone and results with the abutment toward the facial crown contour. An angled prosthetic abutment is required, and these implant bodies are more frequently loaded at an angle. In fact, maxillary anterior teeth are usually loaded at a 12- to 15-degree angle to the occlusal plane.

The natural dentition reduces the increased stress to the maxilla by increasing the size of the roots compared with mandibular incisors and increasing the mobility of the tooth. In the maxilla, a larger-diameter implant or a greater number of implants are indicated to minimize the crestal bone stress on each abutment, especially in patients exhibiting severe bruxism. Ridge augmentation may be necessary before implant placement to improve implant position or facilitate the use of a wider-diameter implant. IPO aims at reducing the force of occlusal contacts, increasing the implant number, or increasing the implant diameter for implants subjected to angled loads.

Occlusal Contact Timing

Most commonly, clinicians use subjective methods when evaluating and determining occlusal contact. This may often lead to false-positive or negative results because of the use of dental anesthesia, the subjective nature of the method, and questionable awareness of contact timing.

Etiology

Occlusal Awareness.

Jacobs and van Steenberghe evaluated patient occlusal awareness by the perception of an interference. When teeth oppose each other, an interference is perceived at approximately 20 μm. An implant opposing a natural tooth

detects an interference at 48 μm; this detection is more than twice as poor. An implant crown opposing an implant crown perceives the interference at 64 μm, and when a tooth opposes an implant overdenture, the awareness is 108 μm (five times poorer than teeth opposing each other).[109] Mericske-Stern et al measured oral tactile sensitivity with steel foils. The detection threshold of minimal pressure was significantly higher on implants than on natural teeth (3.2 vs. 2.6 foils).[110] Similar findings also were reported by Hammerle et al in which the mean threshold value for implants (100.6 g) was 8.75 times higher than that of natural teeth (11.5 g).[111] An occlusal adjustment performed by occlusal awareness—"How does the bite feel? Is the implant crown high?"—is a poor indicator for hyper contacts compared with a crown on a natural tooth. As a consequence of decreased quantity and quality of occlusal awareness, a premature occlusal contact may remain on an implant crown after occlusal adjustment.

The biomechanical concern for the difference in tooth movement and implant movement should not be restricted to situations in which these entities are directly connected within the same prosthesis. When an implant is placed in a partially edentulous arch, many similar biomechanical elements are present, whether the teeth are splinted to the implant or are independent.

Inherent Laboratory Error.

The laboratory cannot equilibrate the occlusion accurately on the working casts. The technician taps two stone casts together to evaluate the occlusal contacts. The stone dies do not move 28 to 108 μm. As a result, the occlusal adjustment in the mouth compensates for the primary and secondary tooth movement. When a heavy bite force occlusal adjustment is not performed at the delivery of an implant crown, the dentist may not be aware that the implant may be overloaded similar to a new crown on a natural tooth that has not been equilibrated in the mouth.

Tooth vs. Implant Movement.

The sudden, initial (primary) tooth movement ranges from 8 to 28 μm in a vertical direction under a 3- to 5-lb load, depending on the size, number, and geometry of the roots and the time elapsed since the last load application.[86] This tooth movement has been called "primary" tooth movement and is a result of the movement within the periodontal complex. An implant has no

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initial or primary vertical tooth movement. An implant with a heavy bite force may move apically up to 5 μm. When the initial tooth movement occurs, secondary tooth movement is present during a greater load and reflects the viscoelastic property of the surrounding bone. The vertical secondary tooth movement is minimal and may approach 3 to 5 μm for a natural tooth.

The secondary tooth movement is similar to the bone-implant movement. In other words, the initial axial movement during a light bite force of an implant has no initial, sudden movement. Contrary to the teeth that move immediately, even with light loads, implants only move under a heavy occlusal load and even under these conditions have almost no mobility. The implant may move up to 5 μm after additional force causes the bone to deform, with little correlation of movement to the implant body length.[87] In fact, the mobility of implant "secondary" movement is more related to bone density than any other factor.

When teeth oppose each other, the combined intrusive movements of the contacting elements may be 56 μm (28 + 28 μm). When a tooth opposes an implant, the initial combined intrusive movement is only 28 μm (28 + 0 μm). In other words, when implant prostheses oppose natural teeth, the difference in movement between teeth in the rest of the mouth and the implants causes a condition with greater loads to the implant.

Prevention/Treatment

Articulation Protocol

1. The clinician should first evaluate the existing occlusion before implant reconstruction and ideally eliminate occlusal prematurities on teeth before the final evaluation of the occlusion for the implant reconstruction.

2. At the delivery of the implant prosthesis, any premature contact on the implant restoration should be eliminated. It is interesting to note that a coating of petroleum jelly on the articulating paper will help release the dye and allow more precise occlusal contact identification on the teeth and implant restoration (Fig. 16.94). After this step, the clinician uses thin articulating paper (less than 25-μm thickness tin foil) for the initial implant occlusal adjustment in occlusion under a light tapping force (Fig. 16.95). The implant prosthesis should barely contact during this light bite force, and the

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surrounding teeth in the arch should exhibit greater initial occlusal contacts. In other words, only light axial occlusal contacts should be present on the implant crown.

FIG 16.94 Petroleum jelly applied to articulating paper helps release the dye and makes the occlusal marks more specific. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 16.95 A light occlusal force is applied first to the implant and teeth. The first molar implant crown has less initial contact than the teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

3. After the equilibration, when a light bite force is completed, the patient applies a heavier occlusal force and grinds on the articulating paper (Fig. 16.96). A plastic articulatory paper is a benefit, so the "paper" will not tear during the heavy bite and grind force on the teeth (e.g., 20 μm, Accufilm; Parkell, Farmingdale, NY). The occlusal contact point on the implant crown should remain axial over the implant body and may be of similar intensity on the implant crown and the adjacent teeth. When greater bite forces are used, all of the occlusal elements react similar under the heavy occlusal load. To harmonize the occlusal forces between implants and teeth, the dentist evaluates a heavy bite force occlusal adjustment because it depresses the natural teeth, positioning them closer to the less depressed implant position, and permits equal sharing of the occlusal load.[45]

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FIG 16.96 The first molar implant crown is evaluated with a heavy bite force during grinding movements (especially in a parafunction patient). The implant crown in this patient needs to be adjusted because the occlusal markings on the lingual cusps and marginal ridge are offset loads. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Occlusal Contact in One Quadrant.

When all posterior teeth in one quadrant of the same arch are implant supported, the same occlusal timing is suggested. Under a light bite force, the occlusal contacts between the anterior and posterior teeth on the opposite side are slightly heavier in centric occlusion than the implant prosthesis. Under a heavy bite force in occlusion, similar contacts are created around the arch. To evaluate these occlusal contacts, a full-arch articulating paper is required.

Implant Prostheses Opposing Each Other.

When implant prostheses oppose each other unilaterally, the heavy bite force occlusal adjustment must account for a 56-μm difference in vertical movement between the opposing implant crowns and the rest of the natural teeth. The light bite force occlusal adjustment should again be performed with a full-arch-size articulating paper, and the implant-implant section should barely contact, but the tooth-tooth anterior and posterior sections have more occlusal contact. Under a heavy bite force in occlusion, similar

occlusal contacts are present on both sides of the arch.

Complete Implant-Supported Prosthesis.

A complete-arch implant-supported prosthesis in one arch opposing complete natural teeth does not require a difference in a light and heavy bite force occlusal evaluation. Likewise, when implants support both maxillary and mandibular prostheses, a light and heavy bite force difference in occlusal timing is not required.

Maxillary Anterior.

When anterior teeth disocclude the posterior teeth in excursions, the lateral tooth movement of the posterior teeth (56–73 μm) does not have to be accounted for because no lateral force exists. Because anterior teeth and implants have lateral movement during mandibular excursion that results in greater discrepancies, the occlusal adjustment in this direction is more critical to the implant system. The clinician will first use light force and thin articulating paper to ensure that little to no implant crown contact occurs during the initial occlusal or lateral movement of the teeth. A heavier force during CO and excursions to develop similar occlusal contacts on anterior implants and natural teeth should then be completed.

To compensate for the difference in 100 μm of horizontal movement between maxillary anterior implants and anterior teeth, two modifications are required. The first is to enameloplasty the facial incisal contact of the mandibular incisal edge. The patient is told the height of the tooth is not reduced, only the facial incisal edge. Very often, when a maxillary anterior tooth is lost, the opposing mandibular incisor shifts to the facial and makes the implant position and occlusal adjustment more critical. The second modification is often that the lingual contour of a maxillary anterior crown is more concave than a natural tooth to accommodate the heavy bite force occlusal adjustment (Fig. 16.97).

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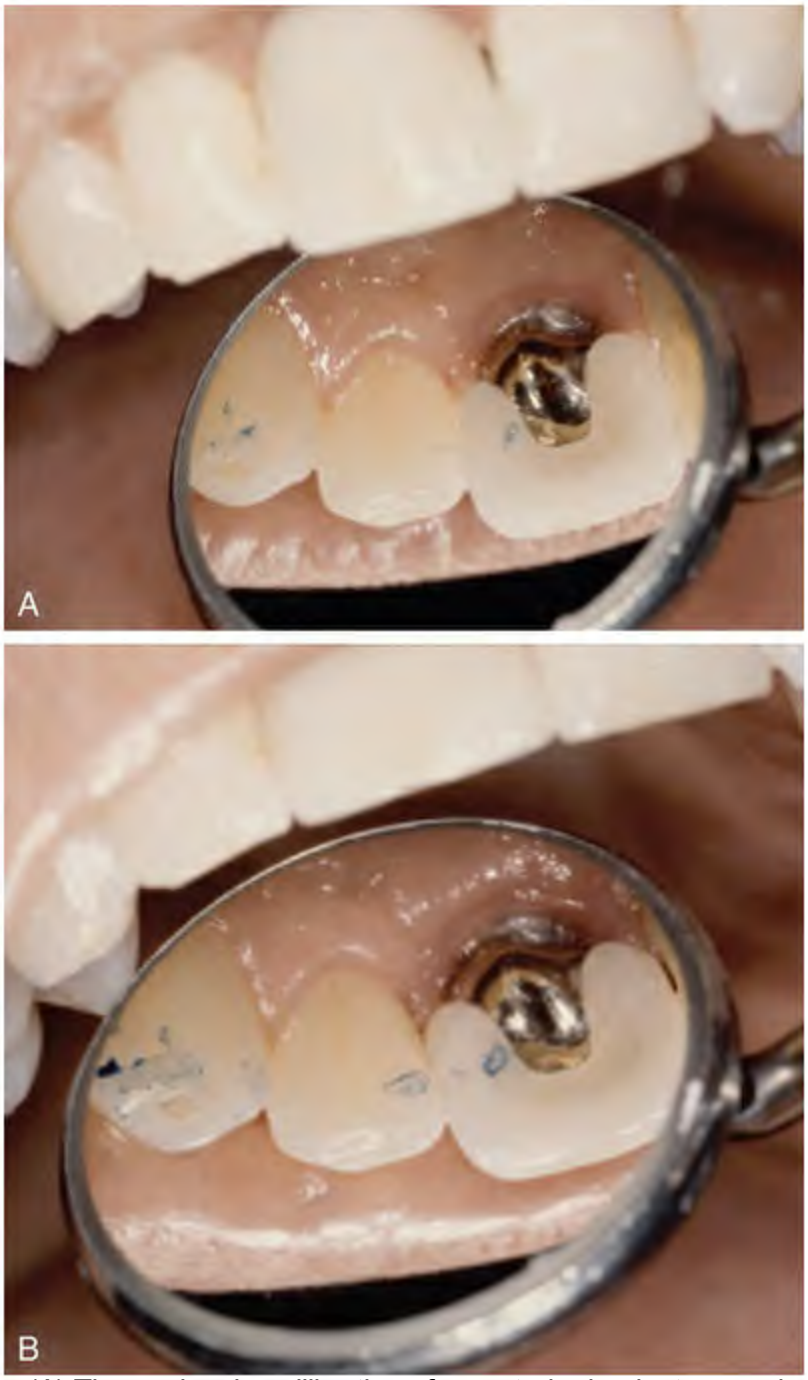

FIG 16.97 (A) The occlusal equilibration of an anterior implant crown is made first with a light occlusal contact in centric occlusion (CO) and during mandibular excursions. (B) The anterior implant crown then is equilibrated under a heavy bite force in CO and during mandibular excursions. The difference between primary tooth movement and implant movement is greater in the anterior regions of the mouth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The proposed heavy bite force occlusal adjustment does not encourage tooth migration or changes in tooth position because regular occlusal contacts still occur. The teeth opposing implants are not taken out of occlusion. Brief occlusal contacts on a daily basis maintain the tooth in its

original position (similar to the rest of the mouth). In addition, because most teeth in a skeletal class I occlusion occlude with two opposing teeth (with the exception of the mandibular central incisor), the opposing teeth positions are even more likely to remain the same. In other words, the two opposing natural teeth to an implant crown still have occlusal contacts on the adjacent natural teeth to the implant. However, teeth do move over time. Unlike teeth, implants do not extrude, rotate, or migrate under occlusal forces. As such, the restoring dentist may vary the intensity of the force applied to an implant without causing the implant to change its position readily in the bone. On the contrary, natural teeth do exhibit mesial drift, and slight changes in occlusal position do occur over time.

Treatment

Recall Examination.

No occlusal scheme will prevent mesial drift and minor tooth movement from occurring. In addition, enamel may wear approximately 30 μm each year. An integral part of the implant-protected occlusion philosophy is the regular evaluation and control of occlusal contacts at each regularly scheduled hygiene appointment. This permits the correction of minor variations occurring during long-term function and helps prevent porcelain fracture and other stress-related complications (abutment screw loosening) on the implant prostheses.

Occlusal Table Too Large

Etiology

The occlusal table of the crown should also be modified in nonesthetic regions to conform to the implant size and position and to direct vertical forces to the implant body. For example, posterior mandibular implant-supported prostheses have narrower occlusal tables at the expense of the buccal contour because the implant is smaller in diameter and placed in the central fossa region of the tooth. Maxillary posterior teeth often have reduced occlusal tables from the palatal aspect because the buccal cusp is often within the esthetic zone (Fig. 16.98).

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FIG 16.98 This full-arch prosthesis has posterior crown contours that are narrower than natural teeth because the implant is smaller in diameter than the tooth. As a general rule, the maxillary arch has reduced lingual contours and the mandibular posterior prosthesis has reduced buccal contours. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

A buccal or lingual cantilever in the posterior regions is called an *offset load,* and the same principles of force magnification from class 1 levers apply. In other words, the greater the offset, the greater the load to the implant system.[112] Offset loads may also result from buccal or lingual occlusal contacts and create moment forces, which increase compressive, tensile, and shear forces to the entire implant system (Fig. 16.99).

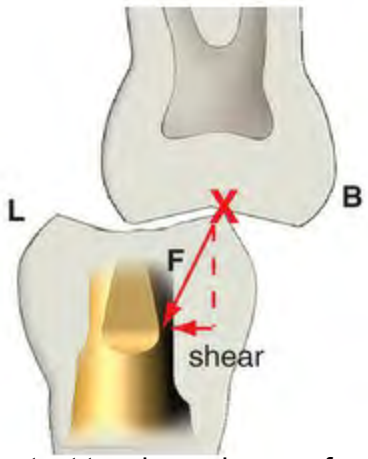

FIG 16.99 An occlusal contact to a buccal cusp of an implant crown is often an offset load to the implant, which increases the shear component of a load. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The laboratory technician often attempts to fabricate an implant crown

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with occlusal facial and lingual contours similar to those of natural teeth. The posterior implant crown should have a reduced occlusal width compared with a natural tooth when out of the esthetic zone. A wide occlusal table favors offset contacts during mastication or parafunction. The narrower occlusal contour of an implant crown also reduces the risk of porcelain fracture.

A facial profile similar to a natural tooth on the smaller-diameter implant (e.g., 10-mm tooth vs. a 4- to 6-mm implant) results in cantilevered restorative materials. This cantilever crown contour is often designed as a ridge lap pontic of an FPD (Fig. 16.100). The facial porcelain most often is not supported by a metal substructure because the gingival region of the crown is also porcelain. As a result, shear forces result on the buccal cusp of the mandibular crown or lingual cusps in the maxillary crown and are more likely to increase the risk of porcelain fracture. This risk is compounded further by the higher impact force developed on implant abutments compared with natural teeth.

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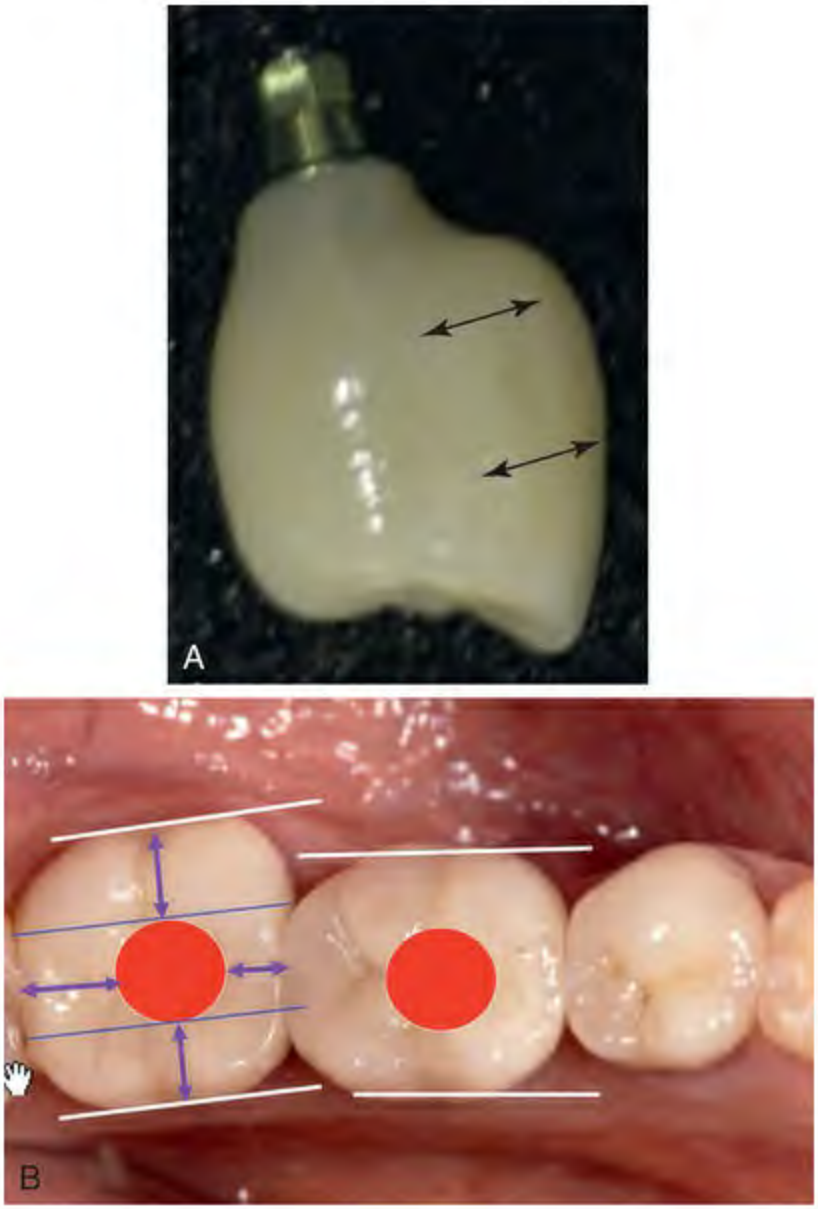

FIG 16.100 (A) Facial cantilever on lingually placed implant. (B) Posterior occlusal table is narrowed to minimize shear forces.

The extended crown contours not only increase offset loads but also often result in ridge laps or porcelain extension at the facial gingival margin of the implant abutment. As a result, home care in the sulcular region of the implant is impaired by the overcontoured crown design. The dental floss or probe may reach under the ridge lap to the FGM, but it cannot enter the gingival sulcus, making daily hygiene almost impossible to perform. The narrower posterior occlusal table facilitates daily sulcular home care.

In conclusion, a narrow occlusal table combined with a reduced contour facilitates daily care, improves axial loading, and decreases the risk of porcelain fracture. However, in the esthetic zone, the ridge lap design may be necessary to restore the implant rather than removing it, bone grafting, and

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replacing the implant in a more ideal position for esthetics.

Prevention/Treatment

Mandibular Posterior Crowns.

The posterior mandible resorbs lingually as the bone resorbs from division A to B. As a result, endosteal implants are also more lingual than their natural tooth predecessors. The division C–h and D mandibular ridge shifts to the buccal compared with the maxillary arch. However, endosteal implants typically cannot be inserted because the available bone above the mandibular nerve is inadequate for endosteal implants.

The mandibular implant crown should be reduced from the buccal (and the maxillary crown reduced from the lingual). The "stamp cusp" offset load is reduced. The reduced buccal contour in the posterior mandible is of no consequence to cheek biting because the buccal horizontal overjet is maintained (and increased). The lingual contour of the mandibular implant crown is similar to a natural tooth (Fig. 16.101). This permits a horizontal overjet to exist and push the tongue out of the way during occlusal contacts (just as natural teeth). As with the natural tooth, the lingual cusp has no occlusal contact.

FIG 16.101 (A) A mandibular first molar implant and abutment. (B) The implant crown is reduced in width on the buccal. The lingual contour is similar to the adjacent teeth to prevent biting the tongue during occlusion. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In the posterior mandible, as the implant diameter decreases, the buccal cusp contour is reduced. This decreases the offset length of cantilever load.

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The lingual contour of the crown remains similar regardless of the diameter of the implant. The lingual contour permits a horizontal overlap with the maxillary lingual cusp, so the tongue is pushed away from the occlusal table during function. The mandibular lingual cusp is not occlusally loaded (as with natural teeth).

Maxillary Posterior Crowns.

In the esthetic zone (high lip position during smiling), the buccal contour of the maxillary implant crown is similar to a natural tooth. This improves esthetics and maintains the buccal overjet to prevent cheek biting. But just as with the natural teeth, there is no occlusal contact on the buccal cusp. Ideally, when maxillary posterior implants are in the esthetic zone, they are positioned more facial than the center of the ridge. The lingual contour of a maxillary implant crown should be reduced because it is out of the esthetic zone and is a stamp cusp for occlusion (which is an offset load).

The ideal functional position for the maxillary posterior implant is under the central fossa when the cervical region is not in the esthetic zone. The lingual cusp is cantilevered from the implant similar to the buccal cusp of the posterior mandible. The reduced lingual contour reduces the offset load to the lingual (Fig. 16.102).

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FIG 16.102 The posterior maxillary first molar implant crown has primary contact over the implant. When the implant is under the central fossa to lingual cusp, the crown contour is reduced on the lingual, and occlusal load is directed along the long axis of the implant. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The maxillary dentate posterior ridge is positioned slightly more facial than its mandibular counterpart because the teeth have a maxillary overbite. When the maxillary teeth are lost, the edentulous ridge resorbs in a medial direction as it evolves from division A to B, division B to C, and division C to D. As a result, the maxillary permucosal implant site gradually shifts toward the midline as the ridge resorbs. Sinus grafts permit the placement of endosteal implants in the posterior maxilla even in previous division D ridges. However, because of resorption in width, the maxillary posterior implant permucosal site may even be palatal to the opposing natural mandibular tooth.

In the esthetic zone, many of the crown contours are made to resemble the natural tooth as closely as possible. However, out of the esthetic zone, in the posterior regions of the mouth, the crown contour should be different than a natural tooth. The implant body buccolingual dimension is smaller than the natural tooth. The center of the implant most often is placed in the center of the edentulous ridge. Because the crest of the ridge shifts lingually with resorption, the implant body is most often not under the opposing cusp tips but rather near the central fossa or even more lingual and in the maxilla may even be under the lingual cusp of the original natural tooth position. Most often, the laboratory fabricates a posterior implant crown that is similar in size to a natural tooth, with a cantilevered facial contour. In addition, the occlusal contacts are often on the “stamp cusp” of the mandible (buccal

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cusps). However, these "stamp cusps" are often offset loads (buccal cantilevers).

When the maxillary posterior teeth are out of the esthetic zone, the crown may be designed for a crossbite (Fig. 16.103). The lingual overjet prevents tongue biting, the buccal overjet (from the mandibular tooth) prevents cheek biting, the implant is axial loaded by the lingual cusp of the mandible, and hygiene is improved.

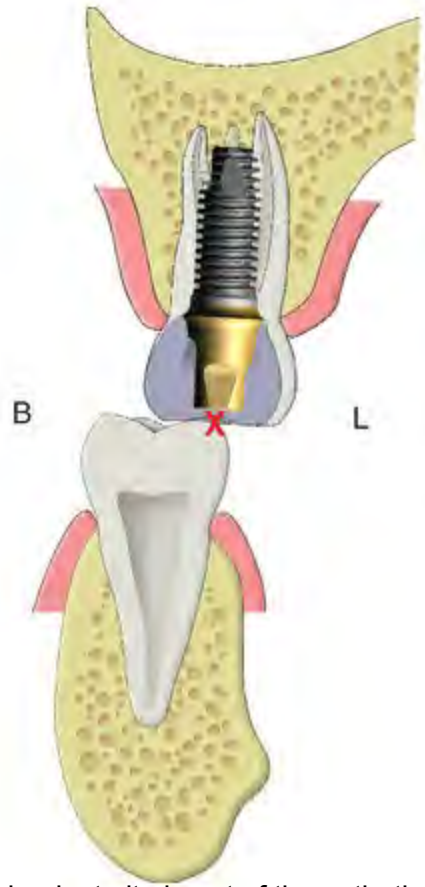

FIG 16.103 When the implant site is out of the esthetic zone and the implant is positioned more lingual, a crossbite may be designed in the implant crown. *B,* buccal; *L,* lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Summary.

Restorations mimicking the crown contour and occlusal anatomy of natural teeth often result in offset loads (increased stress and risk of associated complications), complicated home care, and an increased risk of porcelain fracture. As a result, in nonesthetic regions of the mouth, the occlusal table should be reduced in width compared with natural teeth.

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Increased Posterior Cusp Angle

The angle of force to the implant body may be influenced by the cusp inclination of the implant crown in similar fashion as an angled load to an implant body. The posterior natural dentition often has steep cuspal inclines, and 30-degree cusp angles have been designed in denture teeth and natural tooth prosthetic crowns to fulfill the same contours (Fig. 16.104).

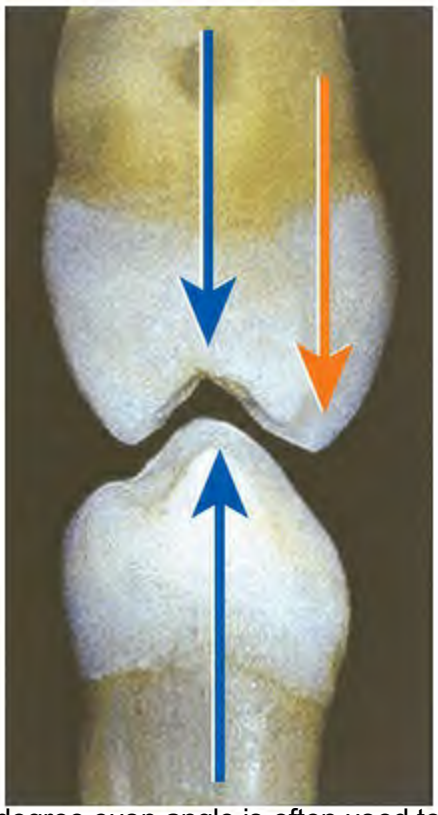

FIG 16.104 A 30-degree cusp angle is often used to restore an implant crown. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Etiology

The greater cusp angles are often considered more esthetic and may even incise food more easily and efficiently. However, to negate the negative effect of an angle cusp contact, the opposing teeth need to occlude at the same time in two or more exact positions on the ipsilateral cusp angles of the crowns (Fig. 16.105). This is usually not possible in a clinical setting with a dynamic dentition.

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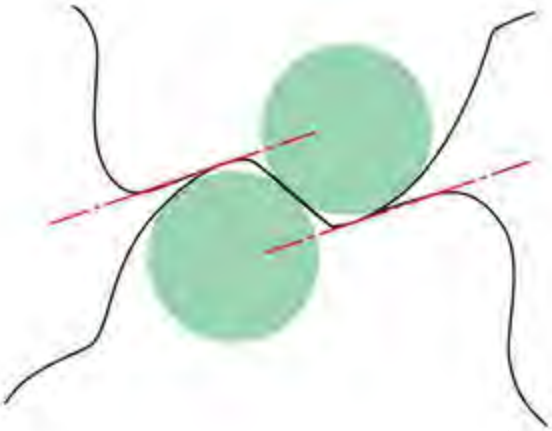

FIG 16.105 To negate an angled load to the implant body from a crown with cusp angles, two or more simultaneous contacts are necessary. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The occlusal contact along only one of the angled cusps results in an angled load to the implant system even when it is not premature to other occlusal contacts (Fig. 16.106). The magnitude of the force is minimized when the angled occlusal contact is not a premature contact but instead is a uniform load over several teeth or implants. However, the angled cusp load does increase the resultant tensile and shear stress with no observable benefit. No advantage is gained, but the biomechanical risk is increased (e.g., increased abutment screw loosening, porcelain fracture, and unretained restoration).

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FIG 16.106 An occlusal contact on an angled cusp results in an angled load to the implant system. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prevention/Treatment

The occlusal contact over an implant crown should ideally be on a flat surface perpendicular to the implant body. This occlusal contact position usually is accomplished by increasing the width of the central fossa to 2 to 3 mm in posterior implant crowns, which is positioned over the middle of the implant abutment. The opposing cusp is recontoured to occlude the central fossa of the implant crown directly over the implant body (Fig. 16.107). The laboratory technician should identify the middle of the implant body and then make a central fossa 2 to 3 mm wide over this position parallel to the curve of Wilson and Spee (Fig. 16.108). The buccal and lingual contours of the crown may then be established (reduced on the buccal for the posterior mandible and the lingual for the posterior maxilla). The opposing tooth may require recontouring of an opposing cusp to help direct the occlusal force along the long axis of the implant body.

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FIG 16.107 A posterior crown usually has a widened central fossa positioned over the implant abutment. This directs the occlusal load along the long axis of the implant body. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

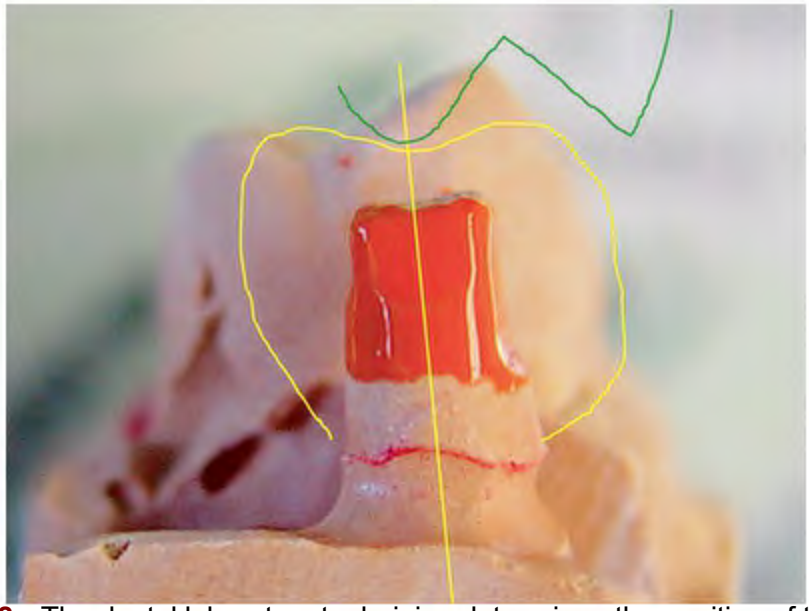

FIG 16.108 The dental laboratory technician determines the position of the implant related to occlusal load on the implant crown. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Poor Emergence Profile

Etiology

The “emergence profile” concept was first introduced in 1977 by Stein et al to describe tooth and crown contours from the soft tissue to the contact area interproximally.[113] When a restoration is fabricated with an unnatural contour, esthetics and soft tissue health will be compromised. The successful restoration of lost teeth in the anterior region of the mouth has to meet both aesthetic and functional parameters. In addition to the correct placement of the implant fixture, it is essential to achieve a soft tissue morphology as physiologically realistic as possible.

Prevention

Ideal Implant Placement.

The most important factor in obtaining an ideal emergence profile is the correct and ideal placement of the implant. Implants should be placed approximately 2.0 mm from a natural tooth, 3.0 mm between implants, and in the ideal buccal and lingual orientation with respect to the incisal edge and occlusal table.

Implant Size.

An implant with too small of a diameter will lead to a nonideal emergence profile. The larger the implant diameter, the more closely the emergence profile resembles the natural tooth, especially in the posterior region of the jaws. Most natural roots are greater than 4 mm in cross section. The closer the implant diameter to the root diameter (2 mm below the cementoenamel junction [CEJ], where the ideal crestal bone level resides), the more similar the crown emergence profile to a natural tooth. This is especially noted in the maxillary first molar region because the root diameter approaches 8 mm, or twice the size of a 4-mm implant. The wider crown contour also decreases the interproximal space of the crown and decreases the incidence of food impaction during function. The wide-diameter implant may also improve sulcular daily oral hygiene by improving the crown emergence, avoiding the need for a prosthetic ridge lap of the crown. The improved contour also allows access to the sulcus for periodontal probing depths (Fig. 16.109).

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FIG 16.109 The diameter of a tooth is often larger than an implant to replace it. As such, the larger the implant, the more the emergence profile at the cervical region resembles a tooth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Abutments.

Most healing abutments and stock abutments have a cylindrical shape that does not reproduce correctly the emerging profile of the natural teeth. The final tissue heights of the papillae and gingival margins are ultimately dictated by the posthealing levels, type of abutment, and position of the interproximal and facial bone. Special emergence profile abutments are often advocated by the manufacturers; however, this is usually not necessary because the emergence profile can be developed with the restoration on a stock abutment.

Modification of Soft Tissue.

The easiest technique to achieve the emergence profile is to sculpture the peri-implant mucosa with the use of a provisional prosthesis. This is most successful with a thick biotype tissue because it may be easily manipulated. With a thin biotype, there is a high risk of soft tissue collapse and gingival recession.

Laboratory.

The emergence profile can sometimes be improperly fabricated based on a

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final cast with nonideal soft tissue foundation. The dental technician should model an implant-supported prosthesis with an ideal emergence profile (Fig. 16.110).

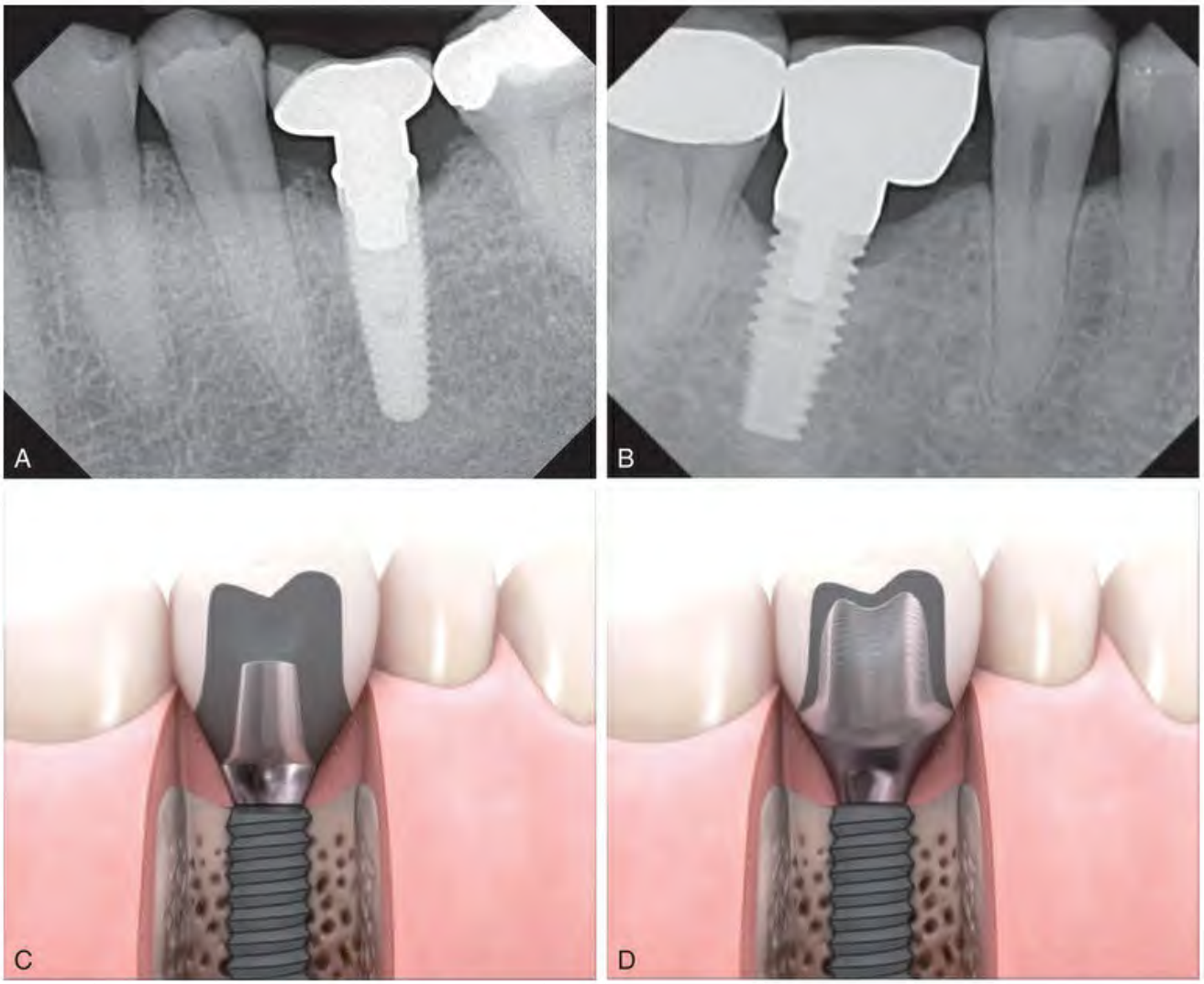

FIG 16.110 (A–B) Poor emergence profile. (C) Emergence profile is easily obtained via the prosthesis, (D) not necessarily a flared prefabricated abutment.

Because of its characteristics, the peri-implant mucosa can be modified by a sculpting process based on the principle that soft tissue becomes modifiable after controlled, constant compression. Especially in patients with a thick gingival biotype, this tissue can be manipulated to reproduce the normal scalloped, parabolic gingival contours. Different approaches have been suggested by the current literature on the soft tissue profiling.

An emergence profile that mimics the natural tooth should be obtained by successful intraoral soft tissue modifications. Prefabricated provisional

crowns cannot mimic the complexity and the variations of the soft tissue that occurs during the healing process. Usually, a chairside modification of the provisional restoration can accomplish the optimal result. Moreover, it is advantageous if the provisional restoration screw is retained to prevent irritating side effects of provisional cement on the peri-implant soft tissues, especially in situations where frequent removals of the provisional restoration are required. However, in some instances, the screw access hole will be facially oriented which may compromise the esthetics.

In highly demanding areas, specially where the esthetic outcome is a priority, the soft tissue should be modified to obtain an optimal emergence profile and gingival contours with physiologic appearance as realistic as possible. The previously described method allows for most accurate duplication of the conditioned soft tissue when the final impression is taken; thus their reproduction on the definitive restoration is possible.

Parafunction: No Occlusal Guard

Etiology

When an implant reconstruction is considered in a bruxing patient, a patient with significant occlusal force, or an irregular plane of occlusion, occlusal analysis is warranted. Premature and posterior contacts during mandibular excursions increase stress conditions.

Prevention

An elimination of eccentric contacts in a patient with myofascial pain dysfunction may allow recovery of periodontal ligament health and muscle activity within 1 to 4 weeks. Occlusal harmony does not necessarily eliminate bruxism; however, it will usually decrease the occurrence and magnitude of parafunction.

Forces from moderate to severe parafunction are the most difficult to address on a long-term basis. Education and informed consent of the patient are helpful to gain cooperation in eliminating or reducing the noxious effects. If the opposing arch is a soft tissue–supported removable prosthesis, the effects of the nocturnal habit may be minimized if the patient removes the prosthesis at night. The use of a night guard is helpful for a patient with a fixed prosthesis in order to transfer the weakest link of the system to the removable acrylic device. Centric contacts in centric relation occlusion and anterior-guided disocclusion of the posterior teeth in excursions are strongly

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suggested.

Treatment

An occlusal guard can be a useful diagnostic tool to evaluate the influence of occlusal disharmony and parafunction. A flat plane, hard-processed night guard exhibits even occlusal contacts circumferentially in centric relation occlusion and provides posterior disocclusion with anterior guidance in all excursions of the mandible.[114] This device may be fabricated with 0.5- to 1-mm colored acrylic resin on the occlusal surface. After 4 weeks of nocturnal wear, the muscles and periodontal ligament are restored. If the patient wears this device for an additional month or more, the influence of occlusion on the bruxism may be directly observed because there are no premature contacts while the device is worn. If the colored acrylic is still intact, the nocturnal parafunction has been reduced or eliminated. Occlusal reconstruction or modification may proceed. If the colored acrylic on the night guard is ground through, an occlusal adjustment will have little influence on decreasing this parafunctional habit. The night guard is still indicated to relieve stresses during nocturnal parafunction, but the prosthetic reconstruction treatment plan should account for the greater forces (Fig. 16.111).

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FIG 16.111 (A–B) Parafunction treatment includes the use of a hard, processed night guard.

Not Utilizing Progressive Bone Loading

Poor bone density may compromise implant success even when key implant position and number are satisfactory. In addition, crestal bone loss may be reduced with progressive loading.

Etiology

As a general rule, the higher the risk factors, the more progressive the recommended loading. The principles of gradual loading are demonstrated best in a cement-retained prosthesis. A longer healing time between stage I and stage II is suggested when forces are greater or bone is softer. This time allows greater mineralization of bone and a more mature lamellar bone interface to form next to the implants before the load of the screws is applied

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to the implant bodies.

Prevention

The concept of progressive loading is to allow the bone to adapt to increasing amounts of biomechanical stress. Rather than immediately loading the bone-implant interface, methods to slowly increase the stress over time are a benefit. The progressive loading protocol uses a cement-retained prosthesis when implants are splinted together. Because a screw-retained splinted restoration is not completely passive and a torque force applied to a screw is greater than a bite force, a traditional screw-retained restoration cannot use progressive loading to gradually load the bone.

The progressive loading protocol has six different methods to gradually load the bone or to increase the bone density around the implant (Box 16.6). These elements help give the implant clinician the ability to evaluate the gradual loading progress (Table 16.6).

Box 16.6

Elements of Progressive Loading

Time interval

Diet

Occlusal material

Occlusal contacts

Prosthesis design

Bone Density

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TABLE 16.6

Treatment Times for Progressive Bone Loading for Cement-Retained Prostheses

Bone Density	Initial Healing (months)	Interval Between Appointments (weeks)	Reconstruction (weeks)	Total Time (months)
D1	3	1	3	4
D2	4	2	6	5.5
D3	5	3	9	7
D4	6	4	12	9

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

Time: Initial Healing.

The histologic type of bone in contact with the implant varies and can affect the amount of stress the bone can sustain within physiologic limits. The ideal bone for implant prosthetic support is lamellar bone. Lamellar bone is highly organized but takes about 1 year to mineralize completely after the trauma induced by implant placement.[115] Woven bone is the fastest and first type of bone to form around the implant interface; however, it is mineralized only partly and demonstrates an unorganized structure less able to withstand full-scale stresses. At 16 weeks, the surrounding bone is only 70% mineralized and still exhibits woven bone as a component. Computer-aided radiographic densitometry studies have confirmed that the bone-implant interface decreases the first several months after surgical insertion of an implant.[116] The percentage of bone mineralization and the type of supporting bone influence whether a load to the bone-implant interface is within its physiologic limits.

It has been reported that the bone-implant contact (BIC) is related to the bone density and the healing time. For example, in a study by Carr et al the BIC was greater in the mandible than the maxilla (the mandible is usually more dense).[117] In addition, the BIC was greater at 6 months compared with 3 months in both jaws. An increase in BIC occurred in both the maxilla and mandible between 3 and 6 months and ranged from a 7% to 9%.[90] The healing time before implant loading may be related to the density of bone because the strength of bone increases and the BIC increases with a longer time period. Hence, 3 to 4 months of healing for D1 and D2 bone and 5 to 6 months for D3 and D4 bone have less risk than a shorter time period for all bone types. The time period between surgical placement and full occlusal loading is variable, depending on the bone density.

The macroscopic coarse trabecular bone heals about 50% faster than dense

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cortical bone. Although it heals more slowly, D1 bone has the greatest strength and greater lamellar bone contact. The suggested healing time between the initial and second-stage surgeries is kept similar for D1 and D2 bone and is 3 to 4 months. A longer time is suggested for the initial healing phase of D3 and D4 bone (5 and 6 months, respectively) because of the lesser bone contact and decreased amount of cortical bone to allow for the maturation of the interface and the development of some lamellar bone. In very immature bone, the healing time may be as long as 8 months.

The D4 implant-bone interface typically found in posterior regions of the maxilla exhibits minimum initial bone contact, with little to no cortical bone at the crest or apex. An implant surgery initially may trigger an increase in the amount of bone in the region. The initial increase of bone cell activity most likely results from the surgical trauma and the regional acceleratory phenomenon.[74] A longer initial healing time is most beneficial to the poorest bone density types.

In softer bone, a longer period of time of initial healing and gradual loading is suggested. As a general rule, D1 bone uses a 3-month (or more) period before loading, D2 bone a 4-month (or more) period, D3 bone a 5-month (or more) initial healing period, and D4 bone uses a 6-month (or more) period.

The combined observations of the macroscopic amount of bone in contact with a nonloaded implant and the microscopic type of bone at the stage II surgery of the implant demonstrates a wide difference in D1 to D4 bone densities. However, the major improvement in bone density and strength long term occurs as a consequence of loading the implant.

Four prosthodontic steps are suggested for the reconstruction of a partially or completely edentulous patient, with endosteal implants supporting a cemented prosthesis. Each of the four major prosthodontic appointments also are separated by a period of time related to the bone density observed at the initial time of surgery. In addition, the dentist attempts to gradually increase the load to the implant at each prosthetic step.

The four prosthetic steps are: (1) abutment insertion, preparation, final impression and temporary (of the esthetic zone); (2) a metal try-in and new bite registration; (3) initial delivery of the prosthesis; and (4) final evaluation of the restoration and hygiene appointment.

In simple restorative cases, the prosthetic appointments may be reduced to three appointments: (1) abutment selection, preparation, final impression, opposing impression, and closed-mouth bite registration; (2) initial delivery

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of the restoration; and (3) final evaluation stage (accompanied by a hygiene appointment).

Type D1 bone benefits from the greatest amount of lamellar bone contact at the beginning of the restoration process. As a result, gradual loading of the implant interface through spacing of the prosthodontic appointments is least important, and the restorative appointments can be separated by as little as 1 week. Type D2 bone responds favorably to physiologic loads. The four prosthetic appointments during which the implant body is loaded sequentially are separated by 2 weeks or more. As a result, the initial 4 months of healing after surgery and 2 months for prosthesis fabrication make the overall treatment time 5.5 months.

The prosthodontic appointments for D3 bone are separated by at least 3 weeks, and overall treatment takes about 7 months to complete, including the 5 months of initial healing. During this time the bone contact percentage can increase, and the fine woven bone trabeculae can mature into coarser lamellar trabeculae, with an increase in mineral content. The progressive loading process is more critical for D3 bone than for D2 or D1 bone because of its weakness and less initial bone contact.

In D4 bone the progressive bone loading protocol is most critical. The scheduling of restorative appointments err on the side of safety, separated by at least 4 weeks. As a consequence, the overall treatment time for D4 bone is twice that of D1 or D2 bone and requires at least 9 months (including 6 months of initial healing). This schedule allows sufficient time for mature lamellar, mineralized bone to develop at the interface and increases the numbers of trabeculae in direct contact and within the network region of the implant (see Table 16.5).

When the dentist uses multiple implants, the weakest bone area determines the gradual load protocol. If the anterior maxilla and posterior maxilla are restored together, the posterior maxilla would determine the initial healing period and the time period between each prosthetic appointment.

Diet.

The implant clinician controls the diet of the patient to prevent overloading during the early phases of the restorative process. During the initial healing phase, the clinician instructs the patient to avoid chewing in the area, especially when the implants are placed in a one-stage approach with an exposed healing abutment. After being uncovered, the implant connected to

an abutment for cement retention is at greater risk of loading during mastication. The patient is limited to a soft diet such as pasta and fish from the final impression stage until the initial delivery of the final prosthesis. The masticatory force for this type of food is about 10 psi. This diet not only minimizes the masticatory force on the implants but also decreases the risk of temporary restoration fracture or a partially uncemented restoration. Either of these consequences can overload an implant and cause unwanted complications.

The diet should not be overlooked during the restorative phase of treatment. Most dentists have observed the fracture of an acrylic prosthesis with harder foods and greater occurrence of uncemented restorations when they ignore the type of diet during the transitional prosthesis stages.

After the initial delivery of the final prosthesis, the patient may include meat in the diet, which requires about 21 psi in bite force. The final restoration can bear the greater force without risk of fracture or uncementation. After the final evaluation appointment, the patient may include raw vegetables, which require an average 27 psi of force. A normal diet is permitted only after evaluation of the final prosthesis function, occlusion, and proper cementation.

It should be noted that the most damaging forces to a transitional (or final) restoration is parafunction, not the function of eating. After the prosthesis is placed into occlusion, the evaluation of parafunction and methods to reduce its negative side effects are critical to the loading process.

Occlusal Material.

The occlusal material may be varied to gradually load the bone-implant interface. During the initial steps, the implant has no occlusal contact and in essence has no material over it. At subsequent appointments, the clinician may use acrylic as the occlusal material, with the benefit of a lower impact force than metal or porcelain. Either metal or porcelain can be used as the final occlusal material.

If parafunction or cantilever length causes concern relative to the amount of force on the early implant-bone interface, the dentist may extend the softer diet and acrylic restoration phase several months. In this way, the bone has a longer time to mineralize and organize to accommodate the higher forces.

Occlusion.

The clinician gradually intensifies the occlusal contacts during prosthesis

fabrication. No occlusal contacts are permitted during initial healing (step 1). The first transitional prosthesis is left out of occlusion in partially edentulous patients (step 2). The occlusal contacts then are similar to those of the final restoration for areas supported by implants. However, no occlusal contacts are made on cantilevers or offset loads (step 3). The occlusal contacts of the final restoration follow the implant-protective occlusion concepts.

Prosthesis Design.

There are four potential prosthesis designs in a restorative process. During initial healing, the clinician attempts to avoid any load on the implants, including soft tissue loads. In a completely edentulous patient, relief and a soft tissue conditioner (also relieved) may be used. The first transitional acrylic restoration in partially edentulous patients has no occlusal contact and no cantilevers. Its purpose is to splint the implants together and reduce stress by the mechanical advantage and to have implants sustain masticatory forces solely from chewing. The second acrylic transitional restoration has occlusal contacts placed over the implants with occlusal tables similar to the final restoration but with no cantilevers in nonesthetic regions. The final restoration has narrow occlusal tables and cantilevers designed with occlusal contacts following implant-protective occlusion guidelines.

Progressive Loading Phases.

After the surgical stage II uncovery procedure or one-stage implant healing, the implant clinician evaluates clinical mobility, bone loss (horizontal and vertical), proper placement in reference to prosthetic design and angulation to load, zones of attached gingiva, and gingival thickness. The surgeon usually attaches a low-profile permucosal extension (PME) to the implant body at the end of this appointment. This component extends through the tissue about 2 mm and is protected from early loading.

In selected cases, often when the implant surgeon and restoring dentist are the same person, one may obtain the preliminary impression during this appointment if the soft tissues are outside the esthetic areas and if no bone recontouring or grafting has been performed or a one-stage surgical approach was used during initial healing. The dentist instructs the patient with a posterior implant in a partially edentulous arch not to wear any removable restoration. If anterior teeth are part of the removable prosthesis, a 7-mm-diameter hole is placed completely through the partial denture framework around each PME so it will not load the implant. In completely

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edentulous patients, the tissue surface of the denture is relieved at least 5 mm over and around the implants and is replaced by a tissue conditioner. The conditioner also is relieved a few millimeters. The patient returns in 2 weeks for suture removal and to replace the tissue conditioner with a soft liner.

The procedures for a partially edentulous Kennedy class I or II patient are first presented. The progressive bone-loading appointment sequence for cement-retained prostheses is as follows (Table 16.7).

1. Initial abutment selection, final impression, and transitional prosthesis I

2. Metal superstructure try-in and transitional prosthesis II

3. Initial insertion of final prosthesis

4. Final evaluation and hygiene

TABLE 16.7

Progressive Loading Appointments for a Cement-Retained Prosthesis

Step	Procedure	Diet	Occlusal Material	Occlusal Contracts
1	Final abutments Final impression Transitional prosthesis	Soft	Acrylic	1; none 2; no cantilever
2	Transitional prosthesis II Metal try-in	Soft	Acrylic	1 and 2; contacts only on implant; no contacts on cantilevers or pontics; occlusal table same as final prosthesis
3	Final prosthesis Adjust occlusion	Harder	Metal or porcelain	Occlusion follows implant-protective occlusion guidelines; narrow occlusal table
4	Final evaluation Hygiene	Normal	Metal or porcelain	Same as above

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

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Postoperative Complications

Food Impaction

Etiology

Food impaction after placement of a fixed implant restoration can be a significant complication that is troublesome to the patient and the soft tissues. There are many reasons for the prosthesis to accumulate food.

Improper Implant Placement.

When implant placement is nonideal, a compromised prosthesis must be fabricated. This leads to improper contours that compromise esthetics and the soft tissue health.

Inadequate Contact Area.

If inadequate contact exists, food accumulation will result. This most often occurs when the restoration is fabricated with angled or tilted adjacent teeth, which prevent a long contact area.

Prevention

Improper Implant Placement.

Implant placement should be ideal, if conditions (lack of bone) do not allow this, hard and soft tissue augmentation should be completed to provide a more ideal condition for implant placement.

Inadequate Contact Area.

When angled or tilted adjacent teeth are present, prior to the fabrication of the prosthesis, guide planes should be made to allow for a long contact area in the prosthesis. This also allows for the greater force distribution, which is advantageous, especially in high stress areas (Fig. 16.112).

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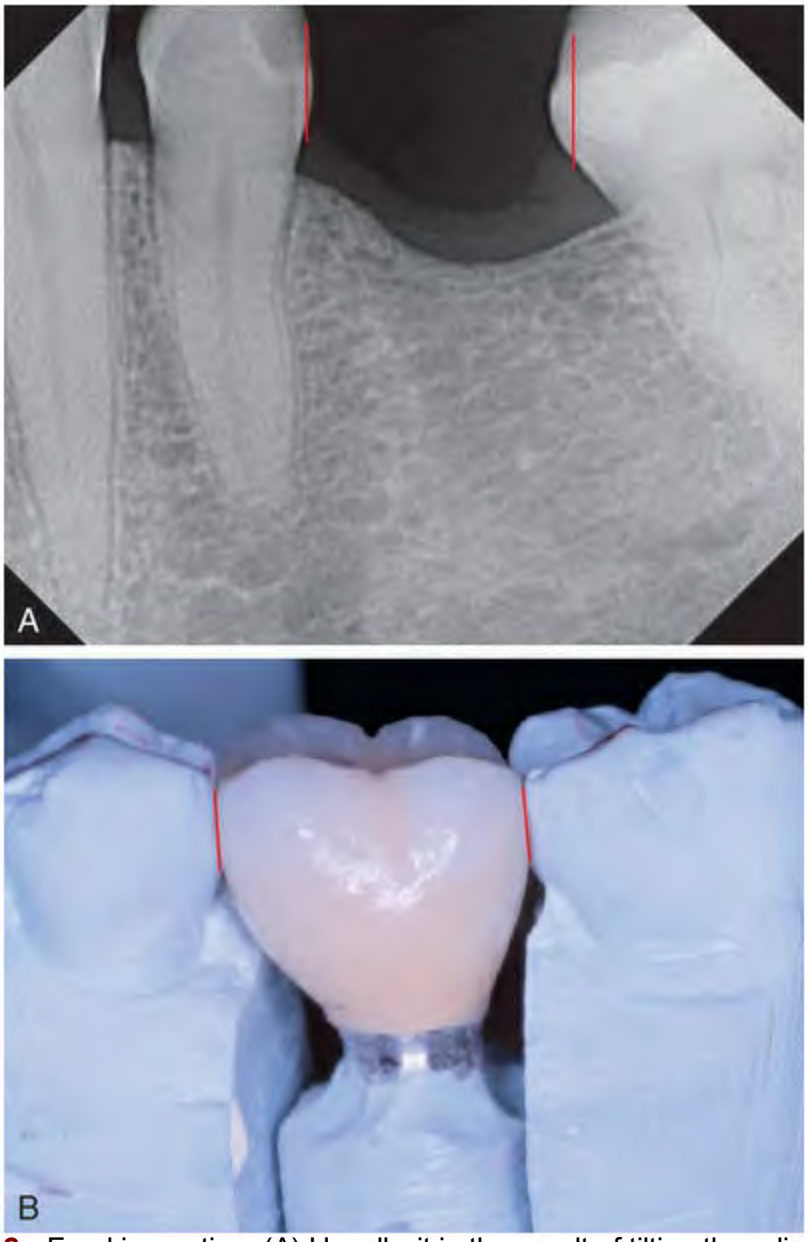

FIG 16.112 Food impaction. (A) Usually, it is the result of tilting the adjacent teeth leading to a point contact. (B) By modifying the adjacent teeth, long contact areas may be utilized to prevent food impaction and help distribute forces.

Treatment

If food impaction occurs on a chronic basis, the prosthesis should be modified or refabricated, especially if soft tissue complications arise.

Cement Retention

Cemented implant prostheses have become popular because of the lower cost, relative simplicity, more passive fit, improved esthetics, and similarity to

traditional prosthetics. However, with all of these advantages comes a significant disadvantage, the retention of postoperative cement. The retained cement has been shown to retain bacteria (similar to calculus with a natural tooth), which leads to peri-implant disease (Fig. 16.113).

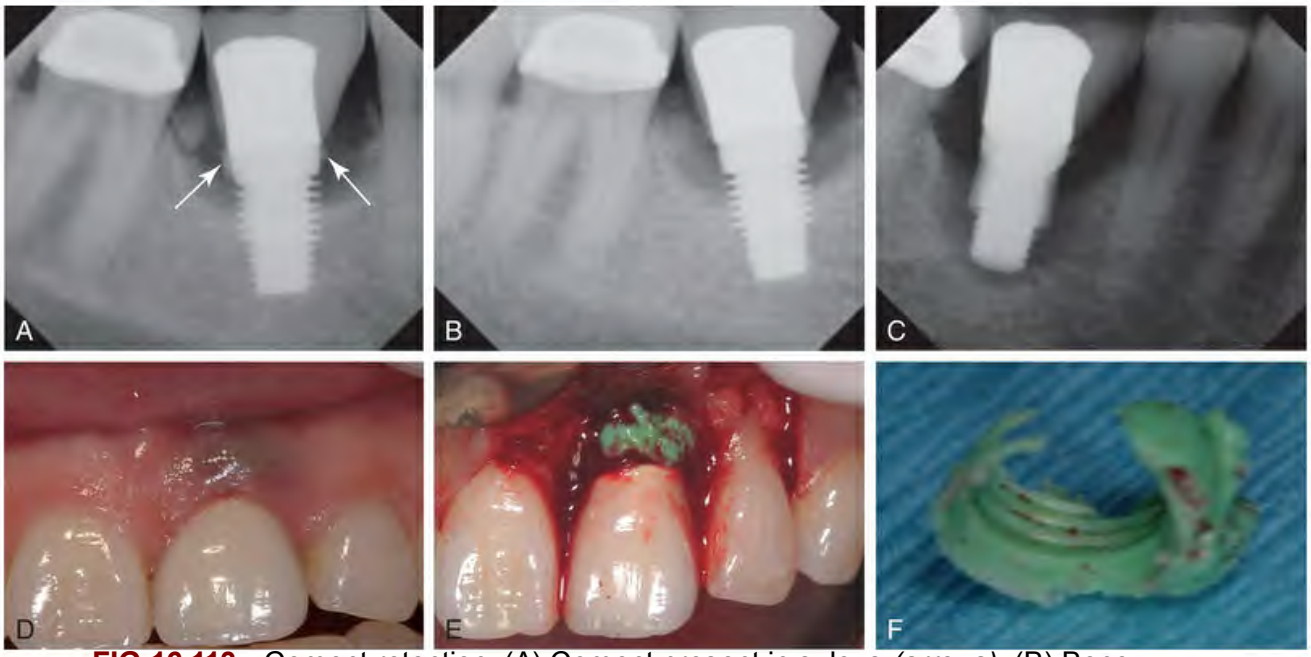

FIG 16.113 Cement retention. (A) Cement present in sulcus *(arrows)*. (B) Bone loss. (C) Failure of implant. (D) Dark hue present 6 months post implant crown insertion, (E–F) Etiologic complication resulting from sulcular retention of impression.

Etiology

The etiology of cement-retained peri-implantitis is the following:

Cement.

The retained cement acts as a nidus for bacterial accumulation and proliferation. The roughened surface of the cement inhibits the hygienic removal of the bacteria, which leads to peri-implant disease. Cement acts the same way that as the etiologic factor in periodontal disease.

Timing.

Wilson has shown that the time it takes for retained cement to become problematic and to eventually be diagnosed is in a range of 4 months to 9.3

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years, with an average of 3 years.[118]

Sulcus Teeth vs. Implant.

Around natural teeth the junctional epithelium and connective tissue attachment insert perpendicularly into the cementum, which tends to prevent the flow of excess cement into the sulcus. In contrast, the connective tissue around dental implants runs parallel, with no attachment into the implant surface. The flow of cement is not restricted, and it easily migrates apically (Fig. 16.114).

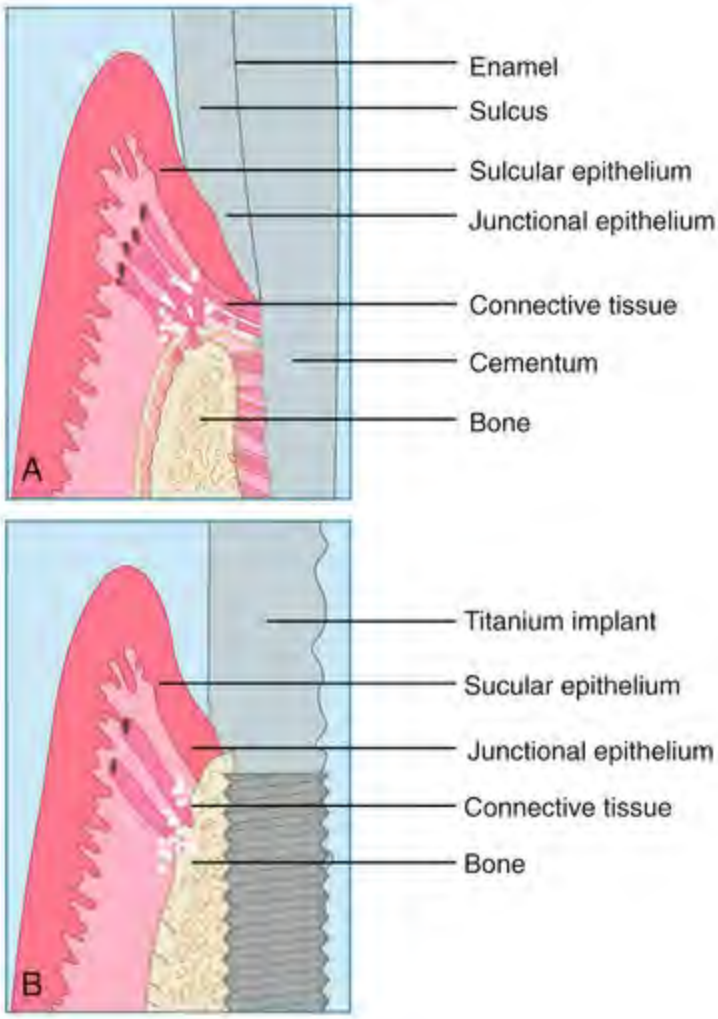

FIG 16.114 Different attachment systems for implant vs. tooth. (A) Circular fibers attach into the cementum minimizing the possibility of cement retention, (B) Because an endosseous implant does not contain an attachment system with the tissue, retained cement can be easily extruded into the sulcular area. (Adapted from LeBeau J: Maintaining the long-term health of the dental implant and the implant-borne restoration, *Compend Contin Educ Oral Hyg* 3[3]:3–10, 1997.)

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Submucosal Margins.

Margins of implant restorations are often placed more than 2 mm subgingivally for a better emergence profile and esthetics. However, studies have shown the deeper the margins, the more difficult the removal of cement. In margins that are greater than 1.5 mm subgingivally, it is almost impossible to remove the cement totally.[119]

Location.

Retained cement may attach to the following: (1) crown, (2) abutment, and (3) bone. If the cement is pushed into the sulcular area and reaches the bone, significant chronic issues will arise (Fig. 16.115).

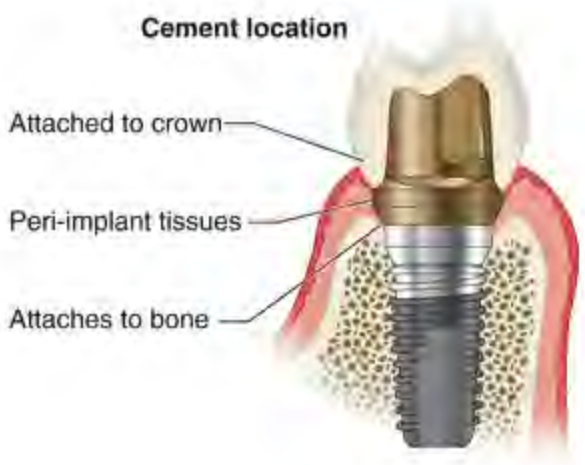

FIG 16.115 Residual cement retention; can attach to crown, tissues, or bone.

Radiographic Evaluation.

Many clinicians believe that two-dimensional radiographs will depict retained cement. However, radiographs are unpredictable because only cement that is present on the mesial or distal surfaces will be shown. Additionally, many cements are not radiopaque and need an adequate thickness to be seen on a radiograph.[120] Linkevicius et al have shown in a clinical study that dental radiographs should not be considered as a reliable method for cement excess evaluation because results show that cement remnants are seen less than 10% of the time mesially and distally and 0% of the time buccally and lingually (Fig. 16.116).[121]

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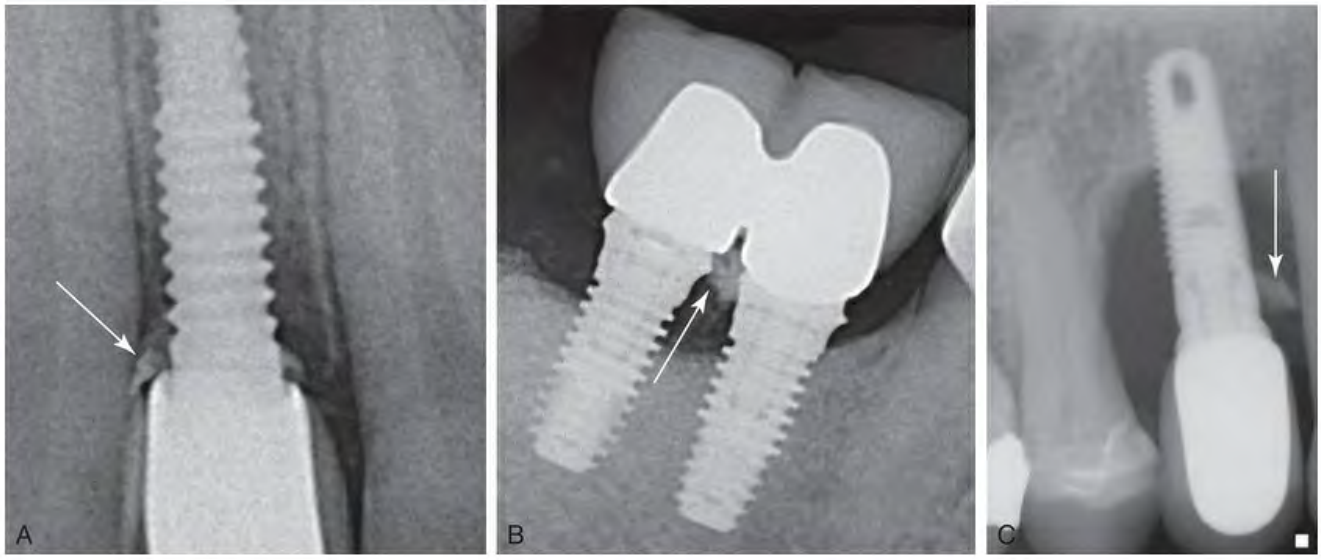

FIG 16.116 (A–C) Radiographic evaluation of cement retention; can only be seen on mesial and distal.

Type of Cement.

There are many types of cement used today in implant dentistry to retain implant-supported crowns. Agar et al have shown that cement with resin components is the most difficult to remove from the abutment surface after cementation.[122] Cements containing zinc have been shown to be ideal for cementing implant crowns as they are the easiest to see radiographically. Zinc phosphate is a well-known popular cement choice, which makes retrievability very difficult. Additionally, because of its solubility in the oral environment, a dry field is definitely needed.

Provisional cements are also popular in cementing implant crowns as they allow for retrieval. However, because provisional cements exhibit weaker retentive strengths, uncementation of the implant prosthesis may be problematic.

Radiopacity of Cement.

There is a large variation in the radiographic detection ability of cements. Some cements have a very high radiographic density, which allows for detection on radiographs. However, many cannot be detected, even at greater thickness (≈2 mm).

Cementation Technique.

A common reason for retained cement is the cervical cementation technique,

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which usually parallels the technique for cementation on natural teeth. Most clinicians place an excessive amount of cement within the internal surface of the crown, which leads to extrusion in the sulcular area. Techniques using different amounts of cement have been evaluated with mixed results (Fig. 16.117).

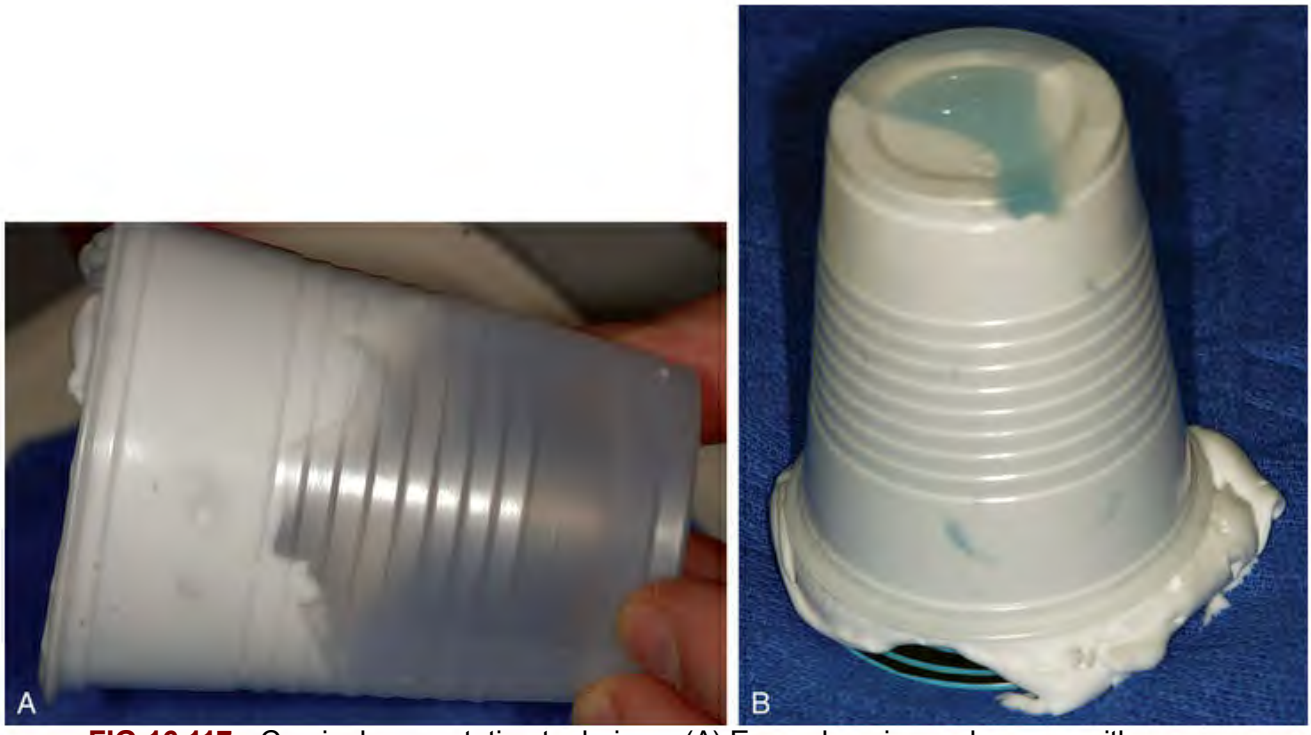

FIG 16.117 Cervical cementation technique. (A) Example using a clear cup with shaving cream placed in the cervical one-third. (B) The cement proceeds up the sides; however, excess cement still extrudes from the margins.

Prevention

Supragingival Margins.

Excess retained cement may be minimized by designing the abutment margins supragingivally. However, dentists are reluctant to place the margins at this level if the crowns are in the esthetic zone. Studies have shown margins placed 1 mm supragingival or at the gingival margins allow for ease of cement removal without a decreased chance of retention.[123]

Ideal Application of Cement.

Controlling the amount of cement that is placed in the implant crown will

allow for a decreased possibility of cement retention. Clinicians are reluctant to use a small amount of cement because this translates into the possibility of leakage and loss of retention. Excess cement may lead to improper seating, alteration of occlusion, and difficulty in cement removal. Ideally, a uniform thickness of 40 μm over the intaglio surface is ideal; however, in a clinical setting, this is very difficult. The internal surface of the crown may sometimes be irregular, and unequal flow patterns may exist between parallel and nonparallel surfaces. Additional factors that complicate ideal cementation are the cement's flow properties, viscosity, dimensional stability, and wettability of the surfaces.

Screw-Retained Prostheses.

Although screw-retained implant prostheses have the disadvantages of higher cost and compromised esthetics, the lack of cement is a significant advantage (Fig. 16.118).

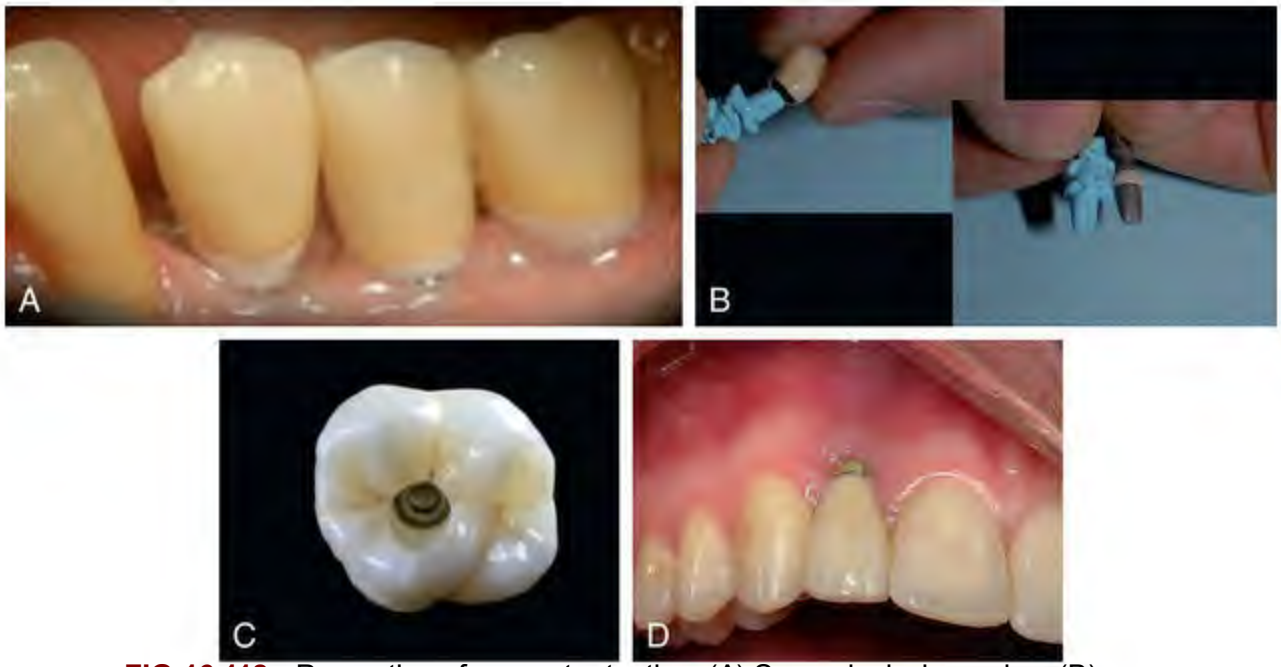

FIG 16.118 Prevention of cement retention. (A) Supragingival margins. (B) Duplicate abutment technique. (C) Screw-retained prosthesis. (D) Cement on supragingival margin.

Implant Abutment Modification.

To reduce the amount of excess cement, studies have shown that

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modification of the abutment leads to less pressure and extruded cement. Ideally, the abutment should be vented with two 0.75-mm radius vent holes placed 3 mm apical to the occlusal area of the abutment and 180 degrees apart. This technique by Wadhwani has shown to limit the amount of cement extruded into the gingival sulcus of implant-retained crowns (Fig. 16.119).[124]

FIG 16.119 To minimize excess cement, maintain an open access and two holes maybe placed 180 degrees apart in the abutment.

Techniques.

Various techniques in the literature have been discussed to reduce retained cement. A popular technique is the abutment copy technique, which utilizes Teflon tape inside the intaglio surface prior to copying the abutment with a polyvinyl siloxane (PVS) material. The cement-filled final implant crown is seated on the copied abutment for excess cement removal before it is quickly transferred intraorally to be fully seated. This technique minimizes the possibility of retained cement; however, it has limitations when cementing a multiple splinted implant prosthesis.[125]

The author has developed a technique (lubrication technique), which utilizes water-soluble petroleum jelly placed on the outer surfaces of the crown or prosthesis and below the implant margin (i.e., sulcular area). This prevents any cement from adhering to the crown, sulcus, or underlying bone (Box 16.7 and Fig. 16.120).

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Box 16.7

Reducing Chance of Cement Retention With Copy Abutment: Lubrication Technique

Step 1: Apply water-soluble petroleum jelly to the outer margin of the crown with a 1 cc tuberculin syringe.

Step 2: Seal the abutment screw (cotton ball, Teflon tape) without sealing the entire access.

Step 3: Place a thin layer of petroleum jelly 360 degrees within the sulcus and around the implant.

Step 4: Apply a thin layer (≈40 μm) of cement to the intaglio surface of the crown abutment.

Step 5: Seat crown, remove crown, remove excess cement adhered to the outer margin surface, remove any sulcular excess cement and Vaseline with a brush.

Step 6: Reseat crown.

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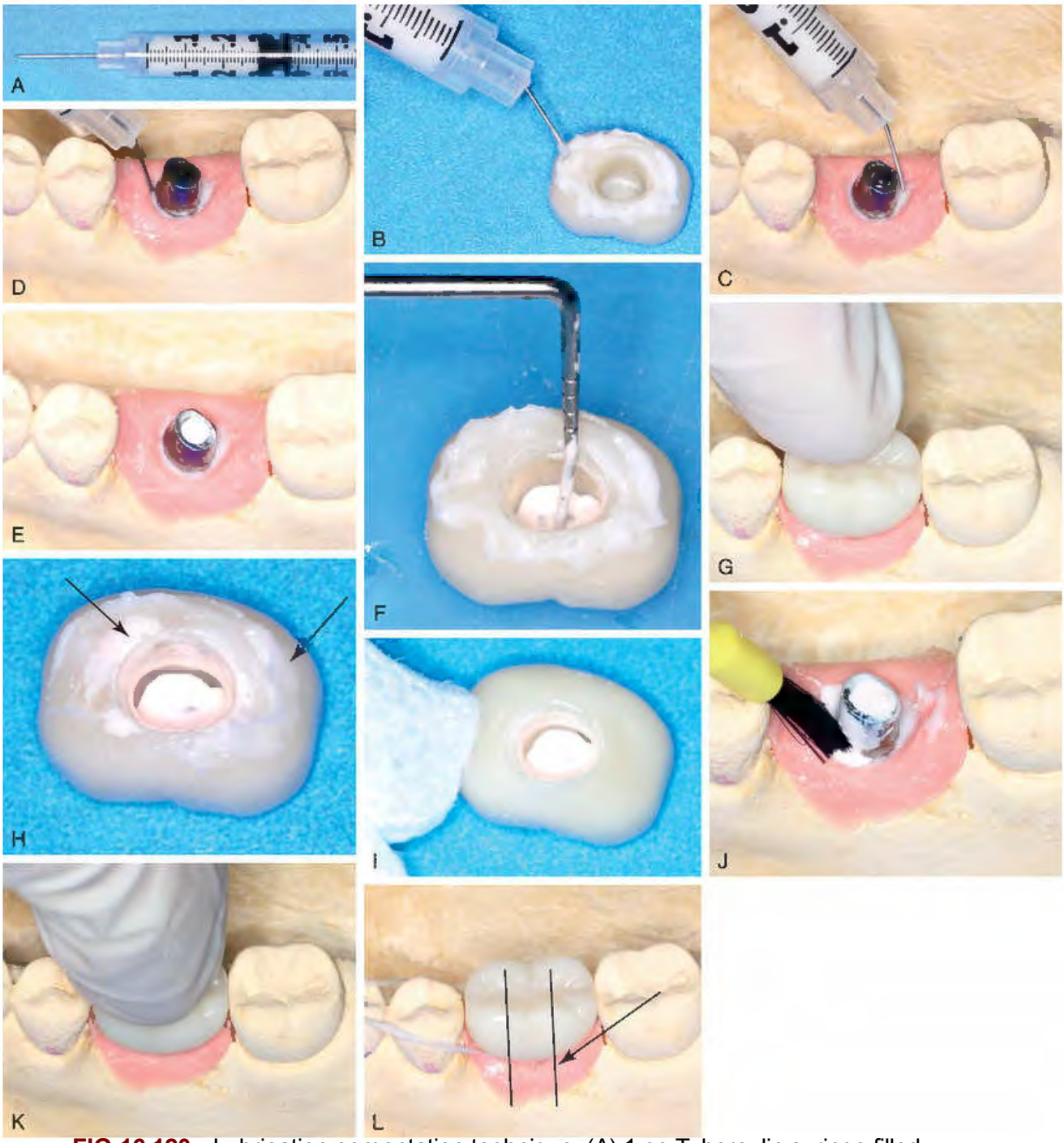

FIG 16.120 Lubrication cementation technique. (A) 1 cc Tuberculin syringe filled with water-soluble petroleum jelly. (B) Water-soluble lubricant is applied to underside of crown (to prevent cement from adhering to crown). (C–D) Water soluble lubricant is syringed in sulcus area (to prevent cement from adhering to bone or sulcular area). (E) Lubricant is placed 360 degrees around abutment. (F) Cement is placed into crown (marginal area is avoided). (G) Crown is completely seated onto abutment. (H) Crown is removed. (I) Excess cement is removed from undersurface of crown. (J) Excess cement is removed in sulcular area with brush. (K) Crown is reseated for final cementation. (L) Crown is flossed on mesial and distal to the implant neck to remove final cement.

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Treatment

Even the most diligent and skilled implant clinician may leave residual cement in the sulcular area of implant crowns. The importance of postoperative appointments for implant patients following cementation of the restoration cannot be overemphasized. Regular maintenance is extremely crucial for cement-retained crowns. Some of the symptoms that may warrant an evaluation for retained cement are localized inflammation, bleeding on probing, exudate, progressively increased probing depths, and radiographic bone loss.

Nonsurgical.

Regular curettage with hand instruments.

Surgical.

In many cases, surgical access is necessary for complete cement removal, which includes flap, curettage, and detoxification with possible grafting (Fig. 16.121).

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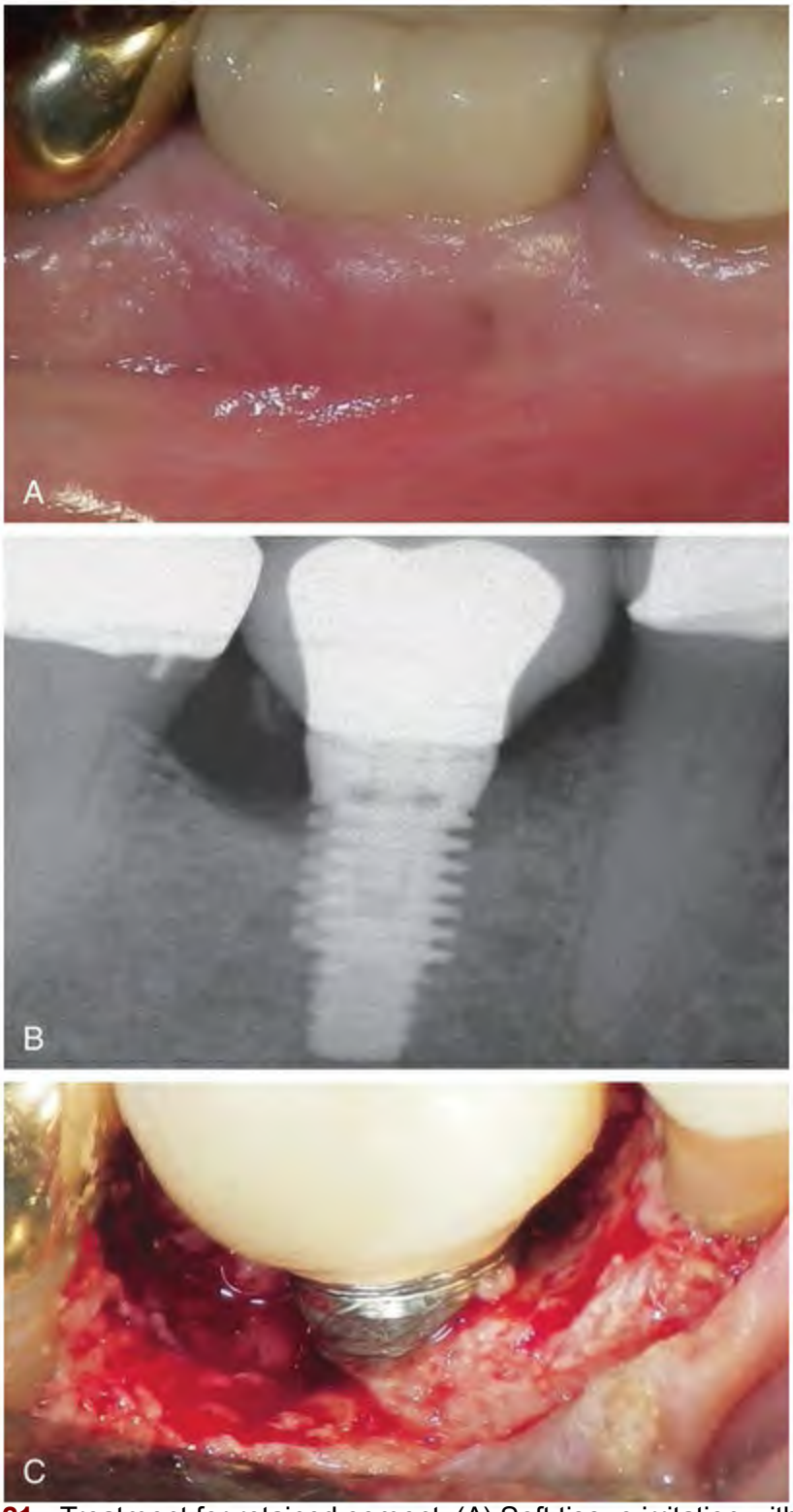

FIG 16.121 Treatment for retained cement. (A) Soft tissue irritation with chronic inflammation. (B) Radiographic confirmation of retained cement. (C) Treatment included surgical access for cement removal that included curettage, detoxification, and grafting.

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Summary

As outlined in this chapter, the principles utilized in dentistry for natural teeth do not necessarily apply to the practice of implant dentistry as it pertains to prosthetics. A dental implant exhibits different attachment mechanisms to the host bone, which changes the force dynamics presented to their respective prostheses. The intricate component mechanisms of a dental implant prosthesis react to forces placed upon them, requiring greater care and attention when designing occlusal schemes. It is paramount that the implant surgeon and restoring dentist have a clear plan in place based on sound fundamentals to ensure that the placement of the necessary implants falls in line with proper biomechanical principles. Steps may be taken to prevent unnecessary loads on the implant prosthesis, from occlusal scheme and design to the fabrication of bruxism guards for patients exhibiting parafunction.

In the prosthetic phase of treatment, possibly more than in any other phase, prevention may be the easiest to achieve. By using sound biomechanical principles, the implant dentist may prevent many of the prosthetic and implant complications that can occur over the life span of a restoration.

Should complications arise, such as screw loosening, porcelain fracture, or retained cement, this chapter has provided protocols to safely and predictably manage these events.

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Occlusion Complications

Randolph R. Resnik, Carl E. Misch

The clinical success and longevity of endosteal dental implants as load-bearing abutments are controlled largely by the mechanical setting in which they function. The treatment plan is ultimately responsible for the design of the prosthesis along with the position and number of the implants. The most common complications of implant prostheses relate to biomechanical factors such as porcelain fracture, unretained prostheses (cement or screw), abutment screw loosening, early implant failure after loading, and implant component fracture.[1-4]

Studies have shown that after an implant achieves rigid fixation with proper crestal bone contour and gingival health, the mechanical stress or strain beyond the physical limits of hard tissues is a primary cause of bone loss around loaded implants.[5-8] After successful surgical and prosthetic rehabilitation with a passive prosthesis, noxious stresses and loads applied to the implant and surrounding tissues result primarily from nonideal occlusal contacts. Complications (prosthetic or bony support) reported in follow-up studies underline occlusion as a determining factor for success or failure.[9,10] However, the choice of an occlusal scheme for implant-supported prostheses is broad and often controversial. The occlusal scheme is especially important during parafunctional activity of the jaws because the magnitude and duration of the parafunctional occlusal stresses are greater than functional stress. It is also more important when the implant foundation is not ideal in number or location to the implant-bone interface, where the overall surface area of load is reduced.

Almost all implant occlusal concepts are based on the concepts developed with natural teeth and are transposed to implant support systems with little to no modification. This approach has some justification. Wearers of complete dentures are reported to exhibit mandibular movement and velocity different from patients with natural dentitions. However, Jemt et al[11] found that after fixed implant reconstructions are placed into previously edentulous patients, the displacement of the jaw during mandibular opening and function is similar in velocity and movement to that in patients with natural teeth. Gartner et al[12] also demonstrated similar habitual chewing for

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patients with implants and patients with natural teeth. During maximal occluding forces, electromyograms demonstrated that the implant patient group activated similar working and nonworking muscles as patients with a natural dentition. It appears logical to derive implant occlusion from occlusal principles for the natural dentition. However, several conditions indicate that implant prostheses are at greater biomechanical risk than natural teeth, which may lead to complications in both the prosthetic components and the overall health of the implants that support them. As a result, some of the occlusal concepts for implants should be modified from concepts for the natural dentition. With a knowledge of the fundamentals of dental implant occlusion, a clinician may significantly impact the longevity of successful implant treatment for his or her patient, while avoiding many complications.

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Differences Between Natural Teeth and Dental Implants

The differences between natural teeth and dental implants are numerous. Most importantly, a natural tooth has a support system that allows for a reduction of forces to the surrounding bone. A natural tooth is encompassed and suspended by a periodontal ligament (PDL), and force and stress are dissipated and distributed away from the axis of natural teeth (Fig. 17.1). Because an implant has no PDL, the concentration of force and stress is at the crestal region (Table 17.1).

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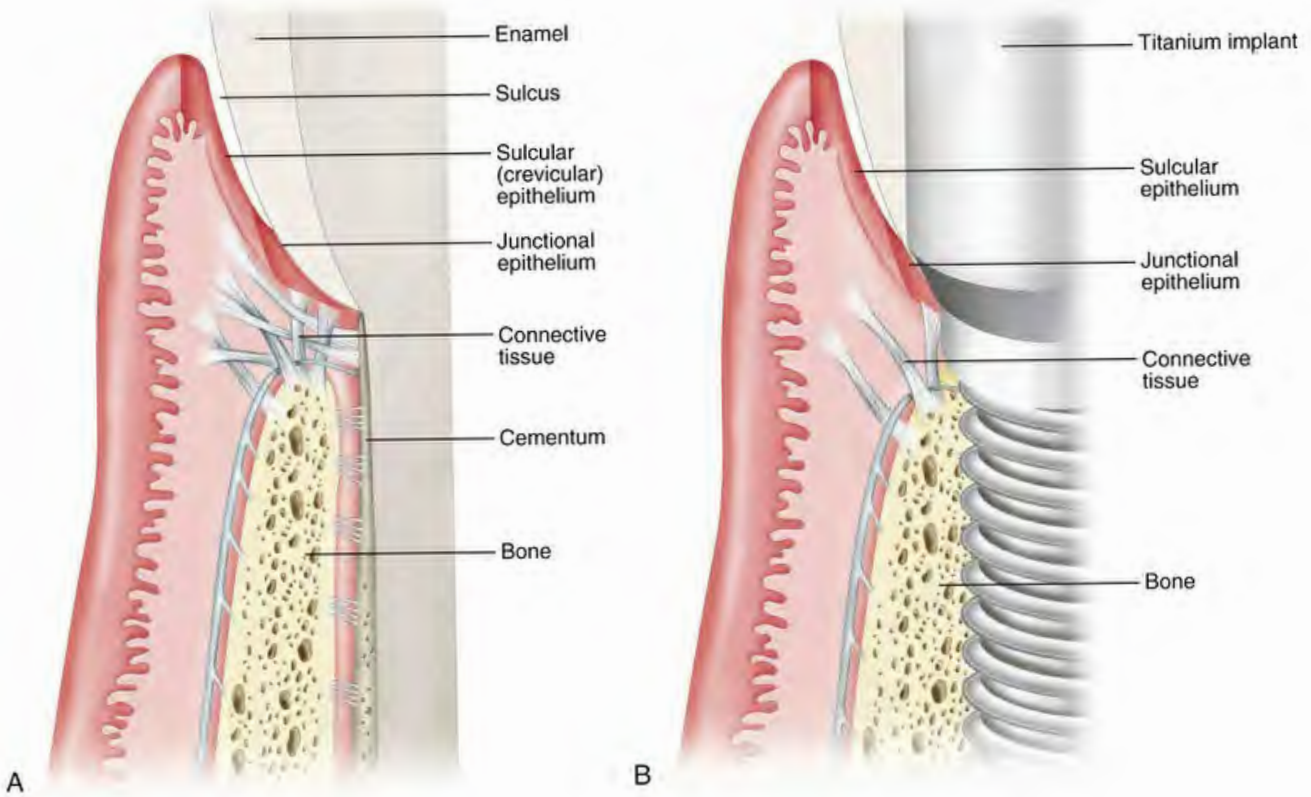

FIG 17.1 Schematic illustration of hard and soft tissue around a tooth and an implant. (A) Hard and soft tissue anatomy around a natural tooth demonstrates bone support with a periodontal ligament, a connective tissue zone above the crest of bone with connective tissue fibers (Sharpey) inserting into dentin, a long junctional epithelial attachment, a gingival sulcus lined with sulcular epithelium, and oral gingival epithelium (outer surface of gingiva). (B) Hard and soft tissue anatomy around an implant demonstrates some similarities and some distinct differences. There is supporting bone in direct approximation to the implant surface without any intervening soft tissues (i.e., no periodontal ligament). A connective tissue zone is present above the level of bone with fibers running parallel to the implant surface and no inserting fibers. There is a long junctional epithelial attachment, a gingival/mucosal sulcus lined with sulcular epithelium and oral gingival/mucosal epithelium (outer surface of soft tissue). (From Rose LF, Mealey BL: *Periodontics: medicine, surgery, and implants,* St Louis, 2004, Mosby.)

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TABLE 17.1

Occlusal Overload in Comparing Natural Teeth vs. Dental Implants

Characteristic	Natural Teeth	Dental Implants
Interface	Periodontal membrane	Direct bone
Junctional epithelium	Hemidesmosomes and basal lamina (lamina lucida and lamina densa zones)	Hemidesmosomes and basal lamina (lamina lucida and lamina densa and sublamina lucida zones)
Connective tissue	12 groups: 6 insert perpendicular to tooth surfaces; ↓ collagen, ↑ fibroblasts	Only 2 groups: parallel and circular fibers; no attachment to implant surface; ↑ collagen, ↓ fibroblasts
Vascularity	Greater; supraperiosteal and PDL	Less; mainly periosteal
Biologic width	2.04–2.91 mm	3.08 mm
Mobility	+	–
Pain	+/– (tooth may be hyperemic)	–
Attrition	+ wear facets, abfraction, fremitus	– (~ porcelain fracture, possible screw loosening)
Radiographic changes	+ increased radiopacity and thickness of cribriform plate	Crestal bone loss
Interference awareness	+ (proprioception)	– (osseoperception)
Nonvertical forces	Relatively tolerated	Results in bone loss
Force related movement	Primary: movement of PDL	Primary: osseous movement
	Secondary: osseous movement	
Lateral force	Apical $\frac{1}{3}$ of root surface	Crestal bone
Lateral movement	56–108 μm	10–50 μm
Apical movement	25–100 μm	3–5 μm
Tactile sensitivity	High	Low
Signs of overloading	PDL thickening, fremitus, mobility, wear facets, pain	Screw loosening, screw fracture, abutment fracture, implant body fracture, bone loss

PDL, Periodontal ligament.

Peripheral Feedback System

The control of the muscles of mastication is directly related to a peripheral feedback system that includes the enamel-dentin-pulp complex and mechanoreceptors in the dentate dentition. However, endosseous implants lack the periodontal proprioception feedback system, resulting in less fine motor control and alteration of the awareness of force.

Teeth

Natural teeth have a unique sense of occlusal awareness in the control of mastication, force, and control of muscles during swallowing. The role of the enamel-dentin-pulp complex has been shown in the control of oral function via the peripheral feedback system.[13] In combination with the periodontal mechanoreceptors (PMRs), afferent information is sent to the brain on the horizontal and vertical forces applied to teeth. The mechanoreceptors are

very sensitive to low forces and allow for the recognition of occlusal force and the discrimination of load magnitude and direction. The sensitivity of teeth varies with anterior teeth being most sensitive to low forces (<1 N), whereas posterior teeth exhibit sensitivity to forces in the range of less than 4 N.

The number of mechanoreceptors have been shown to be more numerous around anterior teeth compared with posterior teeth. The anterior receptors relay information concerning forces in all directions because they have greater sensitivity to occlusal loading. These teeth contribute to the positioning of food in the oral cavity and manipulation of objects between the teeth.[14]

In comparing individual teeth, the cuspid plays a dominant role in the control of function. Anatomy (large crown and long root) and location in the dental arch (cornerstone position) allow for the cuspid to have an ideal physiologic feedback system from the mechanoreceptors. Additionally, the morphologic makeup of the cuspid, featuring a lingual contour that divides the mesial and distal via an axial ridge, allows for crown strength for anterolateral guidance. Because of the contour, arch location, and root length, this allows for the preferred mesial (not distal) canine guidance in mastication to confirm there is a distinct anterior component of the jaw and ipsilateral condylar movement.[14]

The posterior teeth in comparison have fewer mechanoreceptors, which results in a lower static and dynamic sensitivity allowing for posterior teeth to accommodate higher forces during mastication. The posterior teeth are strategically located with large clinical crowns and multiple roots (increased surface area) to sustain the increased posterior forces. Additionally, the first molars provide guidance during the eruption process and are functionally positioned in the center of the occlusal table.[14]

Implants

With dental implants, studies have shown that the lack of mechanoreceptors may influence jaw motor control because of a peripheral feedback system.[15] Because of the absence of these mechanoreceptors, there is lack of afferent information to be relayed to the central nervous system (CNS) during biting and chewing with dental implants. The proprioception associated with dental implants is similar to natural teeth that are blocked by local anesthesia.[16] However, the term “osseoperception” has been used to describe a different type of mechanical stimulation specific to dental implants. This type of sensation has been associated with mechanoreceptors in the orofacial tissues

(e.g., most likely present in muscle, joint, mucosa, periosteal tissues).[17] PMRs have been described to react to very low levels of force, and the detection of static force is approximately 10 times greater for patients with implants compared with dentate patients.[18] The mechanoreceptors that are responsible for osseoperception have been shown to be located a distance from the actual implant and qualitatively remit different sensory signals to static and dynamic loads.

Force-Related Factors

Many differences exist in comparing clinical aspects of force-related factors between natural teeth and dental implants.

Vertical Occlusal Loads

Tooth.

When a vertical occlusal load is applied to a natural tooth, a normal physiologic movement exists that is related to the surface area and root morphology. Therefore, the number, length, diameter, position, surrounding bone density, and health of the PDL has a primary influence on a tooth's mobility. A healthy tooth under normal conditions exhibits zero clinical mobility in a vertical direction. Actual initial vertical tooth movement has been shown to be approximately 28 μm and is the same for anterior and posterior teeth (Fig. 17.2).[19]

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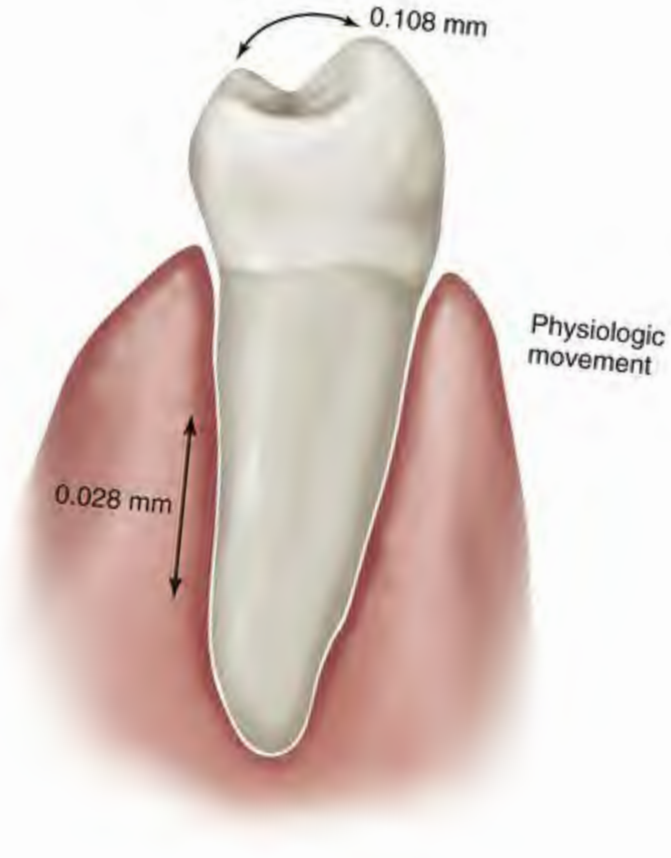

FIG 17.2 Physiologic movement of a healthy natural tooth has been measured as 28 µm in the apical direction and up to 108 µm in the horizontal direction. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Implant.

Rigid fixation is a clinical term used to describe the absence of clinical mobility of an implant tested with vertical or horizontal forces less than 500 g. Osseointegration is a histologic term that is used to define bone in direct contact with an implant surface at the magnification of a light microscope (Fig. 17.3). Over the years, these two terms have been used interchangeably, and implant abutment support is most predictable with rigid fixation. Lack of implant mobility does not always coincide with a direct bone-implant interface.[20] However, when observed clinically, rigid fixation usually means that at least a portion of the implant is in direct contact with bone, although the percentage of bone contact cannot be specified.[21] A mobile implant usually indicates the presence of connective tissue between the implant and bone and soft tissue interface.

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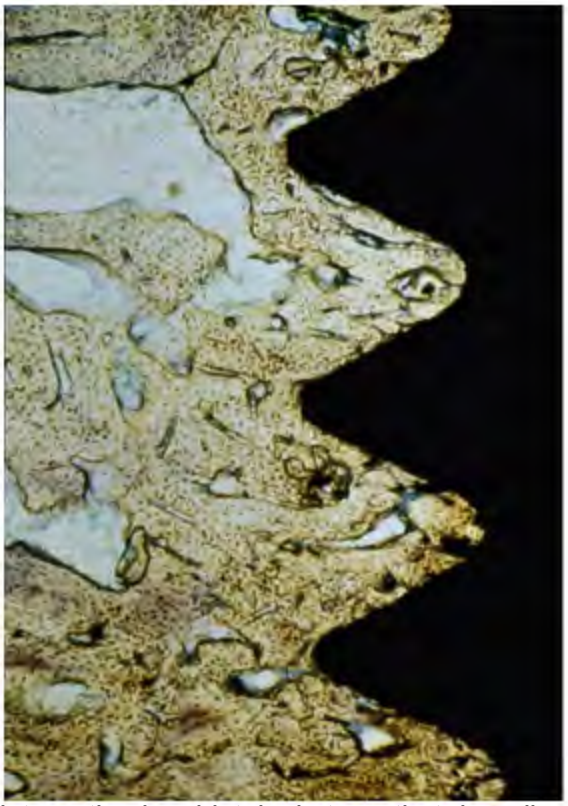

FIG 17.3 Osseointegration is a histologic term that describes a direct bone-to-implant contact at the level of magnification of a light microscope. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Lack of clinically observable movement does not mean the true absence of any movement. A healthy implant moves less than 73 μm; it appears as zero clinical mobility (rigid fixation). Sekine et al[22] applied a gradually increasing load over a 2-second period to a tooth and an implant. The teeth moved immediately with a light load (primary tooth movement) and less with an additional load (secondary tooth movement). The implant, in contrast to the natural tooth, did not feature primary tooth movement. A heavier force caused the implant to move gradually, similar to the secondary tooth movement (Fig. 17.4).

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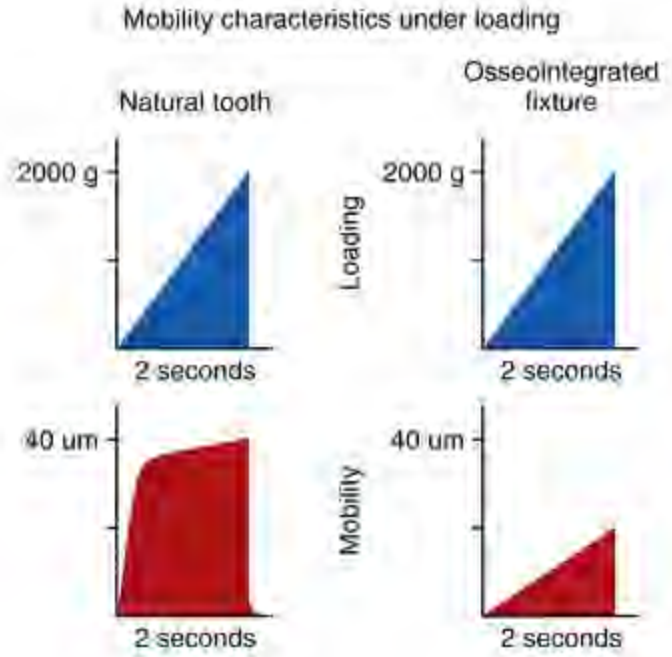

FIG 17.4 A gradually increasing load over a 2-second period was applied to a tooth *(left)* and an implant *(right)*. The natural tooth has two phases of movement which correlates to the compression of the periodontal ligament and then compression of the bone. The implant lacks the initial movement and movement is proportional to the movement of the bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Nonvertical Occlusal Loads (Horizontal)

Tooth.

When evaluating horizontal mobility on natural teeth, it is often difficult to determine the true movement. For example, a "nonmobile" posterior natural tooth actually moves horizontally 56–73 μm. The human eye does not perceive this movement. The anterior teeth, which often have slight clinically observable movement, actually can move approximately 0.1 mm.

With nonvertical loading, forces on natural teeth are better tolerated and will adapt to the force much more favorably than dental implants. Studies have shown that lateral forces on a healthy natural tooth are rapidly dissipated away from the bone crest toward the apex of the tooth. This is because natural teeth may move 56–108 μm with rotation around the apical one-third of the root. Muhlemann[23] found that horizontal tooth movement may be divided into initial mobility and secondary movement. The initial mobility is observed when a light force is applied, will occur immediately, and is a consequence of the PDL. Initial horizontal tooth mobility is greater than initial vertical movement. A very light force (500 g) horizontally moves

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the tooth. The initial horizontal mobility of a healthy, "nonmobile" posterior tooth is less than that of an anterior tooth and ranges from 56–75 μm, which is two to nine times the vertical movement of the tooth. Initial horizontal mobility is even greater in anterior teeth and ranges from 70–108 μm in health.[24]

The secondary tooth movement described by Muhlemann occurs after the initial movement when greater forces are applied. When an additional force is applied to the tooth, a secondary movement is also observed, which is related directly to the amount of force. The secondary tooth movement is related to the viscoelasticity of the bone and can measure 40 μm under considerably greater force (Fig. 17.5).

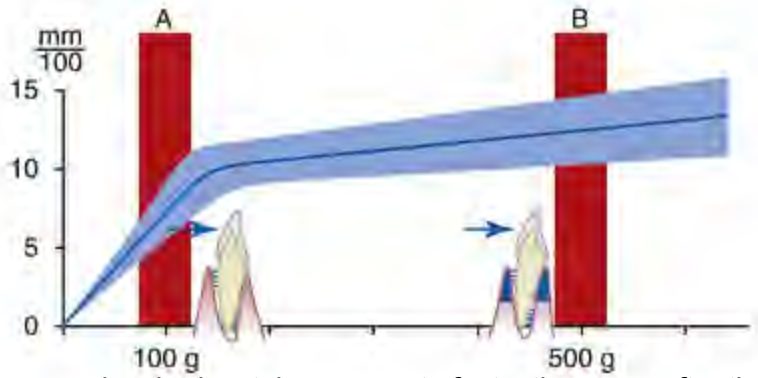

FIG 17.5 A secondary horizontal movement of a tooth occurs after the initial tooth movement when a greater force is applied and is related to the deformation of the alveolar bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Implant.

With dental implants, the nonvertical stress will most likely result in trauma to the supporting bone. An implant will gradually move and may move 10–50 μm.[19] An implant will have greater forces around the crest of the bone because an implant does not pivot as much as a tooth does, and all the forces are generated at the crest, which usually will result in bone loss.

Sekine et al[25] evaluated the movement of endosteal implants with rigid fixation and found a range of 12–66 μm of movement in the labiolingual direction. Komiyama[26] reported 40–115 μm of implant movement in the mesiodistal direction under a force of 2000 g (≈4.5 psi) and a labiolingual range of 11–66 μm. The greater implant movement in the mesiodistal dimension corresponds to the lack of cortical bone between the implants in

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this direction compared with the thicker lateral cortical plates present in the labiolingual dimension. Rangert et al[27] suggested that part of this implant movement may also be due to component flexure of the implant abutment and screw. The mobility of implants varies in direct proportion to the load applied and the bone density, reflecting the elastic deformation of bone tissue.

Excessive Contacts/Occlusal Overloading

When premature contacts or excessive contacts occur on a natural tooth, the tooth will often become mobile, become hyperemic, or fracture. The associated proprioception will allow the neuromuscular system and peripheral feedback system to control the occlusal forces during function. This will minimize the possibilities of prematurities and interferences. In comparison, when a premature contact is associated with a dental implant, the patient usually is asymptomatic, and the implant will have no mobility. Because of the lack of PMRs, there is no feedback system present. This will most likely result in crestal bone loss or mechanical failure will result because there is no feedback system to make the patient aware of a prematurity.

Clinical Significance.

Prematurities on natural teeth are less common and may be uneventful for years. Natural teeth may orthodontically reposition themselves or become symptomatic. However, excessive contacts on dental implants are more damaging because they will usually result in a force overload with resultant crestal bone loss (Fig. 17.6).

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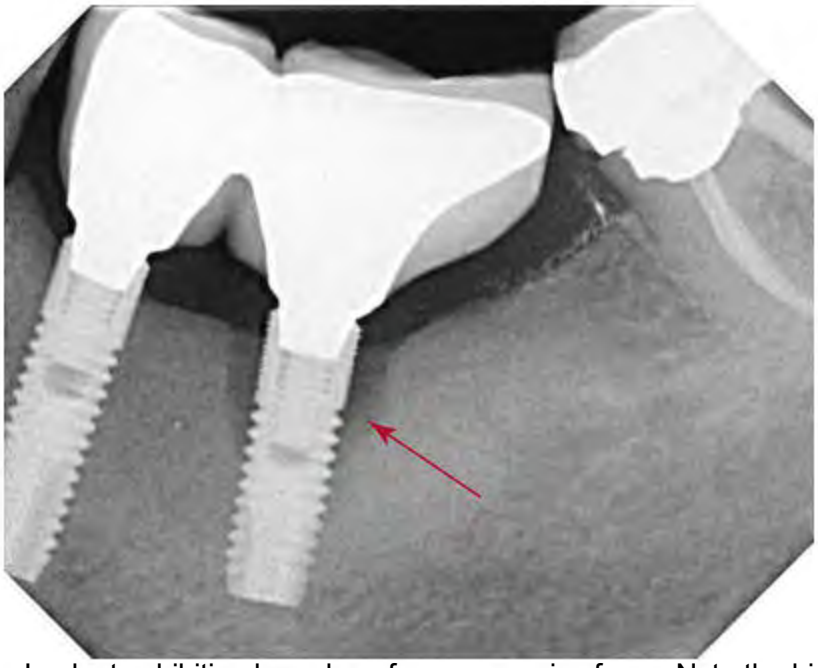

FIG 17.6 Implant exhibiting bone loss from excessive force. Note the high cusps and concavity for the maxillary plunging cusp.

Masticatory

With a natural tooth, the specialized PMRs are responsible for providing neural information to the muscles during mastication. Several hundred of these specialized receptors are present, which are used for fine motor control and conscious perception of tactile forces when applied to the teeth.[17]

The compression of the collagen fibers in the PDL will send nerve signals to the CNS. These receptors surrounding teeth have different sensitivities to the force applied, and each individual receptor is stimulated independently depending on the position within the PDL. The resultant force vectors have varying numbers depending on the anatomic location within the oral cavity. Usually, the number of force vectors decreases from anterior to posterior teeth. The anterior natural teeth may perform very delicate tasks, whereas the posterior teeth are less sensitive. This is why the anterior teeth can split food very precisely, whereas the posterior teeth are mainly used to grind food.[28]

Masticatory Efficiency

Many studies have evaluated the masticatory efficiency between teeth and implants. Svensson et al[29] completed studies on the mastication effectiveness of food between (1) natural teeth, (2) natural teeth with full coverage

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restorations, and (3) implant-supported restorations. Results showed that natural teeth were far superior in the refined action of splitting or incising food. Natural teeth were shown to be significantly better able to position the food boluses between the teeth and be able to fine-tune the direction of the bite force. This is most likely the result of the signal of the PMRs to the CNS on the spatial location and direction of forces needed to chew the food. However, with splinted fixed crowns and implant prostheses, the results showed inconsistent and poor incising of food. With tooth-supported prostheses, even though PMRs are present, the tooth-supported prosthesis (splinted crowns) dissipates the force, and the PMRs are not activated. With an implant prosthesis, because no PMRs are present, no peripheral feedback system exists to allow for the refined motor movement (Fig. 17.7). These findings are consistent with studies by Trulsson and Gunne,[30] in which prostheses supported by the oral mucosa (removable complete dentures) or dental implants (fixed prostheses) had difficulty in holding and splitting food, similar to patients with natural teeth and profound anesthesia. The afferent information is blocked by the local anesthesia (Fig. 17.8).

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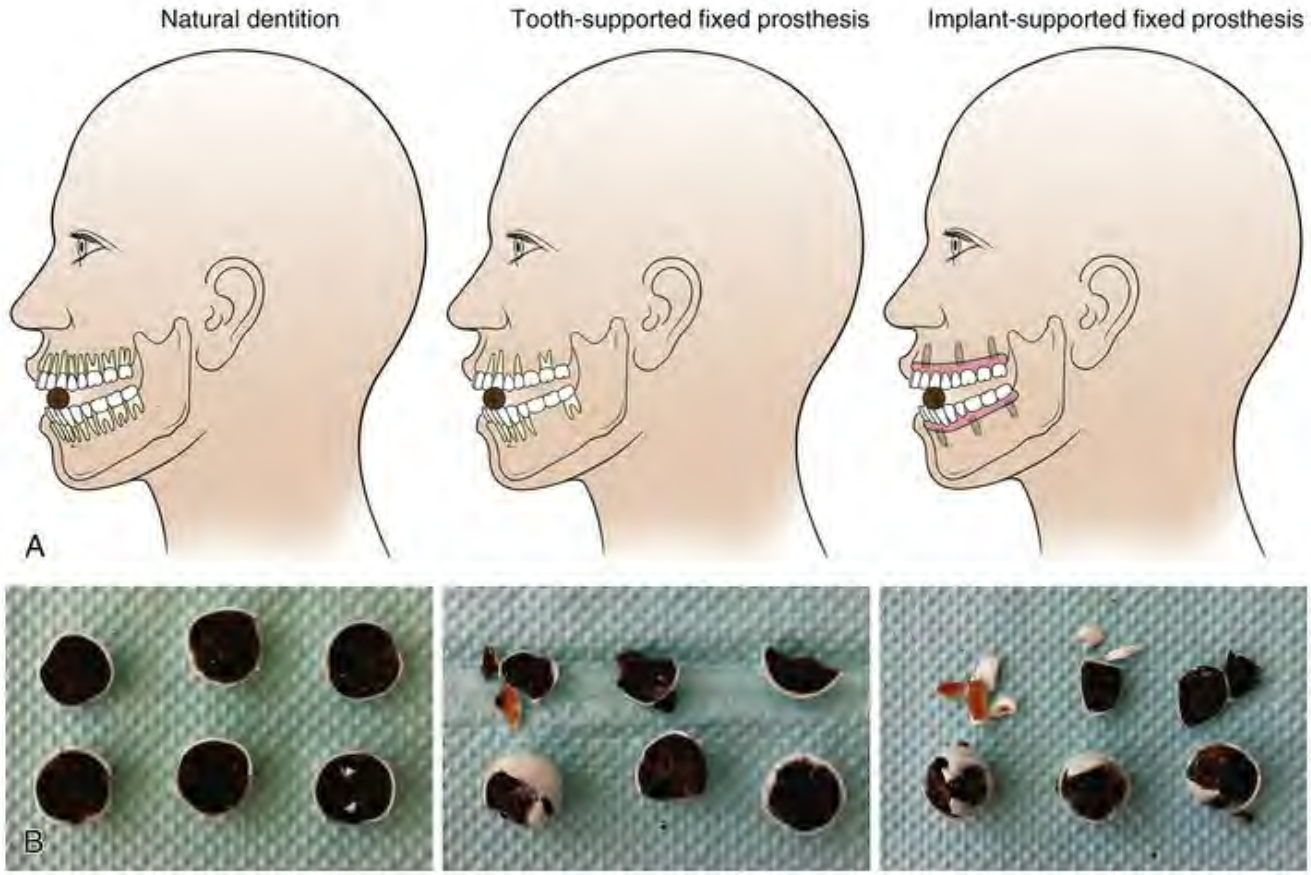

FIG 17.7 (A) Examples of subjects with natural dentition or tooth- or implant-supported fixed prostheses trying to split a spherical piece of chocolate hard candy into two parts of equal size with the anterior teeth. (B) The mandibular movements (frontal view) of these same subjects during a representative "first chewing cycle" of eating a hazelnut. (A, From Svensson KG, Trulsson M: Physiological Considerations of Oral Implant Function. In Klineberg I, Eckert S: *Functional occlusion in restorative dentistry and prosthodontics,* St Louis, 2016, Mosby. B, Modified from Grigoriadis J, Trulsson M, Svensson KG: Motor behavior during the first chewing cycle in subjects with fixed tooth- or implant-supported prostheses, *Clin Oral Implants Res* 27:473–480, 2016.)

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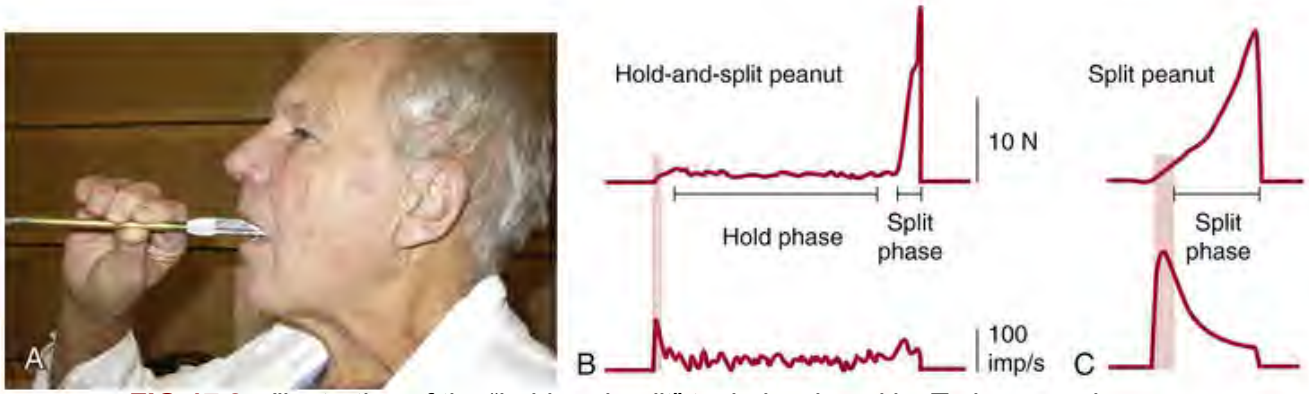

FIG 17.8 Illustration of the "hold-and-split" task developed by Trulsson and Johansson.[16] (A) The handheld apparatus employed to record the bite forces exerted on the morsel of food. This morsel rested on the upper horizontal plate, and the apparatus was positioned between the upper and lower teeth. (B) Representative force profile *(upper trace)* and predicted response (in impulses/s) by the periodontal mechanoreceptors *(lower trace)* for a subject with natural teeth while holding and splitting a peanut. (C) Representative force profile *(upper trace)* and predicted receptor response *(lower trace)* for a subject with natural teeth while splitting a peanut. (From Svensson KG, Trulsson M: Physiological Considerations of Oral Implant Function. In Klineberg I, Eckert S: *Functional occlusion in restorative dentistry and prosthodontics,* St Louis, 2016, Mosby.)

Clinical Significance.

Natural teeth are associated with greater masticatory efficiency, and less trauma to the dental complex will be present. Patients are able to refine their masticatory movements because of the mechanoreceptors that are present. However, with dental implant prostheses (also tooth-supported prostheses), the masticatory refinement is much poorer, leading to the greater possibility of angled- or force-related complications to the implant or prosthesis.

Speed of Mastication

Patients with natural teeth take longer to masticate food compared with tooth-supported and implant prostheses. This is most likely due to natural teeth requiring time for the PMRs to signal the CNS. This slow and delayed response is the result of the timing required to collect and process the spatial information and stimulate the appropriate motor program and efferent output to manipulate the muscles to fire with respect to the direction and amount of bite forces. The processing of PMRs requires time for the central processing, resulting in a longer contact phase of mastication. These results are consistent with other studies that have shown patients with natural teeth will initially hold the food under low force directly after contact and then will

apply greater biting forces. There is a delay between the contact of the food and the splitting of the food.

Clinical Significance.

Patients with a tooth-supported fixed prosthesis and implant prosthesis have altered spatial information. Although patients with tooth-supported fixed partial dentures (FPDs) have PMRs, because of the rigid connection, minimal signals to the CNS exist to initiate motor function. In patients with an implant-supported prosthesis, osseoperception must occur. This involves signaling sensory information concerning contact forces (dynamic loading) to the artificial teeth in an osseointegrated dental implant fixed prosthesis from remote receptors in other tissues activated by vibrations transmitted via the jawbone.[31] The sensory information of PMRs is significant with respect to masticatory efficiency and protection of the dentition. Impairment (tooth-supported FPD) or absence (implant-supported prosthesis) results in poorer performance and altered motor activity. Patients with tooth-supported and implant-supported prostheses also have a compromised protective mechanism in which they masticate their food with higher force, less delay (i.e., may not be able to comprehend that the food is too hard), and less precision. With increased speed of mastication, the greater possibility of damage to the prosthetic system exists.

Biting Force

PMRs present in natural teeth provide proprioception and early detection of occlusal forces and interferences. Bite forces on natural teeth during mastication and parafunction are not as strong because of the fine motor control of the mandible. Trulsson and Johansson[16] showed that the lack of proprioception leads to a heavier bite in patients with implants compared with natural dentition. Mericske-Stern et al[32] measured the oral tactile sensibility with test steel foil and showed that minimal pressure was significantly higher with implants than with natural teeth (3.2 vs. 2.6 steel foil sheets). Jacobs and van Steenberghe[33] evaluated occlusal awareness and found that interference perceptions of natural teeth, implants with opposing teeth, and implants opposing implants were approximately 20 μm, 48 μm, and 64 μm. Hämmerle et al[34] also concluded the mean threshold value of tactile perception for implants (100.6 g) was ninefold higher than that of natural teeth (11.5 g).

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Clinical Significance.

Biting forces are significantly higher with an implant-supported prosthesis compared with natural teeth, and this may lead to excessive forces on the implant system because of lack of awareness. The sensory feedback system present in teeth cannot be modulated the same around dental implants. The increased biting force may lead to abnormal forces on the dental implant system, which may lead to crestal bone loss, screw loosening, or component fracture (Fig. 17.9).

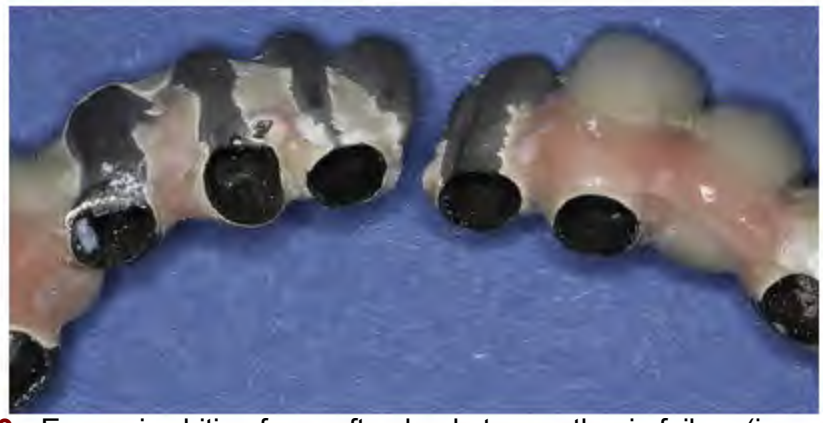

FIG 17.9 Excessive biting force often leads to prosthesis failure (i.e., porcelain fracture).

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Implant-Protected Occlusion

Because of the biomechanical differences between teeth and implants, modifications must be made in the development of occlusal schemes for prosthetic rehabilitation. An ideal occlusal scheme is a primary requisite for long-term implant prosthetic survival, especially when parafunction or a marginal foundation is present. A poor occlusal scheme increases the magnitude of loads and intensifies mechanical stresses (and strain) to the implant system. These factors increase the frequency of complications of the prosthesis and bone support. Crestal bone loss most likely leads to an increase in peri-implantitis. The conditions may also cause tissue shrinkage and loss of interdental papillae and poor esthetic results. All these complications may be initiated by biomechanical stress as a result of excessive occlusal loads (functional or parafunctional).

The concept of implant-protected occlusion (IPO) was developed by Misch. It is unique and specifically designed for the prosthetic rehabilitation of dental implants. This protocol provides for an environment to reduce the biomechanical stress to the implant and prosthesis. Minor modifications from conventional prosthodontic occlusal concepts have been established with the sole purpose of reducing stress on the prosthesis.

The ideal occlusion for an implant prosthesis is to control the stress on the implant system, provide a prosthetic and biologically acceptable implant interface, and maintain long-term stability of the marginal bone and prosthesis. The occlusal scheme should maintain the occlusal load that has been transferred to the implant system within the physiologic and biomechanical limits of each patient. However, these principles are not identical for all patients or restorations. The forces generated by a patient are influenced by ranges of parafunction, masticatory dynamics, implant arch position and location, arch form, crown height, and crown morphology. The treatment planning philosophy for dental implants varies greatly and depends on these several parameters. The implant dentist can address these force factors best by selecting the most ideal implant position, number, and size; using the progressive bone loading concept in poorer bone densities; and selecting the appropriate occlusal scheme using stress-relieving design elements.

The following guidelines and principles have been established to restore fixed and removable implant-supported prostheses. The IPO principles for fixed and removable prostheses address several conditions to decrease stress

to the implant system, including existing occlusion, implant body angle to occlusal load, cusp angle of implant crowns, mutually protected articulation, cantilever or offset loads, crown height, crown contour, occlusal contact position, timing of occlusal contacts, and protection of the weakest component (Box 17.1).

Box 17.1

Principles of Implant Protected Occlusion

1. Evaluate existing occlusion before treatment
2. Ideal treatment plan before treatment
3. No premature contacts
4. No nonaxial loading
5. Shallow anterior guidance
6. Minimal posterior cusp angle
7. Minimize cantilevers
8. Increase surface area
9. Narrow occlusal plane

. Ideal occlusal contact

Preimplant Occlusal Principles

Evaluate Existing Occlusion Before Dental Treatment

The first step in the process of treatment planning for dental implants is the fabrication of accurate diagnostic casts for the evaluation of the patient's existing occlusion. The value of diagnostic casts or study models is crucial in all phases of dentistry, especially in oral implantology. When edentulous sites exist, the combination of continued bone loss and dentition changes related to missing teeth greatly increases the number of factors that must be

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considered for oral rehabilitation compared with traditional prosthodontic treatment. The implant dentist must determine the type of implant prosthesis initially (i.e., FP-1, FP-2, FP-3, RP-4, RP-5), followed by the number and location of ideal and optional abutment sites and the final occlusal scheme.

Diagnostic casts must be accurate reproductions of the maxillary and mandibular arches with complete representation of the edentulous areas (Fig. 17.10). Diagnostic casts mounted on an articulator allow for an initial evaluation for implant site selection, angulation requirements, prosthesis selection, existing occlusion, and fabrication of a surgical template. In addition, these study casts allow for a preoperative assessment of treatment options that may be discussed with other practitioners and laboratory technicians and during patient consultations.

FIG 17.10 It is paramount that diagnostic casts be an accurate representation of the entire dental anatomy including the edentulous ridges. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

To accurately assess the maxillomandibular relationship of the implant patient, proper mounting of the study casts must be completed using an articulator. An articulator is defined as a "mechanical instrument that represents the temporomandibular joints (TMJs) and jaws, to which maxillary and mandibular casts may be attached to simulate some or all mandibular movements."[35] Today, the use and indications for the various types of articulators employed in prosthetic dentistry are very controversial. At the present time, wide arrays of articulator types are available, with

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multiple ranges of movements and adjustments, making classification and nomenclature very confusing. In the dental literature, many different classifications exist; however, today the most simplistic and most often used classification parallels the "Glossary of Prosthodontic Terms." Articulators maybe categorized into four groups according to the adjustability of the articulators. This classification is based on the ability of the articulator to accept the five most common patient records: (1) facebow transfer, (2) centric jaw record, (3) protrusive record, (4) lateral records (Bennett movement), and (5) intercondylar distance (Table 17.2 and Fig. 17.11).[36]

TABLE 17.2
Articulator Options

	Hinge Axis (Facebow)	CR Record	Protrusive Movement	Lateral Excursion	Bennett Movement
Nonadjustable (Simple and Average)	No	Yes	No	No	No
Semiadjustable	Approximate (arbitrary)	Yes	Yes (straight line)	Yes (straight line)	Approximate
Fully Adjustable	Yes (kinematic)	Yes	Yes (curved)	Yes (curved)	Yes

CR, Centric relation.

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

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FIG 17.11 Examples of various articulators used in implant dentistry. (A) Simple hinge. (B) Arbitrary plane line. (C) Semiadjustable. (D) Fully adjustable. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

To evaluate the patient's occlusion, an accurate mounting of diagnostic casts with an open-bite registration and facebow transfer allows for the static and dynamic (semi or fully adjustable articulators) relationships of the teeth and edentulous ridges, without interference from protective neuromuscular reflexes. By evaluating the articulated study casts, abnormalities or interferences that are not easily detectable intraorally can be determined along with comprehensive information that is paramount in dental implant treatment planning (Box 17.2).[37,38]

Box 17.2

Diagnostic Information Obtained From Proper Mounting of Study Casts in Implant Dentistry

1. Occlusal centric relation position, including premature occlusal contacts
2. Edentulous ridge relationships with respect to adjacent teeth and opposing arches
3. Position and location of potential natural abutment sites including inclination, rotation, extrusion, spacing, parallelism, and esthetic considerations
4. Tooth morphology and signs of parafunction (e.g., wear facets, fractures)
5. Evaluation of potential force direction in future implant sites
6. Present occlusal scheme including the presence of balancing or working contacts
7. Edentulous soft and hard tissue angulation, length, width, locations, permucosal esthetic position, muscle attachments, and bony protuberances (tori, tuberosities)
8. Interarch space
9. Occlusal curve of Wilson and curve of Spee

. Skeletal arch relationships

. Evaluation of opposing dentition

. Potential future occlusal schemes

. Site evaluation of edentulous sites

. Arch location of future abutments

. Arch form and symmetry

. Interdental contact location

. Used for a diagnostic wax-up

From Misch, CE: *Dental implant prosthetics,* ed 2, St. Louis, 2015, Mosby.

Ideally, all abnormal contacts should be identified and eliminated before the implant prosthodontic phase. However, to evaluate the patient's current dental status, the implant clinician must have a thorough understanding of the various types of occlusion and interferences that patients may have (Box 17.3).

Box 17.3

Occlusal Terms

Occlusal Planes

Curve of Spee—the anatomic curve of the occlusal surfaces, beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of the premolar and molar teeth, continuing through to the anterior border of the mandibular ramus. In natural dentition, the curve must be sufficiently low in the posterior to allow for disocclusion of the posterior teeth during protrusive movement. In edentulous patients with complete dentures, the curve must be higher to maintain posterior tooth contact in protrusive excursions.[109]

Curve of Wilson—the curve in the frontal plane that is formed by an imaginary line of the buccal and lingual cusp tips of similar teeth on each side of the arch. In theory, the occlusion should be spherical, the curve in the lower arch being concave and the curve in the upper arch being convex. The curvature in the lower arch is affected by an equal lingual inclination of the right and left molars so that the tip points of the corresponding cross-aligned cusps can be placed into the circumferences of a circle. The transverse cuspal curvature of the upper teeth is affected by the equal buccal inclinations of their long axes. That curve, as viewed in the frontal plane, is

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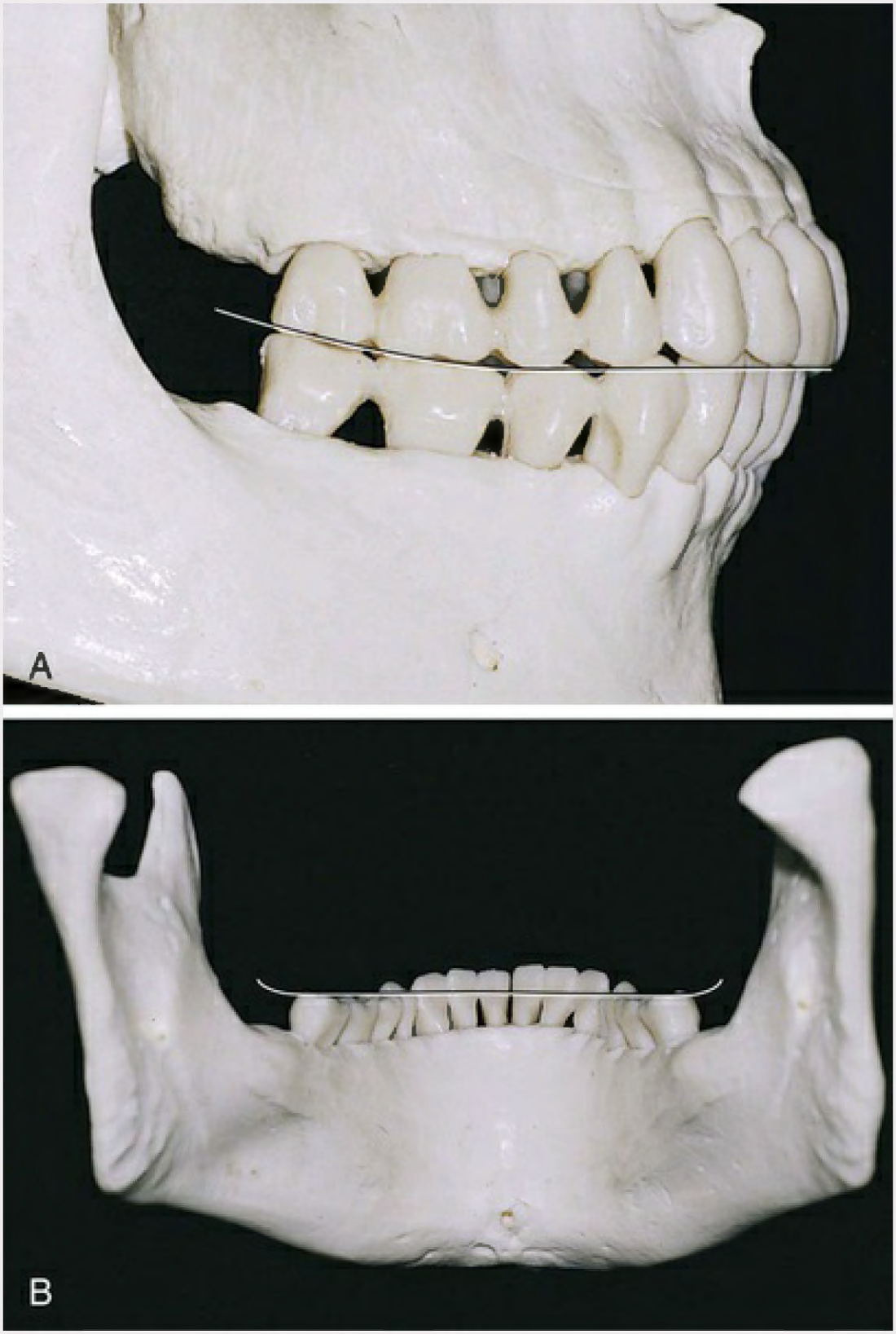
formed by an imaginary line touching the buccal and lingual cusp tips of similar teeth on each side of the mandibular arch. The curve is concave in the lower arch and should be in harmony with lateral anterior guidance to provide disocclusion of the maxillary lingual cusps on the nonworking side during lateral excursions.[110]



(A) Curve of Spee. (B) Curve of Wilson. (From Bath-Balogh MB, Fehrenbach MJ: *Illustrated dental embryology, histology, and anatomy,* ed 3, St Louis, 2011, Saunders.)

Teeth Relationships

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Centric occlusion—the occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximal intercuspal position.[109]

Centric relation—the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective discs with the complex in the anterosuperior position against the shapes of the articular eminencies. This position is independent of tooth contact. Also, centric relation is the most retruded relation of the mandible to the maxillae when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made at any given degree of jaw separation.

Maximum intercuspation—the complete intercuspation of the opposing teeth independent of condylar position, sometimes referred to as the best fit of the teeth regardless of the condylar position.

Occlusion Types

Group function occlusion—a type of occlusion involving multiple contact relations between the maxillary and mandibular teeth in lateral movements on the working side whereby simultaneous contact of several teeth act to distribute occlusal forces.[109]

All facial (buccal) cusps on the working side contact the opposing dentition, and no contact is made on the nonworking side. Schuyler first observed that nonworking side contacts were destructive, resulting in neuromuscular disturbances, temporomandibular joint dysfunction, accelerated or increased periodontal breakdown and excessive wear.[111] This "unilateral" balanced occlusion or "group function" allows for working side contacts to distribute the occlusal load. The absence of nonworking side contacts prevents destructive, obliquely directed forces.

Ideally, in this occlusal scheme, the implant-supported prosthesis should receive stress along the long axis of the implant. In lateral movement, the total stress should be transmitted among the implant or tooth segments. There should be no interferences during closure into the maximum intercuspal position, proper interocclusal clearance should be maintained, and the teeth should contact in lateral movement without interferences.

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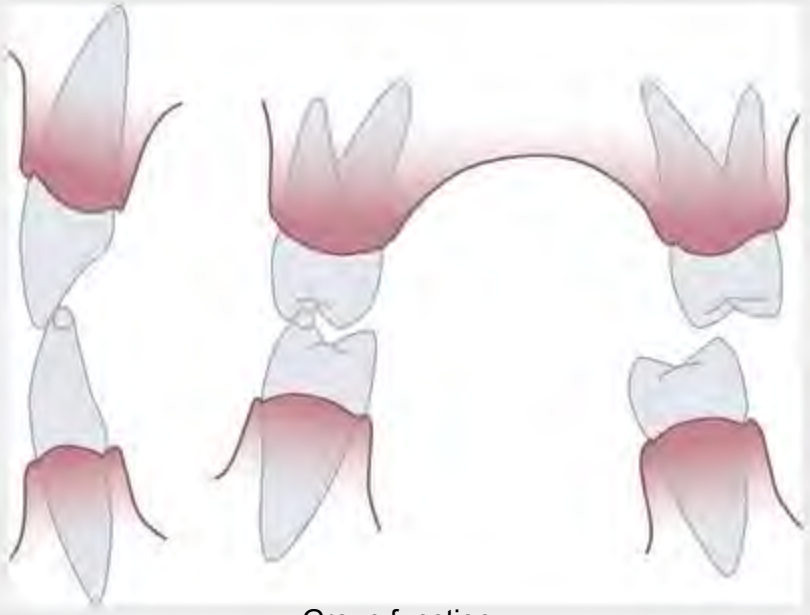

Group function.

Mutually protected occlusion—mutually protected occlusion is an occlusal scheme in which the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation, and the anterior teeth disengage the posterior teeth in all mandibular excursive movements. An alternative occlusal scheme is one in which the anterior teeth disengage the posterior teeth in all mandibular excursive movements, and the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation.[109]

In mutually protected occlusion, also termed canine protected occlusion, maximum intercuspation coincides with the optimal condylar position of the mandible (centric relation). Forces applied to the posterior teeth are directed along their long axis. During lateral and protrusive excursions, the maxillary and mandibular anterior teeth guide the mandible so that no posterior occlusal contacts occur. This results in a decrease in frictional wear. The posterior teeth protect the anterior teeth in centric relation, whereas anterior teeth protect the posteriors in protrusion, and canines protect the incisors and posterior teeth during lateral excursive movements. Centric relation will coincide with maximum intercuspation. Ideally, there should be stable posterior tooth contacts with vertically directed resultant forces.

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Mutually protected occlusion.

Bilateral balanced occlusion—a type of occlusion that has bilateral, simultaneous, anterior, and posterior occlusal contacts of teeth in centric and eccentric positions.[109] Working and nonworking contacts are present. This type of occlusion is present in the construction of complete dentures to prevent tipping of the denture. A balanced occlusion in natural dentition with normal periodontium is very rare and if present is most likely the result of advanced attrition. This type of occlusion is based on the theory that forces are generated horizontally instead of vertically. Wide, maximum contacts in intercuspation and eccentric movements are needed.

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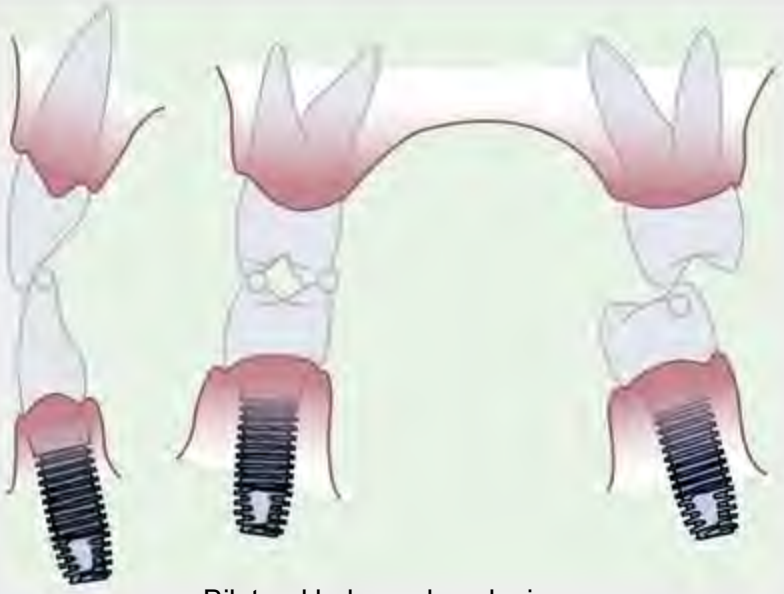


Bilateral balanced occlusion.

Medial-positioned lingualized occlusion—lingualized occlusion was first postulated by Gysi and further modified by Payne (maxillary buccal cusps of posterior teeth are reduced) and Pound (placed the lingual cusp of mandibular posterior teeth between lines drawn from the canine to each side of the retromolar pad). This occlusion is designed to narrow the occlusal table to reduce the forces to the bone and stabilize the lower denture (see Fig. 17.84).

Implant protected occlusion—this type of occlusion was developed by Misch and is defined as techniques that allow for the implants to have an increased longevity. The concept includes the use of implants of the greatest width, the anterior teeth should disclude the posterior teeth, absence of lateral contacts in excursions, occlusal contacts more medial than the natural teeth, and a reduced occlusal table width.

Interferences

Occlusal prematurity—any contact of opposing teeth that occurs before the planned intercuspation.[109]

Deflective occlusal contact—a contact that displaces a tooth, diverts the mandible from its intended movement, or displaces a removable denture from its basal seat.

Occlusal disharmony—occlusal surfaces are not in harmony with other tooth contacts or the anatomic and physiologic components of the craniomandibular complex.

Interferences may also be classified according to the effect the

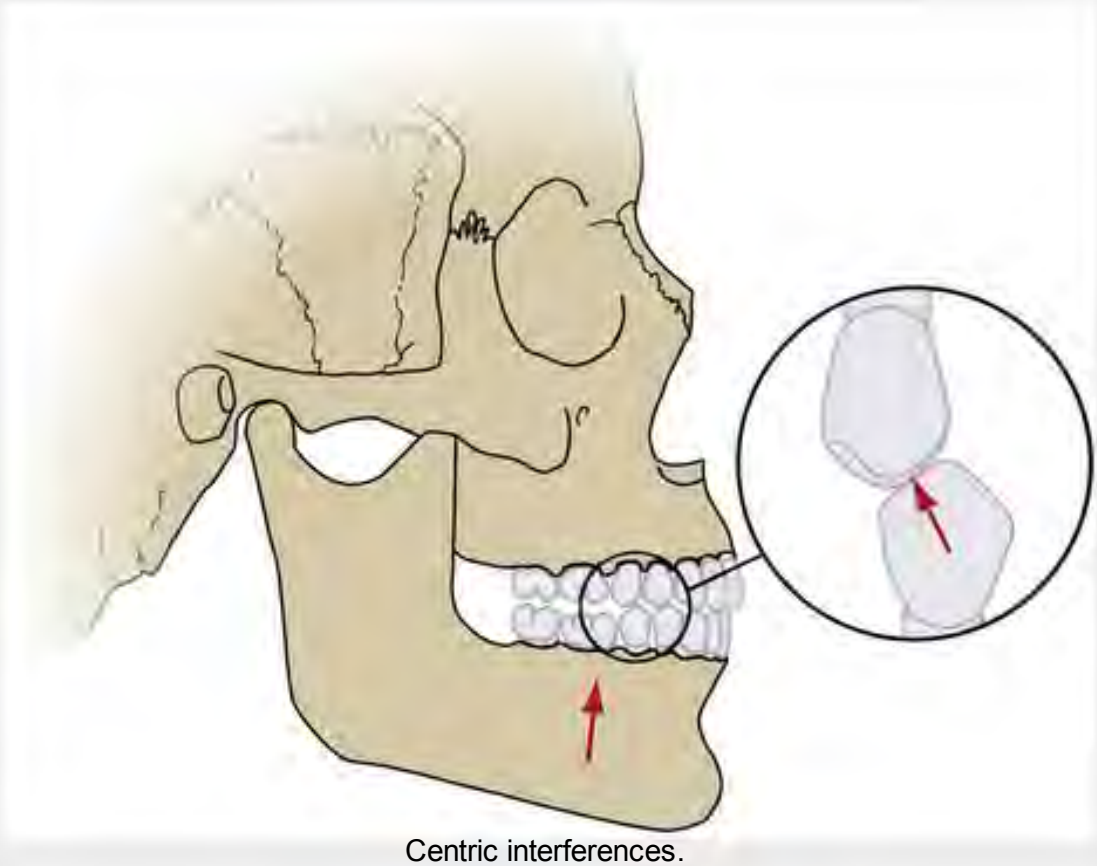
interference has on a particular part of occlusion.[112]

Centric Occlusal Interferences

With a centric occlusal interference, the premature contact causes the mandible to deflect forward or laterally from the optimal superior position of the mandibular condyles in the glenoid fossa. These types of interferences may cause parafunctional habits such as clenching or bruxism with associated muscle fatigue and temporomandibular joint pain.[113] There are two types:

1. Arc of closure interference—a tooth contact that interferes with closure to maximum intercuspation in centric relation by causing the mandible to deflect *forward.*

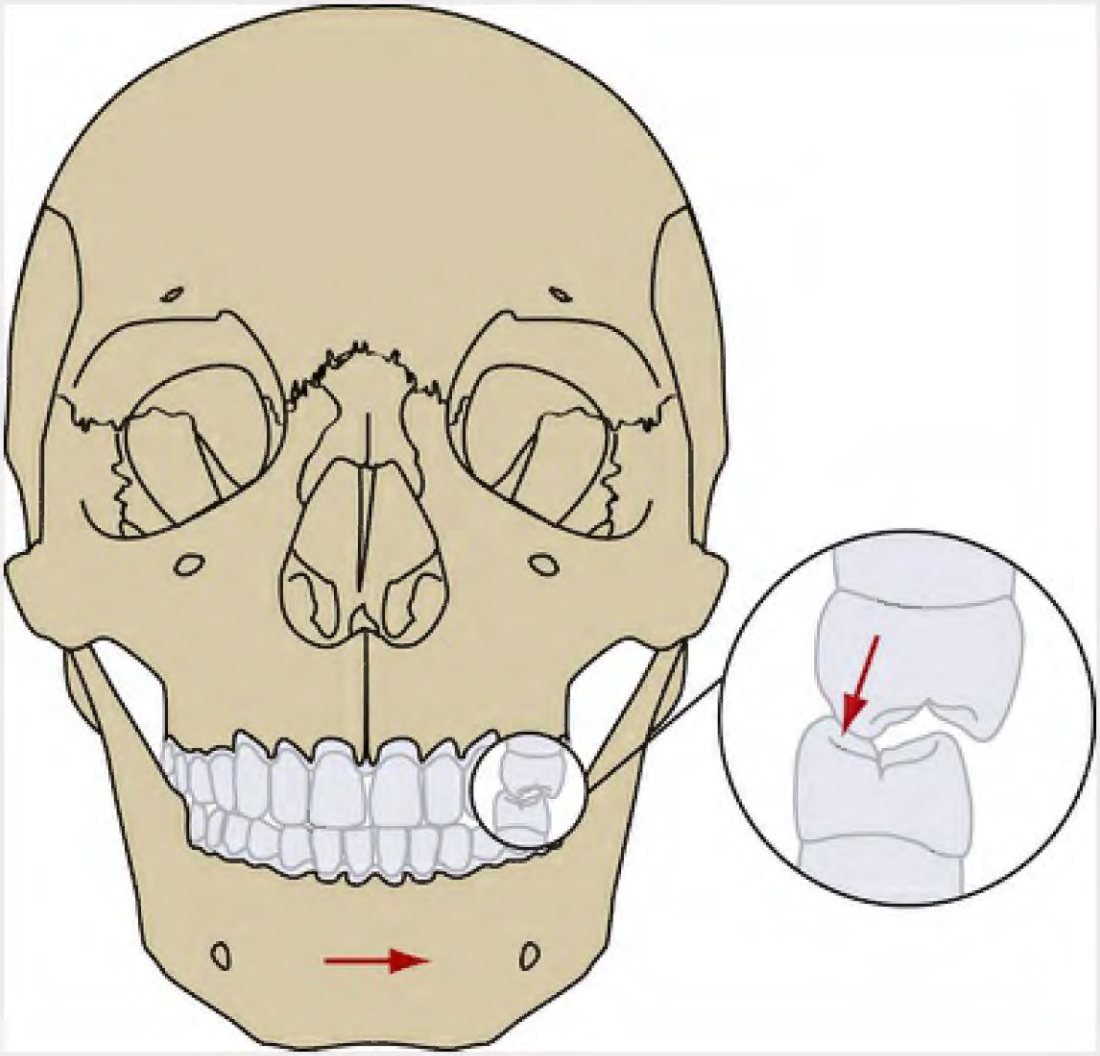
2. Line of closure interference—a tooth contact that interferes with closure to maximum intercuspation in centric relation by causing the mandible to deviate to the *right or left.*



Centric interferences.

Working Occlusal Interferences

A working occlusal interference occurs between the contacting maxillary and mandibular teeth during lateral movement on the side that corresponds to the direction in which the mandible is moving.

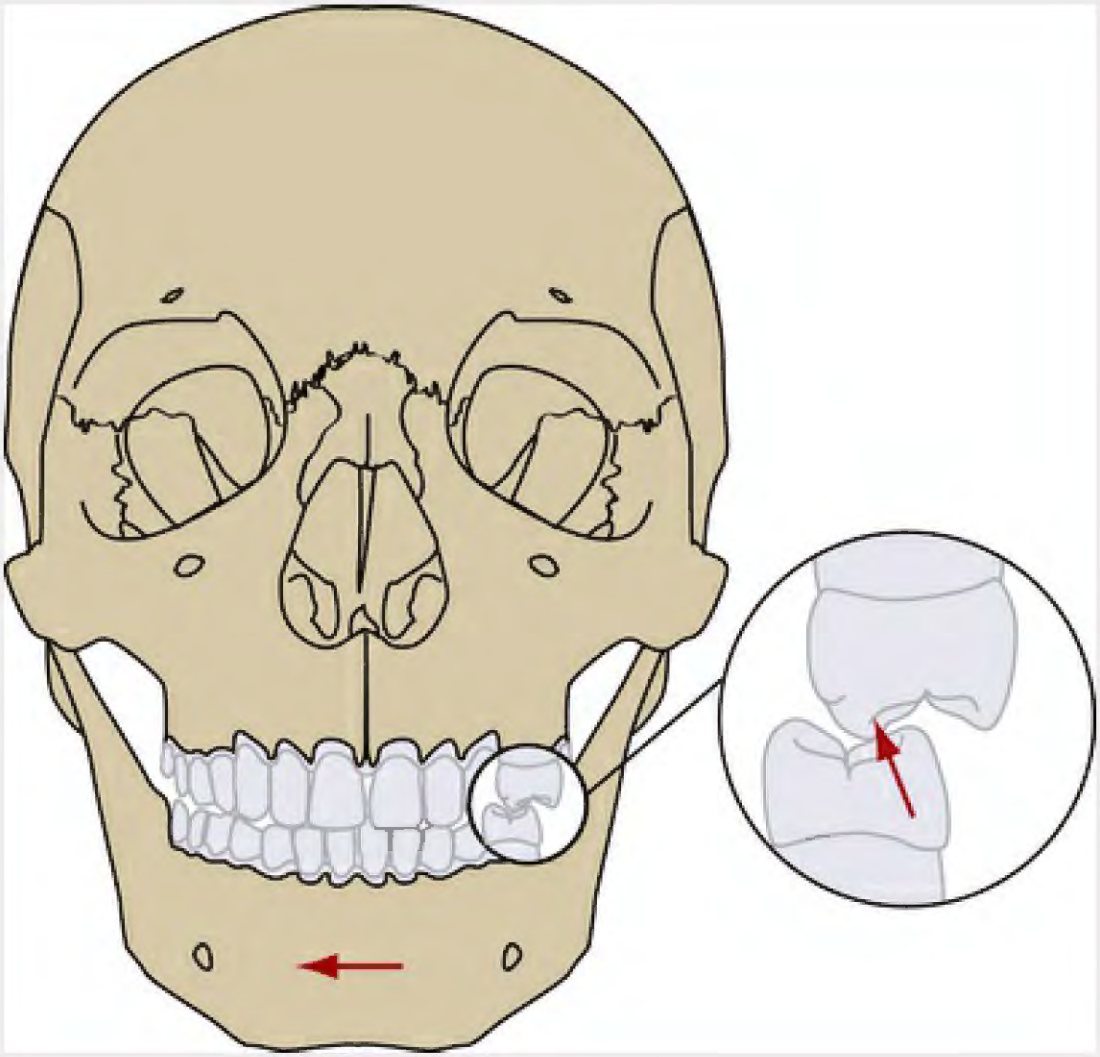


Working occlusal interferences.

Nonworking Occlusal Interferences

A nonworking occlusal interference is a deflective contact that occurs on the opposite side of the direction of mandibular movement. These types of forces are potentially damaging to the masticatory apparatus (especially with implants) because they place shear forces outside the long axis of the teeth (or implants) and may cause bone loss and disruption of normal muscle function. They also increase the amount of force to the dentition during the

excursions because more muscle mass fires in the masseter and temporal musculature.



Nonworking occlusal interferences.

Protrusive Occlusal Interferences

A protrusive occlusal interference occurs during deflective contact between the mesial aspects of the mandibular posterior teeth and the distal aspects of maxillary posterior teeth on protrusive mandibular movement. This is not considered a border movement and is usually less damaging to the stomatognathic system. However, these types of interferences may be damaging to teeth and implants because they result in shear forces because they prevent the posterior teeth from being disoccluded by the incisors.

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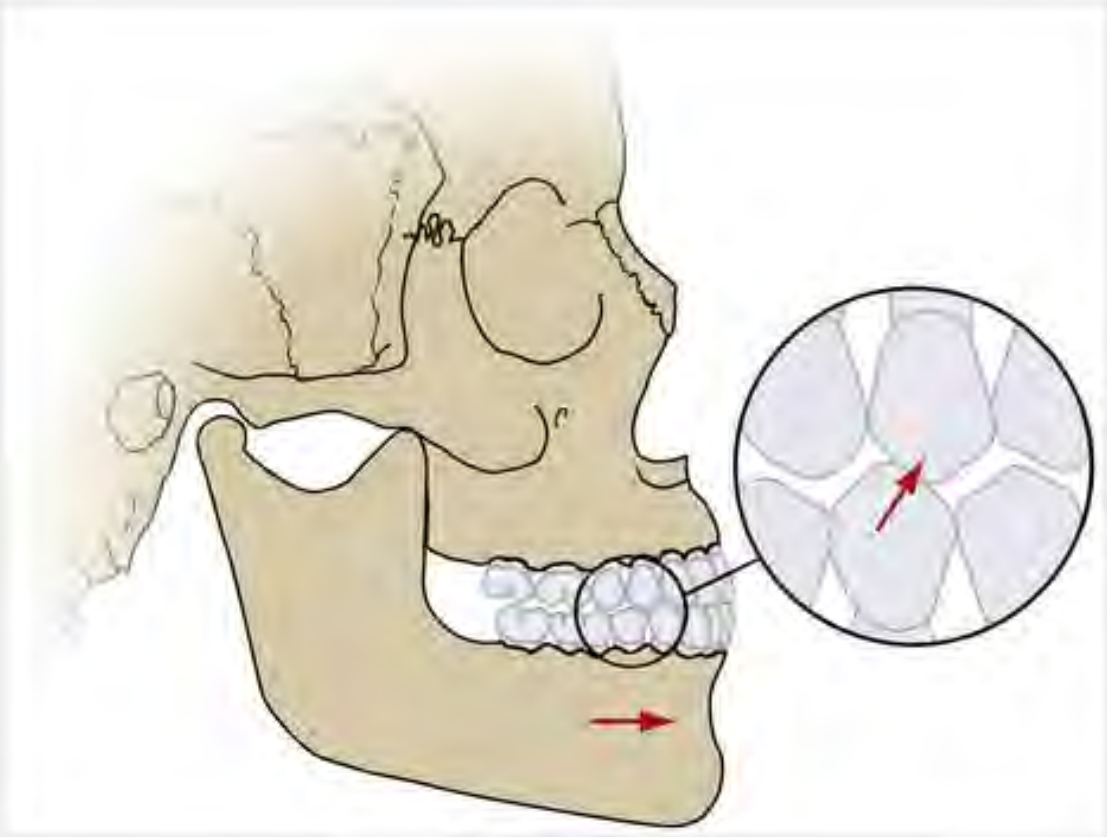

Protrusive occlusal interferences.

Diagnostic Wax-Up Before Treatment

Techniques used to determine the location, angulation, and contours of the final prosthesis are initiated by the completion of a diagnostic wax-up. Procedures range from simplistic (single missing tooth) to complex (full-mouth rehabilitation).

Partially Edentulous

Diagnostic wax-up.

Duplicate diagnostic casts are mounted on an articulator, and a diagnostic wax-up is completed for the desired contour, occlusal scheme, and esthetic aspects of the final restoration. Attention should be given to individual tooth morphology, tooth axis, gingival contours, and interdental contacts. The diagnostic wax-up technique is especially recommended when full-mouth rehabilitation is indicated, particularly if a change in vertical dimension is desired (Fig. 17.12 and Box 17.4).

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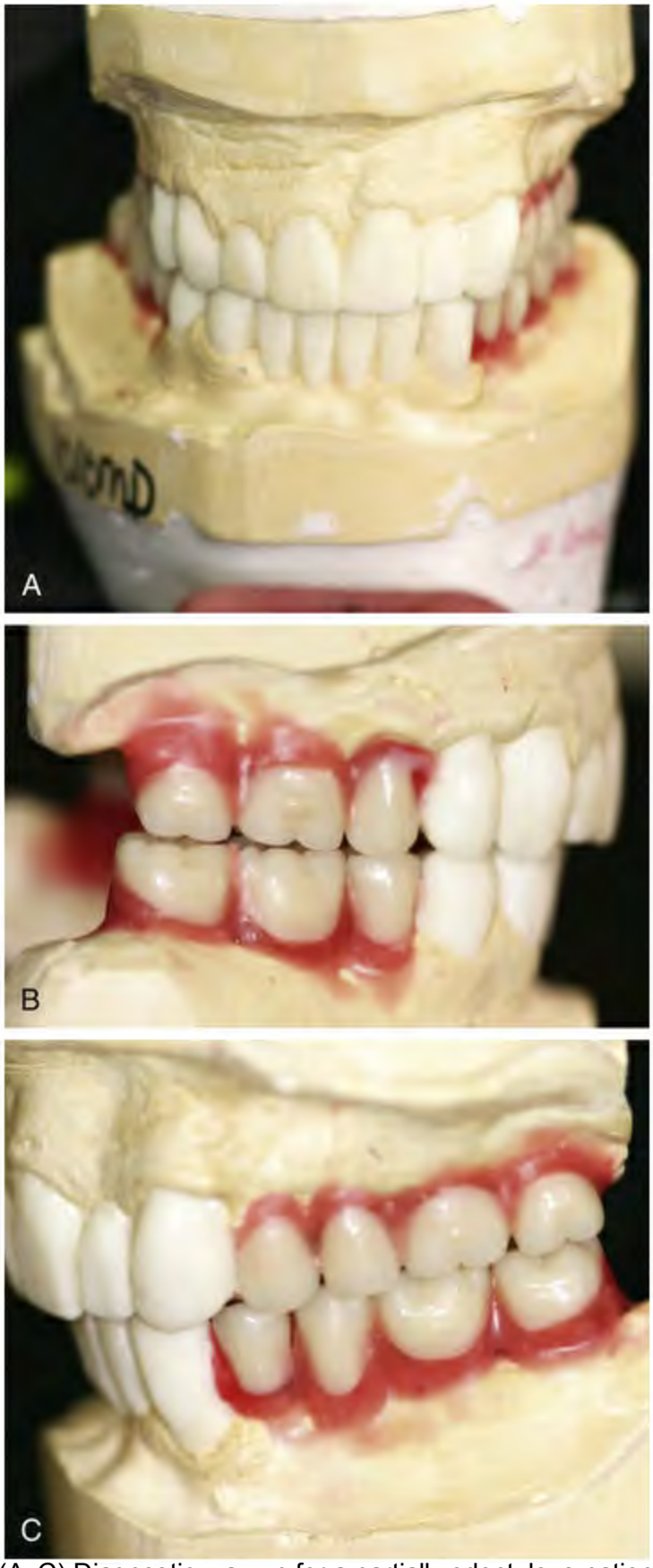

FIG 17.12 (A–C) Diagnostic wax-up for a partially edentulous patient. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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Box 17.4

Diagnostic Wax-Up

1. Fabrication of diagnostic casts: Impressions are made of the maxillary and mandibular ridges. It is more important that the impressions have no voids, as opposed to the dental casts, because they result in a positive mistake compared with a negative representation. If indicated, a facebow transfer is completed to relate the maxillary cast to the articulator along with a centric relation interocclusal record. The impressions should be poured in dental stone with the proper water-to-powder ratio.

2. Selection of an articulator: Select the desired articulator as per the complexity of the case. Ideally, a semiadjustable articulator is used to simulate the jaw movements of the patient when any occlusal disease is present.

3. Mounting of the diagnostic casts: The maxillary and mandibular diagnostic casts are mounted with the facebow transfer and the centric bite.

4. Diagnostic wax-up completed: Future implant sites are evaluated for ideal implant placement, spacing, and contour restrictions. The edentulous spaces are waxed to replicate ideal positioning of the teeth and contours. Denture teeth may be used as a substitute for the wax.

5. Duplication of the final diagnostic wax-up: The final diagnostic cast is duplicated to allow for laboratory-fabricated surgical templates, or a fully edentulous setup may be processed and used as an interim prosthesis.

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

A common clinical situation that may become problematic is when a posterior tooth is missing and the opposing tooth supraerupts into the space. The plunging cusps of the opposing dentition usually will cause either a premature contact or an angled load. Management should include informing the patient before treatment so as to prevent complications from modifications of the offending tooth (i.e., enameloplasty leading to tooth sensitivity) or possible endodontic therapy and full coverage restorations.

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Completely Edentulous

No modification to existing prosthesis is indicated.

For fully edentulous cases, duplication of the patient's existing prosthesis (if esthetically and functionally ideal) may be used for the mounting of the diagnostic casts. The simplest technique is the use of a denture duplicator (Fig. 17.13).

FIG 17.13 If the patient's existing prosthesis is esthetically and functionally acceptable, the prosthesis may be used in the diagnostic process. (A) Denture duplicator. (B) Duplication is completed with the use of alginate and acrylic. (A, Courtesy Lang Dental Manufacturing Company, Inc., Wheeling, IL. B, From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Modification to existing prosthesis is indicated.

If modification of the existing prosthesis is required because of a change in esthetics or function, a traditional complete denture setup is indicated. After

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the try-in approval appointment, the prosthesis may be duplicated to be used as a radiographic or surgical template fabrication (Fig. 17.14).

FIG 17.14 Diagnostic wax-up for a fully edentulous patient. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Management.

The evaluation of the patient's existing occlusion is crucial to the long-term success of the implants and implant prosthesis. Maximal intercuspation (MI) is defined as the complete intercuspation of the opposing teeth independent of condylar position, sometimes described as the best fit of teeth regardless of the condylar position.[39] Centric occlusion (CO) is defined as the occlusion of opposing teeth when the mandible is in centric relation.[40] This may or may not coincide with the tooth position of MI. Its relationship to centric relation (a neuromuscular position independent of tooth contact with the condyles in an anterosuperior position) is noteworthy to the restoring dentist. The potential need for occlusal adjustments to eliminate deflective tooth contacts as the mandible closes in centric relation and the evaluation of their potential noxious effects on the existing dentition and the planned restoration is important to evaluate.

In implant dentistry today, many clinicians begin to evaluate the occlusion of the patient when the final implant prosthesis is delivered to the patient. However, this time-frame is often too late for proper restoration of the patient (Fig. 17.15). The underlying question that helps determine the need

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for occlusal correction before restoration of the implant patient is the observation of negative symptoms related to the existing condition. This may include TMJ conditions, tooth sensitivity, mobility, wear, tooth fractures, cervical abfraction, or porcelain fracture. The fewer and less significant the findings, the less likely an overall occlusal modification is required before restoration of the patient. However, in most cases, to properly assess these conditions, the clinician should perform these diagnostic techniques to minimize future complications.

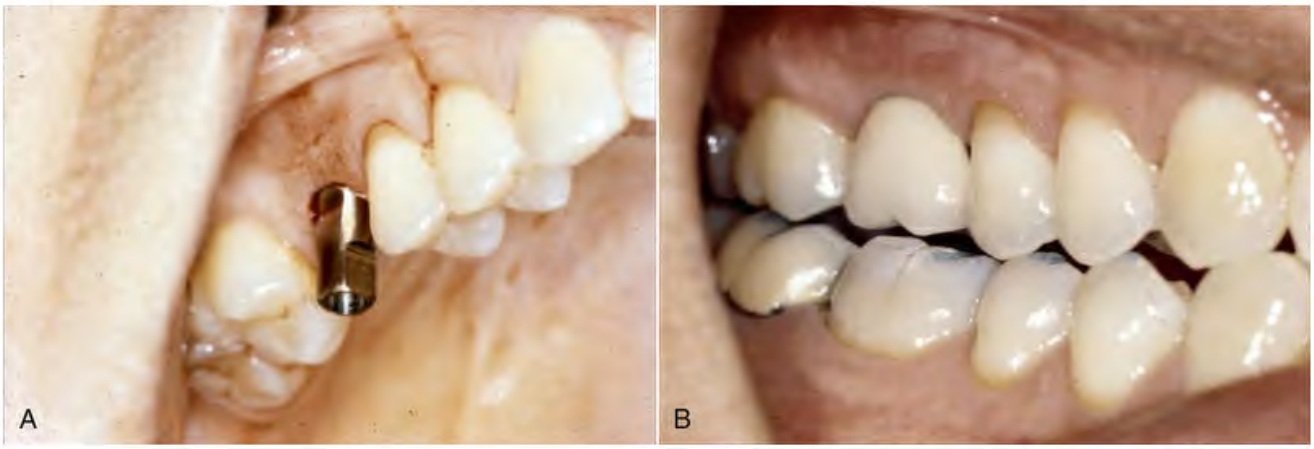

FIG 17.15 (A) A maxillary first molar is replaced with an implant. The lateral forces should be applied to the anterior teeth during mandibular excursions. (B) The implant crown is seated, and the right mandibular excursion is evaluated. The premolars exhibit a slight working interference on the buccal cusps. The maxillary premolars have slight gingival recession and initial cervical abfraction regions below the cementoenamel junction. The excursive force is reduced when the posterior teeth do not interfere during excursions. The buccal cusp inclines of the premolars should be reduced. If the incisal edge of the canine continues to wear in the future, the occlusal contacts will need to be modified further when the posterior teeth contact during excursions. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Clinical significance.

As a general rule, the more teeth replaced or restored, the more likely the patient is restored to CO. For example, if a completely edentulous mandible is to be restored with an implant-supported fixed prosthesis, CO provides consistency and reproducibility between the articulator and the intraoral condition. The slight changes in occlusal vertical dimension and its relationship to the position of anterior implant abutments to the direction of force may be studied and implemented on the articulator without the need to record a new occlusal vertical position on the patient. When one anterior

tooth is being replaced, the existing MI position is often satisfactory to restore the patient even though a posterior interference and anterior slide into full interdigitation may be present (with little clinical variance from the ideal conditions). However, in a partially edentulous patient, the existing occlusion should be evaluated to determine if noxious conditions are present.

A considerable prosthetic advantage is present when centric relation occlusion is harmonious with maximal intercuspal position. Lack of change in the occlusal vertical dimension permits a closed-mouth centric recording during prosthetic reconstruction for the fabrication of the prosthesis without the need for an accurate hinge axis recording of the condyles or fully adjustable articulators. When the incisal edge position of the maxilla is determined, its position usually causes a steeper protrusive or excursive position than the condylar disc assembly on semiadjustable articulators. As a result, posterior disocclusion can be easily established. These conditions permit the prosthetic reconstruction to be fabricated in the laboratory and transferred accurately to the patient.

Correction of the deflective contacts before treatment has many advantages and may follow a variety of approaches depending on the severity of the incorrect tooth position: selective odontoplasty (a subtractive technique), restoration with a crown (with or without endodontic therapy), or extraction of the offending tooth. Premature contacts may be ascertained after proper mounting of the study casts with the use of a wax spacer or bite registration (open-mouth bite). On removal of the occlusal records that separate the teeth, the premature or irregular contacts may be determined and verified when the casts are closed and then modified intraorally.[40]

The occlusion may require complete rehabilitation to eliminate potential unfavorable forces to the implant restoration. In some complex cases, both arches may require prosthodontic treatment to establish the desired occlusal schemes. Parafunctional bruxism with loss of incisal guidance from attrition and an opposing single denture are the most common conditions that mandate more comprehensive opposing dentition modification (Box 17.5).

Box 17.5

Common Occlusion Definitions Used in Prosthodontic Dentistry

Centric relation: The maxillomandibular relationship in which the condyles

articulate with the thinnest avascular portion of their respective discs with the complex in the anterosuperior position against the shapes of the articular eminences. This position is independent of tooth contact.

Centric occlusion: The occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximal intercuspal position.

Maximal intercuspal position: The complete intercuspation of the opposing teeth independent of condylar position; sometimes referred to as the best fit of the teeth regardless of the condylar position.

Anterior (incisal) guidance: The influence of the contacting surfaces of the mandibular and maxillary anterior teeth on mandibular movements.

Data from The glossary of prosthodontic terms, *J Prosthet Dent* 94:10–92, 2005.

Ideal Treatment Planning—Implant Positioning

The positioning of the implant within the bone is vitally important to minimize stress to the implant system. When a force is placed on a tooth or a dental implant, it is referred to as a vector (i.e., defined in magnitude and direction).[41] Occlusal forces are typically three-dimensional, with components directed along one or more of the clinical coordinate axes. The primary forces of occlusion can be resolved into a combination of components in any given plane. The same magnitude of force can have dramatically different effects on the implant system, solely because of the direction of the applied load. This is especially noted on implant support systems because they are more rigid.

Natural teeth are designed primarily to be able to withstand long-axis loads. The natural tooth roots in most of the oral cavity are positioned perpendicular to the curves of Wilson and Spee. Although chewing is in an elliptical “teardrop” pattern, when the teeth finally contact, the forces are directed along the long axis of the roots, especially during power biting (Fig. 17.16). The apical movement of teeth is minimal compared with their lateral movement. Lateral loads are significant in the maxillary anterior teeth. The consequences of a lateral force to a tooth are reduced because of the increased tooth mobility, which decreases the effects of the lateral force component of a load. However, an implant does not withstand this lateral

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load like a tooth.

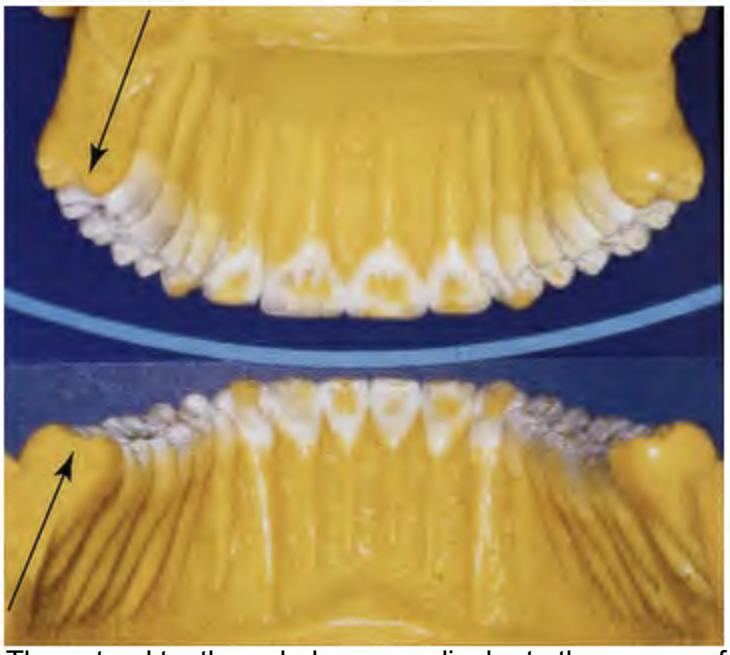

FIG 17.16 The natural teeth occlude perpendicular to the curves of Wilson and Spee. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Implants are also designed for long-axis loads. Two-dimensional finite element analysis by Binderman[42] in 1970 evaluated 50 endosteal implant designs and found that all designs sustained stress contours concentrated primarily at the transosteal (crestal) region. In addition, less stress was observed under a long-axis load compared with angled loads. Since then, two-dimensional and three-dimensional finite element analyses by several authors have yielded similar results (Fig. 17.17).[43,44]

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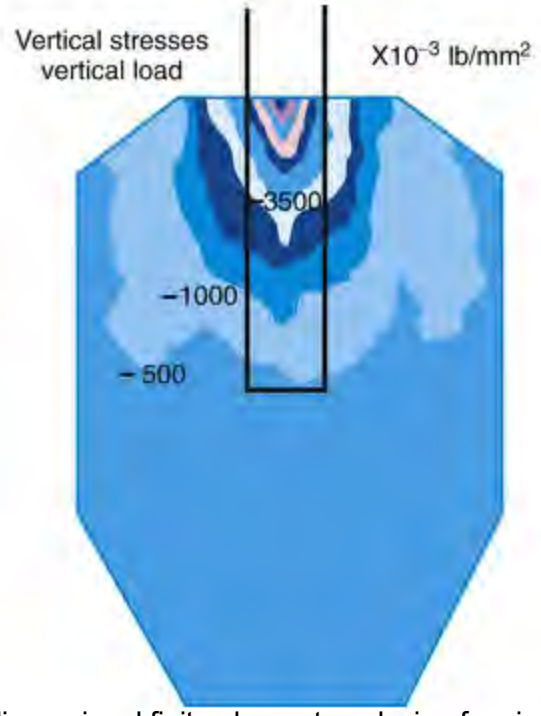

FIG 17.17 A three-dimensional finite element analysis of an implant with a long-axis load. The stresses are mainly at the crestal region and primarily have compressive forces. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

An axial load over the long axis of an implant body generates less overall stress and a greater proportion of compressive stress compared with an angled force to the implant body. For example, when an implant body is loaded along its long axis, a 100-N force results with an axial force component of 100 N, and no lateral force component is observed. The implant body should be positioned perpendicular to the curves of Wilson and Spee, just as with natural teeth.

However, most anatomic variations of the bone (e.g., bony concavities) are located on the facial aspect and influence implant body positioning. An implant body may need to be positioned with a 15-degree angle to avoid the facial concavity and is positioned at 15 degrees to the occlusal load. This angled implant may be restored during prosthetic reconstruction with a 15-degree angle abutment. From the level of the crest of the ridge to the occlusal plane, the implant abutment looks similar to one in an axial implant body. The laboratory technician and restoring clinician often treat the angled implant and axial implant in similar fashion. However, in the 15-degree angled implant body, the load to the facial bone increases by 25.9% compared with an axial load (Fig. 17.18).[45] Additionally, if the implant clinician places the implant body with a 30-degree angulation, the buccal force component of any occlusal load will result in a 50% increase of the load applied to the facial

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bone.

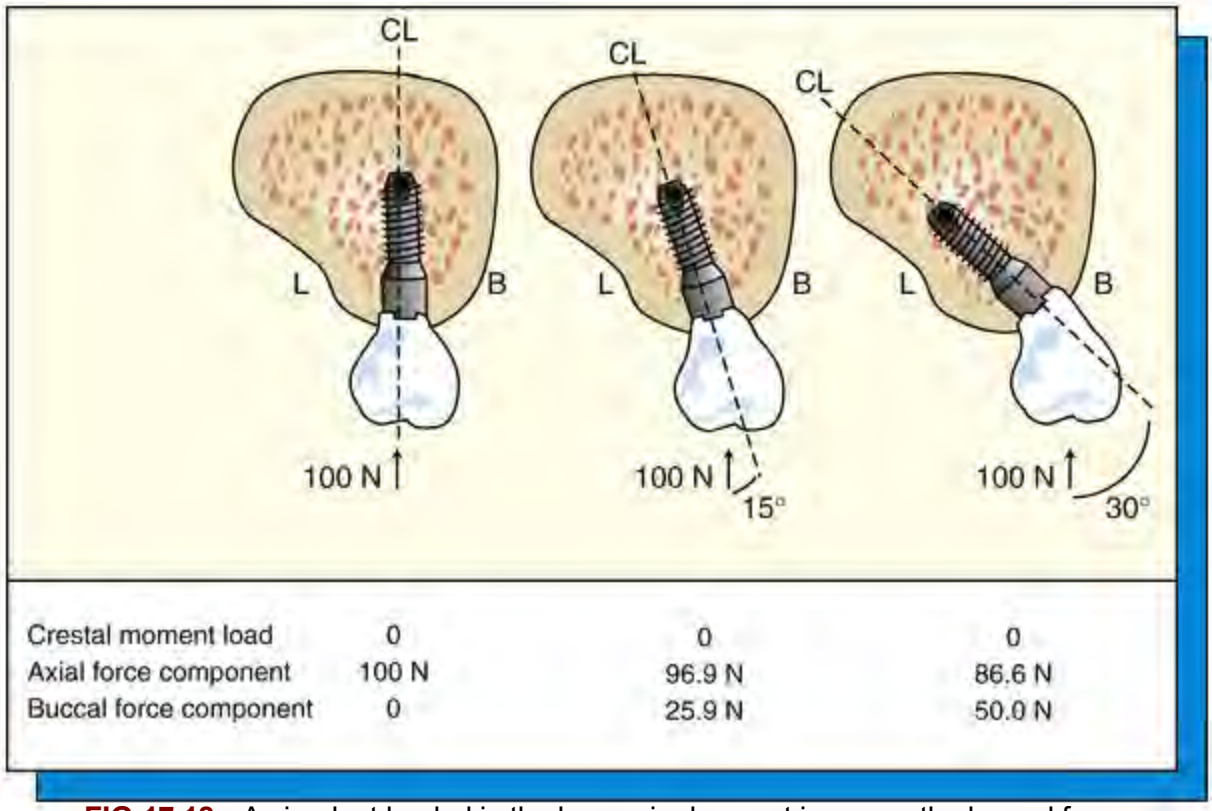

FIG 17.18 An implant loaded in the long axis does not increase the buccal force component of the load *(far left)*. A 15-degree angle increases the buccal force component by 25.9% *(middle)*. A 30-degree angle load increases the force by 50%. When the forces are applied along the long axis of an implant body, stresses are concentrated on the crestal region *(far left)*. The intensity of the stress is not increased as a result of the position of the implant. The implant body in the center is 15 degrees off the long axis. With an angled abutment of 15 degrees, the implant restoration is similar to the previous situation. However, now 25.9% greater stress is on the crestal bone; all other factors are similar. The implant body on the far right is 30 degrees off the long-axis load. With a 30-degree angled abutment, the crown may appear similar. However, the abutment screw, abutment-implant connection, and implant-bone interface are subject to a 50% increase in stress on the facial aspect of the system. *B,* Buccal; *CL,* Crown long axis; *L,* Lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prevention.

The clinician should always adhere to the ideal implant positioning principles as discussed in Chapter 6 to prevent poor force distribution. Ideally, dental implants should be placed perpendicular to the curve of Spee and the curve of Wilson. This will minimize the possibility of angled forces, which may lead to force-related bone loss and component failure.

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Additionally, implants should be placed parallel to the adjacent natural tooth root with ideal spacing (i.e., 3.0 mm between implants and >1.5 mm from adjacent tooth). The possible exception to this rule is the mandibular posterior area because of the curvature of the mandible (i.e., mandibular first molar replacement should bisect the long axis of the second premolar and second molar) (Fig. 17.19).

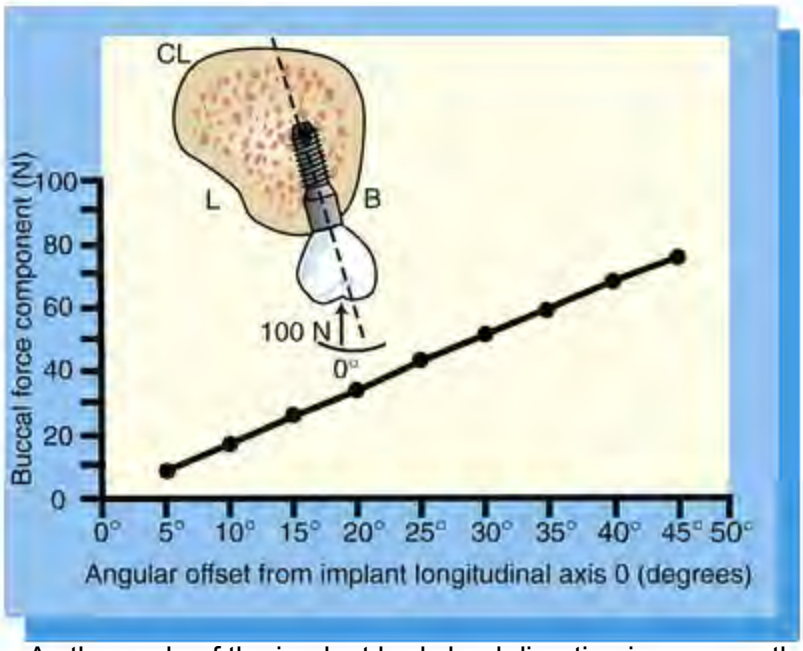

FIG 17.19 As the angle of the implant body load direction increases, the stresses to the entire crown implant-bone system increase. *B,* Buccal; *L,* lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Postimplant Occlusal Principles

No Premature Contacts/Hyperocclusion on Implant Prostheses

A premature contact occurs when an occlusal contact on closure interferes with the normal movement and positioning of the mandible. Studies have shown that premature contacts may cause bone loss or implant failure.[6,46]

Etiology.

A fundamental biomechanical formula is stress equals force divided by the area over which the force is applied (S = F/A).[41] During either maximum intercuspation or CO, no occlusal contacts should be premature, most importantly on implant-supported crowns or prosthesis. Premature occlusal

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contacts often result in localized lateral loading of the opposing contacting crowns.

The surface area of a premature contact is usually minute; however, the magnitude of stress to the bone will increase proportionately (i.e., S = F/A). When a premature contact occurs, the occlusal force will be applied to one region rather than being shared by several abutments and teeth. In addition, because the premature contact is most often on an inclined plane, the horizontal component of the load increases the shear crestal stresses and the overall amount of stress to the entire implant system. The implant system (occlusal porcelain, abutment screw, and cement retaining the crown) is at increased risk because shear loads increase the possibility of complications.

This is a general criterion for natural teeth, but the concept is much more important on implant prostheses with their higher impact force and less occlusal awareness for the several reasons previously addressed. Miyata et al[47] evaluated premature contacts on implant crowns in monkeys *(Macaca fascicularis)*. The crestal bone was histologically evaluated on implant crowns with 100 μm, 180 μm, and 250 μm of premature contacts for 4 weeks.[48] The crowns with 100-μm premature contacts had little bone changes. The 180-μm group demonstrated a V-shaped pattern of bone loss for several millimeters. The 250-μm implant crowns had a large V-shaped defect around the implants for 4 weeks that extended for more than two-thirds of the implant body (Fig. 17.20).

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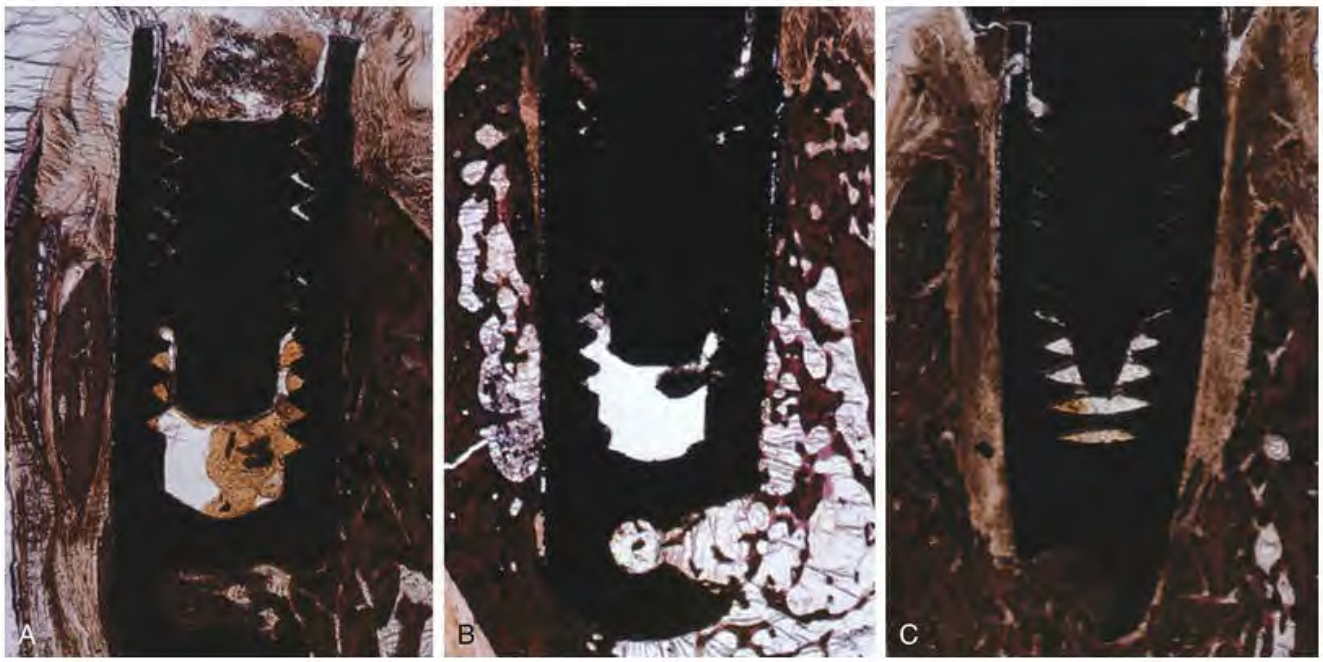

FIG 17.20 (A) An implant crown with 100-μm premature contact for 4 weeks displayed little crestal bone change. (B) An implant crown with a 180-μm premature contact for 4 weeks had 2–3 mm of crestal bone loss. (C) An implant crown with 250-μm premature contact for 4 weeks had marginal bone loss of more than two-thirds of the implant length. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Isidor[9] evaluated excessive premature contacts on implants in monkeys over a 20-month period on eight integrated implants. Implant failure occurred in six of eight implants between 2 and 14 months. The implants that did not fail had greater bone density and crestal bone loss with osteoclastic activity within the threads of the implants (Fig. 17.21). The premature contact on an implant system contributes to a higher risk of early abutment screw loosening, porcelain fracture, early loading failure, and crestal bone loss (Fig. 17.22).

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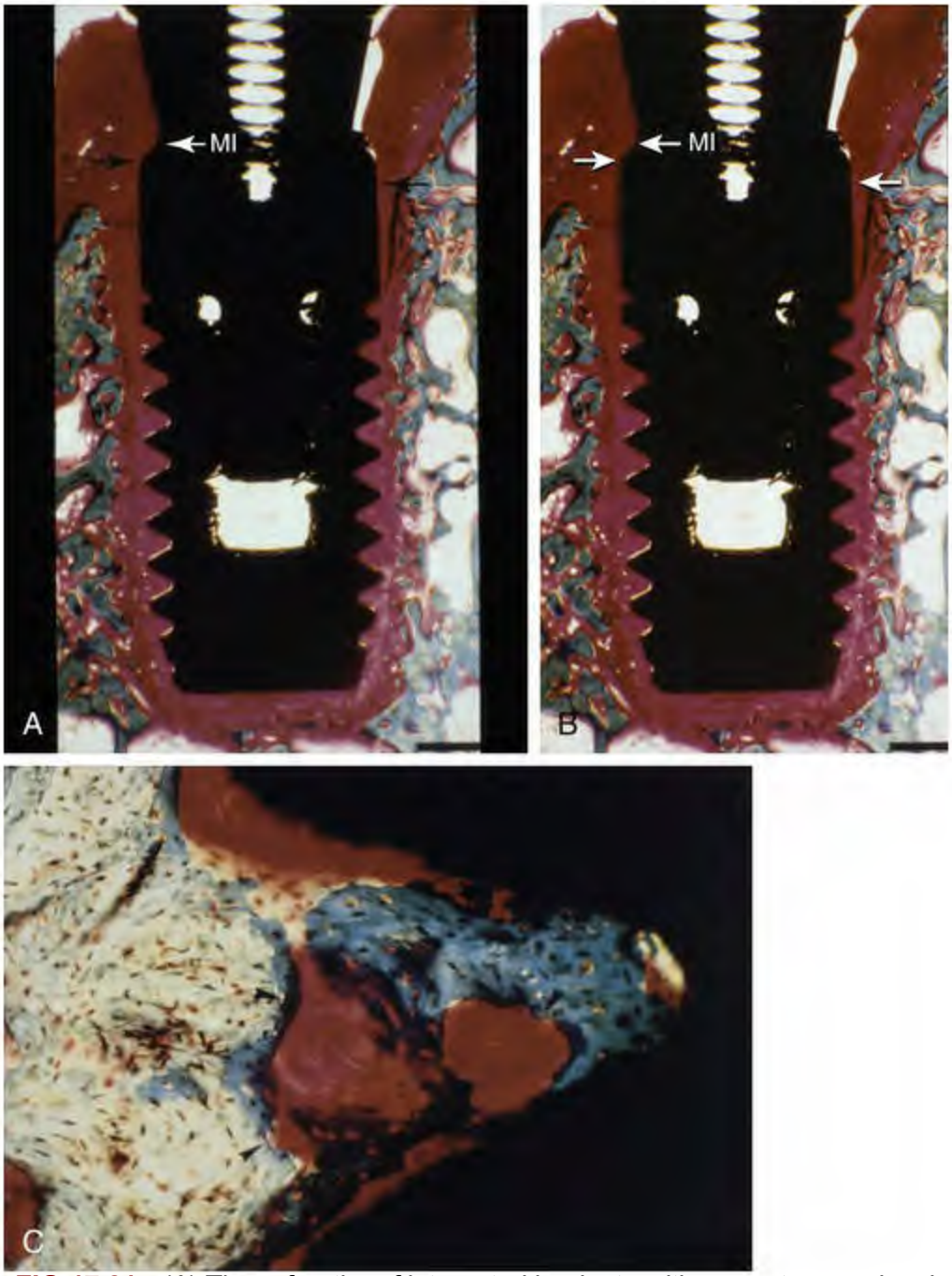

FIG 17.21 (A) Three-fourths of integrated implants with premature occlusal contacts failed 2 to 14 months after loading. (B) The implants that did not fail had crestal bone loss. (C) The implants that did not fail had osteoclastic activity within the threads. (From Isidor R: Histological evaluation of peri-implant bone at implants subjected to occlusal overload or plaque accumulation, *Clin Oral Implants Res* 8:1–9, 1997.)

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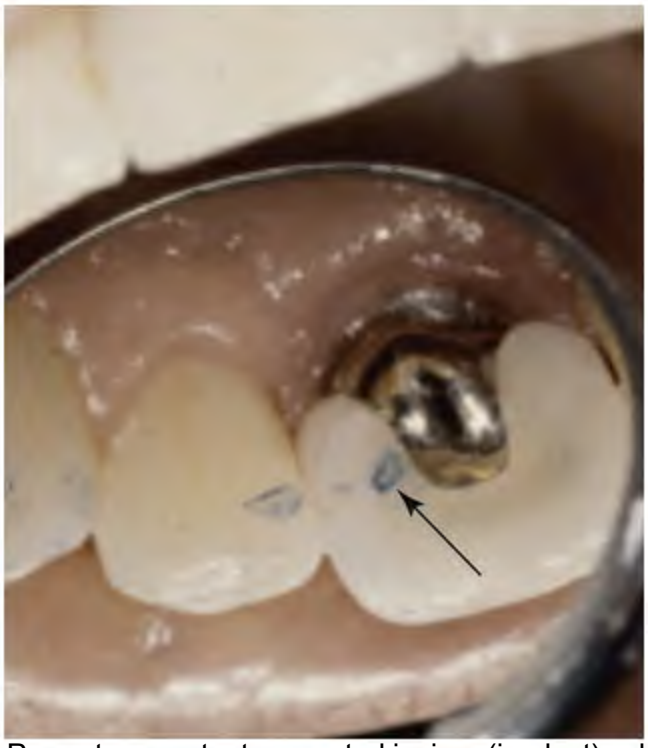

FIG 17.22 Premature contact on central incisor (implant), which is more susceptible to increased biomechanical stress at the implant crest because of increased horizontal movement of the natural teeth.

Prevention.

The elimination of premature occlusal contacts is especially important when habitual parafunction is present because the duration and magnitude of occlusal forces are increased. The elimination of premature contacts is more critical with dental implants because of the lack of proprioception and the inability of the implant to move and dissipate the forces. With the natural dentition and its increased proprioception, an initial premature occlusal contact on a tooth often affects the closure of the mandible to result in an MI position different from CO. A premature contact on an implant crown does not benefit from such protective features; as a result, the implant system is at increased risk. Occlusal evaluation in CO and MI and adjustment as necessary in partially edentulous implant patients are more critical than in natural dentition because the premature contacts can result in more damaging consequences on implants compared with teeth.[49]

Additionally, occlusal contacts should allow for a wide freedom (1.0–1.5 mm) in centric relation and MI position. This will minimize the possibility of premature contacts and allow for a more favorable force distribution.[50]

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Timing.

The occlusal contact in CO on implant prostheses with adjacent natural teeth requires a reduced initial mechanical load on the implants. The most common method an implant clinician uses to determine the timing of occlusal contacts at the implant prosthesis delivery is to ask the patient, "How does the bite feel? Is the crown too high?" This is not the ideal technique to ascertain the ideal occlusion for the patient. Jacobs and van Steenberghe[51] evaluated occlusal awareness by the perception of an interference. When natural teeth oppose each other, an interference is perceived at approximately 20 μm.[39] An implant opposing a natural tooth detects an interference at approximately 48 μm; therefore, it is more than twice as poor. An implant crown opposing an implant crown perceives the interference at 64 μm, and when a tooth opposes an implant overdenture, the awareness is 108 μm (five times poorer than teeth opposing each other). Mericske-Stern et al[52] measured oral tactile sensitivity with steel foils. The detection threshold of minimal pressure was significantly higher on implants than on natural teeth (3.2 foils vs. 2.6 foils). Similar findings were reported by Hämmerle et al[34] in which the mean threshold value for implants (100.6 g) was 8.75 times higher than that of natural teeth (11.5 g). The use of subjective questions (e.g., "How does the bite feel?"; "Is the implant crown high?") is a poor indicator for hypercontacts compared with a crown on a natural tooth. As a consequence of decreased quantity and quality of occlusal awareness, a premature occlusal contact may remain on an implant crown after occlusal adjustment.

The procedure to obtain ideal contact is as follows (Fig. 17.23):

1. Patient bites into centric relation with a very light force. An extra thin articulating paper (<10 μm shimstock) is used, and any contact on the implant is removed. The patient should be able to bite lightly and the shimstock removed unobstructed. GOAL: Natural tooth to take the greater force so this will coincide with the PDL being compressed.

2. The patient is then instructed to bite with heavy force; the shimstock should be placed between the implant prosthesis and opposing dentition with difficulty in removal. GOAL: The heavy force exerted equals the compression of the PDL, resulting in an even contact between the natural tooth and implant.

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3. In patients with parafunctional habits, extra care should be exercised to prevent premature loading of the implant.

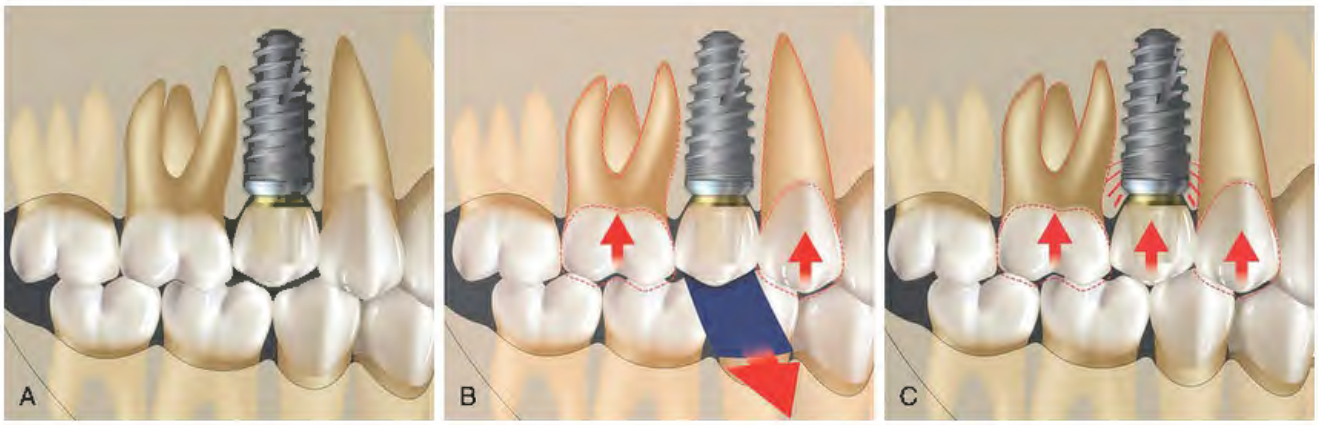

FIG 17.23 Occlusion timing. (A) In light occlusion, no contact should exist on the implant prosthesis as shimstock (approximately 10 µm) is easily pulled through. (B) On heavy occlusion (clenching), the teeth will move apically (periodontal ligament), and the implant crown will have light contact (i.e., shimstock having resistance when pulled through). (C) If implant prosthesis and natural teeth occlude evenly with light occlusion, the implant will be in hyperocclusion and subject to biomechanical overload. (Courtesy Glidewell Dental.)

Clinical significance.

Even though the patient "feels" the occlusion to be ideal, premature contacts may still occur because of the difference in the vertical movement of teeth and implants in the same arch. Ideally, the natural teeth should exhibit greater initial contacts compared with implants through "timed" contacts. When hard or parafunctional bite forces cause depression of the natural teeth, they are closer to the implant, possibly overloading the implant. In cases where implant restorations oppose each other, the implant prostheses must account for the vertical movement of the teeth. An important component of occlusal harmony is the periodic reevaluation of occlusal contacts to ensure longevity and decrease morbidity of the prosthesis (Fig. 17.24).

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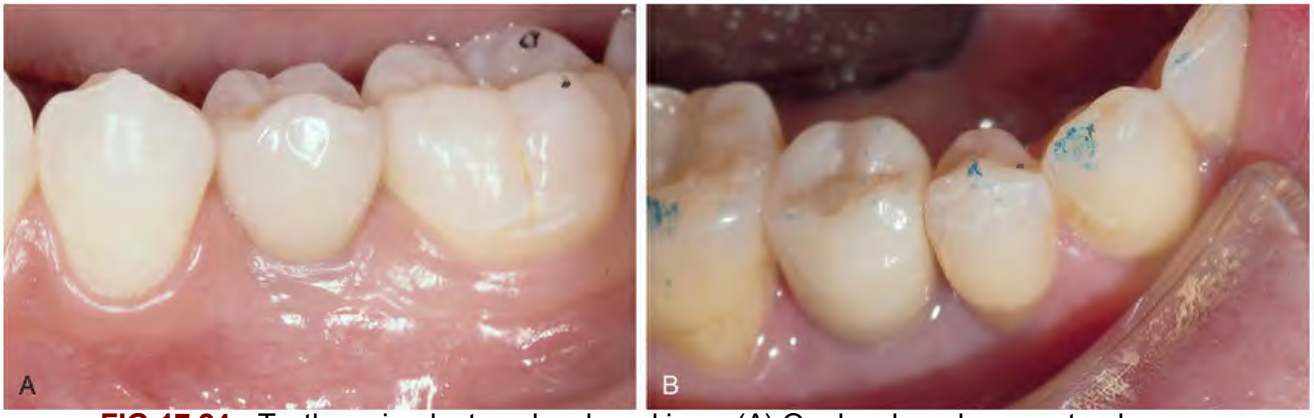

FIG 17.24 Tooth vs. implant occlusal markings. (A) Occlusal marks on natural tooth in light contact, no contact on implant *(second bicuspid)*. (B) Heavy occlusal marks on heavy occlusion *(first bicuspid and first molar)* and minimal markings on implant *(second bicuspid)*.

No Angled Occlusal Loads

Ideally, the implant prosthesis should have no angled occlusal loads. This is based on the anisotropy of bone, which refers to the character of bone whereby its mechanical properties, including ultimate strength, depend on the direction in which the bone is loaded and the type of force applied. For example, studies have shown that the cortical bone of human long bones has been reported as strongest in compression, 30% weaker in tension, and 65% weaker in shear (Fig. 17.25).[53]

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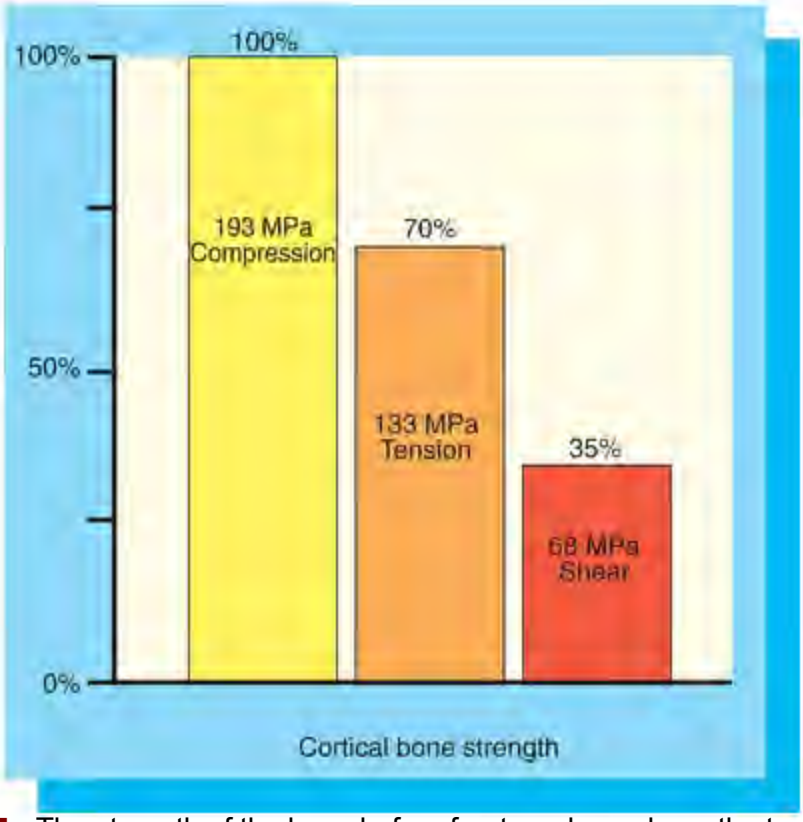

FIG 17.25 The strength of the bone before fracture depends on the type of force applied to the bone. Bone is strongest to compression forces, 30% weaker to tensile forces, and is only 35% as strong to shear loads. Whenever possible, bone should be loaded with compressive loads. (From Misch CE: *Contemporary implant dentistry*, ed 2, St Louis, 2015, Mosby.)

Etiology.

Similar to bone, porcelain, zirconia, titanium components, and cements are also weakest to shear components of a load. The elimination or reduction of all shear loads to the implant system is mandatory because of the inherent weakness of bone, porcelain, titanium components, and cement to shear loads. Occlusal loads applied at an angle to the implant body may be separated into normal (compressive and tensile) and shear forces. As the angle of load to an implant body increases, the amount of compressive and tensile forces is modified by the cosine of the angle. The force is slightly reduced. However, the angled component of force is a shear force, and the shear force is the amount of force times the sine of the load, which considerably increases the load. The force the bone observes is the sum of the compressive, tensile, and shear forces. For example, a 100-N force applied at 12 degrees off-axis will increase the total force to the bone by 100 N Å~ cosine 12 degrees = 97.81 N + 100 N Å~ sine 12 degrees = 20.79 N. The total

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force is 97.81 N + 20.79 N = 118.60 N (or almost a 20% increase in total force). The greater the angle of load to the implant long axis, the greater the compressive, tensile, and shear stresses (Fig. 17.26).

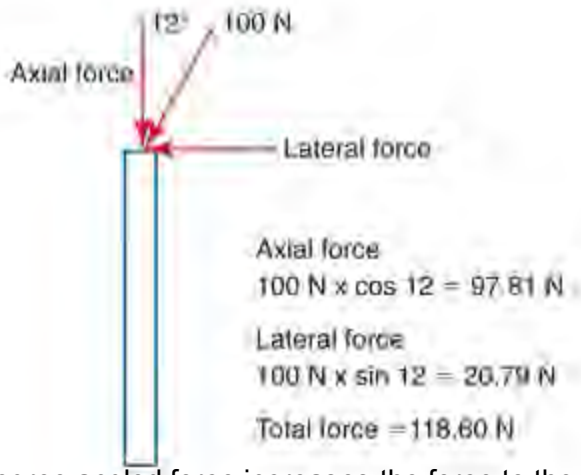

FIG 17.26 A 12-degree angled force increases the force to the implant system by 18.6%. (From Misch CE: *Contemporary implant dentistry,* ed 2, St Louis, 2015, Mosby.)

In finite element analysis, when the direction of the force changes to a more angled or horizontal load, the magnitude of the stress is increased by three times or more.[54,55] In addition, rather than a primarily compressive type of force, tensile and shear components are increased more than ten-fold compared with the axial force. Studies have shown that in a photoelastic block with implants inserted, the strain contours in the bone may be observed (Fig. 17.27). The axial-loaded implants have less strain in the system (left side and lower right of Fig. 17.27). The angled implant has more strain lines indicating greater loads (right upper implant).

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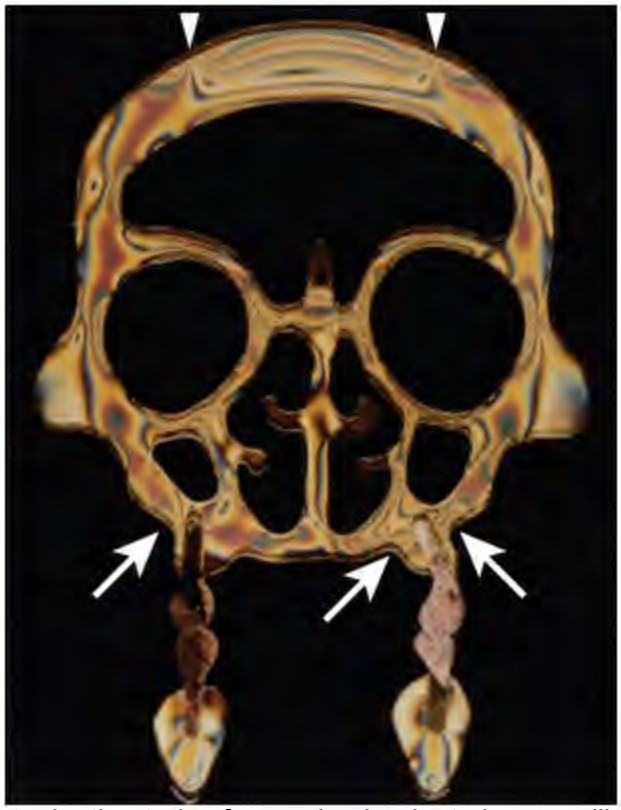

FIG 17.27 A photoelastic study of opposing implants in a maxilla and a mandible. One of the maxillary implant bodies is angled in relation to the direction of load. The number of stress contour lines in the material is similar for the three implants with a long-axis load. The stress contour lines are increased for the angled implant body. (From Misch CE: *Contemporary implant dentistry,* ed 2, St Louis, 2015, Mosby.)

An angled load to the implant long axis increases the compressive forces at the crest of the ridge on the opposite side of the implant, increasing the tension component of force along the same side as the load. The greater the angle of force to the long axis of the implant body, the greater the potentially damaging load at the crest of the bone. For example, three-dimensional finite element analysis demonstrates that a vertical load on an implant with 100% bone contact may have compressive stress of 4000 psi (27.6 MPa) and almost no tensile stress at the bone-implant crest interface.[54] With a load at a 45-degree angle on the same implant design, the compressive stress may increase to 14,000 psi (96.6 MPa), and on the opposite side, tensile stress may increase to 4000 psi (27.6 MPa). The compressive stresses are tripled, and the tensile stress increases 1000-fold with a load from a 45-degree angle.

The stress contours in the bone simulant of the three-dimensional studies resemble the clinical pattern of early crestal bone loss on implants. Not only does the magnitude of stress increase under angled loads, but it also evolves into a more noxious shear component, which is more conducive to bone loss and screw loosening.[56] The greater the angle of the force, the greater the

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shear component. Bone is 65% weaker to shear load. The amount of the force increases, and the strength of the bone decreases. It has been reported that angled occlusal forces decrease the ability of successful bone repair on natural teeth. It may also impair successful bone remodeling around an implant.[57]

Not only is the bone weakest to shear loads, but also forces applied at an angle to the bone further affect the physiologic limit of compressive and tensile strengths of bone. A force applied at a 30-degree angle may decrease the bone tension (Table 17.3). A 60-degree force reduces the strength 30% under compression and 55% under tension. Not only does the crestal bone load increase around the implant with angled forces, but also the amount of stress the bone may withstand (i.e., the ultimate strength) decreases in shear, tension, and compression. The greater the angle of load, the lower the ultimate strength of bone. Therefore, IPO attempts to eliminate lateral or angled loads to an implant-supported prosthesis because the magnitude of the force increases and the strength of the bone decreases. Barbier and Schepers[58] histologically evaluated implants loaded in the long axis vs. off-axis loading in dogs. The long-axis–loaded implants had lamellar bone at the interface. Lamellar bone is mineralized and organized and is called load-bearing bone in orthopedics. The off-axis–loaded implants had woven bone at the interface, which is a weak, embryonic type of bone. It is less mineralized, unorganized, and weaker than lamellar bone (Fig. 17.28). The greater strains in the bone with off-axis loading may cause the bone to repair and places it at a higher risk of overload and resorption.

TABLE 17.3

Cortical Bone Strength Related to Angle of Load

Type	Strength (mPa)	Direction of Load
Compression	193	Longitudinal
	173	30 degrees off axis
	133	60 degrees off axis
	133	Transverse
Tension	133	Longitudinal
	100	30 degrees off axis
	60.5	60 degrees off axis
	51	Transverse

From Reilly DT, Burstein AH: The elastic and ultimate properties of compact bone tissue, *J Biomech* 80:393–405, 1975.

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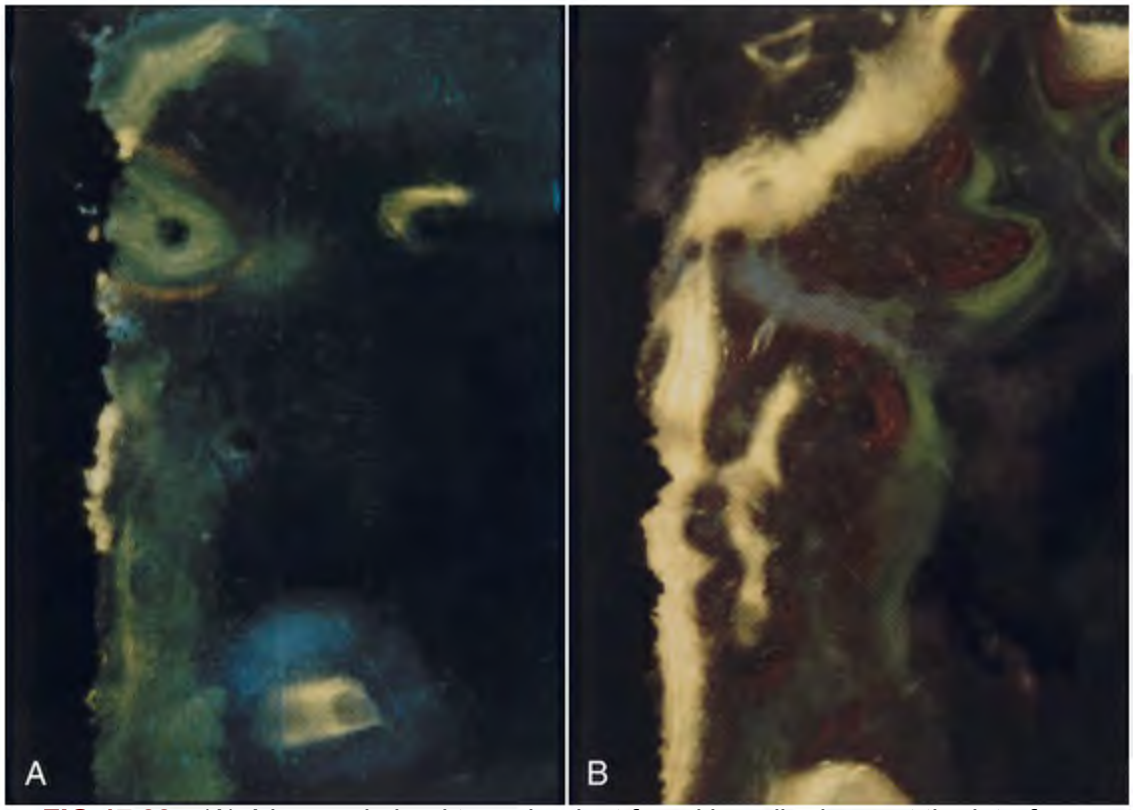

FIG 17.28 (A) A long-axis load to an implant found lamellar bone at the interface. (B) An off-axis load to an implant found woven bone (bone of repair) at the interface, indicating higher strain conditions than ideal. (From Barbier L, Schepers E: Adaptive bone remodeling around oral implants under axial and nonaxial loading conditions in the dog mandible, *Int J Oral Maxillofac Implants* 12:215–223, 1997.)

The microstrain of the crestal bone is increased with an angled load and may shift from an axial load within physiologic limits to an angled load in the pathologic overload zone and, as a consequence, result in bone loss. The greater force, especially in shear, is generated to the entire implant system. The occlusal porcelain is weaker to shear and may fracture, the cement that retains the prosthesis is weakest to shear and may become unretained, the abutment screw more likely becomes loose with shear loads, the crestal bone region may resorb, and implant components fracture more often with higher shear loads. When shear forces are increased with an angled load to the implant system, an attempt should be made to reduce the negative effect of angled loads.[59]

Clinical significance.

The primary component of the occlusal force should be directed along the long axis of the implant body, not at an angle or following an angled abutment post (Fig. 17.29). Angled abutments should be used only to improve the path of insertion of the prosthesis or improve the final esthetic

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result. The angled abutment, which is loaded along the abutment axis, transmits a significant moment load (i.e., tending to rotate or rock the implant) to the entire implant system.

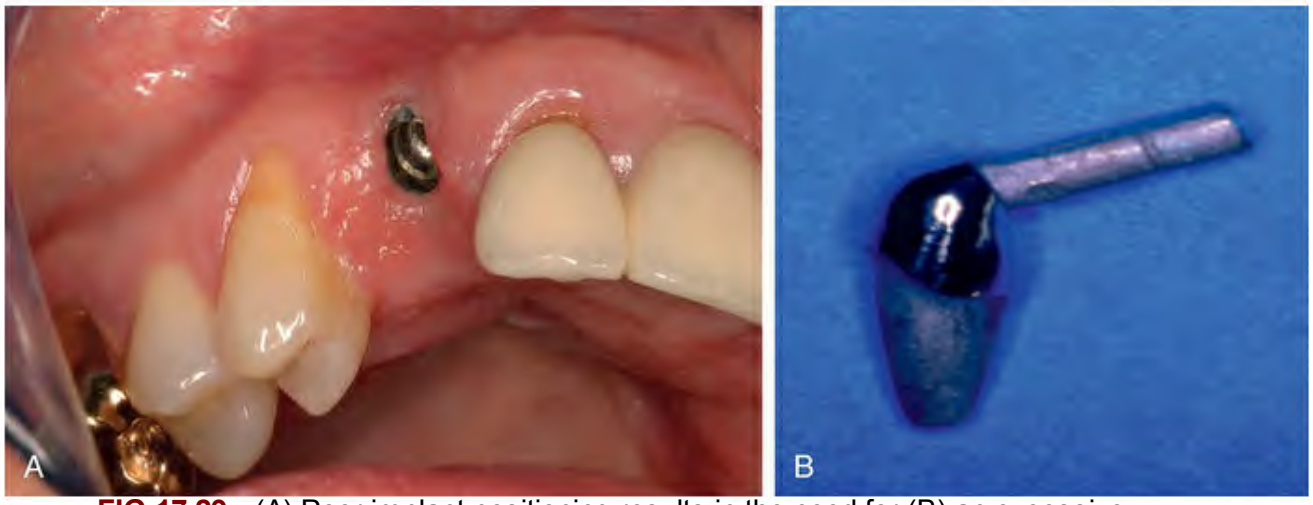

FIG 17.29 (A) Poor implant positioning results in the need for (B) an excessive angled abutment (>30 degrees), which is a significant biomechanical disadvantage.

Prosthetic Angled Loads

Etiology.

Greater crestal bone strains with angled forces have been confirmed with photoelastic and three-dimensional finite element analysis methods. Whether the occlusal load is applied to an angled implant body or an angled load (e.g., premature contact on an angled cusp) is applied to an implant body perpendicular to the occlusal plane, the results are similar (Fig. 17.30). Biomechanical risk to the implant system is increased. The implant surgeon may place the implant body ideally, perpendicular to the occlusal plane, but the restoring dentist then may load the implant crown at an angle. Similar noxious forces are increased in shear, and a decrease in bone strength occurs to the crestal bone, along with increase of shear loads on implant components, and the abutment screws. An angled implant body or an angled load on the implant crown increases the amount of crestal stresses on the implant system; transforms a greater percentage of the force to shear force; and reduces bone, porcelain, and cement strength. In contrast, the surrounding implant system stress magnitude is least, and the strength of bone, porcelain, and cement is greatest under a load axial to the implant

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body and perpendicular to the occlusal plane. All these factors mandate the reduction of angled forces to the implant system (Fig. 17.31).

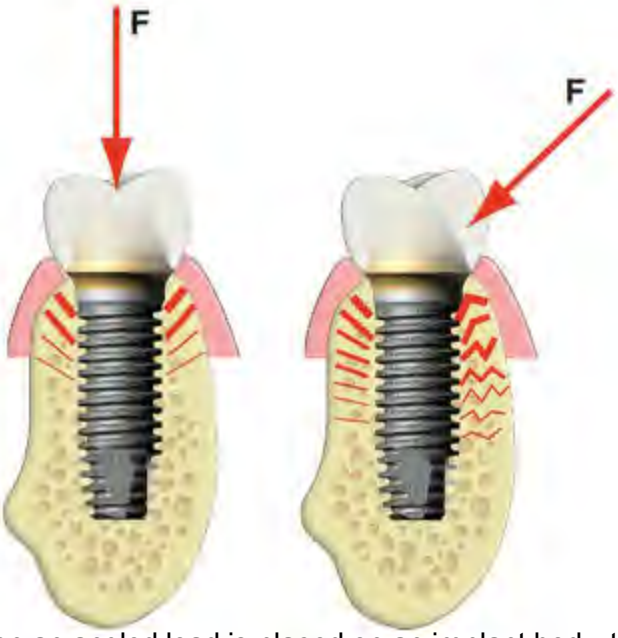

FIG 17.30 When an angled load is placed on an implant body, the compressive stresses on the opposite side of the implant increase, and the tensile and shear loads on the same side of the implant increase. Because bone is weaker to tensile and shear forces, the risks to the bone are increased for two reasons: (1) the amount of the stress increases, and (2) the type of stress is changed to more tensile and shear conditions. *F,* Force. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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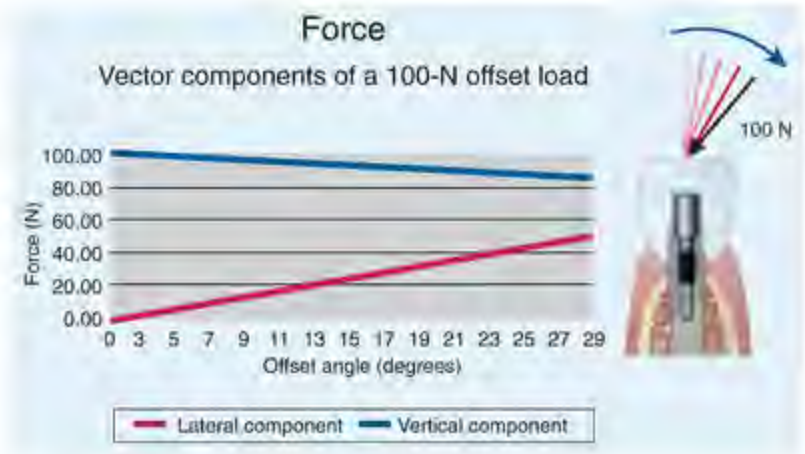

FIG 17.31 The force applied to an implant body with an angled load or angled direction of force is increased in direct relation to the force angle. The major increase of force is a result of the offset angle of the load. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

To decrease the force concentrated to the surrounding bone, the implant should ideally have sufficient surface area to combat the forces. It is well accepted in the literature that implants with decreased surface area that are subject to angled loads are magnified if there is deficient implant surface area.[10,60]

Clinical significance.

Ideally, there should be no clinical nonaxial loading of the implant system. If this cannot be achieved, modifications need to be made such as increased implant number, larger implant diameter (i.e., increased surface area), splinted implants, and a narrow occlusal table. In some cases, the prosthesis may be modified from a fixed to a removable prosthesis to incorporate increased soft tissue support to share the distribution of forces.

Management: Angled Loads.

Most implant bodies inserted at an angle of greater than 12 degrees to the occlusal plane require an angled abutment. The implant clinician should understand that angled abutments are fabricated in two pieces and are weaker in design than a two-piece straight abutment without an angle. Because less metal surrounds the abutment screw on one side of an angled abutment, it is at more risk of fracture or is less able to be reduced in width for ideal crown contours. Furthermore, a larger transverse load component develops at the abutment screw and crest of the ridge as a result of angled loads and increases the risk of abutment screw loosening. In a study by Ha et

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al,[61] the angled abutment was compared with a straight abutment for screw loosening in the anterior maxilla. The angled abutments showed more screw loosening with cyclic loading than the straight abutments.

Surgical Management.

When lateral or angled loads cannot be eliminated, a reduction in the force magnitude or additional surface area of implant support is indicated to reduce the risk of biomechanical complications to the implant system. For example, if three adjacent implants are inserted with the first implant in the long axis to the load, the second at 15 degrees, and the third at 30 degrees, the implant clinician may decrease the overall risk by (1) adding an additional implant in the edentulous space next to the most angled implant, (2) increasing the diameter of the angled implants, or (3) selecting an implant design with greater surface area. Of the three options, increasing the implant number is most effective to reduce overall stress to the system. In addition, a greater number of implants has more retention for the restoration and greater surface area.[62]

Prosthetic Management.

The restorative clinician may reduce the overload risk by (1) splinting the implants together, (2) reducing the occlusal load on the second implant and further reducing the load on the third implant, and (3) eliminating all lateral or horizontal loads from the most angled implant and completely eliminating them in all posterior regions.

The anterior mandible (with a force magnitude similar to the anterior maxilla) often has the implant body positioned perpendicular to the occlusal plane and restored with a straight abutment. In the anterior maxilla, even under ideal conditions, the implant should be angled away from the labial bone, which results in the abutment being angled toward the facial crown contour. An angled prosthetic abutment is required, and these implant bodies are more frequently loaded at an angle. Maxillary anterior teeth are usually loaded at a 12- to 15-degree angle to the occlusal plane (Fig. 17.32).

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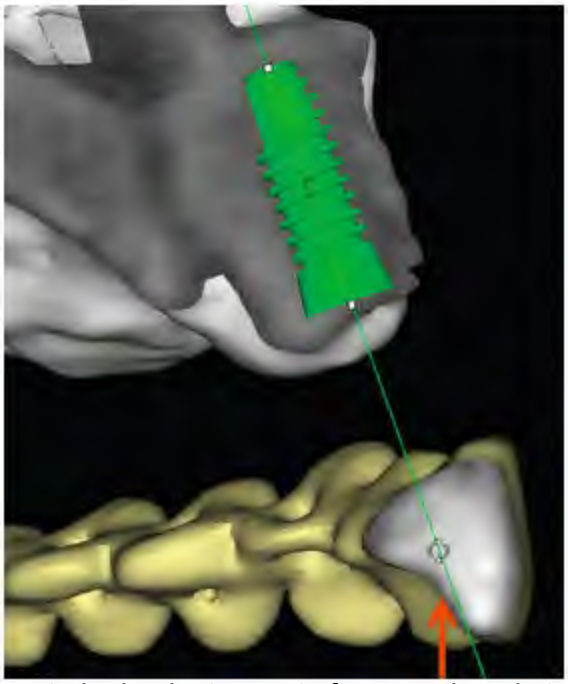

FIG 17.32 Maxillary anterior implants most often are placed at an angled load to the lower anterior teeth. As a result, the amount of the load should ideally be reduced. Clenching patients may develop a considerable anterior bite force. Occlusal contact reduction, larger diameter implants, increasing implant number, splinting implants, and night guards are possible solutions.

The natural dentition reduces the increased stress to the maxilla by increasing the size of the roots compared with mandibular incisors and increasing the mobility of the teeth. In the maxilla, a larger diameter implant or a greater number of implants are indicated to minimize the crestal bone stress on each abutment, especially in patients exhibiting severe bruxism. Ridge augmentation may be necessary before implant placement to improve implant position or facilitate the use of a wider diameter implant. IPO aims at reducing the force of occlusal contacts, increasing the implant number, or increasing the implant diameter for implants subjected to angled loads.

Shallow Anterior Guidance

With healthy natural anterior teeth, apical and lateral movements are significantly larger compared with implant movements, with a larger difference being seen for the lateral movements. Because the differences in lateral movement are greater, this allows for occlusal adjustment. As most ideal occlusal schemes with natural teeth suggest, the anterior teeth disocclude the posterior teeth during eccentric excursion. This is based on the concept of electromyographic studies, which show that the stomatognathic system elicits significantly less force when the posterior

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segments are not in contact in the lateral mandibular position.[63] Other studies have shown that for every 10-degree change in the angle of disclusion, there is a 30% difference in load (Fig. 17.33).[64]

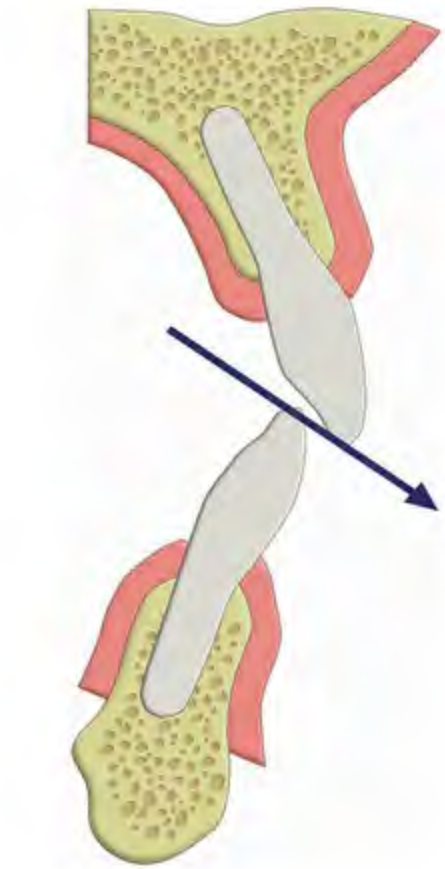

FIG 17.33 The incisal guidance for a patient with moderate to severe bruxism should be shallow (but steeper than the angle of the eminentia of the joint) to reduce the force on the anterior teeth during excursive movement of the mandible. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

If healthy anterior teeth or natural canines are present, the mutually protected occlusion scheme allows those teeth to distribute horizontal (lateral) loads during excursions, while the posterior teeth disocclude during excursions (e.g., canine guidance or mutually protected articulation) (Fig. 17.34). The posterior teeth are protected from lateral forces by the anterior guidance during excursions, and the anterior teeth have lighter forces in excursions because the posterior teeth do not contact.

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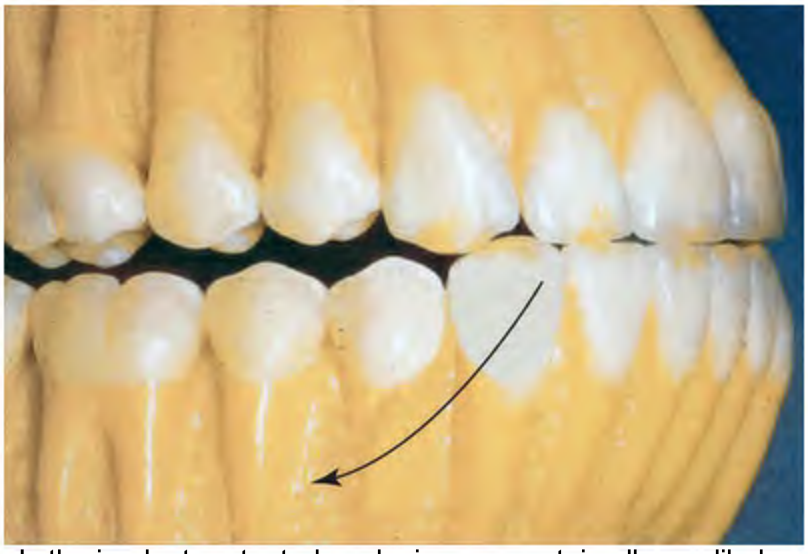

FIG 17.34 In the implant protected occlusion concept, in all mandibular excursions, the anterior teeth should disocclude the posterior teeth. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

When lateral or angled forces are applied to the anterior teeth, the magnitude of the stress is increased. However, when mutually protected occlusal philosophies are applied, the consequences of the lateral forces are reduced. The mutually protected articulation concept is used in the implant-protected concept. In protrusive mandibular movements, the central and lateral incisors disocclude the posterior teeth. In lateral excursions, the canine (and lateral incisor when possible) disocclude the posterior teeth. In CO, the posterior and canine teeth occlude. When the central and lateral incisors are natural, they may also occlude in CO (or MI). When the anterior teeth are implants, they may not occlude in centric occlusion, especially when the opposing dentition is also implant supported.

Group function (or unilateral balance) has been suggested with periodontal bone loss on the remaining teeth. The concept in theory is to allow for the sharing of lateral loads during excursions with more teeth. For example, with this philosophy, a mandibular excursion to the right contacts as many anterior and posterior teeth on the right as possible. This is not indicated in implant-protected occlusion. The lateral posterior forces increase the moment loads to posterior implants. The posterior contacts during excursions also have greater forces to the posterior implants because more muscle mass contracts, and the occlusal contacts are closer to the TMJ (class 3 lever). In addition, the posterior lateral loads increase the force to the anterior teeth or implants during the excursions. As a result, both the anterior and the posterior implant components receive a greater force (Fig. 17.35).

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FIG 17.35 (A) This patient was restored in group function. (B) Posterior maxillary right two implants fractured. (C) Posterior mandibular right two implants fractured. (D) The maxillary anterior implants lost integration. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In a study by Jemt et al,[11] when implant-supported restorations were used in the maxilla opposing natural dentition, the velocity of the mandible during excursions was greater with group function than when incisal guidance was present. The force to the implant system was greater with group function. Kinsel and Lin[65] reported that group function in patients with implant-supported prostheses had a porcelain fracture rate of 16.1% and occurred in 51.9% of implant patients. When anterior disclusion was the occlusal scheme in excursions, the fracture rate on implant crowns was 5.3%, and this complication affected 15.9% of patients (more than a threefold difference).

The steeper the incisal guidance, the greater the force on the anterior teeth or implants. The anterior guidance of an implant prosthesis with anterior implants should be as shallow as practical. According to Weinberg and Kruger,[64] for every 10-degree change on the angle of disclusion, there is a 30% difference in load (Fig. 17.36). A 10-degree force on the anterior implants with a 68-psi load will increase to 100 psi when the incisal guidance is 20 degrees and will further increase to 132 psi if the incisal guidance is 30 degrees. As a

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consequence, the impression by these authors is that the incisal guidance should be less than 20 degrees. However, because the condylar disc assembly is usually 20–22 degrees, the incisal guidance should be greater than this amount to separate the posterior teeth.[40] When the incisal guidance is less than the angle of the eminentia of the TMJ, the posterior teeth will still contact in excursions. In most patients, an incisal guidance of at least 23–25 degrees is suggested in IPO.

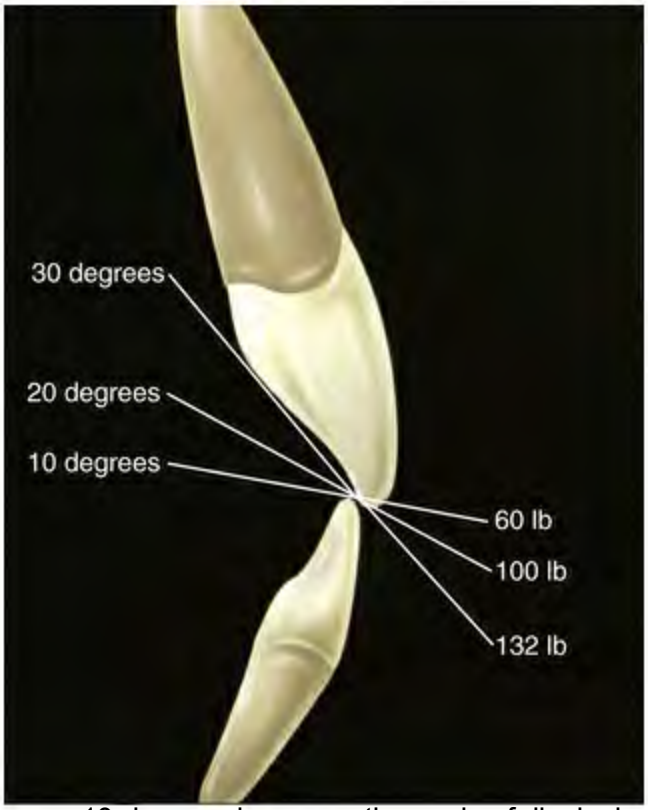

FIG 17.36 For every 10-degree change on the angle of disclusion, there is a 30% difference in load. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

The increase in load that occurs from the incisal guidance angle is further multiplied by the crown height above the initial occlusal contact (the vertical overbite) because it acts as a lever arm while the mandible slides down the incline plane (Fig. 17.37). An ideal vertical overbite in prosthetics has been reported to be 5 mm and often is more, especially in Angle Class II, division II patients. However, especially in parafunctional patients, incisal guidance should be as shallow as possible in implant prostheses (23–25 degrees) and the vertical overbite reduced to less than 4 mm, yet the posterior teeth should disocclude in the excursions (Figs. 17.38 and 17.39).

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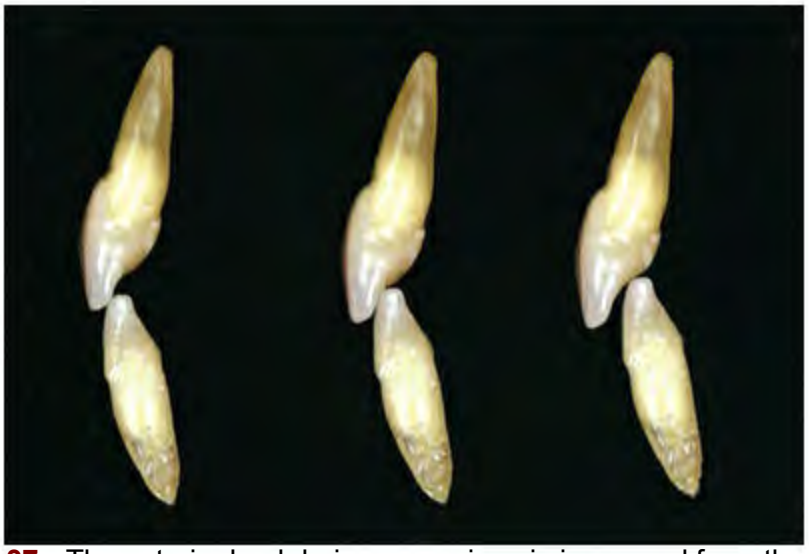

FIG 17.37 The anterior load during excursions is increased from the centric occlusal contact *(far right)* to the incisal edge *(far left)*. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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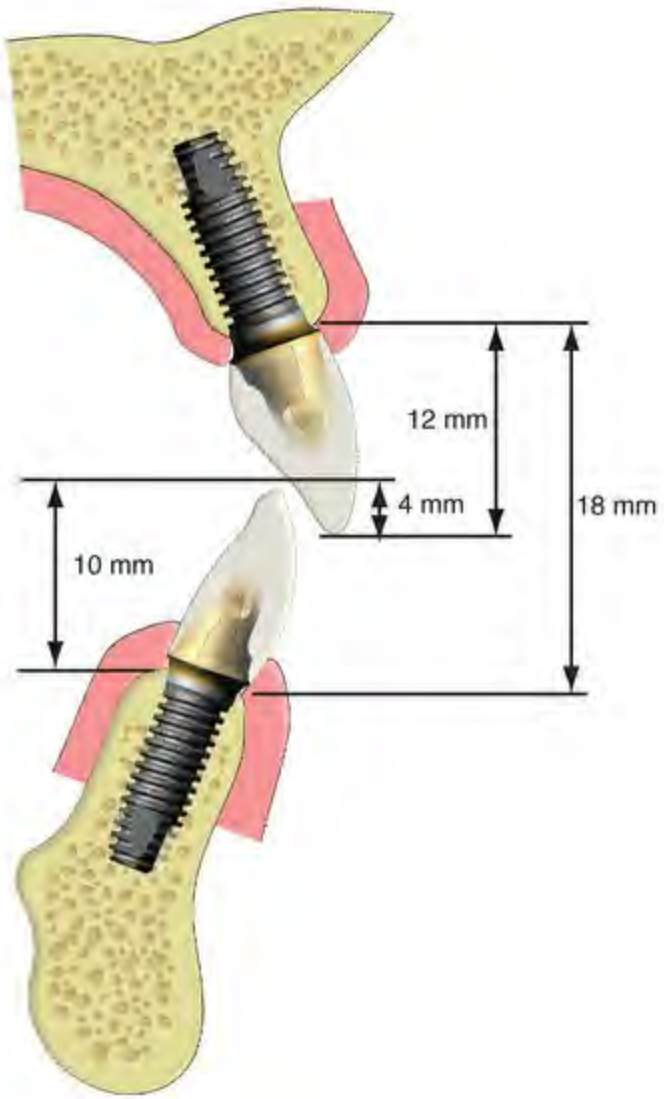

FIG 17.38 The vertical overbite in the implant prosthesis should be reduced to 4 mm or less. When implants oppose each other, there is no occlusal contact between the canines in centric occlusion. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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FIG 17.39 (A) Full-arch maxillary and mandibular implant prosthesis with a vertical overbite of 3 mm. (B) The incisal guidance is 25 degrees, so the posterior teeth separate in any mandibular excursion. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Cuspid Implant.

A clinical condition that sometimes causes confusion is the occlusal scheme for a single-tooth implant replacing a maxillary canine. A missing maxillary canine is indicated for a single-tooth implant crown. The lateral incisor is the weakest anterior tooth, and the first premolar is often the weakest posterior tooth. These abutments are not great candidates for a three-unit prosthesis, especially because lateral forces would be placed on the premolar.

The proprioceptive mechanism of the natural canine in excursions blocks approximately two-thirds of the activity of the masseter and temporalis muscles and decreases the bite force when posterior teeth disocclude.[63] An anesthetized canine has more muscle mass that contracts both in clenching and in the lateral excursion compared with the same patient before anesthesia.[66] The natural canine PDL nerve complex helps decrease the force in excursions. The anesthetized natural canine has been compared with the proprioception of an implant.[67] Proprioception is transmitted through the bone from an implant but in a reduced amount compared with a natural tooth. A mutually protected occlusion is still a benefit when a single-tooth canine implant is restored. In other words, a greater decrease in lateral forces occurs when a natural anterior tooth root is involved in the excursion compared with an implant crown, but an implant crown also can decrease the force and is better than a pontic in the canine position. In addition, the class 3 lever mechanism of the canine position still is able to reduce the force in excursions when the posterior teeth do not contact.

No occlusal contact occurs on the single-tooth canine implant crown

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during mandibular excursions to the opposite side. During protrusion, no contact on the canine implant crown is ideal. If a contact is necessary, it is adjusted so that a light bite force has no occlusal contact on the implant crown. Under a heavy bite force in protrusive movements, the canine implant crown may contact.

The occlusion during the working excursion toward the canine implant crown is of particular concern. The dentist should make an attempt to include a natural tooth in the lateral excursion because teeth have greater proprioception than implants. To create a mutually protected articulation scheme that includes a lateral incisor is preferable because this tooth is farther from the TMJ. With a light working lateral excursion, the lateral incisor occludes first and moves 97 μm (when in health), and then the canine implant crown engages and helps disocclude the posterior teeth. During a heavy bite force excursion, the lateral incisor and implant crown contact with similar magnitude (Fig. 17.40). However, in Angle Class II, division I patients, the first premolar may need to be included in the excursion process, rather than the lateral incisor because the horizontal overjet may be excessive.

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FIG 17.40 (A) A maxillary right canine is replaced with an implant. This patient is an Angle Class II, division 2 patient and has a deep vertical overbite. A steep incisal guidance places greater force than a shallow incisal guidance, which may be why the canine tooth fractured after endodontic therapy. (B) The right mandibular excursion is evaluated first with a light and then a heavy bite force. Ideally, the lateral incisor should contact first and then the canine. The first premolar contact should be eliminated to decrease the force to the implant. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Clinical significance.

All lateral excursions in the concept of implant-protected occlusion opposing fixed prostheses or natural teeth use anterior teeth or implants whenever possible to disocclude the posterior components. The resulting lateral forces are distributed to the anterior segments of the jaws, with an overall decrease in force magnitude. This occlusal scheme should be followed whether or not anterior implants are in the arch. However, if anterior implants must disocclude posterior teeth, natural teeth (whenever possible) are first used

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during the initial primary tooth movement. When multiple anterior teeth are missing, two or more implants splinted together (when possible) should help dissipate the lateral forces. The anterior guidance of implant-supported prostheses should be as shallow as possible to minimize forces on the anterior implants.

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Decreased Posterior Crown Cusp Angle

The angle of force to the implant body may be influenced by the cusp inclination of the implant crown in similar fashion as an angled load to an implant body. The posterior natural teeth often have steep cuspal inclines, and 30-degree cusp angles have been designed in denture teeth and natural tooth prosthetic crowns (Fig. 17.41). The greater cusp angles are often considered more esthetic and may even incise food more easily and efficiently.[68] To negate the negative effect of an angle cusp contact, the opposing teeth need to occlude at the same time in two or more exact positions on the ipsilateral cusp angles of the crowns, which is highly unlikely to be achieved in a clinical setting (Fig. 17.42).

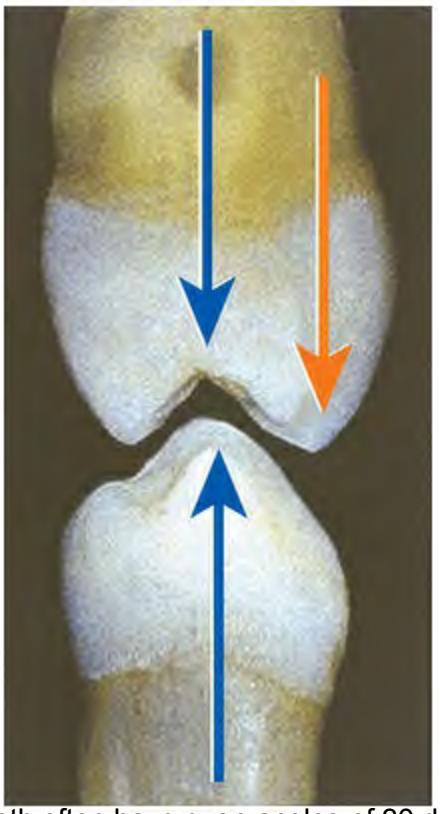

FIG 17.41 Natural teeth often have cusp angles of 30 degrees. If a premature contact occurs on a cuspal incline, the direction of load may be 30 degrees to the implant body if the implant crown duplicates a natural tooth cusp angle. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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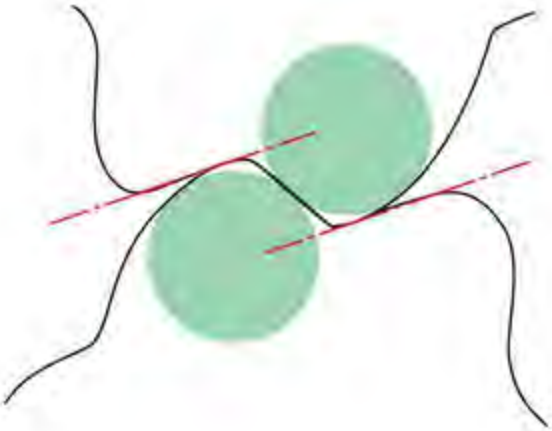

FIG 17.42 When opposing crowns occlude, the three cuspal inclines must hit at the same time to result in a long-axis load. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The occlusal contact along only one of the angled cusps results in an angled load to the implant system even when it is not premature to other occlusal contacts (Fig. 17.43). The magnitude of the force is minimized when the angled occlusal contact is not a premature contact but instead is a uniform load over several teeth or implants. However, the angled cusp load does increase the resultant tensile and shear stress with no observable benefit. No advantage is gained, but the biomechanical risk is increased (e.g., increased abutment screw loosening, porcelain fracture, unretained restoration).

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FIG 17.43 The mandibular buccal cusp incline is occluding with the lingual incline of the maxillary cusp. An occlusal contact on a cusp angle transmits an angled load to the implant body. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Occlusal contact position determines the direction of force, especially during parafunction. A cantilevered load is a force applied on the mesial or distal from the implant, which acts as a fulcrum. An offset load is a force applied to the buccal or lingual and increases the stress to the implant system. An occlusal contact on a buccal cusp of a mandibular premolar and molar or lingual cusp in the maxilla is usually an offset load when the implant is positioned under the central fossa because the occluding cusp is cantilevered from the implant body (Fig. 17.44). In addition, the angle of the cusp tip introduces an angled load to the implant body.

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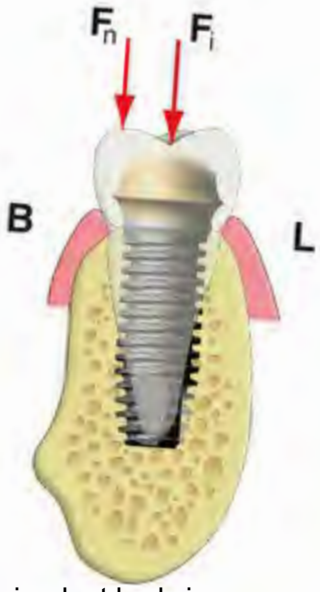

FIG 17.44 An offset load to the implant body increases the stress to the implant system. A buccal cusp occlusal contact in the posterior mandible or lingual cusp contact in the maxilla is an offset load to the implant. *B,* Buccal; F_i, central fossa contact; F_n, buccal cusp contact; *L,* lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Studies have investigated various occlusal designs and bone remodeling. When evaluating cusp inclinations (0, 10, and 30 degrees) and loading locations (central fossa, 1- and 2-mm offsets horizontally), the load concentration was mainly at the crestal part of the implant system. The load concentration increased with steeper cuspal inclinations and broader occlusal tables. This increased shear stress, which can potentially lead to damage of the bone-implant interface and progressively induces micromotion.[14] A more concentrated central fossa loading with a narrow occlusal table is ideal.[69,70]

Prevention.

The occlusal contact over an implant crown should ideally be on a flat surface perpendicular to the implant body. This occlusal contact position usually is accomplished by increasing the width of the central fossa to 2–3 mm in posterior implant crowns, which is positioned over the middle of the implant abutment. The opposing cusp is recontoured to occlude the central fossa of the implant crown directly over the implant body (Fig. 17.45). The laboratory technician should identify the middle of the implant body and then make a central fossa 2–3 mm wide over this position parallel to the curves of Wilson and Spee (Fig. 17.46). The buccal and lingual contour of the crown may then be established (reduced on the buccal for the posterior mandible and the

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lingual for the posterior maxilla). The opposing tooth may require recontouring of an opposing cusp to help direct the occlusal force along the long axis of the implant body.

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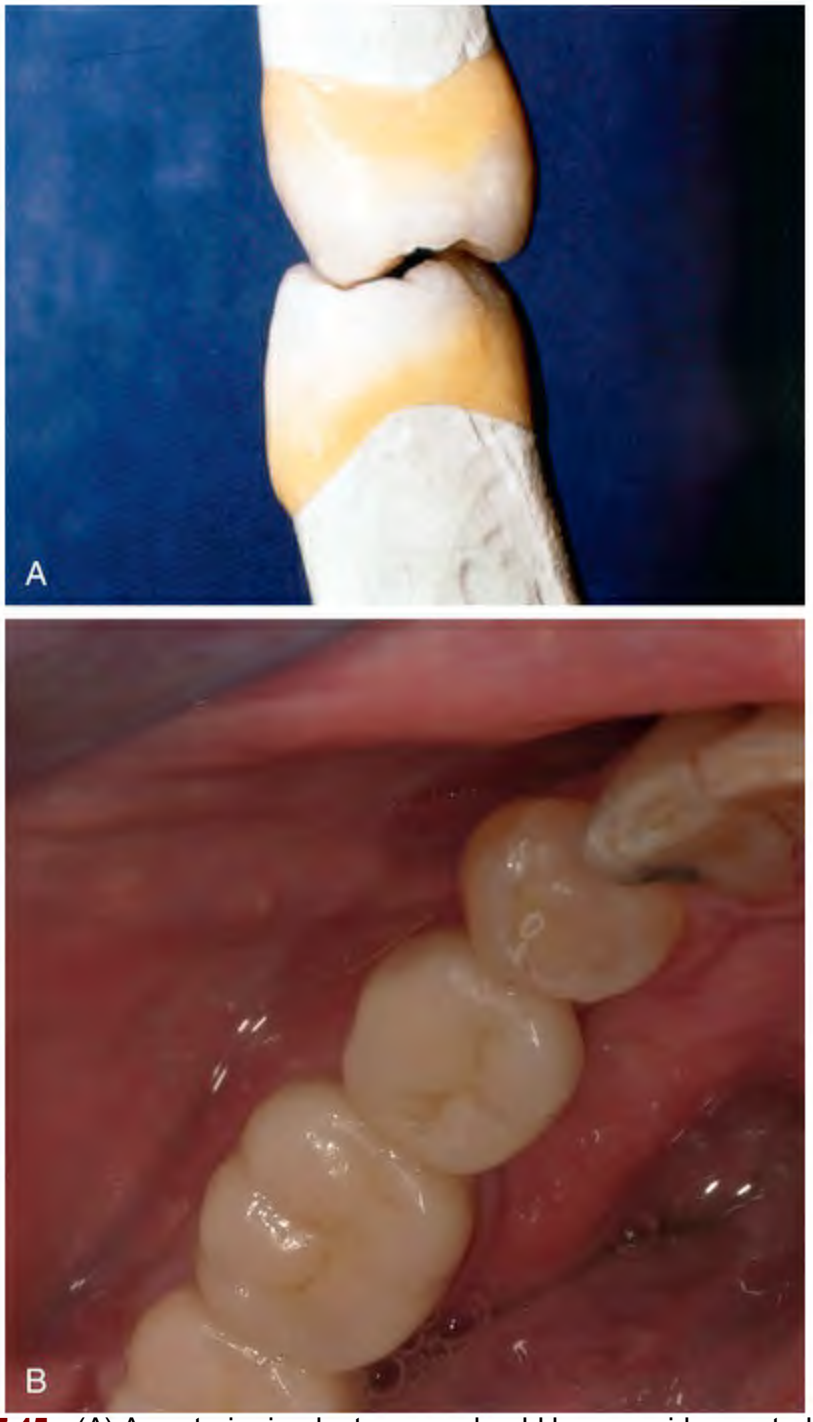

FIG 17.45 (A) A posterior implant crown should have a wider central fossa perpendicular to the implant body and parallel to the occlusal plane. The opposing tooth occluding cusp should be modified to occlude with the widened central fossa. (B) Posterior occlusion displaying minimal cusp height (monoplane occlusal plane). (A, From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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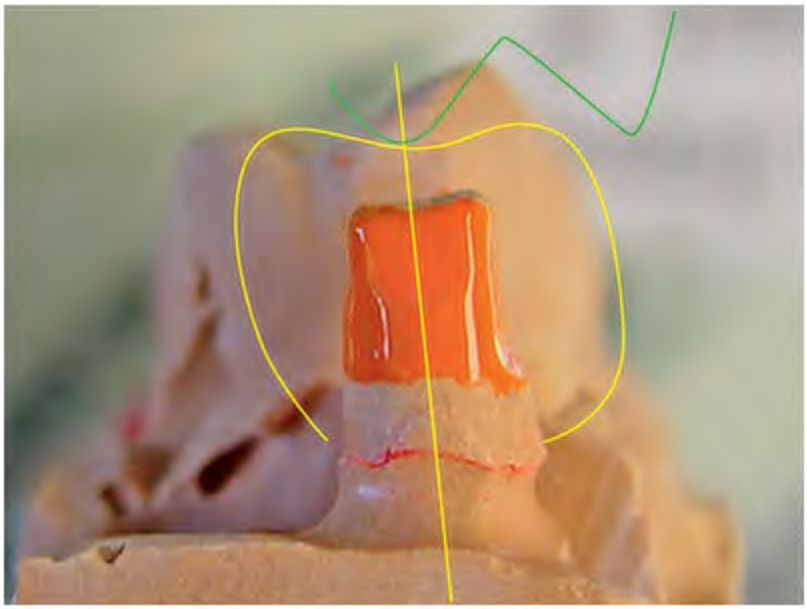

FIG 17.46 The laboratory technician usually will place the implant abutment under the central fossa of the implant crown. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

Ideal Posterior Occlusal Contacts

The ideal number of occlusal contacts in different occlusal schemes varies. For example, Thomas'[71] occlusal theories suggest that there should be a tripod contact on each occluding cusp (stamp cusp), on each marginal ridge, and in the central fossa with 18 and 15 individual occlusal contacts on a mandibular and maxillary molar, respectively (Fig. 17.47).

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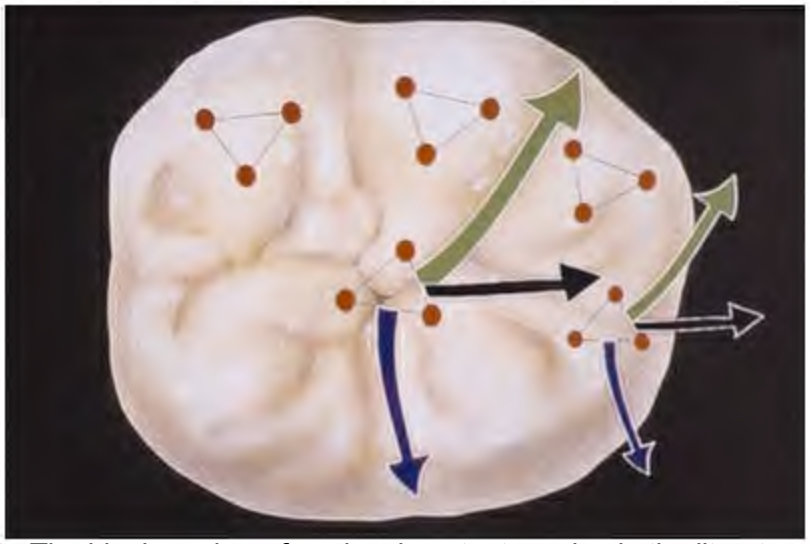

FIG 17.47 The ideal number of occlusal contacts varies in the literature. As many as 15 to 18 tripod occlusal contacts have been designed. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Other occlusal contact schemes indicate that the number of occlusal contacts for molars may be reduced to five or six contacts, including the dominant cusp (stamp cusp) of the buccal cusps in the mandible and the lingual cusps in the maxilla, the marginal ridges, and the central fossa. When a crown morphology is designed, usually no thought is given to how many contacts should be present or where they should occlude. It is almost impossible for the clinician to control the number and locations of occlusal contacts.

The average number of occlusal contacts found on natural posterior teeth of individuals never restored or equilibrated by a dentist and with no occlusal-related pathologic condition has been observed to average only 2.2 contacts (Fig. 17.48) with a range of one to three occlusal contacts per tooth.[72] If the tooth had an occlusal restoration, the occlusal contact number was reduced to an average of 1.6 occlusal contacts. The number of occlusal contacts on a natural tooth apparently may be reduced to one to three contacting areas without consequence. A more simplified occlusal approach than often taught is logical. If the ideal occlusal contacts per tooth should have minimum offset loads to the implant body, the central fossa is the logical primary occlusal contact position when the implant is positioned in this region. The central fossa of an implant crown should be 2–3 mm wide in posterior teeth and parallel to the occlusal plane. The ideal implant body position for function is most often directly under the central fossa in the mandible and maxilla. The ideal primary occlusal contacts will reside within the diameter of the implant within the central fossa. Secondary occlusal

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contacts should remain within 1 mm of the periphery of the implant to decrease moment loads. Marginal ridge contacts usually should be avoided unless implants are splinted together. When the implant is positioned closer to a stamp cusp (buccal in the mandible and lingual cusp in maxilla), the cusp angle is flat, and the contact is over the implant (Fig. 17.49).

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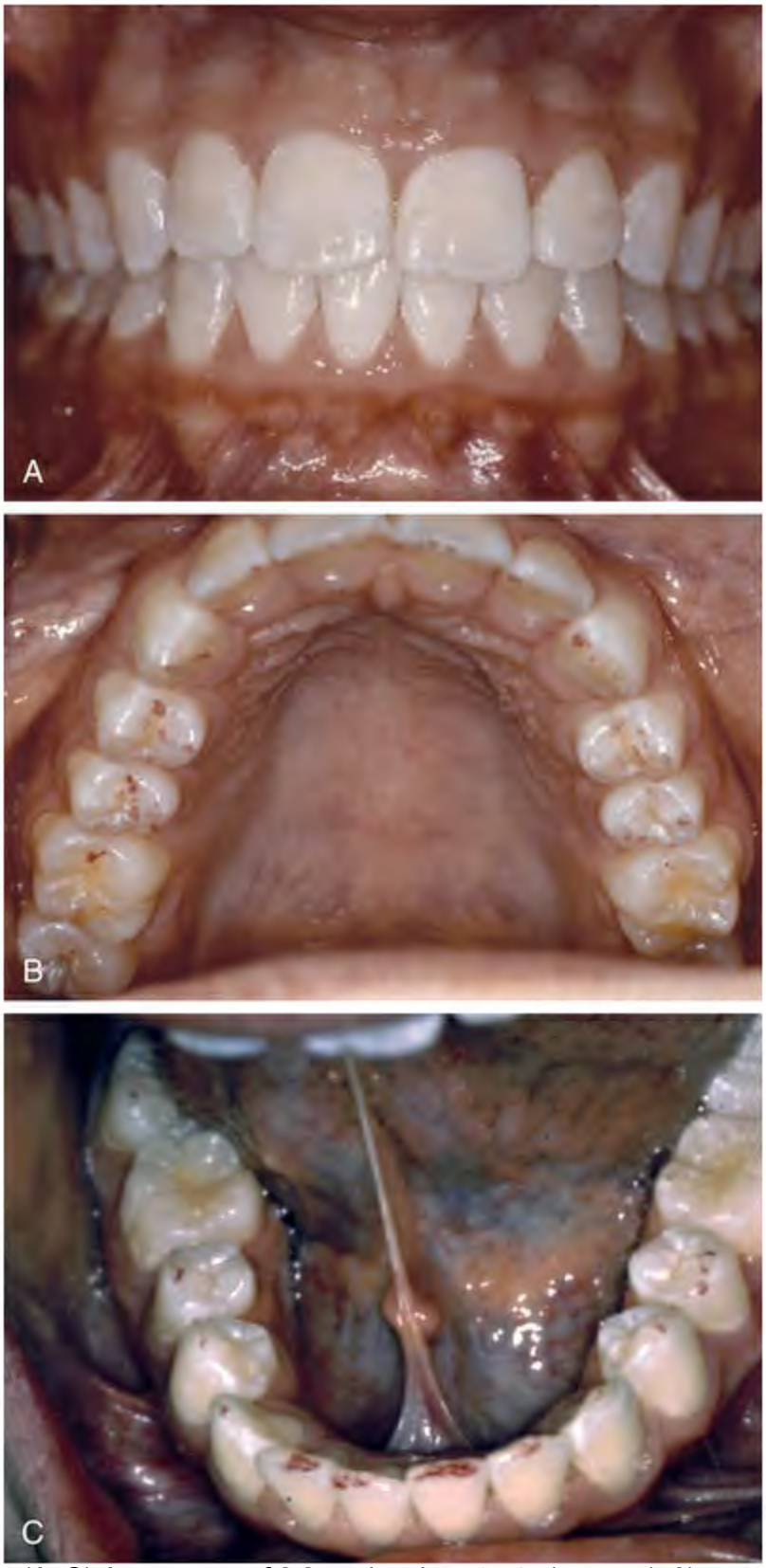

FIG 17.48 (A–C) An average of 2.2 occlusal contacts (range, 1–3) usually is found on natural posterior teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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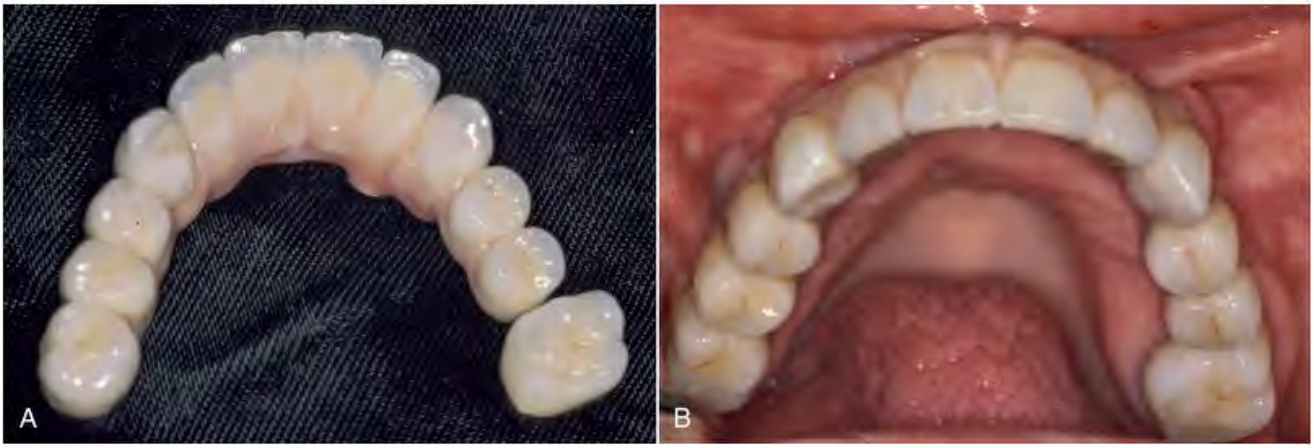

FIG 17.49 (A) The occlusal contact position is ideally directly over the implant. When under a cusp tip, the cusp angle is more flat. (B) The implant crowns are reduced from the lingual compared with the natural tooth molar crown. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Posterior Implant Position.

The most common implant body position for a posterior implant is in the middle of the buccolingual dimension of the bone. The implant surgeon begins the osteotomy in the middle of the ridge, and the implant diameter maintains 1.5 mm or more of bone on each side. The center of an edentulous ridge more often corresponds to the central fossa of a posterior crown in either arch. Occasionally, it may correspond to the natural tooth lingual cusp region but less often is under the buccal cusp in either arch.

The marginal ridge contacts are also a cantilever load on the single-tooth implant crown because the implant is not under the marginal ridge but may be several millimeters away. If the implant body is 5 mm in diameter and replaces a 12-mm molar in the mesiodistal dimension, a marginal ridge contact may create a magnified moment load equal to 3.5 mm times the amount of the force. A 100-N load will be multiplied to a 350–N-mm force on the marginal ridge (Fig. 17.50).

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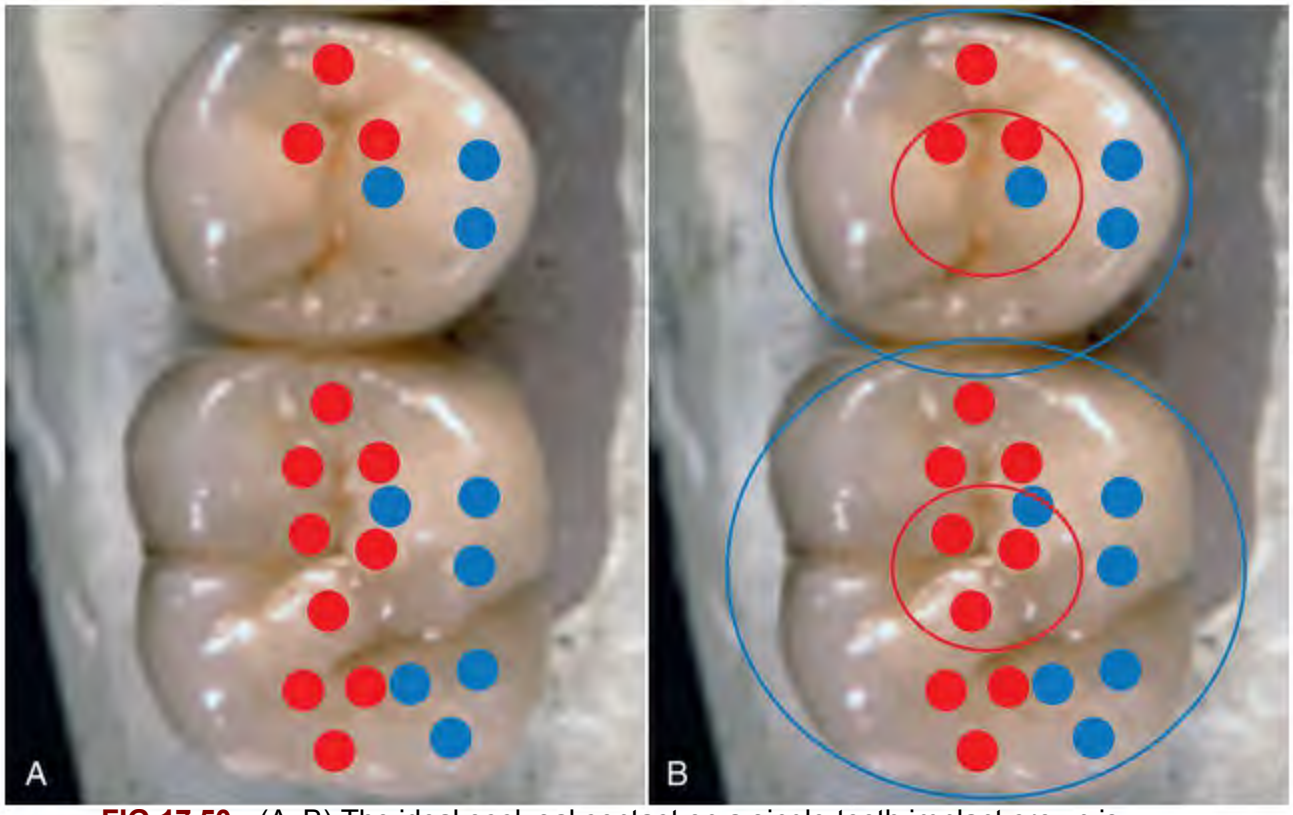

FIG 17.50 (A–B) The ideal occlusal contact on a single-tooth implant crown is directly over the implant. A marginal ridge occlusal contact is an offset load similar to the lingual cusp in the posterior maxilla. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The mesiodistal dimension of the molar crown often exceeds the buccolingual dimension, so the marginal ridge contact may contribute more to the biomechanical risk. In addition, laboratories often create an all-porcelain marginal ridge completely unsupported by the metal substructure, which places a shear load on the porcelain. The shear loads further increase the risk of porcelain fracture. The moment forces on marginal ridges also may contribute to forces that increase abutment screw loosening. Marginal ridge contacts on individual implant crowns or the most mesial or distal splinted crown should be avoided whenever possible.

Splinted Implants.

The marginal ridge occlusal contact is not a cantilevered load when located between two implants splinted to each other. In addition, the metal/zirconia framework that splints the implants supports the porcelain/zirconia in the marginal ridge region and minimizes the risks of fracture. The splinted crowns decrease occlusal forces to the crestal bone, reduce abutment screw loosening, decrease the force to the cement interface, increase retention of

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the crowns, and reduce the force to the bone-implant interface. Adjacent implant crowns should most often be splinted together, and the occlusal contact position may be extended from the most mesial to most distal implants (minus the marginal ridges at each extreme) (Fig. 17.51).

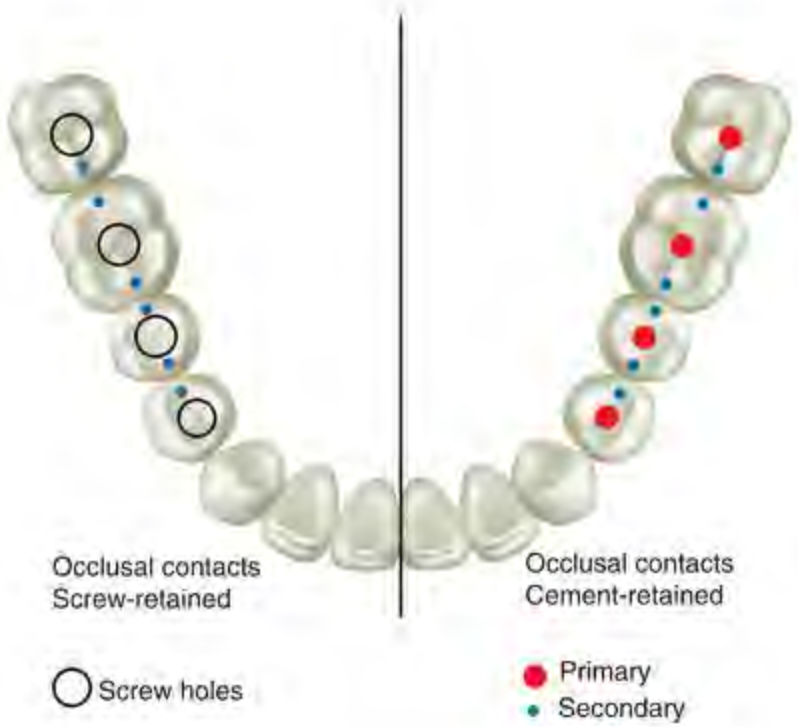

FIG 17.51 When the implants are splinted together, the occlusal contacts ideally should be in the central fossa, over the implant bodies, and in a zone extending between the implants. The marginal ridges between the implants may also have a secondary occlusal contact. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Screw-Retained Prosthesis.

A posterior screw-retained restoration often requires cantilevered occlusal contacts. The occlusal screw hole rarely is loaded because the filling material easily wears or fractures. As a result, the occlusal contacts of screw-retained crowns are not often directed over the top of the implant but are offset several millimeters away. This results in a higher moment load to the implant system, yet the occlusal access hole is the best position for the occlusal contact.

Occasionally, when a maxillary posterior tooth is in the esthetic zone, the implant may be 1–2 mm to the facial aspect of the midcrest (when bone is abundant) to be closer to the buccal cusp to improve the esthetic emergence

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of maxillary implant crowns. Under these conditions, the central fossa is positioned more facial, the lingual contour of the crown is reduced, and the occlusal contact is over the lingual aspect of the implant body (which is under the central fossa).

Minimize Cantilevers

A cantilever in implant dentistry is to be considered a class 1 lever.[41] Cantilevers, especially with nonideal crown-implant ratios, may result in peri-implant disease and prosthetic failure (i.e., porcelain fracture, prosthetic screw loosening or fracture).

A cantilever may be present in implant dentistry in many situations (Fig. 17.52):

1. Single implant crown between natural teeth (buccal-lingual, mesial distal)

2. Malpositioned implant resulting in an atypical prosthesis

3. Prosthesis with distal extension

4. Bar for an overdenture

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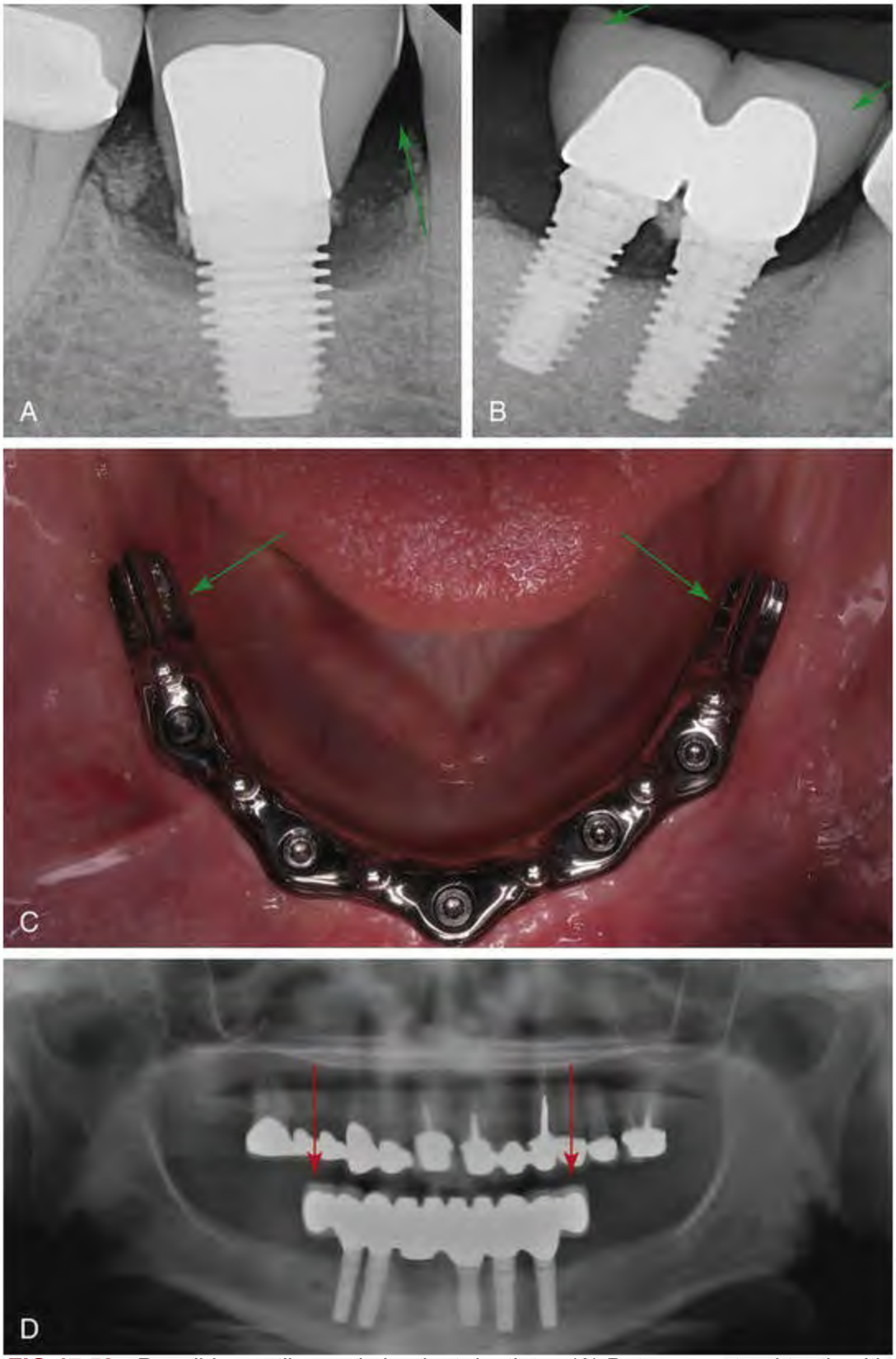

FIG 17.52 Possible cantilevers in implant dentistry. (A) Between natural teeth with marginal ridge occlusal forces. (B) Implant splinted prosthesis with mesial and distal cantilevers. (C) Cantilevered forces on a bar-retained overdenture. (D) Fixed prosthesis with bilateral cantilevers.

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Length of Cantilevers.

Studies have proven the detrimental effects of cantilevers. Longer cantilevers (>15 mm) have been shown to be associated with greater prosthesis failure than shorter (<15 mm) cantilevers.[42] When a biting force is applied to a distal cantilever, the highest axial forces and bending moment forces are on the distal abutment. For example, if two implants are 10 mm apart and are splinted with a cantilever of 20 mm, the following mechanics result: the mechanical advantage of the cantilever is 20 mm/10 mm, or 2. Whatever force is applied to the cantilever, a force twice as great will be applied to the farthest abutment from the cantilever.

Occlusal Contact on Cantilevers.

The occlusal contact on a cantilever may result in the overloading of the implants. For example, when a crown is placed over an implant with a buccal cantilever (i.e., 5-mm implant body replacing a mandibular molar with an 11-mm diameter), the angled buccal cusp will act as a cantilever. A marginal ridge contact may also cause overloading because this is a force-related cantilever.

Forces on Cantilevers.

Although the force on the cantilever is compressive in nature, the force to the distal abutment is a tensile and shear force. The load on the abutment closest to the cantilever (which acts as a fulcrum) is the sum of the other two components and is a compressive force (Fig. 17.53). In this example, a 100-N force on the cantilever equals a 200-N tensile or shear force on the most distal abutment and a 300-N compressive force on the abutment (the fulcrum) next to the lever.

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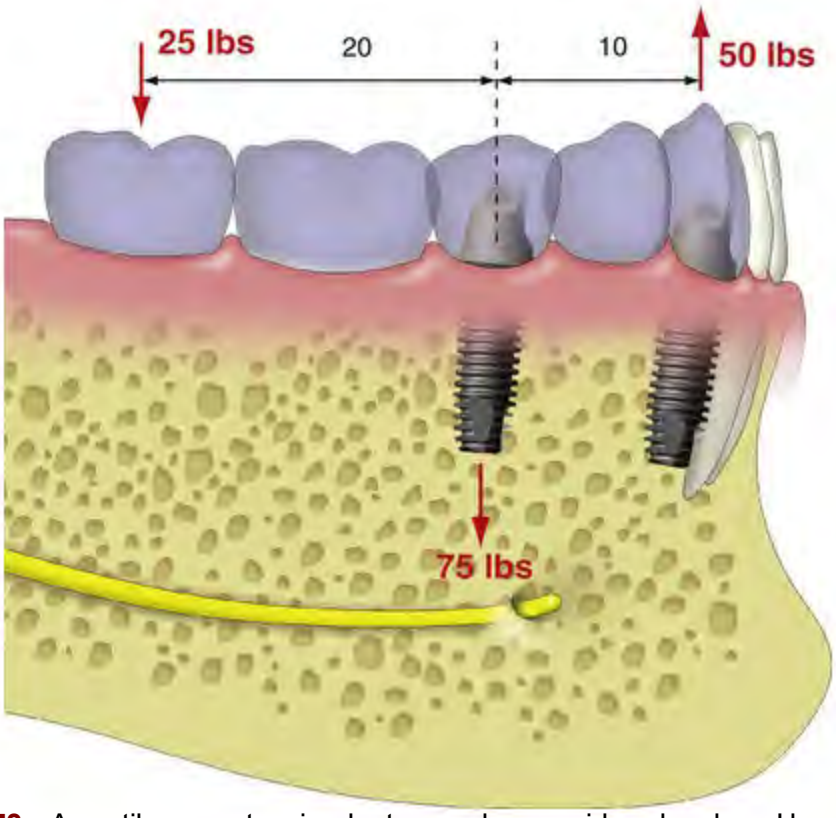

FIG 17.53 A cantilever on two implants may be considered a class I lever. When the implants are 10 mm apart, with a 20-mm cantilever, a mechanical advantage of 2 is created. The load on the cantilever will be multiplied by 2 on the far implant, and the implant close to the cantilever receives the total stress of the two loads. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Because cement and screws are weaker to tensile loads, the implant abutment farthest from the cantilever often becomes unretained, resulting in the fulcrum abutment bearing the entire load. Because the implant is more rigid than a tooth, it acts as a fulcrum with higher force transfer and is at higher risk (Fig. 17.54). As a consequence, crestal bone loss, fracture, and implant failure are often imminent after the distal abutment loses support to the prosthesis.

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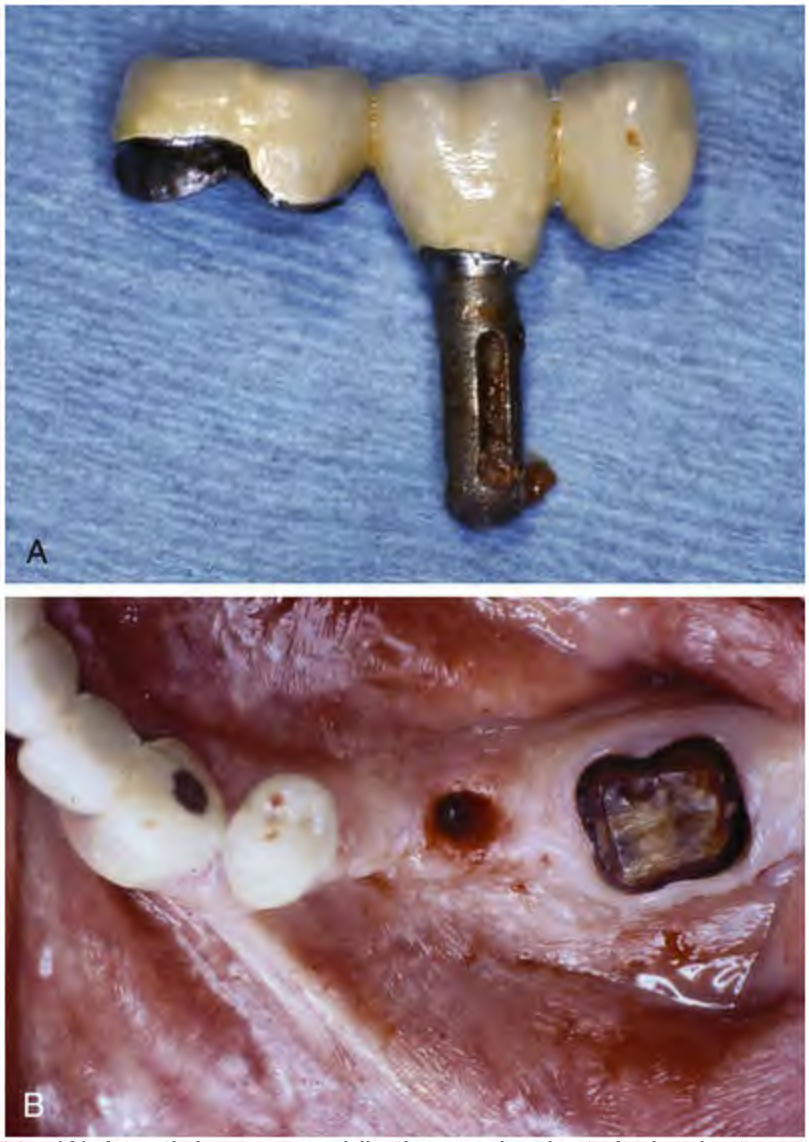

FIG 17.54 (A) A tooth is more mobile than an implant. An implant as a fulcrum transmits more tensile and shear load to the distal abutment from the cantilever than a tooth. (B) The cantilever to the mesial caused the cement seal to break in the distal molar. The fulcrum implant carried all the load, and the implant failed. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Clinical significance.

Cantilevers increase the amount of stress to the implant system. The greater the force on the cantilever, the even greater the forces on the implants because the cantilever is a force magnifier. Parafunctional loads are particularly dangerous for biomechanical overload. The greater the length of the cantilever, the greater the mechanical advantage and the greater the loads on the implants. The shorter the distance between the implants, the greater the mechanical advantage and the greater the force on the implant system (Fig. 17.55).

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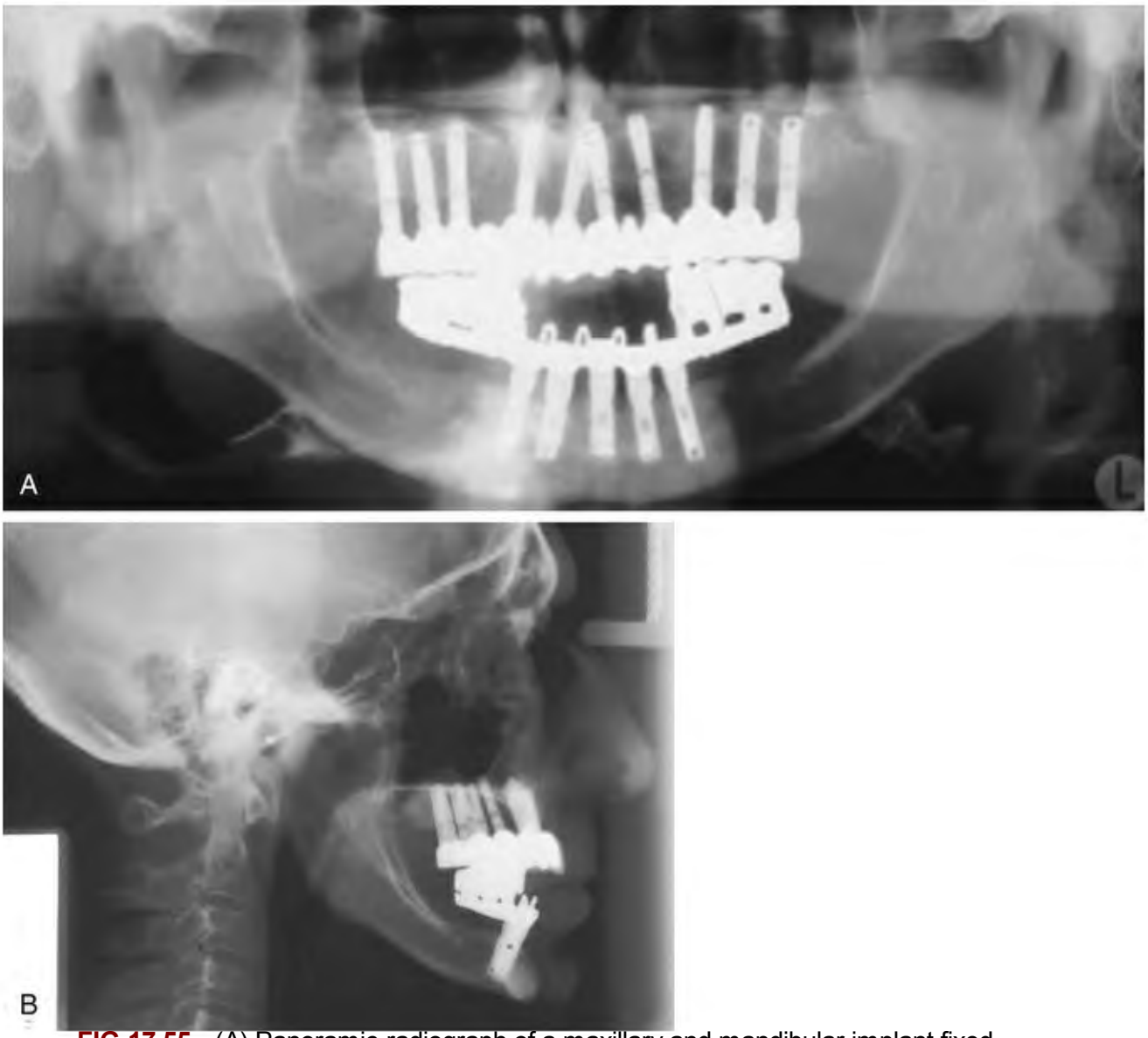

FIG 17.55 (A) Panoramic radiograph of a maxillary and mandibular implant fixed prosthesis. The mandibular restoration is cantilevered from implants positioned between the mental foramina. (B) Lateral cephalogram demonstrates that the anteroposterior distance of the implants is approximately 6 mm. The prosthesis is cantilevered more than four times the anteroposterior distance. The posterior occlusal load is magnified more than four times to the anterior implants, and the most distal implants receive the total sum of the loads. In addition, the opposing arch is implant supported and with less proprioception and higher bite forces than natural teeth. All these risk factors make this mandibular restoration less predictable. The cantilever should be reduced, the posterior occlusal contacts should be reduced, an anterior contact occlusal night guard should be worn, and preventive changes of the prosthetic screws should be done every few years. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The goal for cantilevers is to reduce the force on the pontics of the lever region compared with that over and between the implant abutments. To reduce the amount of force that is magnified by the cantilever, the occlusal

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contact force may be reduced on the cantilevered portion of the prosthesis. A gradient of force type of load that gradually decreases the occlusal contact force along the length of the cantilever is beneficial. In addition, no lateral load is applied to the cantilever portion of the prosthesis (whether it is in the posterior or anterior region). Although the functional forces of occlusion during mastication may not be significantly altered by this technique, parafunctional forces (which are the most damaging) are significantly reduced with a gradient of force occlusal adjustment.

Avoid Excessive Crown Height Space

The interarch distance is defined as the vertical distance between the maxillary and mandibular dentate or dentate arches under specific conditions (e.g., the mandible is at rest or in occlusion).[35] A dimension of only one arch does not have a defined term in prosthetics; therefore, Misch proposed the term “crown height space” (CHS).[73] The CHS for implant dentistry is measured from the crest of the bone to the plane of occlusion in the posterior region and the incisal edge of the arch in question in the anterior region (Fig. 17.56). In the anterior regions of the mouth, the presence of a vertical overbite means the CHS is larger in the maxilla than the space from the crest of the ridge to the opposing teeth incisal edge. In general, when the anterior teeth are in contact in CO, there is a vertical overbite. The anterior mandibular CHS is usually measured from the crest of the ridge to the mandibular incisal edge. However, the anterior maxillary CHS is measured from the maxillary crestal bone to the maxillary incisal edge, not the occlusal contact position. The ideal CHS required for a fixed implant prosthesis should be between 8 and 12 mm. This measurement accounts for the “biologic width,” abutment height for cement retention or prosthesis screw fixation, occlusal material strength, esthetics, and hygiene considerations around the abutment crowns (Fig. 17.57).

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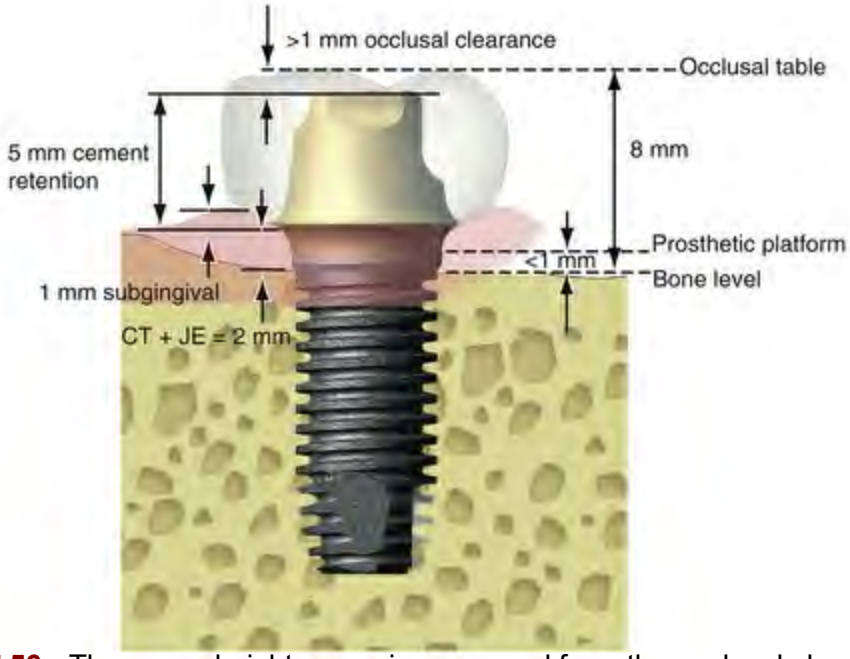

FIG 17.56 The crown height space is measured from the occlusal plane to the crest of the bone. The ideal space for an FP-1 prosthesis is between 8 mm and 12 mm. *CT,* Connective tissue attachment; *JE,* junctional epithelial attachment. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 17.57 Excessive crown height space leading to occlusal overload. The increased crown height space acts as a vertical cantilever.

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Removable prostheses often require a CHS greater than 12 mm. The CHS is measured from the crest of the bone to the plane of occlusion in the posterior region and the incisal edge of the arch in question in the anterior region. The implant crown height is often greater than the original natural anatomic crown even in division A bone. If the implant is loaded ideally on the long axis, crown height does not magnify the force (Fig. 17.58). However, crown height is a force magnifier (vertical cantilever) when any lateral load, angled force, or cantilever load is applied (Fig. 17.59).[41] A crown height with any of these conditions acts as a magnifier of stress to most of the implant system (i.e., cement or screw retaining the crown, abutment screw, marginal bone, and implant-bone interface). The greater the crown height, the greater the resulting crestal moment with any lateral component of force, including forces that develop because of an angled load. Angled abutments loaded in the direction of the angled abutment with an increase in crown height are subject to similar greater crestal moment loads because of the lateral load to the implant body and the increased lever effect from the crown height.

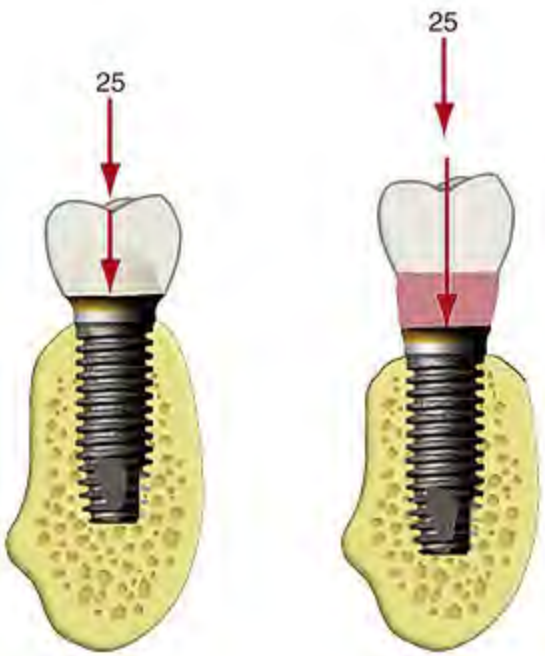

FIG 17.58 Crown height does not magnify the stress to the implant system when the force is applied in the long axis of the implant body. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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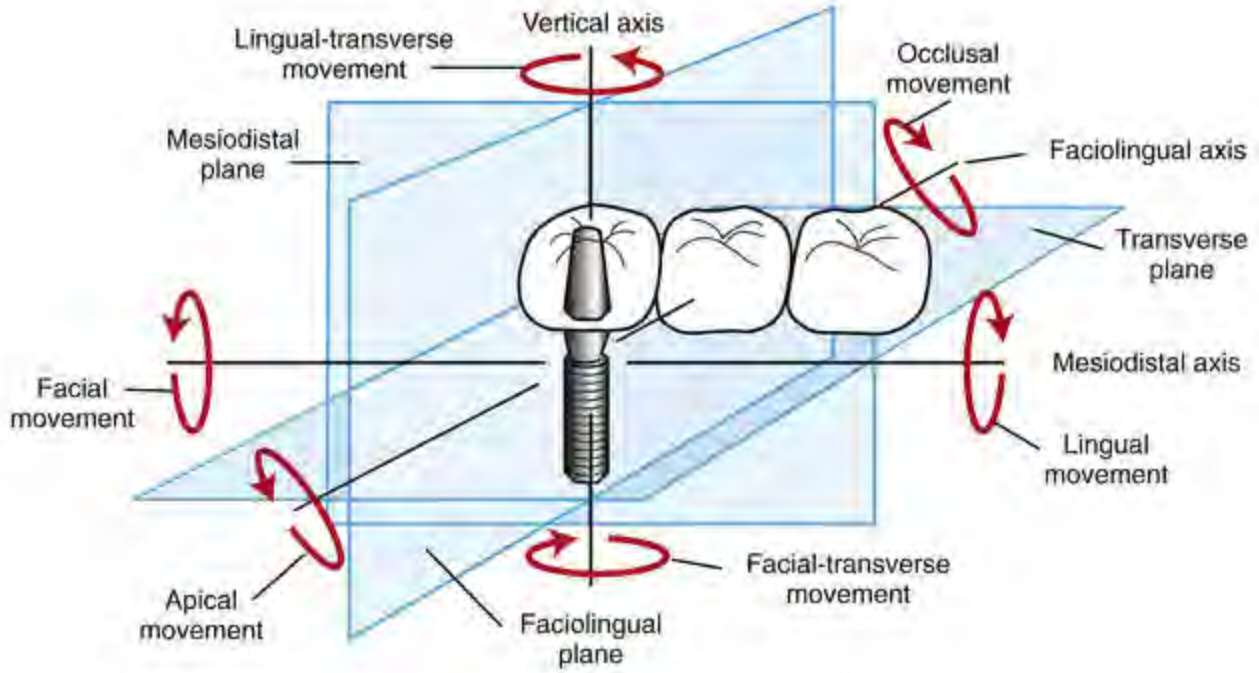

FIG 17.59 A cantilever load on an implant results in six different moments applied to the implant body. An increase in crown height directly increases two of six of the moment forces. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Occlusal loads may be directed to the implant system with an increased CHS if the following occur: a 30-degree angled load to an implant body, an implant crown with a 30-degree load, or a 30-degree cusp angle contact results in a similar condition. In this situation, 50% of the occlusal load is transformed into a horizontal or shear component to the implant system. However, the angled load on an implant crown is at greater risk to the crestal bone than the angled implant body because the crown height acts as a vertical cantilever. Whatever load is applied to the occlusal table (or cusp angle) is magnified by the crown height. For example, a 12-degree angled load of 100 N on the implant crown results in 21 N of additional load as a lateral force component. However, if the crown is 15 mm high, the final load to the crest of bone and abutment screw is 21 N Å~ 15 mm = 315 N-mm moment force. The dentist should be aware of the noxious effects of a poorly selected cusp angle, or an angled load to the implant crown will be magnified by the crown height measurement (Fig. 17.60).

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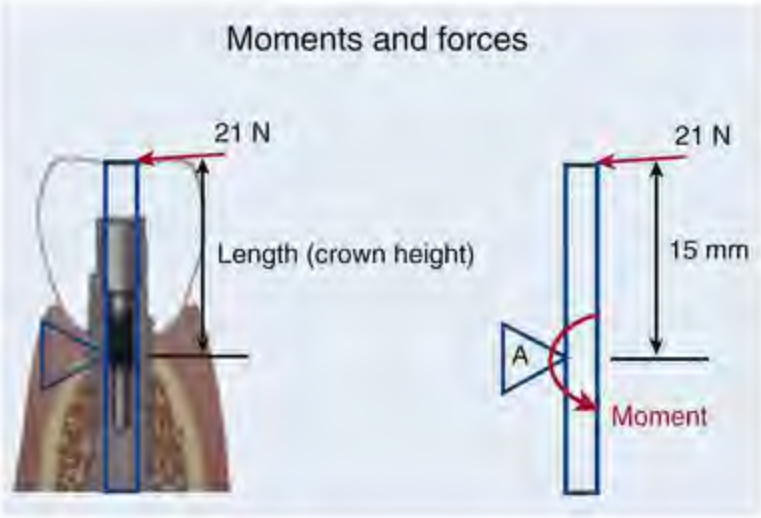

FIG 17.60 The crown height directly increases the effect of an angled force. For example, a 100-N load at a 12-degree angle increases the lateral or shear force component by 21 N. A crown height of 15 mm increases the 21-N force to a 315–N-mm moment force. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

If a load perpendicular to the curves of Wilson and Spee is applied to an angled implant body, the increase in load is not magnified by the crown height. The angled implant will increase the force components but will not be magnified by the crown height. The angle of load to the occlusal surface is more important to control than the angle of the implant body position.

Clinical Significance.

Axial loading of the implant is especially critical when the crown height increases, intensity of force increases, or duration of force increases (i.e., parafunction). The crown height is not a force magnifier (lever) when there is no cantilever or lateral load. A long-axis load of 100 N is similar to the implant system, whether the crown height is 10 mm or 20 mm. Occlusal schemes and crown occlusal anatomy should incorporate axial loads to implant bodies and, when not applicable, should consider mechanisms to decrease the noxious effect of lateral loads. Because horizontal or lateral loads cause an increase in the amount of tension and shear forces to the implant system, these loads should be reduced within the occlusal scheme, especially in mechanical systems that increase the magnitude of the biomechanical load.

Maintain Narrow Posterior Occlusal Tables

In the posterior region, large occlusal table designs present many inherent complications. A buccal or lingual cantilever in the posterior regions is called

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an offset load, and the same principles of force magnification from class 1 levers apply. The greater the offset, the greater the load to the implant system. Offset loads may also result from buccal or lingual occlusal contacts and create moment forces, which increase compressive, tensile, and shear forces to the entire implant system (Fig. 17.61).

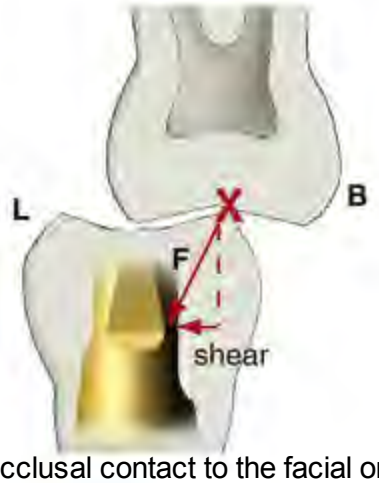

FIG 17.61 A cantilever occlusal contact to the facial or lingual is called an offset load. Cantilever or offset loads increase the force by the length of the lever and increase the shear component of the force. A posterior implant most often is placed under the central fossa of the implant crown. A buccal cusp contact is an offset or cantilever load. The ideal occlusal contact is over the implant body. *B,* Buccal; *F,* force; *L,* lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Etiology

Mandibular posterior crowns.

After tooth loss in the posterior mandible, the resorption process leads to the residual ridge being positioned more lingual. As the ridge resorbs lingually, the bone division will shift from a division A to B. As a result, dental implants (without bone grafting) will be more lingually placed than their natural tooth predecessors. Care should be taken in the placement of dental implants in this area because this may lead to nonaxial loading and impingement on the tongue space.

As the mandible resorbs more, the ridge will shift from a division B to a division C-h and then to a division D. However, because of the angulation of the mandible and the sublingual undercuts, the ridge will actually shift back toward the buccal. However, endosteal implants typically cannot be inserted in these cases because inadequate bone is available above the mandibular

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nerve (Fig. 17.62).

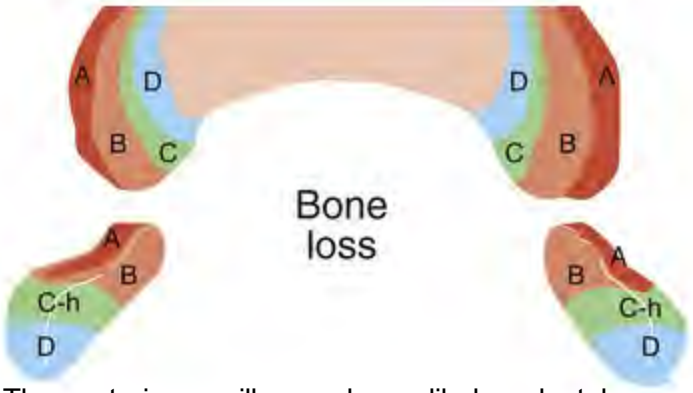

FIG 17.62 The posterior maxillary and mandibular edentulous arches resorb lingually as bone volumes change from division A to B to B minus width to C minus width. The mandibular posterior arch resorbs facially as the edentulous site becomes C minus height and D bone volume. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Complication prevention.

To prevent the nonaxial loading and linguoversion of the implant and implant prosthesis, the implant clinician to should evaluate via cone beam computed tomography interactive treatment planning the position of the implant and final prosthesis. If the implant cannot be placed in an ideal position, bone augmentation to restore the lost buccal bone should be completed before implant placement.

Maxillary posterior crowns.

The maxillary dentate posterior ridge is positioned slightly more facial than its mandibular counterpart because the teeth have a maxillary overbite. When the maxillary teeth are lost, the edentulous ridge resorbs in a medial direction as it evolves from division A to B, division B to C, and division C to D. As a result, the maxillary permucosal implant site gradually shifts toward the midline as the ridge resorbs. However, because of resorption in width, the maxillary posterior implant permucosal site may even be palatal to the opposing natural mandibular tooth.

In the esthetic zone (high lip position during smiling), the buccal contour of the maxillary implant crown is similar to a natural tooth. This improves esthetics and maintains the buccal overjet to prevent cheek biting and retains cheek fullness. However, just as with the natural teeth, there is no occlusal

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contact on the buccal cusp. Ideally, when maxillary posterior implants are in the esthetic zone, they are positioned more facial than the center of the ridge. The ideal functional position for the maxillary posterior implant is under the central fossa when the cervical region is not in the esthetic zone.

Complication prevention.

Although sinus augmentation permits the placement of endosteal implants in the posterior maxilla, there is often a ridge discrepancy. The clinician should evaluate the axial positioning of the proposed implant site, and in some cases horizontal (width) augmentation may need to be completed in association with sinus grafting.

The lingual contour of a maxillary implant crown should be reduced because it is out of the esthetic zone and is a stamp cusp for occlusion (which is an offset load) (Fig. 17.63). The lingual cusp is cantilevered from the implant similar to the buccal cusp of the posterior mandible. The reduced lingual contour reduces the offset load to the lingual aspect of the implant (Fig. 17.64).

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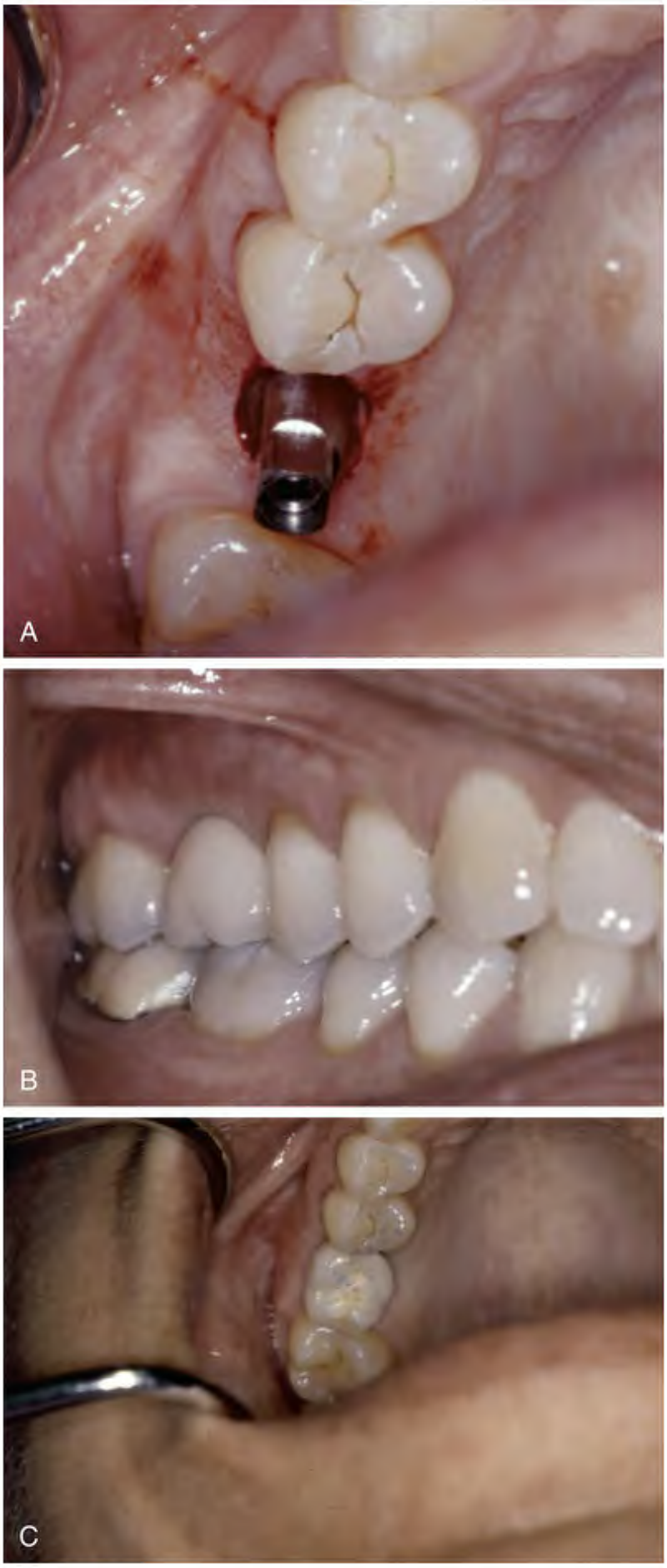

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FIG 17.63 (A) A maxillary posterior implant in the esthetic zone is positioned slightly more to the facial position than the central fossa. (B) The facial contour of the maxillary first molar implant crown is contoured similar to the adjacent teeth. (C) The lingual crown contour of the maxillary first molar crown is reduced compared with the natural tooth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

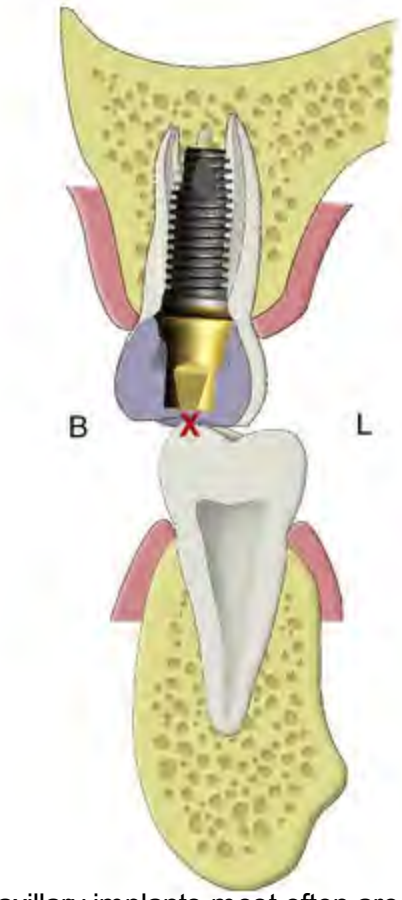

FIG 17.64 Posterior maxillary implants most often are positioned under the central fossa when the cervical region is not in the esthetic zone. The posterior maxillary lingual contours of implant crowns usually are reduced for improved hygiene and less offset loads to the implants. *B,* Buccal; *L,* lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Prevention

Larger implant body.

Wider root form implants can accept a broader range of vertical occlusal contacts while still transmitting lesser forces at the permucosal site under offset loads. Narrower implant bodies are more vulnerable to occlusal table width and offset loads. With the implant protected occlusion concept, the

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width of the occlusal table is related directly to the width of the implant body (Fig. 17.65).[74]

FIG 17.65 Narrow diameter implant showing significant discrepancy between occlusal table and implant body dimension.

Prosthesis fabrication.

The laboratory technician often attempts to fabricate an implant crown with occlusal facial and lingual contours similar to that of natural teeth. When out of the esthetic zone, the posterior implant crown should have a reduced occlusal width compared with a natural tooth (Fig. 17.66). The narrower occlusal contour of an implant crown also reduces the risk of porcelain fracture because of a decreased possibility of unsupported porcelain. A facial profile similar to a natural tooth on the smaller diameter implant (e.g., 10-mm tooth vs. 4- to 6-mm implant) results in cantilevered restorative materials in four areas: buccal, lingual, mesial, and distal. Thus, the cantilevered crown contour is often designed as a ridge lap pontic of a fixed partial denture (Fig. 17.67). The facial porcelain most often is not supported by a metal substructure because the gingival region of the crown is also porcelain. As a result, shear forces result on the buccal cusp on the mandibular crown or lingual cusps in the maxillary crown and are more likely to increase the risk of porcelain fracture. The extended crown contours not only increase offset

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loads but also often result in ridge laps or porcelain extension at the facial gingival margin of the implant abutment. This risk is compounded further by the higher impact force developed on implant abutments compared with natural teeth (Fig. 17.68).

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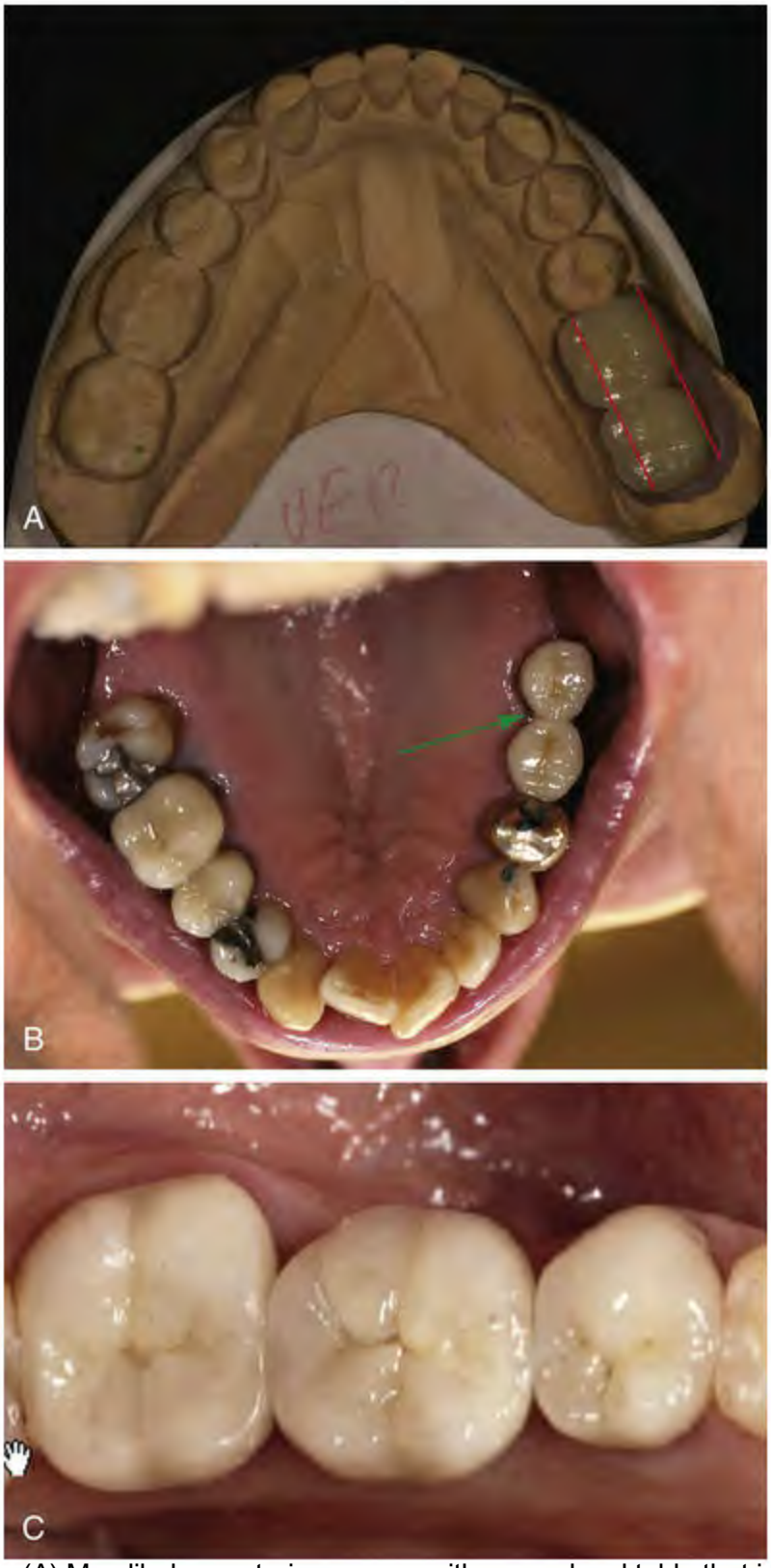

FIG 17.66 (A) Mandibular posterior crowns with an occlusal table that is too large. (B–C) Narrow occlusal table decreases amount of force applied to the implant.

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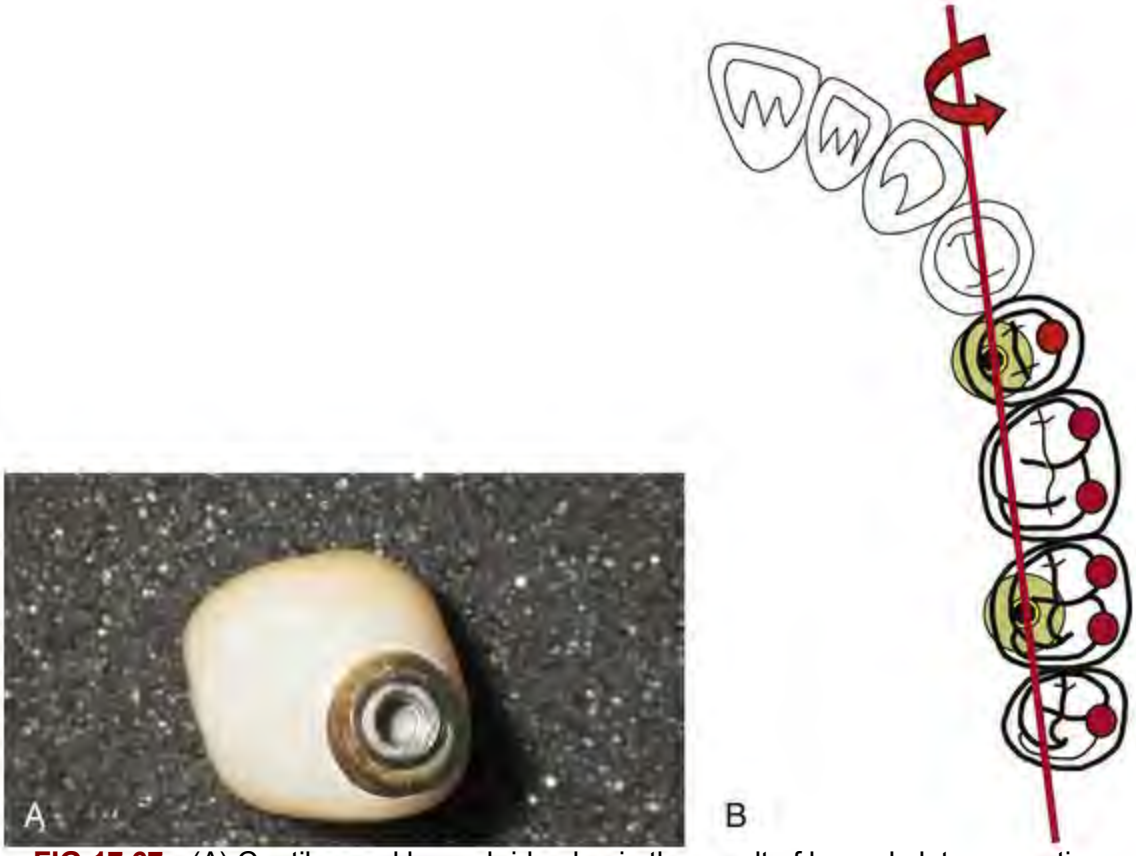

FIG 17.67 (A) Cantilevered buccal ridge lap is the result of buccal plate resorption and the implant placed more lingual than the natural tooth. (B) Where implants supporting a fixed prosthesis lie palatal or lingual to the occlusal platform, vertical forces on the teeth will tend to rotate the prosthesis around its fixing points on the implants. (B, From Hobkirk JA: Occlusion and Principles of Oral Implant Restoration. In Klineberg I, Eckert S: *Functional occlusion in restorative dentistry and prosthodontics*, St Louis, 2016, Mosby.)

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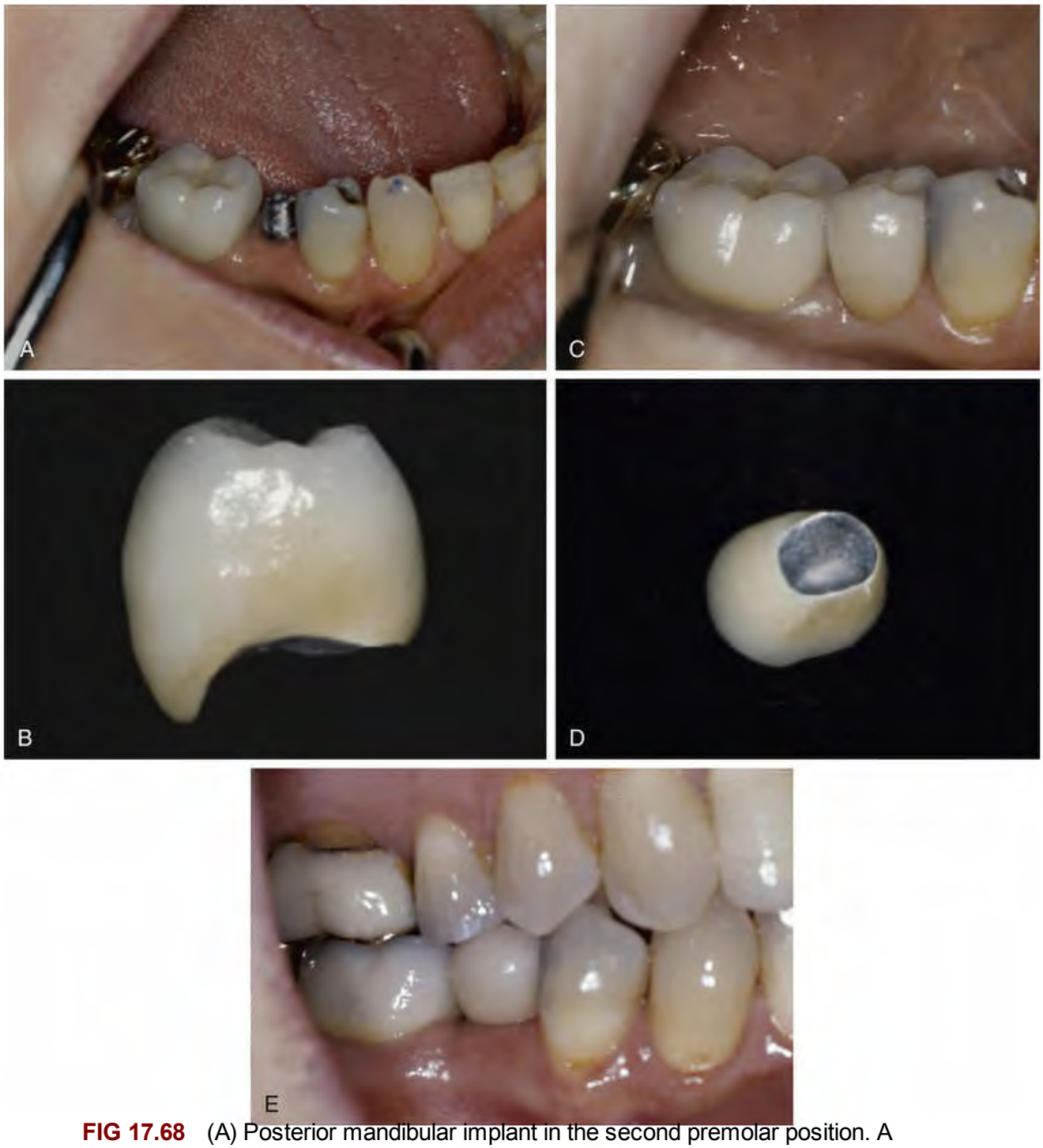

FIG 17.68 (A) Posterior mandibular implant in the second premolar position. A posterior implant (in the position of the second premolar in this case) often is inserted under the central fossa position. (B) The implant body is more narrow than the natural tooth. When the laboratory fabricates an implant crown the same size as the missing tooth, a facial ridge lap crown often results so as to restore the complete tooth contour. The ridge lap crown does not allow sulcular hygiene or facial probing. A ridge lap crown contour was made by the laboratory to restore the full contour of the missing teeth. (C) In situ, the crown appears as a crown on a natural tooth, but the cervical aspect is not in the esthetic zone. Offset loads, porcelain fracture, and abutment screw loosening risk are increased. (D) The ridge lap was eliminated, and the buccal contour was reduced. (Note there was no metal work to support the cantilevered porcelain.) (E) The modified crown in situ. Daily hygiene is improved,

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and biomechanical risk is reduced. The second premolar implant crown restores the function and occlusal aspect of the missing tooth. The esthetic facial cervical region is compromised to improve hygiene and force resistance because this region is not seen during function, speech, or smiling. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Management.

As a result of the ridge laps or porcelain extensions, home care in the sulcular region of the implant is impaired by the overcontoured crown design. The dental floss or probe may reach under the ridge lap to the free gingival margin, but it cannot enter the gingival sulcus. Daily hygiene is almost impossible to perform. The narrower posterior occlusal table facilitates daily sulcular home care. A narrow occlusal table combined with a reduced buccal contour (in the posterior mandible) facilitates daily care, improves axial loading, and decreases the risk of porcelain fracture. However, in the esthetic zone, the ridge lap design may be necessary to restore the implant rather than removing it, bone grafting, and replacing the implant. An increased frequency of hygiene may be indicated.

The mandibular implant prostheses should be reduced from the buccal and the maxillary crown reduced from the lingual. The “stamp cusp” offset load is reduced. The reduced buccal contour in the posterior mandible is of no consequence to cheek biting because the buccal horizontal overjet is maintained (and increased). The lingual contour of the mandibular implant crown should be similar to a natural tooth (Fig. 17.69). This permits a horizontal overjet to exist and push the tongue out of the way during occlusal contacts (just as natural teeth). As with the natural tooth, the lingual cusp has no occlusal contact.

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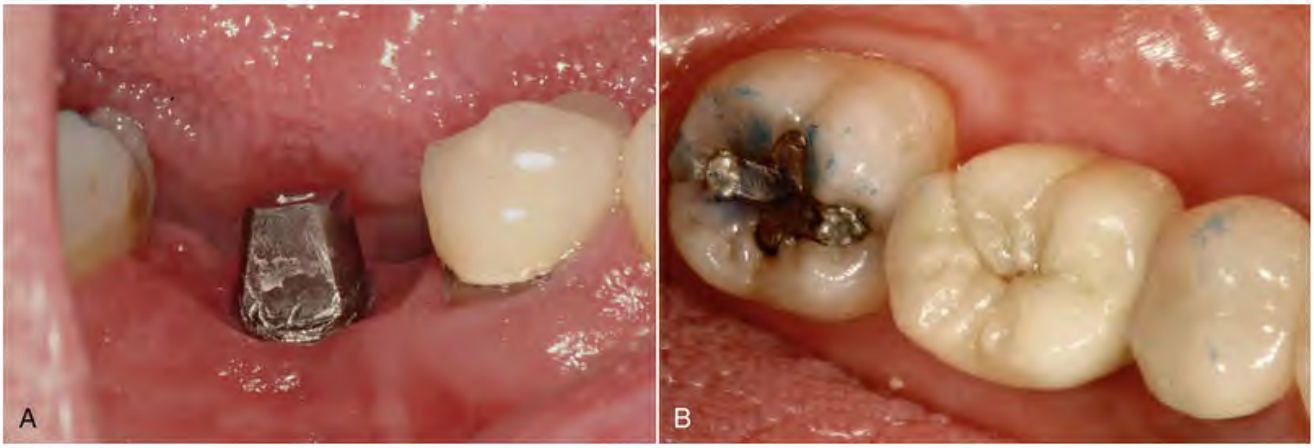

FIG 17.69 (A) Mandibular implant in the first molar position. (B) The first molar crown in situ. The lingual contour is similar to the natural tooth. The buccal contour is reduced in width. (From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

In the posterior mandible, as the implant diameter decreases, the buccal cusp contour is reduced. This decreases the offset length of cantilever load. The lingual contour of the crown remains similar regardless of the diameter of the implant. The lingual contour permits a horizontal overlap with the maxillary lingual cusp, so the tongue is pushed away from the occlusal table during function. The lingual cusp is not occlusal loaded (as with natural teeth) (Fig. 17.70). During mastication, the amount of force used to penetrate the food bolus may be related to occlusal table width. For example, less force is required to cut a piece of meat with a sharp knife (narrow occlusal table) than with a dull knife (wider occlusal table). The greater surface area of a wide occlusal table requires greater force to achieve a similar result. The wider the occlusal table, the greater the force developed by the biologic system to penetrate the bolus of food. Although these functional forces are typically less than 30 psi, with parafunction they can be 10 to 20 times greater.

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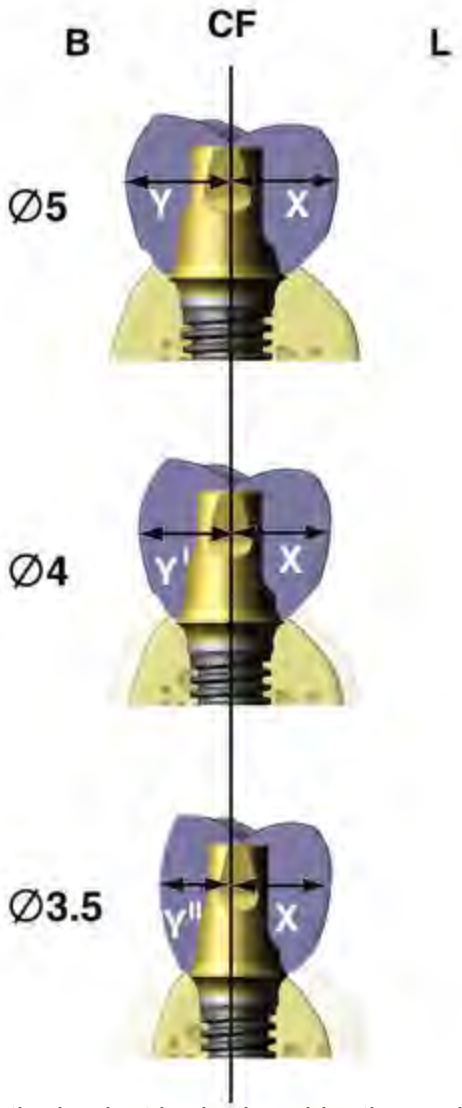

FIG 17.70 The wider the implant body, the wider the occlusal table width of the implant crown. As the mandibular bone width decreases, the implant body may decrease in width. The lingual contour of the implant crown remains similar regardless of the width of implant. The buccal contour is reduced as the implant diameter decreases. A narrow ridge in an esthetic zone may require bone augmentation, so a wider implant may be used to support an implant crown, which appears as a natural tooth. *B,* Buccal; *CF,* central fossa; *L,* lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In the esthetic zone, many of the crown contours are made to resemble the natural tooth as closely as possible. However, out of the esthetic zone, in the posterior regions of the mouth, the crown contour should be different than a natural tooth. The implant body buccolingual dimension is smaller than the natural tooth. The center of the implant most often is placed in the center of the edentulous ridge. Because the crest of the ridge shifts lingually with resorption, the implant body is most often not under the opposing cusp tips but rather near the central fossa or even more lingual and in the maxilla may

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even be under the lingual cusp of the original natural tooth position (Fig. 17.71). Most often, the laboratory fabricates a posterior implant crown that is similar in size to a natural tooth, with a cantilevered facial contour. In addition, the occlusal contacts are often on the "stamp cusp" of the mandible (buccal cusps).

FIG 17.71 The implants in the second premolar and first molar are positioned under the lingual cusps. The laboratory made the buccal crown contour similar to the missing teeth. A facial offset load is present. The cantilever force should not be compounded by occlusal loads in the central fossa from a mandibular buccal cusp. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

However, these "stamp cusps" are often offset loads (buccal cantilevers) (Fig. 17.72). When the maxillary posterior teeth are out of the esthetic zone, the crown may be designed for a crossbite (Fig. 17.73). The lingual overjet prevents tongue biting, the buccal overjet (from the mandibular tooth) prevents cheek biting, the implant is axial loaded by the lingual cusp of the mandible, and hygiene is improved (Fig. 17.74).

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FIG 17.72 In the maxillary posterior region, the implant may be positioned under the lingual cusp *(arrow)*. The laboratory often cantilevers the facial crown profile, to make it appear as a natural tooth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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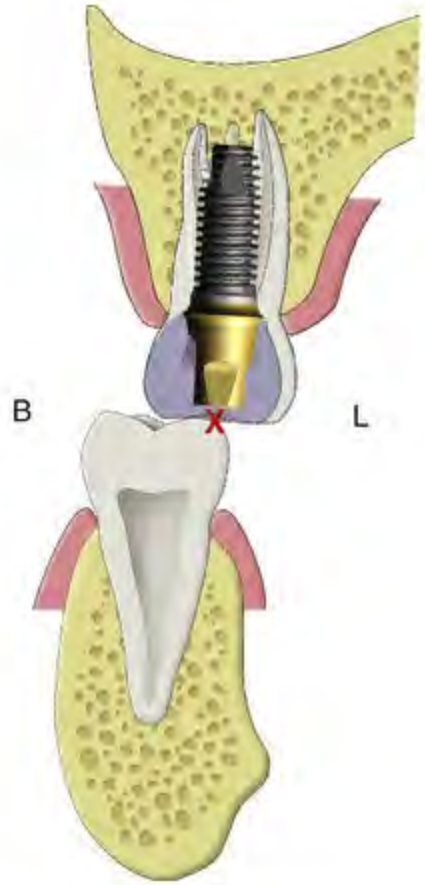

FIG 17.73 When maxillary posterior implants are placed in division B to D bone volumes out of the esthetic zone, the implant crown often is restored in posterior crossbite. The maxillary lingual horizontal overjet prevents tongue biting, the mandibular buccal overjet prevents cheek biting, and the primary occlusal contact is in the central fossa over the implant body. *B,* Buccal; *L,* lingual. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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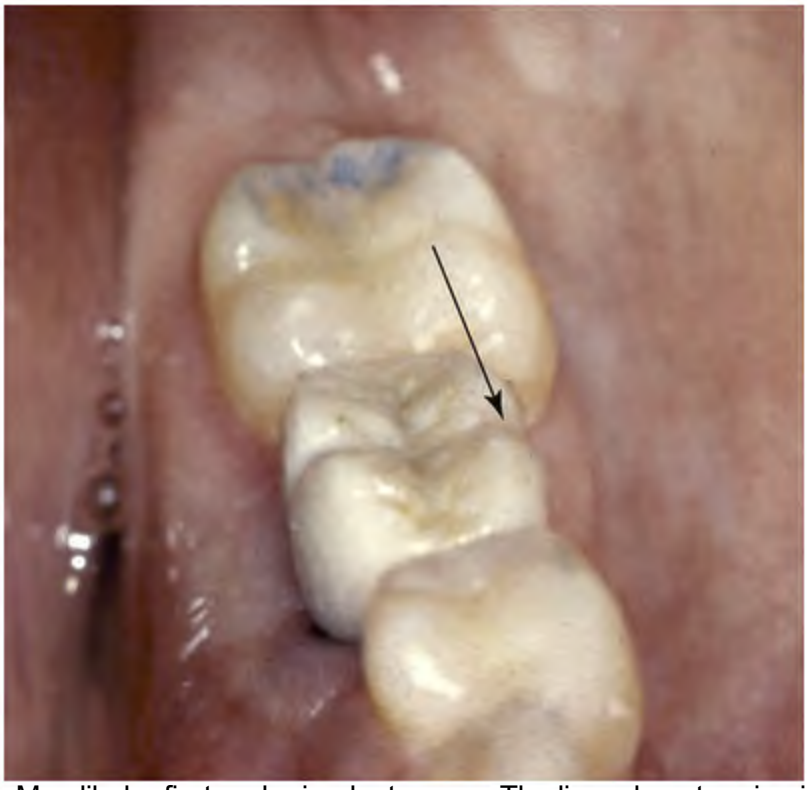

FIG 17.74 Mandibular first molar implant crown. The lingual contour is similar to the adjacent teeth, but the lingual cusp tip is not loaded. The buccal contour is reduced compared with the adjacent teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Staggered Implants.

Alternative techniques exist in the literature that propose staggering of posterior implants (i.e., buccal-lingual dimension) to improve biomechanical resistance to loads.[75] This concept is most effective and indicated when more narrow implants are positioned in wider ridges so that the staggered position is increased. However, a disadvantage of this technique includes the fabrication of an atypical prosthesis, which results in hygiene difficulty and esthetic issues. Additionally, implants placed more lingual may result in lingual overcontouring and impingement on the tongue space, resulting in speech and mastication issues. Compared with placing implants with increased diameter and splinting, the staggering concept will decrease crestal loads and is a better mechanism of stress reduction.

Increased Proximal Contact Area

The proximal contact area is highly variable in patients depending on many factors such as age, sex, past orthodontic treatment, parafunction, and

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missing teeth. Most commonly, the contact area is oval and is usually found toward the buccal aspect of interproximal areas.[76] In the incisal region, the contacts are more vertically oriented and in the posterior are more horizontally oriented. The proximal contacts usually increase in size from anterior to posterior.[77]

When adjacent teeth shift with respect to a single edentulous space, this poses multiple issues. Because of the shifting teeth, only a "point" contact can be accomplished. This not only poses problems in food impaction, formation of a black triangle, increased caries, and periodontal issues, but also complicates the seating of the final prosthesis.

A common problem in the replacement of posterior teeth is lack of sufficient interproximal contact or loss of contact over time. This is most commonly seen with single edentulous sites in which the adjacent teeth have rotated, tilted, or migrated. This results in the fabrication of a prosthesis that has many disadvantages (Fig. 17.75).

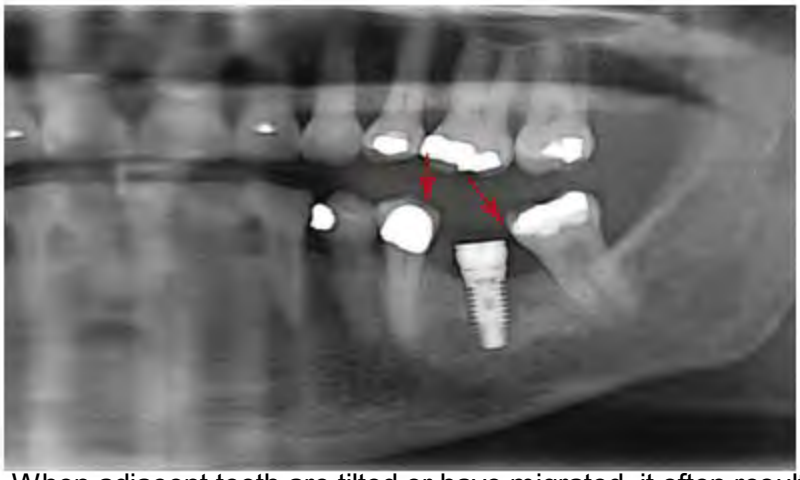

FIG 17.75 When adjacent teeth are tilted or have migrated, it often results in a point contact. An enameloplasty should be completed to allow for one path of insertion and a long contact area.

Difficulty in Seating Prosthesis.

When the interproximal surfaces are not parallel to each other, two paths of insertion are often required to seat the prosthesis properly (i.e., or may prevent complete seating of the restoration). When the two adjacent teeth have interproximal surfaces that parallel each other, only one path of insertion exists, making the seating much easier.

Prevention.

Before the final impression, the adjacent proximal areas should be adjusted with guide planes so that they are parallel. This is most often achieved with the use of a diamond bur (i.e., flat-end cylinder). This will allow for a broader contact area and one path of insertion for the final placement of the prosthesis. Before implant placement (i.e., treatment planning phase), the patient should be informed of the modifications of the adjacent teeth. This communication with the patient will prevent patient questions and possible dissatisfaction later in the prosthodontic process.

Food Impaction.

Point contacts are more prone to impacting food and developing a "black triangle," which can lead to difficulty in hygiene and esthetic compromises.

Prevention.

By increasing the proximal contact areas via guide planes on the adjacent teeth, there is a decreased possibility of spaces for food impaction. The laboratory must be instructed to fabricate an ideal emergence profile for the prosthesis (Fig. 17.76).

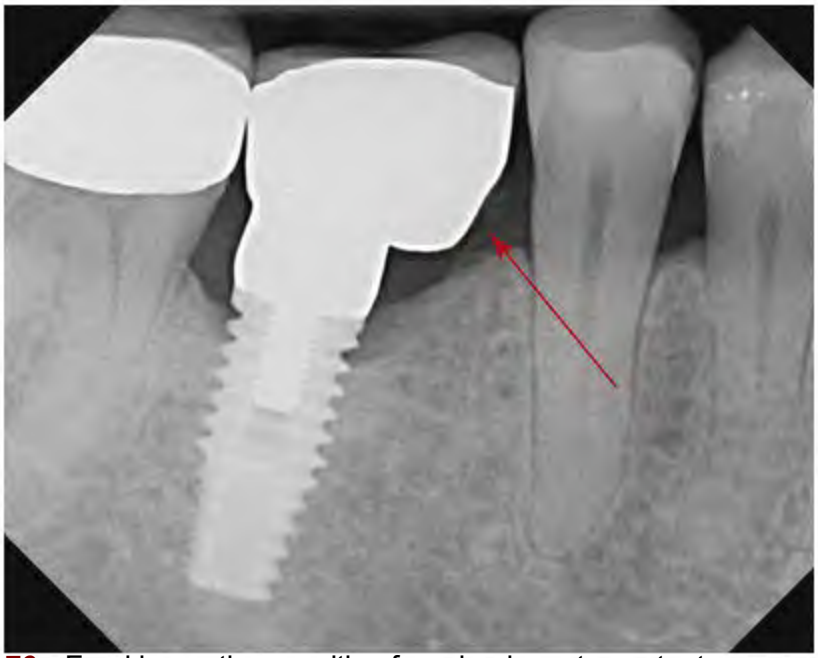

FIG 17.76 Food impaction resulting from inadequate contact areas and poor emergence profile.

Lack of Force Distribution.

With longer contact areas, a better force distribution (i.e., adjacent tooth will absorb more of the force) is present, which decreases the offset loads associated with the cantilevered mesial and distal marginal ridge areas.

Prevention.

Because of the cantilevered and offset loading of the mesial and distal proximal areas, a wider proximal contact area is highly advantageous. There will be greater surface area to distribute the force that is applied (i.e., force distribution to the adjacent tooth because of broader contact) (Fig. 17.77).

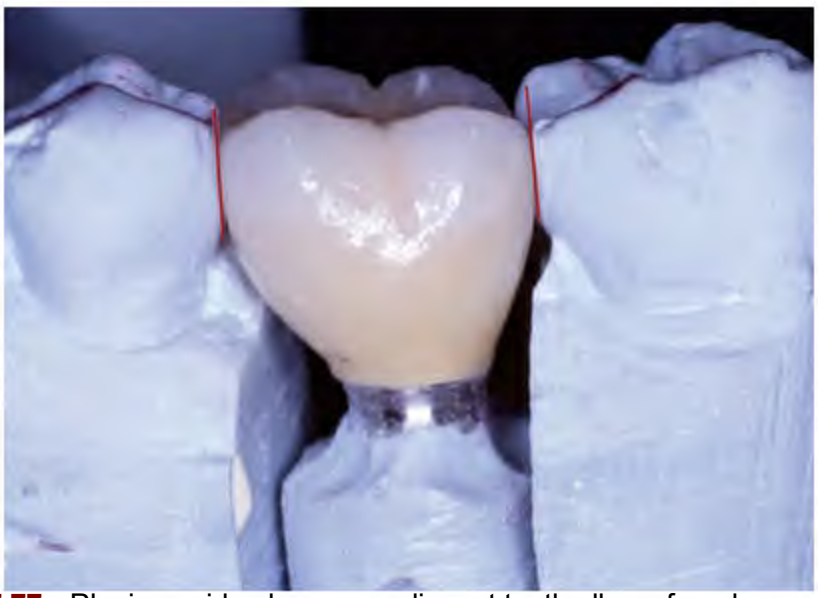

FIG 17.77 Placing guide planes on adjacent teeth allows for a long proximal contact area, which will allow for better force distribution.

Development of Open Contacts.

The etiology of acquired open contacts is unclear, and they are most likely caused by many factors. Studies have confirmed the complication of open contacts. Byun[77a] showed that open contacts (no resistance) occur 38% of the time, and loose contacts (minimal resistance) occur 20% of the time over a mean time of 57 months. Koori et al[78] showed interproximal gaps approximately 43% of the time over a period of 1 to 123 months. Wei et al[79] reported an even higher incidence of 58% with the average time period being 2.2 years. Wong et al[80] showed no difference in open contact areas among

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screw vs. cement prostheses. Several possible factors contribute to open contacts.

Inadequate proximal contact.

A small proximal contact area will most definitely impact this complication. Open contacts usually do not occur between natural teeth because of physiologic drift. When an implant is adjacent to a natural tooth, the osseous interface will not allow for the implant to move in association with the natural tooth. When natural teeth move through natural physiologic movement, attrition, and parafunctional forces, with an implant having an osseous interface, the teeth will not move.

Acquired contact area opening.

Usually, a contact area that opens after some time (e.g., originally strong contact area present) originates from occlusal forces, mainly from the mandibular closure muscles (i.e., lateral and medial pterygoid, masseter, temporalis). The forces directed to the teeth are mainly dictated by inclined cusp planes. Forces exist that push teeth mesial and distal; however, the anterior, forward vector is five times stronger than the posterior force.[80,81]

Additionally, studies have shown the anterior component of force is transmitted via the interproximal contacts and that its strength will decrease with increased distance from the posterior teeth.[82] Another possible reason for the loss of contact area is craniofacial growth. Facial growth has been reported in some patients well beyond adulthood. Even minor facial growth may allow for mesial, buccal, or vertical growth leading to opening of occlusal contacts (Fig. 17.78).[83]

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FIG 17.78 Open contact area after prosthesis insertion.

Management and Prevention

Enameloplasty.

To prevent this complication, before the final impression for a crown, an enameloplasty should be completed to allow for parallel interproximal contact areas. The longer and wider contact areas will allow for better force distribution, especially if there is a significant mesial or distal cantilever over the marginal ridge area. This concept has been advocated in natural dentition via large interproximal contacts to increase tooth position stability.[77]

Occlusal guard.

To maintain a strong contact and prevent this complication, an occlusal guard is warranted to minimize stress to the system.

Occlusal adjustment.

Occlusion is modified to have even contacts on all incline planes, decreasing the distal vector forces on the natural tooth (Fig. 17.79).

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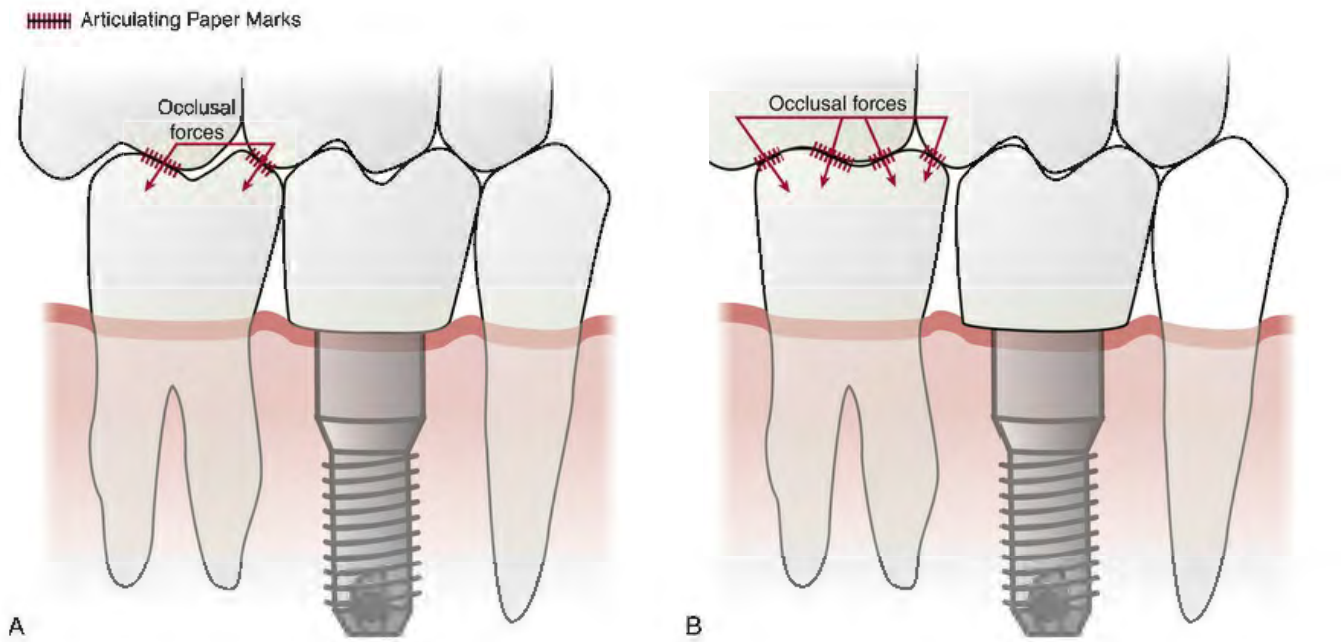

FIG 17.79 Contact Area Opening. (A) If occlusal forces are directed distally via cuspal inclined planes, the natural tooth may become distally oriented. (B) By decreasing the cuspal inclinations along with more favorable contacts, the natural tooth will be less susceptible to movement.

Treatment: if open contact occurs after insert.

Treatment includes remaking the prosthesis or adding a contact to the adjacent tooth via a new crown or composite bonding.

Mutually Protected Articulation

Numerous philosophies exist on the occlusal schemes for natural teeth. One such scheme is termed "mutually protected occlusion," in which the anterior teeth disocclude the posterior teeth during excursions (i.e., incisal guidance steeper than the condylar disc assembly).[84-87] The posterior teeth protect the anterior teeth in CO, and the anterior teeth protect the posterior teeth in mandibular excursions. This occlusal design is based on the concept of using the maxillary canine as the key of this occlusion scheme to avoid lateral forces on the posterior teeth.[88]

Anterior, compared with posterior, bite force measurements and electromyographic studies provide evidence that the stomatognathic system elicits significantly less force when the posterior segments are not in contact when the anterior teeth occlude.[89] For example, the maximum bite force in the posterior regions of the mouth (with no anterior occlusal contact) is 200–250 psi. The maximum bite force in the anterior region (with no posterior

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occlusal contact) is 25–50 psi. This difference results from a biologic response and a mechanical condition when the posterior teeth do not contact. Almost two-thirds of the temporalis and masseter muscles do not contract when posterior teeth do not occlude.[90] In addition, the TMJ and teeth complex form a class 3 lever condition (i.e., the nutcracker).[40] As a result, the closer the object is placed toward the hinge (TMJ), the greater the force on the object. In addition, the greater lateral mobility of the anterior teeth compared with the posterior teeth (108 μm vs. 56 μm) also decreases the consequences of the lateral forces during excursions.

In CO, the anterior teeth contacts are shared and protected by the occlusal contacts of the posterior teeth. When the canine separates the posterior teeth in right or left lateral excursions, the term "canine" or "cuspid protected occlusion" may be used. If healthy anterior teeth or natural canines are present, the mutually protected occlusion scheme allows those teeth to distribute horizontal (lateral) loads during excursions, while the posterior teeth disocclude during excursions (e.g., canine guidance or mutually protected articulation) (see Fig. 17.34). The posterior teeth are protected from lateral forces by the anterior guidance during excursions, and the anterior teeth have lighter forces in excursions because the posterior teeth do not contact. In other words, when lateral or angled forces are applied to the anterior teeth, the magnitude of the stress is increased. However, when mutually protected occlusal philosophies are applied, the consequences of the lateral forces are reduced.

Clinical Significance.

The mutually protected articulation concept is used in the implant protected occlusion technique with the following designs:

- In protrusive mandibular movements, the central and lateral incisors disocclude the posterior teeth.
- In lateral excursions, the canine (and lateral incisor when possible) disocclude the posterior teeth.
- In CO, the posterior and canine teeth occlude. When the central and lateral incisors are natural, they may also occlude in CO (or MI). When the anterior teeth are implants, they should not occlude in centric occlusion, especially when the opposing dentition is also implant supported.

Group function (or unilateral balance) has been suggested with periodontal bone loss on the remaining teeth. The concept was to share the

lateral loads during excursions with more teeth. For example, in this philosophy, a mandibular excursion to the right contacts as many anterior and posterior teeth on the right as possible. This is not indicated in IPO. The lateral posterior forces increase the moment loads to posterior implants. The posterior contacts during excursions also have greater forces to the posterior implants because more muscle mass contracts and the occlusal contacts are closer to the TMJ (class 3 lever). In addition, the posterior lateral loads increase the force to the anterior teeth or implants during the excursions. As a result, both the anterior and the posterior implant components receive a greater force (see Fig. 17.35).

In a study by Jemt et al,[11] when implant-supported restorations were used in the maxilla opposing natural dentition, the velocity of the mandible during excursions was greater with group function than when incisal guidance was present. The force to the implant system was greater with group function. Kinsel and Lin[91] reported that group function in patients with implant-supported prostheses had a porcelain fracture rate of 16.1% and occurred in 51.9% of implant patients. When anterior disclusion was the occlusal scheme in excursions, the fracture rate on implant crowns was 5.3%, and this complication affected 15.9% of patients (more than a threefold difference).

All lateral excursions in IPO opposing fixed resulting lateral forces are distributed to the anterior segments of the jaws, with an overall decrease in force magnitude. This occlusal scheme should be followed whether or not anterior implants are in the arch. However, if anterior implants must disocclude posterior teeth, natural teeth (whenever possible) are first used during the initial primary tooth movement. When multiple anterior teeth are missing, two or more implants splinted together (when possible) should help dissipate the lateral forces. Prostheses or natural teeth use anterior teeth or implants whenever possible to disocclude the posterior components. The resulting lateral forces are distributed to the anterior segments of the jaws, with an overall decrease in force magnitude.

Use Progressive Bone Loading for Poor Bone Quality

Complication.

In poorer quality of bone, occlusal overload is a potentially damaging complication for an implant prosthesis. When unfavorable force magnitude and direction is coupled with poor bone quality, an increase in implant failure results.[92,93] The bone density is a critical factor in the determination of

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the healing time and the type of prosthesis, and it is paramount that a separate surgical and prosthetic technique be given for each bone density type.

Prevention and Treatment.

Misch[94] first proposed the concept of progressive bone loading, which allows for modified prosthetic techniques to increase the bone-implant interface. This is accomplished via principles associated with Wolff's law, where bone mass increases in response to controlled stresses placed on the prosthesis. By gradually increasing the load applied, implants in poor bone quality are allowed to establish increased bone mass and density. The different elements of progressive bone loading include treatment time intervals (approximately 3–8 months), modified diet (softer food), occlusion (gradually intensify the occlusal contacts), and allowing loading to gradually increase during prosthesis construction and a gradual increase in the strength of prosthesis materials (from resin to metal to porcelain).

Rationale for Bone Density: Bone Physiology.

Cortical and trabecular bone throughout the body are constantly modified by either modeling or remodeling.[95] Modeling has independent sites of formation and resorption and results in the change of the shape or size of bone. Remodeling is a process of resorption and formation at the same site that replaces previously existing bone and primarily affects the internal turnover of bone, including the region where teeth are lost or the bone is next to an endosteal implant. These adaptive phenomena have been associated with the alteration of the mechanical stress and strain environment within the host bone.[96]

Bone responds to hormonal and biomechanical regulation and in some instances in which the demand for calcium is great (the primary objective for hormonal regulation), functional loading can compete and maintain bone mass.[97] The stress applied to bone is measured by the magnitude of force divided by the functional area over which it is applied. Strain is defined as the change in length of a material divided by the original length.

The greater the magnitude of stress applied to the bone, the greater the strain observed in the bone.[64] Bone modeling and remodeling are primarily controlled, in part or in whole, by the mechanical environment of strain. Overall, the density of trabecular bone evolves as a result of mechanical

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deformation from microstrain. The deformation of the alveolar bone by mechanical forces is also related to the thickness of the bony plate.

Clinical evaluation confirms an increase in the amount of trabecular bone and cortical plate thickness in patients with natural teeth exhibiting parafunction. A dentist can observe these bone density changes when attempting to extract teeth. In a severely parafunctional patient, the tooth usually fractures when attempting to remove it because the surrounding bone is stronger than the tooth. In a maxillary posterior second molar unopposed by any mandibular tooth, the bone is so soft that the complete tuberosity and surrounding bone fractures and the tooth and attached surrounding bone are removed as one piece. Frost[98] proposed that bone mass is a direct result of the mechanical usage of the skeleton. He redeveloped a mechanical adaptation chart relating trivial loading, physiologic loading, overloading, and pathologic loading zones to ranges of microstrain. His studies demonstrated increases in cortical bone mass related to strains applied to the bone (Fig. 17.80).

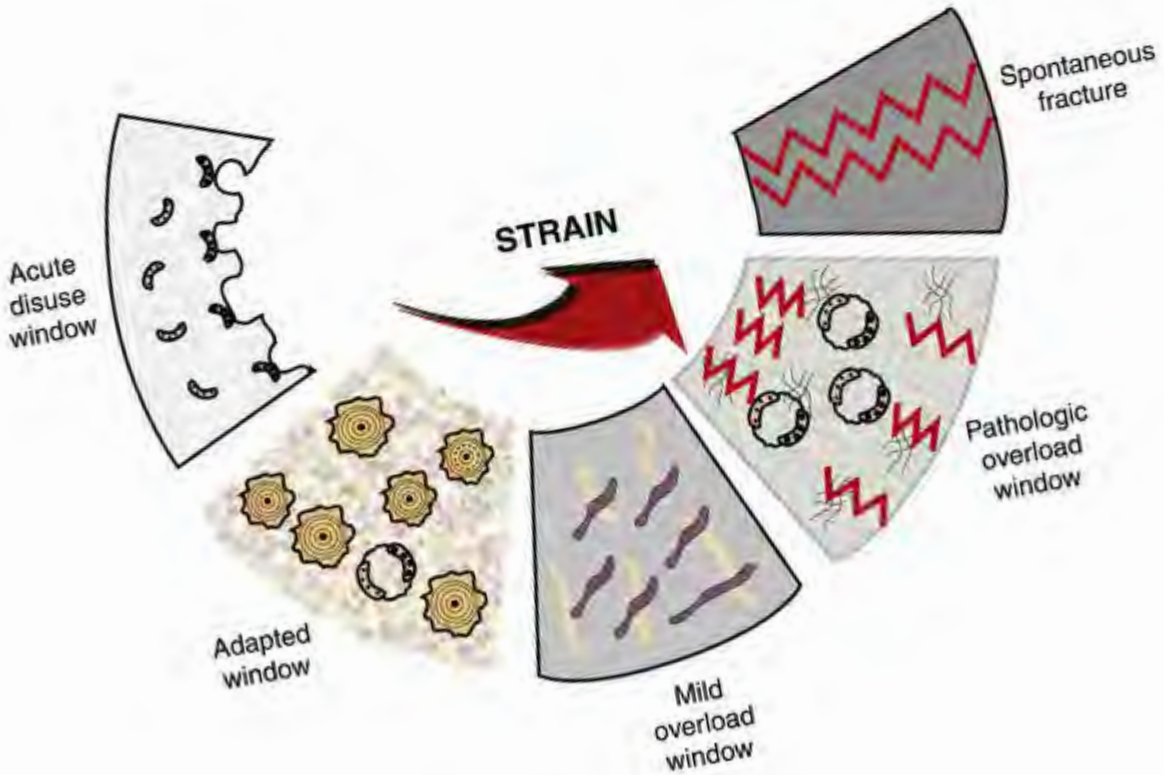

FIG 17.80 The microstrain conditions applied to bone determine the cellular events. The ideal loading zone is the adapted window. The pathologic overload zone causes bone resorption. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Bone cells and the extracellular matrix comprise the strain-sensitive population, and each plays a vital role in the mediation of the interface. A review of the literature of in vivo and in vitro studies has shown that dynamic or cyclic loading is necessary to cause a significant metabolic change in the bone cell population.[99] The greater the rate of change of applied strain in bone, the more bone formation is increased.[100] The effect of applied strains on bone is dictated not only by the rate of the applied load but also by the magnitude and duration.

In other words, the prosthetic loading of the dental implant changes the number and density of bone cells. Cyclic loading is necessary to cause a significant metabolic change in bone cell population. Lower magnitude loads applied for many cycles can cause the same anabolic effects of larger loads applied for a limited number of cycles.[101] A range of clinical conditions may equate to an increase in bone density, with prosthetic loading a logical condition for a dental implant.

Clinical Studies Supporting Progressive Loading.

The biomechanical environment plays an intricate role in the quality and compositional outcome of the new implant-bone interface. Under loading, bone behaves as a structure with material and architectural properties and as a biologic system.[102] Functional loading of the implant brings additional biomechanical influences, which greatly affect its maturation.

Computer-aided assessment of fixated implants through digital subtraction radiographic image analysis and an interactive image-analysis system demonstrate an increase in density of peri-implant bone structures over a 6-month to a 4-year period after the implant was placed.[103] The major changes of bone condensation around the implants occurred after the first 2 years they were loaded (Fig. 17.81). Bone density increase is primarily reflective of the local stress factors, and endosteal implants are the major method to alter the strain and increase bone density in the edentulous jaws. Continuously loaded implants remain stable within the bone with bone formation in areas under compression and the orientation of trabeculae corresponding to lines of stress.[104] As bone responds to physiologic forces, a gradual increase in loads during prosthetic fabrication stimulates an increase in density. The implementation of progressive loading is more critical for lesser bone densities because they are several times weaker than loads with significant cortical bone. Parafunction, cantilevers, and other stress magnifiers can increase the forces applied to the prosthesis and their shear

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components and cause bone microfracture or microstrains in the pathologic zone around the implant.[105] Progressive bone loading aims at increasing the density of bone, decreasing the risk of implant-bone failure, and decreasing crestal bone loss.

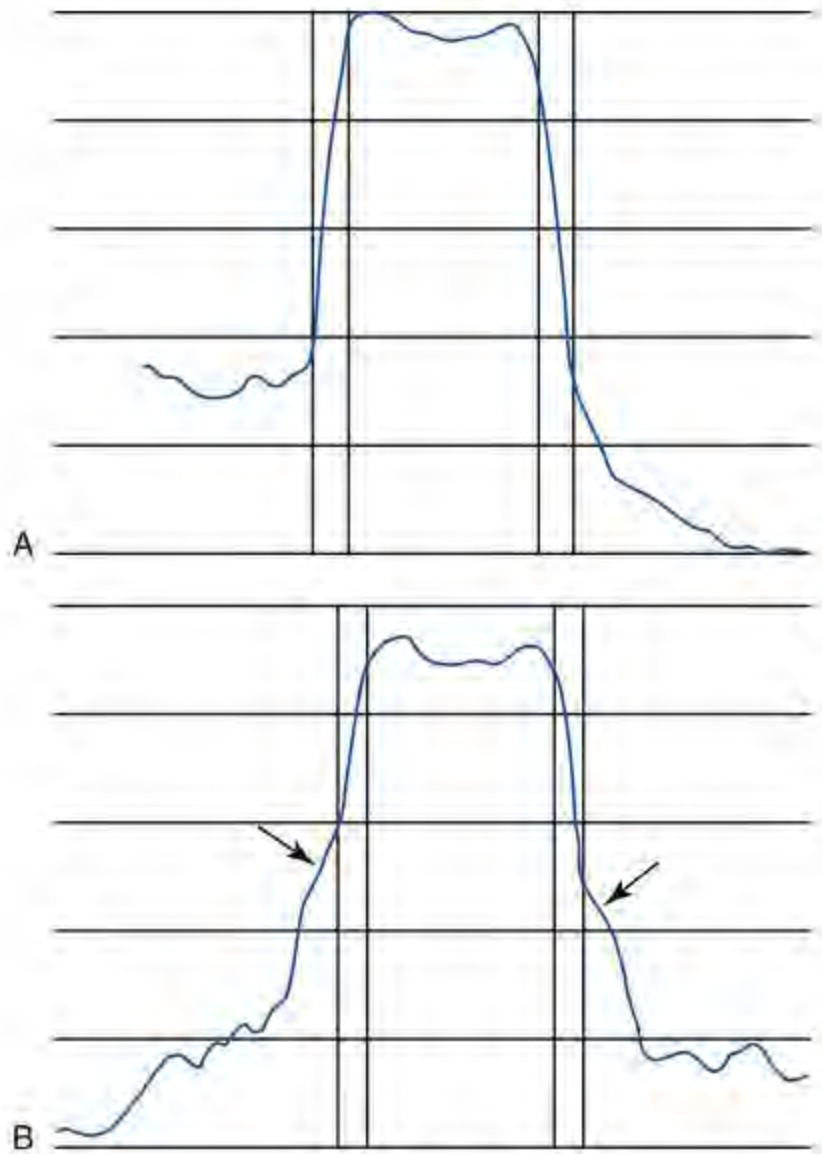

FIG 17.81 (A) An implant interface after initial healing is weaker than the day of surgery because woven bone is primarily present next to the implant. (B) After loading, the implant-bone interface is stronger than the original bone condition because the bone remodels in relation to the local strain condition. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby; data from Brägger U, Bürgin W, Lang NP, et al: Digital subtraction radiography for the assessment of changes in peri-implant bone density, *Int J Oral Maxillofac Implants* 6:160–166, 1991.)

Progressive Loading Protocol

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Full-arch prostheses with little or no cantilever and adequate implant number, position, and size rarely require progressive loading unless the bone density is poor. The favorable biomechanics of an arch are even compatible with immediate occlusal load applications.[100] However, the fewer the number of implants or the softer the bone types, the more progressive loading is needed and recommended.

Cantilevers, patient force factors, and implant position may influence risk factors in implant dentistry. Poor bone density may compromise implant success even when key implant position and number are satisfactory. In addition, crestal bone loss may be reduced with progressive loading.

The concept of progressive loading is to allow the bone to adapt to increasing amounts of biomechanical stress. Rather than immediately loading the bone-implant interface, methods to slowly increase the stress over time are beneficial. The progressive loading protocol uses a cement-retained prosthesis when implants are splinted together. Because a screw-retained splinted restoration is not completely passive and a torque force applied to a screw is greater than a bite force, a traditional screw-retained restoration cannot use progressive loading to gradually load the bone.

As a general rule, the higher the risk factors, the more progressive loading is recommended. The principles of gradual loading are demonstrated best in a cement-retained prosthesis and are least applicable for the screw-retained bar of a mandibular removable prosthesis type 5 (RP-5) restoration. In addition, gradually loading an RP-4 or RP-5 prosthesis with a screw-retained superstructure bar is difficult because the transitional prosthesis often remains removable during the prosthesis fabrication. In addition, most of the forces placed onto the implants for a screw-retained bar or prosthesis are generated at the delivery from nonpassive superstructures. As a result, screw-retained prostheses do not use a progressive loading protocol.

A longer healing time between stage I and stage II is suggested when forces are greater or bone is softer. This time allows greater mineralization of bone and a more mature lamellar bone interface to form next to the implants before the load of the screws is applied to the implant bodies.

The progressive loading protocol has five different methods to gradually load the bone or to increase the bone density around the implant (Box 17.6). These elements help the dentist evaluate the gradual loading progress.

Box 17.6

Elements of Progressive Loading

- Time interval
- Diet
- Occlusal material
- Occlusal contacts
- Prosthesis design

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

Time

Initial healing.

The histologic type of bone in contact with the implant varies and can affect the amount of stress the bone can sustain within physiologic limits. The ideal bone for implant prosthetic support is lamellar bone. Lamellar bone is highly organized but takes approximately 1 year to mineralize completely after the trauma induced by implant placement. Woven bone is the fastest and first type of bone to form around the implant interface; however, it is mineralized only partly and demonstrates an unorganized structure less able to withstand full-scale stresses. At 16 weeks, the surrounding bone is only 70% mineralized and still exhibits woven bone as a component. Computer-aided radiographic densitometry studies confirm that the bone-implant interface decreases the first several months after surgical insertion of an implant.[106] The percentage of bone mineralization and the type of supporting bone influence whether a load to the bone-implant interface is within its physiologic limits.

It has been reported that the bone-implant contact is related to the bone density and the healing time. For example, in a study by Carr et al,[107] the bone-implant contact was greater in the mandible than the maxilla (the mandible is usually more dense). In addition, the bone-implant contact was greater at 6 months compared with 3 months in both jaws. An increase in bone-implant contact occurred in both the maxilla and the mandible between 3 and 6 months and ranged from a 7% to 9% increase (Fig. 17.82). The healing

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time before implant loading may be related to the density of bone because the strength of bone increases and the bone-implant contact increases with a longer time period. A period of 3–4 months of healing for D1 and D2 bone and a period of 5–6 months for D3 and D4 bone have less risk than a shorter time period for all bone types. The time period between surgical placement and full occlusal loading is variable, depending on the bone density.

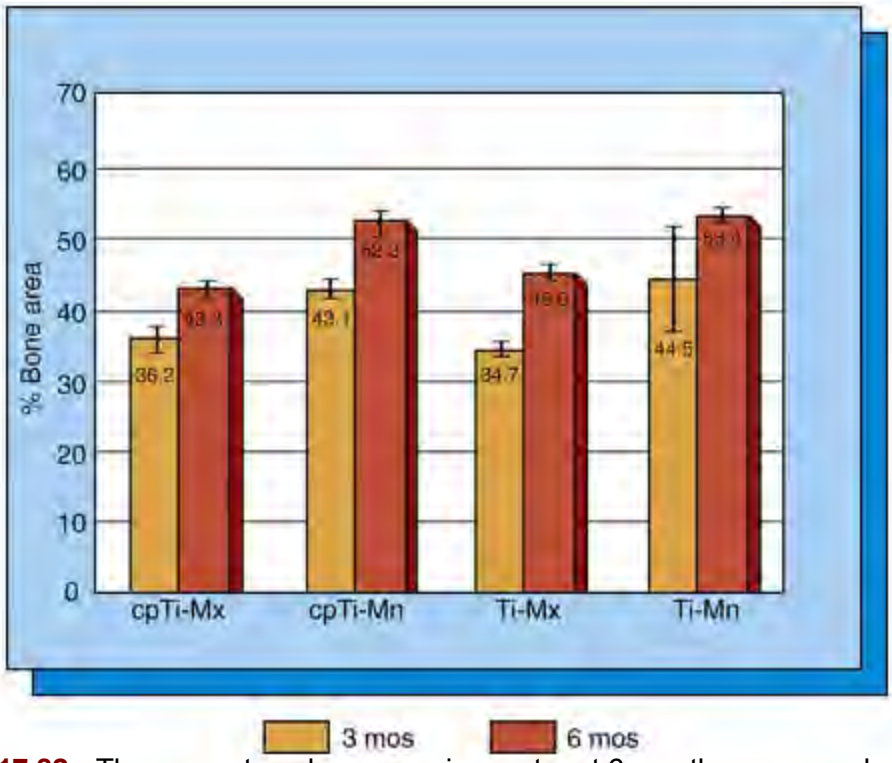

FIG 17.82 The percentage bone area is greater at 6 months compared with 3 months in both the maxilla and the mandible. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The macroscopic coarse trabecular bone heals approximately 50% faster than dense cortical bone. Although it heals more slowly, D1 bone has the greatest strength and greater lamellar bone contact. The suggested healing time between the initial and second-stage surgeries is similar for D1 and D2 bone and is 3–4 months. A longer time is suggested for the initial healing phase of D3 and D4 bone (5 and 6 months, respectively) because of the lesser bone contact and decreased amount of cortical bone to allow for the maturation of the interface and the development of some lamellar bone. In very immature bone, the healing time may be 8 months.

The D4 implant-bone interface typically found in posterior regions of the maxilla exhibits minimum initial bone contact, with little to no cortical bone

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at the crest or apex. An implant surgery initially may trigger an increase in the amount of bone in the region. For example, bone has been shown to grow in contact with a submerged titanium screw inserted into an open marrow chamber of the femur.[108] The initial increase of bone cell activity most likely results from the surgical trauma and the regional acceleratory phenomenon. The longer initial healing time is most beneficial to the poorest bone density types. In softer bone, a longer period of time of initial healing and gradual loading is suggested. Generally, D1 bone uses a period of 3 or more months before loading, D2 bone uses a period of 4 or more months, D3 bone uses a period of 5 or more months, and D4 bone uses a period of 6 or more months.

The combined observations of the macroscopic amount of bone in contact with a nonloaded implant and the microscopic type of bone at the stage II surgery of the implant demonstrates a wide difference in D1 to D4 bone densities. However, the long-term major improvement in bone density and strength occurs as a consequence of loading the implant.

Four prosthodontic steps are suggested for the reconstruction of a partially or completely edentulous patient, with endosteal implants supporting a cemented prosthesis. Each of the four major prosthodontic appointments also are separated by a period of time related to the bone density observed at the initial time of surgery. In addition, the dentist attempts to gradually increase the load to the implant at each prosthetic step. The four prosthetic steps are (1) abutment insertion, preparation, final impression, and temporary (of the esthetic zone); (2) a metal try-in and new bite registration; (3) initial delivery of the prosthesis; and (4) final evaluation of the restoration and hygiene appointment. In simple restorative cases, the prosthetic appointments may be reduced to three appointments: (1) abutment selection, preparation, final impression, opposing impression, and closed mouth bite registration; (2) initial delivery of the restoration; and (3) final evaluation stage (accompanied by a hygiene appointment).

Type D1 bone benefits from the greatest amount of lamellar bone contact at the beginning of the restoration process. As a result, gradual loading of the implant interface through spacing of the prosthodontic appointments is least important, and the restorative appointments can be separated by 1 week.

Type D2 bone responds favorably to physiologic loads. The four prosthetic appointments during which the implant body is loaded sequentially are separated by 2 weeks or more. The initial 4 months of healing after surgery and 2 months for prosthesis fabrication result in the overall treatment time

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of 5.5 months.

The prosthodontic appointments for D3 bone are separated by at least 3 weeks, and overall treatment takes approximately 7 months to complete, including the 5 months of initial healing. During this time, the bone contact percentage can increase, and the fine woven bone trabeculae can mature into coarser lamellar trabeculae, with an increase in mineral content. The progressive loading process is more critical for D3 bone than for D2 or D1 bone because of its weakness and less initial bone contact.

In D4 bone, the progressive bone loading protocol is most critical. When scheduling restorative appointments, one should err on the side of safety; the appointments should be separated by at least 4 weeks. As a consequence, the overall treatment time for D4 bone is twice that of D1 or D2 bone and at least 9 months (including 6 months of initial healing). This schedule allows sufficient time for mature lamellar, mineralized bone to develop at the interface and increases the numbers of trabeculae in direct contact and within the network region of the implant (Table 17.4).

TABLE 17.4

Treatment Times for Progressive Bone Loading for Cement-Retained Prostheses

Bone Density	Initial Healing (months)	Interval Between Appointments (weeks)	Reconstruction (weeks)	Total Time (months)
D1	3	1	3	4
D2	4	2	6	5.5
D3	5	3	9	7
D4	6	4	12	9

From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.

When the dentist uses multiple implants, the weakest bone area determines the gradual load protocol. If the anterior maxilla and posterior maxilla are restored together, the posterior maxilla would determine the initial healing period and the time period between each prosthetic appointment.

Diet.

The dentist controls the diet of the patient to prevent overloading during the early phases of the restorative process. During the initial healing phase, the dentist instructs the patient to avoid chewing in the area, especially when the implants are placed in a one-stage approach, with an exposed healing abutment.

After being uncovered, the implant connected to an abutment for cement retention is at greater risk of loading during mastication. The patient is limited to a soft diet such as pasta and fish from the final impression stage until the initial delivery of the final prosthesis. The masticatory force for this type of food is approximately 10 psi. This diet not only minimizes the masticatory force on the implants but also decreases the risk of temporary restoration fracture or a partially uncemented restoration. Either of these consequences can overload an implant and cause unwanted complications.

The diet should not be overlooked during the restorative phase of treatment. Most dentists have observed the fracture of an acrylic prosthesis with harder foods and greater occurrence of uncemented restorations when they ignore the type of diet during the transitional prosthesis stages.

After the initial delivery of the final prosthesis, the patient may include meat in the diet, which requires approximately 21 psi in bite force. The final restoration can bear the greater force without risk of fracture or uncementation. After the final evaluation appointment, the patient may include raw vegetables, which require an average 27 psi of force.

A normal diet is permitted only after evaluation of the final prosthesis function, occlusion, and proper cementation. The most damaging forces to a transitional (or final) restoration are from parafunction, not the function of eating. After the prosthesis is placed into occlusion, the evaluation of parafunction and methods to reduce its negative side effects are critical to the loading process.

Occlusal Material.

The occlusal material may be varied to gradually load the bone-implant interface. During the initial steps, the implant has no occlusal contact and in essence has no material over it. At subsequent appointments, the dentist uses acrylic as the occlusal material, with the benefit of a lower impact force than metal or porcelain. Either metal or porcelain can be used as the final occlusal material.

If parafunction or cantilever length causes concern relative to the amount of force on the early implant-bone interface, the dentist may extend the softer diet and acrylic restoration phase several months. In this way, the bone has a longer time to mineralize and organize to accommodate the higher forces.

Occlusal Contacts.

The dentist gradually intensifies the occlusal contacts during prosthesis

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fabrication. No occlusal contacts are permitted during initial healing (step 1). The first transitional prosthesis is left out of occlusion in partially edentulous patients (step 2). The occlusal contacts then are similar to those of the final restoration for areas supported by implants. However, no occlusal contacts are made on cantilevers or offset loads (step 3).

Prosthesis Design.

There are four potential prostheses designs in a restorative process. During initial healing, the dentist attempts to avoid any load on the implants, including soft tissue loads. In a completely edentulous patient, relief and a soft tissue conditioner (also relieved) may be used. The first transitional acrylic restoration in partially edentulous patients has no occlusal contact and no cantilevers. Its purpose is to splint the implants together and reduce stress by the mechanical advantage and to have implants sustain masticatory forces solely from chewing.

The second acrylic transitional restoration has occlusal contacts placed over the implants with occlusal tables similar to the final restoration but with no cantilevers in nonesthetic regions. The final restoration has narrow occlusal tables and cantilevers designed with occlusal contacts following implant-protective occlusion guidelines.

Progressive Loading Phases.

After the surgical stage II uncovery procedure or one-stage implant healing, the surgeon evaluates clinical mobility, bone loss (horizontal and vertical), proper placement in reference to prosthetic design and angulation to load, zones of attached gingiva, and gingival thickness. The surgeon usually attaches a low-profile permucosal extension to the implant body at the end of this appointment.

This component extends through the tissue approximately 2 mm and is protected from early loading (Fig. 17.83). In selected cases, often when the surgeon and restoring dentist are the same person, one may obtain the preliminary impression during this appointment if the soft tissues are outside the esthetic areas and if no bone recontouring or grafting has been performed or a one-stage surgical approach was used during initial healing. The dentist instructs the patient with a posterior implant in a partially edentulous arch not to wear any removable restoration. If anterior teeth are part of the removable prosthesis, a 7-mm-diameter hole is placed completely through the partial denture framework around each permucosal extension so

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that it will not load the implant. In completely edentulous patients, the tissue surface of the denture is relieved at least 5 mm over and around the implants and replaced by a tissue conditioner. The conditioner also is relieved a few millimeters.

FIG 17.83 A permucosal extension was placed by the surgeon at the implant insertion or at stage II uncover. Ideally, the soft tissue is healed before prosthetic reconstruction. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The patient returns in 2 weeks for suture removal and to replace the tissue conditioner with a soft liner. The procedures for a partially edentulous Kennedy Class I or II patient are first presented. The progressive bone-loading appointment sequence for cement-retained prostheses is as follows (Table 17.5):

1. Initial abutment selection, final impression, and transitional prosthesis I

2. Metal superstructure try-in and transitional prosthesis II

3. Initial insertion of final prosthesis

4. Final evaluation and hygiene

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TABLE 17.5

Progressive Loading Appointments for a Cement-Retained Prosthesis

Step	Procedure	Diet	Occlusal Material	Occlusal Contacts
1	Final abutments	Soft	Acrylic	None
	Final impression			No cantilever
	Transitional prosthesis			
2	Transitional prosthesis II			
	Metal try-in	Soft	Acrylic	Contacts only on implant; no contacts on cantilevers or pontics; occlusal table same as final prosthesis
	Bite registration			
3	Final prosthesis	Harder	Metal porcelain, or zirconia	Occlusion follows implant-protective occlusion guidelines; narrow occlusal table
	Adjust occlusion			
4	Final evaluation	Normal	Metal porcelain, or zirconia	Same as above
	Hygiene			

From Misch, CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

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Summary

The prosthodontic rehabilitation of patients with dental implants is one of the most complicated and complex parts of dentistry. The occlusal loading of the implant prosthesis is much different than traditional prosthetic principles on natural teeth. In the earliest years of the discipline, implant dentistry primarily existed as a multidisciplinary, team-based practice. Surgical principles were followed for implant placement, and restorative concepts were then put into action that created prostheses for the integrated implants. In many instances, the surgical and prosthetic plans lacked cohesiveness in design and planning, resulting in numerous complications and failures.

As knowledge regarding implant dentistry has increased, we now see the importance of blending these phases together. The occlusion scheme for implant-supported prostheses becomes most important to the longevity of the restoration because that scheme will dictate biomechanical stress placement along integrated implants. Failure to account for these fundamentals of implant occlusion will result in numerous complications in both the prosthesis and the implants proper.

It is paramount that any clinician, whether on the surgical, restorative, or both ends of implant treatment, be well versed in occlusal design before commencing with therapy. Force factors may need to be addressed, bone volumes may need to be augmented to allow for larger diameter (or more) implants, and key implant positions may need to be modified to offset potential loads. Knowing the optimal occlusal concept for a specific treatment plan will also assist the surgical phase of treatment because the surgeon has a clearer understanding of the demands of each implant as it pertains to function and optimal direction of force within the arch (Figs. 17.84 to 17.87, Boxes 17.7 to 17.11, and Table 17.6). The concepts in this chapter will allow for practitioners in all phases of implant dentistry to gain a clearer understanding of the prosthetic concepts that ensure stable, successful long-term dental implant restorations.

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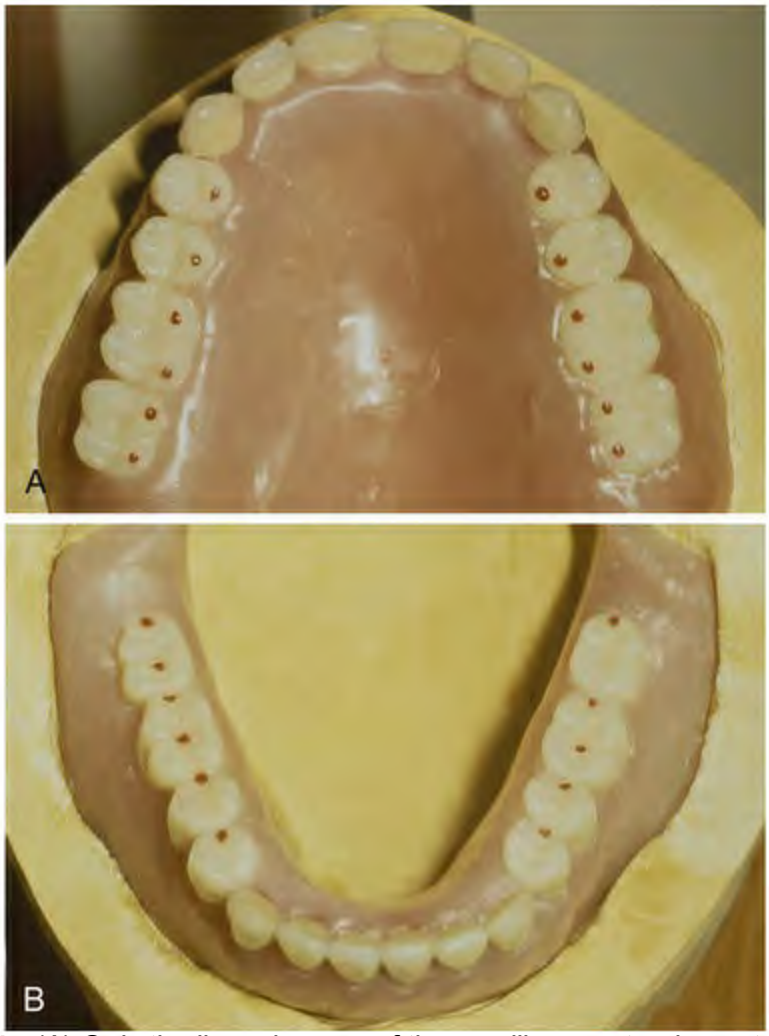

FIG 17.84 (A) Only the lingual cusps of the maxillary anatomic posterior teeth occlude with the mandibular teeth. This brings the occlusal contact closer to the crestal bone support and helps stabilize the denture. (B) The mandibular teeth have occlusal contact in the central fossa; the buccal cusps are reduced in height, with no occlusal contact in centric occlusion. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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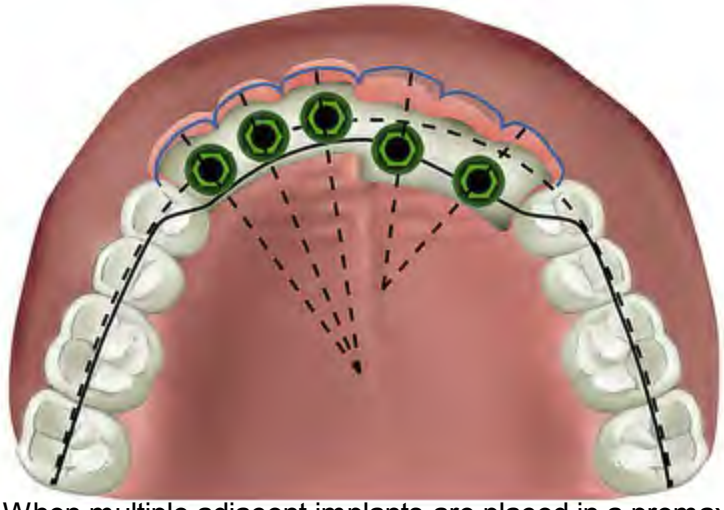

FIG 17.85 When multiple adjacent implants are placed in a premaxilla, the arch dimension often does not allow implant placement in the original teeth location without placing the implants closer than 3 mm apart *(left)*. When multiple anterior teeth are missing, most often only two implants can be positioned to replace the three anterior teeth *(on the right)*. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 17.86 When four anterior incisors are missing, most often three smaller diameter implants are used as prosthetic support. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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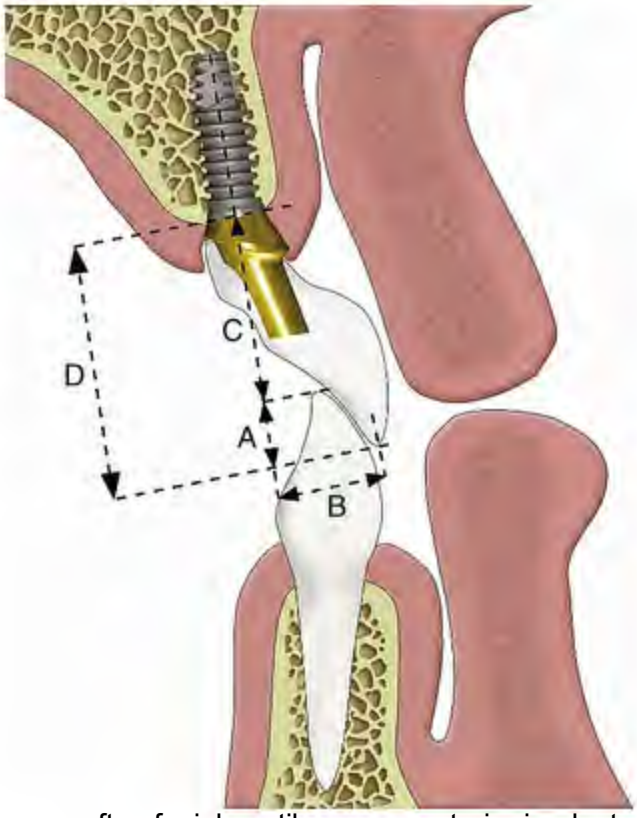

FIG 17.87 There are often facial cantilevers on anterior implants (points *A* and *B*). The crown height is also larger than the natural tooth (*C* in centric occlusion and *D* in protrusive). (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Box 17.7

Occlusal Recommendations for Single Implant-Supported Prostheses

- Implant diameter—correspond as closely to the mesial-distal diameter of edentulous space. A mandibular first molar has an average mesial-distal diameter of 11 mm. A 3- to 4-mm implant is usually contraindicated. Ideally, a 5- to 6-mm implant should be placed.
- Implant length—longer implants (i.e., >12 mm indicated in patients with poorer bone quality).
- Narrow occlusal table—minimize nonaxial loading forces (i.e., cantilever effect).
- Implant angulation—ideally perpendicular to curve of Spee and curve of

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Wilson; less than 30 degrees is contraindicated.

- Centered contacts in maximum intercuspation—to be in centric fossa with a larger contact area (approximately 2–3 mm; e.g., centric contacts to be avoided on marginal ridge because of cantilever effect).
- Minimal cusp height (i.e., monoplane occlusion).
- No contact with light biting force/light contact at heavy biting force—maximize force to adjacent teeth.
- No offset excursive contacts
- Increased interproximal contact area—dissipate occlusal forces
- Occlusal guard when parafunction present
- Progressive bone loading in poorer bone quality

Box 17.8

Occlusal Recommendations for Multiple Implants—Anterior Implant-Supported Restorations (Kennedy Class IV [Anterior Edentulous])

- Number of implants: In most cases, fewer implants are placed because of decreased length present (e.g., as bone resorbs from buccal, length of bone decreases, resulting in less space for implants).

Examples:

Replacing No. 6–11: Implants usually placed at No. 6, 8, 9, 11.

Replacing No. 23–25: Two implants placed between No.

23–24 and No. 25–26 (see Figs. 17.85 and 17.86).

- Canine position (if missing) is the most important position for implant placement.
- Implant diameter should correspond to diameter of natural tooth that is being replaced. Bone augmentation is often indicated.
- Implants should always be splinted together to distribute forces. Most often facial cantilevers are present because of the residual ridge resorption, which increases the moment force (see Fig. 17.87).
- Crown height space should always be evaluated in the anterior region because it is a force magnifier, which increases the cantilever effect.
- Progressive bone loading is often indicated because of inherent poor bone quality in the premaxilla (approximately D3 bone quality).
- Occlusal guard is indicated when parafunction is present.

Box 17.9

Occlusal Recommendations for Multiple Implants—Posterior Implant-Supported Restorations

- Number of implants: Usually one implant for each tooth replacement (e.g., fewer implants indicated when favorable force factors are present).
- Interbone distance between implants: approximately 3 mm.
- Splinting of implants indicated to increase force distribution.
- Narrow occlusal table.
- Minimal cusp height.
- Avoid nonaxial loading.

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- Avoid cantilevers when possible (e.g., biomechanically a mesial cantilever is more favorable than a distal cantilever).
- Infraocclusion on cantilever part of occlusal table.
- Maintain excursive guidance on healthy natural teeth while discluding the posterior implant segment.
- Centric contacts should be evenly placed over occlusal table corresponding to implant positions.
- Crossbite may be used when indicated.
- Use of occlusal guards is indicated especially when parafunctional forces are present.
- Kennedy Class I (bilateral posterior edentulous) and II (unilateral posterior edentulous): No protrusive contacts, narrow occlusal table, minimal cusp height, timed occlusal contacts.
- Kennedy Class III (edentulous space with anterior and posterior natural teeth): Timed occlusal contacts, disclusion is determined by natural tooth incisal guidance.

Box 17.10

Occlusal Recommendations for Fully Edentulous Implant Fixed Prosthesis

- Implant number:

Maxilla: 6–9 implants (e.g., <6 implants is controversial)

Mandible: 5–7 implants (e.g., <5 implants is controversial)

- Angulation—implant position to be lingual to incisal edge.

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- Splinting—should always be completed on maxilla and mandible except on mandible when bilateral implants posterior to the mental foramen (i.e., separate prosthesis usually separated distal to the cuspid on one side).
- Cantilever—amount of cantilever depends on force factors; cantilever should be in infraocclusion (approximately 100 μm).
- Occlusion—is dependent on opposing arch, skeletal relationship, and force factors; however, anteroposterior simultaneous contacts in centric relation and maximal intercuspation position.
- Shallow anterior guidance when opposing natural teeth.
- Freedom in centric relation (1–1.5 mm).
- Occlusal guard when parafunction is present.

Box 17.11

Occlusal Recommendations for Fully Edentulous Implant Removable Prosthesis

- Implant number:

Maxilla: 4–8 implants depending on RP-4 or RP-5 (e.g., <4 implants is controversial).

Mandible: 2–5 implants depending on RP-4 or RP-5 (e.g., 2 implants is controversial).

- Angulation—implant position to be center of ridge.
- Implant position—dependent on number of implants and anteroposterior spread.
- Anteroposterior simultaneous contacts in centric relation and maximal intercuspation position.

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- Occlusion—bilateral balance occlusion (i.e., medial positioned lingualized occlusion), true balanced occlusion opposing natural teeth may be difficult to obtain (i.e., minimum of three-point balance contacts on lateral and excursions). For poor ridge form (i.e., Division D, severe posterior ridge resorption), monoplane occlusion may be used.

- Support—usually bar-retained implant overdentures are implant supported (RP-4), and stud attachments usually exhibit primary soft tissue support (RP-5).

TABLE 17.6
Recommended Occlusion for Implant Prosthesis and Opposing Dentition

	Implant Prosthesis	Opposing Dentition	Ideal Occlusal Scheme	Additional Information
Edentulous	FP-3	Natural dentition	Mutually protected	Shallow incisal guidance
	FP-3	Complete denture	Bilateral balanced	Lingualized occlusion
	FP-3	FP-3	Mutually protected	
	FP-3	Overdenture	Bilateral balanced	
Edentulous	Overdenture	Natural dentition	Mutually protected	
	Overdenture	Complete denture	Bilateral balanced	Lingualized occlusion
	Overdenture	Overdenture	Bilateral balanced	
	Overdenture	FP-3	Mutually protected	
Dentate Kennedy Class I/II	FPD	Natural dentition	Mutually protected	Ideal splinting crowns
	FPD	Complete denture	Balanced	Lingualized occlusion
Dentate Kennedy Class III/IV	FPD	Natural dentition	Mutually protected	Ideal splinting crowns
	FPD	Complete denture	Balanced	Lingualized occlusion
Single tooth	Single implant crown	Any	Mutually protected	

FPD, Fixed partial denture.

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Periodontal and Maintenance Complications

Jon B. Suzuki, Carl E. Misch

Implant dentistry has evolved into an evidence-based, clinical science with well-documented research to validate previously unsupported clinical practice procedures. Significant efforts that focus on the biology and biomechanics of implant dentistry have helped develop and refine clinical techniques based on peer-reviewed findings. The evolution of research and understanding of biologic concepts in implant dentistry has caused many areas of conflict and controversy. Innovative theories have been developed that have resulted in technique changes. Science has spurred implant dentistry to new pinnacles of success.

The tremendous expansion of knowledge in this field has created new ideas and terminology that is redefined based on new principles. In many instances, new research may contradict established paradigms. It may be confusing for clinicians to select correct protocols, procedures, instruments, and techniques. As materials and techniques are further investigated, dogma may undergo criticism and controversy. Seasoned clinicians consistently update and modify techniques and instruments to maintain clinical excellence as technology and research advance.

One area of expansion of knowledge and conflict of views relates to the maintenance of dental implants. Early research explored techniques and instruments that were current for the methods and materials of that time. Although many of those implants still exist and are functional in patients, research and advances in technology have given us newer materials and advances in implant design and structure, minimizing previous challenges from a maintenance perspective.

An understanding of the mucoepithelial implant attachment is essential before commencing maintenance procedures. Controversies and parameters for probing and crestal bone loss are important for clinicians to recognize. There are anatomic and histologic differences between the attachment apparatus of teeth compared with implants that have undergone osseointegration. The bacterial plaque biofilm challenges on these implant-

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tissue attachments may be significant to clinical success.

When the clinician understands the parameters of implants and teeth, specific maintenance plans may be established for the patient. Clinicians should inform patients of expectations and outcomes during treatment and demonstrate oral hygiene options appropriate during each stage. Patients need to recognize the importance of maintenance protocols, and clinicians should assess compliance to home care routines. Patients also should be competent to perform home maintenance procedures. As the acceptance of and demand for dental implants increase, the need to understand the importance of maintenance as it relates to long-term implant success also increases. The role of the dental hygienist in implant maintenance and care is also increasing and becoming more defined.

Implants and associated prostheses are much different than natural teeth and may require adjunctive procedures and instruments for professional and patient care. Complications may arise when clinicians fail to comprehend these differences, which may increase the morbidity of treatment. The instrumentation utilized must be effective at removing biofilms and accretions, and procedures performed by patients and clinicians should avoid damage to all components of the implant, abutment, restoration, and associated tissue. Establishment and maintenance of the soft tissue seal around the transmucosal portion of the implant enhances the success of an implant. This barrier is fundamentally a result of appropriate wound healing and connection of epithelial attachments. The maintenance of healthy peri-implant tissues may contribute to implant success. In addition, tissues free of inflammation and a biofilm-free implant sulcus will support the patient's general and oral health.

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Peri-Implant Disease

Diagnosis

Complication

One important but often neglected component of comprehensive dental implant treatment is the postoperative evaluation and treatment of peri-implant issues. There are many conflicting thoughts and controversies on the diagnosis and treatment of these complications. Failure to effectively and promptly diagnose and treat peri-implant disease with dental implants leads to an increase in implant and prosthetic failure.

Etiology

Dental professionals are initially trained to have a firm understanding of the disease processes associated with the natural dentition. A variety of tests, indices, and radiographic signs are used to determine the health of a natural tooth. Dental implants and their related prostheses have fundamentally different relationships to the oral environment than teeth, and these differences necessitate a change in diagnostic protocol for the determination of health. Failure to understand these differences may lead to a lack of recognition of early disease processes. Without early intervention, increased morbidity may result.

Prevention

The following section of this chapter will outline various anatomic and histologic differences between natural dentition and the dental implant as they pertain to periodontal structures. By having this background established, the clinician may appreciate these necessary differences and will be better equipped to effectively diagnose peri-implant disease processes. Inflammatory conditions around dental implants or dental implant prostheses are collectively defined as peri-implant disease. The most common terms accepted in implant dentistry, *peri-mucositis* and *peri-implantitis*, originated from the First European Workshop on Periodontology in 1994.[1] These terms remain current with slight modifications and have similar comparisons to periodontal diseases around natural teeth (i.e., gingivitis, periodontitis).[2] An implant clinician should have a thorough understanding of the related definitions.

Gingivitis is a bacteria-induced inflammation involving the region of the

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marginal gingiva above the crest of bone and next to a natural tooth. It is always associated with plaque and may be classified as (1) acute necrotizing, (2) ulcerative, (3) hormonal, (4) drug induced, or (5) spontaneously occurring.[3] These categories also can relate to the gingival tissues around an implant because the mode of attachment of the gingiva to a tooth and implant has been reported to be partially similar.[4]

The bacteria responsible for gingivitis around a tooth may affect the epithelial attachment without loss of connective tissue attachment. Because the connective tissue attachment of a tooth extends an average of 1.07 mm above the crestal bone, at least 1 mm of protective barrier above the bone is left. In contrast, no connective tissue attachment zone exists around an implant because no connective fibers extend into the implant surface. Therefore, no connective tissue barrier exists to protect the crestal bone around an implant.[5]

Periodontitis around teeth is characterized by apical movement of junctional epithelium and periodontal attachment coupled with loss of alveolar bone. Bacteria is thought to be responsible by stimulating the body's immune response, which results in an overall resorptive effect on the periodontal attachment apparatus. The American Academy of Periodontology recognizes two main types of periodontitis: chronic and aggressive periodontitis. Each encompasses many specific subtypes for each category such as adult chronic periodontitis, progressive periodontitis, localized juvenile, prepubertal, etc.

In contrast to teeth, early crestal bone loss around an implant postprosthetically usually is not caused by bacteria. Most often the bone loss results from stress factors too great for the immature, incompletely mineralized bone-implant interface or an extension of the biologic width onto a smooth metal crest module.[6] An implant may exhibit early crestal bone loss with a different mechanism or cause compared with natural teeth. However, on occasion, bacteria may be the primary factor. Anaerobic bacteria have been observed in the microgap between the implant and the abutment or in the sulcus of implants, especially when sulcus depths are greater than 5 mm (Box 18.1).[7]

Box 18.1

Stable Integrated Implants: Bacteria Related to

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Pocket Depth Increases

Shallow

Gram-positive facultative cocci, rods

Gram-negative anaerobic cocci, rods

Motile rods

Spirochetes

Black-pigmented *Bacteroides*

Fusobacterium

Deep

Vibrios organisms

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

Periodontal disease that develops around dental implants has been classified into two separate entities: peri-implant mucositis and peri-implantitis. These classifications were proposed via a consensus report from the First European Workshop on Periodontology (EWOP). Peri-implant mucositis was defined as a reversible inflammatory reaction in the peri-implant tissues surrounding an implant, and peri-implantitis is defined as inflammatory reactions with loss of supporting bone around an implant.[1]

Periimplant mucositis is an inflammatory condition of the soft tissue surrounding an implant, which is similar to gingivitis around a tooth. This has been defined as a reversible condition with no loss of attachment or bone loss. The primary etiologic factor has been shown to be plaque biofilm, the removal of which easily reverses the disease process. If allowed to progress, peri-implantitis may result, which includes loss of bone and loss of osseointegration, similar to loss of attachment and bone with periodontitis. The prevalence of peri-implant mucositis (bleeding on probing and no loss of bone) has been shown to be approximately 79% to 90% of subjects and 50% of implants.[8]

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Peri-implantitis exhibits similar microbial flora as adult periodontitis. Changes involve both the hard and soft tissues surrounding an implant. The implant may exhibit all the signs of peri-implant mucositis as well as exudate, increased pocket depth, and bone loss. If left untreated, significant bone loss, infection, and mobility could result, leading to the failure of an initially integrated implant. According to Mombelli et al, the microbiota are site specific and similar to chronic adult periodontitis.[9] The clinical signs include radiographic or probing vertical bone loss, peri-implant pockets, bleeding upon probing (with or without exudate), mucosal swelling and redness, and an absence of pain (Box 18.2). The crestal bone loss may be induced by stress, bacteria, or a combination of both. Stress-induced bone loss occurs without bacteria as the primary causative agent. However, after the bone loss from stress or bacteria, the sulcular crevice deepens and decreases the oxygen tension, and anaerobic bacteria may become the primary promoters of the continued bone loss. An exudate or abscess indicates exacerbation of the periimplant disease and possible accelerated bone loss. The prevalence of peri-implantitis has been found in 28% to 56% of subjects and 12% to 43% of implant sites (Fig. 18.1).[8]

Box 18.2

Clinical Signs of Peri-implantitis

- Vertical bone loss (radiographic, probing, or both)
- Periimplant pockets
- Bleeding upon probing
- ± Exudate
- Mucosal swelling
- Erythema
- No pain

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.

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FIG 18.1 (A) Spongiotic gingivitis exhibiting erythematous marginal tissue with cyanotic tissue. (B) Periodontitis: mandibular anterior exhibiting severe horizontal bone loss. (C) Perimucositis: erythematous buccal gingiva with associated bleeding around implant crown. (D) Peri-implantitis: significant bone loss with erythematous tissue with significant plaque accumulation.

Evaluation of Periodontal Indices

Periodontal indices are often used for evaluation of dental implants. A comparison of natural teeth and implants for each criterion provides insight into their differences in the health-disease continuum. After one understands the basis for evaluation, these criteria may then be used to establish a health-disease implant quality scale related to patient treatment.

Mobility

Natural Tooth vs. Implant Support Systems.

A dental implant and a natural tooth differ in many ways. In general, a natural tooth is better designed to reduce the biomechanical forces distributed to the tooth/restoration and the crestal bone region. The periodontal attachment apparatus, biomechanical design of the tooth root

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and material, nerve and blood vessel complex, occlusal material (enamel), and surrounding type of bone blend to decrease the risk of occlusal overload to the natural tooth system.[10]

Tooth movement.

A tooth exhibits normal physiologic movements in vertical, horizontal, and rotational directions. The amount of movement of a natural tooth is directly related to its surface area and root design. The factors that dictate the movement include: the number and length of the root surface, the root diameter, shape, position, health of the periodontal attachment apparatus, and the bone density primarily influence a tooth's mobility. A healthy tooth exhibits zero clinical mobility in a vertical direction. Studies have shown an initial vertical tooth movement to be about 28 μm and is the same for anterior and posterior teeth.[11] The vertical movement of a rigid, fixated implant has been measured to be approximately 2 to 3 μm under a 10-lb force and is due mostly to the viscoelastic properties of the underlying bone.[12]

Muhlemann found that horizontal tooth movement may be divided into initial mobility and secondary movement.[13] The initial mobility is observed when there is a light force applied, which occurs immediately, and is a consequence of the periodontal ligament (PDL). Initial horizontal tooth mobility is greater than initial vertical movement. A very light force (500 g) may horizontally move a tooth. The initial horizontal mobility of a healthy, "nonmobile" posterior tooth is less than that of an anterior tooth and ranges from 56 to 75 μm, which is two to nine times the vertical movement of the tooth. Initial horizontal mobility is even greater in anterior teeth and ranges from 70 to 108 μm in health (Fig. 18.2).[14]

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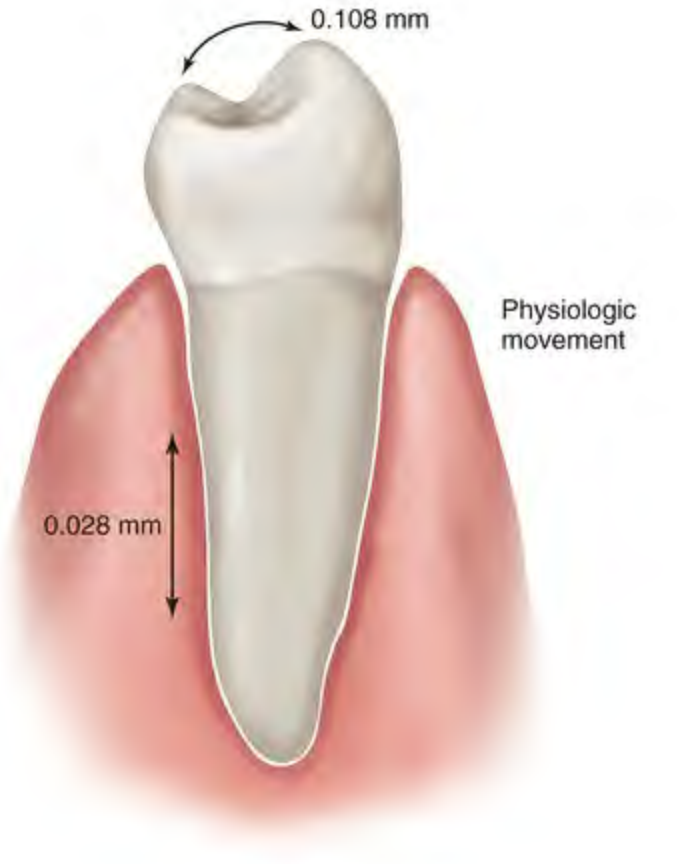

FIG 18.2 The physiologic movement of a healing tooth has been measured as 28 µm in the apical direction and up to 108 µm in the horizontal direction. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The secondary tooth movement described by Muhlemann occurs after the initial movement when greater forces are applied. When an additional force is applied to the tooth, a secondary movement is also observed, which is related directly to the amount of force. The secondary tooth movement is related to the viscoelasticity of the bone and measures as much as 40 µm under considerably greater force (Fig. 18.3).[13]

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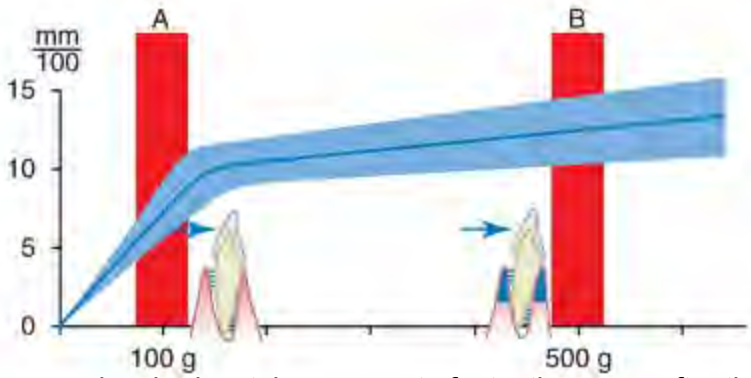

FIG 18.3 A secondary horizontal movement of a tooth occurs after the initial tooth movement when a greater force is applied and is related to the deformation of the alveolar bone. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Implant movement.

The term *rigid fixation* is used to describe the absence of clinical mobility of an implant tested with vertical or horizontal forces less than 500 g. However, rigid fixation is a clinical term. *Osseointegration* is a histologic term that is defined as bone in direct contact with an implant surface at the magnification of a light microscope (Fig. 18.4).[15] Over the years, these two terms have been used interchangeably, and implant abutment support is most predictable with rigid fixation. Lack of implant mobility (IM) does not always coincide with a direct bone-implant interface. However, when observed clinically, rigid fixation usually means that at least a portion of the implant is in direct contact with bone, although the percentage of bone contact cannot be specified. When an implant has mobility, there is most likely connective tissue between the implant and bone.

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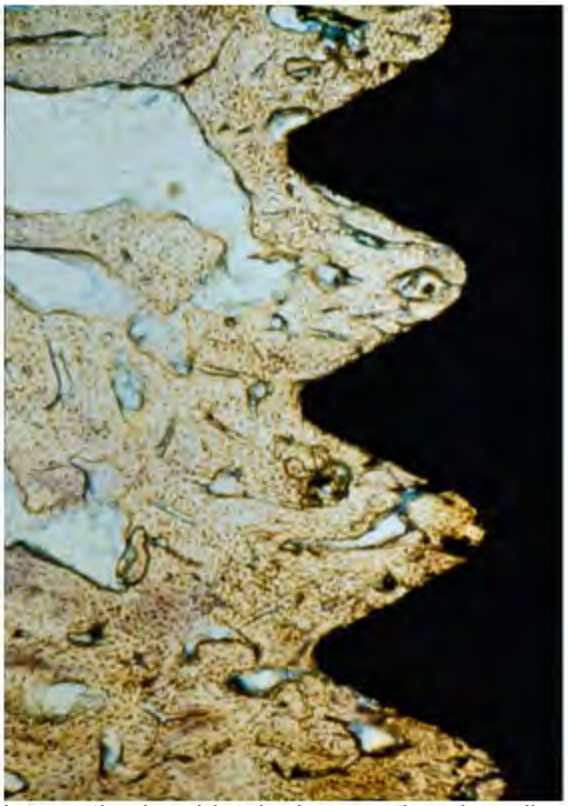

FIG 18.4 *Osseointegration* is a histologic term that describes a direct bone-to-implant contact at the level of magnification of a light microscope. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

In some situations, the presence of implant mobility may be difficult to discern. The absence of clinically observable movement does not indicate the true absence of any movement. For example, a "nonmobile" posterior natural tooth actually moves horizontally 56 to 73 μm. The human eye does not perceive this movement. The anterior teeth, which often have slight clinically observable movement, actually move approximately 0.1 mm. A healthy implant may move less than 73 μm; it appears as zero clinical mobility (rigid fixation).

Similar to a natural tooth, the implant-bone interface exhibits more lateral than apical movement. Sekine et al evaluated the movement of endosteal implants with rigid fixation and found a range of 12 to 66 μm of movement in the labiolingual direction.[12] Komiyama reported 40 to 115 μm of implant movement in the mesiodistal direction under a force of 2000 g (≈4.5 psi) and a labiolingual range of 11 to 66 μm.[16] The greater implant movement in the mesiodistal dimension corresponds to the lack of cortical bone between the implants in this direction compared with the thicker lateral cortical plates present in the labiolingual dimension. Rangert et al suggested that part of this implant movement may also be due to component flexure of the implant

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abutment and screw.[17] The mobility of implants varies in direct proportion to the load applied and the bone density and reflects the elastic deformation of bone tissue.

Sekine et al applied a gradually increasing load over a 2-second period to a tooth and an implant. The teeth moved immediately with a light load (primary tooth movement) and less with an additional load (secondary tooth movement). The implant did not move when the tooth had its primary tooth movement. A heavier force caused the implant to gradually move, similar to the secondary tooth movement (see Fig. 18.3).[12] These mobility characteristics corroborate the findings of Fenton et al, who applied a 500-g load for 4 seconds to maxillary anterior teeth and osseointegrated implants.[18] Whereas the implants were displaced a mean of 10 μm with a rapid elastic return (less than 1 millisecond), the teeth showed a mean displacement of 57 μm with a prolonged viscoelastic return.

Evaluating Dental Implant Mobility

Mirror handles.

Increased tooth mobility may be caused by many factors including occlusal trauma or bone loss. Increased tooth mobility alone is not a criterion of periodontal health or pathology. Unlike a tooth, for which mobility is not a primary factor for longevity, mobility is a primary determining factor for implant health.[15] Rigid fixation of an implant is also an excellent indicator of the implant health status because it is an easy, objective test. As such, rigid fixation is usually the first clinical criterion evaluated for a dental implant. The techniques to assess rigid fixation are similar to those used for natural tooth mobility. Two rigid instruments apply a labiolingual force of approximately 500 g, and no observed mobility indicates rigid fixation (Fig. 18.5).[3]

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FIG 18.5 Evaluation of implant mobility with the use of a mirror handle.

The amplitude of tooth mobility may be rated from 0 to 4, where 0 is normal mobility from physiologic movement; 1 is detectable increased mobility; 2 is visible mobility up to 0.5 mm; 3 is severe mobility up to 1 mm; and 4 is extreme mobility, including vertical movement.[3] This same gradient may be used for oral implants with slight modification. As Table 18.1 depicts, IM-0 corresponds to the absence of clinical mobility, IM-1 demonstrates detectable increased movement, IM-2 is visible mobility movement up to 0.5 mm, IM-3 is severe horizontal mobility greater than 0.5 mm, and IM-4 is visible horizontal and vertical movement. The IM scale was used frequently for plate (blade) form implants or disc implants because a clinical goal was for slight mobility when joining the device to natural teeth. However, the ideal goal for root form implants should always be rigid fixation and IM-0 status (no movement).

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TABLE 18.1
Clinical Implant Mobility Scale

Scale	Description
0	Absence of clinical mobility with 500 g in any direction
1	Slight detectable horizontal movement
2	Moderate visible horizontal mobility up to 0.5 mm
3	Severe horizontal movement greater than 0.5 mm
4	Visible moderate to severe horizontal and any visible vertical movement

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby; data from Misch CE: Implant quality scale: a clinical assessment of the health-disease continuum, *Oral Health* 88:15–25, 1998.

Periotest.

The Periotest (Gulden-Medizinteknik) is a computer-mechanical device, developed by Schulte, that measures the dampening effect or attenuation degree against objects by developing a force of 12 to 18 N against a pistonlike device, which then measures the distance the piston recoils into the chamber after striking an object.[19] A soft surface or mobile object gives higher recordings than a hard or rigid object. The recordings range from negative 8 to positive 50 numbers.

Teeth with zero clinical mobility have typical Periotest ranges from 5 to 9. The degree or absence of clinical movement around an implant corresponds to values ranging from −8 to +9, or a range of 17 units. The bone density around the implant may be correlated with Periotest numbers. Whereas softer bone types give higher numbers, harder bone around the implant results in lower numbers. A nondestructive resonance frequency analysis technique to measure implant stability and osteointegration has also been introduced to the profession and provides similar valuable information as to the clinical movement and bone density around implants (Table 18.2).[20,21]

TABLE 18.2
Periotest Values vs. Clinical Interpretation

Periotest Value	Clinical Interpretation
−8 to 0	Satisfactory integration
+1 to +9	Clinical examination recommended because integration is not sufficient for prosthetic loading
+10 to +50	Integration insufficient, progressive bone loading recommended

Osstell.

A second device exists to evaluate the implant-bone interface that is

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nondestructive and noninvasive. The Osstell (Ostell) is based on resonance frequency analysis (RFA) and was developed by Huang.[22] The Osstell has been shown to have quantitative and reproducible measurements on the presence of integration, immediate load feasibility, and follow-up evaluation at the prediction of an implant failure. RFA is a technique that is based on continual excitation of the implant interface through the use of dynamic vibration analysis (piezo effect). A specialized transducer, which contains two piezoceramic elements, is either attached directly to the implant or abutment. The first piezo element generates an excitation signal that is a sinusoidal wave (5–15 kHz), leading to vibration of a whole transducer-implant-tissue complex. The oscillation response is measured by the second piezo element.[23]

The RFA technique measures implant stability as a function of stiffness of the bone/implant complex. The health of the implant is measured on an implant stability quotient (ISQ) that is calculated on a scale from 1 to 100. The full integration of an implant is most usually measured in the range from 45 to 85 ISQ. Measurements of less than 45 are indicative of implant failure, whereas an ISQ value of 60 to 70 indicates success.[24] Studies have shown that the Osstell is more reliable than the Periotest in evaluating and measuring implant stability in hard and soft tissue interfaces (Fig. 18.6 and Table 18.3).[25]

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FIG 18.6 Implant Stability Quotient (ISQ) is a scale from 1 to 100 that measures the stability of an implant. The ISQ scale has a nonlinear correlation to micro mobility. High stability means >70 ISQ, between 60 and 69 is medium stability and <60 ISQ is considered as low stability. (A) Osstell Smart Peg that is implant specific. (B) Hand driver that is used to place Smart Peg into implant. (C) Smart Peg hand-torqued into implant. (D) Handle removed, Osstell reader is placed in approximation (without touching the Peg). (E) Osstell reading exhibiting high stability.

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TABLE 18.3

Osstell Values vs. Clinical Interpretation

Osstell Value (ISQ Score)	Clinical Interpretation
<60	Low stability = Implant at risk
60–65	Medium stability = Traditional two-stage loading protocol
65–70	Medium to high stability: Early loading
>70	High stability: Immediate loading

Plaque Biofilm

The differences between tooth and implant biologies make dental implants more susceptible to inflammation and bone loss in the presence of bacterial plaque accumulation.[26] Biofilms are the primary causative factor of periodontal disease processes. Sticky masses of bacteria with a polysaccharide matrix, water, and bacteria accumulate on hard and soft surfaces in the oral cavity and can be disturbed and removed with mechanical or chemical obliteration. If undisturbed, mature plaque will form. Current chemotherapeutics cannot penetrate thick biofilm, and rough surfaces have been found to hold more biofilm than smooth surfaces.[27] Bacteria will migrate from teeth to implants and from implant to implant. Similar to teeth, clinical findings of failing implants include inflammation, pockets, and progressive bone loss. Another similarity lies in the bacteria responsible for periodontitis and peri-implantitis.

When evaluating the peri-implant microbiota, Lee et al. compared microbial changes between patients with a history of periodontal or peri-implant infections and implants that have been in function for a length of time.[28] This study found a history of periodontitis had a greater impact on the peri-implant microbiota than implant loading time. The major influence on the peri-implant microbiota was, however, the microbiota on remaining teeth. *Porphyromonas gingivalis* and *Bacteroides forsythus* (Tannerella forsythia), red complex periodontal pathogens, colonized several implants, although all implants were successfully osteointegrated. It is important to educate patients about their responsibility to decrease plaque effectively, especially if they have a history of periodontal disease.

Plaque biofilm development and maturation have similarities for natural teeth and dental implants. The gingival sulcus in periodontal health and the perimucosal attachment of a successful dental implant are essentially similar. In a study by Mombelli and Mericske-Stern of the plaque from 18 edentulous

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patients with successful dental implants, facultative anaerobic cocci (52.8%) and facultative anaerobic rods (17.4%) were reported.

However, the pathogens *P. gingivalis* and spirochetes were absent, and minimal (7.3%) gram-negative rods were present.[29] Generally, pellicle—a naturally occurring glycoprotein in the saliva—first adheres to the intraoral structure, whether it be a tooth or an implant. Gram-positive cocci bacteria are the first "early colonizers," beginning with single cocci and progressing to streptococci forms (Box 18.3).

Box 18.3

Plaque Biofilm Development and Colonization

Identify potential implant patients
↓
Bacterial adhesion
↓↓
Supragingival plaque
Gram+, streptococci, Actinomyces
↓↓↓
Plaque maturation (gram−, rods, and filaments)
↓↓↓↓
Well-differentiated subgingival plaque
(Gram−, anaerobes)

From Misch CE: *Contemporary implant dentistry*, ed 3, St. Louis, 2008, Mosby.

Without appropriate oral hygiene measures (e.g., brushing, flossing, interdental cleaning), additional bacterial colonies including gram-negative rod-shaped bacteria synergistically grow with the established gram-positive bacteria. The gram-negative bacteria are frequently facultative or strict anaerobic bacteria and are considered "late colonizers." Many, if not the majority, of these gram-negative bacteria are black pigmented and are classified under a number of genera (e.g., *Bacteroides, Prevotella, Porphyromonas, Fusobacterium*).

Plaque biofilm reported to be associated with failing dental implants also consists largely of gram-negative rods.[30] Clinically, failing dental implants are characterized by soft tissue inflammation, increased probing depths, increased mobility, and peri-implant radiolucency.

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Specific pathogens in implant pockets greater than 6 mm include *Actinobacillus actinomycetemcomitans* (Aggregatibacter actinomycetemcomitans), *Prevotella intermedia,* and *P. gingivalis* in more than one third of the sites, as confirmed by DNA analysis.[31]

In other studies on plaque biofilm around dental diseases and failing implants, differences in bacterial type have been reported.[32,33] Mombelli did not detect spirochetes in plaque samples from well-maintained and clinically healthy implants. Rams et al noted higher proportions of staphylococci (15.1%)[19] than usually found in gingivitis (0.06%) and periodontitis (1.2%) sites.[34] This finding suggests that staphylococci may be more significant in developing peri-implantitis lesions than previously recognized.

Changes involve both the hard and soft tissues surrounding an implant. The implant may exhibit all the signs of peri-implant mucositis, as well as exudate, increased pocket depth, and bone loss. If left untreated, significant bone loss, infection, and mobility could result, leading to the failure of an initially integrated implant.

Comparisons of plaque biofilms have been reported in a limited study of Brånemark and ITI (Straumann Institute) implants and are remarkably similar in controlled studies. Mombelli et al compared 10 patients with Brånemark implants and 10 patients with ITI implants and sampled the deepest pockets around the implants.[35] After 3 and 6 months, several periodontal pathogens were cultured and isolated, including *P. gingivalis, P. intermedia, Fusobacterium nucleatum,* and various spirochetes. None of the implants were colonized by *A. actinomycetemcomitans.* Longer investigations by Leonhardt et al extended these microflora reports on dental implants in 19 patients. At 3 years, the osteointegrated implants were colonized predominantly by *P. gingivalis, P. intermedia,* and *A. actinomycetemcomitans*.[36]

Natural dentitions with dental implants appear to increase the risk for implant infections, compared with completely edentulous patients. This suggests that natural teeth may serve as a reservoir for periodontal pathogens that may extend their growth to contiguous implants in the same oral cavity.[37] Quirynen and Listgarten reported that proportions of coccoid forms (65.8%), motile rods (2.3%), and spirochetes (2.1%) in implant pocket areas were similar to the microorganisms in natural teeth (55.6%, 4.9%, and 3.6%, respectively). Fully edentulous patients exhibited more coccoid forms (71.3%), fewer motile rods (0.4%), and no spirochetes.[38] They also concluded that microflora in partially edentulous implant patients were potentially more pathogenic than they were in fully edentulous patients. Implants with

longevity of more than 3 or 4 years appear to have greater numbers of bacteria than implants in place for 1 or 2 years.

Clinical Significance

Plaque biofilms are the main reason peri-implantitis treatments fail. Host tissue is unable to reform attachments onto implant surfaces if titanium surface is not thoroughly cleaned. Bacterial deposits produce toxins that prevent fibroblast and osteoblast growth, which prevents proximal regeneration onto implant surface. To ensure the most optimal condition for treatment success, plaque biofilms need to be thoroughly removed. It is important to note that while it is impossible to guarantee 100% sterility of exposed implant surfaces, the body is capable of removing small amounts of bacterial deposit via cellular defense mechanisms. Carefully removing macro deposits of plaque biofilm and irrigating with antimicrobial solution is generally sufficient to allow a favorable environment for new attachment formation.

In essence, the patient should have a full-mouth debridement to reduce overall oral load of bacterial colonies while making an effort to remove all plaque biofilms on exposed implant surfaces. This gives the body a chance to reform a healthy-associated colonization of biofilm.

Percussion

Percussion often is used on teeth to determine which tooth is sensitive to function or if pulpal necrosis is beginning. In the past, percussion was used to evaluate the presence of rigid fixation for osseointegrated implants.[15] However, percussion is an indicator neither of clinical health nor of rigid fixation for osseointegrated implants. The ringing sound that occurs on percussion only corresponds to the presence of some amount of bone at the interface because 2 mm of bone and 16 mm of bone-implant interface sound almost identical.

Clinical Significance

Percussion may be used to diagnose pain or tenderness with an implant but is misleading if used to determine the status of rigid fixation.

Probing Depths

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Probing depths around teeth is an excellent proven means to assess the past and present health of natural teeth. The increasing sulcus depth around natural teeth is directly related to disease and bone loss. However, probing depth indices used to evaluate dental implants are more controversial because implant sulcus depth and health are not always directly related. A thorough appreciation of the soft tissue interface is needed for the clinician to understand the inherent differences between natural teeth and dental implants.

Soft Tissue Interface Around Teeth and Implants

For a natural tooth the surrounding soft tissue has an average biologic width of 2.04 mm between the depth of the sulcus and the crest of the alveolar bone. It should be noted the biologic "width" is actually a height dimension with a greater range in the posterior region compared with the anterior and may be greater than 4 mm in height.[39] With respect to natural teeth, the biologic width is composed of a connective tissue attachment (1.07 mm average) above the bone and a junctional epithelial attachment (JEA) (0.97 mm average) at the sulcus base, with the most consistent value among individuals being the connective tissue attachment (Fig. 18.7).

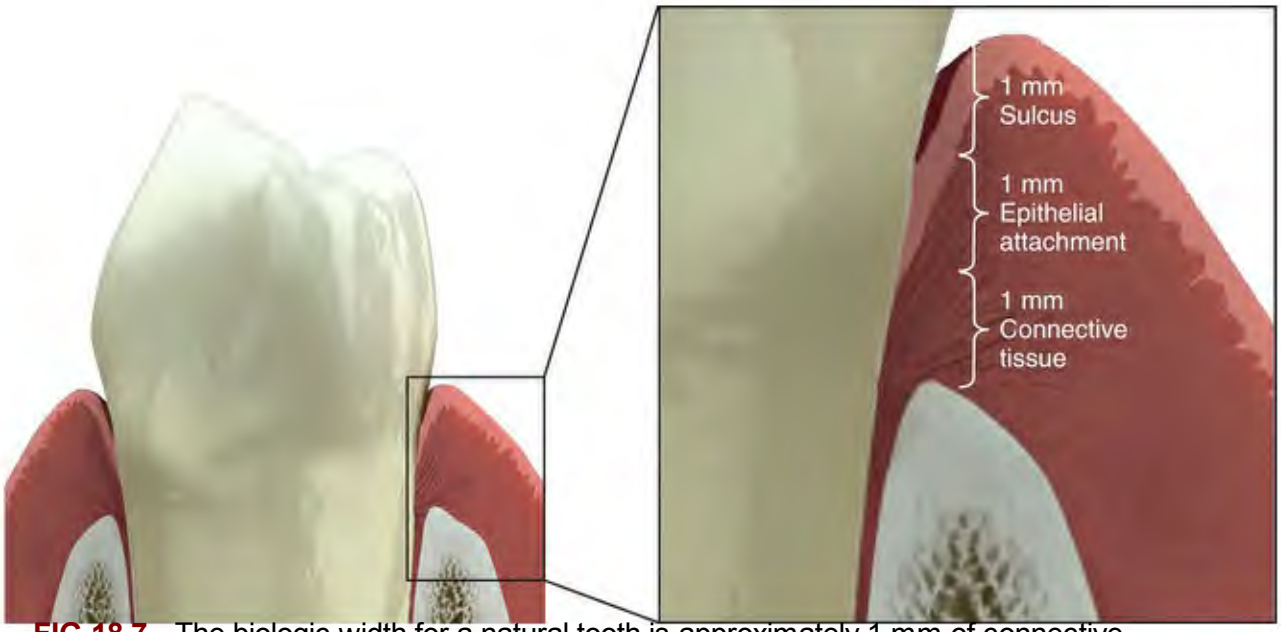

FIG 18.7 The biologic width for a natural tooth is approximately 1 mm of connective tissue above the bone and 1 mm of epithelial attachment between the sulcus and the connective tissue. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

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The sulcular regions around an implant and around a tooth are similar in many respects. The rete peg formation within the attached gingiva and the histologic lining of the gingiva within the sulcus are similar in implants and teeth.[40] A free gingival margin forms around a tooth or implant with nonkeratinized sulcular epithelium, and the epithelial cells at its base are also similar to teeth and implants, with junctional epithelial cells for both. However, a fundamental difference characterizes the base of the gingival complex around teeth. Whereas a tooth has two primary regions that make up the biologic width, an implant only has one (Fig. 18.8).

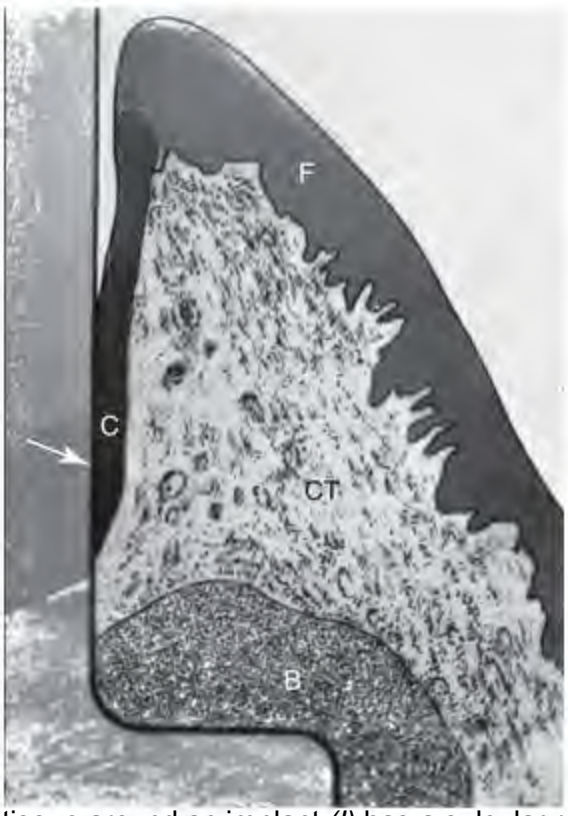

FIG 18.8 The soft tissue around an implant *(I)* has a sulcular region very similar to a tooth. A free gingival margin *(F)* with nonkeratinized sulcular epithelium and cells at the base *(C)* have junctional epithelial attachment above the bone *(B)*. *CT,* Connective tissue. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

When probing next to a tooth, the probe not only measures the sulcus depth but also penetrates and measures the JEA.[41] The junctional epithelial "attachment" of a tooth is not a true attachment. It attaches to teeth via hemidesmosomes, but these attachments are light in general and are easily disrupted. A periodontal probe, plaque, or impression material can easily separate the hemidesmosomal attachment. At the apex of the sulcus is the

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junctional epithelium, which is a few cells thick and supported by the connective tissue attachment zone (see Fig. 18.8).

The connective tissue attachment zone of the "biologic width" around a tooth prevents the probe from penetrating deeper into the sulcus and allows gingival fibers of the connective tissue attachment zone to establish direct connection with the cementum of the natural tooth. It acts as a physical barrier to the bacteria in the sulcus to the underlining periodontal tissues. Eleven different gingival fiber groups compose the connective tissue attachment zone observed around a natural tooth and tissue: dentogingival (coronal, horizontal, and apical), alveologingival, intercapillary, transgingival, circular, semicircular, dentoperiosteal, transseptal, periosteogingival, intercircular, and intergingival.[3] At least six of these gingival fiber groups insert into the cementum of the natural tooth: the dentogingival (coronal, horizontal, and apical), dentoperiosteal, transseptal, circular, semicircular, and transgingival fibers. In addition, some crestal fibers from the periodontal fiber bundles also insert into the cementum above the alveolar bone. These Sharpey fibers form a true attachment to the tooth. They prevent a periodontal probe from invading the PDL space and delay the ingress of plaque.

James and Schultz were the first to begin a systematic study to investigate the biologic seal phenomenon of the soft tissue around dental implants.[40] Hemidesmosomes from the JEA region help form a basal lamina-like structure on the implant, which can act as a biologic seal. However, collagenous components of the linear body cannot physiologically adhere to or become embedded into the implant body.[26] The hemidesmosomal seal has a circumferential band of gingival tissue to provide mechanical protection against tearing. However, the mucopolysaccharide layer is less adherent to an implant surface than a natural tooth root. The hemidesmosome of the natural tooth has a lamina lucida and a lamina densa, which are part of the basement membrane. The hemidesmosome next to an implant has a lamina lucida, lamina densa, and sublamina lucida (which is less adherent).[42]

The biologic width for implants has been reported by Cochran et al to be 3.3 mm, but unlike the biologic width dimension for teeth, they also included the sulcus depth.[43] In a typical implant gingival region, only two of the gingival fiber groups found around a tooth (circular and periosteogingival fibers) and no periodontal fibers are present.[44] These fibers do not insert into the implant body below the abutment margin as they do into the cementum of natural teeth. Instead, the collagen fibers around an implant run parallel

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to the implant surface, not perpendicular, as with natural teeth.[45] Hence, the implant only has a junctional epithelial "attachment" system.

The gingival and periosteal fiber groups are responsible for the connective tissue attachment component of the biologic width around teeth, and these are not present around the transosteal region of an implant. The "biologic width" around the abutment-implant connection should not be similarly compared with the connective tissue attachment of a tooth. The biologic seal around dental implants can prevent the migration of bacteria and endotoxins into the underlying bone. It is unable, however, to constitute an attachment component of the biologic width similar to the one found with natural teeth (Fig. 18.9).

FIG 18.9 The sulcus and epithelial attachment above the implant body do not have a true connection to the implant. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Consequences of Probing Around an Implant

A dental probe introduced into an implant sulcus may proceed through the junctional epithelial close approximation of tissue and the probe may

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proceed to the crestal bone (Fig. 18.10).

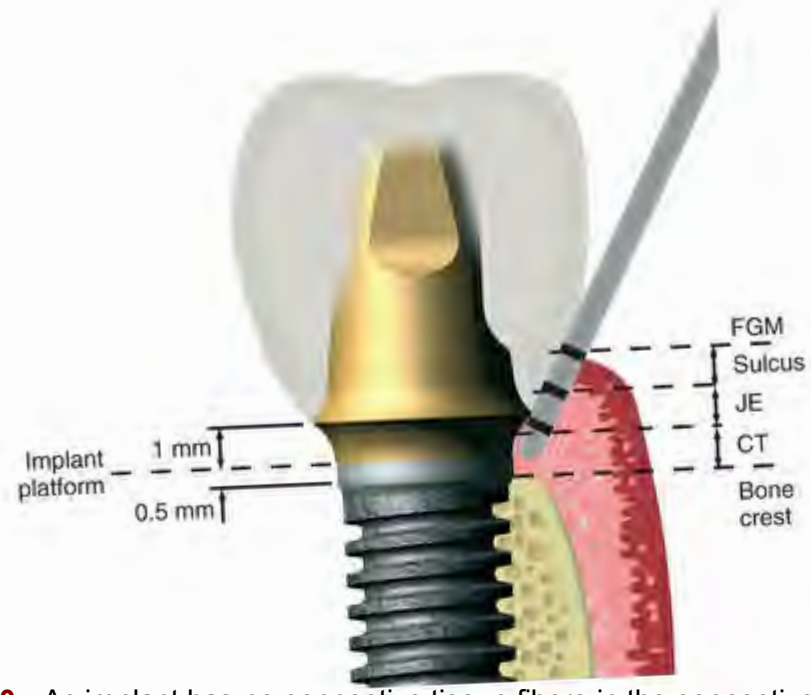

FIG 18.10 An implant has no connective tissue fibers in the connective tissue zone that insert into the implant. The periimplant probe penetrates the sulcus, junctional epithelial attachment *(JE)*, and most of the connective tissue zone. *CT,* Connective tissue; *FGM,* free gingival margin. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The connective tissue zone for an implant has only two fiber groups, and neither of them inserts into the implant. As a result, with an implant the probe goes beyond the sulcus, through the JEA, and through the type III collagen connective tissues and reaches closer to the bone.[46] Because the probe penetrates deeper next to an implant compared with a tooth, one should take care not to contaminate the implant sulcus with bacteria from a diseased periodontal site (Table 18.4).

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TABLE 18.4

Comparison of Tooth and Implant Support Structures

Structure	Tooth	Implant
Connection to bone	Cementum, bone, periodontium	Osseointegration, bone functional ankyloses
Junctional epithelium	Hemidesmoses and basal lamina (lamina lucida and lamina densa zones)	Hemidesmosomes and basal lamina (lamina lucida, lamina densa, and sublamina lucida zones)
Connective tissue	12 groups: six insert perpendicular to tooth surfaces ↓ collagen, ↑ fibroblasts	Only two groups: parallel and circular fibers; no attachments to the implant surface ↑ collagen, ↓ fibroblasts
Biologic width	2.04–2.91 mm	3.08 mm (includes sulcus)
Vascularity	Greater; supraperiosteal, and periodontal ligament	Less periosteal
Probing depth	3 mm in health	2.5–5.0 mm (depending on previous soft tissue depth)
Bleeding on probing	More reliable	Less reliable

From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.

The benefit of probing the implant sulcus has been challenged in the literature because sound scientific criteria for the rationale are lacking. The location of the probe tip subgingivally for a tooth depends on the pressure used, the presence of inflammation, and the angle at which the probe is introduced in the sulcus depth between the junctional epithelium and the root surface. The correct pressure recommended for probing is 20 g, yet conventional probing often exerts a force more than five times this level and greatly varies. The potential for damage to the fragile hemidesmosome attachment to the implant or marring of the implant surface exists during probing. In addition, reports in the literature suggest that the reproducibility of attachment level measurements may be questionable independently from the instrument used to perform the measurements.[47,48] Many of these variables are similar for a dental implant. Unlike natural teeth, fixed implant prostheses with subgingival margins of crowns often have wide emergence profiles, making probe positioning difficult around most implant bodies.

The implant sulcus depth may be a reflection of the original soft tissue thickness of the area before implant placement. The posterior maxillary tissue can be thicker than 4 mm after tooth extraction and subsequent bone volume loss before implant placement. As a result, the tissue above the bone before implant insertion may be 4 mm thick or more. As a result of greater tissue thickness before surgery and a greater probing depth compared with teeth, the probing depth next to a healthy implant may be greater than that of a healthy natural tooth.

When the tissues are thick, gingivoplasty to reduce the flap thickness and

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pocket depth can be performed at the initial surgery. The advantage of the reduction in tissue thickness at this time is the tissue heals and matures as the bone-implant interface develops. However, thinning the flap at the initial surgery may cause greater loading of the implant body during healing from an overlying soft tissue–borne temporary prosthesis. After initial bone healing, the stage II uncovery surgery also may correct tissue thickness.

Lekholm et al found that the presence of deep pockets was not accompanied by accelerated marginal bone loss.[49] Stable, rigid, fixed implants were reported with pocket depths ranging from 2 to 6 mm. Healthy, partially edentulous implant patients consistently exhibit greater probing depths around implants than around teeth. An increasing probing depth next to an implant is a more significant sign than a probing depth unrelated to a time interval because it usually signifies bone loss except in cases of gingival hyperplasia or hypertrophy. Probing using fixed reference points on the abutment or crown margin allows evaluation of crestal bone loss vs. tissue hypertrophy.

Despite the limitations, charting the attachment level in implant permucosal areas does aid the clinician in monitoring these regions. As the sulcus depth increases, the oxygen tension decreases. The bacteria in an implant sulcus are similar to those of a natural tooth. A toothbrush and daily hygiene procedures has been shown to be unable to clean a sulcus greater than 2 mm.[50] Sulcus depths greater than 5 to 6 mm have a greater incidence of anaerobic bacteria (Table 18.5). As a consequence, this sulcus depth often requires gingivectomy or bone revision surgery. As a general rule, to enable the patient to perform effective daily hygiene, the ideal implant sulcus should be maintained at less than 5 mm.

TABLE 18.5

Subgingival Microflora Associated With Human Dental Implants

	Pocket Depth (mm)	
Microflora	<5	>6
Spirochetes (%)	2	32
Motile rods (%)	16	18
Coccoids (%)	64	30

From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby; data from Rams TE, Roberts TW, Tatum H Jr, et al: The subgingival microflora associated with human dental implants, *J Prosthet Dent* 5:529–534, 1984.

The monitoring of early crestal bone loss is most important during the first

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critical year of stress accommodation of the bone. Minor bone changes are clinically easier to observe with a periodontal probe than with radiographs. Early bone loss may occur on the facial aspect of the implant; radiographs demonstrate clearly only the mesial and distal regions.

Changes in crestal bone levels warrant close monitoring and early intervention. Patient education to reduce parafunctional stress on the implant system, the use of parafunctional appliances, and other stress-reducing methods is required when early crestal bone loss beyond the first thread is detected.

Despite the uncertain meaning of pocket depth increase, probing is an appropriate method to assess potential deleterious changes in the periimplant environment and should be performed every 3 to 4 months for 1 year after prosthesis delivery. After this time, if crestal bone levels are stable, probing is still relevant. Probing also reveals tissue consistency, bleeding, and exudate. Probing is important not only to measure increasing sulcus depths but also to allow the dentist to evaluate several periimplant parameters at the same time and at the same sites.

Controversy exists as to the material from which the probe should be fabricated. In theory, different metal types (e.g., stainless steel, titanium) should not come into contact because of a risk of contamination of the two metals and the resulting galvanic corrosion that may develop and cause crestal bone loss. As a result of this concern, the suggestion has been made that only titanium surgical instruments be used to contact the implant and that only titanium or plastic instruments be used to probe or scale the implant (Fig. 18.11).

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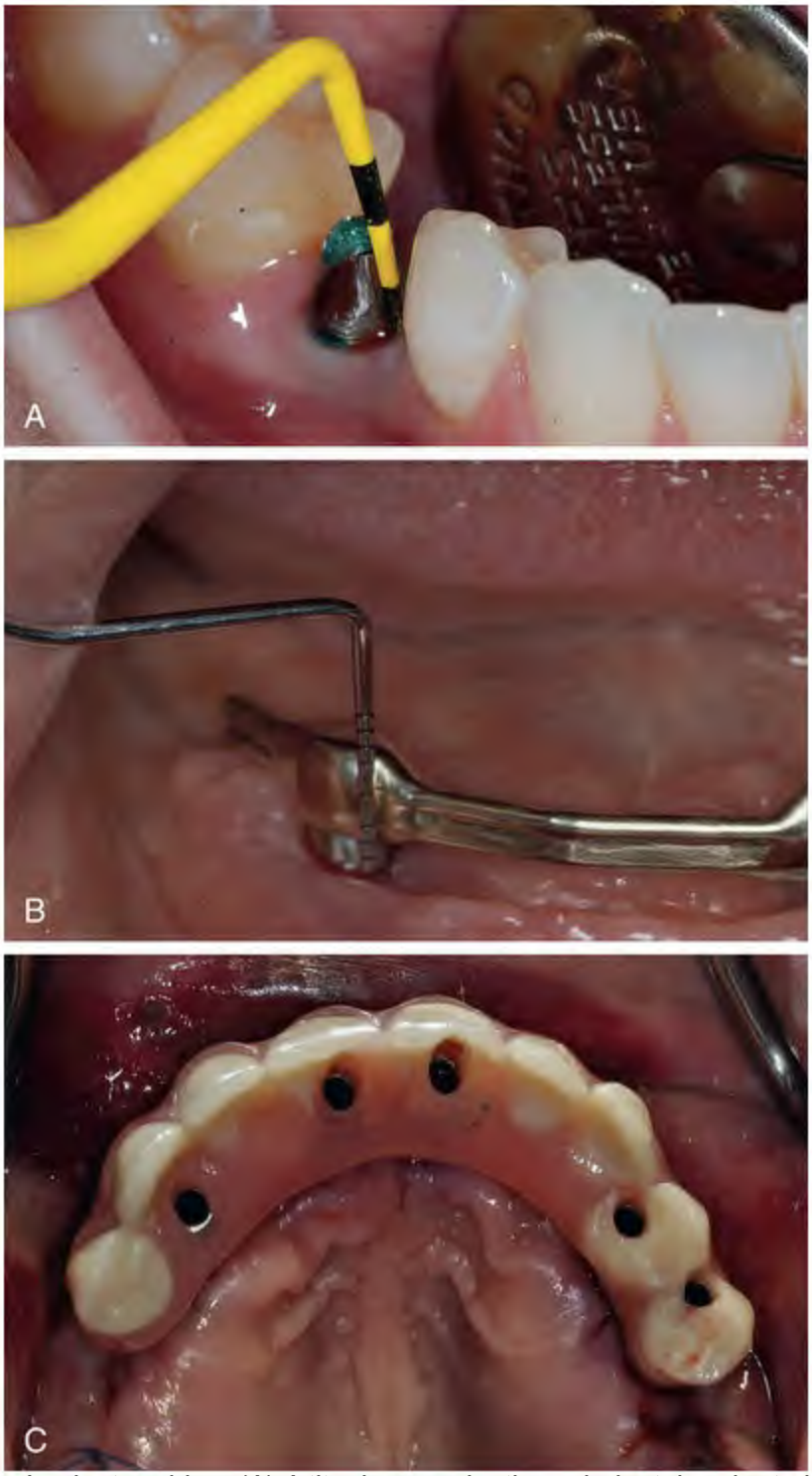

FIG 18.11 Implant probing. (A) A titanium or plastic periodontal probe to be used to evaluate pocket depth. (B) Because of nontypical prosthetics, in some cases it may be difficult to probe along the long axis of the implant because of access. (C) Impossible to probe.

Touching the surface of the abutment subgingivally with a stainless steel instrument is not of clinical concern. However, scratching the surface may contribute to plaque migration following the direction of the scratch. Plaque

follows the direction of scratches on a titanium plate even though right angles and a maze pattern may be scratched onto the surface. When probing almost to the bone level around the implant, one should take care not to scratch the surface because plaque that forms at the surface may follow the scratch subgingivally to the bone level. This is particularly important during scaling procedures and during the removal of cement below a crown margin. One should use semicircular strokes, parallel to the sulcus or crown margin, to scale the implant above the bone. If a scratch on the implant body occurs, plaque will not have a direct "highway" below the tissue.

Clinical Significance.

Baseline probing depths should be taken at the time of prosthesis insertion. The baseline measurement is important because these measurements will be used as a reference point. The probing depths should be measured as six points (i.e., mesiobuccal, midbuccal, distobuccal, mesiopalatal, midpalatal, distopalatal). However, it should be noted that implant type may complicate the probing process. If the implant is platform switched (abutment smaller than implant neck), probing may be difficult or misleading because the perio probe will not show the true extent of the pocket depth. Additionally, an overcontoured or atypical prosthesis may prevent achieving accurate probing depths.

Bleeding Index

Gingival bleeding when probing around teeth correlates with sulcular inflammation and plaque index. Easily ulcerated sulcular epithelium represents inflammation from plaque and is the primary cause of bleeding when probing. A bleeding index is an indicator of sulcus health. Bleeding also can be provoked by undue pressure on the probe.

Controversy surrounds the issue of using bleeding and gingival health as an implant health indicator. Unlike a natural tooth, implant success in the first few years is related more often to biomechanical equilibrium than to gingival health. Compared with a natural tooth, the soft tissue inflammation from bacteria may be more restricted to above the crestal bone because of the lack of a periodontal membrane or fibrous tissue between the implant and the bone interface. As a result, the bleeding index may not be as important a factor when evaluating the early implant quality of health.

The correlation between gingival health and implant success appears in

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part to be related to the cervical surface condition of the implant. Adell et al found no evidence that gingivitis was a precursor of progressive bone loss.[51] Lekholm et al also found that gingivitis and deep sulcular pockets were not accompanied by accelerated bone loss.[49] Both of these reports evaluated a machined-surface titanium screw design (e.g., Nobel Biocare).

In contrast to the previous reports with machined-surface implants, Kirsch and Mentag found a correlation between the gingival sulcus depth and implant failure.[52] The implant design studied in this report had an intramobile element with a larger implant body abutment crevice and a roughened, titanium plasma spray body (IMZ Maschinen Vertriebs GmbH). A similar correlation between implant failure and gingival health status was observed when a porous titanium alloy microball surface was exposed above the bone (Endopore [Sybron Implant Solutions]).[53]

In addition to the surface condition of the implant, other studies show a correlation to gingival health and implant teeth. Jepsen et al identified elevated levels of proteolytic enzymes in an implant sulcus with inflammation and bleeding on probing as predictors of implant disease.[54] Lekholm et al and Quirynen et al found that plaque and gingivitis around implants were correlated.[55] Steflik et al found that the gingival bleeding index correlated highly with the plaque index and the crevicular fluid index.[56]

Clinical Significance

Bleeding on probing is a simple and accurate indicator of the health of the peri-implant tissues. The presence or degree of peri-implant mucositis can be associated by the degree of bleeding and the possibility of progression into peri-implantitis. The clinician is encouraged to probe the sulcular region to evaluate crestal bone loss around the implant. Periodontal probing is less demanding than the determination of a gingival sulcular fluid volume index. One may observe the bleeding index while probing for sulcus depth and may record it easily to help evaluate gingival health.

Regardless of whether gingival health is relative to success, all clinicians agree that the ideal soft tissue condition around an implant is an absence of inflammation. Radiographic bone loss and increased pocket depth have been correlated with sulcular bleeding. The gingival status around an implant should be recorded and used to monitor the patient's daily oral hygiene. However, surrounding soft tissues around implants have fewer blood vessels than teeth; therefore, inflammation is typically less around implants than

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around teeth.[57]

The most common bleeding gingival index used for implants is the Loe and Silness gingival index.[3] When used on teeth, this index scores gingival inflammation from 0 to 3 on the facial, lingual, and mesial surfaces of all teeth. The symptom of bleeding comprises a score of at least 2 (Table 18.6).

TABLE 18.6

Gingival Index (Loe and Silness)

Normal	Description
0	Mild inflammation, slight color change and edema, no bleeding
1	Moderate inflammation, redness, edema, bleeds on probing
2	Severe inflammation, marked redness and edema ulceration, spontaneous bleeding

(From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.)

The gingival index scores may also be used on implants to record the gingival inflammation on the facial, lingual, and mesial surfaces. The facial and lingual are already being probed to evaluate bone loss that cannot be seen on a radiograph. Because the bleeding index evaluates inflammation, the Loe and Silness index is adequate for implants, and because fewer implants typically are used to restore a region compared with the presence of natural teeth, one also may evaluate the distal surface when bleeding is present because the implants are more than 2 mm apart and access often is unobstructed.

During the first year of clinical examinations for the periimplant tissues, the clinician should record color, form, and consistency along with bleeding on probing and should probe depths for all sites. After 1 year of stable probing depths, the examination may be restricted to facial and lingual checks at maintenance appointments and may be correlated with radiographic observation for the mesial and distal surfaces. Removal of the prosthesis for more accurate probing and evaluation is not indicated unless warranted by changing conditions. Repeated removal of a screw-retained fixed prosthesis causes wear of the screw attachment system and causes more frequent partially unretained restorations over the long term.

Pain

Subjective findings of pain, tenderness, and sensitivity are common dental conditions that the dentist treats as part of a general practice. Pain and tenderness are subjective criteria and depend on the patient's interpretation

of the degree of discomfort. *Pain* is defined as an unpleasant sensation ranging from mild discomfort to excruciating agony. Tenderness is more an unpleasant awareness of the area in question. In comparison to an implant, a natural tooth often becomes hyperemic and sensitive to cold as the first indicator of a problem. A tooth with a more serious condition becomes sensitive to heat and painful to percussion, indicating pulpitis. Dental emergencies usually are associated with pain, and the clinician is adept at its diagnosis and treatment planning.

Clinical Significance

Pain is often a poor indicator of the presence of peri-implant disease, especially in the early stages. In many cases, patients do not experience pain until sufficient osseous destruction has occurred and/or there exists an active infection with pus. Because dental implants do not have PDL support and associated sensory apparatus, low-grade infections and osseous atrophy are not detected by marginal gingiva. As the disease process begins around an implant, the patient may feel slight irritation, but normally not enough pain to cause alarm. It is recommended that the dentist be proactive in evaluating the status of dental implants with the incorporation of a routine maintenance protocol for patients.

Marginal Bone Loss

The marginal bone around the implant crestal region is usually a significant indicator of implant health. Unlike natural teeth, the causes of crestal bone loss around the implant are multifactorial and may occur at different time periods. These bone loss types include surgical bone loss, initial “biologic width” bone loss, early-loading bone loss, intermediate-term bone loss, and long-term bone loss. Each time period may have a different cause for the bone loss. Most often the surgical trauma causes little bone loss, but on occasion, bone loss may reach several millimeters. The clinician may assess the presence of surgical bone loss when a two-stage surgery is used to obtain initial rigid fixation. The level of the crestal bone is measured from the crestal position of the implant at the stage II uncovery surgery. When the abutment is attached to the implant body, approximately 0.5 to 1 mm of connective tissue forms apical to this connection.[55] This bone loss may be caused by an “implant biologic width.” Initial bone loss during the surgical healing phase may vary for submerged and unsubmerged healing protocols.

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For example, an implant originally placed 2 mm above the bone and another countersunk 2 mm below the bone also have a different initial bone loss history after the abutment is attached to the implant.[42] Whenever possible, the implant should be inserted at or above the bone crest to avoid an increase in the sulcus depth around the implant related to the crestal bone loss after abutment placement.

After the implant is connected to a permucosal element, the marginal bone may be lost during the first month from (1) the position of the abutment-implant connection or (2) the crest module design of the implant. The abutment-implant connection will cause 0.5 to 1.0 mm of bone loss when it is at or below the bone. In addition, when smooth metal is below the abutment-implant connection and extends onto the neck of the implant, additional bone loss will occur in direct relation to the smooth metal region. The bone levels will most often recede to the first thread or at a roughened surface; after the first month a permucosal element or abutment extends through the soft tissue (Fig. 18.12).[43]

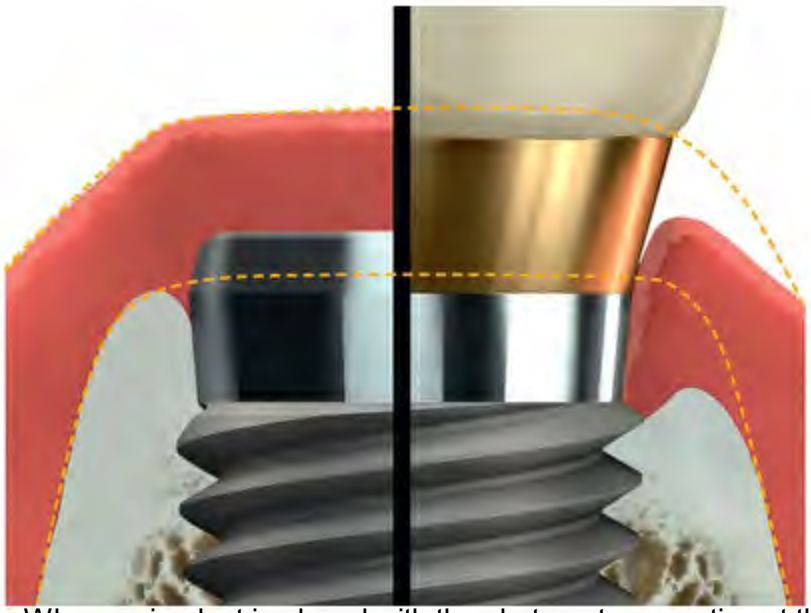

FIG 18.12 When an implant is placed with the abutment connection at the crest of the ridge *(left side)*, after the permucosal abutment is connected, the bone is usually lost to the first thread, especially when the crest module is machined or smooth *(right side)*. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Crestal bone loss has been observed around the permucosal portion of dental implants for decades. It has been described in the crestal region of successfully osteointegrated implants regardless of surgical approaches. It

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can range from loss of marginal bone to complete failure of the implant and dramatically decreases after the first year.

Early Marginal Bone Loss

Adell et al were the first to quantify and report marginal bone loss. The study also indicated greater magnitude and occurrence of bone loss during the first year of prosthesis loading, averaging 1.2 mm during this time frame, with a range of 0 to 3 mm. This report measured bone loss from the first thread as the 0-mm baseline, not from the original level of crestal bone at insertion, which was 1.8 mm above this baseline point.[15] Thus, the actual first-year crestal bone loss averaged 3.3 mm around the implants observed. Years subsequent to the first showed an average of 0.05 to 0.13 mm bone loss per year. Other studies report an average first-year bone loss of 0.93 mm, with a range from 0.4 to 1.6 mm and a mean loss of 0.1 mm after the first year.[58] The early crestal bone loss has been observed so frequently that proposed criteria for successful implants often do not even include the first-year bone loss amount.

The initial transosteal bone loss around an implant forms a V- or a U-shaped pattern, which has been described as *ditching* or *saucerization* around the implant. The current hypotheses for the cause of crestal bone loss have ranged from reflection of the periosteum during surgery, preparation of the implant osteotomy, the position of the microgap between the abutment and implant body, micromovement of the abutment components, bacterial invasion, the establishment of a biologic width, and factors of stress.[51,59,60,57] An understanding of the causes of marginal crestal bone loss around dental implants and early implant failure is critical in preventing such occurrences, fostering long-term peri-implant health, improving long-term implant success rates and, foremost, implant prosthesis success. Marginal crestal bone loss may influence esthetics because the height of the soft tissue (e.g., interdental papilla) is directly related to the marginal bone. If the tissue shrinks as a consequence of the bone loss, the emergence profile of the crown elongates and the papilla may disappear next to the adjacent tooth or implant. If the soft tissue does not shrink, the increase in pocket depth may be related to the presence of anaerobic bacteria and peri-implantitis (Fig. 18.13).

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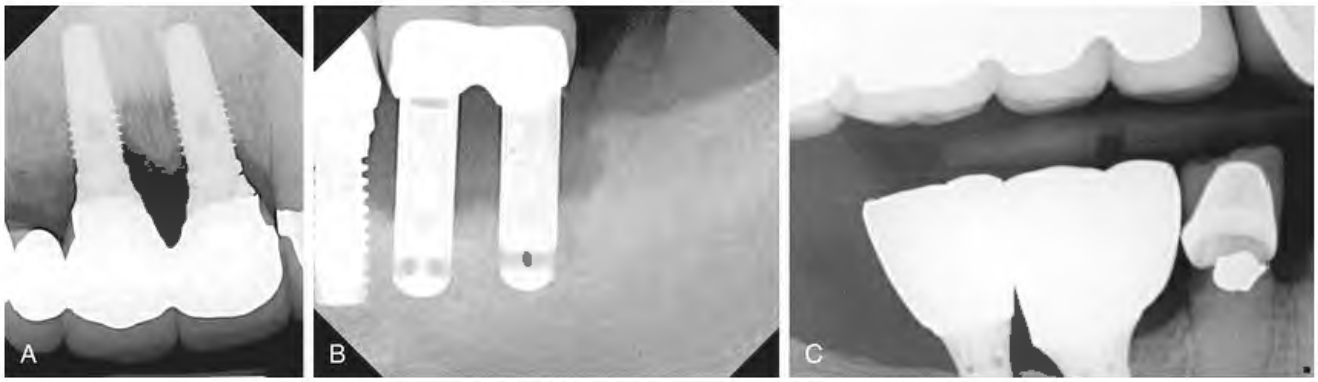

FIG 18.13 Radiographic evaluation of bone loss. (A) Crestal bone loss. (B) Significant horizontal bone loss, not the ideal angulation as all implant threads are seen clearly. (C) Bitewing radiograph showing bone loss.

Etiology

There are many theories on the potential etiologic factors that may cause marginal bone loss around dental implants. These include Periosteal Reflection Hypothesis, Implant Osteotomy Hypothesis, Autoimmune Response to the Host Hypothesis, Occlusal Trauma, Cellular Biomechanics, Engineering Principles, Bone Mechanical Properties, Implant Design Biomechanics, and Implant Design Mechanics. Limited marginal bone loss during the first year of function after stage II surgery has been observed around the permucosal portion of dental implants for decades. Hypotheses for the causes of crestal bone loss have included the reflection of the periosteum during surgery, preparation of the implant osteotomy, level of the microgap between the abutment and implant body, bacterial invasion, the establishment of a biologic width, the implant crest module design, and occlusal overload.[6,60]

Periosteal Reflection Hypothesis.

Periosteal reflection causes a transitional change in the blood supply to the crestal cortical bone. Ninety percent of the arterial blood supply and 100% of the venous return are associated with the periosteum in the long bones of the body.[61] When the periosteum is reflected off the crestal bone, the cortical bone blood supply is affected dramatically, causing osteoblast death on the surface from trauma and lack of nutrition. These events have fostered the periosteal reflection theory as a cause for early bone loss around an endosteal implant.

Although crestal bone cells may die from the initial trauma of periosteal

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reflection, the blood supply is reestablished once the periosteum regenerates. Cutting cones develop from monocytes in the blood and precede new blood vessels into the crestal regions of bone. Osteoblasts then are able to remodel the crestal bone anatomy.[36] Composite bone forms rapidly on periosteal surfaces to restore its original condition. In addition, the underlying trabecular bone is also a vascular source because its blood supply often is maintained in spite of crestal periosteal reflection. The greater the amount of trabecular bone under the crestal cortical bone, the less crestal bone loss is observed. To place the implant in sufficient available bone, an implant ridge is usually 5 mm or wider at the crest. As a result, trabecular bone is readily available to assist in cortical blood supply and remodeling around the implants. The cortical bone is remodeled to its original contour, without significant loss of height. The periosteal reflection theory would lead to a generalized horizontal bone loss of the entire residual ridge reflected, not the localized ditching pattern around the implant that typically is observed. In addition, generalized bone loss already would be directly noticeable at the second-stage uncovery of the implant body, 4 to 8 months after stage I implant placement surgery. Yet generalized bone loss rarely is observed at the second-stage uncovery surgery. The periosteal reflection hypothesis does not appear as a primary causal agent of marginal crestal bone loss around an implant (Fig. 18.14).

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FIG 18.14 At stage II uncovery, the marginal bone level most often is similar to the level the initial day of surgery and may even have grown over the top of the implant. Because the periosteum is reflected and bone is prepared to insert the implants, the cause of frequently occurring early crestal bone loss may not be related to the reflection of the periosteum or the osteotomy preparation. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Implant Osteotomy Hypothesis.

Preparation of the implant osteotomy has been reported as a causal agent of early implant bone loss. Bone is a labile organ and is sensitive to heat. The implant osteotomy causes trauma to the bone in immediate contact with the implant, and a devitalized bone zone of about 1 mm is created around the implant. A renewed blood supply and cutting cones are necessary to remodel the bone at the interface. The crestal region is more susceptible to bone loss during initial repair because of its limited blood supply and the greater heat generated in this denser bone, especially with the less efficient cutting of countersink drills used in this region.[62] This condition supports implant osteotomy preparation as a causal agent for marginal crestal bone loss around the implant.

However, if heat and trauma during implant osteotomy preparation were responsible for marginal crestal bone loss, the effect would be noticeable at the second-stage uncovery surgery 4 to 8 months later. The average bone loss of 1.5 mm from the first thread is not observed at stage II uncovery. In fact, bone often has grown over the first-stage cover screw, especially when level or slightly countersunk below the bone. Reports in the literature indicate different surgical trauma causes and numbers for bone loss. For example, Manz observed that bone loss at second-stage surgery ranged from 0.89 to

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0.96 mm regardless of the bone density.[63] Hoar et al reported only 0.2-mm bone loss at stage II uncovery.[64] The surgical system or approach may influence these data, but usually this bone loss remains minimal. One should remember that these are averages of bone loss reported. If 2 mm of bone loss is found on one implant and the next nine implants exhibit no bone loss, the average bone loss would be 0.2 mm. Most implants at stage II uncovery do not demonstrate any bone loss. The implant osteotomy hypothesis for marginal crestal bone loss cannot be primarily responsible for this routinely observed phenomenon.

Autoimmune Response of Host Hypothesis.

The primary cause of bone loss around natural teeth is bacterially induced. Repeat studies demonstrate that bacteria are the causative element for vertical defects around teeth. Occlusal trauma may accelerate the process, but trauma alone is not deemed a determining factor.[65] The implant gingival sulcus in the partially edentulous implant patient exhibits a bacterial flora similar to that of natural teeth. A logical assumption is that if implants are similar to teeth, the marginal implant bone loss is caused primarily by bacteria, with occlusal factors playing a contributing or accelerating role.

In a prospective study of 125 implants, Adell et al reported 80% of implant sulcular regions were without inflammation.[51] Lekholm et al found that deep gingival pockets around implants were not associated with crestal bone loss.[66] Yet the marginal crestal bone loss to the first thread of screw-type implants is a common radiologic finding. If bacteria were the causal agent for the initial bone loss, why does most bone loss occur the first year (1.5 mm) and less (0.1 mm) each successive year? The implant sulcus depth progressively increases from the early bone loss, impairing hygiene and making anaerobic bacteria more likely as the cause of bacteria-related bone loss. If bacteria are responsible for 1.5-mm early crestal bone loss, what local environmental changes occur to reduce their effect by 15 times after the first year? The bacterial autoimmune theory cannot explain the marginal bone loss condition when it follows the pattern most often reported. Although the bacteria theory does not explain adequately the marginal crestal bone loss phenomenon, this does not mean that bacteria are not a major contributor to bone loss around an implant. Threads and porous implant surfaces exposed to bacteria are reported to cause a more rapid loss of bone around an implant.[66] Poor hygiene also is reported to accelerate the bone loss observed around endosteal implants.[67] To state that bacteria are never involved in

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marginal bone loss around an implant would be incorrect. Bone loss often is associated with bacteria as a causal agent. However, when most bone loss occurs in the first year and less bone loss is observed afterward, the hypothesis of bacteria as the primary causal agent for the early crestal bone loss cannot be substantiated.

Biologic Width Hypothesis.

The sulcular regions around an implant and around a tooth are similar in many respects. The rete peg formation within the attached gingiva and the histologic lining of the gingiva within the sulcus are similar in implants and teeth. A free gingival margin forms around an implant with nonkeratinized sulcular epithelium, and the epithelial cells at its base are similar to the functional epithelial cells described with natural teeth.[68] However, a fundamental difference characterizes the base of the gingival sulcus.

For a natural tooth, an average biologic width of 2.04 mm exists between the depth of the sulcus and the crest of the alveolar bone. It should be noted the biologic "width" is actually a height dimension with a greater range in the posterior region compared with the anterior, and may be greater than 4 mm in height. In teeth, it is composed of a connective tissue (CT) attachment (1.07 mm average) above the bone and a junctional epithelial attachment (0.97 mm average) at the sulcus base, with the most consistent value between individuals being the CT attachment.[39]

The biologic width allows gingival fibers and hemi-desmosomes to establish direct contact with the natural tooth and acts as a barrier to the bacteria in the sulcus to the underlining periodontal tissues. When a crown margin invades the biologic width, the crestal bone recedes to reestablish a favorable environment for the gingival fibers (Fig. 18.15).[69]

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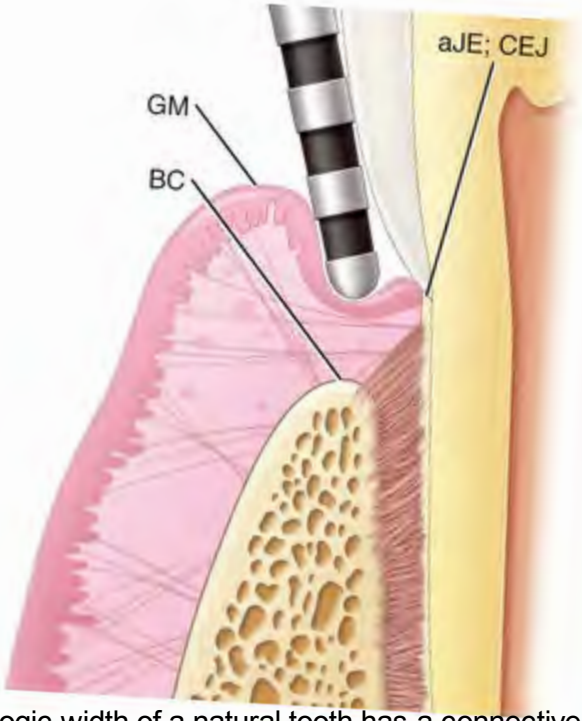

FIG 18.15 The biologic width of a natural tooth has a connective tissue zone that inserts into the cementum of the tooth. A periodontal probe will penetrate the sulcus and the junctional epithelial attachment. *BC,* bone crest; *GM,* gingival margin; *aJE,* junctional epithelium attachment; *CEJ,* cementoenamel junction. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Many surgical protocols recommend the placement of endosteal implants at or below the crest of the ridge during the first-stage surgery. The abutment-to-implant body connection may be compared with a crown margin. Berglundh et al observed 0.5 mm of bone loss below the implant-abutment connection within 2 weeks after stage II uncovery and abutment connection in dogs.[26] Lindhe et al reported an inflammatory connective tissue extending 0.5 mm above and below this implant abutment connection.[70] Wallace and Tarnow stated that the biologic width also occurs with implants and may contribute to some of the marginal bone loss observed.[71] The biologic width theory seems attractive to explain the lack of bone loss from the first stage of surgery and the early bone loss seen within the first year after the second-stage abutment placement. However, it should be noted that the biologic "width" in implants, as reported, often includes the sulcus depth, whereas the natural tooth biologic width does not include the sulcus depth. Eleven different gingival fiber groups are observed around a natural tooth: dentogingival (coronal, horizontal, and apical), alveologingival, intercapillary, transgingival, circular, semicircular, dentoperiosteal, transseptal, periosteogingival, intercircular, and intergingival. At least six of these gingival fiber groups insert into the cementum of the natural tooth: the

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dentogingival (coronal, horizontal, and apical), dentoperiosteal, transseptal, circular, semicircular, and transgingival fibers. In addition, some crestal fibers from the periodontal fiber bundles also insert into the cementum above the alveolar bone.[3] However, in a typical implant gingival region, only two of these gingival fiber groups and no periodontal fibers are present. These fibers do not insert into the implant body below the abutment margin as they do into the cementum of natural teeth.[72] Instead, the collagen fibers in the CT attachment around an implant run parallel to the implant surface, not perpendicular, as with natural teeth.[73] The gingival and periosteal fiber groups are responsible for the connective tissue attachment component of the biologic width around teeth, and these are not present around the transosteal region of an implant. The CT attachment around the abutment-implant connection cannot be compared with the CT attachment of a tooth. James and Keller were first to begin a systematic scientific study to investigate the biologic seal phenomenon of the soft tissue around dental implants.[72] Hemidesmosomes help form a basal lamina–like structure on the implant that can act as a biologic seal. However, collagenous components of the linear body cannot physiologically adhere to or become embedded into the implant body as they do in the cementum of the tooth.[54] The hemidesmosomal seal only has a circumferential band of gingival tissue to provide mechanical protection against tearing.[55] The biologic seal around dental implants can prevent the migration of bacteria and endotoxins into the underlying bone. It is unable, however, to constitute a junctional epithelial attachment component of the biologic width similar to the one found with natural teeth. The amount of early crestal bone loss seems unlikely to be solely the result of the remodeling of the hard and soft tissues to establish a biologic width below an abutment connection. No connective tissue attachment zone or components of the linear body are embedded into an implant. The importance, amount, and mechanism for these anatomical structures require further investigation (Fig. 18.16).

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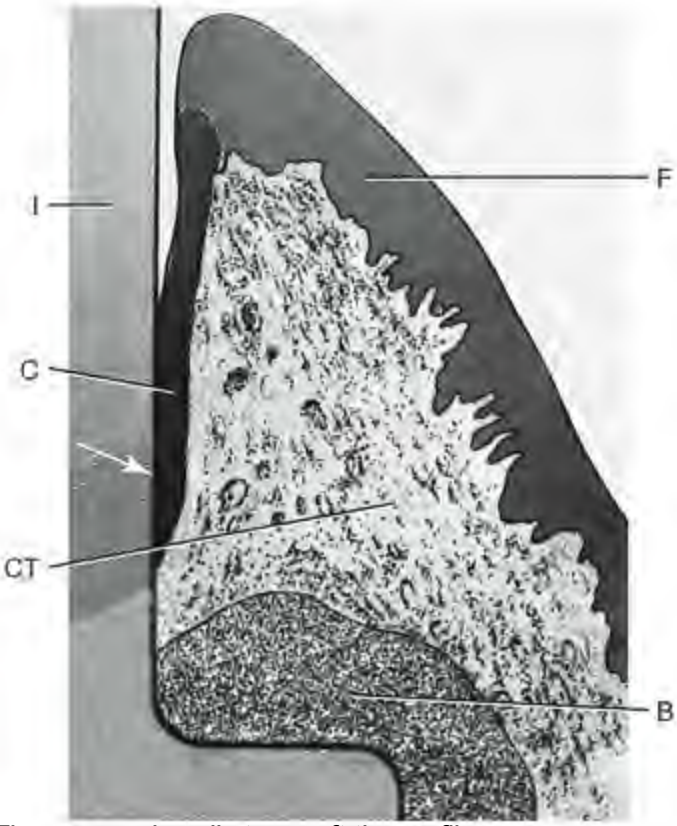

FIG 18.16 There are primarily two soft tissue fiber groups around an implant: circular fibers and crestal bone fibers. Neither of these fiber types insert into the implant or the abutment. The peri-implant probe penetrates the sulcus, junctional epithelial attachment, and most of the connective tissue zone. *CT,* connective tissue. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

The crevice between the cover screw and the implant body during initial healing is similar to the crevice of the abutment-implant connection. Yet bone can grow over the cover screw, and the crevice, in and of itself, may not be the cause of bone loss. The crevice between the implant and the abutment connection has been called a "microgap." The actual dimension of this connection is usually 0 mm and has a direct metal-to-metal connection. However, when the crevice is exposed to the oral environment, bone loss is usually observed for at least 0.5 mm below the connection.[74] The biologic width hypothesis cannot fully explain the several millimeters of marginal crestal bone loss, which also has been observed readily with one-stage implants that extend through the tissue at the initial implant placement surgery and have no abutment-implant connections. For example, plate form (blade) implants, transosteal implants, pins, one-piece screw implants, and even subperiosteal implants demonstrate the marginal crestal bone loss phenomenon.

It is true that bone loss does occur around an exposed abutment-implant

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connection placed below the bone (observed within 2 to 4 weeks) once the connection is exposed to the oral environment. The bone loss often occurs before the implant is loaded with the prosthesis. It is logical to call this marginal bone loss the *biologic width*. The primary question remains, when the surgeon places the implant abutment connection below the bone, how much bone loss is from the implant biologic width and out of the influence of the dental practitioner? Several reports in the literature note implant macro- and microgeometry may affect the biologic width dimensions or the amount of early crestal bone loss.[75]

The bone loss to the first thread observation implies the amount of bone loss is similar for different implant designs. However, the first thread is a different distance from the abutment margin for several implant designs. A smooth polished 4-mm collar below the bone has been associated with greater bone loss than a smooth 2-mm collar below the bone. The implant biologic width concept does not explain completely the total amount of vertical bone loss observed. In addition, the amount of bone loss from the biologic width occurs within 1 month whether the implant is loaded or not and is related to the crest module implant design and the position of the abutment-implant connection in relation to the bone but is unrelated to the density of the bone. The concept does not explain why greater crestal bone loss often is observed in soft bone compared with denser bone after loading, nor does it explain the higher implant failure rates in lesser-quality bone after loading.

Occlusal Trauma.

Marginal bone loss on an implant may be from occlusal trauma.[60] *Occlusal trauma* may be defined as an injury to the attachment apparatus as a result of excessive occlusal force. A controversy exists as to the role of occlusion in the bone loss observed after an implant prosthesis delivery. Some articles state that peri-implant bone loss without implant failure is primarily associated with biologic formations or complications.[76] Other authors suggest a correlation of crestal bone loss to occlusal overload.[57,77] The determination of the etiology of bone loss around dental implants is needed in order to minimize its occurrence and foster long-term peri-implant health that may ultimately determine implant prosthesis survival.

The association of occlusal trauma and bone loss around natural teeth has been debated since Karolyi claimed a relationship in 1901.[78] A number of authors conclude trauma from occlusion is a related factor in bone loss,

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although bacteria is a necessary agent.[79] On the other hand, Waerhaug and many others state there is no relationship between occlusal trauma and the degree of periodontal tissue breakdown.[80] According to Lindhe et al, "trauma" from occlusion cannot induce periodontal tissue breakdown.[81] However, occlusal trauma may lead to tooth mobility that can be transient or permanent.

To establish further a correlation between marginal bone loss and occlusal overload, related articles from cellular biomechanics, engineering principles, mechanical properties of bone, physiology of bone, implant design biomechanics, animal studies, and clinical reports were procured.[60]

Cellular biomechanics.

Bone remodeling at the cellular level is controlled by the mechanical environment of strain.[82] *Strain* is defined as the change in length divided by the original length, and the units of strain are given in percentages. The amount of strain in a material is directly related to the amount of stress applied.[10] Occlusal stress applied through the implant prosthesis and components can transmit stress to the bone-implant interface. The amount of bone strain at the bone-implant interface is directly related to the amount of stress applied through the implant prosthesis. Mechanosensors in bone respond to minimal amounts of strain, and microstrain levels 100 times less than the ultimate strength of bone may trigger bone remodeling (Fig. 18.17).[83]

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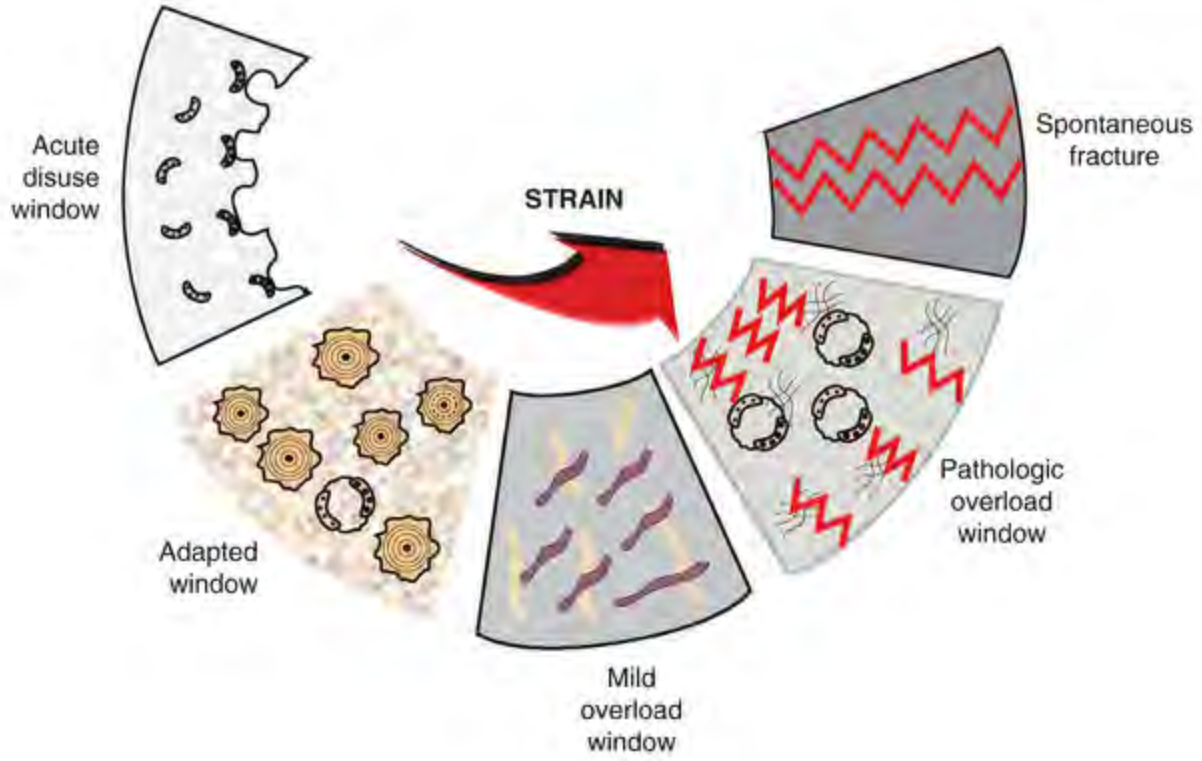

FIG 18.17 Mechanical stress applied to bone cells causes a change in shape or strain. The microstrains may trigger the release of cytokines and bone resorption. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

One of the earliest remodeling theories for a direct relationship between stress and the magnitude of bone remodeling was proposed by Kummer in 1972.[84] More recently, Frost reported on the cellular reaction of bone to different microstrain levels.[85] He observed that bone fractures at 10,000 to 20,000 microstrain units (1% to 2% deformation). However, at levels 20% to 40% of this value (4000 units), bone cells may trigger cytokines to begin a resorption response. In other words, excessive bone strain may not only result in physical fracture but may also cause bone cellular resorption. The hypothesis that occlusal stresses beyond the physiologic limits of bone may result in strain in the bone significant enough to cause bone resorption is plausible from a cellular biomechanics standpoint. To date, bone cellular studies have not replicated this bone condition next to a dental implant. However, cytokines in the bone-implant interface tissue obtained from failed hip replacement devices leading to bone loss have been reported in humans.[86]

Engineering principles.

The relationship between stress and strain determines the modulus of elasticity (stiffness) of a material. The modulus conveys the amount of

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dimensional change in a material for a given stress level. The modulus of elasticity of a tooth is similar to that of cortical bone. Dental implants are typically fabricated from titanium or its alloy. The modulus of elasticity of titanium is 5 to 10 times greater than that of cortical bone (Fig. 18.18). An engineering principle called the *composite beam analysis* states that when two materials of different elastic moduli are placed together with no intervening material and one is loaded, a stress contour increase will be observed where the two materials first come into contact.[87] In an implant-bone interface, these stress contours are of greater magnitude at the crestal bone region. This phenomenon was observed in both photoelastic and three-dimensional finite element analysis (Fig. 18.19) studies when implants were loaded within a bone simulant.[88] These authors note that the marginal bone loss observed clinically and radiographically around implants follows a similar pattern to the stress contours in these reports.

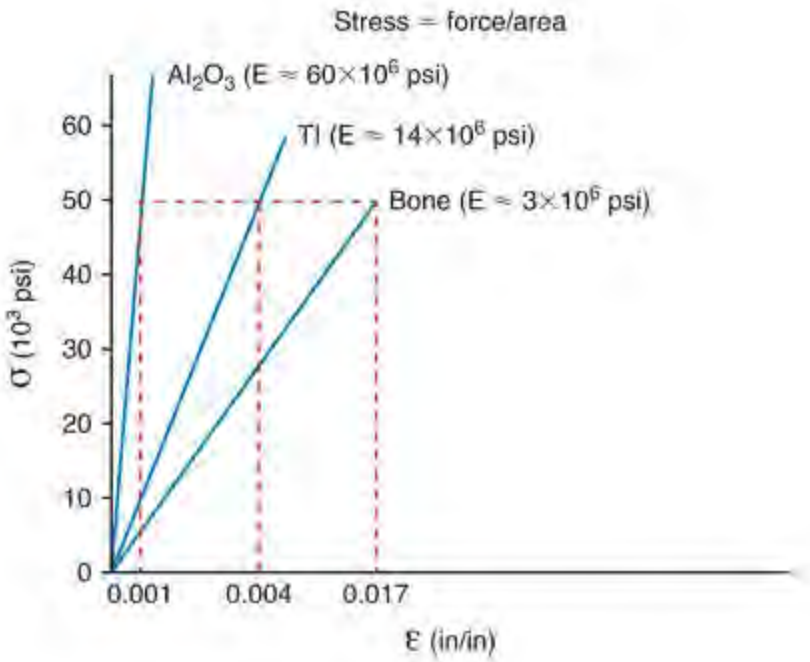

FIG 18.18 The modulus of elasticity is greater for titanium *(Ti)* compared with bone. When stress is plotted on the Y axis and strain on the X axis, the modulus of elasticity can be obtained. Titanium is 5 to 10 times more rigid than cortical bone. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

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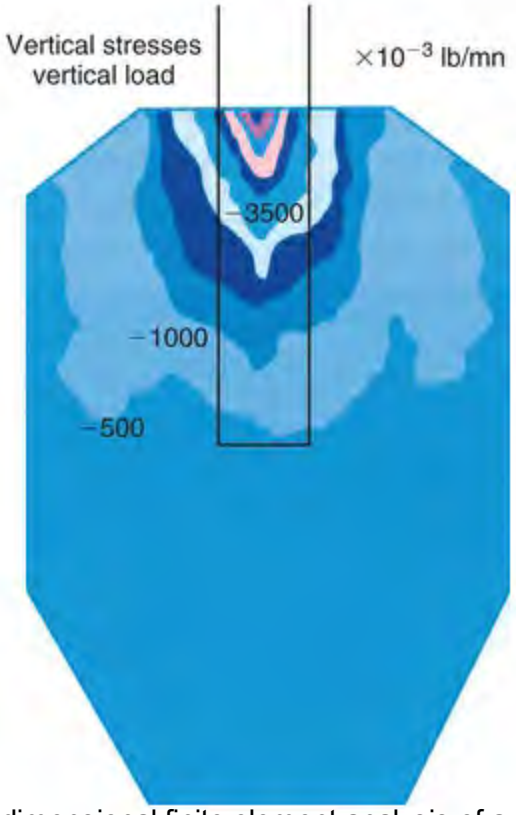

FIG 18.19 A three-dimensional finite element analysis of a titanium implant in a bone model after axial loading. The V-shape pattern of strain is greatest at the crestal region and decreases in intensity as the stress is dissipated throughout the implant length. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Bone mechanical properties.

Bone density is directly related to the strength and elastic modulus of bone.[72] In denser bone, there is less strain under a given load compared with softer bone. As a result, there is less bone remodeling in denser bone compared with softer bone under similar load conditions. A decrease in bone remodeling can result in a reduction of bone loss. In a prospective human study, Manz observed the amount of marginal bone loss next to an implant was related to the density of bone.[63] The initial peri-implant bone loss from implant insertion to uncovery was similar for all bone qualities. However, 6 months after prosthesis delivery, the additional radiographic-observed peri-implant bone loss ranged from 0.68 mm for quality 1 to 1.1 mm for quality 2, 1.24 mm for quality 3, and 1.44 mm for quality 4-type bone (Fig. 18.20). In other words, the more dense the bone, the less peri-implant bone loss was observed after prosthesis delivery. A clinical report by Appleton et al[89] demonstrated that progressively loaded single-tooth implants in the first premolar region of human beings exhibited greater bone density increase in

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the crestal half of the implant interface and less marginal bone loss compared with nonprogressively loaded implants in the same jaw region and even the same patient on the contralateral side without progressive loading. Because an increase in bone density is related to bone strength, elastic modulus, bone remodeling, and a decrease in marginal bone loss, these entities may be related to each other.

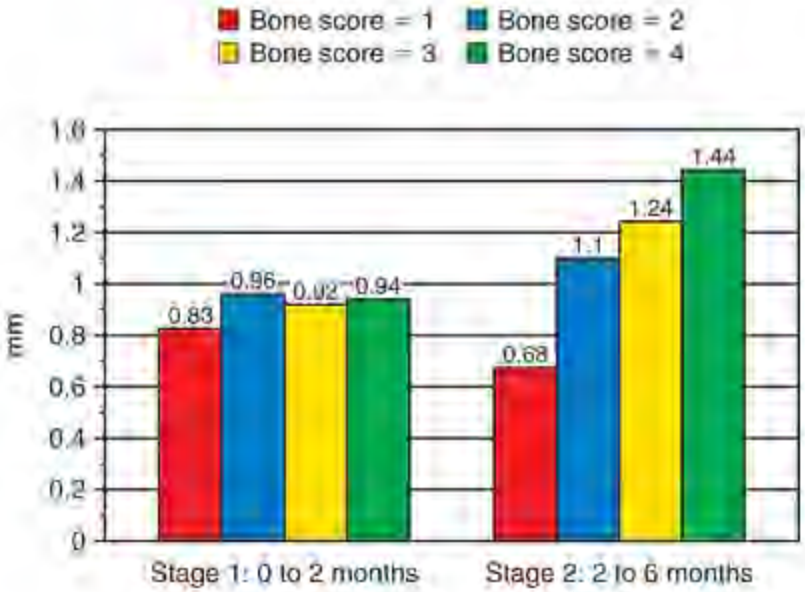

FIG 18.20 Mean peri-implant vertical bone change for study intervals by bone quality score. Many observed the amount of bone loss from stage 1 to stage 2 was similar, regardless of bone quality. However, after 6 months of loading, the amount of marginal bone loss was directly related to the quality of the bone, with type 4 (the softest bone) exhibiting the greatest bone loss. (Reproduced from Manz MC: Radiographic assessment of peri-implant vertical bone loss: DIRG Implant Report No 9, *J Oral Maxillofac Surg* 55(Suppl):62–71,1997.)

Several animal studies in the literature demonstrate the ability of bone tissue to respond to a dental implant. For example, Hoshaw et al inserted dental implants into a dog femur perpendicular to the axis of the long bone and perpendicular to the direction of the osteons.[90] After applying a tensile load to the implants for only 5 days, the bone cells reorganized to follow the implant thread pattern and resist the load. This unique bone pattern was observed for only 3 to 4 mm around the implants. Crestal bone loss was also noted around these implants and explained as stress overload. To rearrange its osteal structure, bone must remodel.

Miyata placed crowns on integrated dental implants with no occlusal contacts (control group), and premature interceptive occlusal contacts of 100

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mm, 180 mm, and 250 mm in a monkey animal model.[91] After 4 weeks of premature occlusal loads, the implants were removed in a block section and evaluated. The crestal bone levels for 100 mm and control implants with no loading were similar. However, statistically significant crestal bone loss was observed in the 180-mm group. The 250-mm group experienced two to three times the bone loss of the crowns with moderate prematurities. Duyck used a dog model to evaluate the crestal bone loss around screw-type dental implants with no loads (controls), static loads, and dynamic loads.[92] The dynamic-loaded implants were the only group to demonstrate crestal bone loss. Because the only variable in these two studies was the intensity or type of occlusal load applied to the implants, these animal reports imply dynamic occlusal loading may be a factor in crestal bone loss around rigid fixated dental implants.

Clinical reports have shown an increase in marginal bone loss around implants closest to a cantilever used to restore the lost dentition.[93] Cantilever length and an increase in occlusal stress to the nearest abutment are directly related and point to the fact that the increase in marginal bone loss may be related to occlusal stress. Quirynen et al evaluated 93 implant patients with various implant restorations and concluded that the amount of crestal bone loss was definitely associated with occlusal loading.[58] These authors also reported increased crestal bone loss around implants in patients with no anterior occlusal contacts and parafunctional habits in full-arch fixed prostheses in both jaws. These clinical reports do not provide statistical analyses to demonstrate a clear link between occlusal stress and bone loss. However, they indicate a consensus by some authors that occlusal overload may be related to the incidence of peri-implant bone loss around the cervical aspect of an implant. In fact, in a study of 589 consecutive implants, Naert et al suggested overload from parafunctional habits may be the most probable cause of implant loss and marginal bone loss after loading.[94]

Rangert et al have noted that occlusal loads on an implant may act as a bending moment, which increases stress at the marginal bone level and can cause implant body fracture.[95] Before the fracture of the implant body, marginal bone loss was noted in this retrospective clinical evaluation. The same stress that caused implant fracture is the logical cause of the peri-implant bone loss before the event. Rosenberg et al found microbial differences in implant failures from both overload and biologic complications.[96] Uribe et al presented the case of a mandibular implant crown with a marginal peri-implantitis and osseous defect.[97] Histologic

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analysis revealed an infiltrate and a central zone of dense fibroconnective tissue with scanty inflammatory cells. According to the authors, this finding differs from chronic inflammatory tissue associated with infectious peri-implantitis and can be directly related to occlusal overload. A clinical report by Leung et al observed radiographic angular crestal bone loss to the seventh thread around one of two implants supporting a fixed prosthesis in hyperocclusion 2 weeks after prosthesis delivery.[98] The prosthesis was removed, and over the next few months radiographic observation showed the crestal defect was repaired to almost the initial level, without any surgical or drug intervention. The prosthesis was then seated with proper occlusal adjustment. The bone levels stabilized at the second thread of the implant and remained stable over the next 36 months. This report indicates bone loss from occlusal overload is not only possible but may even be reversible when found early in the process. Although no prospective clinical study to date has clearly demonstrated a direct relationship between stress and bone loss without implant failure, several practitioners agree a causal relationship may exist.

The fact that occlusal overload may be an etiology for crestal bone loss does not mean other factors are not present. For example, the microgap position of the implant platform and abutment and the biologic width often affect the marginal bone during the first month after the implant becomes permucosal. However, the clinician has certain variables under their control that may influence the amount of peri-implant bone loss. The position of the microgap in relation to the bony crest and the implant crest module design are primarily under the control of the implant surgeon. On the other hand, the autoimmune or bacterial response of the patient, the biologic width, and the patient response to the surgical trauma of implant placement are variables often escaping the control of the dentist. Once the final prosthesis is delivered to the patient, many events responsible for marginal bone loss have already occurred, whereas others such as occlusal overload and its relationship to the quality of bone persist. Occlusal overload is one factor most in control of the restoring dentist. If a relationship between occlusal overload and crestal bone loss exists, approaches to decrease stress to an implant interface appear appropriate. A puzzling element in the relationship between occlusal force and peri-implant bone loss is the lack of continued bone loss until the implant fails. Implant crown height may be measured from the occlusal plane to the crest of the bone. The crown height is a vertical cantilever, which may magnify the stresses applied to the prosthesis. As a

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result of the greater crown height from the vertical bone loss, occlusal overload will be increased after crestal bone loss occurs. If occlusal loading forces can cause crestal bone loss, the resulting increased moment forces should further promote the loss of bone until the implant fails. Yet most clinical studies indicate the rate of bone loss decreases after the first year of loading and is minimal thereafter. There are two reasons why the bone levels may become stable after initial marginal bone loss, even when the cause is from occlusal overload: bone physiology and implant design mechanics.

Bone physiology.

The bone is less dense and weaker at stage 2 implant surgery than it is 1 year later after prosthetic loading.[99] Bone is 60% mineralized at 4 months and takes 52 weeks to complete its mineralization.[100] Partially mineralized bone is weaker than fully mineralized bone. In addition, the microscopic organization of bone progresses during the first year. Woven bone is unorganized and weaker than lamellar bone, which is organized and more mineralized. Lamellar bone develops several months after the woven bone repair has replaced the devitalized bone caused by the surgical insertion trauma around the implant.[101] The occlusal stress levels may be high enough to cause woven bone microfracture or overload during the first year, but the increase in bone strength achieved after complete mineralization and organization may be able to resist the same stress levels during the subsequent years.

As functional forces are placed on an implant, the surrounding bone can adapt to the stresses and increase its density, especially in the crestal half of the implant body during the first 6 months to 1 year of loading.[102] In a histologic and histomorphometric study of bone, Piatelli et al reported reactions to unloaded and loaded nonsubmerged implants in monkeys (Figs. 18.21 and 18.22). The bone changed from a fine trabecular pattern after initial healing to a more dense and coarse trabecular pattern after loading, especially in the crestal half of the implant interface.[103] Hoshaw loaded threaded implants in dogs with a tensile load and noted that the fine trabecular bone pattern became coarse trabecular bone around the implant.[90] In addition, the bone reorganized to a more favorable condition to assist the direction and type of occlusal load (Fig. 18.23). Fine trabecular bone is less dense than coarse trabecular bone. Because the density of bone is directly related to its strength and elastic modulus, the crestal bone strength and biomechanical mismatch between titanium and bone may diminish

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gradually during the functional loading phase. In other words, the stresses applied to the peri-implant bone may be great enough to cause bone resorption during the first year because bone strains are greatest at the crest. However, the stresses applied below the crest of bone are of less magnitude and may correspond to the physiologic strain that allows the bone to gain density and strength. As a result, the occlusal load that causes bone loss initially (overload) is not great enough to cause continued bone loss once the bone matures and becomes more dense.

FIG 18.21 In evaluating the bone around an implant after healing in a monkey model, a fine trabecular pattern is noted. (From Piatelli A, Ruggeri A, Franchi M, et al: A histologic and histomorphometric study of bone reactions to unloaded and loaded nonsubmerged single implants in monkeys: a pilot study, *J Oral Implantol* 19:314–319, 1993.)

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FIG 18.22 Once the implant was loaded, the fine trabecular bone became coarse trabecular bone, especially at the crestal region. When the stresses are too great, bone loss occurs. When the stresses are within the physiologic range, the bone density increases. (From Piatelli A, Ruggeri A, Franchi M, et al: Ahistologic and histomorphometric study of bone reactions to unloaded and loaded nonsubmerged single implants in monkeys: a pilot study, *J Oral Implantol* 19:314–319, 1993.)

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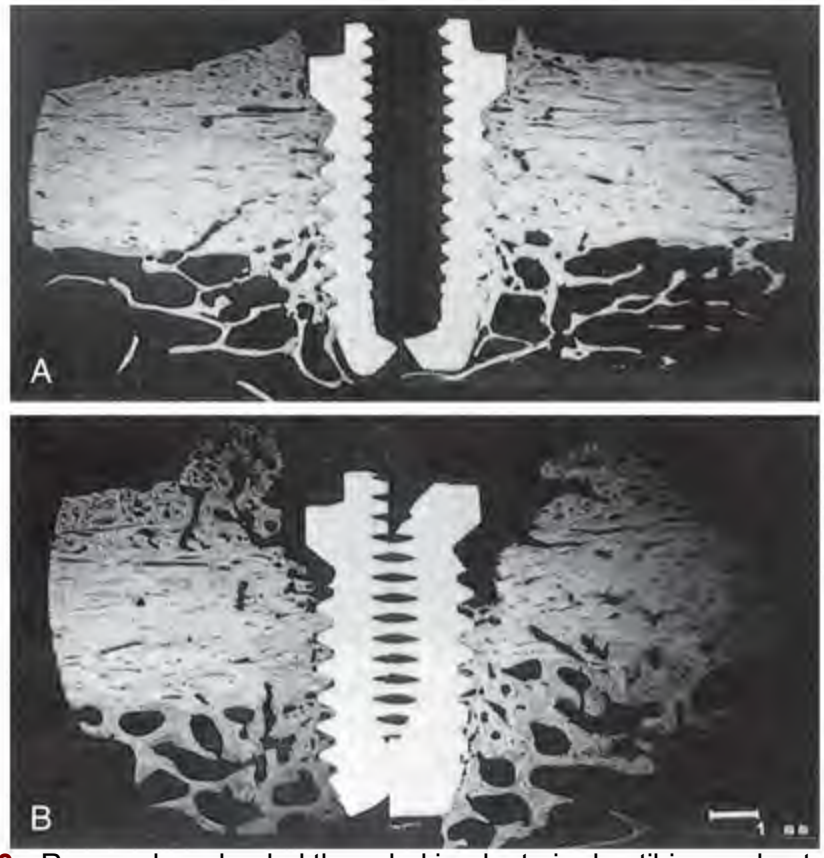

FIG 18.23 Researchers loaded threaded implants in dog tibiae and noted the fine trabecular bone in the apical region (A) became coarse trabecular after loading. In addition, crestal bone loss was observed on the loaded implant. (From Hoshaw SJ, Brunski JB, Cochran GVB: Mechanical loading of Brånemark fixtures affects interfacial bone modeling and remodeling, *Int J Oral Maxillofac Implants* 9:345–360, 1994.)

A clinical report by Appleton et al demonstrated that progressively loaded single-tooth implants in the first premolar region of humans exhibited less bone loss and greater bone density increase in the crestal half of the implant interface compared with nonprogressively loaded implants in the same jaw region, and even in the same patient, on the contralateral side.[104] (Fig. 18.24). Marginal bone loss is less in the mandible compared with the maxilla in several clinical reports. The bone is denser in the mandible than the maxilla. The reduced crestal bone loss that has been reported in the mandible in greater bone densities and in progressively loaded implants point to the fact that stress/strain is a primary etiology of crestal bone loss after the implant is loaded. The stresses at the crest of the ridge may cause microfracture or overload during the first year, and the change in bone strength after loading and mineralization is complete alters the stress/strain relationship and reduces the risk of microfracture during the following years.[105]

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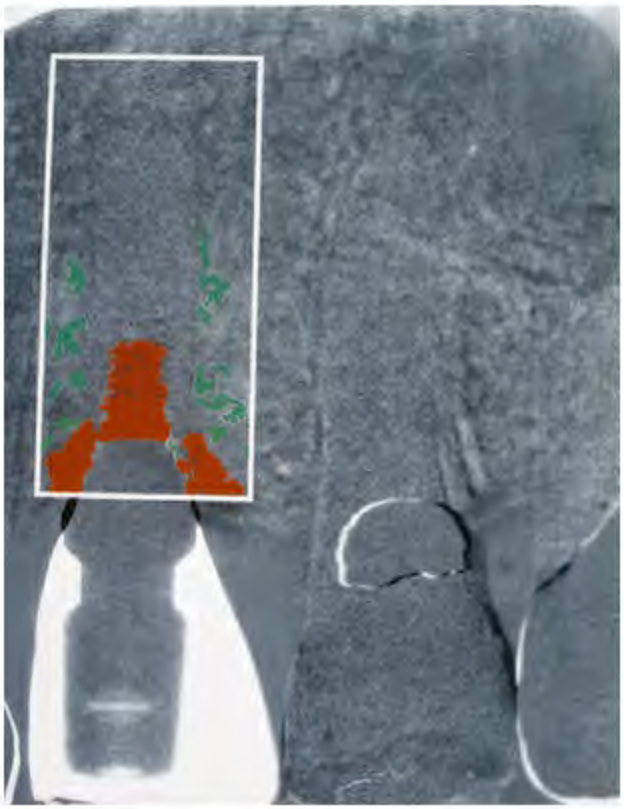

FIG 18.24 Researchers observed in humans that less crestal bone loss and an increase in bone density were present around implants progressively loaded in the maxillary first premolar region. (From Appleton RS, Nummikoski PV, Pigno MA, et al: A radiographic assessment of progressive loading on bone around single osseointegrated implants in the posterior maxilla, *Clin Oral Implants Res* 16:161–167, 2005.)

Implant design biomechanics.

Different amounts of marginal bone loss have been reported for different implant body designs. The design and surface condition of the implant body may affect the amount of strain distributed to an implant-bone interface. A report by Zechner et al evaluated the peri-implant bone loss around functionally loaded screw-type implants with machined surfaced V-threads or a sandblasted, acid-etched square-thread design (Fig. 18.25).[106]

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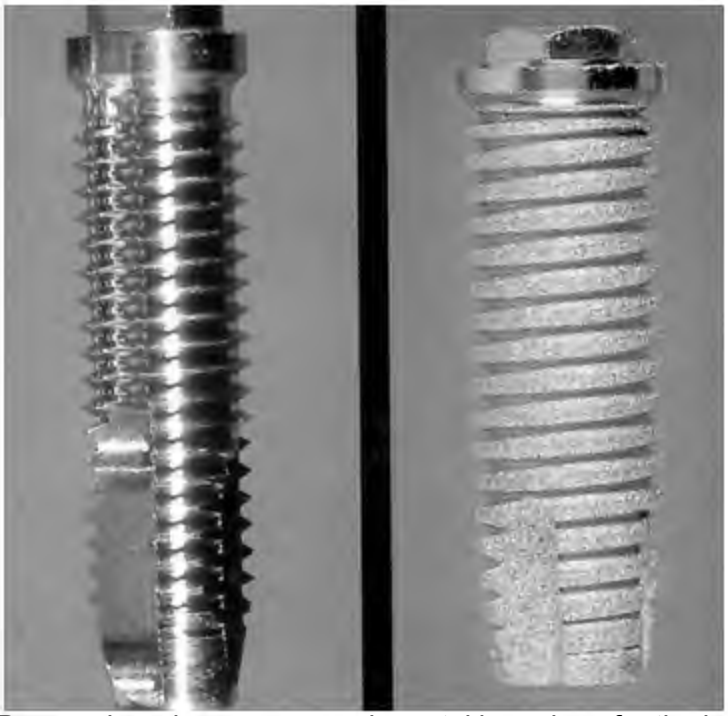

FIG 18.25 Researchers have compared crestal bone loss for the implant design on the *left* (a V-shaped machined thread) with the implant design on the *right* (a roughened square thread) in the anterior mandible for 3 to 7 years. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

Both these implant designs had a similar crest module and external hex connection. Four interforaminal implants were placed in the mandible in 36 patients and followed for 4 years. Over this period, the average bone loss was 2.4 mm (V-thread) versus 1.6 mm (square thread). However, the range of bone loss in the study was 0.1 to 8.5 mm for machined V-threaded implants and 0.2 to 4.8 mm for rough-surfaced square-threaded implants. Twenty-two V-threaded implants lost more than 4 mm of bone of less than 1 mm was reported for 16 rough-surface square-threaded implants compared with only two machined-surfaced V-threaded implants (Fig. 18.26). There were no clinical findings of inflammation or exudate. The range of bone loss with the different implant surface conditions and designs in a clinical report suggests that more than the biologic width, microgap position, and/or surgical causes are involved in the individual implant marginal bone loss process. The three most probable factors that influenced the amount of crestal bone loss in this report are the amount of force applied to the prosthesis, the quality of the bone to resist these forces, and the implant body design. All three of these conditions implicate occlusal overload as the cause of marginal bone loss around an implant.

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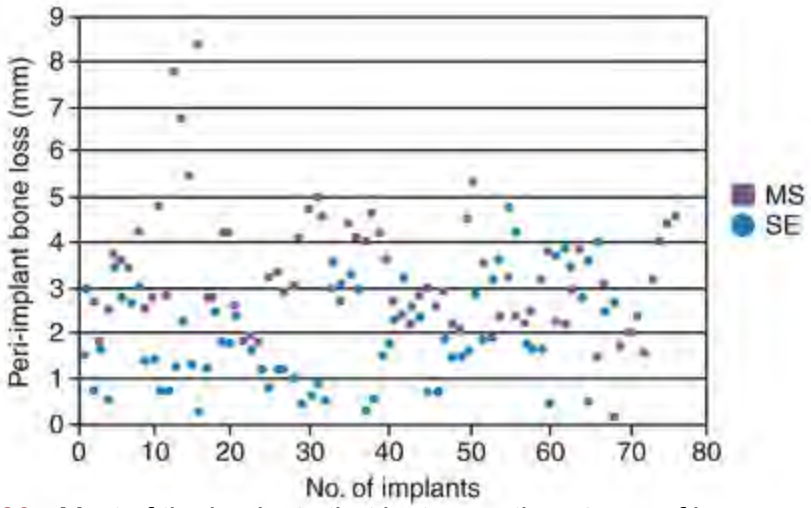

FIG 18.26 Most of the implants that lost more than 4 mm of bone were of the machined V-shaped thread design *(MS)*. The implants that lost less than 1 mm of bone were primarily roughened square thread designs *(SE)*. (From Misch CE: *Contemporary implant dentistry,* ed 3, St. Louis, 2008, Mosby.)

A prospective study by Karousis et al also indicated that different implant designs and surface conditions correspond to different incidences of crestal bone loss.[107] Three different implant designs from the same manufacturer were evaluated over 10 years in a prospective report. One implant body design lost more than 5 mm of bone 26% of the time, whereas the other two designs reported 37% and 39% incidence. More than 6 mm of marginal bone loss occurred in 22% of the implants with the first design, compared with 35% and 33% for the other two designs. These results indicate that one implant design may result in less marginal bone loss than another and point to the fact that clinical reports with similar healing and loading protocols, but of variable implant body designs and surface conditions, may yield different amounts of crestal bone loss. Because the implant design and surface condition affect the amount of stress transferred to the bone, one of the reasons for a different amount of bone loss for different implant designs may be related to the stress transmitted to the bone.

In the field of orthopedics, hip joint replacement has several complications, including wound infection, periprosthetic fracture, dislocation, mechanical failure, and osteolysis.[108] *Osteolysis* refers to the bone resorption that occurs around both cemented and uncemented orthopedic implants. Aseptic loosening from osteolysis of the bone-implant interface is the leading cause of late joint replacement failure (10% within 10 years). Mechanical loading factors primarily are associated with this condition. Patient factors that increase loading failure include body weight and activity level. An animal model and human report have linked the resorption of bone

at the interface to mechanical overload.[109] Treatment of the disorder, if the patient is asymptomatic with a large osteolytic defect but no implant mobility, includes curettage of the osteolytic membrane and bone grafting.[110] These orthopedic reports accept that mechanical overload can cause bone resorption at the bone-implant interface. The metal most often used in hip replacement therapy is titanium alloy, and the bone-implant interface is very similar to a dental implant. In addition, potential causative elements encountered intraorally, such as oral bacteria contamination, microgap position, and microbial-related bone loss, are eliminated in this aseptic environment. It is logical to assume these studies further support a relationship between marginal bone loss around implants and biomechanical stress.

Radiographic Evaluation of Bone Loss.

The radiographic assessment of natural teeth assists in determining the presence of decay, lesions of endodontic origin, and periodontal bone loss. Radiographs may be used to evaluate the result of periodontal diseases on the supporting bone but cannot indicate the presence or absence of the disease process. Assessments of bone loss for natural teeth may include (1) the presence or absence of intact lamina dura; (2) the width of the PDL space; (3) the bone crest morphology (even or angular); and (4) the distance from the cementoenamel junction (CEJ) and the coronal level of the PDL (normal or abnormal width). Normal radiographic bone levels next to natural teeth are typically between 1 to 3 mm from the CEJ.

Implants do not decay and do not develop endodontic-related conditions. However, the crestal bone region is often the most diagnostic for the ranges of optimum, satisfactory, and compromised health conditions. Radiographic interpretation is one of the easiest clinical tools to use to assess implant crestal bone loss but has many limitations. A radiograph only illustrates clearly the mesial and distal crestal levels of bone. However, early bone loss often occurs on the facial aspect of the implant.

An absence of radiolucency around an implant does not mean bone is present at the interface, especially in the anterior mandible. As much as 40% decrease in density is necessary to produce a traditional radiographic difference in this region because of the dense cortical bone.[111] When the bone is wide, a V-shaped crestal defect around an implant may be surrounded by cortical bone and, as a result, the radiograph is less diagnostic.

Parallel periapical radiographs are more difficult to obtain for implants

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than for teeth. An implant is often apical to the apex of the preexisting natural tooth. As a result, the apex of the implant often is located beyond muscle attachments or in regions almost impossible to capture with a parallel radiographic method. A foreshortened image to accommodate the apical portion of the implant defeats the purpose of radiographic interpretation of the crestal bone. Crestal bone loss is often best evaluated with vertical bitewing films or periapical radiographs that do not include the apical portion of the implant (Fig. 18.27).

FIG 18.27 Vertical bitewings are often more diagnostic to determine radiographic bone loss compared with radiographs, which attempt to capture the apex of the implant. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The clear depiction of the threads on the radiograph indicates use of a proper angulation. If the threads are clear on one side but fuzzy on the other, the angulation was incorrect at least 10% (Fig. 18.28). If both sides of a threaded implant are unclear, the radiograph is not diagnostic for crestal bone loss assessment. Ideally, the abutment-implant connection should appear as a clear line between the two components. When the top of the implant is placed at the crest of the regional bone, the amount of crestal bone loss is easiest to evaluate.

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FIG 18.28 On this periapical radiograph, the threads are clear on one side only. The central ray was not directed completely perpendicular to the implant body but was within 10 degrees. This film is not ideal but is clinically acceptable in most situations. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Clinical significance.

The implant quality of health evaluation protocol depends on clinical and radiographic observations. A baseline radiograph is obtained at the initial delivery of the prosthesis. By this time the "biologic width" and influence of the implant crest module design have already contributed to its influence on crestal bone loss. Because crestal bone changes often occur during the first year of loading, preventive maintenance appointments are scheduled every 3 to 4 months, and a periapical/vertical bitewing radiograph at 6 to 8 months may be compared with the baseline if probing depths increase. Vertical bitewing radiographs may be taken at 1 year and compared with the previous two images. If no changes are apparent, subsequent radiographic examinations may be scheduled for every 3 years unless other clinical signs warrant more frequent examinations.

If crestal changes are evident by probing or radiographs, stress reduction and hygiene are modified accordingly. Radiographs are taken and reviewed every 6 to 8 months until the bone is stable for two consecutive periods. If bone loss greater than 2 mm is observed from the bone levels noted at the prosthesis delivery, the dentist should strongly suspect parafunction on too few implants. Night guards and stress reduction on the affected implants are indicated.

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Peri-Implant Disease

The following section outlines the major types of peri-implant disease, while offering a comprehensive treatment and prevention protocol (Table 18.7).

TABLE 18.7

Diagnostic Comparison of Peri-Mucositis vs. Peri-Implantitis

	Bleeding on Probing	Suppuration	Probing Depths	Radiographic Bone Loss	Implant Mobility
Peri-implant mucositis	+	+/−	>4 mm	+	−
Peri-implantitis	+	+/−	<4 mm	−	+/−

Peri-implant Mucositis

Peri-implant mucositis is an inflammatory condition of the soft tissue surrounding an implant, which is similar to gingivitis around a tooth. This has been defined as a reversible condition with no loss of attachment or bone loss. The prevalence of peri-implant mucositis (bleeding on probing and no loss of bone) has been shown to be approximately 79% to 90% of subjects and 50% of implants.[8]

Clinically, peri-implant mucositis may be diagnosed as bleeding on probing with or without suppuration, probing depths less than 4 mm, with no evidence of radiographic evidence of bone loss (Fig. 18.29).

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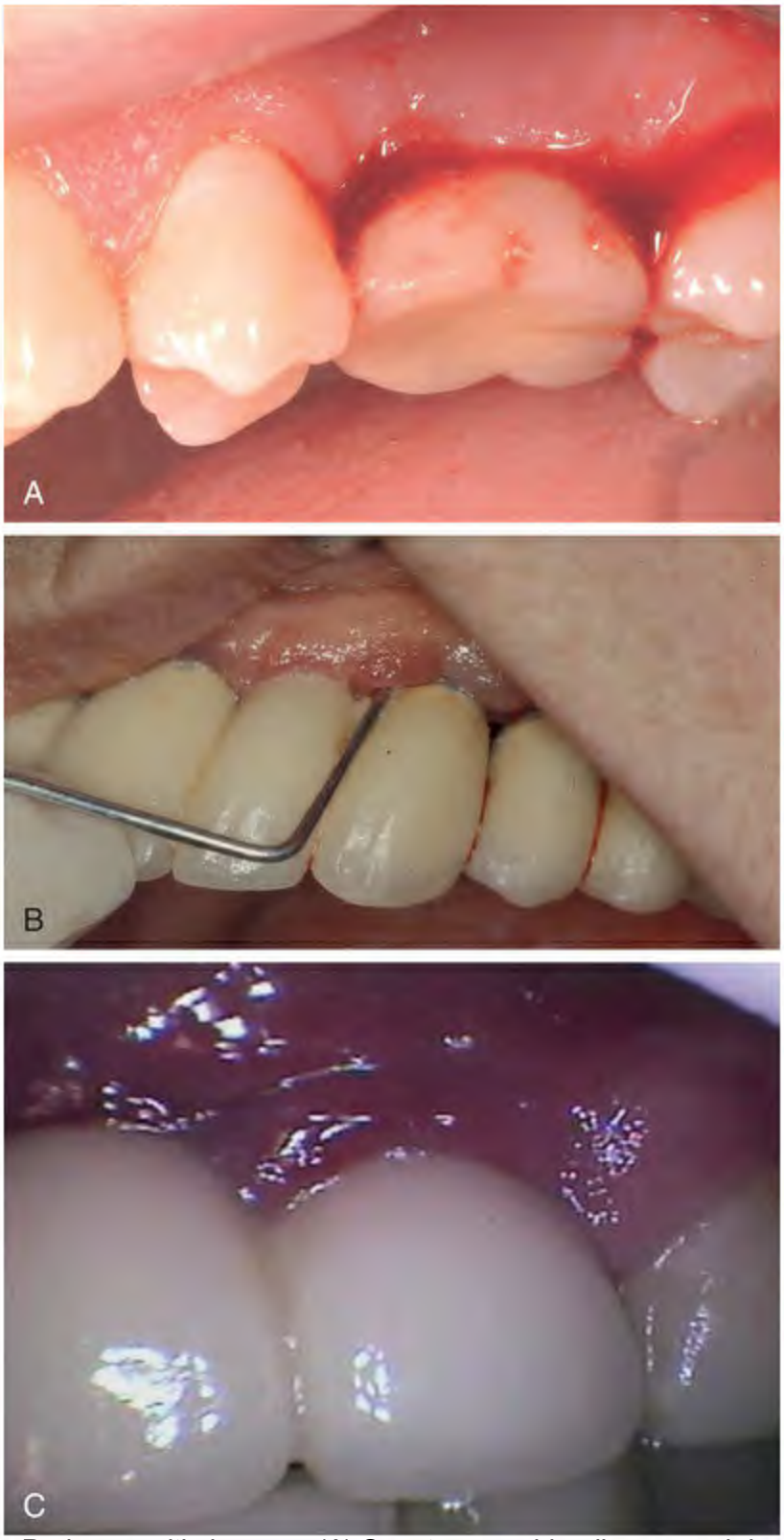

FIG 18.29 Peri-mucositis images. (A) Spontaneous bleeding around dental implant prosthesis. (B) Erythematous marginal diseased tissue with bleeding on probing. (C) Cyanotic buccal gingiva indicating chronic bacterial challenge.

Etiology.

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The primary etiologic factor has been shown to be plaque biofilm, the removal of which easily reverses the disease process. If allowed to progress, peri-implantitis may result, which includes loss of bone and loss of osseointegration, similar to loss of attachment and bone with periodontitis. The relationship between plaque accumulation and peri-implant mucosal inflammation has been proven through numerous studies.[112,113] Histologically, peri-implant mucositis is composed of T cells with an apical extension that is limited to the barrier epithelium.[114] Most cases of peri-mucositis are due to poor oral hygiene, inability to clean the implant or prosthesis, poor implant position, poor fit of the prosthesis, and retained cement.

Additionally, peri-mucositis may also be caused by titanium alloy hypersensitivity. Most dental implants today are covered by a titanium dioxide layer that gives the implant a high surface energy that facilitates the interaction between the host tissues and the dental implant. When the implant becomes exposed to the oral environment, a lower surface energy may provoke a type IV hypersensitivity reaction that may contribute to peri-mucositis.[115]

Prevention.

Because of the high prevalence of peri-mucositis, it is imperative the implant clinician be able to assess the risk profile of each patient and take this into consideration when treatment planning is initiated. A recent consensus report by the American Academy of Periodontology has shown risk factors to include poor oral hygiene, history of periodontal disease, smoking, retained cement, and occlusal disharmonies. Systemic factors also have been shown to include such disorders as diabetes and cardiovascular disease.[116] The clinician should be well versed on the role of systemic diseases and medications have on the soft tissue interface that may result in peri-mucositis.

Another key component of peri-mucositis prevention is ideal implant placement. The implant should be placed in the ideal buccal-lingual, mesial-distal, and apical-coronal dimension to ensure soft tissue health. This will also allow for ideal prosthesis design, which will facilitate ideal hygiene procedures.

Management.

Peri-implant mucositis has been shown to be a reversible inflammatory process.[8] However, if not treated properly, the persistent inflammatory

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condition may progress to peri-implantitis that includes irreversible bone loss. In most cases, peri-mucositis is required for the development of peri-implantitis.[117,118]

Nonsurgical mechanical debridement coupled with antimicrobial rinse therapies is the primary therapeutic approach for peri-implant mucositis. Factors contributing to poor management of peri-implant mucositis may include lack of patient compliance, inconsistent maintenance intervals, and impairment of implant prosthesis for proper plaque control.[119]

Because peri-implantitis is reversible, it is imperative the biofilm be eliminated from the implant surface. If the biofilm remains, peri-mucositis may progress to peri-implantitis.

The goal of peri-implant mucositis treatment is to reestablish a healthy peri-implant mucosa by means of removing the peri-implant biofilm and calculus without damaging or altering the implant surface.

It is crucial to implement a comprehensive patient and professional oral hygiene program to combat the peri-implant mucositis. Power brushes, interproximal and irrigation power devices, dentifrices, and antimicrobials have been recommended in the management of peri-implant mucositis.

Professional Mechanical Debridement.

For the removal of the supra- and subgingival biofilm and bacteria, debridement of the exposed implant surface and implant abutment must be completed. There exist many different debridement systems.

Curettes.

The selection of scalers for titanium implant debridement is important to minimize surface changes following treatment. There are various types of curettes available for debridement procedures.

- *Titanium-coated curettes* are specifically made for dental implant debridement because they have a similar hardness to the titanium surface and will not scratch or mar the surface.
- *Carbon-fiber curettes* are softer than the implant surfaces and will not damage the implant surface. These types of curettes are prone to fracture.
- *Teflon curettes* are similar to carbon-reinforced curettes and will not scratch the surface of the implant.
- *Plastic curettes* have been advocated as the instrument of choice to prevent damage from the implant surface. However, the efficacy and efficiency of

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these instruments are questionable. These types of curettes are also prone to breaking.

- *Stainless steel curettes* are much harder than titanium alloy and are not recommended for use around dental implants because they may alter the implant surface.
- *Amorphous resin scalers* come with unfilled or filled resin. Unfilled resin scalers have no reinforcements for shape or stiffness while filled resin fillers may use materials like silica, graphite, or glass. These scalers have replacement tips on a stainless steel handle. Longevity of these curettes tends to be relatively short.
- *Titanium brush burs* (Salvin) insert into implant motor. They have a variety of shapes allowing them to adapt around implant surface circumferentially, single surface, and groove cleaning. Brushes are used at 600 rpm and adapted against implant surface to remove debris.

Hasturk et al compared six different types of scaler materials and their tendency to scratch surfaces of different brands of implants abutments under scanning electron microscope. The result showed glass-filled resin curettes caused the most scratches while the unfilled resin scalers had the least surface alteration. However, these studies are on smooth titanium abutments and not on the rough implant surface.[120] A study by Anastassiadis suggested that there may not be any clinical relevance on whether curettes scratch implant surfaces or not. It has been previously demonstrated that metal scalers do not readily scratch cementum; it is questionable that a titanium implant surface, which has a higher Mohs hardness, should be of any concern.[121] Furthermore, scalers as a whole may be effective in removing large calculus particles or granulation tissues but are rather ineffective trying to navigate the perimeter and grooves of an exposed implant surface. For that reason, curette material may not be a significant concern, but rather the act of curetting is (Fig. 18.30).

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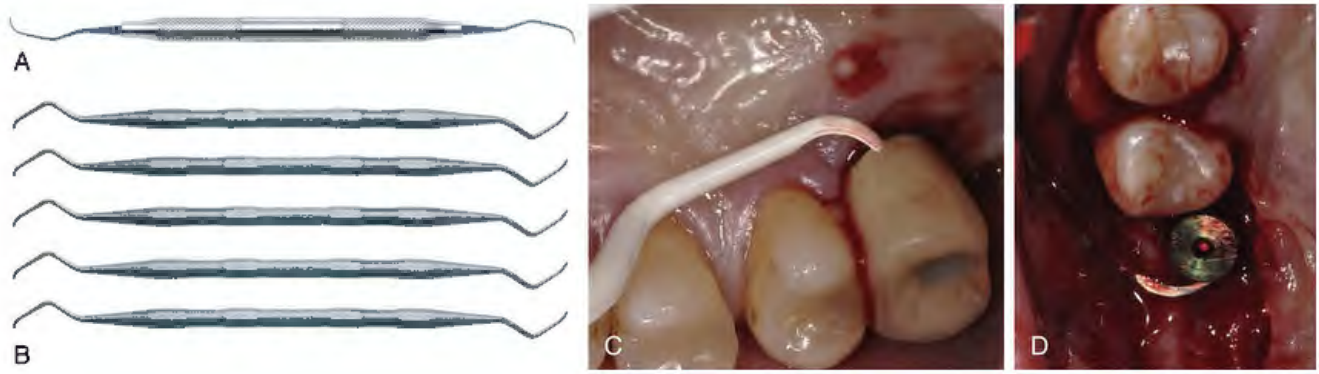

FIG 18.30 (A) Titanium curette. (B) Carbon-reinforced curette. (C) Teflon/plastic. (D) Steel curette. (A and B, From Salvin Dental Specialties, Inc., Charlotte, NC.)

Ultrasonic devices.

Ultrasonic devices with special polyetheretherketone-coated tips have been used to debride the implant surface. This tip is made of a plastic material with a stainless steel core. This ultrasonic device allows the debridement of plaque and calculus while leaving a smooth and clean surface.

While metal tips are not recommended, plastic tips may have high chances of shredding when cleaning around implant grooves and threads. Tips made of PEEK material by Hu-Friedy have been shown to be resistant to shredding and may be considered.

Neither the American Dental Association nor American Academy of Periodontology have released a consensus on the use of ultrasonic devices around implants. Evidence is currently anecdotal and not sufficient to support use of devices.

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Antimicrobials.

Antiseptics are defined as antimicrobial substances that are nondamaging to living tissue/skin while reducing the possibility of infection, sepsis, or putrefaction. There are several types of antiseptics ready for dental use: sodium hypochlorite 1.0%, hydrogen peroxide 3.0%, chlorhexidine gluconate 0.12% (USA) or 0.2% (Europe, Asia, Canada), citric acid 40.0%, EDTA 24%, povidone iodine 10%, phenols and essential oils. In regards to peri-implantitis, several qualities are needed for antiseptics to be effective: biofilm penetration, long substantivity, tissue biocompatibility, and low resistance. For these reasons, we recommend the use of citric acid. Removal of macro deposits should be performed with scalers first. A cotton pellet is soaked with 40% citric acid. It is gently dabbed to remove excess fluid then burnished onto exposed implant surfaces for 30 to 60 seconds.[122] Although there are many other potential antiseptics such as povidone iodine, hydrogen peroxide, chlorhexidine, and saline, citric acid has the most biocompatible characteristics and ease of use. Citric acid is shown to be able to reduce bacterial endotoxin, specifically *Porphyromonas gingivalis,* by up to 90% with 2 minutes of contact.[123] The body is capable of handling minimal amount of bacterial colonies. With mechanical and antiseptic use, it allows cells a chance to try to regenerate onto clean implant surfaces.

In regards to other antiseptics, chlorhexidine applied on a cotton pellet and burnished against machined surface has shown a 92.9% Pg endotoxin reduction but is known to be toxic to fibroblasts.[124] Povidone iodine has high antiseptic capability but has a highly irritating effect if any residue comes in contact with osseous structure. Bürgers et al studied several of the antiseptics and their effectiveness on *S. epidermis, C. albicans,* and *S. sanguinis*. While sodium hypochlorite was most effective in the reduction of all three bacterial biofilms, it has the highest tissue toxicity. Hydrogen peroxide was only active against *C. albicans,* while chlorhexidine gluconate, phenols, and essential oils only had activity against *S. sanguinis* and *C. albicans*.[125]

Not enough supportive studies have deemed any of the listed antiseptics as the clear choice, but 40% citric acid is recommended for ease of use, tissue compatibility, and effectiveness in reducing bacterial residue (Fig. 18.31).[126]

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FIG 18.31 0.12% chlorhexidine rinse.

Locally delivered antibiotics.

The recommended locally delivered antibiotic (LDA) is tetracycline at 50 mg/ml solution. Tetracycline capsules can be opened and mixed with small amounts of saline solution to create a paste. This paste is burnished onto implant surfaces for 60 seconds then thoroughly rinsed away with saline. Tetracycline is bacteriostatic because it targets the 30s ribosomal subunit in the mRNA translation complex of bacterial protein synthesis. It is also found to have inhibition effect on matrix metalloproteinases; the application of tetracycline solution needs to be completely removed. A study with pure tetracycline application showed reosseointegration after 4 months.[127] It is highly recommended to incorporate tetracycline in treatment of peri-implantitis.

Clinical significance.

Tetracycline capsules may be mixed with few drops of saline to form a slime gel consistency. It should stay gelled when scooped up to be delivered to exposed implant surfaces. The gel is allowed to sit on implant surface for 1 to 5 minutes then thoroughly rinsed off. It allows proximal contact of antibiotics to implant surface colonies and may assist in success in treatment of peri-implantitis (Fig. 18.32).

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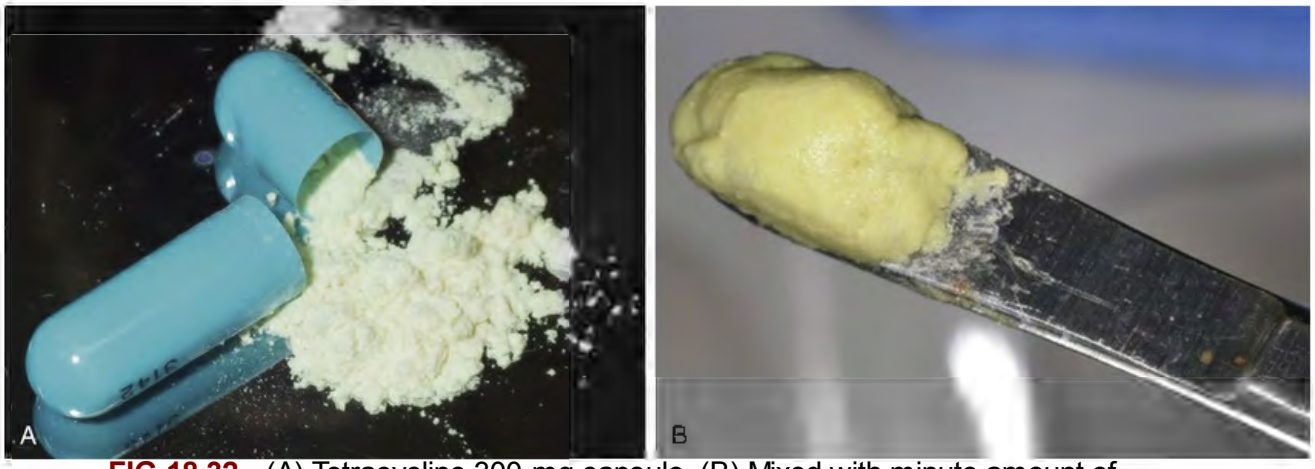

FIG 18.32 (A) Tetracycline 300-mg capsule. (B) Mixed with minute amount of sterile saline to form a workable paste.

Systemic antibiotics.

The use of systemic antibiotics has been well studied for treatment of periodontitis.[128] However, peri-implantitis treatments with use of systemic antibiotics are relatively few. It is known that patients with periodontitis are three times more likely to develop peri-implantitis, but the bacterial colonies found in peri-implantitis and periodontitis share few characteristics. Still, many studies have demonstrated the most effective combination as amoxicillin and metronidazole. Metronidazole is bactericidal to anaerobic organisms. It disrupts DNA synthesis. This antibiotic has been shown to be especially effective against *A. actinomycetemcomitans* and effective against *P. gingivalis* and *P. intermedia*.[129] The amoxicillin and metronidazole combination has also been shown to have long-term effects against *A. actinomycetemcomitans*.[130] Use of amoxicillin and metronidazole mixture is recommended. For patients who are allergic to amoxicillin, doxycycline 10% controlled release gel such as atridox may be considered.

Clinical significance.

Script formulation:

Amoxcillin 500 mg tid, metronidazole 250 mg, 21 tabs tid till finish

Doxycycline hyclate 10% (atridox) applied subgingivally

Patient At-Home Mechanical Debridement.

The mechanical reduction of supragingival plaque by removal with

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toothbrushes (manual or powered) significantly reduces the amount and composition of subgingival microbiota around teeth. This reduction should translate to a decreased risk of periodontal disease initiation or recurrence. Furthermore, the decreased prevalence of periodontal pathogens in supragingival plaque lowers potential reservoirs of these species (Fig. 18.33).[131]

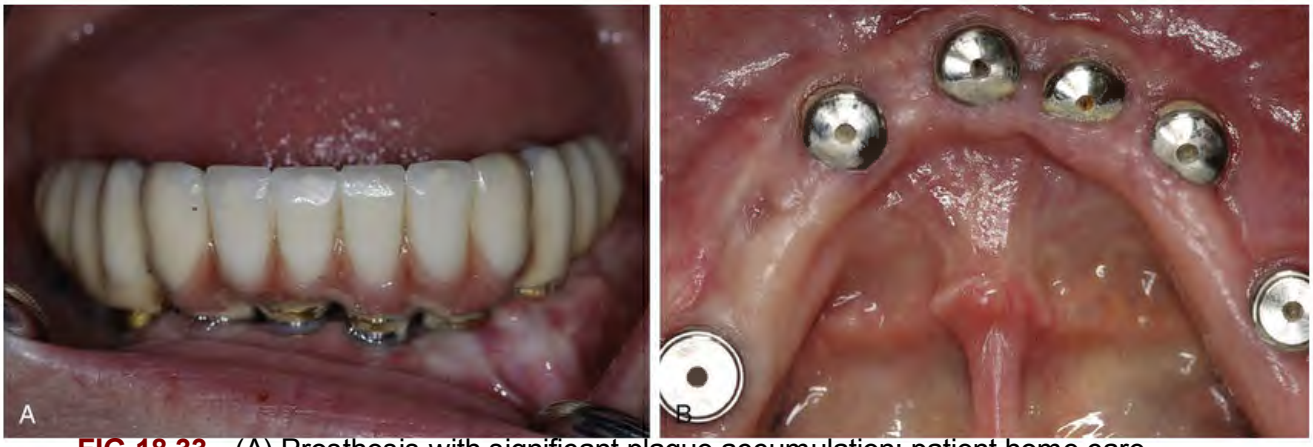

FIG 18.33 (A) Prosthesis with significant plaque accumulation; patient home care instruction is crucial to the long-term health of the soft tissue. (B) Patient home care is also important during the implant healing phase because plaque and calculus accumulation results in poor tissue health.

The absence of adequate keratinized mucosa in endosseous dental implants, especially in posterior implants, was associated with higher plaque accumulation and gingival inflammation but not with more annual bone loss, regardless of the implant's surface configurations.[132] The implant type, with the presence or absence of keratinized tissue, may be a challenge for oral hygiene procedures for many patients. The clinician should stress the importance of adequately performing plaque control and select products and procedures that are well suited to the needs and ability of the patient.

Toothbrushing: Manual and Power.

There are many types of toothbrushes available for implant patients to clean exposed implant surfaces and prostheses. The patient should be instructed to initially attempt to use a soft, multitufted, nylon toothbrush. Because of often nonideal implant locations or prostheses, the clinician should choose a handle that will allow for easy access to all areas. The toothbrush technique should be the modified Bass technique or a short, horizontal back-and-forth

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movement can be utilized. The modified Bass technique allows for the brush to be held at a 45-degree angle where the abutment post meets the gingival tissue. A location that is often missed is lingual aspect of the abutments or prosthesis.

In some instances, patients will be able to use rotary unitufted power brushes, oscillating-rotating brushes, and sonic brushes. Most available powered brushes will not damage the exposed implant surfaces or abutments. Most manufactured power brushes have soft interchangeable bristle heads (flattened, rubber cup–like, short and long pointed in shape) that may be used. The short and long pointed tips are ideal for reaching proximal areas, wide embrasures, and pontic areas under a splinted prosthesis. The hollowed, rubber cup may be used on the facial and lingual aspects of the implant and prosthesis (Fig. 18.34).[133]

FIG 18.34 Toothbrushing aides. (A) Oral-B Superfloss. (B) Oral-B Power Tip. (C) Interproximal cleaning device (Philips AirFloss Pro). (A and B, Courtesy Oral-B Laboratories Inc., Iowa City, IA. C, Courtesy Philips Oral Healthcare, Stamford, CT.)

Auxiliary Aids.

Interdental brushes may be used to massage the peri-implant tissue around an implant, which results in increased blood flow to enhance the tone of the surrounding gingiva. Instructions should be given to insert the tip interdentally in an occlusal direction, pressing the side of the tip against the marginal gingiva and applying a gentle rotary motion. In some cases, interproximal brushes with small brush heads (e.g., GUM End Tuft [Sunstar Americas, Inc.]) may be required for easier access. However, caution should be exercised to use plastic-coated devices because metal may potentially damage or scar the implant or prosthesis surface.

There are numerous types of floss on the market for implant hygiene use. A commonly used brand is Oral-B Super Floss, which is a thicker, wide ribbon that has one end that allows for ease of threading. This type of floss may also be used in conjunction with an antimicrobial solution (e.g., chlorhexidine gluconate), which may be used in a side-to-side motion. This allows the thick ribbon to clean on both sides of the exposed implant. In areas with tighter, small openings, a traditional unwaxed floss may be used with a floss threader.

Oral irrigators may be used as an adjunct for removing supragingival soft debris around implants and prostheses. However, caution should be exercised because incorrect use or excessive water pressure may damage the peri-implant tissues. Patients should be instructed to use these modalities on low-medium settings, with the irrigator tip placed in the interproximal area horizontal to the implant and along its gingival margin to avoid subgingival spray. Additionally, an antimicrobial solution may be used (e.g., chlorhexidine gluconate).[133]

The main goal of auxiliary aids is mechanical debridement. Patient adherence to home care is essential. Superfloss and interdental brushes work by physically engaging plaque and tartar. Oral irrigators function by hydraulic pressure to force fluid into the subgingival space. It functions by both introduction of oxygen to an anaerobic bacteria dominant space and removal of debris. In addition, chemical agents may be of benefit (e.g., chlorhexidine gluconate, peroxide, low-concentration bleach) and are advocated. Each of these solutions has high capabilities to penetrate bacterial biofilm and induce reduction of colonies. Irrigation around implants should be incorporated into patient's home care regime on a daily basis.

Antimicrobial Agents.

Chlorhexidine gluconate is an antimicrobial safe and nontoxic adjunct to oral

hygiene procedures in the maintenance of dental implants. Chlorhexidine is effective in reducing peri-mucositis because of its substantivity (i.e., binding to tissue or implant surfaces). Additionally, it allows for fibroblast attachment to implant surfaces. It has a long half-life because the pellicle maintains bacteriostasis.

Clinical significance.

Although regular use may assist in patient home care, several adverse side effects may occur for patients on routine use of chlorhexidine. Reports of alteration of taste and staining of teeth are common. It is not recommended to put a patient on long-term use of chlorhexidine; prescribing use should be at the discretion of prescriber. It is recommended to be given postsurgery for use to assist in soft tissue healing.

Chlorhexidine regimen.

Patients are given scripts for 1 bottle 0.12% or 0.2% chlorhexidine and are instructed to rinse both in the morning after brushing teeth and at night before going to sleep. Due to side effects, patients should be under close monitoring. It should be noted that other countries may have different concentrations of chlorhexidine.

Peri-Implantitis

Etiology.

Peri-implantitis has been associated with a gram-negative anaerobic microbiota, similar to that found in severe periodontitis around natural teeth.[134]

Peri-implantitis encompasses the criteria of peri-mucositis and the addition of loss of osseous support. Although some natural bone remodeling post implant placement is normal, a stabilized implant that continues to exhibit bone level change is indicative of peri-implantitis.

Although bacterial insult is identified as the main cause of peri-mucositis, peri-implantitis is considered to be initiated by stress factors caused by a poor biomechanical environment. In addition, several other factors exist, such as poor implant placement, poor oral hygiene, residual cement, the body's rejection, poor implant surface, unfavorable osseous density, untreated periodontitis, drinking and smoking, untreated endodontic lesions, diabetes, etc. More etiologies are being identified as studies

continue. Unfavorable stress factors can initiate crestal bone loss, and bacterial presence can further propagate the rate of osseous destruction. In recent studies, Rodrigues et al found that bacterial biofilms attached onto the surface of implants can create a highly acidic environment that causes corrosion, pitting, cracking, etc.[135] Furthermore, new studies have shed light on the release of titanium ions from the implant surface, which causes a significant increase in local inflammatory effect.[136]

Prevention

Home care.

An effective oral hygiene program is paramount to minimize peri-implant disease. This has been shown through multiple studies. Lindquist found a direct association between poor oral hygiene and peri-implant bone loss in a 10-year follow-up study.[137] Other studies have shown a correlation with poor oral hygiene and a higher plaque score.[138] Additionally, patients who have lost their teeth to periodontal disease are more susceptible to peri-implantitis.[139]

Professional care.

A thorough periodontal charting and review is essential. Patients with periodontitis need to have this condition controlled before implant placement. Patients who do not demonstrate the ability to maintain oral hygiene need to be educated and put on a stringent professional care regimen.

Prosthetic design.

A thoroughly evaluated cone beam computed tomography (CBCT) scan with favorable biomechanical design for prosthetics is required. Refer to Misch's book, *Dental Implant Prosthetics, ed 2*, for detailed treatment designs and recommendations in treatment cases.

Cementation technique.

The meticulous use of cements when delivering a prosthesis is imperative, or the clinician can choose to use screw-retained prostheses. If cementation is desired, be careful to apply only on the edge of intaglio surfaces of the crown. Overfilling or complete coverage of all inner surfaces of the crown is not conducive to avoidance of cement extrusion.

Control of parafunctional forces.

A bite guard is critical to prevent unfavorable occlusal stress. The night guard is adjusted to be on flat plane occlusion to disperse stress. Careful discussion should be conducted with the dental laboratory to convey the desired design for successful application.

Management.

The objective of treatment for peri-implantitis is for osseous regeneration of the osseous defect. However, this proves to be challenging because the implant surface needs to be detoxified along with modifying the soft and hard tissues. This may involve nonsurgical and surgical treatment (Box 18.4).

Box 18.4

Treatment of Peri-Implant Mucositis/Peri-Implantitis

Patient Self-Administered Mechanical and/or Chemical Plaque Control

Toothbrushes

Toothpastes

Antimicrobial rinses/flossing/oral irrigators

Topical application of gel

Systemic antibiotics

Probiotic *Lactobacillus reuteri*–containing tablets

Professional Nonsurgical

Mechanical plaque control

- Hand instruments

- Powered instruments

Chemical plaque control

- Local delivery of antibiotics
- Chlorhexidine
- Phosphoric acid
- Ozone, oxygen, and saline solution

Mucogingival

Prostheses

Peri-Implantitis

Nonsurgical

Different mechanical instruments

- Nonmetal instruments
- Rubber cups
- Air abrasive
- Metal instruments
- Burs

Adjunctive treatments

- Microbiologic test
- Local antimicrobials
- Systemic antimicrobials

Disinfect titanium surfaces

- Antiseptics
- Air polishing
- Laser

Mucogingival

Prostheses

Peri-Implantitis

Surgical

- Animal studies
- Open flap debridement
- Surface decontamination
- Regenerative approach
- Biologics

- Guided tissue regeneration
- Guided bone regeneration

Human studies

- Systemic antibiotics
- Access surgery
- Resective surgery
- Regeneration surgery

Retrograde Peri-Implantitis

Maintenance and Prevention

Patient self-administered preventive regimens

Supportive periodontal therapy/maintenance (professionally)

- Mechanical nonsurgical therapy
- Mucogingival
- Prostheses

Nonsurgical Management of Peri-Implantitis

Whereas the nonsurgical treatment of peri-mucositis is often successful, the nonsurgical treatment for peri-implantitis has a questionable efficacy. This is most likely due to the inability to remove the bacterial biofilm from the exposed implant surface. Usually this is more significant when the implant

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design involves a rough surface.[140]

The nonsurgical treatment of peri-implantitis usually involves the debridement and detoxification of implant surfaces, similar to the treatment of peri-mucositis. However, the issue that arises is that these exposed surfaces usually have concurrent subgingival pockets.

Low-Abrasive Amino Acid Glycine Powder.

Low-abrasive amino acid glycine powder has been shown to be an effective treatment for removing biofilm without damaging the implant surface, hard, and soft tissues. This technique uses a special handpiece with a plastic tube nozzle with three orthogonally oriented holes. An air-powder mixture with reduced pressure is expelled through the nozzle, which prevents the formation of air emphysema complications. The nozzle is moved in a circumferential movement around the implant surface.[141]

Although more extensive studies need to be conducted as to technique efficacy, glycine powder can be incorporated into a treatment regimen. The clinician should be careful to use the powder only in areas where access is available and a posttreatment rinse can remove any residue. This modality is best utilized in cases with buccal dehiscence and or horizontal bone loss without crater or infrabony pocketing. Hu-Friedy/EMS produces a device that can be used to effectively dispense glycine air-powder mixtures (Fig. 18.35).

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FIG 18.35 Low-abrasive powder. Hu-Friedy glycine powder jet used to debride titanium implant surfaces.

Ultrasonic Devices.

When used for treatment of peri-implantitis, tip modifications (i.e., carbon fiber, silicone, or plastic) must be made. Care must be exercised to not use metal tips because they may alter the implant surface.

Ultrasonic devices should be used only when a plastic tip is available. Irrigation and meticulous cleaning is recommended in treatment for either open flap debridement or closed flap irrigation.

Laser.

The use of lasers is becoming a more recognized treatment for peri-implantitis. Although there are many varieties of different wavelength lasers and each serves different type of purposes, only Nd:YAG laser has been showing promise. The American Academy of Periodontology (AAP) has continued to express reservations on use of lasers in treatment of peri-implantitis disease. There is minimal evidence to support any lasers as the lone treatment modality, although the Er:YAG laser has been shown to be effective for root debridement by assisting calculus removal and reducing endotoxin.[142] It is important to note that the Er:Yag is a hard tissue laser and it is rather damaging when used on implant surfaces without careful monitoring. The damaging effect that accompanies the use of such lasers does not warrant recommendation.

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Invariably, more studies are starting to gravitate toward the regeneration capability of the Nd:YAG laser. Nicholson et al published very promising results of visible osseous regeneration around failing implants.[143] In 2016, the FDA awarded clearance for the Nd:YAG LANAP Protocol for periodontal regeneration (FDA Clearance 510 (k) 151763). The LANAP Protocol results in the "true regeneration of the attachment apparatus (new cementum, new periodontal ligament, and new alveolar bone)" on previously diseased root surfaces. A companion protocol, LAPIP, may be used to address mild to moderate peri-implantitis.[143a] (Fig. 18.36).

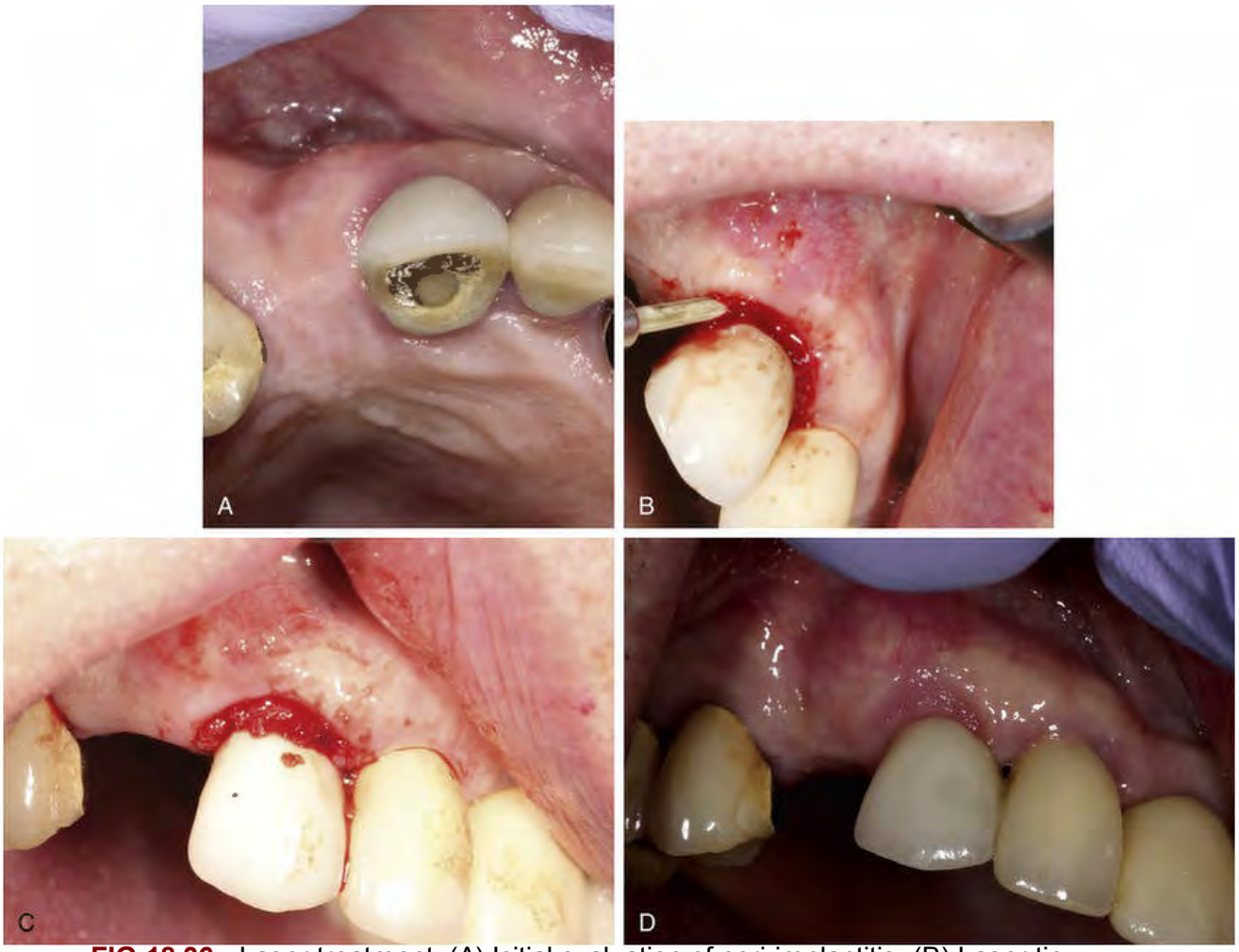

FIG 18.36 Laser treatment. (A) Initial evaluation of peri-implantitis. (B) Laser tip activated around sulcular margins of implant. (C) Immediate postsurgical appearance. (D) Two-week postoperative with granulation tissue reforming around implant collar.

Treatment procedure.

If the clinician desires to use lasers, the first step is to verify with manufacturer whether the specific brand of lasers under consideration is suitable for implant use or not (e.g., Er-YAG hard tissue lasers are contraindicated for dental implant use). Further, a detailed treatment sequence should be acquired from the manufacturer. Each laser has various settings, different heat dispersions, and other limitations.

In general, the goal of the use of a laser is to detoxify the implant surface, being careful to not produce heat that may damage the integration of the implant.

Mild peri-implantitis.

Without flap exposure, the laser may be used to perform a sulcular incision-like action around implant collar (i.e., neck). Specific soft tissue lasers are able to ablate diseased tissue around implants and create access for use with curettes.

Advanced peri-implantitis (crestal bone loss exceed 3 mm or requiring access).

A sulcular incision is made around the implant (one tooth mesial to one tooth distal). A full-thickness flap is reflected, exposing the implant surface. Debridement of the implant surface is performed initially with curettes or titanium brush. The surface is irrigated with 40% citric acid, 17% EDTA (ethyl-diamine tetra acetic acid), and/or choice of antimicrobial agent. Laser settings are specific to each individual laser according to manufacturer protocol. Care should be exercised to cover all exposed surfaces (i.e., each exposed thread) for the detoxification process. Use of regenerative material (allograft and extended resorbable membrane) is highly recommended. Tissues are modified and sutured to reapproximate tissue for tension-free primary closure. The Nd:YAG LANAP Protocol (discussed earlier) can also be used with advanced peri-implantitis. In addition, there are also rescue approaches which combine laser and surgical therapies.

Note: It is critical to limit time exposure of the implant surface with the laser application to avoid overheating or charring. This may increase implant morbidity and possibly lead to premature loss of the implant due to bone disintegration.

Surgical Management of Peri-Implantitis

Though nonsurgical treatment of peri-implantitis may be effective in some

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cases, the majority of cases require a more invasive approach to ensure an effective treatment outcome. There are various surgical techniques to treat peri-implantitis, depending on the final objective (Fig. 18.37)[144]:

- Access flap: for cleaning and decontamination of implants with pus, heavy bleeding, or with evidence of probing or craterlike radiographic bone loss.
- Regenerative procedures: provides access for cleaning, plus regeneration procedures for deep crater defects past the first thread of nonmobile implants.
- Apically positioned flap: provides access for cleaning and decontamination, and is used for implants showing generalized horizontal bone loss past first thread.

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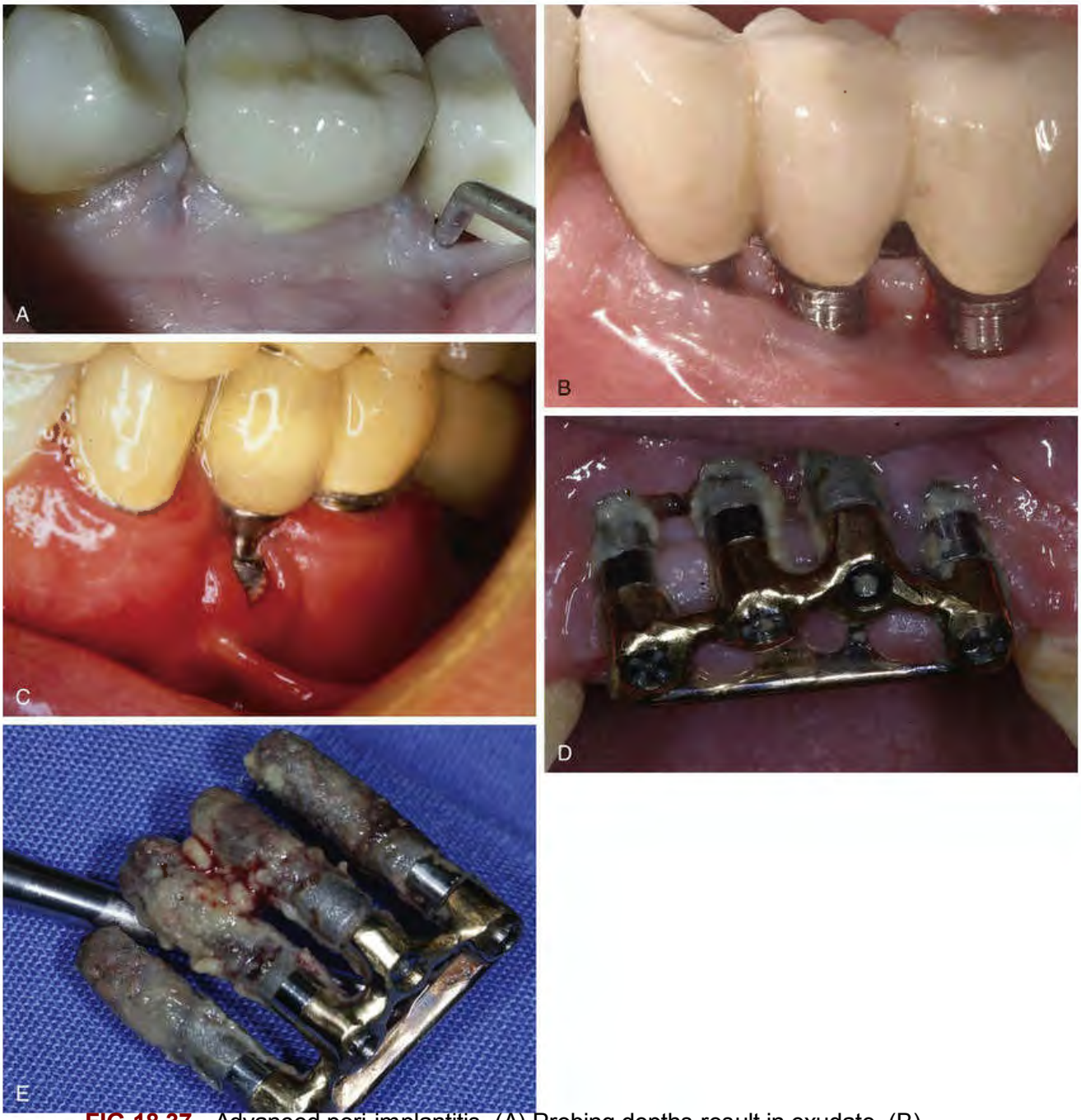

FIG 18.37 Advanced peri-implantitis. (A) Probing depths result in exudate. (B) Vertical bone loss. (C) Poor tissue health exhibiting inflammation and bleeding. (D) Extensive hard and soft tissue loss associated with poor hygiene. (E) Resulting in failure of the suprastructure and prosthesis.

Access Flap.

This surgical technique is used to maintain the soft tissues around the implant with the goal of decontamination (Fig. 18.38). A sulcular incision is made around the implant and extends at least one tooth mesial and one tooth distal on both the buccal and palatal/lingual side. This allows the

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clinician to have proper visualization and access for the next step. A full-thickness flap reflection is performed to gain access to the implant and bone surface. Although it is desirable to minimize the incision on healthy tissue, if access is inadequate, a vertical incision may be included to gain further access. Degranulation can be completed with curettes, specialized titanium brushes with an implant handpiece, and/or a glycine polishing handpiece. Along with mechanical decontamination, a chemical decontamination process should be followed, using compounds such as doxycycline or citric acid. The flaps are then reapproximated in their original position using a horizontal mattress suture, which helps adapt tissue around the implant while creating a ferrule effect. Interrupted sutures will also serve this purpose.

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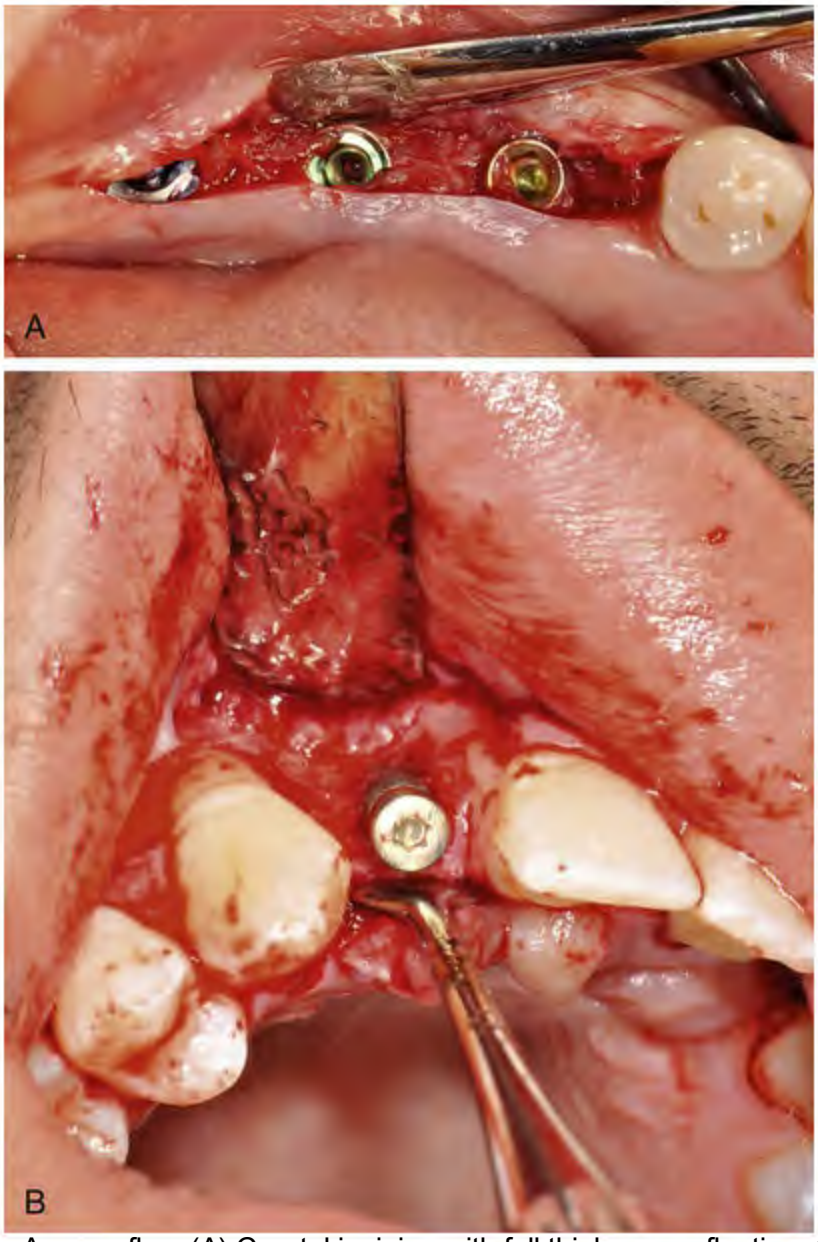

FIG 18.38 Access flap. (A) Crestal incision with full thickness reflection. (B) Buccal and lingual flap to obtain full exposure.

Heitz-Mayfield et al published a 12-month prospective study with antiinfective surgical therapy outcomes. Thirty-six patients with moderate to advanced peri-implantitis had access flap disinfection followed with a combination of systemic antibiotics (amoxicillin and metronidazole). They found at 1 year the patients were 92% with stable crestal bone height, and all had a marked reduction of probing depth; 47% had complete resolution of bleeding on probing.[145] It is possible to also complete a subepithelial tissue augmentation while performing the access flap debridement. Schwarz et al concluded that simultaneous tissue grafting with debridement had a significant reduction of bleeding on probing, pocket depth, and clinical

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attachment loss at a 6-month postoperative evaluation.[146]

1. Sulcular incision around desired dentition being careful to extend at least one tooth mesial and one tooth distal in anticipation to the area of treatment

2. Full thickness flap reflection is complete past the mucogingival junction on both buccal and palatal/lingual if necessary

3. Implants are detoxified with citric acid, cleaned with curettes and titanium brush if needed.

4. Flaps are readapted over osseous structure and should be in relatively similar position

5. Horizontal mattress sutures or interrupted sutures can be used being careful to not exert too much tension that causes bunching of tissues. Tissue does not have to be completely approximated; new tissue will form and granulate in the wound site.

Regenerative Procedures.

For peri-implantitis cases where a craterlike defect is present, regeneration is recommended (Fig. 18.39). Even though regeneration is an ideal treatment modality for all peri-implantitis cases, there are many criteria that must be fulfilled to allow successful treatment. In a similar principle to bone regeneration for natural teeth, the higher the number of osseous walls remaining in a defect, the better the anticipated result. Also, the prosthesis must be free from any premature contacts that may introduce excessive force to the implant interface. Ideally, especially in single-tooth implant cases, removal of the crown would be performed to ensure proper healing. A sulcular incision is performed from one tooth mesial to one tooth distal of the implant. A full-thickness flap is reflected to gain adequate access to defect. Thorough removal of granulation tissue is vital. Mechanical debridement is then begun, using the methods previously outlined in this chapter. A titanium brush with a small tip may be needed to access the implant surface if the osseous crater around the implant has very little access. After thorough mechanical debridement, freeze dried bone allograft (FDBA) allograft or bovine xenograft can be packed in with a resorbable membrane layered over. Soft tissue augmentation may also be included, which will enhance healing. Flap advancement may sometimes be needed to

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achieve soft tissue primary closure around implant. A longer-lasting suture is recommended to ensure the flap does not open prematurely.

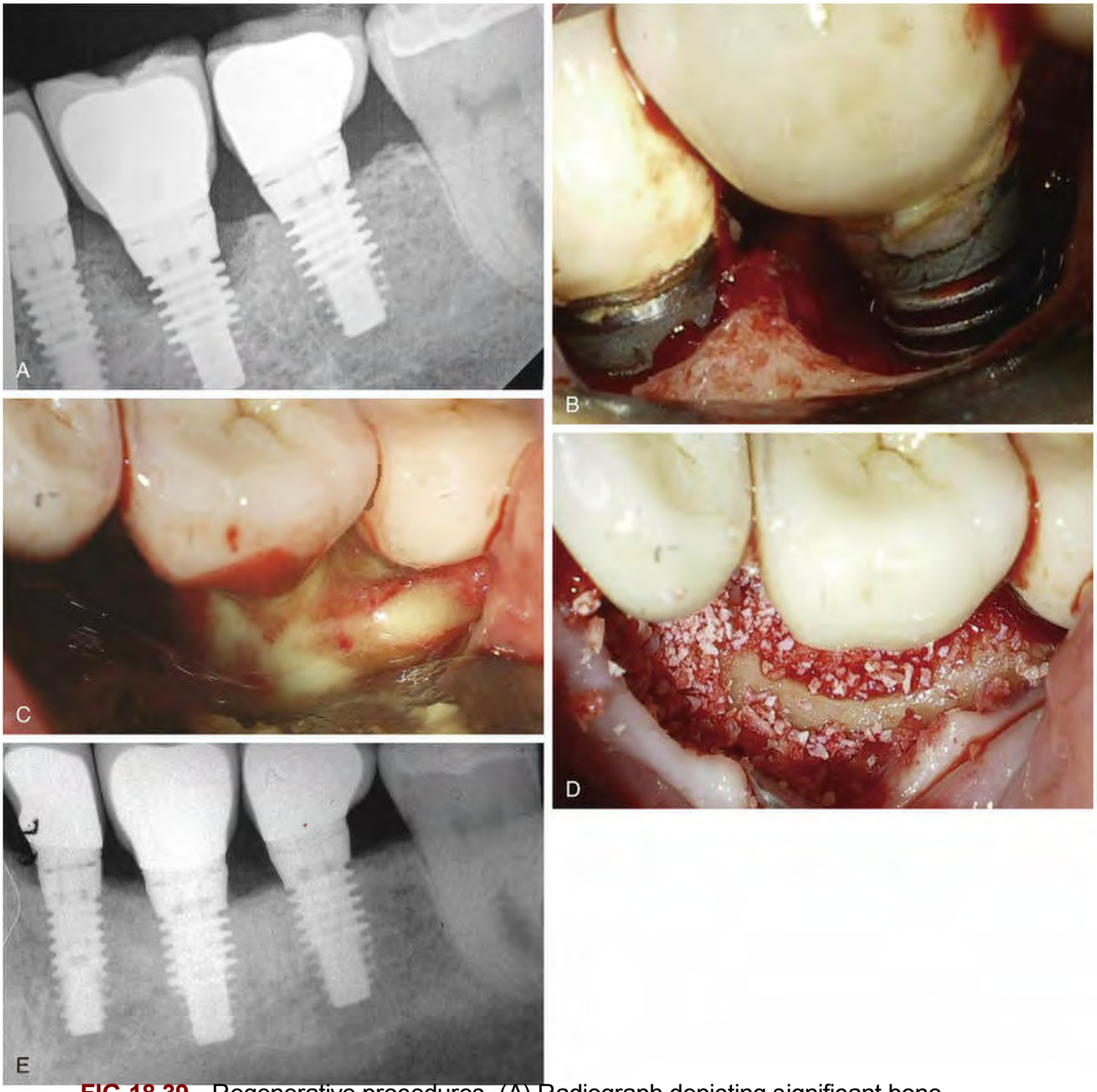

FIG 18.39 Regenerative procedures. (A) Radiograph depicting significant bone loss surrounding implant in the first molar position. (B) Full-thickness reflection showing extent of defect with retained cement. (C) Detoxification with tetracycline hydrochloride, after removal of cement. (D) Augmentation with allograft. (E) Postoperative radiograph two years postoperative. (Courtesy of Dr. Nolen Levine.)

In addition to the steps listed above, Froum and Rosen proposed the use of enamel matrix derivative, platelet-derived growth factor, and human allograft

or bovine xenograft in conjunction with a collagen membrane or subepithelial tissue graft. The study followed 51 consecutive patients treated with up to 7.5-year follow-up, and the result is encouraging.[147]

Regenerative technique:

1. Sulcular incision around area of interest with one tooth mesial and one tooth distal

2. Full-thickness flap is reflected past mucogingival junction being careful to ensure enough tension release from flap tissue. It is essential to produce adequate release so there is minimal tension when closing flap. Inadequate reflection will result in incision line opening, which will increase morbidity of the graft.

3. The bone surface is curetted to clean and remove all soft tissue remnants. Bone surface is curetted being careful to remove all remnants of soft tissue. Detoxification:

a. Citric acid is applied to exposed surface for 30 to 60 seconds.

b. Rinse with sterile saline for 30 seconds.

4. Bone graft of choice is placed on defect.

5. A resorbable membrane (extended resorbable collagen membrane: 4–6 months) is then draped over bone graft being careful to cover 3 mm past all edges of bone graft

6. Tissue tension is reduced via tissue-stretching techniques. Flap is resutured (i.e., high-tensile strength suture material: vicryl) being careful to provide tension-free closure to produce maximal contact between tissue edges (primary closure).

Apically Positioned Flap.

This surgical technique is used for implants that have generalized horizontal bone loss past the first thread when regeneration is not considered feasible

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(Fig. 18.40). An internal bevel incision or sulcular incision following the implant is made. Two vertical incisions are added on the mesial and distal of the implant creating a pyramidal flap. The clinician should be mindful of the blood supply of the flap, and a wide base is necessary to ensure the sulcular margin of the flap does not necrose. On the lingual/palatal a gingivectomy may be performed at the level of the anticipated final gingival height. Being mindful of the attached keratinized tissue, a submarginal incision may be performed in cases where ample amounts of keratinized tissue are present (e.g., palate). Ideally, a partial-thickness flap is recommended because it will help apical flap adaptation; however, a full-thickness flap elevation technique may be easier in tight-access areas.

FIG 18.40 Apical-positioned flap. (A) Apical repositioning of the tissue to decrease pocket depth. (B) Closure showing stabilized apically repositioned flap.

Once reflected, similar treatment as the access flap may be performed. Granulation tissue needs to be completely removed, followed by thorough cleaning of implant surfaces. A chemical detoxification can similarly be performed. A decision may be made to remove implant threads with a handpiece if significant loss of osseous support is present and regeneration is unlikely.[146] The final flap is sutured to the underlying periosteal tissue if a split-thickness flap was used. If a full-thickness flap was performed, it can be adapted apically via individual interrupted sutures. The goal is to readapt

tissue back onto remaining osseous support to minimize thickness of a soft tissue collar, thereby minimizing probing depth. Apically repositioned surgical technique:

1. Sulcular incision around desired dentition being careful to extend at least one tooth mesial and one tooth distal in anticipation to the area of treatment

2. Full-thickness flap reflection is complete past the mucogingival junction on both buccal and palatal/lingual if necessary.

3. Osseous recontouring is complete at this time to create a positive architecture.

4. Implants are detoxified with citric acid, cleaned with curettes and titanium brush if needed.

5. Flaps are readapted over remaining osseous structure and should be apical in comparison to original flap position.

6. Horizontal mattress sutures or interrupted sutures can be used being careful to not exert too much tension that causes bunching of tissues. Tissue does not have to be completely approximated; new tissue will form and granulate in the wound site.

Miscellaneous Soft Tissue Complications

Lack of Keratinized Tissue

The absence or presence of a zone of keratinized gingiva around teeth and oral implants remains a controversial issue. No direct evidence confirms or denies the need for nonmobile keratinized tissue next to natural teeth. The tooth with the least amount of keratinized tissue is often the mandibular first premolar.[3] Yet this tooth is rarely the first tooth lost from periodontal disease. If all other periodontal indices are normal, the amount or absence of keratinized gingiva has little to do with the expected longevity of the tooth. In longitudinal studies, Wennstrom et al demonstrated that the lack of adequate keratinized and attached tissue does not compromise the long-term health of soft and hard tissue as long as patients maintain good oral hygiene (Fig. 18.41).[148,149]

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FIG 18.41 Lack of keratinized tissue. (A) Postimplant placement showing deficient attached tissue. (B) Postprosthesis chronic pain and soreness from inadequate attached tissue.

On the other side of the issue, some authors consider keratinized attached gingiva important. Lang and Loe advocate a minimum of 2 mm of keratinized gingiva and 1 mm of attached gingiva to maintain gingival health.[150] Stetler and Bissada addressed mucogingival considerations in restorative dentistry in 1987.[151] They concluded that if subgingival restorations were to be placed in areas of minimally keratinized gingiva and less than optimal plaque control, augmentation to widen the zone of keratinized tissue may be warranted. However, they also noted that in unrestored teeth, the difference in the inflammatory status of sites with or without a wide zone of keratinized tissue was not significant.

Although keratinized tissue around a tooth may not be mandatory for long-term health, a number of benefits are present with keratinized mucosa. The color, contour, and texture of the soft tissue drape should be similar around implants and teeth when in the esthetic zone. The interdental

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papillae should ideally fill the interproximal spaces. A high smile line often exposes the free gingival margin and interdental papillae zones. The keratinized tissue is more resistant to abrasion. As a result, hygiene aids are more comfortable to use, and mastication is less likely to cause discomfort. The degree of gingival recession appears related to the absence of keratinized gingiva. Root sensitivity and esthetic concerns may be associated with gingival recession. From a restorative dental aspect, keratinized mucosa is more manageable during the retraction and impression-making process. Subgingival margin placement is improved, as is long-term stability in the presence of keratinized tissue. Many of these benefits directly apply to the soft tissue around an implant.

Natural teeth typically have two primary types of tissue: attached, keratinized gingiva and unattached, nonkeratinized mucosa. The type of tissue around a dental implant is more varied than natural teeth. After bone loss in the maxilla, excess tissue is often found, and the tissue is usually keratinized, unattached gingiva. An implant placed in the region may also have keratinized, unattached tissue. The tissues around the implant may also be similar to most natural teeth, surrounded by keratinized, attached gingiva (Fig. 18.42). The tissues may be nonkeratinized, unattached mucosa, more often in the mandible after bone height loss or after a bone graft and flap advancement to approximate the gingiva (Fig. 18.43). The nonkeratinized tissue may also be attached when acellular tissue (Alloderm [BioHorizons IPH, Inc.]) is positioned under the periosteum and bounds the overlying tissues to the bone.

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FIG 18.42 The soft tissues around these implants are keratinized, attached gingiva, similar to natural teeth. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

FIG 18.43 The soft tissue on the facial of the implant crown for the maxillary right central incisor is unkeratinized, unattached mucosa. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The need for keratinized tissue around dental implants seems more controversial than that around teeth. In theory, structural differences in implants compared with teeth make them more susceptible to the development of inflammation and bone loss when exposed to plaque accumulation or microbial invasion (e.g., less vascular supply, fewer fibroblasts, lack of connective tissue attachment to cementation).[26,152] Some

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reports indicate the lack of keratinized tissue may contribute to implant failure. Kirsch and Ackermann reported that the most important criterion for implant health in the posterior mandible was related to the absence or presence of keratinized gingiva.[153] In this report, mobile, nonkeratinized mucosa exhibited greater probing depths, which was histologically confirmed. A study by Warrer et al in monkeys found that an absence of keratinized mucosa increases the susceptibility of peri-implant regions to plaque-induced destruction.[154]

The presence of keratinized tissue next to an oral implant presents some unique benefits compared to natural teeth. Keratinized gingiva has more hemidesmosomes; the JEA zone may be of benefit when in keratinized tissue. Whereas the orientation of collagen fibers in the connective tissue zone of an implant may appear perpendicular to the implant surface, these fibers in mobile, nonkeratinized tissue run parallel to the surface of the implant. Schroeder et al, James et al, and Listgarten et al have suggested that mobile mucosa may disrupt the implant-epithelial attachment zone and contribute to an increased risk of inflammation from plaque (Fig. 18.44).[40,155] In addition to the general advantages of keratinized tissue stated for teeth, keratinized tissue around implants may also be beneficial in several other ways. In a two-stage protocol the implant is less likely to become exposed during the healing process. The formation of an interdental/implant papillae is completely unpredictable with mobile nonkeratinized tissues. When the nonkeratinized tissue is mobile, several reports state that this is unsatisfactory. Ono et al have proposed a classification of attached gingiva and surgical alternatives to improve soft tissue types in edentulous sites for implant placement.[156] Meffert et al recommend ideally adequate keratinized tissue before implant placement, especially in the posterior regions.[157]

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FIG 18.44 Mobile mucosa around a dental implant results in more complications than nonmobile tissues. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

Interestingly, the studies that have advocated the need for keratinized mucosa around dental implants have primarily investigated implants with rough surfaces. Failure of rough-surface implants (e.g., hydroxyapatite-coated and plasma-sprayed cylinder-shaped implants) have been related to a lack of keratinized mucosa.[158] On the other hand, the studies that have questioned the need of keratinized mucosa around dental implants have examined implants with smooth surfaces. A meta-analysis of the literature performed on the subject by Esposito et al reported 20% fewer instances of peri-implantitis in smooth-surface implants compared with rough-surface implants.[159]

Another benefit of keratinized tissue is the clinical ease of treatment to reduce pocket depths if crestal bone loss occurs. Probing depths 6 mm or more are more often associated with anaerobic bacteria. If the implant is out of the esthetic zone, a gingivectomy to reduce pocket depth is very predictable. An apically positioned flap with nonkeratinized mucosa is less predictable and is more difficult to perform.

However, it should be noted that several reports demonstrate the long-term implant survival in the absence of keratinized tissue. Although reports are more cautious with mobile mucosa next to an implant, nonmobile tissue rather than keratinized tissue appears to be the primary criterion relative to tissue type.

A study by Chung et al evaluated the significance of keratinized mucosa in the maintenance of dental implants with different surface conditions.[160] All 69 patients and 339 implants in the study had implant restorations for at

least 3 years and as long as 24 years with an average of 8.1 years. Bleeding index, modified plaque index, gingival index, probing depth, width of attached keratinized mucosa, and amount of attached mucosa were recorded. In addition, average annual bone loss was calculated using past and present radiographs. Gingival inflammation and plaque accumulation were significantly higher in patients with less than 2 mm of keratinized mucosa or 1 mm of attached mucosa. The surface condition of the implant was not statistically significant in this study, although the smooth implants with less than 2 mm of keratinized mucosa were less stable than other groups relative to the soft tissue profile.

This study also found the average annual bone loss was not influenced by the amount of keratinized or attached mucosa or the type of implant surface configuration (smooth vs. rough). The greatest amount of bone loss was observed with rough implants in keratinized mucosa of less than 1 mm, but the difference was not statically relevant. The presence of keratinized mucosa in this study was most significantly advantageous in the soft tissue health of posterior implants, as indicated by the gingival index. Posterior implants, even in the presence of keratinized tissue, had a 3.5-fold higher annual bone loss than anterior implants in this study (0.14 vs. 0.04 mm).[158] Implant location appears more important than the presence or absence of keratinized mucosa.

The question relative to the need for keratinized tissue around implants should be modified to, “Which would you prefer?” No one in the literature has stated that the nonkeratinized tissue is more preferable than keratinized tissue; the controversy is abated. Some authors prefer keratinized mucosa more intensely than others. If one side of the controversy demonstrates benefits while the other side states that keratinized tissue is not mandatory, both sides may be correct.

In specific clinical instances, attached, keratinized gingiva is more often desirable. For example, a fixed prosthesis (FP-1) in the esthetic zone requires keratinized mucosa to develop the soft tissue drape around the implant crowns. A second prime example is a mandibular overdenture, which benefits from a vestibule and zone of nonmobile tissue around the implant abutments.

Management of Lack of Keratinized Tissue

Tissue augmentation can be completed prior to surgery, concurrent with surgery, or post implant surgery. The most ideal time to graft is prior to

surgery; however, patients may not like to have additional surgeries. The treatment at all three timeframes is similar.

Use of Alloderm requires periods of familiarity with material. Prior experience with handling is recommended.

Presurgical Augmentations.

Presurgical augmentation steps are as follows:

1. A trapezoidal flap is reflected from the desired areas of grafting.

2. Although a split-thickness tissue flap is recommended, a full-thickness flap will invariably be effective as well.

3. Alloderm (soaked in saline for 20 minutes prior to use) is applied to area.

4. Chromic gut suture is used (5-0 recommended) to secure Alloderm to attached tissue.

5. Flap is modified to be tension free and pulled over to cover Alloderm and sutured with 4-0 or 5-0 non-resorbable suture.

Concurrent Augmentation.

Concurrent augmentation steps are as follows:

1. Full-thickness flap is reflected at site of desired implant position (one tooth mesial and one tooth distal).

2. After implant placement and or bone augmentation, Alloderm can be layered over desired location.

3. It is critical to have abundant tissue release to allow coverage of soft tissue over bone graft, and soft tissue. It may be the most difficult task of the entire procedure; it should be done only after one feels comfortable with tissue advancement procedures.

4. The flap is sutured with no tension and secured for primary intention healing.

Postimplant Tissue Augmentation.

After flap is allowed to heal post–implant surgery, ideally the soft tissue augmentation can be performed during the abutment change appointment or uncovery appointment (3 months healing). The steps are as follows:

1. A full-thickness flap is reflected being wide enough to cover size of Alloderm membrane.

2. Presoaked Alloderm is applied and sutured to neighboring attached tissue (chromic 5-0).

3. The flap is advanced over Alloderm being careful to cover entire Alloderm tissue (nonresorbable suture 4-0 or 5-0).

Note: exposed Alloderm tissue can produce a pungent, necrotic smell that makes the patient uncomfortable. It is important to notify patient that the normal transformation of Alloderm may have undesired side effects during the early stages of healing.

Peri-Implant Mucosal Hyperplasia

Gingival overgrowth (hyperplasia) around the peri-implant mucosa has been recognized as a significant clinical issue in implant dentistry today. The hyperplastic[161] tissue complication has been also termed in the literature as *implant gingival hyperplasia, mucosal proliferation, proliferative gingivitis,* and *implant-related tissue hyperplasia*.[162] The gingival overgrowth results in extreme difficulty for the patient to maintain adequate hygiene and the clinician in performing debridement. When gingival overgrowth is associated with radiographic bone loss, the resultant periodontal pockets are expressed as "true" periodontal pockets. If there is no associated bone loss, the pockets are termed *pseudopockets*. These hyperplasia-induced pockets may harbor pathogenic anaerobic bacteria. The plaque biofilm colonization and maturation in implant pockets initiates inflammation. The resultant hyperplastic tissue is most commonly composed of compact collagenous fibers, fibroblasts, and inflammatory cells.[163] This may result in osseous resorption and soft tissue destruction, which can lead to peri-implantitis.

Gingival hyperplasia may also result in an esthetic issue for the patient. This will require surgical intervention to reduce the tissue. Additionally, gingival hyperplasia may make it impossible for a prosthesis to be completely seated (i.e., bar overdenture) or give rise to chronic tissue

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soreness.

Etiology.

After clinical diagnosis of implant-related gingival overgrowth, potential etiologies must be identified such as hormonal, medication induced, allergy induced, and patient-related habits. Various hormonal factors (e.g., related to pregnancy or puberty) and medications have been associated with the gingival overgrowth. Medications such as phenytoin (i.e., Dilantin), immunosupressants (e.g., cyclosporine), calcium channel blockers, and amphetamines have been associated with gingival hyperplasia. Gingival overgrowth has also been associated with patient habits such as mouth breathing. Allergy-induced hyperplasia is also becoming more prevalent in implant dentistry. With the use of titanium alloys for the fabrication of the dental implants and abutments, exacerbated allergic reactions are becoming a more common problem. Nickel (Ni), combined with titanium or in the final prosthesis, may exacerbate and cause an acute allergic reaction. Aluminum (Al) and beryllium (Be) have been associated with eczema and soft tissue reactions that result in gingival overgrowth.[164]

Prevention.

If a patient is considered to be at high risk for implant-related gingival hyperplasia (e.g., because of medications), they should be instructed to maintain meticulous hygiene. Additionally, a more frequent recall protocol (3–4 times per year) should be implemented that includes debridement. The prosthesis should be evaluated and maintained with a minimum of 1 mm of space between the tissue and the prosthesis for ease of cleaning and prevention of prosthesis-induced irritation.

Management.

Management of peri-implant gingival overgrowth should include the determination of the etiology (e.g., medication or humoral). If the etiology is determined to be medication induced, consultation with the patient's physician is recommended for possible alternative treatment (Table 18.8).

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TABLE 18.8
Peri-Implant Hyperplasia Etiologic Factors

Causative Agent	Example
Anticonvulsants	Phenytoin Phenobarbital Lamotrigine Vigabatrin Ethosuximide Topiramate Primidone
Calcium Channel Blockers	Nifedipine Amlodipine Verapamil
Immunosuppressant Drugs	Cyclosporine
Systemic Factors	Pregnancy Puberty Vitamin C deficiency Leukemia Neoplasms (fibromas, papillomas, carcinomas)

The treatment of peri-implant hyperplasia should begin with conventional periodontal therapies to reduce plaque biofilm and inflammation. The surgical management of implant gingival overgrowth may require gingivectomy (if adequate keratinized gingiva is present) or apically positioned flaps (without adequate keratinized gingiva).

The use of 0.12% chlorhexidine daily has been shown to be successful in reducing tissue overgrowth and bacteria counts.[165] When gingival hyperplasia is present around implants associated with overdentures, care should be exercised to minimize further enlargement (Fig. 18.45). Commonly, practitioners will relieve the denture so the path of insertion does not cause irritation or mucosal injury. Ideally, the tissue enlargement should be reduced and the causative agent identified and treated accordingly. It is important to note that even with meticulous care and removal of etiology, gingival overgrowth may recur. Communication with the patient is key to avoid misunderstanding.

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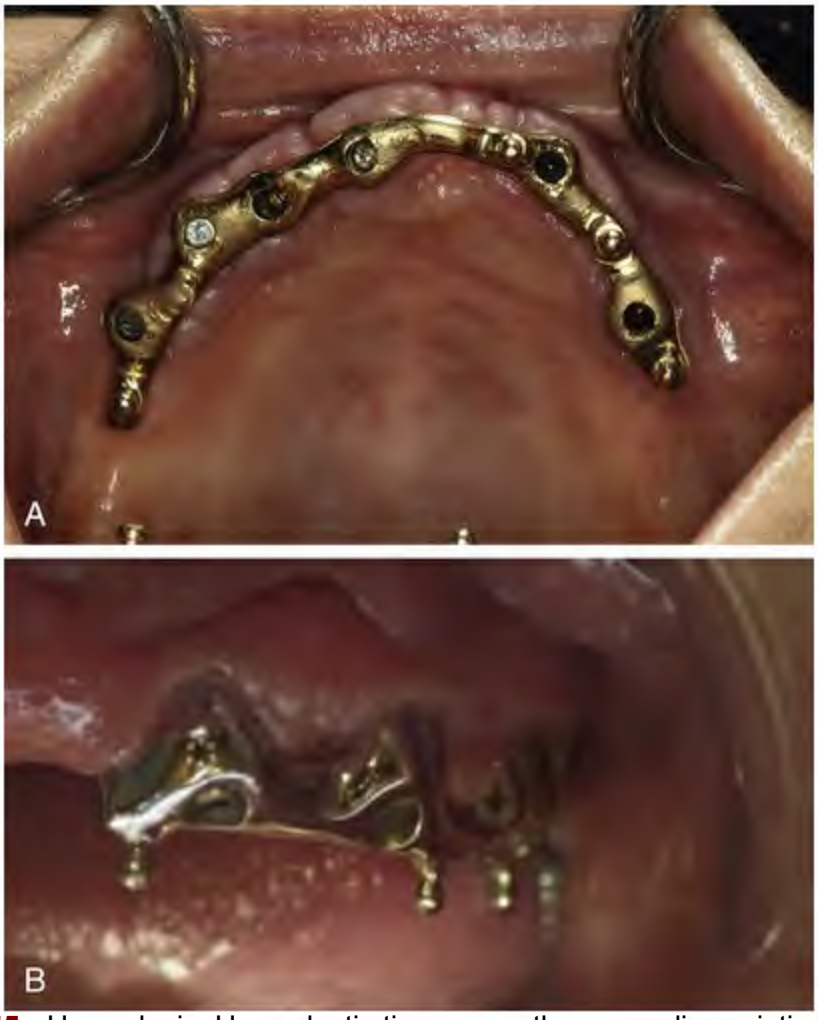

FIG 18.45 Hyperplasia. Hyperplastic tissue growth surrounding existing implant prosthesis resulting in home care difficulty.

Quality Scale

Implant Quality of Health Scale: A Clinical Assessment of the Health-Disease Continuum

The criteria for success in implant dentistry remain complex. The vast majority of clinical studies reporting success and failure do not qualify the type of success achieved. Instead, the term *success* primarily has been used interchangeably with survival of the implant. The term *failure* has been used to indicate the implant is no longer present in the mouth. Nearly all reports in the prosthetic literature also report survival as success.

What is success for a natural tooth? In the periodontal literature, a quality of health is presented, and well-established guidelines based on clinical criteria describe the ideal health of natural teeth. The general term *success* in

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implant dentistry should be replaced with the concept of quality of health, with a health-disease continuum describing the status of implants.

Success criteria for endosteal implants have been proposed previously by other authors, including Schnitman and Shulman,[166] Cranin et al,[167] McKinney et al,[168] Albrektsson et al,[169] and Albrektsson and Zarb.[170] An implant quality of health scale with five levels has been established by James and modified by Misch.[171] The James-Misch scale also proposes management modalities corresponding to these five levels. In 2007, a consensus conference in Pisa, Italy (sponsored by the International Congress of Oral Implantologists; www.icoi.org) modified the James-Misch scale to four conditions that describe success, survival, and failure (Table 18.9).

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TABLE 18.9

New Proposed Classification of Peri-Implant Diseases

Implant Quality Scales	Clinical Conditions	Management
Success (optimal health) Osseointegration/Stage 0 osseoseparation	No pain or tenderness upon function 0 mobility <2 mm radiographic bone loss from initial surgery PD <4 mm No suppuration No BOP	Normal maintenance
Survival (satisfactory health) Stage I osseoseparation Peri-mucositis	No pain 0 mobility <2 mm radiographic bone loss from initial surgery Peri-mucosal inflammation PD ± 4 mm (bleeding and/or suppuration on probing)	Frequent SPT Nonsurgical debridement (hand, machine, air powder, lasers, etc) Patient self-administered care Adjunct local and systemic antimicrobials Soft tissue and/or prosthetic corrections if required
Survival (potentially compromised) Stage II osseoseparation Early peri-implantitis	No pain 0 mobility 2–4 mm radiographic bone loss PD ± 4 mm (bleeding and/or suppuration on probing) Perimucosal inflammation Bone loss <25% of the implant length	
Survival (compromised health) Stage III osseoseparation Moderate peri-implantitis	Variable pain 0 mobility Peri-mucosal inflammation PD ≥6 mm (bleeding and/or suppuration on probing) Bone loss 25% to 50% of the implant length	Treatment as above plus surgical reentry and revision Laser Implant surface decontamination Regeneration
Failure (clinical failure) Stage IV osseoseparation Advanced peri-implantitis	Peri-mucosal inflammation Pain upon function PD >8 mm (bleeding and/or suppuration on probing) Bone loss >50% of the implant length Mobility Uncontrolled exudate Maybe no longer in mouth	Surgical reentry and revision Lasers Removal of implant
Others (such as retrograde peri-implantitis)	Variable perimucosal inflammation Radiographically: periapical lesion around implant Clinical: pain, tenderness, fistula formation or swelling	Surgical reentry and revision or removal of implant

BOP, bleeding on probing; *PD*, probing depth; *SPT*, supportive periodontal therapy.

(Data from Suzuki JB, Hsiao YJ, and Misch CE: Personal communication, 2017.)

Ideal clinical conditions for natural teeth include absence of pain, less than 0.1 mm of initial horizontal mobility under lateral forces of less than 100 g, less than 0.15 mm of secondary mobility with lateral forces of 500 g, absence of observed vertical mobility, periodontal probing depths of less than 2.5 mm, radiographic crestal bone height 1.5 to 2.0 mm below the cementoenamel junction, intact lamina dura, no bleeding on probing, no exudate, and absence of recession or furcation involvement on multirooted teeth (Box 18.5).[172]

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Box 18.5

The Role of the Dental Hygienist in Implant Maintenance

- Identify potential implant patients
- Education and motivation throughout treatment
- Development, continual assessment, and modification of patient-specific oral hygiene procedures
- Evaluation of prosthesis (components, attachments, mobility, and retention)
- Evaluation of peri-implant tissue
- Probing
- Exposing clinically acceptable radiographs
- Removal of biofilms, soft and hard accretions
- Recommendation of oral hygiene implements
- Determine a patient-specific recall interval
- Cotherapist to identify potential problems and complications
- Documentation of implant(s) status

From Misch CE: *Dental implant prosthetics*, ed 2, St Louis, 2015, Mosby.

The AAP and ADA defined five periodontal types for diagnosis and treatment of natural teeth: type I: gingivitis; type II: early periodontitis; type III: moderate periodontitis; type IV: advanced periodontitis; type V: refractory and juvenile periodontitis.[173] The categories of disease do not simply indicate success or failure but rather a range from health to disease. This classification allows a clinical approach to treatment in each category. A similar scale for implants has been established as an aid to diagnosis and

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treatment that also proposes management approaches according to the signs and symptoms.[174]

The James-Misch scale presented for implant quality of health based on clinical evaluation was supported by the International Congress of Oral Implantologists in 2007 (Table 18.10).[172] This quality of health scale allows the implant dentist to evaluate an implant using the listed criteria, place it in the appropriate category, and then treat the implant accordingly. The prognosis also is related to the quality scale.

TABLE 18.10
Human Studies on Peri-Implantitis Treatment

		Number of Patients and Implants and Time of Follow Up	Treatment	Outcome
Leonhardt et al 2003	Access surgery	9 patients 26 implants 60 months	Systemic antibiotics (according to microbiologic analysis) + access surgery + decontamination of the implant surface using 10% hydrogen peroxide 0.2% CHX 2× a day rinse	Healing: 58% of the implants 7 implants lost 4/19 ongoing bone loss 6/19 bone gain Mean gingival bleeding was reduced from 100% to 5% Disease progression at 2 other implants
Romeo et al 2007	Apically repositioned flap surgery + implant surface modification Resective surgery	19 patients 38 implants (11 hollow screw and 7 solid screw) 12–24–36 months	Systemic antibiotics (amoxicillin for 8 days) + full mouth disinfection 9 patients with resective surgery and 10 with resective surgery and modification of surface topography Implant surface decontamination with metronidazole gel, tetracycline hydrochloride, and saline	Radiographic assessment: Implantoplasty is an effective treatment procedure Significantly better results w/apical reposition flap surgery + implant surface modification
Behneke et al 1997a, b	Bone grafts and bone graft substitutes surgery • Nonsubmerged	10 patients 14 implants 6 months–2 years	Irrigation with iodine + systemic antibiotics (Ornidazole 500 mg × 2 for 7 days) Implant surface treated with air powder and irrigation with saline 7 implants with 2–3 wall defects got bone chips and 7 implants with 1 wall defect got bone blocks	Clinical: (6 months/14 implants) BI: 2.4–0.3 PD: 5.9–2.3 mm Clinical: (2 years/5 implants) BI: 2.4–0.4 PD: 5.9–2.5 mm Radiographic: (3–12 months/14 implants) Average bone fill: 3 mm
Behneke et al 2000	Bone grafts and bone graft substitutes surgery • Nonsubmerged	25 implants 6 months to 3 years	Irrigation with iodine for 1 month + debridement with mucoperiosteal flap surgery Implant surface decontamination with air abrasive instruments for 30 second + saline irrigation + 7 bone chips and 18 bone blocks (Metronidazole 400 × 2 for 7 days)	Clinical: (1 year/18 implants) PD: 5.3–2.2 mm Clinical: (3 year/10 implants) PD: 5.3–1.6 mm Radiographic: (1 year/18 implants) Mean bone fill: 3.9 mm Radiographic: (3 year/10 implants) Mean bone fill: 4.2 mm

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Aughtun et al 1992	Barrier membranes • Nonsubmerged	12 patients 15 implants 6–12 months	ePTFE membrane + systemic antibiotics (tetracycline 200 mg × 1 for 12 days) + implant detoxification (air powder) + irrigation with saline	Clinical: PI: 1.9–1.0 BI: 1.1–1.1 PD: 5.2–4.1 mm Radiographic Mean bone loss: 0.8 mm Minor improvements on soft tissue conditions Membrane exposure
Jovanovic et al 1992	Barrier membranes • Nonsubmerged	7 patients 10 implants 6 months to 3 years	ePTFE membrane + systemic antibiotics (Tetracycline 250 mg × 4 for 7 days) + implant detoxification (air-powder + chloramine T + saline irrigation)	Clinical: PI: 1.7–0.6 GI: 2.1–0.3 PD: 6.8–4.1 mm All clinical signs improved Radiographically: 7 defects showed bone fill 3 defects: no bone fill
Khoury and Buchmann 2001	Grafting materials + barrier membranes	25 patients 41 implants 36 months	Systemic antibiotics Group 1 (12 implants): detoxification with chlorhexidine irrigation + citric acid + hydrogen peroxide + saline + bone blocks and particulate bone Group 2 (20 implants): treatments as group 1 + ePTFE Group 3 (9 implants): treatments as group 1 + collagen membrane (submerged)	Clinical: 1: PD reductions: 5.1 mm 2. PD reductions: 5.4 mm 3. PD reductions: 2.61 mm Radiographic: 1. 2.4 mm bone fill 2. 2.8 mm bone fill 3. 1.9 mm bone fill 58.6% of the barrier treated implant sites were compromised by early post therapy complications The additional application of barriers does not improve the overall treatment outcomes 3 years following therapy
Mattout et al 1995	With and without grafting material	19 patients	23 defects: ePTFE alone 11 defects: ePTFE + DFDBA + hydrated tetracycline Postoperative: 0.1% CHX + amoxicillin 500 mg (2× for 8 days)	Mean success rate 68% for the membrane group and 90% for the membrane + bone allograft
Schwarz et al 2006	Grafting materials + barrier membranes • Nonsubmerged	22 patients 22 implants 6 months	Granulation tissue removed + implant surface debridement with plastic curettes + irrigation with saline Group 1: Nanocrystalline HA Group 2: Bovine xenograft + resorbable collagen membrane	Clinical: 1: PD: reductions: 2.1 mm 2. PD: reductions: 2.6 mm "In both groups, radiological observation revealed a decreased translucency within the intrabony component of the respective periimplant bone defect." Additionally, both treatments resulted in clinically reductions in PD and gains of CAL at 6 months after surgery
Schwarz et al 2008	Grafting materials + barrier membranes • Nonsubmerged	22 patients 2 years	Group 1: Access flap surgery + nanocrystalline hydroxyapatite Group 2: Access flap surgery + natural bone mineral + collagen membrane	2 patients in NHA: severe pus formation at 12 months Clinically: PD: Group 1: 1.5 ± 0.6 mm Group 2: 2.4 ± 0.8 mm CAL gains: Group 1: 1.0 ± 0.4 mm Group 2: 2.0 ± 0.8 mm Both treatment showed efficacy over 2 years. Natural bone mineral + collagen membrane showed better clinical improvements
Roos-Jansaker et	Grafting materials +	36 patients	Systemic antibiotic (amoxicillin 375 × 3 + metronidazole 400 mg × 2) for 10 days starting 1 day before surgery	Group 1: PD reduction: 2.9 mm

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al 2007a	barrier membranes • Nonsubmerged	65 implants 12 months	Debridement of the granulation tissue, implant surface decontamination with hydrogen peroxide and irrigated with saline Group I: Bone substitute + resorbable membrane Group 2: Bone substitute but no membrane	Mean bone fill: 1.5 mm Group 2: PD reduction: 3.4 mm Mean bone fill: 1.4 mm
Roos-Jansaker et al 2007b	Grafting materials + barrier membranes • Submerged	12 patients 16 implants 12 months	Systemic antibiotics (amoxicillin 375 × 3 + metronidazole 400 mg × 2) for 10 days starting 1 day before surgery Debridement of granulation tissue. Implant surface decontamination with hydrogen peroxide and irrigation with saline Bone substitute + resorbable membrane	Clinical and radiographic improvements were observed. PD reduction: 4.2 mm Mean bone fill: 2.3 mm
Haas et al 2000	Diode Laser treatment during surgery	17 patients 24 implants 3–9.5 months	Implant surface decontamination with curettage + laser + defect filled with autogenous bone + ePTFE membrane + systemic antibiotics for 5 days	Radiographically: 3 months from time of membrane removal: 21.8% 9.5 months: mean bone gain: 36.4%
Bach et al 2000	Diode Laser treatment during surgery	30 patients 5 years	Group 1: Scaling + 1.5% CHX + open flap debridement, apical repositioning the flap + osseous augmentation and/or mucogingival corrections Group 2: Treatments as group 1 + laser decontamination with diode laser (810 nm w/6 W)	Group 1: 18 months: no increased PD, BOP or sign of inflammatory process 2 years: 2 patients with increase PD, BOP and clinical sign of inflammation 4 years: 5 patients with increase PD, BOP and clinical sign of inflammation Between 3 and 5 years: 4 implants removed Group 2: 3 years: no relapse 5 years: 5 patients with increase PD and clinical signs of inflammation No implant removed Significant reduction of gram-negative, anaerobic bacteria in laser group than conventional group
Dortbudak et al 2001	Diode laser treatment during surgery	15 patients 15 implants	Implant surface: Curettage + rinsing with saline for 1 minute, then stained with toluidine Half of the implants further treated with diode laser for 1 minute	TBO alone results in a significant bacterial reduction of *P. intermedia* and AA on plasma flame-sprayed contaminated implant surfaces, while a combined treatment leads to a reduction to AA, *P. gingivalis*, and *P. intermedia*. Complete elimination of bacteria was not achieved
Romanos and Nentwig 2008	CO_2 laser + bone augmentation + membrane	15 patients 27.10 ± 17.83 months	Open flap debridement w/ titanium curettes + CO_2 laser (2.84 ± 0.83 watts) for 1 minute Bone augmentation (bovine or autogenous bone) and collagen membrane No systemic antibiotics	PI: Preoperative: 1.01 ± 1.37 Postoperative: 0.98 ± 1.20 BI: Preoperative: 2.76 ± 0.35 Postoperative: 1.03 ± 0.85 PD: Preoperative: 6.00 ± 2.03 mm Postoperative: 2.48 ± 0.63 mm Keratinized tissue BI: Preop: 2.30 ± 1.45 mm Postop: 2.41 ± 1.39 mm
Deppe et al 2007	CO_2 laser + bone augmentation	32 patients 73 implants 4 months and 5 years	Group 1 (19 implants): Soft tissue resection + conventional decontamination Group 2 (15 implants): Treatment as group 1 + βTCP + autogenous bone grafts Group 3 (22 implants): Soft tissue resection + CO_2 laser decontamination Group 4 (17 implants): Treatment as group 3 + βTCP + autogenous bone	3 implants lost in group 1 4 implants lost in group 2 2 implants lost in group 3 4 implants lost in group 4 Beginning of hygiene phase PI: Group 1: 1.8 ± 1.2 Group 2: 1.4 ± 1.2

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				Group 3: 1.4 ± 0.9 Group 4: 2.6 ± 0.5 BI: Group 1: 2.7 ± 0.9 Group 2: 2.3 ± 1.4 Group 3: 2.8 ± 1.2 Group 4: 3.3 ± 0.6 PD: Group 1: 6.2 ± 1.8 Group 2: 5.1 ± 1.7 Group 3: 5.7 ± 1.4 Group 4: 5.7 ± 1.4 Immediately prior to surgery PI: Group 1: 0.7 ± 0.8 Group 2: 0.9 ± 0.4 Group 3: 0.7 ± 0.8 Group 4: 0.5 ± 0.6 BI: Group 1: 0.7 ± 0.8 Group 2: 0.5 ± 0.8 Group 3: 0.6 ± 0.3 Group 4: 1.2 ± 0.6 PD: Group 1: 5.1 ± 1.3 Group 2: 4.8 ± 1.4 Group 3: 6.1 ± 1.6 Group 4: 5.0 ± 1.3 4 months PI: Group 1: 0.6 ± 0.7 Group 2: 0.6 ± 0.6 Group 3: 0.8 ± 0.6 Group 4: 0.5 ± 0.4 BI: Group 1: 0.9 ± 0.5 Group 2: 0.6 ± 0.6 Group 3: 0.7 ± 0.6 Group 4: 0.9 ± 0.8 PD: Group 1: 3.2 ± 0.9 Group 2: 2.4 ± 0.7 Group 3: 2.1 ± 1.3 Group 4: 1.0 ± 0.7 5 years PI: Group 1: 0.8 ± 0.8 Group 2: 1.1 ± 0.8 Group 3: 1.0 ± 1.3 Group 4: 1.2 ± 1.3 BI: Group 1: 1.1 ± 1.2 Group 2: 2.1 ± 1.4 Group 3: 1.8 ± 1.1 Group 4: 1.9 ± 1.0 PD: Group 1: 4.3 ± 1.2 Group 2: 2.5 ± 1.1 Group 3: 3.4 ± 1.5 Group 4: 2.5 ± 1.4 Treatment of peri-implantitis may be accelerated by using a CO_2 laser + soft tissue resection Long-term results in augmented defects, no difference between laser and conventional decontamination
Froum et al 2012	Regenerative approach	51 implants	Systemic antibiotics (2000 mg amoxicillin or 600 mg clindamycin) 1 hr prior to surgery and continue 500 mg	No implant lost PD reduction:

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	Biologics + bone + membrane	38 patients 3 to 7.5 years	amoxicillin tid or clindamycin 150 mg qid for additional 10 days Surface decontamination w/ bicarbonate powder for 60 seconds (air abrasive device), 60-second irrigation with sterile saline, tetracycline (50 mg/mL with cotton pellets or brush for 30 seconds, then second bicarbonate air abrasion 60 seconds, application of 0.12% CHX for 30 seconds, then 60 seconds reirrigation with sterile saline + enamel matrix derivatives + anorganic bovine bone soaked in platelet derived growth factor for at least 5 minutes or mineralized freeze-dried bone + collagen membrane or subepithelial CT graft at area (<2 mm KG) Group 1: Greatest defect depth radiographically Group 2: Greatest bone loss on the facial of implant	Group 1: 5.4 mm Group 2: 5.1 mm Bone level gain: Group 1: 3.75 mm Group 2: 3 mm

Group I: Optimum Health

Group I represents implant success with optimum health conditions.

No pain is observed with palpation, percussion, or function. No mobility is noted in any direction with loads less than 500 g of implant movement (IM). Less than 2.0 mm of crestal bone has been lost since the placement of the implant. This bone loss is typically a result of the implant biologic width below the abutment connection and surface of the implant. The implant has no history of exudate, and no radiolucency is present around the implant body (Fig. 18.46). The probing depth is equal to or less than 5 mm and is stable after the first year. Ideally, the bleeding index is 0 to 1. Group I implants follow a normal maintenance program every 6 months.

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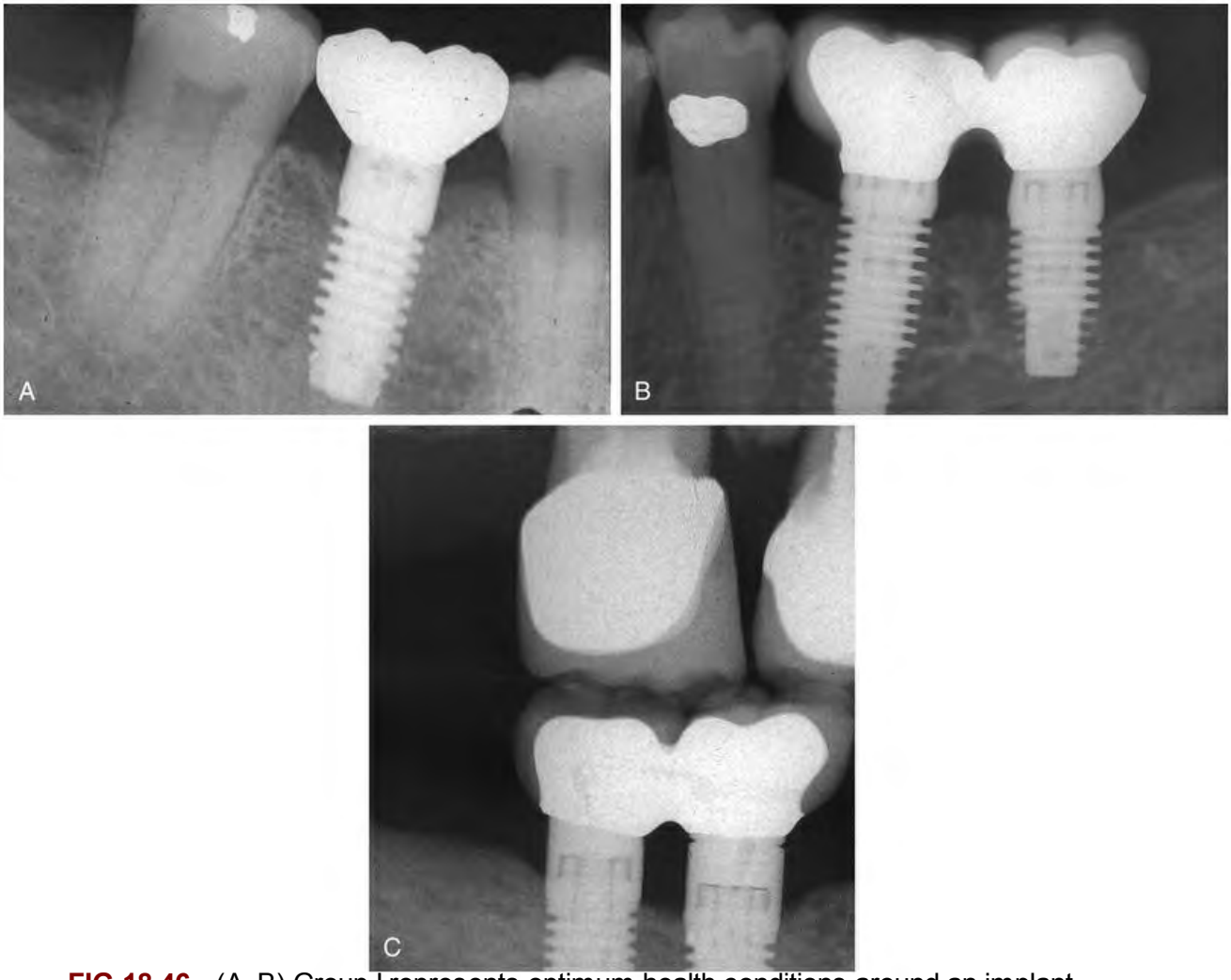

FIG 18.46 (A–B) Group I represents optimum health conditions around an implant. Less than 1.5 mm of crestal bone loss occurs during the first year of occlusal loading from the time of prosthesis delivery. (C) A vertical bitewing radiograph can be obtained to assess mesiodistal bone levels. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The prognosis is very good to excellent.

Group II: Satisfactory Health

Group II implants exhibit satisfactory health and are stable, but tenderness is observed on palpation, percussion, or function.

No observable mobility exists in the horizontal or vertical direction with loads less than 500 g. Crestal radiographic bone loss is between 2 and 4 mm from implant placement (Fig. 18.47). The most common cause is the early loading bone loss related to the amount of occlusal force and the density of the bone. No pain or bone. The probing depths may be as much as 5 to 6 mm because of the original tissue thickness and marginal bone loss but are stable. Bleeding upon probing index is often 1 or even 2. These implants may

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be considered to have peri-implant mucositis. The treatment indicated for group II implants consists of a stress reduction protocol for the implant system, shorter intervals between hygiene appointments (e.g., 9 months), reinforcement of oral hygiene instructions, annual radiographs until the crestal bone has stabilized, and gingivoplasty or sulcus reduction procedures where indicated. The prognosis is good to very good depending on the depth of the implant sulcus.

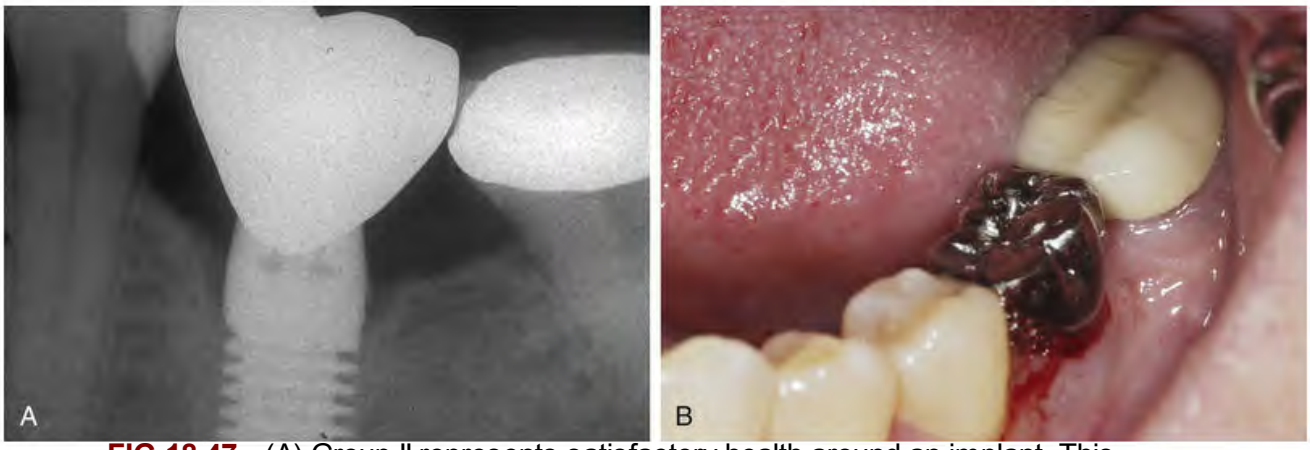

FIG 18.47 (A) Group II represents satisfactory health around an implant. This implant has lost 2 mm of crestal bone. (B) The implant crown has bleeding upon probing index of 2. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

For pockets less than 6 mm in depth, the following can be concluded[175]:

1. Mechanical therapy alone or combined with chlorhexidine results in the clinical resolution of periimplant mucositis lesions.

2. Histologically, both treatments result in minimal inflammation compatible with health.

3. The mechanical effect alone is sufficient to attain clinical and histologic resolution of mucositis lesions.

Group III: Compromised Survival

Group III implants are classified as compromised survival and exhibit a slight to moderate peri-implantitis and compromised health status. Peri-implantitis is defined as an inflammatory process affecting the tissue around an implant that results in loss of supporting bone.

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Group III implants are characterized by radiographically evident vertical bone loss, periimplant pocket, bleeding on probing (plus occasional suppuration), and mucosal swelling and redness but no pain upon function (Fig. 18.48).

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FIG 18.48 (A) Group III implants have a compromised health status and warrant a surgical procedure to decrease the risk of further deterioration. Probing on the facial of this implant indicates a 6-mm pocket, and exudate is present. (B) This implant required surgical reentry to decontaminate the surface of the implant and remove the noxious elements. A reduction of thread depth and a bone graft or apical-positioned flap was indicated. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

These implants warrant more aggressive clinical therapy. No pain is apparent in function, but tenderness may be slight on percussion or function. No vertical or initial horizontal mobility (IM-0) is evident. Greater than 4 mm of crestal bone loss has occurred since implant insertion but less

than half the length of the implant. Greater than 7 mm and increasing probing depths are also present, usually accompanied by bleeding when probing. Exudate episodes may have lasted more than 1 to 2 weeks and may be accompanied by a slight radiolucency evident around a crestal region of the implant.

Group III implants warrant aggressive surgical and prosthetic intervention. Stress factors are also addressed. The prosthesis may be removed in nonesthetic regions, or the bar may be removed under overdentures during the surgical therapy. Modification of the occlusal scheme and methods to decrease the forces in the afflicted regions after hard and soft tissue surgical treatment include decreasing cantilever length, occlusal adjustment, and occlusal splint therapy.

In cases of rapid bone changes, the prosthesis design may be modified completely from a fixed to a removable restoration to stress relief and soft tissue support. Additional implants to support the restoration may be indicated, especially if the patient is unwilling to wear a removable prosthesis.

Systemic and topical antibiotics and local chemical agents such as chlorhexidine are indicated in the presence of exudate.

However, this method is usually of short-term benefit if the causative agents of implant failure are not eliminated. Bacterial culture and sensitivity tests (Oral Microbiology Testing Service, Temple University, Philadelphia; www.temple.edu) may be indicated, especially if existing signs and symptoms do not subside within a few weeks. Surgical management most often consists of soft tissue removal or exposure of a portion of the implant. Bone grafts may be used along with these approaches around the implant. A three-step approach is implemented for this category in the following order: (1) antimicrobial therapy (local or systemic), (2) stress reduction, and (3) surgical intervention.

The prognosis is good to guarded, depending on the ability to reduce and control stress after the surgical corrections have improved the soft and hard tissue health.

Group IV: Clinical Failure

Group IV of implant health is clinical or absolute failure. The implant should be removed under any of these conditions: (1) pain on palpation, percussion, or function; (2) greater than 0.5 mm of horizontal mobility; (3) any vertical mobility; (4) uncontrolled progressive bone loss; (5) uncontrolled exudate; (6)

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more than 50% bone loss around the implant; (7) generalized radiolucency; or (8) implants surgically placed but unable to be restored (sleepers). Implants that are surgically removed or exfoliated are also in the category of failure.

This category also includes implants surgically removed or exfoliated and no longer in the mouth. The remaining edentulous area often is treated with autogenous or synthetic bone graft procedures, which are performed to replace the missing bone. After the favorable bony conditions are restored, implants may be inserted again with a good prognosis (Fig. 18.49).

FIG 18.49 (A) Implants in group IV represent clinical failure and implants no longer in the mouth. The center implant in this radiograph is an implant with more than 50% loss; it is category IV. (B) The implant should be removed when group IV exudates are present. (C) The implant is removed from the site. The implant now is converted to group V (absolute failure). (D) The prosthesis is modified to become a three-unit fixed partial denture. (From Misch CE: *Dental implant prosthetics,* ed 2, St Louis, 2015, Mosby.)

The terminology for implant failure often is confusing, with different terms describing similar situations. Terminology for implant failure using the time period of failure has been suggested as a primary criterion. Many

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implant failures are not described ideally by the time of the complication and are not addressed in this nomenclature.

Occasionally, the patient will not permit removal of the implant. Regardless of whether the patient returns for implant removal, the implant is recorded as a failure in all statistical data. The patient should be warned against the irreversible damage to the surrounding bone with implants retained in this condition. Consideration should be given to their removal because future treatment may be compromised.

Conclusion

Once the surgical and prosthetic phases of implant therapy have been completed, the work of the clinician is not over. Patients must be educated in regards to proper maintenance of their implant-supported restorations, and routine examinations should be performed to monitor overall health. Many differences exist in the biologies of natural teeth vs. implants as they pertain to periodontal status, and it is critically important that the implant dentist recognize these differences, properly diagnose disease states, and effectively manage issues should they arise. By understanding the etiologies of the various peri-implant disease states, a clinician can work with the patient to build an effective protocol of prevention.

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Medicolegal Aspects of Implant Dentistry

Randolph R. Resnik, Francis R. DeLuca

In dentistry today, dental practitioners are exposed to an array of possible legal liability claims. These claims may arise from the various components of civil, criminal, and administrative legal systems at either the state or federal level (Fig. 19.1). In the field of oral implantology an ever-increasing number of legal claims are occurring. For this reason, any discussion of implant dentistry complications must necessarily include a review of the legal risks and ramifications associated with this type of treatment. Practitioners engaged in oral implantology must practice effective risk management, or they may predispose themselves to the loss of time and money associated with unwanted litigation and administrative proceedings. Although the possibility of legal claims may be an accepted risk and complication of implant dentistry, it is largely an avoidable risk.

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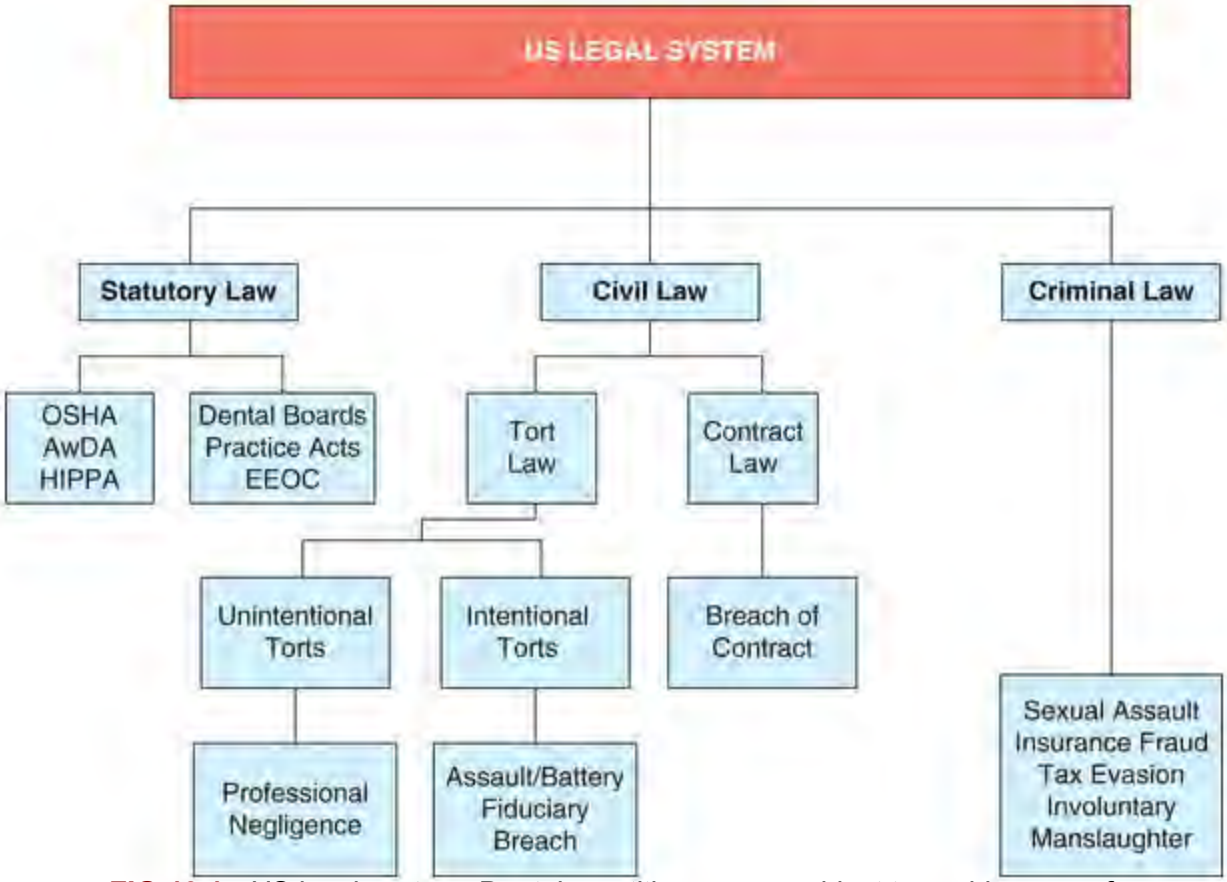

FIG 19.1 US legal system. Dental practitioners are subject to a wide array of potential legal issues within the statutory, civil, and criminal legal systems. The most common legal action to be brought against a dental practitioner is a civil tort law negligence claim.

As a dentist, the chances of being named in a medical negligence lawsuit are approximately 1 : 200 per year depending upon your jurisdiction, and to some extent, your specialty.[1] According to recent data from the National Practitioner Data Bank (NPDP), 11% of medical malpractice cases involved the practice of dentistry. NPDP studies show that approximately 8500 dentists in the United States are named as defendants each year in dental malpractice suits, with an average payout of approximately $68,000.[2] Over 97% of these payments are from out-of-court settlements prior to trial.[3] As the cost of modern dental care rises, it is likely these numbers will only grow because it becomes more economically worthwhile to pursue dental malpractice claims. On the other hand, risk is something that can and should be managed and avoided. However, in reality, even with the best planning and care, oral implantology complications may predispose the practitioner to legal action (Box 19.1).

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Box 19.1

Most Common Types of Malpractice in Dentistry

- Lack of informed consent
- Failure to refer to a specialist
- Failure to properly treat complications of care (e.g., infection, paresthesia)
- Failure to properly perform prosthodontic work, including crown and bridgework
- Failure to diagnose various conditions, including infection, periodontal disease, tumors, and cancer
- Failure to properly treat periodontal disease
- Failure to render appropriate endodontic care
- Failure to appropriately place, treat, or follow up with all types of implants
- Failure to appropriately extract teeth or improper extraction of teeth
- Failure to appropriately treat with orthodontics
- Failure to diagnose or treat TMJ dysfunction
- Failure to properly supervise or oversee actions of employees, actual agents, or apparent agents
- Slips, falls, burns, or cuts while in dental chair or office
- Anesthesia incidents

The prevalence and type of complications in implant dentistry are increasing and evolving over time. This is most likely due to three factors. First, there is an increase in the number of implants being placed every year. Secondly, more complex and difficult procedures with higher morbidity are

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being performed. And lastly, more dentists with limited training are providing implant treatment, including practitioners with a lack of experience and knowledge in the prevention and treatment of complications. The standard of care in oral implantology is not precise in part because there is an absence of a recognized specialty of oral implantology. Yet the standard of care in oral implantology is an ever-rising bar due to the increasing complexity of cases and the expertise demanded by patients.

Unfortunately, complications do occur in implant dentistry, and they are sometimes unavoidable. In the early days of oral implantology, complications were merely termed “risks” of the procedure. In today's litigious society, patients often equate complications with “malpractice” or a deviation from the standard of care by the practitioner. Many patients have invested substantial amounts of time, energy, and money in their appearance and dental care. When complications arise or expectations are not met, patients often demand answers and seek a legal course of action. Strategically and correctly managing complications is paramount in the prevention of medical negligence liability claims.

Implant dentistry is an acquired skill requiring extensive training, continuous practice, and refinement of skills and technique. Some dentists will take a 2-day weekend course sponsored by a dental implant manufacturer and assume they have the knowledge and skills necessary to treat even the most difficult cases and complications. However, they are mistaken, and this has been substantiated through various studies. Lambert et al, in a landmark study evaluating inexperienced surgeons (<50 implants placed), found that doctors early on their learning curve were twice as likely to have failed implants in comparison to experienced surgeons.[4]

The authors have noticed a trend in dental malpractice litigation termed the “500–4000 syndrome.” Dental implant litigation seems to spike in the first 500 implants placed by a dentist simply because dentists on the front end of the learning curve are more likely to experience complications. The good news is that, with additional experience, the number of litigation cases levels out in the range of 500–4000 implant placements. However, a second spike of litigation occurs after the placement of approximately 4000 implants. Clinicians often become complacent, and there is a greater chance to “take shortcuts” in the treatment of implant patients. They tend to be lax with their preoperative assessment (clinical and radiographic evaluation), do not keep current with the literature, and fail to attend appropriate continuing education programs while managing their busy practices.

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The malpractice litigation process is embarrassing, time consuming, and financially and psychologically draining on the practitioner. This long, drawn-out malpractice process has been shown to have an average time from injury to resolution of 5 years, with 33% of cases lasting over 6 years.[5] However, dental implant practitioners can take proactive steps to decrease their risk liability and to minimize their exposure. In this chapter we will examine the best ways to avoid lawsuits and also review the litigation process, including presuit, the discovery process, and malpractice trial (Fig. 19.2).

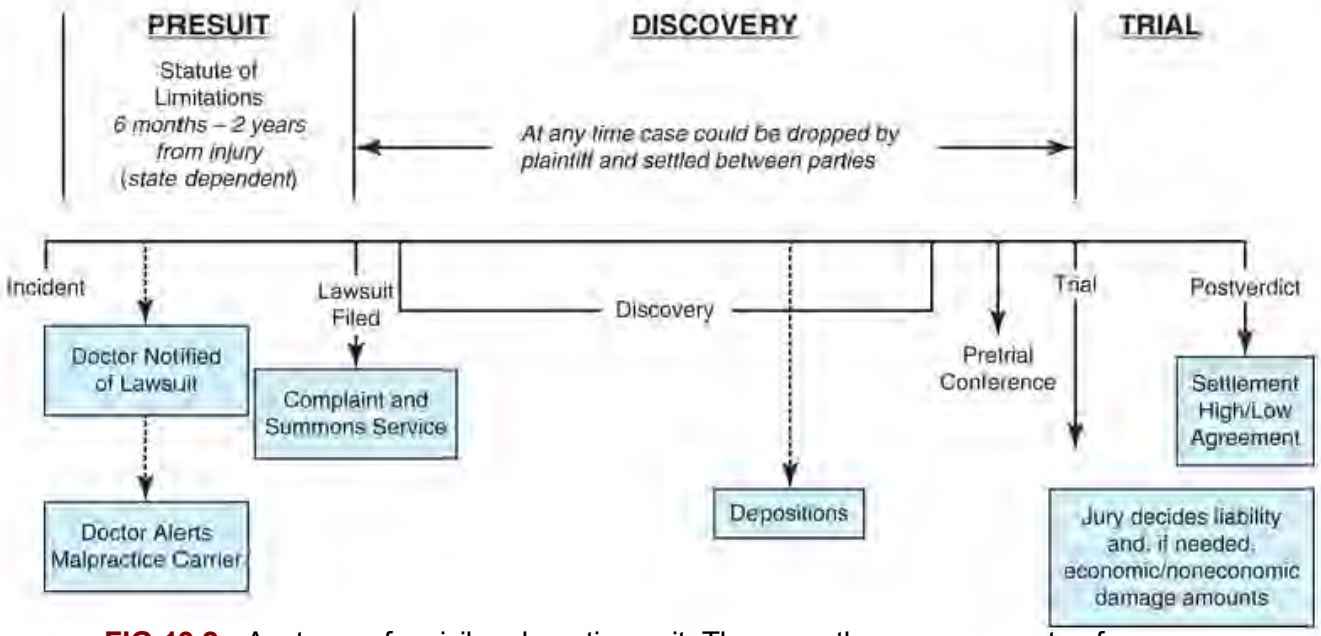

FIG 19.2 Anatomy of a civil malpractice suit. There are three components of a dental malpractice case: (1) the presuit period, (2) the discovery period, and (3) trial.

Litigation Process Part 1

Presuit

When a patient enters into a civil lawsuit, they will initiate a process termed *litigation*. Litigation is governed by various rules of civil procedure (i.e., the court's rules and standards during a lawsuit) in the state and federal courts. The first part of the litigation is called the “presuit period.” The presuit period is very important because the clinician will usually receive notice of commencement of a legal action, and they must react promptly. Most doctors are not taken by surprise when a patient initiates legal action against them because there are often subtle signs. These include the patient not returning for scheduled appointments, failure to return phone calls from the doctor or the office, or refusing to pay their bill. More significant indications that are consistent with a patient bringing a legal action include a formal notice or a request for their dental chart by the patient, another practitioner, or a patient's lawyer. Most often in such situations verbal communication between the dentist and patient has deteriorated or may have become nonexistent.

Notification

Records Request.

The initiation of a lawsuit usually starts with a request for records. When presented with a records request from a patient, it is imperative that the practitioner not ignore the request no matter how unfounded the potential claim may be. In most states, there is a statute (law) that governs the time period that the dental provider has to comply with the request. Refusing to fulfill a patient's request for a copy of their treatment record in a timely manner will only complicate and exacerbate the situation and may prejudice the dentist's position in future litigation. This will also cast the doctor in a negative light from the outset of the litigation in the eyes of the court and also with the state dental board. Although the doctor owns the actual dental record, the patient owns the diagnostic images, and they are entitled to a copy of both parts of their dental records. When a patient is denied access to their records by a dentist, their only recourse may be to file a complaint with the state board of dentistry. Under those circumstances, it is unlikely the state board will be sympathetic to the claims or concerns of the practitioner

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and may expose the dentist to discipline (Fig. 19.3).

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Patient Authorization for Release of Medical/Dental Records to External Parties

I authorize _____ to disclose information from the medical/dental records of _____
(patient)

Date of Birth: _____

The information is to be disclosed to:

Francis R. DeLuca, Esq.
Suite 208
3475 Sheridan St.
Hollywood, FL 33021
954-822-4954
Email: deluca1958@yahoo.com

I authorize this information to be disclosed in the following ways:
Written/Photocopy/Paper ☐ Verbal ☑ Fax ☐ Electronic Mail

Purpose of the disclosure: Legal investigation

3 **Specific reports/records to be disclosed:**

☑ Progress Notes	☐ Laboratory Reports	☐ Operative Reports
☐ Discharge Summary	☐ Radiology Reports	☐ Consultation Reports
☐ X-ray films or other images	☐ Photographs/Videotapes	☐ Records from other facilities

☐ Entire Health Records (including, but not limited to, information regarding medical/health treatment, insurance, demographics, referral documents, and records from other facilities).
☐ Other (Specify): _____

I give specific authorization to disclose the following information:

☐ HIV test results	☐ Documentation of AIDS diagnosis
☐ Drug and alcohol abuse treatment records	☐ Psychiatric/Mental Health treatment records

I understand that I may withdraw or revoke my permission at any time. If I withdraw my permission, my information may no longer be used or released for the reasons covered by this authorization. However, any disclosures already made with my permission are unable to be taken back.

My treatment will not be based on the completion of this authorization form. The information to be released by this authorization may be re-released by the person or organization that receives it and may no longer be protected by Federal or Florida privacy regulations.

Unless revoked earlier, this authorization expires in one year unless I specify another time: _____

I release the individual or organization named in this authorization from legal responsibility or liability for the disclosure of the records as authorized on this form. I understand that this authorization is voluntary and that I may refuse to sign it. I will be provided a copy of this signed authorization, if requested. A photocopy of this authorization is as valid as the original.

_____ _____
Signature of Patient (or Patient Representative) Date

_____ _____
Printed Name of Patient (or Patient Representative) Authority of Representative to Act for Patient (Relationship to Patient)

FIG 19.3 Records request form. To ensure compliance with HIPAA laws, the patient should always sign a patient request form prior to any documents being released.

Time to respond.

The time to respond to a request by a patient for their records is dictated specifically by individual state law, with the average deadline to provide records being approximately 30 days. Some states do not have associated time periods (e.g., Alaska) or use terminology such as “a reasonable time” (e.g., Alabama).[6] A records request does have to be accompanied by a HIPAA-compliant medical authorization form.

Documentation of records request.

As a matter of office policy, no records should be provided by a dental office or its personnel to a patient either “in person” or via written request without the treating doctor's prior approval. In doing so, the doctor will be able to ensure the patient is provided with the exact information requested. The patient chart should be documented accordingly, including notations documenting the exact records provided (i.e., make an additional copy), the date the records are delivered, and the manner in which the records were provided (e.g., US mail, fax, wire, or email). It is best to keep records establishing the exact date such materials were provided (example, “certified mail/return receipt requested”). Documenting the date the record request was made by the patient is especially important where the statute of limitations (i.e., maximum time after the alleged negligent event to initiate legal action to pursue a claim relating to it or otherwise it may be deemed “time barred” by law) may become an issue with respect to the filing of the lawsuit. The term *time-bar* refers to a legal claim that is barred by the passage of time under a statute of limitations.

Official Notice Letter.

The dentist may also receive a letter from the patient's attorney informing them of their intent to initiate a legal action on behalf of a patient and that the attorney is investigating the matter. Some states require that the patient provide a “Presuit Notice” prior to the formal filing of a lawsuit. This will initiate the presuit period, which allows the patient and doctor the ability to obtain records and provides both sides an opportunity to settle the matter prior to litigation. The form and method of the notice of commencing a presuit is usually dictated by state statute or rule. For example, the state of Florida requires that notice be provided by certified US mail or return receipt requested (Fig. 19.4).

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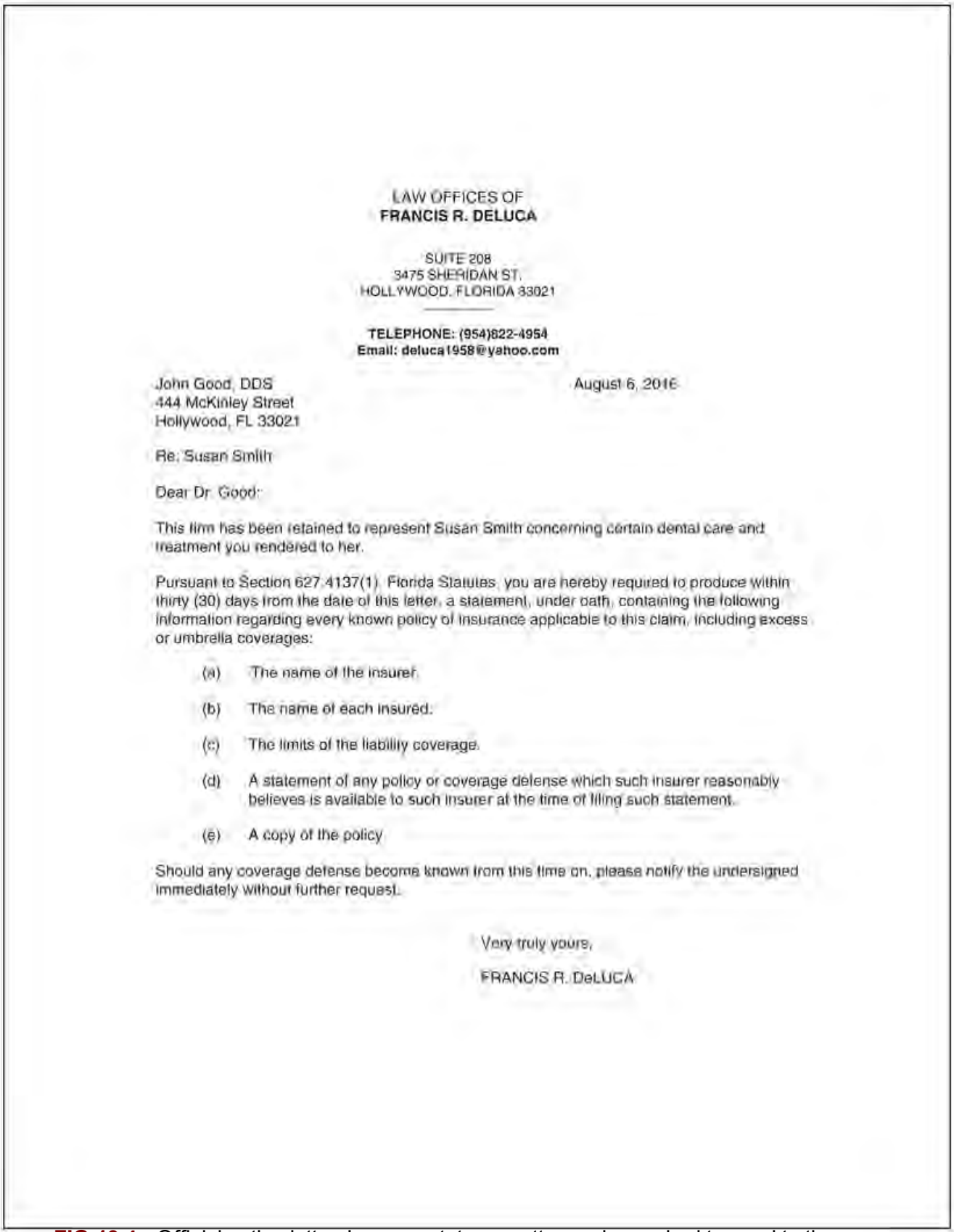

LAW OFFICES OF
FRANCIS R. DELUCA

SUITE 208
3475 SHERIDAN ST.
HOLLYWOOD, FLORIDA 33021

TELEPHONE: (954)822-4954
Email: deluca1958@yahoo.com

John Good, DDS
444 McKinley Street
Hollywood, FL 33021

August 6, 2016

Re: Susan Smith

Dear Dr. Good:

This firm has been retained to represent Susan Smith concerning certain dental care and treatment you rendered to her.

Pursuant to Section 627.4137(1), Florida Statutes, you are hereby required to produce within thirty (30) days from the date of this letter, a statement, under oath, containing the following information regarding every known policy of insurance applicable to this claim, including excess or umbrella coverages:

(a) The name of the insurer.

(b) The name of each insured.

(c) The limits of the liability coverage.

(d) A statement of any policy or coverage defense which such insurer reasonably believes is available to such insurer at the time of filing such statement.

(e) A copy of the policy.

Should any coverage defense become known from this time on, please notify the undersigned immediately without further request.

Very truly yours,

FRANCIS R. DeLUCA

FIG 19.4 Official notice letter. In some states an attorney is required to send to the doctor a letter informing them of an initiation of a legal action.

Requirements After Receiving Notice

The first step or action that an insured dentist should take after receiving notice is to inform their dental malpractice insurance carrier of the possibility of a malpractice suit. By placing the dental malpractice insurance carrier on notice, the dentist will have access to immediate guidance and legal advice from the carrier or an appointed attorney for all aspects of the ensuing process. In general, by informing the carrier, no adverse consequences will result, such as losing coverage or increased premiums.

Responsibility of the Insured Dentist

Proactive response.

If the doctor receives a request for dental records from the patient or their attorney, a proactive response to inform the insurance carrier is mandatory. To preserve malpractice coverage, most policies require the insured to inform the carrier with prompt notice of any potential claims. An insured dentist's failure to provide notice in a timely manner could potentially jeopardize the carrier's obligations both to defend and to indemnify (pay for the damage or loss allegedly suffered by the patient) in the potential lawsuit. The dental malpractice insurance carrier requires immediate notice to become involved as early possible in the matter of a dental malpractice claim.

Cooperation.

Most dental malpractice insurance policies contain a “cooperation clause,” which requires the insured (dentist) to cooperate in the defense of a legal claim. If the insured dentist fails to cooperate with the defense of the suit, the malpractice carrier may refuse to indemnify for a lawsuit. No matter how much of a nuisance or how frivolous a dentist may feel a lawsuit may be, it is important to take the time to cooperate in defending it.

Responsibility of Insurance Carrier

Defense and indemnity.

The insurance carrier has two main obligations to the insured with respect to malpractice policies. The “duty to defend” will require the insurance carrier to retain legal counsel for the insured in the defense against any legal claims brought against the dentist. There also exists the “duty to indemnify,” which requires the insurance carrier to pay for any settlement or judgment on

claims within the policy limits.

Assignment of counsel.

An insurance carrier has an obligation to retain legal counsel when a legal action is brought against a dentist. Typically, the insurance carrier will assign an attorney who has had past experience with the type of malpractice suit filed. All attorneys' fees will be paid by the carrier; however, a dental malpractice insurance carrier will not pay for personal counsel hired by a dentist. Most insurance carriers will take into consideration a dentist's recommendation for legal council, as long as the attorney has experience in dental litigation cases.

Consent to settle.

With most dental malpractice insurance policies, a “consent clause” is contained within the contract. This requires the insurance carrier to obtain the dentist's consent in order to settle a case. If the dentist does give the carrier consent, the dentist will surrender his or her right to the insurance company on the decision to settle the case. However, for the insurance carrier to protect their interests, they will include a “Hammer Clause” in the malpractice policy. This clause will stipulate that if the dentist refuses to consent to an out-of-court settlement recommended by the insurer, the insurer's liability for the claim will not exceed the amount for which the claim could have been settled. Therefore, the dentist may be responsible for any additional defense costs incurred and any excess amount above the recommended settlement amount.

Appointment of Legal Council

Defense Counsel Appointment.

The dentist should inquire relative to the assigned attorney's dental knowledge, how many dental implant malpractice cases the lawyer has settled or tried to a jury, and the results obtained in such proceedings. If the doctor is not comfortable with their appointed attorney, they may request new counsel from their insurance carrier. This request should be made early in the litigation process. In most cases, a dentist may request a particular defense attorney, if the attorney has the necessary qualifications or experience, and in some cases, if counsel is on the carrier's “approved” list, the dental malpractice insurance provider will most likely approve the

doctor's request.

The defense attorney will handle all matters with respect to the presuit period and subsequent litigation. Counsel will provide guidance concerning the discovery process. The defense attorney will be responsible for filing the appropriate responsive pleadings and ensuring the dentist's legal rights are protected. Presuit time periods and requirements are dictated by the applicable state law and vary greatly.

Personal Counsel.

Depending on the significance of the potential claim or issues relating to insurance coverage, the dentist should consider retaining independent personal counsel to assist and serve as the doctor's liaison with counsel hired by the dental malpractice insurance company. The hiring of personal counsel is particularly important if the claim exposes the doctor to a potential judgment in excess of their policy limits or if the insurance carrier has indicated it may not indemnify the doctor against the claims asserted by the patient. Personal counsel may be particularly helpful in cases where the doctor's insurance carrier has the right to settle a claim without the doctor's consent (i.e., no consent to settle clause). However, a personal council should have a background and experience with dental malpractice cases.

If the dentist's malpractice insurance policy does not contain a deductible, all legal fees and litigation expenses (except legal fees paid to personal counsel) will be paid for by the dental malpractice insurance carrier. Despite this fee arrangement, the defense attorney has a fiduciary duty to the dentist, not the dental malpractice insurance carrier. The attorney retained on behalf of the insured has an obligation to preserve the doctor's confidences and may not allow the dental malpractice insurance carrier to interfere with the attorney's professional judgment and recommendations (e.g., settlement of a case because it would be in the best interests of the insurance carrier).

Plaintiff's Requirements for the Filing of a Lawsuit

Prior to initiating a lawsuit against a doctor, the following four elements must be proven by the patient/plaintiff by a preponderance (greater than 50%) of the evidence.[7]

1. *Existence of Duty:* The patient must prove there exists a patient-doctor relationship, and the doctor had a duty to treat the patient. First, a professional relationship must be established, which usually involves the

doctor initiating treatment.

2. *Breach of Duty:* The patient must demonstrate the doctor breached or deviated from the standard of care (i.e., was negligent). This would include treatment that is outside the scope of what a prudent practitioner would do in a similar circumstance. Standard of care is typically determined by the individual experts retained by each side to give their opinions concerning the circumstances involving the case.

3. *Causation Directly Related to the Treatment:* There exists a connection between the treatment rendered, or failure to render treatment, that failed to meet the standard of care and as a result caused or contributed to cause injury.

4. *Occurrence of Related Damages:* The patient must demonstrate there are damages that have resulted from the doctor's deviation from the standard of care. Damages may include physical and/or mental claims.

Affidavit of Merit.

In many states a medical or dental malpractice suit may not be filed until an expert witness signs an affidavit of merit. To obtain an affidavit of merit, the plaintiff's council will need to send the pertinent records to a potential expert witness for evaluation of negligence and proximate cause issues. The expert witness does have to be familiar with the appropriate standard of care with regards to the case and be willing to sign an affidavit of merit, which is usually filed with the complaint. The affidavit of merit in simple terms must state that in the opinion of the expert witness, the dentist in question deviated from the standard of care. The reviewing expert does not necessarily have to agree to testify as an expert witness. This affidavit of merit is a relatively recent requirement intended to minimize the filing of frivolous malpractice actions clogging an otherwise overloaded court system (Fig. 19.5).

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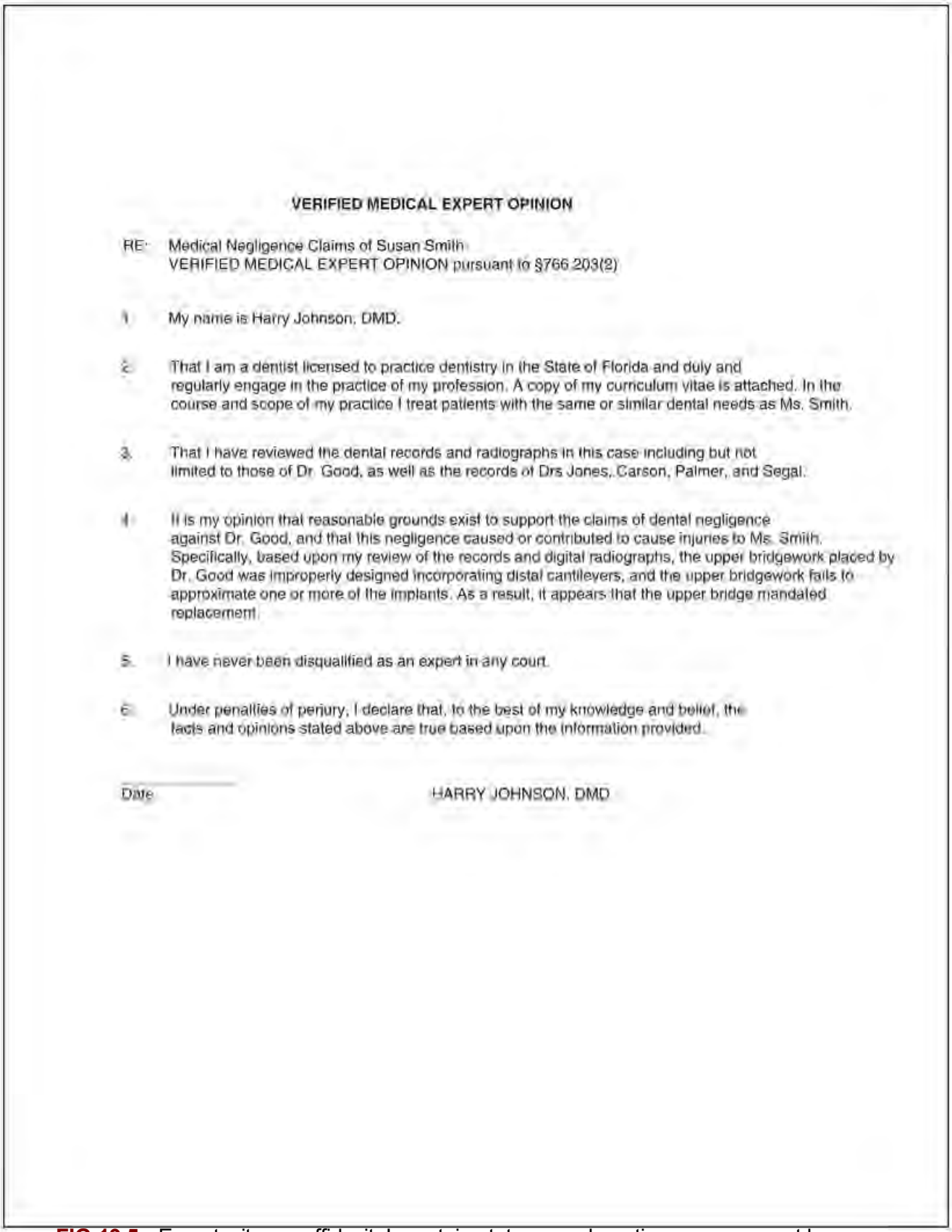

VERIFIED MEDICAL EXPERT OPINION

RE: Medical Negligence Claims of Susan Smith
VERIFIED MEDICAL EXPERT OPINION pursuant to §766.203(2)

1. My name is Harry Johnson, DMD.

2. That I am a dentist licensed to practice dentistry in the State of Florida and duly and regularly engage in the practice of my profession. A copy of my curriculum vitae is attached. In the course and scope of my practice I treat patients with the same or similar dental needs as Ms. Smith.

3. That I have reviewed the dental records and radiographs in this case including but not limited to those of Dr. Good, as well as the records of Drs Jones, Carson, Palmer, and Segal.

4. It is my opinion that reasonable grounds exist to support the claims of dental negligence against Dr. Good, and that this negligence caused or contributed to cause injuries to Ms. Smith. Specifically, based upon my review of the records and digital radiographs, the upper bridgework placed by Dr. Good was improperly designed incorporating distal cantilevers, and the upper bridgework fails to approximate one or more of the implants. As a result, it appears that the upper bridge mandated replacement.

5. I have never been disqualified as an expert in any court.

6. Under penalties of perjury, I declare that, to the best of my knowledge and belief, the facts and opinions stated above are true based upon the information provided.

_____
Date

HARRY JOHNSON, DMD

FIG 19.5 Expert witness affidavit. In certain states a malpractice case may not be filed until an expert signs an affidavit of merit stating there exists a deviation from the standard of care.

Statute of Limitations.

In most states a patient must bring a medical malpractice claim fairly quickly —often between 6 months and 2 years, depending on the state. Generally, this time period within which to file a lawsuit is termed the *statute of limitations*. A failure on the part of the patient to initiate a claim within the applicable statutory time limit will lead to the claim being "time-barred" or past the deadline to file a lawsuit (Table 19.1). However, in special circumstances, the statute of limitations may be extended by three possible situations:

1. *Failure to Discover the Basis of the Lawsuit:* When a patient has been unable to discover the "basis" (cause of injury) of the lawsuit, the patient may be allowed to file within a "reasonable time" after the discovery of the issue in question. This may result from "fraudulent concealment by the dentist." Most notably, this occurs when the dentist does not inform the patient of a complication (e.g., broken file or bur, retained cement). In such instances, the time for calculating the statute of limitations does not begin until the patient could have reasonably known they were the victim of negligence, and most often this is when a subsequent doctor is consulted who informs them of the circumstances.

2. *Notice Letter:* in most states, the sending of a notice letter will extend the statute of limitations (e.g., Texas will extend the statute of limitations by 75 days after filing notice). In Pennsylvania, it is the *Writ of Summons,* which is filed with the courts to toll the statute of limitations, and this informs the doctor they are about to be named in a lawsuit. Counsel for the doctor may then file a *Rule to File Complaint,* which gives the patient or their lawyer 2 weeks, within which a suit must be filed.

3. *Minor Plaintiff:* The statute of limitations does not begin to run until the minor plaintiff is 18 years old. In certain states, this will allow for the delay of the filing of the lawsuit to the age of 20 (i.e., 18 years of age + 2 years) for a minor patient and guardian to initiate a legal action.

TABLE 19.1
Statute of Limitations by State

State	Statute of Limitation
Alabama*	2 or 4 years
Alaska	2 years
Arizona	2 years
Arkansas	3 years
California*	1 or 3 years
Colorado	2 years
Connecticut*	2 or 3 years
D.C.	3 years
Delaware	2 years
Florida*	2 or 4 years
Georgia	2 years
Hawaii*	2 or 6 years
Idaho	2 years
Illinois	2 years
Indiana	2 years
Iowa	2 years
Kansas	2 years
Kentucky	1 year
Louisiana	1 year
Maine	3 years
Maryland*	3 or 5 years
Massachusetts	3 years
Michigan	2 years
Minnesota	4 years
Mississippi*	2 or 7 years
Missouri*	2 or 10 years
Montana	3 years
Nebraska	2 years
Nevada*	2 or 4 years
New Hampshire	3 years
New Jersey	2 years
New Mexico	3 years
New York	2 and a half years
North Carolina*	3 to 10 years
North Dakota	2 years
Ohio*	1 or 4 years
Oklahoma	2 years
Oregon	2 years
Pennsylvania	2 years
Rhode Island	3 years
South Carolina	3 years
South Dakota	2 years
Tennessee	1 year
Texas	2 years
Utah	2 years
Vermont	3 years
Virginia*	2 to 10 years
Washington	3 years
West Virginia	2 years
Wisconsin	3 years
Wyoming	2 years

*time varies according to type of injury or when injury was discovered.

Filing of the Lawsuit

A malpractice suit will formally begin with the filing of a petition with the court and service (i.e., delivery to the doctor/defendant or his/her authorized representative) of the initiating legal pleading.

Complaint.

Once the matter has proceeded through the presuit period, a formal legal complaint is filed. A "complaint" is a legal document that initiates a lawsuit and serves to inform the doctor, referred to as the "defendant," of the jurisdiction of the court and basis for the requested relief (i.e., negligence). The complaint includes a concise statement of the claim, the relief (compensation) and remedies (damages and restitution) requested by the patient (referred to as the "plaintiff"), and a demand for judgment. The complaint usually will contain allegations of facts, which, if proven, entitle the patient/plaintiff to the damages they are seeking. Often the allegations within the complaint are very brief and generalized and may omit important, pertinent information (Fig. 19.6).

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IN THE CIRCUIT COURT OF THE 17th JUDICIAL CIRCUIT
IN AND FOR BROWARD COUNTY, FLORIDA
CASE NO.: 5624492-9089

SUSAN JONES (Plaintiff)
v.
JOHN SMITH, DMD (Defendant)

COMPLAINT

COMES NOW, the Plaintiff, SUSAN JONES, and sues Defendant, JOHN SMITH, DMD, and alleges:

1. This is an action for damages in excess of $15,000.00.

2. At all times material to this action, Plaintiff, SUSAN JONES, was a resident of Broward County, Florida.

3. The Plaintiff has complied with the provisions of Florida Statutes, §766.106, and all conditions preceding to the filing of this action. Specifically, Plaintiff has provided a written Notice of Intent to Initiate Medical Negligence action to Defendant, JOHN SMITH, DMD, by Certified Mail, Return Receipt Requested on October 3, 2016, which was received by the Defendant on October 9, 2016.

4. At all times material to this action, the Defendant, JOHN SMITH, DMD was a dentist, licensed to practice, and practicing dentistry in Broward County, Florida.

COUNT I - NEGLIGENCE OF GOOD

Plaintiffs reaffirm and reallege Paragraph numbers 1–4 as if fully set forth herein.

5. Plaintiff, SUSAN JONES was a patient in the dental practice of Defendant JOHN SMITH, DMD beginning on July 14, 2014 and continuing through December of 2015.

6. Defendant JOHN SMITH, DMD performed extensive dental services on Plaintiff, SUSAN JONES, including but not limited to the placement of dental implants and dental crowns and bridges in Plaintiff's upper dental arch.

7. Defendant, JOHN SMITH, DMD owed a duty to the Plaintiff, SUSAN JONES to exercise reasonable care commensurate with his skill and training in the care and treatment of Plaintiff's dental needs.

8. Defendant, JOHN SMITH, DMD care and treatment of Plaintiff, SUSAN JONES, was negligent in that it fell below the prevailing standard of care and that he, among other things:

   (a) Failed to properly fabricate the implant supported dental restorations delivered to Plaintiff;

   (b) Failed to check the fit and form of the restorations prior to delivery;

   (c) Failed to establish a proper dental occlusion;

   (d) Delivering various dental restorations to Plaintiff when the Defendant knew or should have known that such restorations had deficiencies such that they should not have been delivered;

   (e) Failing to protect the Plaintiff from serious physical harm.

9. As a proximate result of the failure of Defendant, JOHN SMITH, DMD negligence, Plaintiff suffered bodily injury and resulting pain and suffering, disability, disfigurement, mental anguish, loss of capacity for the enjoyment of life, expense of medical and dental care and treatment, and aggravation of a previously existing condition. The losses are either permanent or continuing in nature, and Plaintiff, SUSAN JONES, will suffer the losses in the future.

FIG 19.6 Complaint. A complaint is a legal document that informs the doctor of the lawsuit and allegations and damages.

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Service of Process.

If a lawsuit is filed, the doctor/defendant should notify their counsel and request that their attorney contact the lawyer for the patient/plaintiff and arrange for acceptance of service of process (usually by receipt of a summons and complaint). Defense counsel should offer to accept service on behalf of doctor/defendant or offer to schedule a time for service. This alleviates the stress and embarrassment of a sheriff or process server appearing in the doctor's waiting room to serve papers in the presence of the doctor's patients. Most plaintiff attorney firms will comply with this request.

Summons.

The doctor/defendant, or in the alternative, their counsel, will be served with the complaint together with a legal document called a *summons*. The summons is the document that notifies the doctor/defendant a legal action has been filed. The summons will include the name of the case, location of the court, and the name and address of the attorney for the patient/plaintiff. It will also inform the doctor/defendant of the deadline for responding to the complaint.

It is imperative that upon receipt of the summons and complaint, the doctor/defendant immediately contact their defense attorney and provide their attorney with a copy of the summons and complaint, along with any attached exhibits. In the event the doctor/defendant has had no prior notice of the impending legal action or has not been appointed insurance defense counsel, they should immediately contact the professional liability carrier and provide the insurance carrier with copies of the documents provided. The fact that counsel has not been appointed by the insurance carrier does not change the time for responding to the complaint (Fig. 19.7).

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IN THE CIRCUIT COURT OF THE 17th JUDICIAL CIRCUIT
IN AND FOR BROWARD COUNTY, FLORIDA

CASE NO.:

SUSAN JONES (Plaintiff)
v.
JOHN SMITH, DMD (Defendant)
_____/

SUMMONS
PERSONAL SERVICE ON A NATURAL PERSON

THE STATE OF FLORIDA:

To All and Singular the Sheriffs of said State:

YOU ARE HEREBY COMMANDED to serve this Summons and a copy of the Complaint or Petition in this action on Defendant,

SERVE JOHN SMITH, DMD
100 South 1st Ave
Fort Lauderdale, FL 33301

Each Defendant is required to serve written defenses to the Complaint or Petition on Plaintiff's Attorney, whose address is 100 Southeast 6th Street, Fort Lauderdale, Florida 33301 (9-54) 555--1212, within twenty (20) days after service on that Defendant, exclusive of the day of service, and to file the original of the defenses with the Clerk of this Court either before service on Plaintiff's attorney or immediately thereafter. If a Defendant fails to do so, a Default will be entered against that Defendant for the relief demanded in the Complaint or Petition.

WITNESS my hand and the Seal of said Court _____.

HOWARD C. FORMER
As Clerk of said Court

By
As Deputy Clerk

IN ACCORDANCE WITH THE AMERICANS WITH DISABILITIES ACT OF 1990 (ADA), DISABLED PERSONS WHO, BECAUSE OF THEIR DISABILITIES, NEED SPECIAL ACCOMMODATION TO PARTICIPATE IN THIS PROCEEDING SHOULD CONTACT THE ADA COORDINATOR AT 201 SE 6TH STREET, ROOM 136, FORT LAUDERDALE, FL 33301, OR TELEPHONE VOICE/TDD (954) 357-6364 NOT LATER THAN FIVE BUSINESS DAYS PRIOR TO SUCH PROCEEDING.

FIG 19.7 Summons is a legal document that usually accompanies the complaint that informs the doctor a legal action has been filed with the court.

Response to the Complaint.

The doctor/defendant's counsel will need to file a response to the complaint. This response may take a number of forms depending on the legal sufficiency of the complaint. A typical response is in the form of a pleading (i.e., formal statement presenting legal documents or arguments) known as the *answer*. The answer filed on behalf of the doctor/defendant serves three functions:

1. It is a response to each of the individual allegations of the complaint. Each allegation will be either admitted or denied or will state that the doctor/defendant is without knowledge of the specific assertion.

2. It will contain any affirmative defenses that the doctor/defendant is interposing to any cause of action alleged in the complaint. An affirmative defense is a legal reason why doctor/defendant should not be held liable for the events alleged in the complaint. For example, a cause of action may be barred by the applicable statute of limitations. This affirmative defense claims that the lawsuit has not been filed within the time limit provided by state law.

3. The answer may seek relief against the patient/plaintiff by asserting what is referred to as a *counterclaim*. A counterclaim is a claim being redirected back against the patient/plaintiff. Typically, this occurs when the patient has failed to pay for their services and has in turn sued for malpractice.

The doctor/defendant should always be consulted by their attorney before filing of an answer. Any allegations admitted in the answer are established as a matter of law (i.e., the information may be used at trial). As a consequence, the doctor/defendant should specifically approve the proposed answer before it is served on the patient/plaintiff's attorney and carefully review any proposed admissions. In general, these admissions may not be withdrawn during the litigation process or trial and are binding on the doctor/defendant.

In the event that a response is not filed on behalf of the doctor/defendant in a timely fashion, a default may be entered by the plaintiff's counsel. The effect of a default is the doctor/defendant admits to the allegations in the complaint and agrees to the relief (financial claim) requested by the patient/plaintiff. Unless the default is set aside by the court (reversed), the only issue at trial will be to determine the amount of the patient/plaintiff's

damages.

Miscellaneous Presuit Recommendations

Discussing the Claim.

Upon receiving a notice letter, a doctor/defendant may attempt to discuss the situation with other colleagues to obtain their opinions. If a lawsuit is initiated, the doctor/defendant may be asked to recount the conversations, even if they are unfavorable to the defense of the case. It is highly recommended that the doctor/defendant have no discussion of the case with anyone other than their attorney or insurance carrier.

Do Not Attempt to Communicate With Patient/Plaintiff Lawyer.

Attempting to contact the patient/plaintiff or their attorney is not recommended. Often, the doctor/defendant may feel the need to plead their case and dissuade a disgruntled patient or attorney from continuing legal action. However, this is almost always futile and may have significant negative ramifications. Another common error made by the doctor/defendant is to offer the patient a refund in lieu of the filing of the lawsuit. Although generally inadmissible (i.e., cannot be used against the doctor/defendant in court) in any subsequent court proceeding, at the very least it creates the appearance that the doctor/defendant may be guilty of wrongdoing.

Calling Subsequent Providers.

Similarly, contacting subsequent treating doctors is not recommended. If a case is brought against a doctor, records of all subsequent treating providers will be easily obtained through the discovery process. Calling the subsequent treating provider may potentially result in an uncomfortable situation wherein the subsequent treating doctor may request that the implant clinician take financial responsibility for the patient's subsequent medical needs, no matter how open ended. In turn, the subsequent treating provider may promise to encourage the patient to drop any legal claims. However, the payment of remedial medical/dental expenses is rarely successful in persuading a patient to drop their legal claims.

Secure All Records.

The original chart, radiographs, study casts, surgical templates, laboratory prescriptions, pharmacy prescriptions, appointment logs, and any other documents or materials relating to the patient's care should be secured and copies placed in a safe location (e.g., doctor's home or safe deposit box). Although only a remote possibility, computer failures do occur (sometimes without effective backup), as well as fires, floods, or other catastrophes, resulting in the permanent loss the patient's records.

Uninsured Defendant.

In most states, medical practitioners are required to secure active malpractice insurance. The fact that a doctor does not have malpractice insurance to cover a specific claim does not mean that the doctor cannot be sued. If doctor/defendant is not insured, it is imperative they retain counsel to represent their interests. The old adage is “a person who acts as their own lawyer has a fool for a client” applies with equal force to health care professionals, including doctors. Having no, or inadequate, legal counsel may be devastating to the defense of an otherwise defensible lawsuit.

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Litigation Process Part 2

Discovery Phase

The second phase of the litigation process is known as the *discovery* phase. In this part of the case, each side is afforded the opportunity to acquire information about the other's case. The defendant/doctor, through the discovery process, is able to determine the exact nature of the claims of the patient, the damages allegedly suffered, the names of subsequent treating practitioners, and names of any supporting witnesses, including experts. The plaintiff/patient is likewise given the opportunity to obtain information concerning the case rendered, including access to the records, radiographs, study casts, photographs, and defenses asserted by the defendant/doctor.

Forms of Discovery

The methods, means, and timing of the various forms of discovery are governed by the *rules of civil procedure* (i.e., the body of law that sets the rules and standards the courts must follow in civil lawsuits) of the particular state.[8]

Interrogatories.

Interrogatories are written questions that are formally asked by one side to the other. Answers to interrogatories are usually drafted by the attorney in consultation with their client. Similar to admissions made in response to the complaint, interrogatory answers may not be withdrawn during the litigation process or trial and are binding (i.e., cannot be withdrawn) by the defendant/doctor.

Interrogatories are most effectively directed to the issue of damages, including any expenses (i.e., medical and dental bills) the plaintiff/patient contends were incurred as a result of the alleged negligence by the doctor/defendant (Fig. 19.8).

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IN THE CIRCUIT COURT OF THE 15TH JUDICIAL CIRCUIT,
IN AND FOR PALM BEACH COUNTY, FLORIDA

CASE NO.: 78783-89637

FREDRICK MASON (Plaintiff)
v.
JACKIE JOHNSON, DMD (Defendant)

INTERROGATORIES TO DEFENDANT

Pursuant to F.R.C.P. 1.280 and 1.340, the Plaintiff, FREDRICK MASON, propounds to the Defendant, JACKIE JOHNSON, DMD, the attached Interrogatories numbered 1 through 10 to be answered under oath and in writing within forty-five (45) days after receipt hereof.

I HEREBY CERTIFY that the original facesheet has been filed with the Clerk of the Court, an original and one copy of the Interrogatories has been served with the Summons and Complaint herein.

MEDICAL MALPRACTICE - INTERROGATORIES TO DEFENDANT

NOTE: When the word "Plaintiff" is mentioned, these interrogatories are directed to be answered regarding FREDRICK MASON.

1. What is the name and address of the person answering these interrogatories, and, if applicable, the person's official position or relationship with the party to whom the interrogatories are directed?

2. List all former names and when you were known by those names. State all addresses where you have lived for the past ten years, the dates you lived at each address, your social security number, and your date of birth.

3. Have you ever been convicted of a crime, other than any juvenile adjudication, which under the law under which you were convicted punishable was by death or imprisonment in excess of one year, or that involved dishonesty or a false statement regardless of the punishment? If so, state as to each conviction the specific crime, the date and the place of conviction.

4. Describe any and all policies of insurance which you contend cover or may cover you for the allegations set forth in Plaintiff's Complaint, detailing as to such policies: the name of the insurer, number of the policy, effective dates of the policy, the available limits of liability, and the name and address of the custodian of the policy.

5. Describe in detail how the incident described in the Complaint happened, including all actions taken by you to prevent the incident.

6. State the facts upon which you rely for each affirmative defense in your answer.

7. Do you contend any person or entity other than you is, or may be, liable in whole or part for the claims asserted against you in this lawsuit? If so, state the full name and address of each such person or entity, the legal basis for your contention, the facts or evidence upon which your contention is based, and whether or not you have notified each such person or entity of your contention. This is to include but is not limited to the manufacturer and/or distributor of the Frialit-2 implant system.

8. List the names and addresses of all persons who are believed or known by you, your agents or attorneys to have any knowledge concerning any of the issues in this lawsuit; and specify the subject matter about which the witness has knowledge.

FIG 19.8 Interrogatory. An interrogatory is a list of questions that one side sends to the other side during the discovery process. Each side is required to answer the questions under oath and within a specified time period.

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Requests for Disclosure.

Requests for disclosure are statutorily (i.e., governed by law) predetermined requests for information that must be produced without objection by either plaintiff or defendant. Disclosures cover basic information that is involved in a lawsuit, which includes witnesses, experts, contentions of the parties, damages incurred, and the identity of any health care providers that treated the plaintiff.

Production of Documents and Things.

This form of discovery allows either party the opportunity to obtain for evaluation and/or copying documents, records, bills and other materials. The production of these documents is not without limitation. The materials requested must be somehow relevant to the case or potentially applicable to the pending action (Fig. 19.9).

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IN THE CIRCUIT COURT OF THE 15TH JUDICIAL CIRCUIT,
IN AND FOR PALM BEACH COUNTY, FLORIDA

CASE NO.:

KATHLEEN SWAN (Plaintiff)

v.

RONALD ROBERTSON, DMD (Defendant)

REQUEST FOR PRODUCTION OF DOCUMENTS

Plaintiff, KATHLEEN SWAN by and through her undersigned attorney, herewith requests the Prospective Defendant, RONALD ROBERTSON, DMD, produce in the offices of Francis R. DeLuca, Esq., Suite 208, 3475 Sheridan St., Hollywood, Florida, for copying within the time specified in the applicable Florida Statutes, the following:

1. Any and all office records, including, but not limited to, notes, correspondence, memoranda, reports, records, x-rays, test results, etc., with regard to the instant claim. This request includes the folder, notebook, or other such binding devices in which these records are kept (if not already provided).

2. Any and all x-rays, radiographs, scans, CT scans, etc., taken by you or any other practitioner which are in your possession, with regard to the instant claim (if not already provided).

3. Any and all guides, manuals, procedure books, or similar documents which relate to or concern the implant system used on the Plaintiff.

4. Any and all still photographs, moving pictures, video tapes, slides, and/or audio tapes in the possession of Defendant herein, which are relevant to the incidents complained of.

5. Any and all dental models of the Plaintiff, KATHLEEN SWAN. This is to include any and all study models, models used in the fabrication of a surgical stent, or post surgical models taken of Plaintiff.

6. Any and all correspondence, phone message slips, notes, records, letters, memos or other such documentation concerning the Plaintiff.

7. All package inserts which accompanied the implants delivered to Plaintiff.

8. All surgical manuals for the implant system utilized on Plaintiff.

FIG 19.9 Production of documents and things are requests made by either side for the disclosure of documents or associated materials (e.g., study casts) dealing with the case.

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Request for Admissions.

In a request for admission, the party served is required to admit or deny or state that the party lacks sufficient information to respond, concerning certain facts and contentions of the case. If a responding party gives lack of information or knowledge as a reason for a failure to admit all or part of a request for admission, that party shall state in the answer that a reasonable inquiry concerning the matter in the particular request has been made and that the information known or readily obtainable is insufficient to enable that party to admit the matter. The purpose of requests for admissions is to eliminate unnecessary proof of undisputed facts at trial. Extreme care must be taken in responding to requests for admissions. A request that has been admitted may be presented (i.e., read) by the opposing attorney to the jury during trial and may establish the matter(s) admitted. These requests are usually time sensitive, and failure to respond in a timely manner will result in admissions being deemed against the party served (Fig. 19.10).

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**IN THE CIRCUIT COURT OF THE 15TH JUDICIAL CIRCUIT,
IN AND FOR PALM BEACH COUNTY, FLORIDA**

CASE NO.: 2016 CA 000000XXXXMB AG

FRED MARTIN (Plaintiff)
v.
JACK JOHNSON, D.D.S., (Defendant)

REQUEST FOR ADMISSIONS

COMES NOW the Plaintiff, FRED MARTIN, by and through undersigned counsel, and requests the Defendant, JOHNSON, pursuant to Florida Rules of Civil Procedure 1.370, to admit the following within thirty five (35) days from the service of this Request:

1. Defendant JOHNSON admits that the placement of antibiotics into the sites where Defendant removed the initial set of dental implants, deviated from acceptable standards of dental care.

2. Defendant JOHNSON admits that the preoperative radiographic studies were undiagnostic and as such deviated from acceptable standards of dental care.

3. Defendant JOHNSON admits that failure to take a CT scan of Plaintiff's mandible, prior to implant placement, deviated from acceptable standards of dental care.

4. Defendant JOHNSON admits that the failure to administer corticosteroids to Plaintiff after Defendant suspected Plaintiff had suffered a nerve injury, deviated from acceptable standards of dental care.

5. Defendant JOHNSON admits that his use of a "flappless" surgical technique on Plaintiff on August 25, 2016, deviated from acceptable standards of dental care.

6. Defendant JOHNSON admits that his failure to refer Plaintiff to a microsurgeon, neurosurgeon or other similar specialist capable of performing nerve repairs, after receipt of the MidTown Imaging report, deviated from acceptable standards of care.

7. Defendant JOHNSON admits that his immediate replacement of the dental implants into Plaintiff's mandible on September 9, 2016 deviated from acceptable standards of care.

8. Defendant JOHNSON admits the authenticity of the MidTown Imaging Report of September 1, 2016 and stipulates to its admissibility.

10. Defendant JOHNSON admits that his placement of anterior lower right dental implant on August 25, 2016 deviated from acceptable standards of dental care.

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11. Defendant JOHNSON admits that his placement of posterior lower right dental implant on August 25, 2011 deviated from acceptable standards of dental care.

12. As a proximate result of Defendant JOHNSON's deviation from acceptable standards of care, Plaintiff FRED MARTIN, suffered an injury to his right inferior alveolar nerve.

13. Defendant JOHNSON had a legal duty pursuant to Section 64B5-17.002 Florida Administrative Code to maintain dental records of all care and treatment rendered to Plaintiff.

14. Defendant JOHNSON has no dental record of his restoration of Plaintiff's lower anterior teeth.

15. Defendant JOHNSON admits that his failure to maintain dental records of his restoration of Plaintiff's lower anterior teeth is a violation of Section 64B5-17.002 Florida Administrative Code.

16. Defendant JOHNSON admits that the dental restorations placed in Plaintiff's lower anterior region deviated from acceptable standards.

17. Defendant JOHNSON admits that the dental restorations placed in Plaintiff's upper anterior region deviated from acceptable standards.

18. The reasonable cost to repair or otherwise replace the upper and lower dental crowns is $20,800.00.

I HEREBY CERTIFY that a true and correct copy of the foregoing was furnished by

U.S. Mail this__day of January, 2016 to: Counsel of record.

FRANCIS R. DeLUCA, ESQ.
Attorney for Plaintiff
100 SE Sixth Street
Fort Lauderdale, FL 33301
954/523-2700

BY:
FRANCIS R. DeLUCA
FLA. BAR #843636

FIG 19.10 Request for admissions requests to admit or deny any potential allegations during the discovery process.

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Expert Reports.

An expert report is a report written by either side's medical expert stating their facts and findings within the case. The use of expert reports varies greatly among states. In some states, either party may request the expert's opinion and the basis for their opinions. However, in some states, written expert reports are not required for the filing of a lawsuit (Fig. 19.11).

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After evaluating Ms. Smith clinically and reviewing the above records, it is my opinion with a reasonable degree of medical/dental certainty that Dr. Jones deviated from the standard of care by:

1. Preoperatively failing to take into consideration the significant bone loss in the mandibular arch (Division D). Because of the advanced bone loss, Dr. Jones should have provided Ms. Smith the option of soft and hard (bone) tissue grafting prior to implant placement.
2. Failing to diagnosis and understand the complexity of Ms. Smith's condition and failure to refer her to a specialist for evaluation and treatment of soft and hard tissue grafting.
3. Failing to utilize a radiopaque template during the cone beam computerized tomographic examination. A radiopaque template would have shown the exact location of the final prosthesis in reference to the anatomic contours of the mandibular bone and the intended implant sites.
4. During the surgical placement of the implants, failing to utilize a surgical template which would have allowed for the ideal and proper placement of the implants with respect to the bony anatomy. This would have allowed the implants to be placed in a more favorable position with respect to the available bone present (buccal-lingual orientation) and soft tissue present.
5. Not recognizing the lack or absence of attached tissue in the anterior mandible. Compounding this situation is the poor placement of the implants, which resulted in the implants being positioned in movable mucosa (nonattached tissue).
6. Because of the positioning of the five implants, corrective surgery including the removal of the implants will place Ms. Smith at great risk of further complications. Due to the lack of bone and the perforation of the lingual mandibular cortex, removal of the implants will most likely result in a mandibular fracture and loss of bone.
7. I am familiar with and perform the same procedures that were completed by Dr. Jones on Ms. Smith. I am familiar with the fees charged by similar practitioners for the services rendered by Dr. Jones. I have reviewed the annual Fee Survey for the specific procedures in this region of the country and Dr. Jones fees for these procedures were unreasonable and highly inappropriate.

In summary, as a direct and proximate result of the negligence and carelessness of Dr. Jones' treatment of Ms. Smith, the patient has suffered significant pain and suffering, embarrassment, undue stress, and significant medical expenses. Additionally, because of Dr. Jones' improper treatment, Ms. Smith is in a very unfortunate position as there exists no ideal remediation treatment to decrease the chronic pain and soreness from the poor implant placement and lack of attached tissue. Ms. Smith will most likely incur continuous dental appointments and related expenses indefinitely.

I believe the pretreatment, intraoperative procedures, and the postoperative care rendered by Dr. Jones for Ms. Smith falls well below the standard of care. All opinions rendered here and above are to a reasonable degree of professional certainty. If additional records become available, I reserve the right to add/amend with further finding of facts.

FIG 19.11 Plaintiff expert report example.

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Depositions.

The last and possibly the most important form of discovery is the deposition. A deposition is a formal question-and-answer session in which the attorney is given the opportunity to ask questions of the opposing party under oath. The deposition will also serve as a road map for the trial testimony. Once a question is answered in a deposition, it is difficult to contradict the testimony at a later date. A seasoned attorney will readily identify the contradiction and "impeach" (i.e., discredit the witness) the testimony. Therefore, whatever is stated in deposition cannot be easily amended or changed during trial. Preparation for a deposition should occur in the days or weeks prior to the date of the actual deposition.

Preparation for the Deposition

The doctor/defendant should meet with their counsel and discuss the case in its entirety prior to the deposition. They should be fully aware of the allegations of the claim, the alleged damages, specific dates, and the issues of potential liability.

At the predeposition conference, the doctor/defendant should be intimately familiar with their care and treatment of the patient, their justification for the treatment provided, as well all written dental charting, and the billing ledger. The doctor/defendant should ensure that the dental charting matches the billing ledger or be prepared to explain any discrepancies. The chart should be organized in such a fashion as to allow the doctor/defendant to easily find the various items contained therein.

The objective of the conference is to prepare the doctor/defendant to testify at deposition. The deposition is under oath, and the doctor will be expected to tell the truth. In some jurisdictions the deposition may be videotaped. Often it is not what is said but how it is said that matters most.

If the radiographs are digital, photographic quality prints should be made available to the attorney for use during the deposition, if necessary. Poor-quality or copied radiographs often result in possible incorrect testimony and will often be confusing to the jury (Box 19.2).

Box 19.2

Recommendations/Ground Rules for a Deposition

- The doctor should be well prepared and have a complete knowledge of the records.
- Answer only what is asked, do not volunteer information.
- If you do not understand the question, answer as such.
- Keep your answers short, responsive, and to the point.
- Answer the question only after the attorney is done asking it.
- Do not attempt to convince the attorney that you are right and that he or she and his or her client are wrong.
- If an objection is made by your attorney, do not answer unless instructed to do so by your counsel.
- Feel free to look at the chart/records and radiographs—it is not a memory test.
- If you are shown radiographs and need a light box to view them, advise that one is necessary.
- Do not comment on radiographs that are inadequate or poor copies.
- Do not guess or speculate on questions.
- If you don't know, answer as such.
- Do not discuss any conversations or emails you had with your counsel.
- Be careful not to state that an author, text, or an expert is authoritative. This places the practitioner at risk because if some component of the treatment rendered differs from what has been written, the practitioner may be impeached by anything the author or expert states.
- Always follow your attorney's recommendations or suggestion because they are required to represent your best interests.
- Do not become argumentative or adversarial with the opposing attorney.

The doctor/defendant should ask their attorney to provide them with a copy of any depositions taken by the patient's attorney. This is particularly important if the doctor has never been deposed before. Although it would be advantageous to have a transcript from a similar case, it is not imperative. The purpose of reviewing such a transcript is for the doctor/defendant to become familiar with the process and to obtain an idea of the attorney's general deposition procedure. Trial attorneys are generally creatures of habit, and the roadmap they follow in deposition is the same or similar from case to case. Additionally, this will give the doctor an idea of the dental acuity of their opponent. Many plaintiff attorneys have limited knowledge with respect to dental procedures and complications. Do not, however, sell your adversary short; most jurisdictions now have lawyers who are very seasoned in handling dental malpractice actions.

Doctor/Defendant Testimony at Deposition.

On the day of the deposition the defendant should dress professionally, arrive promptly, and be cooperative. Although the doctor may believe strongly in their position, arguing and fighting the process will accomplish nothing more that lengthening the duration of the deposition. In some cases the patient may appear in person to witness the doctor's testimony; however, there should be no communication with the patient. The patient may not ask questions and is not permitted to interfere with the doctor's testimony. The doctor/defendant cannot charge for their time at deposition, and expenses (e.g., court reporter, videographer) are usually covered by the patient/plaintiff's attorney.

Patient/Plaintiff Testimony at Deposition.

Just as the patient/plaintiff is entitled to take the doctor's deposition, the doctor/defendant counsel has the right to depose the patient. As with all depositions the doctor/defendant has the legal right to appear at the deposition. The doctor may provide questions to their counsel and may discuss the testimony but may not interfere with or disrupt the process. All expenses for the patient/plaintiff's deposition are covered by the doctor/defendant's malpractice carrier.

If the doctor/defendant elects to attend a treating doctor or expert's deposition, they should do the following:

1. Do not arrive before your attorney and attempt to engage the witness in

conversation, whether related to the case or not.

2. Be polite and introduce yourself to the plaintiff's attorney.

3. Do not interfere in any way with counsel's questioning. If you believe information needs to be addressed by your attorney, write the information on a notepad and wait till a break occurs to discuss.

Mediation

Prior to the 1990s, mediations were essentially nonexistent. Settlements typically occurred based on telephone conversations between opposing counsel, similar to the manner in which settlements occurred in routine personal injury claims. As liability insurance companies became more and more concerned about attorney fees associated with the defense of medical malpractice claims, mediation became more prevalent. In recent years, when settlements of medical malpractice claims occur, the majority of them do so at mediation conferences.

In most jurisdictions a mediation conference is required prior to trial. Mediation is a nonbinding alternative dispute resolution process. With time, it was found that cases often settled on the proverbial “courthouse steps.” In an effort to facilitate the settlement process and encourage discussion prior to the day of trial, the mediation process was developed.

Mediation involves a potential settlement process in which a third party (mediator) attempts to find points of agreement and to resolve conflicted issues. Usually the mediator (typically an attorney or retired judge) is agreed upon by both sides or appointed by the trial court. The mediator has been educated and trained in the art of opening dialogue and addressing contested issues with the goal of resolving the case and putting an end to the litigation process. The mediation conference is strictly confidential, and concessions or resolutions are inadmissible in a court hearing. In most cases the doctor/defendant will be required to attend. The doctor/defendant should be prepared to provide guidance to their attorney concerning claims and allegations that are made in the conference. The doctor may be asked either at the time of the conference or shortly before to consent to a potential settlement. In most instances the doctor/defendant must consent to an agreement in mediation.

A potential tactic that mediators use is to provide a “mediator number” at the conclusion of the mediation conference if the mediator believes the case

should be settled but the parties cannot reach an agreed-upon amount. The mediator provides a settlement figure on a piece of paper, providing each party with the opportunity to say “yes” or “no” to the suggested number. The mediator does so after conclusion of the mediation conference, providing a deadline for the parties to say “yes” or “no.” The parties are told to return the sheet of paper indicating their response within a certain timeframe. If the parties agree to the proposed settlement figure, the mediator notifies the parties of the settlement. After agreement, the mediation settlement is a binding agreement. When both parties sign the agreement, neither party can deviate from the mediation settlement agreement. The patient/plaintiff basically agrees to waive their right to sue the doctor/defendant in exchange for compensation.

Pretrial Modes of Disposition

If a lawsuit is resolved before trial, the resolution is accomplished by one of the following methods[8]:

Motion for Summary Judgment.

A summary judgment is a motion by either party that asserts that all factual issues in the case are settled, therefore there is no need for a trial. The motion is supported by affidavits, depositions under oath, and admissions of fact, as well as a legal argument. This motion has the following components:

Facts: the party initiating the motion will present its version of the facts.

Law: a memorandum discussing the statutes that govern the case.

Summary: the party will summarize and anticipate the opposing counsel's arguments and will explain why those arguments are not valid.

Opposing Party Response: the opposing counsel will respond to the information contained within the summary judgment.

Judge's Decision: the judge will review the motion and responses and will either grant (agree) the motion or deny the motion.

In a dental malpractice suit, this motion is usually filed by the defense to test the patient/plaintiff's ability to obtain an expert witness that can

establish negligence and proximate cause.

Motion to Dismiss.

Typically, a motion to dismiss is filed in lieu of an answer to test the legal sufficiency of the plaintiff's complaint. Matters typically raised in a motion to dismiss include adequacy of the facts alleged. For purposes of motion to dismiss, all well-pleaded allegations of the complaint are accepted as true. In such circumstances the plaintiff will generally be given the opportunity to correct the defect and proceed. A motion to dismiss may also be filed when the plaintiff cannot produce a qualified expert witness that can establish negligence and proximate cause. The time period is governed by statutes with each state. (e.g., Texas = 180 days). Most statutes will provide the plaintiff an extension to comply with the provision.

Voluntary Nonsuit.

In some situations the patient/plaintiff may elect to drop the lawsuit against the doctor/defendant. This is most commonly done to simplify and narrow the case when there are multiple doctor/defendants named in the lawsuit. However, the voluntarily dismissed claim may be resubmitted if the statute of limitations period has not expired.

Settlement.

When the plaintiff and defendant parties agree to settle the lawsuit prior to a trial, a settlement agreement will be filed. This agreement will usually contain language stating that the doctor/defendant does not admit negligence and the settlement agreement is agreed upon to avoid the time, cost, and harassment of defending a lawsuit. Both parties will then mutually execute an agreed motion for nonsuit to be filed in court, which will be granted by the judge.

Settling a Lawsuit

Ramification of Settling a Malpractice Case.

The doctor/defendant is often confronted with the difficult question of whether to settle the lawsuit or continue to litigate with the possibility of a trial. Studies show that over 70% of cases decided by judge or jury are resolved in favor of the defendant doctor.[9] Many doctors look at this statistic

and believe their chances are very good. However, this statistic is misleading because most of the strongest cases against doctor/defendants are settled out of court, prior to a trial.

Whether the doctor/defendant agrees to settlement or suffers an adverse verdict at trial, the doctor may be subject to a number of possible adverse consequences:

1. The trial may be personally humiliating to the doctor and their practice. In some cases the local newspaper or television station have covered the trial result and even have published the names involved.

2. The malpractice carrier is compelled by law to report the settlement to the National Practitioner Data Bank (NPDB) and the state dental board.

3. The state licensing division may open a disciplinary investigation against the dentist's license, and sanctions and fines may be implemented.

4. If the doctor has clinical privileges at a hospital or ambulatory surgical centers, the malpractice carrier is compelled to report such settlements, which may affect the doctor/defendant's privileges.

5. If the doctor participates with dental insurance plans, the doctor/defendant's contract may require them to report the settlement to these plans, which may affect the status of participation.

6. If the doctor/defendant is board certified in a dental specialty, the doctor/defendant may be required to report the action to the specialty board, which may affect the doctor's certification.

Consent to Settle Policy.

Most doctor/defendants do not know what their rights are when it comes to making a decision on a proposed settlement. Each malpractice policy has a “consent to settle” provision, which sets forth the rights, duties, and obligations of both the insurer and the insured with regard to settlement of a claim. Usually, a consent to settle clause will require the insurance company to obtain the doctor/defendant's approval before settling any claim. It is recommended that every doctor check this in their policy because some provisions will give authority regarding settlement back to the insurance company. Examples include[10]:

Hammer Clause: A hammer clause will entitle the insurance company to be only responsible for the amount of a claim that has been "settled," even though the doctor/defendant does not consent. For example, if the insurance company negotiates a settlement of $100,000 and the doctor does not give consent for settlement, the doctor would be responsible for any monies paid on a claim over $100,000, plus attorney fees.

Unreasonable Provision: This clause will override the doctor's consent authority if the insurance company determines the doctor is unreasonable in withholding consent. The insurance company may settle the case without the doctor's permission.

Board Approval Provision: With a board approval provision, the insurance company's review board has the ability to override the doctor/defendant's wishes if they agree that the doctor's actions deviated from the standard of care.

Binding Arbitration: In some insurance policies, if the insurance company disagrees with the doctor's refusal to consent to settlement, the case must be sent to binding arbitration. Binding arbitration is when the dispute is given to an unbiased third party to resolve and their decision is agreed upon by both parties as final or binding.

No Active Insurance: If the doctor no longer owns an active malpractice policy with the carrier, this provision causes the doctor/defendant to lose their ability to withhold consent to settlement.

License Revoked/Deceased: with these provisions, if the doctor has their license revoked or is deceased, the consent for settlement provision is deemed null and void.

Potential Nonsettlement Ramifications.

The doctor/defendant should be fully aware of the ramifications of a refusal to settle. The hammer clause, also known as the "nuclear option," will sometimes force a doctor/dependent to settle the lawsuit. If the doctor/defendant refuses to settle pursuant to the insurance policy, the insurer's liability for the claim will not be greater than the amount for which they could have settled the claim. Further, the defendant may be liable for the defense costs, including attorney's fees, following a refusal to settle.

While the defendant/doctor may feel strongly about their position, proceeding to trial is not without potential consequences. Confronted with this situation, it is highly recommended that the doctor/defendant seek personal council for advice.

Litigation Process Part 3

Malpractice Trial

When all attempts to resolve the dispute have been futile, the final option for resolution is a trial. Dental malpractice lawsuits rarely end in a trial. Statistics show that approximately 7% of malpractice suits are decided by a jury.[11] In the event that settlement negotiations fail and the doctor/defendant is unable to have the matter thrown out by the court on legal grounds, the matter will proceed to trial. A malpractice trial may be described as a "theater with rules."

The doctor/defendant should ensure they are fully prepared for trial. This should involve meeting with their attorney a minimum of 1 week before trial to discuss the process and to rehearse their testimony. The defendant/doctor should have a complete set of their dental records and be intimately familiar with the chart's contents. The defendant/doctor should be able to easily identify and acquire any document, radiograph, scan, or study cast being discussed. Being disorganized in front of a jury is troublesome because it gives the appearance of "sloppiness."

Malpractice trials are often a lengthy process. The doctor/defendant should be prepared to devote as much time as is necessary to defend the case. This usually involves at a minimum of 1 week with the possibility of, on rare occasions, multiple weeks of trial time. The trial duration is usually dependent on the complexity of the malpractice case. Although attendance of the doctor/defendant is not mandatory, absence is not recommended because it gives a negative connotation in the eyes of the jury.

Court Docket

The exact date and time a trial will commence is often not clearly defined. The court usually places the trial on a "docket," which is a range of time that the court may call for the start of the trial. This may happen with as little as 24-hours notice. The doctor/defendant must be prepared to change their schedule and devote the time necessary for trial. The scheduling of the trial, which includes coordinating all witnesses, attorneys, judge, and jurors, is not always easy and often conflicts exist (Fig. 19.12).

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IN THE CIRCUIT COURT OF THE 15TH JUDICIAL CIRCUIT,
IN AND FOR PALM BEACH COUNTY, FLORIDA

CASE NO.: 2007 CA00000000XXXXMB AG

FRED MARTIN (Plaintiff)
v.
JACK JOHNSON, D.D.S. (Defendant)

_____/

NOTICE TO SET CAUSE FOR JURY TRIAL

PURSUANT to Rule 1.440(b) of the Florida Rules of Civil Procedure, the Plaintiff, FRED MARTIN shows unto the Court that this cause is at issue and moves that it be set for jury trial.

It is estimated that the trial in this cause will take five (5)days.

I HEREBY CERTIFY that a copy of the foregoing was furnished by postal delivery this 28 day of April, 2016, to: Counsel of Record.

FRANCIS R. DeLUCA, ESQ.
Attorney for Plaintiff
100 Southeast Sixth Street
Fort Lauderdale, FL 33301
(954) 523-2700

By:
FRANCIS R. DeLUCA
Florida Bar No. 843636

FIG 19.12 Court docket. The court will give notice to the doctor/defendant on when the trial will commence. This will usually be a range of time (≈4–8 weeks).

Continuance

In American procedural court law, a continuance is a postponement of the trial at the request of either or both the defendant and plaintiff or the judge. A motion for continuance is usually granted when there is reasonable cause. In some states “fast-track” rules limit the ability of judges to grant continuances. There exist many reasons for a continuance:

1. Inadequate time to prepare

2. Conflicting obligations of counsel

3. Illness of any of the involved

4. Expert witness conflict

5. An agreement between the parties

6. Religious holidays

Civil Courtroom Layout

The courtroom layout for a civil malpractice trial includes (Fig. 19.13):

Judge's bench: the presiding judge will sit behind a raised desk, known as the bench.

Witness stand: adjacent to the judge's bench is the witness stand in which the various witnesses will present their testimony.

Court reporter: the court reporter usually will sit in front of the judge's bench and is responsible for recording verbatim all testimony, objections, and judge's rulings.

Judge's clerk: the clerk is located in front of or to the side of the judge's bench and will usually administer the oath to jurors and witnesses. The clerk is also in charge of all physical exhibits that are introduced into evidence.

Bailiff: the bailiff has many duties including calling the witnesses, being in charge of the jury, and acting as the liaison between the judge and jury.

Council tables: in front of the court reporter table, two tables (plaintiff and

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defense) will be present for the plaintiff and defendant and attorneys.

Jury box: on the far side of the courtroom will be the jury box, where the jury will sit while testimony is given.

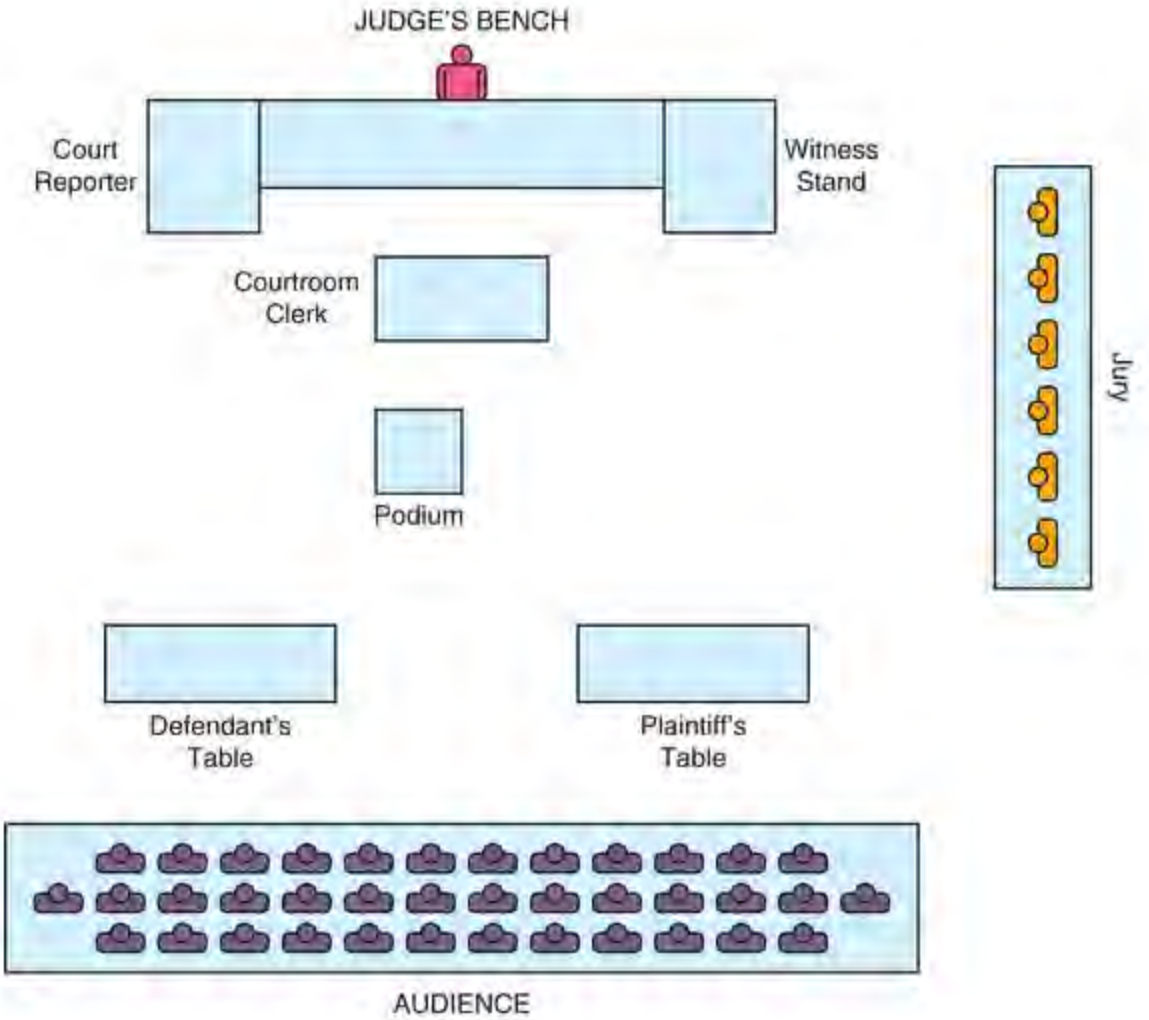

FIG 19.13 Civil courtroom layout diagram. Although variations exist, the civil courtroom is setup with the judge's box in the center, with the witness stand directly to the judge's left side (closet to the jury box). A court reporter (to the right of the judge box) and court clerk (front of the judge's box) are positioned around the judge's bench. The defendant's table (defendant and defendant's attorney) and plaintiff's table (plaintiff and plaintiff's attorney).

Jury Selection

The first step in the trial process is the jury selection. Also referred to as *voir dire*. Voir dire is a Latin phrase that literally means "to say what is true, what is objectively accurate or subjectively honest." A group of potential jurors are

summoned to the courthouse to be questioned by the lawyers and judge to determine their suitability for jury service. The potential jurors may also be required to complete a questionnaire. The jury pool is usually selected from the voter registration list or from the driver's license registrations in most jurisdictions. The attorneys on both sides are given an opportunity to question the prospective jurors about their backgrounds to determine if they have any biases or prejudices that would prevent them from being fair and impartial to either side. During voir dire process, lawyers strive to achieve four major goals in evaluating the jury candidates: (1) eliciting information from each potential juror, (2) developing a rapport with the potential juror, (3) educating potential jurors on the process, and (4) attempting to educate potential jurors concerning their case.

After questioning is completed, the selection process begins. The court will take into consideration what is referred to as *challenges for cause*. The court will be asked to "strike" (i.e., remove) any potential juror who has indicated they cannot be fair and impartial or who is otherwise unfit to serve as a juror on that case. An example of unfitness is being a convicted felon. Once the for-cause challenges have been addressed, each side is given a certain number of "peremptory challenges." A peremptory challenge allows attorneys to dismiss a prospective juror for any reason they deem necessary. These challenges are used by each side to eliminate potential jurors who would be otherwise qualified. After these potential jurors are removed from the pool, those who remain will become the jury. The rules in each state are different, with the jury panel usually comprising from 6 to 12 jurors. In most states, one or more alternate jurors may be selected. Alternate jurors will attend trial and are called on to replace a juror who is unable to complete their jury service (e.g., for health reasons).

Opening Statement

Once the juror panel is selected and sworn in, the plaintiff and defense attorneys for both sides are asked to give an opening statement. The plaintiff's attorney will be first to give their opening statement, followed by the defense attorney. The opening statement is an overview or roadmap of what each side intends on proving and explaining to the jury what they can expect from each of the witnesses. Attention should be paid to the opening statements because the opponent's claims will be discussed in detail. It is bad practice to assert that you intend on proving a particular fact and claim and then not doing so.

Patient/Plaintiff Case Presentation

Upon completion of the opening statements, the patient/plaintiff will begin their case. The patient/plaintiff presents their case in the hopes of proving that the doctor/defendant deviated from the standard of care. The plaintiff attorney must prove each and every legal aspect of their claim. If each element is not proven, the court may take the case away from the jury and enter a judgment (defendant verdict) in favor of the doctor/defendant.

The term *standard of care* is often used and rarely understood. Unfortunately, there exists no universal definition. The jury, in some jurisdictions, will be instructed that the standard of care means what "a similar practitioner would do under the same or similar circumstances." In other states, including Florida, the jury will be instructed that the standard of care is "reasonable and appropriate care." This does not mean perfect care, nor does it mean what another practitioner would have done.

The mere occurrence of a bad outcome or result does not entitle the patient/plaintiff to a verdict in their favor (i.e., failed dental implant). The tort system in this country is fault based; some fault or deviation from the standard of care must be proven by the patient/plaintiff in order for them to prove their claim.

Proof of a deviation from the standard of care is usually accomplished through an expert witness or, on occasion, via a subsequent treating doctor. The term *expert* is likewise frequently used in the litigation process but is similarly not well understood by doctors or lawyers. An expert designation does not mean that the witness is an exceptional dentist, researcher, instructor, or author. It merely means that the witness possesses specialized training and education (dental school education at a minimum) on a topic at issue and will be able to aid the finder of fact (jury) in making its determination of the ultimate issues.

Specially retained experts are the so-called "hired guns." They are paid to review all the documents with respect to the case and testify during trial. Because "experts" are witnesses for hire, the credibility of a specially retained expert is always an issue, and the jury is free to believe or not believe the testimony of any witness, including a specially retained expert.

Subsequent treating doctors tend to be more troublesome when they provide opinion or expert testimony. Unlike the hired guns, they are not handpicked like specially retained experts, and they usually testify on the basis of their clinical evaluation of the patient/plaintiff. They are also not generally paid a fee for their "expert witness" testimony. Most commonly,

these witnesses will be attacked on the basis that they are testifying on behalf of a patient who remains under their care. Additionally, a subsequent treating dentist must defend their own conduct. For example, if the subsequent treating dentist has removed all or part of the dental work delivered to the patient by the doctor/defendant, the subsequent treating dentist must offer a valid reason for removing what is otherwise perfectly acceptable dental work. The subsequent treating dentist is locked into testifying there was some deficiency that necessitated the subsequent care and treatment, including the removal of the dental work. Otherwise, it is the subsequent treating dentist, and not the defendant, who has subjected the patient to unnecessary care and treatment.

Witness Order

The general order of witnesses to be called to testify is left to the discretion of the attorneys. Generally, the plaintiff attorneys will select the doctor/defendant as the first witness, the treating doctors next, followed by witnesses to discuss damages, the expert witness, with the patient/plaintiff generally going last. In some cases, the plaintiff's attorneys may vary this plan by placing the plaintiff on the stand first with the doctor/defendant going last.

The doctor/defendant must be completely prepared to testify, and their answers should be intelligently thought out, given in a concise manner consistent with the dental chart and the prior testimony (i.e., deposition). A common pitfall for the doctor/defendant is to argue with the opposing counsel, which never results in a positive outcome. The questions should be answered as phrased; however, further explanation may be given. At the very least it makes it appear that the attorney is not allowing the doctor/defendant to tell the full story and not given the opportunity to expound on your response.

Once the plaintiff's attorney has finished asking their questions, the doctor/defendant's attorney is given an opportunity to question their own client. This is generally brief and is used as a means of clarifying the doctor's testimony. The doctor/defendant will be given an opportunity to testify a second time if their attorney deems it necessary to testify in the defense side of the case. This is called *cross-examination,* or simply referred to as “cross.” On completion of the cross-examination, the patient/plaintiff attorney is given one more opportunity to question the witness, which is referred to as a *redirect*. This inquiry is limited to areas covered in the cross-examination.

After the plaintiff's attorney has presented their case, they will “rest,” and the defense will be given the opportunity to present their case or move for dismissal. If the judge does not dismiss the case, the defense will call their witnesses, with the plaintiff's attorney having the opportunity to cross-examine.

For a successful verdict against a doctor/defendant, the plaintiff's attorney must prove there was a deviation from the standard of care. However, they only need to prove evidence of probability (not necessarily a certainty) of a breach in the standard of care. This is termed *preponderance of evidence*. The legal definition of probability means that, even if the jury has 49% doubt that the plaintiff's version of the facts is true, they will still find the doctor/defendant failed to meet the standard of care.[12]

Expert Witnesses

In a dental implant malpractice suit the jury is requested to determine if the doctor/defendant violated the standard of care by evaluating the evidence provided by each side. Usually, with respect to standard of care, the most compelling evidence is from the expert witnesses. Expert witnesses can be general dentists, specialists, or other health care professionals. In some states, the expert is required to have training identical to or greater than that of the defendant (e.g., Arizona). The jury will evaluate the information provided by the expert witness to determine their credibility and knowledge concerning the subject.

There are two types of expert witnesses, nonretained and retained. Nonretained are usually subsequent care providers who have expressed criticism and testify on the injuries involved in the defendant's treatment.[13] Retained expert witnesses are witnesses who have not necessarily seen the patient for treatment but are hired by the attorney for their opinions on standard of care and causation by reviewing the records.[14] In most cases, the doctor/defendant may request their expert witness for testimony on their behalf.

Impeachment

The doctor/defendant should have a copy of all discovery, including their deposition, answers to interrogatories, and requests for admissions. The doctor should be fully prepared to discuss in detail each of these items, including their deposition testimony. If, during testimony, the

doctor/defendant contradicts themselves, they may be subject to "impeachment" by the inconsistent statement. This is a process whereby the opposing attorney is able to bring the inconsistency to the attention of the jury. It is an unpleasant event and is very embarrassing. The more times a witness is "impeached," the more the witness loses credibility with the jury. It is imperative the doctor/defendant know exactly what was answered in all interrogatories and deposition testimony.

Inadmissible Information

In most states, peer review records and testimony regarding peer review activities are immune from discovery and are inadmissible (i.e., not allowed) as evidence in dental malpractice suits. Additionally, quality assurance committees, utilization committees, and incident and risk management reports also are not discoverable or admissible. This information, which may include findings or retributions against the doctor/defendant, may not be used against them in a malpractice court hearing.[15]

Closing Arguments

Once both parties have completed presentation of their cases each will rest and closing arguments will commence with the plaintiff side going first. The closing argument or summation is the final opportunity for the attorneys to persuade the jurors to find in favor of their side. The facts will be summarized to show their side has proven their case and to point out the failures of the opponent's claims and contentions. The attorneys may not discuss or comment about any information that was not presented during the course of the trial; commentary is limited to the evidence presented. After the defense presents their closing argument, the plaintiff's attorney is entitled to make a concluding argument or rebuttal. This is the last opportunity for the plaintiff to discuss any points made by the defense attorneys in their final arguments. At the conclusion of closing arguments, the judge will instruct the jury as to the appropriate rules of the law that they must follow in reaching a verdict.

Deliberation

After the final arguments and instructions from the judge, the jury will proceed to the jury room to begin the process of deliberation. The jury will have all of the items and materials introduced into evidence with them to

consider in the deliberations. Initially, a presiding juror will be elected to direct over discussions and voting. This juror is referred to as the *foreperson*. The bailiff will oversee the jurors and will be the go-between between the judge and jury.

In the deliberation process the jury will attempt to reach a decision on the outcome of the case. In most jurisdictions a majority (i.e., over 50%) of the jurors must agree on a final verdict; in some jurisdictions the verdict must be unanimous. During this process the jury may ask for the judge to explain or instruct them on certain aspects of the law. In some jurisdictions it is permissible for the jury to request that certain aspects of the trial testimony be read back to them. Once the jury reaches a decision, they will allocate and decide the amount of the award of damages, if any. Damages may be categorized as either economic, noneconomic, or punitive (damages awarded as punishment in excess of the actual damages). The amount and availability of the various damages is dependent on state laws.

Verdict

After the jury decides on the final verdict, the jury will notify the bailiff, who will in turn notify the trial judge. All the participants in the trial will then reconvene in the courtroom for the announcement of the verdict. The judge will usually read, or "publish," the verdict in open court. If the verdict is for the plaintiff, the jury will usually set forth the amount the defendant must pay the plaintiff for damages. The attorney for either side may ask for the jury to be polled. When the jury is polled, each juror will be asked if they agree with the decision announced. The losing party has the right to appeal, in which they petition a higher court to review various aspects of the case and trial with the hope that the appellate court may find fault with decisions of the trial court and reverse the jury verdict. An appelate court, also know as an appeals court, reviews the decisions and process of a lower court. Although damages are not paid until the appeal is heard by an appeals court and a final ruling is completed, a bond may be required to secure the verdict.

Damages

If a doctor/defendant has breached the standard of care, the patient may be awarded by two types of damages: general or special. General damages are awarded for physical and emotional pain and suffering. The amount of the award is solely in the jury's discretion but is subject to statutory caps. Special damages are provided as compensation for financial loss, such as medical

bills, hotel and travel expenses, lost wages, or loss of future earning capacity.

Comparative Fault

If the patient is found to be negligent or to have caused or contributed to the adverse event or complication (e.g., failure to take antibiotic, missed appointments), the award may be reduced or withdrawn. Such comparative fault reduces or extinguishes the award based on the percentage of patient's fault. It behooves every practitioner to make detailed notes on missed appointments, failed instructions, or a false or deceptive history. In some states the doctrine of contributory negligence is followed, which provides that if a patient is at fault to any degree, there can be no recovery and the malpractice claim is dismissed by the court.[16]

Postverdict Adjustments

In many large verdict cases, upon judicial review, awards are reduced. Because the jury verdict must be ratified by the trial judge in the form of a "judgment," many judges will readjust the damages if they appear excessive. A higher court may also reduce the award if they feel the evidence does not support the full amount awarded. And lastly, the damages may be negotiated between the plaintiff and defense teams. The defense may threaten to appeal to a higher court, which could overturn the verdict or reduce the award. An appeal will increase the plaintiff's costs, which will result in many cases the plaintiff accepting a lesser amount in settlement.

Excess Verdict

Jury awards in liability cases are often unpredictable and may exceed the doctor/defendant's liability coverage. Most doctors do not realize they or their corporation are responsible for the excess verdict amount (i.e., reward amount above the maximum malpractice limits). For example, if the doctor has a $1 million policy limit and a judgment against the doctor is $2.5 million, the doctor is responsible for the excess $1.5 million. For doctors concerned about excess verdicts, policy limits may be raised to $3 million or $5 million. It is highly recommended that if a doctor/defendant has a case that may potentially result in an excess verdict, personal counsel should be retained to safeguard the interests of the defendant dentist.

Types of Malpractice Insurance

Occurrence.

Occurrence dental insurance is the most popular dental insurance carried by dental practitioners. This coverage is based on when the actual dental treatment in question occurred, not when the claim is made. As long as the incident in question is made during the active policy period, the malpractice carrier will adhere to the terms and conditions of the policy. For example, if a claim against an insured doctor is made in 2015 for treatment rendered in 2012 (i.e., while the policy was active), the malpractice carrier will cover the claim. The occurrence policy offers permanent coverage for incidents during the policy period.

Claims-Made.

Claims-made insurance provides coverage when claims occur when both the alleged incident and resulting claim occur during period the policy is in force. Claims-made policies provide coverage as long as the doctor continues to renew the initial policy and any subsequent renewals. Once the doctor stops paying the premiums, the coverage stops. Claims brought against a doctor after the coverage ends will not be covered, even if the incident occurred while the policy was in force.

For claims-made policies, a "tail" coverage (extended reporting endorsement) must be purchased at the end of the termination of the policy. This extended policy is needed upon retirement, taking a leave of absence from practice, joining a group practice with different insurance, or moving to a different state. Usually, malpractice carriers will offer free tail coverage in the event of death, disability, and retirement, provided a certain age is reached. Tail coverage can be expensive, often three times the last premium paid by the practitioner.

Extreme care must be used if a practitioner switches insurance carriers with a claims-made policy. The new policy will not generally cover conduct occurring prior to the date of the new policy. Doctors should request "prior acts" coverage, commonly referred to as "nose" coverage, to cover this potential gap. Alternatively, the doctor may purchase prior acts coverage from the new insurance company. This will cover any incidents which occur before the date on which the new coverage begins.

Limits of Malpractice Insurance

A policy limit stipulates the maximum amount of compensation an insurance

company will cover upon the result of a claim against a doctor. With an occurrence policy, a separate set of limits will be given for each year you purchase the policy. The limits of the policy remain available to pay for future claims, which are based upon claims that occur during that specific policy period. With claims-made coverage, only the current limits apply to pay for claims, which arise from the previous years of practice. For example, a standard $1 million/$3 million policy limit will allow for $1 million available to pay any single claim and $3 million total for the span of the policy period.

Entity Coverage

Most doctors do not realize that their practice entity may be named in a lawsuit along with themselves. If the doctor owns their own practice, there are two possible forms of coverage.

Separate Limits Coverage.

With most insurers the practice may be eligible for an entity malpractice policy with separate limits of liability. This will allow for defense costs and indemnity payments to be covered separately from the individual policy limits.

Shared Limits Coverage.

Doctors who own 100% of a solo practice may combine their individual policy limits with their practice policy limits. Defense costs and indemnity payments will be paid on behalf of both the individual and the practice.

Reporting to National Data Base

The National Practitioner Data Bank (NPDB) was created by Congress as a federal repository of health care provider information within the United States. The NPDB was implemented in 1990, and it requires reporting of any licensure, hospital privileges, and professional society actions against dentists related to quality of care. Additionally, the NPDB monitors and provides information on malpractice payments made for all health care practitioners on settled malpractice cases. The information is not available to the general public and is only provided to hospitals, health care entities, and licensing boards.

If a doctor is reported to the NPDB, the doctor is given the opportunity to respond to the allegations of the reported incident. This statement is

available on the NPDB website. Additionally, there is a self-query service for health care professionals to view and request information about themselves contained in the NPDB.

State Dental Licensure Complaints

Complaints against practitioners to state boards are on the rise in most states. Complaints against dentists to the state board usually occur by two avenues. First, if money is paid to a patient by an insurance company in resolution of a claim, the malpractice carrier is in most circumstances obligated to inform the state board. This report often results in an investigation by the state licensing board. Secondly, a patient may have difficulty in obtaining legal representation in pursuing dental malpractice litigation against a dentist. Many attorneys will not represent patients unless there is serious injury to the patient. With no other recourse, the patient files a licensure complaint to the state licensing board.

After the state board is informed or receives a complaint about a licensed dentist, an investigation will follow. The procedures to be followed will vary according to a particular state's public health code, dental practice act, or health department administrative. It is highly recommended that the practitioner be well versed on the processes and procedures for their own state.

Additionally, some states may require dentists to self-report any convictions of crimes, which most likely will result in a board investigation. Most state legislatures have enacted legislation that mandates the state dental board to investigate every complaint (e.g., patient insurance carrier, self-reporting) asserted against a licensed dentist.

The investigation process usually begins with a request for records by the state board. In some situations, a records request is not the result of a complaint against the dentist but could involve a complaint against another licensed practitioner. When sending records, is it imperative to make a notation of what records were sent and confirmation of their delivery. Most states have dental investigators who will review the requested records, radiographs, and other related documents and make a recommendation to the state board. If the investigation recommends further investigation, the dentist may be interviewed, and the process will continue according to the state's dental practice act.

After evaluation by the state board and the investigator, if the board determines there has been a violation of the state dental practice act, a wide

array of sanctions may be imposed against the dentist. This may include a monetary fine, restriction of certain practice procedures, continuing education, restitution in the form of repayment to a patient or third-party carrier, or licensure suspension or revocation.

Most commonly, the highest expenditures involving a complaint against a licensed dentist are the legal costs associated with its defense. Most dental professional liability policies will not provide for coverage for any state board fines, restitution, continuing education costs, or other discipline that may be imposed.

Legal Representation.

Although many dentists feel that a state board complaint is not as serious as a dental malpractice suit, they are often mistaken. It is highly recommended that the dentist seek legal representation immediately upon being notified of a state board complaint. Most insurance carriers will provide legal representation for state board issues if they arise from a dental injury or incident during an active policy period. An attorney will ensure full compliance with state laws and will aid in the process.

If the state investigator requests an interview, an attorney is highly recommended to be present. This will prevent the doctor from putting themselves in a compromised or a vulnerable position. More importantly, if the licensing board requests a settlement conference, the practitioner should be accompanied by legal representation. This will minimize the possibility of the dentist making ill-advised statements that may be detrimental to the final outcome of their case.

Avoiding Lawsuits

Maintaining Accurate, Concise Dental Records

The first step in an effective overall risk avoidance philosophy is to maintain good, accurate, and timely dental records and charting. The dentist with detailed and complete records has a significant advantage in any litigation or administrative proceeding.

Proper documentation is important for a number of reasons. First, it is a legal requirement of the various state licensing boards. Each practitioner should be familiar with the record-keeping and charting requirements of the jurisdiction in which they practice. Second, the record is a means of communication to keep the doctor, as well as other practitioners caring for the patient, apprised of what treatment has been completed and a summary of future treatment indicated. Third, charting creates documentation in both litigation and administrative proceedings. If charting is inadequate, it will create a negative connotation in the eyes of the court and jury and may expose the practitioner to discipline.

No practitioners can remember every interaction, phone call, medication, conversation, and procedure involving every patient. In the event of a legal action, the practitioner will most likely need to rely upon what has or has not been documented, to some degree. In addition, in the litigation environment the practitioner's expert is going to formulate their opinions based upon the available documents and records. The expert should be able to read the documentation and understand what treatment has been performed, the clinical and radiographic basis for the care, and the treatment's final outcome. The age-old adage “if it's not written it did not happen” still holds true today. Conversely, it is difficult for a patient's expert to contradict the documentation in a patient's chart if the record is detailed and accurate both before and after a complication arises. The logical inference is that a practitioner who keeps accurate records as a matter of course has records that are more trustworthy.

The plaintiff's attorney and expert will also scrutinize the patient's records. If the records are poor, this may have a negative effect on the implant clinician's credibility. For example, the plaintiff's attorney and expert will explain to the jury that the records are “sloppy” and a deviation from the state board's requirements. On the other hand, good records suggest that appropriate time and care has been devoted to the patient's medical-dental needs.

One often-overlooked area of documentation is missed or cancelled appointments. It is crucial, particularly in cases with complications, to note patient appointment failures or cancellations. It is difficult, if not impossible, to reconstruct a history of missed or cancelled appointments years after they occur. This is especially important where the patient's failure to keep appointments makes it more difficult for the dentist to monitor and treat a complication.

Additional information that is often overlooked and not documented includes:

- Medical history updates
- List of current medications
- Medications prescribed (include name of pharmacy/phone number if called in)
- Consultation referrals
- Recommended posttreatment care
- Postoperative instructions
- Lack of patient compliance

The minimum content of progress notes/treatment notes is generally governed by the various state dental practice acts. However, some general principles apply to all such records that extend beyond the minimal requirements established by the state boards. The SOAP format is a method of documentation recommended for health care providers for progress notes in the patient's chart. The SOAP acronym has four components: subjective, objective, assessment, and plan (Box 19.3).

Subjective: includes the patient's chief complaint and should include comments, desires, expectations, and physical complaints.

Objective: includes information that the practitioner observes from the patient's clinical presentation. This may include the medical history review, physical examination, clinical findings, diagnostic test results, radiographic evaluation, and observations.

Assessment: should include a summary of the patient's main symptoms and diagnosis including a differential diagnosis. The assessment should also include possible and likely etiologies of the patient's problem.

Plan: should include all aspects of the actual treatment plan including:

Patient preparation: includes informed consent, preoperative medications, NPO status, local anesthesia, etc.

Patient treatment: includes all aspects of the treatment performed.

Postoperative instructions and medications prescribed (prescription and over-the-counter)

Next visit summary: treatment to be performed at the next visit.

Box 19.3

Ideal Patient Records

1. All entries in the written patient record should be completed by the doctor, not the assistant or staff member.

2. If a staff member does make an entry into the chart, the information should be initialed and dated.

3. The record should be completed as soon as possible after treatment is completed; delays in documentation lead to errors.

4. The record should represent the facts in an objective manner.

5. Document any complication or unexpected event in detail with treatment and follow-up information.

6. Document any change in the treatment plan and a reason for such change.

7. Document how the patient tolerated the procedure.

8. Document any medications administered including quantity of local anesthetic.

9. Provide postoperative instructions to patient verbally and in written form; explain the purpose and proper dosage of any medications prescribed.

. Document that the patient was discharged in good condition.

. Document treatment to be rendered at the next appointment.

Potential Complications

Inadequate Documentation Concerning Implant Procedures.

Implant-related treatment must to be documented in a comprehensive, detailed manner with respect to the course of treatment. Some important documents that are often missing from practitioner's treatment records include:

Medical history: any changes in the patient's medical history including medications and recent medical procedures

Implant details: surgery report describing implant location, size specifications, serial numbers, and manufacturer

Unexpected treatment: documentation of nonideal placement (e.g., anatomic variants, malposition, grafting)

Anesthesia: type, quantity, and method of administration of anesthesia used in case of medical emergency or postoperative complication

Bone graft material: type, source, quantity, location, and label in surgery report

Fixation screws: number, size, and location of bone or tack screws

Membrane: type, source, quantity and size, location and label in surgery report

Complications: detailed, accurate recording of any intra- or postoperative complication

Altering, Adding, Deleting Information From the Patient Records.

When confronted with litigation or a licensing board inquiry, the implant clinician may often be inclined to make additions or modifications to the chart. The practitioner will often look back at events or pertinent facts that were not documented and make alterations to place themselves into a more favorable position.

Altered records are discovered in a number of ways. Often, unbeknownst to the dentist, staff has already provided copies of the unaltered chart to the patient. Staff often view a request for records as an administrative task and unnecessary burden for the doctor. Secondly, the popularity of electronic records has raised many validity issues with progress notes and imaging. Most software programs today contain tracking and theft mechanisms that will detect if any alterations were made.

There are numerous forensic expert witnesses who are specialists at analyzing questioned documents. These include document/handwriting examiners, chemists who analyze ink, and computer specialists. From a legal perspective, the consequences of altered records can be catastrophic for the doctor, even where the resulting litigation or administrative proceeding is otherwise defensible. The practitioner will lose their credibility when found guilty of document alteration. The practitioner may also lose their malpractice insurance coverage, as well as the legal representation provided by their insurance malpractice. They may be subject to court sanctions, including the striking of legal defenses, and/or subject themselves to claims for exemplary or punitive damages, or even criminal prosecution.

If a change needs to be made to a patient's record, the added information should be included as an addendum, not in the original document. When corrections need to be made, a single line should be made through any information to be deleted. These changes should be signed and dated appropriately.

Comprehensive Medical-Dental History Forms

A common problem in many dental offices is the failure of practitioners to periodically review and amend their forms and record systems. Older, dated medical histories tend to ask broad-based questions (e.g., “Do you suffer from any serious medical condition?” or “Are you in good health?”). This is not a good practice and often results in significant medical issues being missed. The modern trend in medical histories is towards specific “condition-based” inquiries. These type of questions are more easily understood by the patient and are less likely to be overlooked.

A good example are bisphosphonate medications. Most older medical history forms do not ask whether there is a history of bisphosphonate use because 20 years ago this entire drug category was in its infancy. Today, practitioners regularly and routinely encounter patients who have a current or past history of bisphosphonate use. Where the use of these medications is not known, implant clinicians place their patients at risk and expose themselves to potential litigation and administrative action. Herbal remedies present similar problems. Many supplements affect bleeding, inflammation, and healing and cause drug interaction complications. As such, questions about their use should be an integral part of the patient's medical history form.

Potential Complications

Not Updating Forms.

If a medical update is not obtained by the doctor, this may show evidence of lack of diligence that may support a patient's claim of professional negligence. Practitioners need to recognize that the practice of dentistry is always evolving and that forms require periodic updating. In the event something is missed on the medical history, it is not a valid defense in a legal action that “it was not on the form” or that “it's the software's fault.” Should a medical complication occur and litigation result, a patient's lawyer and expert witness will analyze the patient's past and current medical history forms with great care. An updated medical history form should be an essential part of a dentist's office risk management program.

Prior to each appointment the written medical history should be reviewed along with the patient's current medications and dietary supplements. Patients should be asked if there have been “any changes in the medical

history since the last appointment." At a minimum, a notation should be made in the chart confirming that the patient's health status and medications were reviewed by the practitioner and discussed with the patient, including (when applicable) the lack of any changes in the patient's health status or medications.

At a minimum, patients should have their medical forms reviewed or a new medical history questionnaire completed on an annual basis. A problem arises if an older medical history is continuously updated: it may be difficult to understand because it will be crowded with notations and dates. In such cases a new questionnaire is always recommended.

Lack of Attention to What the Patient States in the Medical Forms.

Practitioners must always review the patient's medical history in detail. The doctor should ask questions about positive responses and inconsistencies. For example, a patient may list prescription medications on the history form yet fail to list a treating or primary care physician. Or a patient may indicate that they are a "controlled" diabetic. If the doctor does not follow up with questions concerning how the patient's diabetes is being treated and their A1c level, the doctor places their patient, and ultimately themselves, at unnecessary risk.

Failure to Obtain Medical Clearance

Another significant area of concern that dentists commonly fail to address is obtaining medical clearance from the patient's physician. If a practitioner has any doubts concerning a patient's current medical status or condition, additional inquiry is required. The patient's primary care physician or treating medical physician is in the best position to address questions and issues concerning the patient's care. In the event of an adverse event, the physician will most likely be supportive. Conversely, should the dentist fail to consult with the physician, they could be the most harmful witness in any subsequent litigation or administrative proceeding.[17]

Potential Complications

Not Providing Physician With Adequate Information.

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The content of the medical clearance request is extremely important. Over the years the trend has been to merely request clearance to “perform a dental procedure” or to “perform dental surgery.” This is completely inadequate because insufficient information is provided to the physician. The practitioner's medical clearance request should at a minimum contain the following[18] and should be accompanied by a cover letter (Fig. 19.14).

- A brief description of the procedure(s) to be performed including time duration and expected estimation of blood loss.
- The patient's current medical conditions and medication list.
- A list of pre- and postoperative medications to be administered and type of anesthesia (local anesthesia (LA), intravenous sedation (IV), oral sedation, general anesthesia) to be administered for the procedure.
- A request for any special instructions the physician may have on the modification of any current or proposed medications.
- Most Important: NO MEDICATION SHOULD EVER BE ALTERED WITHOUT PHYSICIAN'S CLEARANCE.

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MEDICAL CONSULTATION FOR DENTAL IMPLANT SURGERY

Patient: _____ **Date:** _____

The above patient is scheduled for dental implant surgery. The outpatient surgery will be performed in my office under intravenous conscious sedation. The following information has been provided by the patient.

Medical History: _____

Current Medications: _____

Allergies to Medications: _____

The following medications are proposed for the dental implant surgery:

ANTIMICROBIAL	ANTIINFALMMATORY	ANALGESIC	ANESTHESIA	SEDATION
___ Amoxicillin	___ Ibuprofen	___ Hydrocodone	___ 2% Lidocaine 1/100k Epi.	___ Halcion
___ Cephalosporin	___ Dexamethasone	___ Codeine	___ 2% Carbocaine 1/20k Neo.	___ Valium
___ Clindamycin		___ Acetaminophen	___ 3% Carbocaine	___ N2O
___ Augmentin		___ Percocet	___ .5% Marcaine 1/200k Epi.	___ IV (Versed, Fentanyl)
		___ Ultram		

PLEASE PROVIDE ANSWERS TO THE FOLLOWING QUESTIONS

1. Date of most recent physical exam: _____
2. Significant medical condition, treatment, disease, injury or comments:
   _____
   _____
   _____
   _____
3. Any Recommendations or Modifications of Medications YES_____ NO _____
   Current Medications _____
   Proposed Medications (Surgery) _____
4. The above patient is an acceptable candidate for outpatient dental implant surgery YES_____ NO _____
5. Please contact me prior to treating this patient YES_____ NO _____

Signature of Physician **Date**

FIG 19.14 Medical clearance form. This is a summary of patient-reported medical issues and a list of medications, list of proposed medications, and questions for the physician to complete and forward back to the practitioner.

Ordering Lab Tests.

Because of the increased prevalence of patients with systemic diseases, laboratory tests such as hemoglobin A1c (diabetes), CBC (complete blood count) and INR (anticoagulant therapy) are often warranted. However, the tests should always be ordered by the physician and interpreted by the physician. If the implant clinician orders a test, they are placing themselves at risk of being responsible for the interpretation and referral when there are abnormal values.

Not Following Up With Physician's Office.

The implant clinician should follow up on a regular basis with the patient's physician, especially for patients with multiple comorbidities, to determine if there is any change in the patient's health or status. A patient may have a change in health status or prescribed medication, which affects treatment planning and/or appropriate treatment options.

Verbal Communication.

Care should be taken when obtaining medical clearance via verbal communication. It is highly unlikely the physician will document the conversation. If a problem arises and litigation results, testimony most likely will occur many years later. It is often difficult, if not impossible, for the physician to remember all the details concerning a phone conversation.

Dentists often are confronted with a physician not responding to a request for medical clearance. This is not a green light to move forward with treatment. It is entirely appropriate to have the patient contact the medical office and insist that the physician complete the clearance. It is simply not a valid defense to a civil or administrative proceeding to say that “the physician did not return my calls so I performed the procedure anyway.”

Inadequate Information From Physician.

One must make sure the clearance is complete prior to undertaking a procedure. If the medical clearance is equivocal in any respect or not responsive to the practitioner's specific concerns, additional inquiry is appropriate. If the medical history and/or subsequent clearance reveals a matter potentially affecting the care or treatment, the practitioner should have a detailed discussion with the patient and the informed consent should be modified accordingly. In this situation, the patient will be well aware of

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the potential risks and complications of the procedure, not just from the dentist's standpoint, but from the physician's perspective as well.

Comprehensive, Detailed Treatment Plan

A detailed treatment plan should be thoroughly discussed with the patient, and the patient should be provided with a copy of the proposed plan in writing. All possible options, along with the advantages and disadvantages of each option, should be discussed in a manner that is easily understood by the patient. Often, practitioners give the patient a single option, which, in reality, is simply the option preferred by the doctor. Finally, the treatment plan should include an estimate of the cost and anticipated duration of the treatment, as well as language addressing the fact that the treatment plan is “only an estimate” and “additional procedures and expenses may be necessary” (Fig. 19.15).

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Treatment Options for Stephen Russell: (Upper)

a. Complete Upper Denture $$$$

Advantage: *Minimal Treatment, Fast*
Disadvantage: *Removable Prosthesis, Difficulty in Eating/Speaking, Palate Coverage*

b. Implant Supported Overdenture (Removable)

Advantage: *Removable prosthesis that "clips" in, horseshoe shaped (no full palate)*
Disadvantage: *Have to remove at night, removable, "clips" need changed on regular basis*

Phase 1:	Implant Placement (5–6 Implants)	$$$$
	Possible Additional Bone Grafting	$$$$
	IV Sedation	$$$$
	(Bone grafting indicated because of extensive loss of bone)	
Phase 2:	(4–6 months after Phase 1)	
	Attachments	$$$$
	Overdenture	$$$$
	(Fabrication of final prosthesis)	

Or

c. Implant Supported Fixed Prosthesis (Fixed)

Advantage: *Fixed prosthesis, is not removable*
Disadvantage: *Need for extensive bone grafting + more implants, will add pink porcelain or acrylic because of the amount of bone loss, teeth will be larger (FP-2/FP-3)*

Phase 1:	Bilateral Sinus Grafts	$$$$
	IV Sedation	$$$$
	(Bone grafting indicated because of extensive loss of bone)	
Phase 2:	(4–6 months after Phase 1)	
	Implants (7–8 implants)	$$$$
	IV Sedation	$$$$
	(The number of implants will be determined after evaluation of bone graft)	
Phase 3:	(4–6 months after Phase 2)	
	Fixed Prosthesis	$$$$
	(Fabrication of final prosthesis)	

FIG 19.15 Treatment plan example.

Potential Complications

Unforeseen Treatment.

From time to time, unexpected procedures are necessary in the treatment of dental implant patients. This may result in a dispute between the patient and the doctor.

Example: An example of this situation in oral implantology is the extraction of a tooth along with a socket graft. Caution should be noted to describe the socket graft as a "preliminary graft." If a tooth is extracted and no buccal plate is present, an additional graft may be necessary in the future, prior to implant placement. By using the term "preliminary graft," the practitioner will have informed the patient about the possibility and the need for a second graft.

Detailed Cost Breakdown.

If the practitioner does not give a detailed fee summary, the patient may not understand the total extent of treatment. A financial disagreement may very well lead to the patient pursuing litigation.

Example: Patients often believe the cost of the implant is inclusive of the restoration. The patient must be informed and understand that separate fees exist with the implant, abutment post, and implant crown.

Giving Patient One Treatment Option.

Furnishing the patient with all treatment options minimizes the possibility of miscommunication. The patient should be instructed to initial the plan selected, and both doctor and patient should sign the form. The document, including the plans rejected by the patient, should be made part of the chart. In many instances, this may be beneficial for future treatment if the patient decides to upgrade to a different prosthesis.

Example: An edentulous patient is interested in an overdenture; however, after receiving the final prosthesis, the patient is not happy with the movement associated with the overdenture. The doctor can then show the patient the other options that were discussed previously with the patient. This will minimize the possibility of the patient becoming upset over unreasonable expectations and costs.

Informed Consent

Most practitioners are unaware of the precise language of their informed consent forms. Ideally, informed consent is an educational process that includes the following:

- An explanation of the problem, condition, or area of concern
- The consequences of the condition if left untreated
- The proposed treatment plan
- The reasonable expectations for the treatment
- All realistic treatment options, including no treatment
- The risks and potential benefits of your proposed treatment

This information needs to be provided in a form the patient can understand, and the patient should be given adequate time to evaluate and ask questions if necessary.

The adequacy of informed consent is in part determined by state dental board laws. Each practitioner should be familiar with the obligations imposed by the state board. The standard against which a practitioner's conduct is measured falls within two broad categories. In the more traditional approach the dentist's conduct will be measured or evaluated against what a “reasonably prudent practitioner” would have told their patient when presented with the same or similar clinical circumstances. A newer and evolving approach adopted by a number of states is the “reasonable patient” standard. The dentist's conduct will be measured against what a reasonable patient would want to have known prior to agreeing to undergo a particular procedure.

In summary, the practitioner has a legal obligation to disclose in an understandable fashion all significant and relevant information necessary for the patient to make an intelligent and reasonable decision concerning whether to proceed with the proposed course of treatment. Experience has shown that a well-informed patient who has been fully advised of what to expect and what complications can occur is less likely to pursue litigation when a complication occurs.

Many practitioners also incorrectly believe that an informed consent will protect them from potential liability. In reality, the fact that the patient consented to the care and treatment provided is a different question than whether the practitioner acted within the applicable standard of care. Patients cannot consent to negligence.

Example: Many practitioners believe that if the patient signs an informed consent and an adverse complication (nerve impairment from not accessing

the quantity of bone) arises, the practitioner will not be held liable.

Potential Complications

Broad Language.

The language of the informed consent form should be clear and direct, with no room for misinterpretation. Language that is too broad will lead to impeachment of the informed consent because of misinterpretation.

Example: A consent form states that "excessive smoking" may lead to complications resulting in implant failure. In this example, a practitioner would have a very difficult time explaining what "excessive" actually means (i.e., 10, 20, 25 cigarettes/day?).

Obtaining Consent Day of Surgery.

Consent is best obtained prior to the day of surgery. Ideally, the consent should be available on the practice's website or given to the patient prior to the surgical appointment. A good protocol would be to have the patient sign the consent form during a "work-up" appointment, which is completed prior to making the surgical appointment.

Example: When a consent form is signed the day of surgery, patients often state they "did not read" or "were pressured into signing" the consent document. Additional allegations in informed consent lawsuits include: "I was sedated when the form was placed in front of me to sign," "The front desk handed it to me and said it was nothing," or "I did not get a chance to ask questions."

Not Understanding Various Types of Consent

Implied consent.

This form of consent is based on the words or conduct of the patient. Conduct often speaks louder than words. A patient seeks out care and voluntarily submits to the proposed treatment.

Example: A patient who opens his mouth for the administration of local anesthetic will not be permitted to deny they consented to local anesthesia. This is by far the weakest form of consent and should never be used as the sole type of consent.

Written consent form.

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Formal written consent documents have been the hallmark of dental consent for decades. They are often provided from insurance companies or implant organizations or they are taken from various textbooks or downloaded off the Internet. The ideal consent form will allow the patient to initial each different aspect of the consent (Fig. 19.16).

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Consent for Implant Surgery

1. I have been informed and afforded the time to fully understand the purpose and the nature of the implant surgery procedure. I understand what is necessary to accomplish the placement of the implant under the gum or in the bone.

2. My doctor has carefully examined my mouth. Alternatives to this treatment have been explained. I have tried or considered these methods, but I desire an implant to help secure the replaced missing teeth.

3. I have further been informed of the possible risks and complications involved with surgery, drugs, and anesthesia. Such complications include pain, swelling, infection and discoloration. Numbness of the lip, tongue, cheek, or teeth may occur. The exact duration may not be determinable and may be irreversible. Also possible are thrombophlebitis (inflammation of the vein), injury to teeth present, bone fractures, sinus penetration, delayed healing, allergic reactions to drugs or medications used, etc.

4. I understand that if nothing is done any of the following could occur: bone disease, loss of bone, gum tissue inflammation, infection, sensitivity, looseness of teeth followed by necessity of extraction. Also possible are temporomandibular joint (jaw) problems, headaches, referred pains to back of the neck and facial muscles, and tired muscles when chewing. In addition, I am aware that if nothing is done an inability to place an implant at a later date due to changes in oral or medical conditions could exist.

5. My doctor has explained that there is no method to predict accurately the gum and bone healing capabilities in each patient following the placement of an implant.

6. It has been explained that in some instances implants fail and must be removed. I have been informed and understand that the practice of dentistry is not an exact science, no guarantees or assurances as to the outcome of the results of treatment or surgery can be made. I am aware that there is a risk that the implant surgery may fail, which might result in further corrective surgery or the removal of the implant with possible corrective surgery associated with the removal.

7. I understand that any amount of smoking, alcohol, or elevated blood sugar may affect gum and bone healing and may limit the success of the implant. I agree to follow my doctor's home care instructions. I agree to report to my doctor any complications maintain regular examinations as instructed.

8. I agree to the type of anesthesia, depending on the choice of the doctor. I agree not to operate a motor vehicle or hazardous device for at least 24 hours or more until fully recovered from the effects of the anesthesia or drugs given to me for my care.

9. To my knowledge, I have given an accurate report of my physical and mental health history. I have also reported any prior allergic or unusual reactions to drugs, food, insect bites, anesthetics, pollens, dust, blood or body diseases, gum or skin reactions, abnormal bleeding or any other conditions related to my health.

10. I Have Been Informed And Understand The Existing Anatomy (Bone And Tissue) Which May Place Limitations On The Final Implant Crown Height And Position. The Implant Crown Will Most Likely Be Higher (Longer) Than The Adjacent Teeth (Fp-2), With Lack Of Gum Tissue On Each Side. Pink Porcelain May Also Need To Be Used In Conjunction With The Final Crown.

11. I agree to notify the doctor's office of any and all changes to my address and/or telephone number within a reasonable timeframe (two to four weeks).

12. I request and authorize medical/dental services for myself, including bone grafts and other surgery. I fully understand the contemplated procedure, surgery, or treatment conditions that may become apparent, which warrant, in the judgment of the doctor, additional or alternative treatment pertinent to the success of comprehensive treatment. I also approve any modifications in design, materials, or care, if it is felt this is for my best interest. If an unforeseen condition arises in the course of treatment, which calls for performance of procedures in addition to or different from that now contemplated, I further authorize and direct my doctor, associate, or assistant, to do whatever they deem necessary and advisable under the circumstances, including the decision not to proceed with the bone graft procedure.

Signature of Patient	Date
Signature of Witness	Date
Signature of Doctor	Date

FIG 19.16 Consent form.

Verbal consent.

Ideally, the practitioner should discuss with the patient all of the risks, benefits, and alternatives to the proposed treatment. This verbal consent will act to supplement the written form and should not be used as the sole type of consent. The practitioner should document in the patient's chart that verbal consent was completed as further evidence that informed consent was obtained from the patient.

Video consent.

The newest and most comprehensive form of consent is based on a video review of the procedure by the patient. In the event the patient denies all or part of what was explained in the video presentation, the video may be played for the jury.

An area often overlooked by dentists and many seasoned lawyers is the concept of informed consent as a cause of action. Lawyers often combine a claim for failure to obtain informed consent together with a standard negligence claim. In order to prevail on such an informed consent claim, the patient and lawyer must prove a number of legal and factual elements.

When consent was obtained irregularly, these elements will include:

1. The dentist failed to obtain the consent of the patient at a time and in a manner consistent with acceptable standards of care among members of the profession with similar training and experience in the same or similar medical community;

2. Had the patient been properly informed, the patient would not have consented to the procedure;

3. As a result, the patient sustained loss, injury, or damages.

When the issue is whether insufficient information was given, these elements will include:

1. The dentist failed to provide the patient with sufficient information to give a reasonable person a general understanding of the proposed treatment or procedure. This may entail failing to provide acceptable alternative treatments or procedures or failing to advise the patient of the substantial risks and hazards inherent in the proposed treatment or procedure that are recognized by other dentists in the same or a similar community who perform similar treatments or procedures;

2. If the patient had been properly informed, the patient would not have reasonably consented to the procedure;

3. As a result, the patient sustained loss, injury, or damages.

It is difficult for a patient to prove they would have refused treatment had they received appropriate consent, and for that reason, attorneys find it difficult to prove claims based on lack of informed consent.

Not Utilizing Informed Refusal.

If a patient refuses a recommended treatment or procedure, the practitioner has a legal obligation to advise the patient of the potential adverse consequences, and to document the patient's refusal to consent. Informed refusal occurs where a patient refuses to accept recommended treatment, therapy, or medication. The dentist still has a duty to provide reasonable and appropriate care consistent with the applicable standards of care. The practitioner should obtain and clearly document the informed refusal. However, an informed refusal does not constitute approval to **proceed with treatment when the proposed treatment is against the practitioner's clinical judgment**.

Example: A patient refuses a cone beam computed tomography (CBCT) scan prior to dental implant surgery. If it is against the dentist's clinical judgment to proceed without the scan, the practitioner must advise the patient accordingly and not proceed with the surgery, irrespective of the patient's “consent” to the procedure.

Not Documenting Refusal for Referral.

In some situations, the implant clinician may recommend referral to another dentist or specialist. If the patient refuses the referral, the patient's decision must be well documented.

Particularly in the absence of a referral to a specialist, experts working on behalf of the patient will most often focus on the implant clinician's failure to: (1) predict the potential for complications; (2) recognize the occurrence of a complication and initiate appropriate treatment; or, (3) recognize the occurrence of a complication and make a timely referral.[16]

Battery.

Theoretically, if treatment is rendered to a patient without proper informed

consent, in certain states this may be construed as “battery” (i.e., intentionally touching a patient without obtaining consent). Battery is a criminal offense, which can be the basis of a civil lawsuit. The key element of battery is the touching (treatment) is not authorized by the patient, not that it be intended to harm the patient. Forcing beneficial or needed care on an unwilling patient would be considered battery. An example of this is the performance of a sinus lift and bone graft on a patient who is sedated and has not consented to such procedures.

Managing Complications

In the event a complication occurs, at a minimum the practitioner should record:

- What occurred in a detailed, objective manner
- Detailed plan for addressing the event
- Discussions with the patient including comprehensive instructions

The practitioner's response to a complication will likely be a significant factor in the outcome of any subsequent litigation: it may even determine whether there is any litigation in the first instance. The dentist should explain to the patient that complications sometimes arise and they will work through the situation together. Any discussion with the patient should be clear and detailed, including the events leading to the complication, and documented by the dentist.

Potential Complications

Placing Blame on the Patient.

Put simply, it is best to avoid blaming the patient for a complication, even in instances where the patient failed to follow instructions or is otherwise responsible. Ideally, the complication should be addressed with the patient and resolved before the dentist-patient relationship is compromised by ill will or severed completely.

Example: Many dentists will blame a failed implant (early failure) on the patient's lack of hygiene.

Not Documenting After Hours Phone Calls.

One of the most important aspects of the treatment of complications is the

documentation of “night of surgery” or “after hours” communications. These communications are particularly important in instances where the complication results in litigation or administrative proceedings. For this reason, practitioners should maintain an “After Hours Contact Form” or alternative method of documenting “after hours” communications with patients. This includes “night of surgery” postoperative checks, patient calls regarding complications, and/or medication issues. Such notes should include specific information (Box 19.4).

Box 19.4

After Hours Contact Form

- Date and time of the call
- Who initiated the call
- Who was spoken to: the patient, family member or other individual
- Any subjective complaints of the patient
- Inquiry as to whether the patient had prescriptions filled and if they are taking the medications as directed.
- Instructions given, if any
- Prescriptions called in with the name and phone number of the pharmacy
- Any offers to see the patient apart from the scheduled follow up
- Any additional information

Good Rapport With Patient

When adverse complications arise, doctors should be as accommodating as possible to their patient. Studies have shown the two main reasons patients take legal action following dental surgery are deviations from the standard of care and professional attitude.[19] If the patient feels betrayed by the doctor or the doctor is less than receptive to the patient's concerns or complaints, the

patient may seek a second opinion. That, in turn, may lead to the patient contacting an attorney. For these reasons, spending time with the patient and discussing the issue and treatment options is far more likely to deter a patient from seeking legal action than ignoring the patient's concerns or blaming the patient for the complication. If a patient genuinely feels that their doctor is compassionate and cares about their well-being and is committed to achieving a desirable outcome, the threat of litigation decreases significantly.

Keep Current

All implant clinicians should stay current with the newest research and protocols within the profession. An excellent avenue is continuing education from a course not presented by a manufacturer. Practitioners should remain skeptical of questionable new products, as well as manufacturer-based studies. In other words, implant dentists seeking to manage their risk should adhere to the “don't be the first, but don't be the last,” line of logic.

Understand the Basics of CBCT Technology

One of the fastest growing diagnostic areas in implant dentistry is the use of CBCT. However, as CBCT technology advances, so does the potential for litigation. There are several factors that predispose a doctor to liability with CBCT scans.[20]

Potential Liability

To Take a Scan or Not.

In medicine, radiographic equipment is usually not approved for a particular purpose or indication. Nor is there any actual “standard of care” or universally accepted guidelines for the use of CBCT technologies. Instead, any applicable standard of care is mandated by the legislature, a court, or dental board.[20]

On the other hand, even in the absence of an express guideline, an implant clinician is more likely to be questioned for failing to use available CBCT technologies preoperatively if a complication arises.[21]

Technical Parameters.

The doctor ordering the scan must be careful to select the correct parameters of the scan. Inadequate or improper CBCT settings and parameters may lead to liability. Examples include ordering a scan with low resolution when a high resolution is indicated (e.g., tooth fracture).

Field of View.

The field of view (FOV, anatomic limits of the scan) is crucial in the preoperative assessment of an implant patient. Ideally, the FOV should be the smallest possible to reduce the patient x-ray dosage and improve spatial resolution. However, if the FOV is too small, inadequate sufficient evaluation of the anatomic area will result. This is most commonly seen in the posterior maxillary augmentation when too small a field of view is used. If there is any type of pathology in the sinus and the scan is not taken high enough to determine the patency of the ostium, the doctor is at risk of causing serious sinus issues because of the inability to determine the patency of the ostium and the nature of the pathology.

Interpreting the Scan.

There is no current consensus on the legal ramifications of interpreting CBCT scans. However, as a general proposition the implant dentist remains responsible for interpreting the entire scan.[22] The implant clinician has three options. The implant clinician may: (1) interpret the scan themselves; (2) send the CBCT data to a licensed radiologist, or (3) have the CBCT data evaluated by the hospital or imaging center radiologist.

Referral to Radiologist.

Ideally, most clinicians will decrease their liability by referring their CBCT scans to a radiologist for evaluation. However, if the doctor sends the scan to a radiologist who is unqualified to interpret the scan, the dentist may have liability for the negligent referral.[23] Additionally, the CBCT scan must be read by a radiologist licensed in the same state as the implant clinician. Otherwise, the dentist may be subject to disciplinary action by the state dental board for aiding and abetting the radiologist's unlicensed practice of medicine and for negligent referral of the patient's scan to the unlicensed provider.[24] The implant clinician also should confirm that the radiologist's malpractice insurance covers the reading of CBCT scans.

Waiver of Liability.

Many implant clinicians who are untrained in CBCT interpretation request their patients sign a waiver of liability regarding the interpretation of the CBCT scans or a waiver of the right to have the scan read by a radiologist. In general, a patient cannot consent to the negligence of their dentist or other health care provider.[25] Waivers of liability typically have no legal effect and are inadmissible.

Guaranteed Outcome of Treatment

Caution should be exercised to avoid guaranteeing the results of treatment such as the ability to masticate certain types of food (e.g., eat an apple). Marketing advertisements may also indirectly be interpreted by patients as guaranteed results. These issues may be minimized by good verbal communication prior to treatment on the possible complications and associated longevity of the prosthesis. Usually, dissatisfaction with esthetics can be explained by unreasonable expectations by the patient. However, if the doctor has marketing materials such as before and after photos of previous cases, this may be construed by the patient as the expected outcome.

Example: This will most likely occur with maxillary anterior implant in which the final crown will be elongated or longer than the adjacent teeth. Ideally, this possibility should be included in the consent form prior to treatment.

Patient Abandonment

In the medical field a doctor has an obligation to treat the patient once the dentist-patient relationship has been established. However, there may be instances where it is unreasonable or impossible to fulfill the demands of the patient to complete treatment. Sometimes a patient will become unreasonably demanding or refuse to accept proposed treatment recommendations. It is prudent to send a letter to the patient indicating that the dentist-patient relationship is being terminated and clearly outline the treatment needs of the patient, including follow-up care. To guard against being accused of abandonment, the dentist should take the following steps:

1. Document completely the noncompliant actions of the patient

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2. Send a termination letter (certified) to the patient with the following information:

- The reason for dismissal from the practice
- The consequences of not seeking treatment by another practitioner
- An offer to see patient on an emergency basis for a reasonable period of time (≈30 days)
- Recommendation on possible avenues for the patient to obtain another dentist (e.g., local dental society)
- Offer to forward progress notes and radiographic information to the new practitioner upon receipt of a release (Fig. 19.17).

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Re: Termination of Doctor-Patient Relationship

Date
[patient address]

Certified receipt # _____ Also sent first-class mail.

Dear Mr. Smith:

Please be advised that I will no longer be able to treat you as a patient. The termination of our doctor/patient relationship will be effective in 30 days from the date of this letter. Your current dental condition includes _____, which requires immediate attention and care.

Our office will be available for any emergencies that may arise for 30 days. We recommend you seek dental treatment immediately. You may call the local dental society or our office will be glad to forward a recommendation at your request.

Upon written authorization, a copy of your dental record will be sent to your new dentist. A release form is enclosed.

Sincerely,

Dr. Jones

FIG 19.17 Patient dismissal form.

Summary

Malpractice suits are a feared, often devastating and infuriating, event that changes a doctor's life. Especially in the field of oral implantology today, the legal ramifications are significant. Complications do occur and will continue to occur despite even the best care of the practitioner. With the number of implants being placed increasing at an alarming rate, along with a wide spectrum of general dentists and specialists placing implants, legal issues will most likely increase in the future. Malpractice actions are governed by the individual state laws and rules; thus the implant clinician must have a complete understanding of the laws and rules in the state they practice. In general, however, all states require a malpractice claim to contain the same elements: (1) duty; (2) breach of duty (i.e., deviation from the standard of

care); (3) legal causation between the deviation from the standard of care and resulting injury; and (4) damages. The implant dentist should have a strong understanding the legal system and terminology along with a strong foundation on how to avoid the possibility of a lawsuit (Box 19.5).

Box 19.5

Common Legal Terminology

Action: Another term for a legal case or lawsuit.

Appeal: A review by a higher court concerning the decision of a malpractice trial court verdict.

Arbitration: Submitting a case or dispute to designated parties (group of attorneys) for a decision instead of using a judge or jury.

Claim: The receipt of a demand for money naming the insured and alleging dental malpractice. Claims may also include dental licensing board complaints.

Compensatory Damages: Reimbursement for actual loss or injury.

Complaint: A legal document that informs the court of the malpractice case and is usually served with a summons on the defendant to begin the case.

Continuance: The adjournment or postponement of a court case to another day.

Counter-Claim: A claim by the defendant in a malpractice case stating the defendant is entitled to damages or other relief from the plaintiff.

Cross-Examination: The questioning of a witness for a particular party by an opposing party.

Damages: Money a party receives as compensation for a legal wrong.

Defendant: In malpractice cases, the doctor being sued, also called a *respondent*.

Deliberation: The process by which a judge or jury makes a decision or a verdict.

Deposition: Testimony of a witness taken, under oath, in response to another party's questions. This testimony is usually given outside the courtroom in a doctor's office or lawyer's office.

Direct Examination: The questioning of a witness for a particular party by that party.

Discovery: A formal request or gathering of information by one party in a lawsuit to disclose information or facts known by other parties or witnesses.

Finding: The court or jury's decision on issues of fact.

Inadmissible: Evidence that is not allowed to be presented because it is deemed unreliable.

Interrogatories: Formal, written questions used to get information from another party in a lawsuit.

Injunction: A court order to stop doing or to start doing a specific act.

Judgment: A court decision. Also called a *decree* or an *order*.

Jury Instructions: Statements made by the judge to the jury that instruct the jurors on the pertinent law in the jurisdiction applicable to the action about which they will deliberate.

Malpractice: When treatment provided by a dentist falls below or fails to comply with the standard of care exercised by other similarly trained dentists in similar situations.

Mediation: A dispute resolution process in which an impartial third party assists the parties to voluntarily reach a mutually acceptable settlement.

Motion: Request (usually written) to the court in a case. Filed with the clerk's office.

Motion in Limine: A motion usually made at the start of a trial requesting the judge rule that certain evidence may not be introduced in trial.

Negligence: Failure to exercise the care similar to what a reasonable or prudent practitioner would do in the same circumstance.

Notarize: To formally complete a document by acknowledgement or oath.

Perjury: Making false statements under oath.

Plaintiff: The person who sues or starts a civil case; also called the *petitioner* or the *complainant*.

Pleading: A formal statement of the cause of an action or defense.

Preponderance of Evidence: A requirement that states more than 50% of the evidence is present and is the burden of proof in a civil trial.

Pretrial Hearing: Conference with attorneys to determine scope of possible trial with view toward resolving issues through agreement.

Recovery: The acquisition of something of value through the judgment of a court.

Relief: Compensation sought by the plaintiff for their injuries.

Remedies: Is the means with which a court of law enforces a right, imposes a penalty, or makes a court order to impose its will.

Settlement: The resolution of a lawsuit without going forward to a final court judgment.

Statute of Limitation: A law that prevents patients from bringing malpractice claims against a doctor once a specified period of time has passed since treatment.

Subpoena: Legal process that commands a witness to appear and testify.

Summons: A legal paper used to start a civil case and get jurisdiction over a party.

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Tort: A wrongful act or an infringement of a right, which leads to a civil legal liability.

Verdict: The determination of a jury on the facts and, usually, the legal consequences of those facts.

Voir dire: A legal phrase that refers to an oath taken by jurors to tell the truth. This is the process by which attorneys question, or examine, prospective jurors to determine whether they are qualified to serve as jurors.

Writ: An order issuing from a court of justice and requiring the performance of a specified act, or giving authority and commission to have it done.

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