George A. Freedman

CONTEMPORARY ESTHETIC DENTISTRY



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ESTHETIC DENTISTRY

George Freedman, BSc, DDS, FAACD, FACD, FADFE



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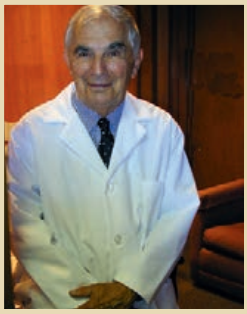
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To my parents
***Bella and Wilhelm Freedman**,*
who believed in me
and taught me to believe in myself



Foreword

Esthetic dentistry did not exist when I graduated from dental school. One of the most important disciplines was denture fabrication. It was assumed that beyond a certain age everyone would have lost their teeth and would require removable prostheses. Many simply looked awful with their dentures. When my father needed dentures, I could not stand that they made his features collapse and his face sink in. I repositioned the teeth more naturally and plumped the denture acrylic to support the facial muscles. My father's teeth looked better than ever before, and the natural form of his face was restored; he looked like his younger self, and no one knew that he had lost his teeth. The demands of treating my father made me realize the importance of esthetics to dentistry.

In the early years of my practice, direct restorations were limited to silver amalgam. Then silicate fillings were introduced. Initially they were not very retentive and tended to discolor. The introduction of composites and acid etching dramatically improved the process, and esthetic dentistry became a reality. I realized the potential of tooth-colored restorations and began using them extensively. During this time I was a regular guest on a popular radio show where I discussed dental innovations. In the pre-interview I mentioned that I would talk about "acid etching"—what the technique was commonly called at the time. The horrified host said, "You can't say that on air. Listeners will get frantic about dentists putting acid in their mouths. What else can you call it?" I responded that we were actually bonding materials to the teeth. "Then call it bonding!" he answered. And that is how the term *bonding* began.

It is rarely easy to develop something brand new. Many within the profession challenged and even ridiculed the new technique, but I knew how great bonding was. I had the good fortune to be asked to do a segment on *That's Incredible,* a very popular television show at the time. The producers asked me to treat a beautiful ballerina with very dark teeth, and they documented every step. I bonded her teeth, changed her smile, and made her look like a different person. The exposure was extensive; dentists everywhere wanted to know more because all their patients were asking about "bonding." The impact of television was truly phenomenal; one show changed dentistry completely!

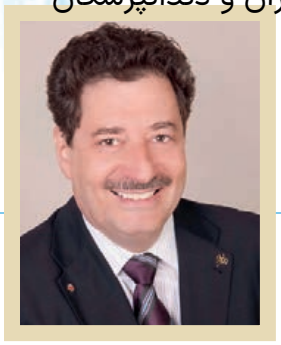
Esthetic dentistry has transformed patients' perspectives of dentistry tremendously. In the past, most people disliked going to the dentist; the dental visit was associated with fear and pain. Many deprecating jokes were told about dentists, and our profession was often symbolized by a suffering patient with a bandaged head. Once esthetic dentistry came into vogue, people realized how painless bonding was and how beautiful the results could be. Everyone wants to look better, and patients quickly realized that dentists could be artists, improving smiles and appearances in very short periods of time. Within a generation, the perceptions associated with dentistry were changed from ugly amalgam fillings, extractions, and dentures to an art form providing beauty, youth, and function.

Bonding was the beginning of esthetic dentistry. Veneers were the next step, generating patient anticipation and demand that led to a host of more advanced appearance-related procedures. It was now possible to use the restorations to raise the cheekbones, soften the nasal labial lines, and fill out the lips without surgery, and to make the results very long-lasting. These treatments were designed to provide an alternative to plastic surgery, enhance facial esthetics, and provide touch-ups "without a scalpel." Dentistry has evolved to an art that not only improves smiles but changes faces in a lasting manner.

The full scope of esthetic dentistry is just beginning to be defined. Dentists are, after all, the professionals who are most familiar with the hard and soft tissues of the smile and the lower face. We understand the teeth, lips, cheeks, and musculature and their functions as well as their limitations. We are familiar with the changes caused by aging and how to overcome the sagging, wrinkling, and shrinking of the face in order to make a person look younger. We can offer more precise and predictable facial effects than professionals who are limited to treating the soft tissues. The public now recognizes that dentists are the physicians and the artists of the smile. Everyone wants to stay young for as long as possible. This is the future of esthetic dentistry.

Irwin Smigel, DDS

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Preface

The first materials and techniques dedicated to appearance-related dentistry emerged in the late 1970s. The interest from the dental profession and the public was very limited in the beginning. The dental profession began to recognize this innovative and highly desirable treatment approach and the benefits for all concerned rather quickly over the next decade, however. In the early 1990s the concurrent popularization of porcelain veneers and tooth whitening created an explosive rise in interest among the public that has not abated in the slightest degree to this very day.

As a direct result, there was a great need and tremendous demand for effective professional education and the sharing of clinical experience among practitioners. On the academic side, the Postgraduate Programs in Esthetic Dentistry (PPED) presented a comprehensive introduction to appearance-related disciplines at numerous university venues. More than 2200 PPED graduates (1991 to 2001) began to form the cadre of the esthetic revolution that was sweeping the profession. On the organizational side, some of the earliest esthetic groups were closed: attendance was by invitation only, and membership was highly restricted. There existed a tremendous need for an open forum for dental education that welcomed all professionals with an interest in appearance-related dentistry.

The American Academy of Cosmetic Dentistry (AACD) was founded in December 1984 by 60 dentists who converged on Las Vegas for 2 days of lectures, discussions, and strategic planning. The "Cosmetic" denomination was chosen because several "Esthetic" and "Aesthetic" societies were already in operation, and confusion was to be avoided. The first AACD board of directors set important parameters: the Academy must be open to all who seek education and professional development, dental laboratory technicians must be included, and this innovative area of treatment must establish accessible levels of clinical recognition (which later became Accreditation and Fellowship). This formula proved very popular; in less than a decade the AACD was the largest cosmetic or esthetic organization in the world and has more than 8000 members.

This successful and open prescription is applicable to all forms of continuing education; the subject material and the format must be accessible, understandable, clinically relevant, and immediately applicable to everyday practice. That is why this text, focusing on the clinical applications of scientifically based esthetic procedures, is so opportune. It offers a comprehensive and detailed guide to both routine and complex esthetic procedures for practitioners who seek practical direction. The selected topics cover the vast majority of esthetic situations that are likely to be encountered in the clinical practice. A brief but thorough review of the relevant knowledge base leads into a discussion of the various treatment options that are available and those that the authors believe are the best choices. Discussions of recent relevant innovations and advances are followed by illustrative clinical cases that put each chapter into context. The organization of the topics and the chapters makes it easy to grasp the new concepts, techniques, and materials.

The field of esthetic dentistry has grown so rapidly that no single individual can be expert in all its domains. The many talented contributors to this definitive textbook have been instrumental in the philosophy, development, and teaching of the art and science of esthetic dentistry. They are recognized internationally as the leaders in research, clinical application and education. It is with great and humble appreciation that I thank each and every one of these authorities for his or her remarkable efforts in acquiring basic knowledge and skills, adapting and advancing these techniques to new technologies and existing patient conditions, and then sharing the resulting benefits with their colleagues.

Contemporary Esthetic Dentistry represents the vanguard of the transition in dental education and information transfer. The text is offered both in print and online, with each format associated with an opportunity to earn continuing education credits. Every chapter, or part of a longer chapter, has an associated multiple choice quiz that is accessed online at the reader's convenience. On successful completion, an evidence-based educational credit is issued.

Scientific textbooks have the disadvantage of becoming temporally challenged shortly after publication. This is because the process of developing a text can take 2 or 3 years or longer, and the contents represent a slice of knowledge at a particular time. *Contemporary Esthetic Dentistry* is the first "live" book wherein the online version can be regularly updated as the underlying clinical science and art change and develop. Thus it will always

be as current as possible—a compendium of the latest information at any given time.

Gutenberg's development of print publication made knowledge and education universally accessible, facilitating the Renaissance. Today's Web technologies make knowledge and education immediately and affordably accessible. We cannot even begin to imagine the progress that will be unleashed in the next few decades.

I am often asked why I make the effort, and spend the time, to write and to lecture about innovations, materials, techniques, ongoing development, and, of course, past mistakes. I find it very gratifying to share professional experiences with my colleagues for our mutual benefit. Transferring and distributing this information benefits our patients' oral health, improves our practices, and makes our everyday clinical tasks easier and more predictable. Most important, an open exchange is a great advantage for the younger members of the profession, who can use the established knowledge base to achieve ever better treatment concepts and modalities. To teach is to touch the future.

George Freedman, BSc, DDS, FAACD, FACD, FADFE

Acknowledgments

When I first agreed, reluctantly, to undertake the task of developing this definitive text on the topic of esthetic dentistry, I had a fair concept of the work that was involved. Or at least I thought that I did. As we progressed, I realized the myriad concepts, techniques, and materials in the field of Esthetic Dentistry had grown exponentially since I first became involved in its earliest days. The task was daunting but the outcome extremely important.

The knowledge base for esthetic dentistry is so vast and varied, and the expertise so broadly distributed, that it was incumbent upon me to involve world-renowned authorities on many of the areas under discussion in the development of this textbook. I humbly thank each and every one of the contributors for their tremendous efforts, sincere commitment, and invaluable contribution to the progress of dentistry.



I hold Jennifer Murphy largely responsible for cajoling me to accept the burden of writing *Contemporary Esthetic Dentistry*. On the other hand, she has also been the individual who has responsibly held all the loose ends of this massive project together, and enabled it to come to fruition.

Every long-term project takes its toll on family life, and I extend my heartfelt thanks and sincerest apologies to Dr. Fay Goldstep, my wife, and our daughter, Judy.

Many dental professionals have contributed to my personal development over the years, but the following individuals deserve a special mention. I first met Dr Jack Kammer in 1984. He was the founding president of the American Academy of Cosmetic Dentistry, and he helped me to begin my exciting journey in organized dentistry. Dr Geza Terezhalmy was the Dean of Case Western Reserve University School of Dental Medicine in 1991. During a discussion about the lack of esthetic dentistry training available to dentists, he challenged me to develop a suitable course of study. This conversation resulted in my organizing the first Post-graduate Program in Esthetic Dentistry 6 months later. Within a decade, more than 2200 dentists had graduated from these programs in the United States and around the world. Dr Irwin Smigel, founder and president of the American Society for Dental Aesthetics, has been a mentor and a shining light to all of us in the profession. His energy, his vision, and unabashed love for dental esthetics are standards that we can live and grow by.

At Elsevier, John Dolan (Executive Editor) was the first to envision the *Contemporary Esthetic Dentistry* textbook and was instrumental in developing this project, both with me and with Elsevier. He shepherded the project through the many gauntlets that are part and parcel of every book that publish. He prodded when necessary, and commiserated over wine when appropriate. Most significantly, he was open to the many innovative concepts that are the hallmarks of this publication. The successful conclusion of this project has been made possible by the tireless dedication and professional contributions of Courtney Sprehe (Senior Developmental Editor), Celeste Clingan (Senior Project Manager), Brian Loehr (Senior Development Editor) and Kari Terwelp (Editorial Assistant) through a very long and extensive project.

It is also important to thank the dental manufacturers who have supplied and permitted the use of images which add much to the practical relevance of a clinical text. These same companies are largely responsible for funding and driving the research and development that has propelled esthetic dentistry so rapidly to the forefront of the dental profession.

George Freedman, BSc, DDS, FAACD, FACD, FADFE

Contributors



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Dr. Freedman is a founder, accredited member, and past president of the American Academy of Cosmetic Dentistry and co-founder of the Canadian Academy for Esthetic Dentistry. He was the founding associate director of the Esthetic Dental Education Center at the State University of New York at Buffalo. He was the director of Post-graduate Programs in Esthetic Dentistry at Case Western Reserve University, Baylor College of Dentistry, State University of New York at Buffalo, Tufts University, University of Minnesota, University of Missouri (Kansas City), University of Florida, University of California at San Francisco, Eastman Dental Center (Rochester), Catholic University (Seoul, South Korea), and Schaan, Liechtenstein. He has chaired numerous dental conferences and symposia internationally, including at the Universita di Firenze and the World Aesthetic Congress (London). He coauthored the first textbooks on porcelain veneers (1990) and tooth whitening (1991), was the editor of *Dental Clinics of North America* (1998 and 2001). Accredited by the American Board of Aesthetic Dentistry, he is a founder and Regent of the Academy of Dental-Facial Esthetics and Fellow of the AACD, IADFE, American Society for Dental Aesthetics, American College of Dentists and the Academy of Dentistry International. He has served as Materials Editor of *Dentistry Today* for almost 20 years and is the editor-in-chief for *Dental Tribune International* and on numerous boards including Oral Health (Canada), Reality, and Dental Asia. He divides his time between patient treatment and dental education, lecturing frequently at dental conferences internationally, and maintains a private practice limited to Esthetic Dentistry in Toronto, Canada.



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Dr. Antonson is the Director of Education and Professional Services at Ivoclar Vivadent and Clinical Associate Professor and Director of Dental Biomaterials at SUNY, School of Dental Medicine. In 2000, the Products Manager at DENTSPLY Caulk, she invented and launched PoGo, the first one-step composite finishing and polishing device. She served as the president for the International Association of Dental Research, Dental Materials Group in 2007-2008 and is currently the councilor. Her research interests include predictability and longevity of ceramic and resin-based restorations, cements and interface mechanisms, alternative applications of glass ionomers, fiber post systems, thermal effects of curing light units, lasers and clinical procedures, and characterization of impression materials and techniques. She is studying the mechanical and physical properties of dental materials, and the new category of smart dental materials.



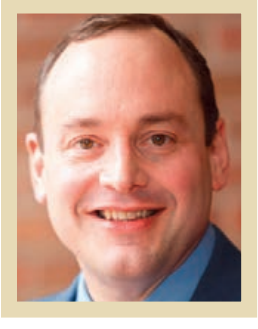
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Dr. Bambara is in private practice in Staten Island, New York; is on the teaching staff of University of Medicine and Dentistry of New Jersey; and is an Adjunct Assistant Professor at the College of Staten Island. He is also on the Attending Staff at New York Methodist Hospital and Seaview Hospital on Staten Island. He is a member of the American Dental Association, the Academy of General Dentistry, the New York State Dental Society, and the Richmond County Dental Society, where he served as President in 1998. He holds Fellowships in the American College of Dentists, the International College of Dentists, and the International Academy for Dental Facial Esthetics.



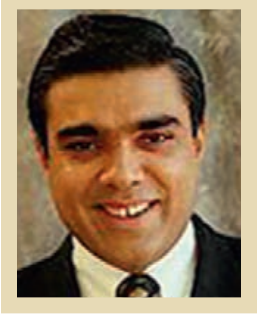
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Dr. Benjamin is in private practice and is Visiting Professor at SUNY Buffalo School of Dental Medicine and a Research Associate at the NYU College of Dentistry. He is an internationally recognized lecturer on oral cancer and advanced dental technologies and was a participant in the World Health Organization (WHO) Collaborating Centre for Oral Cancer and Precancer 2005 Working Group on "Potentially Malignant Oral Mucosal Lesions and Conditions." He has authored more than 150 articles on dental technology and is a member of the editorial board of several prestigious peer-reviewed dental journals.



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Dr. Berg is Professor and Lloyd and Kay Chapman Chair for Oral Health of the Department of Pediatric Dentistry at the University of Washington in Seattle, Washington and is Director of the Department of Dental Medicine at Children's Hospital Regional Medical Center in Seattle, Washington. He is a board-certified pediatric dentist and is a trustee of the American Academy of Pediatric Dentistry. He is the author of a multitude of manuscripts, abstracts, and book chapters regarding a variety of subjects, including restorative materials for children and other work related to biomaterials. His current research interests include the development of dental caries prevention programs using risk assessment models.



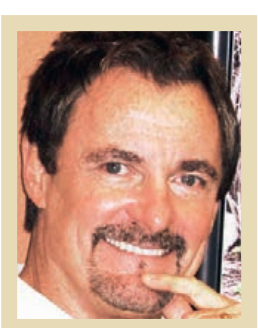
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Dr. Blank maintains a full time private practice in Rock Hill, South Carolina, where he emphasizes complex restorative reconstruction and cosmetic enhancement procedures. He is an Adjunct Instructor in the Department of General Dentistry, Medical University of South Carolina, College of Dental Medicine and has authored dozens of clinical manuscripts on clinical techniques and materials. He is a Fellow of the Academy of Comprehensive Esthetics and an active member of the International Association for Dental Research, the Academy of Operative Dentistry, the American Academy of Cosmetic Dentistry, the Pierre Fauchard Academy, the American Dental Association and the Academy of General Dentistry. He has lectured throughout the United States, Europe, and in Asia; holds a U.S. patent for a composite finishing instrument, and is the creator of the CEBL technique for direct veneer layering.



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Dr. Clark, one of the pioneers of the microscope in restorative dentistry, founded the Academy of Microscope Enhanced Dentistry. He is a course director at the Newport Coast Oral Facial Institute, co-director of Precision Aesthetics Northwest, and an associate member of the American Association of Endodontists. He lectures and teaches hands-on seminars internationally on a variety of topics related to microscope enhanced dentistry and has authored several landmark articles about microscope dentistry. He was the editor in chief for the 2005 launch of the *Journal of Microscope Dentistry.* He has recently published a completely new approach to diagnosis and treatment of cracked teeth, based on a new nomenclature and classification system for enamel and dentinal cracks observed at 16×. He is developing new techniques and materials to better restore endodontically treated teeth, including the endo-restorative casting.



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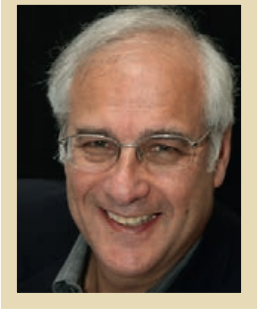
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Robert W. Gerlach, DDS, MPH

Dr. Gerlach is a Research Fellow in Worldwide Clinical Investigations at Procter & Gamble. His clinical trial research includes initiatives in the areas of caries prevention, periodontal therapy, and esthetic dentistry, with a particular focus on tooth whitening. With over 100 studies, his research has led to novel delivery systems for vital bleaching as well as new dentifrice formulations. Dr. Gerlach is a public health dentist, and his work experience includes various government and academic appointments, as well as extensive private practice experience.



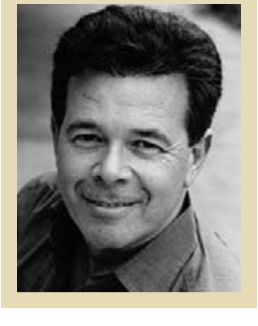
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Jeff Golub-Evans, DDS

Dr. Golub-Evans uses bonding, bleaching, porcelain laminates, and crowns in his pioneering work in smile design, including smiles that have appeared on the covers of 300+ fashion and beauty magazines. He has appeared on *Live with Regis and Kathie Lee, The Today Show, CBS Morning News, Inside Edition,* and other shows. He is an accredited member, a Fellow, and a past president of the American Academy of Cosmetic Dentistry, founding president of AACD's New York Chapter and founder of the Smile Design Council. He is a member of the editorial board of *Esthetic Dentistry for the GP* and was the editor in chief of *Current Opinion in Cosmetic Dentistry,* clinical editor of *Dentist,* and associate editor of the *Journal of the AACD.* He was an Associate Clinical Professor at New York University, Department of Dental Materials Science and Restorative Dentistry. He holds visiting faculty appointments to the postgraduate programs in esthetic dentistry at the State University of New York at Buffalo, Baylor University, Harvard University, Boston University, and Northwestern University.



Linda Helene Greenwall, BDS (Rand) MGDS, RCS (Eng), MSC (London), MRD RCS (ENG), FFGDP (UK)

Dr. Greenwall is a Fellowship Examiner for the Royal College of Surgeons of England and a specialist in Restorative Dentistry and Prosthodontics. She has a multidisciplinary private practice in Hampstead, which has been awarded the Investor in People status. She is also the editor of the journal *Aesthetic Dentistry Today.* She lectures extensively in the United Kingdom and internationally on the subjects of tooth bleaching, esthetic dentistry, practice management, and the controversies surrounding tooth whitening. She has written many papers for dentistry magazines. She is an Associate Course Director for the Advanced Certificate in Aesthetic Dentistry for the Royal College of Surgeons Faculty of General Dental Practices.



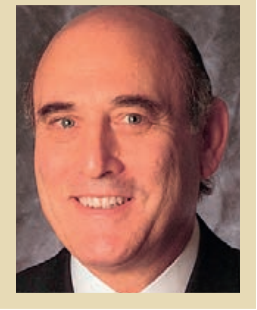
Galip Gurel, DDS

Dr. Gurel is the founder and the honorary president of EDAD (Turkish Academy of Aesthetic Dentistry). He is the president of the European Academy of Esthetic Dentistry for 2011 and 2012, a member of the American Society for Dental Aesthetics, and an honorary Diplomate of the American Board of Aesthetic Dentistry. He is the editor in chief of *Quintessence Magazine* in Turkey and serves on the editorial board of the *Journal of Cosmetic Dentistry, Practical Procedures and Aesthetic Dentistry: PPAD*, and the *European Journal of Esthetic Dentistry.* He lectures on dental esthetics internationally and teaches postgraduate lectures on esthetic dentistry. He is a Visiting Professor at New York University (United States), Marseille Dental University (France), and Istanbul Yeditepe University (Turkey). He has been practicing in his own clinic in Istanbul, specializing in esthetic dentistry, since 1984.



Wayne Halstrom, BA, DDS, D-ADSM, FICD, FACD, FPFA, FADI

Dr. Halstrom is a pioneer in the area of dental sleep medicine. He is the inventor of a family of oral appliances proven effective in the treatment of sleep-disordered breathing. Dr. Halstrom has been in practice for 49 years, and for the last 18 years his practice in Vancouver, British Columbia, has been limited to the treatment of sleep apnea and snoring. He is a Diplomate of the American Academy of Dental Sleep Medicine. He is an Adjunct Professor of the Thompson Rivers University Respiratory Therapy Program, where he teaches the principles of oral appliance therapy to undergraduates on their way to becoming respiratory therapists. He is a past president of the Canadian Dental Association and the British Columbia Dental Association.



David L. Hoexter, DMD, FIADFE

Dr. Hoexter is a Clinical Professor at Temple University Dental School in the Periodontal Department (Philadelphia, Pennsylvania). He was formerly a Clinical Professor at the University of Pittsburgh School of Dentistry, Department of Periodontics, and a Clinical Associate Professor at Mt. Sinai Hospital, New York. He is a Diplomate of the American Board of Aesthetic Dentistry, director of the International Academy for Dental Facial Esthetics, editor-in-chief of *Dental Tribune USA*, and a contributing editor for *Dentistry Today*.



Ron Jackson, DDS

Dr. Jackson maintains a practice in Middleburg, Virginia. He publishes regularly and lectures across the United States and abroad. He is an Accredited Fellow of the American Academy of Cosmetic Dentistry, a Diplomate of the American Board of Aesthetic Dentistry, and a visiting faculty member at the Las Vegas Institute for Advanced Dental Studies.



Steven R. Jefferies, MS, DDS, PhD

Dr. Jefferies is Professor in the Department of Restorative Dentistry, Maurice H. Kornberg School of Dentistry, Temple University, where he holds the Donald and Cecelia Platnick Professorship in Restorative Dentistry. Dr. Jefferies is also the Director of the Biomaterials Research Laboratory in the Department of Restorative Dentistry and Director of Clinical Research for the School of Dentistry. Previously, he was Corporate Vice President for Advanced Technology at DENTSPLY International, Vice President of Corporate Product Development, and Director of Clinical Research for the Caulk Division. He was Associate Clinical Professor in the Advanced Education in General Dentistry Program of the Department of Health Promotion and Policy, Dental School, University of Maryland at Baltimore. Dr. Jefferies has been an inventor or co-inventor on 25 issued U.S. patents and 52 worldwide patent disclosures; has been an author or coauthor of 50 scientific articles and abstracts, including two book chapters; and has delivered approximately 70 oral presentations. He is a Fellow of the American College of Dentists, the Academy of Dentistry International, and the Academy of General Dentistry.



V. Kim Kutsch, DMD

Dr. Kutsch is an inventor holding numerous patents in dentistry, a product consultant, and an internationally recognized speaker; he is a past president of the International Academy of Laser Dentistry, Academy of Laser Dentistry, and the World Congress of Minimally Invasive Dentistry. He also has served on the board of directors for the World Clinical Laser Institute and the American Academy of Cosmetic Dentistry. He has published dozens of articles and abstracts on minimally invasive dentistry, caries risk assessment, digital radiography, and other technologies in both dental and medical journals and has contributed to several textbooks. He also acts as a reviewer for several journals. He currently serves as chief executive officer of two dental companies and maintains a private practice in Albany, Oregon.



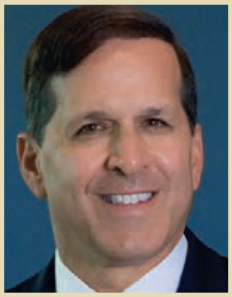
Emanuel Layliev, DDS

Dr. Layliev is the director of the New York Center for Cosmetic Dentistry. He is president of the New York Academy of Cosmetic Dentistry, a Fellow of the Academy of General Dentistry and the International Academy for Dental Facial Esthetics. He specializes in comprehensive cosmetic dental care including porcelain veneers, bondings, crowns, bridges, and dental implants. He is an active member of the American Academy of Cosmetic Dentistry, Academy of General Dentistry, American Dental Association, New York State Dental Association, and New York City Dental Society. He serves as a consultant for whitening toothpastes, toothbrushes, and mouthrinses and is the national spokesperson for Dentisse, a line of natural, organic dental care products.



Karl F. Leinfelder, DDS, MS

Dr. Leinfelder served for 8 years on the faculty at Marquette University before he joined the faculty at the University of North Carolina School of Dentistry, where he attained the position of Professor and Director of Biomaterials Clinical Research in the Dental Research Center. In 1983 he joined the School of Dentistry at the University of Alabama where he accepted the Joseph Volker Endowed Chair. He also served as Chairman of the Department of Biomaterials until 1994. Presently he holds positions at both universities—Adjunct Professor at the University of North Carolina and Professor Emeritus at the University of Alabama. He is the recipient of the Dr. George Hollenbeck Award (1995), the Norton N. Ross Award for Outstanding Clinical Research (1997), and the American College of Prosthodontists Distinguished Lecturer Award (1998). He has served as associate editor of the *Journal of the American Dental Association* and is a dental materials research consultant for numerous materials companies. Dr. Leinfelder has published 275+ papers on restorative materials, 150+ scientific presentations and a textbook on restorative materials and techniques, and lectures internationally on clinical biomaterials.



Roger P. Levin, DDS

Dr. Levin is chairman and chief executive officer of the Levin Group, Inc., the leading international dental practice management and marketing consulting firm, which he founded in 1985. Dr. Levin brings his Total Practice Success seminars to thousands of dentists and dental specialists each year. Under his guidance, the Levin Group has taught dentists how to continually increase practice production, profit, and referrals, creating a low-stress practice environment, experience high professional satisfaction, and build the path toward financial independence.



Eric Levine, DDS

Dr. Levine is a full-time faculty member of the Department of Endodontics, Prosthodontics, and Operative Dentistry at the University of Maryland Dental School and is the course director for the Year I preclinical course in Operative Dentistry. He has an intramural practice with a focus on restorative dentistry, and his research interests include the study of dental materials and incorporating technology into practice and teaching.



Jenn-Yih (Simon) Lin, DDS

Dr. Lin is a Clinical Assistant Professor and the Predoctoral Program Director for Pediatric Dentistry in the Pediatric Dentistry Department at the University of Washington. He is enthusiastic about integrating computing technology into effective instructional materials. He also directs the Early Childhood Oral Health program at the Department of Pediatrics at the UW Medical Center Roosevelt Clinic. He is currently involved in several clinical research projects.



Edward Lowe, BSc, DMD

Dr. Lowe is the clinical director of the Pacific Aesthetic Continuum (PAC-live) in San Francisco, California, and an adjunct faculty member at the University of the Pacific in San Francisco. He is an evaluator and speaker for several dental product manufacturers including Discus Dental, Ivoclar Vivadent, 3M, Kerr, and DENTSPLY. He is on the advisory board of *Signature,* Ivoclar Vivadent's clinical journal; *Collaborations; Spectrum;* and several other publications. He has published articles on esthetic dentistry *Dentistry Today, Contemporary Esthetics and Restorative Practice, Oral Health, Signature,* and *Practical Periodontics and Aesthetic Dentistry: PPAD.* He is an active member of the Canadian Dental Association, the American Dental Association, and the American Academy of Cosmetic Dentistry and a charter member and director of the Western Canadian Academy of Cosmetic Dentistry.



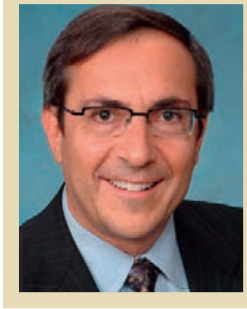
Robert A. Lowe, DDS

Dr. Lowe was an Assistant Professor in Operative Dentistry at Loyola University School of Dentistry until its closure in 1993. Since 2000, he has been in private practice in Charlotte, North Carolina. He lectures internationally and publishes on esthetic and restorative dentistry. He is a clinical evaluator of materials and products with many prominent dental manufacturers. He received fellowships in the AGD, ICD, ADI, ADFE, and ACD and received the 2004 Gordon Christensen Outstanding Lecturers Award at the Chicago Midwinter Meeting. He is a Diplomate of the American Board of Aesthetic Dentistry.



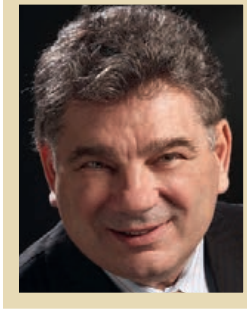
Edward Lynch, BA, MA, BDentSc, DMD, TCD, FDSRCSEd, FDSRCSLond, PhD Lond, FADFE

Dr. Lynch is the Head of Dental Education and Research at Warwick University. He was elected the most influential person in U.K. Dentistry in 2010 by his peers. Professor Lynch previously held the position of Professor of Restorative Dentistry and Gerodontology of the Queen's University Belfast as well as Consultant in Restorative Dentistry to the Royal Hospitals from 2000 to 2010. He has served as Senior Lecturer in Conservative Dentistry and Consultant in Restorative Dentistry and Postgraduate Course Organizer for the University of London. Dr. Lynch has been awarded a total of 94 research grants and has more than 500 publications, including chapters in books and refereed abstracts. Professor Lynch is a specialist in three disciplines—endodontics, prosthodontics, and restorative dentistry—and presents worldwide. He is a consultant to the ADA, a spokesperson for the BDA, and a scientific board member of the International Health Care Foundation and ISBOR and serves on the editorial board of numerous international journals.



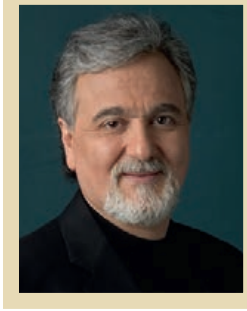
Louis Malcmacher, DDS

Dr. Malcmacher is a general and cosmetic dentist in Bay Village, Ohio and an internationally known lecturer and author. An evaluator for Clinical Reports, Dr. Malcmacher is a consultant to the Council on Dental Practice of the American Dental Association. He is also the President of the American Academy of Facial Esthetics.



Chuck N. Maragos, CDT

Mr. Maragos is a member of the internationally renowned Oral Design Group lead by Willi Geller and serves on the clinical board for Montage Media's "Collaborative Techniques." He also is one of three privileged dental artisans (technicians) to be accredited by the American Society for Dental Aesthetics. He is chief executive officer of Valley Dental Arts and Valley Dental Technologies and chairman of the Amara Institute. Known as the "Father of Contemporary Diagnostics," he has received numerous innovation awards and has published various articles on esthetic and implant dentistry. He also lectures internationally on the profitability of esthetic dental materials. He is an active consultant and product evaluator to dental manufacturers in the area of research and development.



Joseph Massad, DDS

Dr. Massad is an internationally renowned clinician in the field of prosthodontics and lectures internationally. He is the creator, producer, director, and moderator of two popular teaching videos on removable prosthodontics—1997's *Predictable Complete Dentures* and 2001's *Helpful Hints—Predictable Complete Dentures, Part 2*. He has published scientific articles in the *International Journal of Periodontics and Restorative Dentistry, Compendium of Continuing Dental Education, Dentistry Today, Dental Economics,* and the *Journal of Prosthetic Dentistry*. He holds faculty positions at the Pankey Institute in Florida, Tufts University School of Dental Medicine in Boston, the University of Texas Health Science Center at San Antonio Dental School, and the Oklahoma State University College of Osteopathic Medicine. Dr. Massad is a Fellow of the American College of Dentists and the International College of Dentists.



Sandesh M. Mayekar, MDS

Dr. Mayekar is the director of the Indian Institute of Continuing Education & Research and the Founder and President of the Indian Academy of Aesthetic and Cosmetic Dentistry. He is a past president of the Asian Academy of Aesthetic Dentistry and has authored several articles on esthetic dentistry. He is a visiting faculty member of the University of New York, Buffalo and Adjunct Professor in the Department of Restorative Dentistry at the New Jersey School of Dentistry. He is also a visiting faculty member at Padmashree Dr. D Y Patil Dental College and Hospital, Navi Mumbai. He is a member of the American Academy of Cosmetic Dentistry, the American Society for Dental Aesthetics, and the editorial team for REALITY Publishing Company. He is a Fellow of the International College of Dentists and the Pierre Fauchard Academy and a Diplomate of the American Board of Aesthetic Dentistry. He maintains a private practice in Mumbai, India.



Simon Mcdonald, BDS, MSc, DDPH, RCS

Dr. McDonald, dentist and inventor, is founder and CEO of Triodent Ltd, an international dental manufacturing and innovations company. His breakthrough products have revolutionized how Class II composite restorations and other dental procedures are done worldwide.



Elliot Mechanic, BSc, DDS

Dr. Mechanic practices esthetic dentistry in Montreal, Canada. He is the esthetic editor of Canada's *Oral Health Journal* and the cofounder of the Canadian Academy for Esthetic Dentistry. He maintains membership in numerous professional organizations, including the American Academy of Cosmetic Dentistry, the Academy for Dental Facial Esthetics, the American Society for Dental Aesthetics, and the European Society of Esthetic Dentistry.



Graeme Milicich, BDS

Dr. Milicich lectures internationally on minimal intervention, caries risk assessment and management, minimal intervention restorative techniques, and the physics and clinical applications of hard and soft tissue lasers. He is a Fellow, Diplomate, and founding board member of the World Congress of Minimally Invasive Dentistry (WCMID). He is also a Fellow, Master, and board member of the World Clinical Laser Institute and is a founding board member and honorary lifetime member of the New Zealand Institute of Minimal Intervention Dentistry. In 2001 he was the recipient of the WCMID Clinician of the Year Award, and in 2004 he received the WCMID Clinical Research Award. He has conducted research on Er,Cr:YSGG laser hard tissue ablation physics and the associated clinical applications and has several peer-reviewed publications in the field of minimal intervention dentistry, as well as produced several educational CDs.



Michael Miller, DDS

Dr. Miller has authored a 3-year series of articles on bonding in the *Journal of the Greater Houston District Dental Society* and has lectured internationally. He is a Fellow of the Academy of General Dentistry and a founding and accredited member and Fellow of the American Academy of Cosmetic Dentistry; he has memberships in the International Association for Dental Research, Academy of Dental Materials, and Academy of Operative Dentistry. He has contributed to several texts, is on the editorial board of *Practical Procedures and Aesthetic Dentistry: PPAD*, and is the cofounder, editor in chief, and president of REALITY Publishing Company. Dr. Miller maintains a private practice in Houston, Texas.



K. William Mopper, DDS, MS

Dr. Mopper (Bud) is in private practice in Glenview, Illinois, where he has created dental esthetics for 39 years. He is an internationally renowned lecturer in esthetic dentistry with an emphasis on direct application composite bonding. He coauthored *A Complete Guide to Dental Bonding,* the first definitive book on bonding techniques. He is a member of the Academy of Esthetic Dentistry, a Fellow of the American Academy of Cosmetic Dentistry, a Diplomate of the American Board of Pediatric Dentistry, and a Fellow of the American College of Dentists. He teaches CE level direct resin bonding at major universities including State University of Iowa and University of Illinois. He received the American Academy of Cosmetic Dentistry Award for Lifelong Commitment to Providing Excellence in Continuing Education in Cosmetic Dentistry and an award for Outstanding Contribution to Cosmetic Dentistry. He received the New York University College of Dentistry Irwin Smigel Prize in Aesthetic Dentistry. He recently received a Lifetime Achievement Award from the World Aesthetic Congress for Outstanding Contribution to Aesthetic Dentistry. He is director of education for the Center for Esthetic Excellence, in Chicago, Illinois, and is cofounder and Chairman of Cosmedent, Inc., where he is responsible for education and product development.

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Carlos Muñoz-Viveros, DDS, MSD

Dr. Muñoz-Viveros is a member of the American College of Prosthodontists, International Association for Dental Research, Hispanic Dental Association, Academy of Dental Materials, and several other organizations. In 1999 he became a Fellow of the American College of Dentists. He has presented lectures in Central and South America, the United States, Asia, and Europe. He has authored over 50 scientific articles, contributed to clinical dental texts, serves as journal reviewer, and is very active in adhesives, composite, and ceramic research. He is Professor and Chair, Department of Restorative Dentistry, SUNY at Buffalo, School of Dental Medicine, and Director of the Undergraduate Esthetics Minors course.



Ross W. Nash, DDS

Dr. Nash is cofounder and president of the Nash Institute in Charlotte, North Carolina, where he provides esthetic and cosmetic dental treatment for patients and continuing dental education for dentists and team members. He is an editorial advisor and regular writer for several dental publications and has also authored a chapter in a dental textbook on esthetic dentistry. He is an international lecturer on subjects in esthetic and cosmetic dentistry. He is a Fellow of the American Academy of Cosmetic Dentistry and a Diplomate of the American Board of Aesthetic Dentistry. He is a consultant to numerous dental product manufacturers.



Christopher Orr, BSc, BDS

Dr. Orr practices cosmetic and restorative dentistry in a multidisciplinary clinic in central London. He is an accredited member of the British Academy of Cosmetic Dentistry and also a certified member of the European Society of Cosmetic Dentistry. He is a past president of both the British Academy of Cosmetic Dentistry and the Odontological Section of the Royal Society of Medicine and is a former director of the American Academy of Cosmetic Dentistry and former course director for the MSc in Aesthetic Restorative Dentistry at the University of Manchester. Through Advanced Dental Seminars, he runs a 1-year comprehensive course in cosmetic dentistry and esthetic restorative dentistry for general dentists. In addition, he lectures internationally.



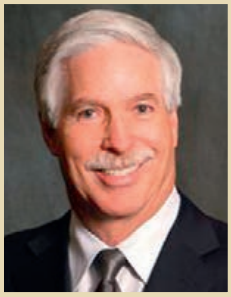
Carlo Alberto Piacquadio

Mr. Piacquadio is a specialist in macro photography, specifically in the area of intraoral photography. He is the owner of Fotoscientifica in Turin, Italy, and has been teaching the art of dental photography for over 20 years. In 1997 he published the *Dental Practical Handbook of Photography* and in 2002 published the *Practical Handbook of Dental Digital Photography*. He is also a consultant for authors of photographic books in the dental industry.



Gary Radz, DDS

Dr. Radz is an Associate Clinical Professor at the University of Colorado, School of Dentistry in the Department of Restorative Dentistry, where he teaches cosmetic dentistry courses for third- and fourth-year dental students. For the past 6 years he has served on the editorial board for REALITY Publishing Company. He is an active member of the Academy of General Dentistry, American Dental Association, Colorado Dental Association, Metro Denver Dental Society, and Colorado Prosthodontic Society. He is a sustaining member of the American Academy of Cosmetic Dentistry. He has written over 120 articles related to cosmetic dentistry materials and techniques, serves on the editorial board of seven dental journals including the *Journal of Cosmetic Dentistry,* and has served as the editor in chief of *Mentor* and *ACEsthetics* magazines.



Brock Rondeau, DDS, IBO, DABCP

Dr. Rondeau is a general dentist whose practice is limited to the treatment of patients with orthodontic, orthopedic, temporomandibular joint, and snoring and sleep apnea problems. He is a Diplomate of the International Board of Orthodontics and has approximately 700 active patients. Dr. Rondeau lectures internationally for more than 100 days per year and has done so for the past 24 years. He has taught in Canada, the United States, England, Hong Kong, Australia, and Poland. Dr. Rondeau is also a Diplomate of the American Board of Craniofacial Pain.



Lakshman P. Samaranayake, Hon DSc, Hon FDSRCSE, DDS, BDS, FRCPath, FCDSHK, HKAM(Path), FHKAM(DSurg), MIBiol, FHKCPath

Professor Samaranayake is the Dean and Chair of Oral Microbiology at the Faculty of Dentistry and Tam Wah-Ching Professor of Dental Sciences at the University of Hong Kong, as well as the Director of the Prince Philip Dental Hospital. He has held teaching and consultant positions at the University of Glasgow, United Kingdom, University of Alberta, Canada, and the University of Peradeniya, Sri Lanka, and has served as a director of the FDI World Dental Federation and the chairman of its Science Commission. He has authored over 400 research and review articles, 28 book chapters, and eight books, some translated into five languages. In 2010 he was the recipient of the IADR Distinguished Scientist Award in Oral Medicine and Pathology. He has lectured on five continents and is the editor in chief of the *Journal of Investigative and Clinical Dentistry* and a World Bank Consultant on problem-based learning.



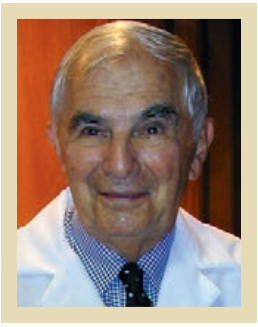
Jonathan Scharf, DMD, FAACD

Dr. Scharf has maintained a private practice in Exton, Pennsylvania, United States, for the past 39 years. He has served as a Visiting Associate Professor in the department of Esthetic Dentistry at the University of Buffalo School of Dental Medicine, has lectured at the Pankey Institute, and has trained dentists internationally in cosmetic dental technology, cosmetic dental practice management, and fiber reinforcement in dentistry. He is a member of the American Dental Association, Pennsylvania Dental Association, Chester County and Delaware County Dental Society, Academy of General Dentistry, International Association for Orthodontics, and American Equilibration Society. He is the technologies media spokesperson for the Academy of General Dentistry. He has served as a member of the editorial team of the Esthetic Dentistry Research Group (REALITY Publishing Company), as well as a consulting editor for Cosmetic Dentistry for the GP and *Cosmetic Dentistry Update.* He has numerous articles on advanced dental topics and is responsible for the development and international patenting of several dental materials and techniques. He has provided interviews and clinical photographs for features in national publications such as *Glamour, Woman's World,* and *American Health Magazine*.



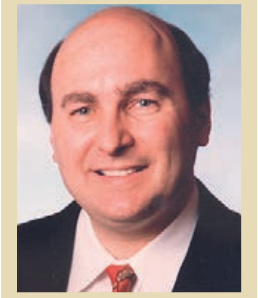
Tomás Seif, DDS

Dr. Seif is an invited Professor in the Department of Operative Dentistry at the Universidad Central de Venezuela and the Universidad Santa María in Caracas. He is the founder and past-president of the Venezuelan Academy of Esthetic Dentistry and an active member of the International Federation of Esthetic Dentistry. In addition, he is a member of the Venezuelan Dental Prosthetic Society, the American Academy of Cosmetic Dentistry and American Academy of Operative Dentistry. Dr. Seif lectures extensively both nationally and internationally, having presented lectures in the main programs of the American Academy of Esthetic Dentistry, American Academy of Cosmetic Dentistry, the American Academy of Operative Dentistry, the European Academy of Esthetic Dentistry, and the International Federation of Esthetic Dentistry. He is editor and co-author of the following books, *Cariology: Contemporary Diagnosis, Prevention and Treatment of Dental Decay* and *Unlimited Success in Your Dental Office, Maximizing Patient Satisfaction* (both textbooks published in Spanish-speaking countries). Dr Seif is founder and director of the Venezuelan Institute for Dental Updating (Instituto Venezolano de Actualización Odontológica—IVAO). He also attends many lectures and continuing education courses year-round in Venezuela and abroad. His private practice dedicated exclusively to restorative dentistry and esthetics in Caracas, Venezuela.



Irwin Smigel, DDS

Dr. Smigel, New York cosmetic dentist and visionary, is called the "Father of Aesthetic Dentistry" by his peers. He was at the forefront of cosmetic tooth bonding, laminate veneers, and both in-office and at-home bleaching techniques. He is the founder and current president of the American Society for Dental Aesthetics and has been instrumental in establishing esthetic dental societies in France, Italy, Japan, Korea, India, Brazil, and Turkey. He is a Diplomate of the American Board of Aesthetic Dentistry. In 1979 he made a historic appearance on the TV show "That's Incredible," in which he performed the first nationally televised dental bonding cosmetic dentistry demonstration for 50 million viewers. This changed the face of dentistry forever as thousands of callers flooded the network's phone lines hoping to discover how they too could improve their smiles. Since then he has appeared on *The Today Show, Good Morning America, Regis & Kathy Lee, NBC News, ABC News, Fox News,* and *CBS News.* In addition, New York University School of Dentistry has named its prestigious award for lifetime achievement in cosmetic dentistry the Irwin Smigel Prize.



Howard E. Strassler, DMD, FADM, FAGD, FACD

Dr. Strassler is Professor and Director of Operative Dentistry at the University of Maryland Dental School, Department of Endodontics, Prosthodontics and Operative Dentistry. He has lectured nationally and internationally on techniques and selection of dental materials in clinical use and esthetic restorative dentistry. He is on the editorial board of several publications and reviews for several major journals. He is on advisory boards and is a consultant and clinical evaluator for over 15 dental manufacturers. He has published more than 450 articles in the fields of restorative dentistry and innovations in dental practice and seven chapters in dental texts. He has presented over 400 continuing education programs throughout the United States, Canada, Mexico, and Europe.



Jon B. Suzuki, DDS, PhD, MBA

Dr. Suzuki has a Presidential Appointment as Professor of Microbiology and Immunology in the School of Medicine and Professor of Periodontology and Oral Implantology in the School of Dentistry at Temple University, Philadelphia. He also serves as the Associate Dean for Graduate Education as well as Director of Graduate Periodontology and Oral Implantology. He is a current panel member and the immediate past-chairman of the Food and Drug Administration Dental Products Panel. He is on the faculty of the U.S. Navy National Naval Medical Command and also holds professorships at Nova Southeastern University, Ft. Lauderdale, Florida; the University of Maryland, Baltimore; and Maimonides University, Buenos Aires, Argentina. He served as chairman of the American Dental Association (ADA) Council on Scientific Affairs and continues to serve as an ADA consultant on the Scientific Council, the Dental Practice Council, and the Commission on Dental Accreditation, Chicago. He served on the National Institutes of Health National Dental Advisory Research Council and on numerous NIH Study Sections. He has hospital appointments at Temple Episcopal Hospital and the Veterans Affairs Medical Centers. He is a Fellow of the American College of Dentists and the International College of Dentists, a Specialist Microbiologist of the American College of Microbiology, a Diplomate and Board Examiner of the International Congress of Oral Implantologists, and a Diplomate of the American Board of Periodontology. He has published over 100 papers, chapters, and symposia, 175 abstracts, and one textbook on medical technology. He is in private practice limited to periodontics in Philadelphia.



Peter Chiu Shun Tsang, BDS, PhD, FRACDS

Dr. Tsang is the Assistant Professor of Oral Rehabilitation at the University of Hong Kong. With more than 16 years' experience in research on the oral biology of HIV, his main research interest is on oral microbiology of healthy as well as medically compromised individuals, including patients with HIV infection, those with diabetes, and those undergoing irradiation.



William E. Turner

Dr. Turner has published numerous articles on direct fiber-reinforced composite bridges and other aspects of esthetic dentistry. He holds fellowships in the Academy of General Dentistry, the Academy of Dentistry International, and the International Academy for Dental Facial Esthetics. He currently practices in Thunder Bay, Ontario, Canada.



Corky Willhite, DDS

Dr. Willhite has been awarded Fellowship by the Academy of General Dentistry, the American College of Dentists, and the American Academy of Cosmetic Dentistry (AACD). He is one of 50 Accredited Fellows in the AACD, which has more than 8000 members worldwide. He has served on the AACD's board of governors (currently the American Board of Cosmetic Dentistry) and spent years as an Examiner for Accreditation. He is on the faculty of the Center for Esthetic Excellence in Chicago and postgraduate programs at Eastman Dental Center and the University of Minnesota. He has been published and has lectured nationally and internationally. Over the years, his private practice in suburban New Orleans, The Smile Design Center, has become limited to cosmetic dentistry. His experience is based on a dedication to the belief that "excellence" and "esthetics" not only are compatible but can take dentistry to a new level of satisfaction and success.



Jenny L. Wohlberg, MDT

Jenny Wohlberg is vice president of Valley Dental Arts and a Master Ceramist who heads the training program for the Ceramics Department. She has been fortunate to study with many world-class ceramists, including Enrico Steger, Claude Sieber, Pinhasi Adar, Taki Nishihata, Matt Roberts, Thilo Voch, and Willi Geller. She spent nearly 8 years under the instruction of Dr. Robert Nixon in a number of hands-on seminars, and in 1998 she participated in a live-patient series through PAC-live, working under the instruction of Dr. David Hornbrook and Master Ceramist Matt Roberts. She is one of only 16 individuals in the world to be named accredited technicians by the American Academy of Cosmetic Dentistry.

Cariology and Caries Management

SECTION A

Caries Risk Assessment

V. Kim Kutsch

RELEVANCE TO ESTHETIC DENTISTRY

Dental caries is a transmissible infectious bacterial disease, a biofilm disease of the teeth that leads to decay and ultimate loss of the teeth. It is not corrected by eliminating a patient's cavities, but requires diagnosis and treatment of the biofilm disease to correct the infection. Patients who undergo major restorative dentistry (often esthetic dentistry) are generally patients who have had a lifelong, chronic experience with dental caries. Unless the infection is diagnosed and treated, they remain in a diseased state, putting all of their expensive restorative dentistry at high risk for recurrent decay and loss.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Historically dentistry has treated dental decay with a surgical model, drilling the decayed tooth structure away and replacing it with a restorative material. Dental caries has been recognized for over 100 years as a disease that contributes to decay. Early pioneers—G.V. Black, Leon Williams, and others—recognized the relationship of dental plaque to decay. Over a period of decades, several bacteria have been identified and connected to the decay process. These bacteria include primarily *Streptococcus mutans* and *Lactobacillus.* Both of these types of bacteria are saccharolytic (metabolize carbohydrates), acidogenic (produce small molecular organic acids from the carbohydrate metabolism), aciduric (survive in acidic or low pH environments, pH ranges that dissolve the calcium and phosphate minerals from the teeth), and cariogenic (contribute to the decay process as a result of these characteristics). The prolonged periods of low pH on the teeth lead to a net mineral loss from the dental tissues and produce decay, cavitation, and loss of the teeth. Many studies over the last 30 years correlate high levels of *mutans streptococci* and lactobacilli with dental caries. However, this is more than a single- or double-pathogen disease process in the classic model of infection. Dental caries has multifactorial causation, with environmental risk factors, individual risk factors, and behavioral and dietary influences as well as the biofilm component. Literally any saccharolytic, acidogenic, and aciduric bacteria could contribute to the caries biofilm and lead to dental caries. In 1989 Philip Marsh demonstrated conclusively through a series of studies that it is not the sugar availability that leads to decay, but rather the acid production from the metabolism of the sugars. The resulting low pH environment provides the selection pressure to favor these bacteria in a patient's mouth. Today up to 24 different bacterial species have been implicated in dental caries. Preza and co-workers demonstrated that additional species of bacteria need to be considered in the root surface caries biofilm, including *Atopobium, Olsenella, Pseudoramibacter,* and *Selenomonas.* In 2008, Takahashi and Nyvad demonstrated that during protracted periods of low pH in the oral biofilm, even the potential commensal oral streptococci become more acidogenic and aciduric and contribute to the disease process. They identified *Streptococcus gordonii, Streptococcus mitis, Streptococcus oralis,* and *Streptococcus anginosus* and termed these bacteria *low-pH, non-MS streptococci.* They described this phenomenon as an extension of Marsh's earlier "ecological plaque hypothesis." But it brings to light that it is important not only which bacteria are present in a patient's biofilm, but what those bacteria are doing. In addition, other factors have been reported and studied with regard to their role in the disease process. Known risk factors now include previous history of decay, radiographic lesions, white spot lesions, visible plaque on the teeth, frequent snacking, low saliva and poor saliva buffering capability, xerostomia-producing medications, poor diet, suboptimal fluoride exposure, poor dental care habits, and low

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socioeconomic status. Today dental caries necessitates a caries risk assessment with a validated questionnaire to evaluate and correct the modifiable risk factors for an individual patient. It necessitates diagnosis of the bacterial infection using bacterial metric testing or culture. Finally, it necessitates specific targeted antimicrobial therapy of the biofilm infection to predictably and effectively treat the disease. Simply drilling and filling cavities, a surgical approach to treating a bacterial infection, does not diagnose or treat the disease and is no longer acceptable as a standard of care.

RELATING FUNCTION AND ESTHETICS

Caries risk assessment is related to function and esthetics in that drilling and filling restorative dentistry has little to do with treating the infection, although it does restore the teeth to function and eliminates pain in the short term. For predictable long-term success with regard to function and esthetics in restorative dentistry, the dental caries biofilm disease must be assessed, diagnosed, and treated as the disease process it is. Unless this is done, most restorative dentistry is destined to fail with "recurrent decay" (although the disease process is actually left in place). About 70% of all restorative dentistry is the replacement of previous restorations.

CLINICAL CONSIDERATIONS

Indications

Caries risk assessment should be performed at least annually on every patient. Although a patient may be in a low risk category and not have any signs or symptoms of the disease, risk factors change over time. A patient may become at high risk for dental caries at any point of life. For example, an adult who has been decay free for 20 years may develop hypertension and begin taking antihypertensive medications, which have the side effect of xerostomia, or a dry mouth. This alone may be enough to tip the scales and create an environment that favors cariogenic bacteria, placing the patient at high risk for caries and leading to decay. This condition might be further complicated if the patient begins chewing gum, candy, or lozenges that contain sugar. The goal of caries risk assessment is to identify patients at risk for the disease and treat them before cavities appear.

Contraindications

There are no contraindications to caries risk assessment, because all of the benefits outweigh any risks. However, there is little benefit to providing caries risk assessment for people who are edentulous, although they may benefit if they also have xerostomia and are experiencing problems. *Candida albicans* is acidogenic and aciduric and may be a problem for these patients. *C. albicans* can be treated with pH-elevating or pH-neutralizing products.

MATERIAL OPTIONS

Dental Caries Treatment Strategies

For all patients, any restorative and biomechanical needs must be addressed. Restoration of the defects may return the teeth to function but have little to do with correcting the dental caries biofilm disease. Many different options are available for treating the biofilm disease process. A comprehensive approach to treating the dental caries patient involves addressing every aspect of the disease. These strategies can be broken down into major groups and ideas. First in most treatment considerations are the reparative procedures required to correct the physical damage to the teeth. This includes remineralization of lesions that have not cavitated and still have an intact enamel surface with fluoride and calcium phosphate or hydroxyapatite, plus minimally invasive restorations using biomimetic materials for lesions that have cavitation and decay present. The next strategies are focused on the therapeutic approach to correcting the bacterial biofilm component of the disease. These procedures include antimicrobial agents, pH corrections, and metabolic agents (xylitol). Additional strategies include behavioral changes to improve the oral environment to favor a healthy biofilm. Typically this involves oral hygiene instructions for improved home care and plaque control plus dietary counseling. Some nonmodifiable factors may need to be addressed by adding more protective factors to the patient's risk-and-caries balance equation. Special needs patients and those with xerostomia or medication-induced xerostomia fall into this category.

Remineralization Therapy

Remineralization has historically involved the use of topical fluoride. Stannous fluoride and acidulated fluorides were introduced first, but more recently neutral fluoride products have been used. The fluoride is applied in many different methods, such as 1 ppm public water fluoridation, 1100 ppm fluoride dentifrice, 5000 ppm fluoride gels and foams, 223 ppm fluoride rinse, and 23,000 ppm fluoride varnish. Fluoride's basic mode of action enhances remineralization and inhibits demineralization. Fluoride ions incorporate into remineralizing enamel and dentin carbonated apatite to produce a more acid-tolerant fluorapatite-like form. Fluoride also makes hard tissues more acid resistant and inhibits bacterial intracellular enzymes.

More recently, nano-particle hydroxyapatite and CPP-ACP have made calcium and phosphate ions bioavailable to aid in the remineralization process. The benefits of additional sources of these ions is unclear. Some clinicians believe that the need to supplement sources of calcium and phosphate is limited to the xerostomic patient, in whom these molecules may be in short supply. Others believe there is added benefit to increasing the availability of calcium and phosphate in high-risk caries patients. Clearly, more studies are needed to answer this question. Products include Recaldent (Recaldent Pty Ltd, Australia), NovaMin (GlaxoSmithKline, United Kingdom), Trident (Warner-Lambert, Morris Plains, New Jersey), MI Paste (GC America, Alsip, Illinois), and pHluorigel HA and HA Nano Gel (Carifree, Albany, Oregon).

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Restorative Strategies with Minimally Invasive Dentistry

Dental caries can be site, tooth, patient, and population specific. Ideally, successful caries prevention implies there will be no irreversible changes to any tooth site or surface (occlusal, approximal, smooth, or root surface). If prevention fails at any site, the greatest benefit for the patient begins with early lesion detection. Such detection should trigger protocols for chemical remineralization and interventions to arrest and reverse early damage caused by demineralization before surface cavitation occurs. Only if surface cavitation develops should surgical restoration be performed, and then it is done by using the most minimally invasive approach possible, maintaining the maximum amount of healthy tissue and structural integrity of the tooth. The restoration is completed with the most appropriate dental restorative material suited for that particular lesion and that particular patient.

Traditionally dentists identified cavitated lesions using a sharp explorer tip, visual examination, and/or radiographs. The explorer in a given dental practice may not have been sharp, so defining lesions in specific states of cavitation varied from dentist to dentist. Numerous studies report that the use of a dental explorer is not adequate for detecting early occlusal lesions at all and not only may lead to a significant number of undetected lesions, including some false positives, but may, if it is sharp, cause traumatic surface defects in teeth. Radiographs are not useful for early occlusal lesions because of the masking effect of the facial and lingual enamel. New research has suggested the use of a visual ICDAS code system. ICDAS, an acronym for International Caries Detection and Assessment System, can be thought of as a coding system of 0 to 6 that correlates what is seen clinically with a definition and what research has reported histologically. The gradient starts with a code 0, which is a completely intact and healthy occlusal fissure system, and ends with a code 6, a fissure that is cavitated with a frank carious lesion. Recently Jenson and colleagues published various protocols based on ICDAS code and caries risk. Included is how one would use laser detection technology such as a DIAGNOdent (KaVo Dental, Charlotte, North Carolina) in the decision-making process (Figure 1-1).

With traditional methods of lesion detection, patients who saw different dentists could be given conflicting information as to whether they had cavities. Confusion led to issues of trust and situations in which needed care was not rendered (undertreatment) or restorations were placed when chemical remineralization would have been more appropriate (overtreatment). In the past the issue of cavitated and precavitated lesions was not relevant for many practitioners. Whether the enamel surface is cavitated or not is the determining factor in deciding to chemically remineralize a lesion. If the enamel surface is still intact, the bacteria are physically too big to diffuse through the enamel surface to infect the dentin and can successfully be managed with remineralization protocols. Interproximal or bitewing radiographs can be interpreted differently, so there is no definitive way to detect early lesions. Lesions penetrating minimally into the enamel may be surgically restored by some clinicians, whereas others wait for the dentin breech to be confirmed radiographically. Based on scientific evidence, current recommendations are to surgically intervene on the approximal smooth surface only if the bitewing radiograph shows both a solid enamel radiolucency going from the surface through the enamel and that the dentin has been penetrated. Digital radiographs have the benefit of exposing the patient to less radiation. The digital image can also be enhanced and enlarged easily, enabling better detection and monitoring of early lesions.

Lesion detection on the tooth root is best accomplished by visual inspection. The chemistry of remineralization is the same on the root (cementum) as it is for enamel. However, early lesion detection is difficult, because in theory no visible change is present in an early lesion. Many individuals have proposed that any exposed root is a root at risk because of its lower mineral content and vulnerability to acid and enzyme dissolution. Careful monitoring of remineralization of early lesions is needed because of the more porous nature of cementum and dentin (less mineral compared with enamel) and the close proximity to the dental pulp in deeper root lesions. If restoration is needed on a root surface, chemical adhesion and fluoride release (charging and recharging) of glass ionomer restorative materials should be considered, especially when use of a rubber dam is not feasible.

The current state of lesion detection leaves behind the dental explorer and involves a more scientific approach with the use of ICDAS, DIAGNOdent, digital radiographs, and some interesting new technologies. Quantitative light-induced fluorescence (QLF) measures the degree of demineralization by using the natural fluorescence of teeth. With this computer-assisted technology, white spot lesions can be monitored over time to determine if the lesion is progressing or remineralizing. Simply put, healthy enamel structure has different optical properties than decalcified enamel; it has a different optical signature. The fluorescent signal reflected from the decalcification (white spot lesion) of the enamel is captured by a fiberoptic sensor and interpreted through a computer-based algorithm to determine the amount of demineralization.

Therapeutic Caries Strategies

Antimicrobial therapy has traditionally involved chlorhexidine as a first defense in treating dental caries. It was thought to be effective at attacking the *Mutans* streptococci but has little effect on lactobacilli. Recent research has indicated that following chlorhexidine therapy, one phylotype of *Mutans* streptococci consistently remains and appears to be not only resistant but also strongly pathogenic. Ethyl alcohol and essential oils have also been used in the past. There have been new reports of efficacy with 10% povidone iodine and recommendations for 0.10% sodium hypochlorite as an antimicrobial rinse. A recent study raises the issue of a potential link between ethyl alcohol–containing oral mouthrinses and oral cancer in individuals otherwise not at risk for cancer. Products from the chlorhexidine category include Peridex and PeriGuard (DermaRite Industries, Paterson, New Jersey). In the sodium hypochlorite category, a product is CariFree Treatment Rinse (Oral BioTech, Albany, Oregon).

Occlusal Protocol ***							
ICDAS code	0	1	2	3	4	5	6
Definitions	Sound tooth surface; no caries change after air drying (5 sec); or hypoplasia, wear, erosion, and other noncaries phenomena	First visual change in enamel; seen only after air drying or colored change "thin" limited to the confines of the pit and fissure area	Distinct visual change in enamel; seen when wet, white or colored, "wider" than the fissure/fossa	Localized enamel breakdown with no visible dentin or underlying shadow; discontinuity of surface enamel, widening of fissure	Underlying dark shadow from dentin, with or without localized enamel breakdown	Distinct cavity with visible dentin; frank cavitation involving less than half of a tooth surface	Extensive distinct cavity with dentin; cavity is deep and wide involving more than half of the tooth
Histologic depth		Lesion depth in P/F was 90% in the outer enamel with only 10% into dentin	Lesion depth in P/F was 50% inner enamel and 50% into the outer 1/3 dentin	Lesion depth in P/F with 77% in dentin	Lesion depth in P/F with 88% into dentin	Lesion depth in P/F with 100% in dentin	Lesion depth in P/F 100% reaching inner 1/3 dentin
Sealant/restoration Recommendation for low risk	Sealant optional DIAGNOdent may be helpful	Sealant optional DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration
Sealant/restoration Recommendation for moderate risk	Sealant optional DIAGNOdent may be helpful	Sealant recommended DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration
Sealant/restoration Recommendation for high risk *	Sealant recommended DIAGNOdent may be helpful	Sealant recommended DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration
Sealant/restoration Recommendation for extreme risk **	Sealant recommended DIAGNOdent may be helpful	Sealant recommended DIAGNOdent may be helpful	Sealant optional or caries biopsy if DIAGNOdent is 20-30	Sealant or minimally invasive restoration needed	Minimally invasive restoration	Minimally invasive restoration	Minimally invasive restoration

* Patients with one (or more) cavitated lesion(s) are high-risk patients. ** Patients with one (or more) cavitated lesion(s) and xerostomia are extreme-risk patients.

*** All sealants and restorations to be done with a minimally invasive philosophy in mind. Sealants are defined as confined to enamel. Restoration is defined as in dentin. A two-surface restoration is defined as a preparation that has one part of the preparation in dentin and the preparatio extends to a second surface (note: the second surface does not have to be in dentin). A sealant can be either resin-based or glass ionomer. Resin-based sealants should have the most conservatively prepared fissures for proper bonding. Glass ionomer should be considered where the enamel is immature, or where fissure preparation is not desired, or where rubber dam isolation is not possible. Patients should be given a choice in material selection.

FIGURE 1-1 The International Caries Detection and Assessment System (ICDAS). *(From Jenson L, Budenz AW, Featherstone JD, et al: Clinical protocols for caries management by risk assessment, J Calif Dent Assoc 35:714, 2007.)*

pH strategies include raising the pH or buffering the oral environment to promote remineralization and encourage repopulation of commensal bacteria. The demineralization-remineralization gradient for enamel peaks at roughly pH 5.5. Below this pH, demineralization occurs, whereas at above 5.5, remineralization occurs. Prolonged periods of low pH in the mouth favor acidogenic, aciduric, and cariogenic bacteria, so pH strategies should be a component of the overall plan for patients at high risk for caries. Products addressing pH include Arm and Hammer Baking Soda products and CariFree products (Oral BioTech). These are available as gums, dentifrices, oral neutralizing gels and sprays, and rinses.

Xylitol is a naturally occurring alcohol sugar not metabolized by *mutans* streptococci that has effective anticaries activity. In addition to inhibiting the attachment of the biofilm, it also interferes with intracellular metabolism. The *mutans* streptococci cannot use or break down xylitol and use up energy to expel it from the cell. Xylitol is available in many forms: gum, lozenges, mints, sprays, rinses, pastes, and a baking substitute for sugar or other sweeteners. Xylitol has the advantages of being low calorie and not stimulating insulin production in diabetics. Xylitol can create gastrointestinal distress at high levels of consumption and may be toxic for dogs. A multitude of xylitol products is available, including Omnii 3M (3M ESPE, St Paul, Minnesota), Epic (Epic Industries, Provo, Utah), Spry (Xlear, Orem, Utah), and CariFree (Oral BioTech).

Modifiable Caries Risk Factors

The most common modifiable risk factors for dental caries are dietary habits. Scientific studies clearly demonstrate that the pH drop from the dietary sugars is the selection pressure for dental caries. One of the most important factors is not the amount of sugar consumed, but the frequency of consumption during the day. Frequent between-meal snacking leads to prolonged periods of low pH in the mouth. Based on the traditional Stephan curve, with frequent snacking, the mouth never has the opportunity to buffer the low pH and return the environment to the state that promotes remineralization. This favors the cariogenic bacteria (Marsh); conditions the low-pH, non-MS streptococci to become acidogenic and aciduric (Takahashi and Nyvad); and leads to dental caries. Overall bacterial numbers are also important in the caries process, and daily plaque control is important to control the disease. Good oral hygiene instructions can improve a patient's plaque control ability.

Advantages

In the reparative process, remineralization is best approached with fluoride. The efficacy of fluoride varnish is supported by the best scientific evidence, followed by fluoride rinses and fluoride dentifrice. Provisional restoration is best accomplished with a product for high–caries-risk patients that is biomimetic and provides fluoride release. Final restorations consisting of adhesive, bonded esthetic restorations provide the best result once the patient is caries free.

In the therapeutic process, sodium hypochlorite is very effective as an antimicrobial agent. It penetrates a biofilm, kills bacteria on contact, is broad spectrum, and is least likely to produce resistant bacteria and adverse host reactions. It also has the advantage of having a high pH. Xylitol has the advantage of interfering with the metabolism of cariogenic bacteria, which poorly metabolize it. It significantly reduces the levels of these bacteria when administered in various products and in the diet. Based on the results of Philip Marsh's early work and Takahashi and Nyvad's recent research, a product that helps balance or raise the pH is a significant part of caries treatment.

Disadvantages

Chlorhexidine is a good antimicrobial agent but alters taste sensations and stains the teeth; both of these side effects can easily be managed. It has virtually no effect on lactobacilli. Povidone iodine is an effective antimicrobial agent for children but demonstrates no net effect in adults. Aside from the side effects of a strong unpleasant taste, taste alteration, and staining of surfaces, it can be applied only once a month. Sodium hypochlorite has a strong chlorine flavor. There is limited evidence that fluoride has any beneficial anticaries effects in adults. Xylitol causes gastrointestinal distress, diarrhea, and cramping if too much is consumed, and it is toxic to dogs. No scientific studies demonstrate any problems associated with the long-term use of pH-elevating products.

Current Best Approach

The current best approach to treating dental caries is to address the specific risk factors for each patient and modify factors that can be modified, while creating more protective factors to compensate for risk factors that cannot be modified. Patients should then be treated with a fluoride varnish every 3 months until they are disease free. Their cavitations can be restored using glass ionomer–based products as provisional restorations. These patients are given a regimen of antimicrobial products and maintenance products that improve the pH environment of the biofilm to eliminate cariogenic bacteria and favor commensal and healthy bacteria. High–caries-risk patients should be monitored until they are healthy and then screened at least annually.

OTHER CONSIDERATIONS

The most important consideration in performing a caries risk assessment and the medical management of dental caries is to use a standardized, validated caries risk assessment form. Several forms and sources are available (e.g., *Journal of the California Dental Association,* October-November 2007; www.cdafoundation.org; and other resources). In addition, in January 2009 the Scientific Council of the American Dental Association (ADA) endorsed caries risk assessment and provided a form available on the ADA website: www.ada.org/prof/resources/topics/topics_caries_over6.doc. Many forms include disease indicators, risk factors, and protective factors. Some forms stratify patients into high, moderate, or low risk categories; other forms also stratify them into extreme risk categories; and yet other forms include a determination of whether the

caries is active or inactive. A simple caries risk assessment form that identifies the patient's specific caries risk factors is all that is necessary. A simplified version based on a published form is presented in Figure 1-2.

Performing caries risk assessment must be simple and straightforward. In private practice, most risk assessments are done in the hygiene operatory. The most important decision to be made in the operatory in real time is whether the patient is at risk for dental caries and continued or future lesion development. The decision must be made accurately and in relatively simple terms. Is the patient not presently at risk for disease, so he or she can be placed on an annual or biannual recare schedule with routine prevention measures and selection of restorative material? Or does the patient currently have dental caries and remain at continued risk for this disease, needing a more aggressive approach to treatment of the biofilm disease and specifically targeted prevention protocols in addition to any restorative needs? The assessment process should differentiate between these two groups of patients and identify the specific risk factors for each individual patient that potentially contribute to the biofilm disease process. This patient-specific information then becomes useful for treatment recommendations.

As already noted, risk factors that are not modifiable, such as age, amount and quality of saliva, or medication-induced xerostomia, must be counterbalanced in the treatment and prevention protocol with positive influences. With all the normal requirements and procedures already included in the hygiene operatory during a recare or new patient visit, this process must be precise and timely to be incorporated into an active dental practice. A simple risk assessment form that asks the right questions and produces the right patient profiles is the most desirable.

Special needs patients, patients with medication-induced xerostomia who cannot have their medication regimen altered, and children in low socioeconomic situations also have nonmodifiable risk factors. For these patients, it is important to increase the protective factors and help compensate for their risk factors to achieve a balanced state of health. This includes reinforcing home care instructions, modifying the toothbrush handle for a special needs patient if applicable, adding more fluoride to the daily regimen, providing dietary counseling, and prescribing pH-neutralizing products that can be used frequently during the day.

INNOVATIVE ELEMENTS

Scientific Advances

Current scientific studies are focusing on caries risk assessment and validating risk factors, along with demonstrating the efficacy of the medical model of caries treatment and management. New studies examine the potential benefits of elevating the dental biofilm pH to promote the growth of healthy commensal bacteria and discourage the growth of cariogenic bacteria. Studies can create laboratory biofilm models to help our understanding of the nature of the dental biofilm. Additional studies are using rRNA extraction and profiling of the bacterial biofilm to develop a more applicable biofilm model of the disease. Studies also compare the presence or absence of bacterial species in healthy and diseased states. Using biofilm profiling with the 16S gene sequence, research is now accurately identifying exactly which bacteria are present and estimating their relative numbers. This is slowly creating a much clearer picture of the dental caries disease process.

Technologic Advances

Traditionally, cariogenic bacteria levels were determined using a bacterial culture, typically by taking a saliva sample and culturing the saliva for *Mutans streptococci* and lactobacillus and extrapolating the data to determine the levels of these bacteria on the teeth. Disadvantages of the culturing technique as a screening test, diagnostic metric, or surrogate endpoint are that the cultures are not that sensitive or specific and do not correlate well with the patient's actual caries risk. Cultures are helpful from an educational and motivational standpoint but are not accurate enough for more delineated decision making. They also are time-consuming; cultures typically require an incubation of 48 hours to yield a result, so in a busy general practice, adding this step is a management and systems issue. New applications of older technology have been developed, tested, and validated as screening tests for dental caries. All acidogenic and aciduric bacteria can survive in a low-pH environment through various adaptive mechanisms. For example, some bacterial intracellular enzymes can adjust activity to lower levels during prolonged periods of acidic pH (below 5.5). They can also pump the hydrogen (acidic) ions back out of the cell to retain intracellular neutrality while they are in an acidic environment. This hydrogen pump runs continuously and uses a tremendous amount of energy. All living cells derive energy from adenosine triphosphate (ATP). The ATP levels in a patient's dental biofilm can be extrapolated to reflect energy use, which provides a high degree of correlation to the acidogenic and aciduric bacteria present. This can be accomplished in a simple chairside, real-time test with a light-sensitive meter and bioluminescence technology. The CariFree CariScreen system (Oral BioTech) is a newly developed test that has proved effective as a 15-second chairside screening test for dental caries.

ARTISTIC ELEMENTS

Artistic elements apply directly to the restorative aspect of dental caries. Unfortunately, the best provisional restorative material for high–caries-risk patients during the initial treatment phase are glass ionomer materials, which are not as esthetic as composite resins or porcelain. The recommended procedure is to eliminate all cavitations quickly and restore initially with fluoride-releasing glass ionomers until the caries biofilm infection can be resolved and more definitive esthetic restorations can be placed. Fluoride varnish is important for delivering fluoride in the early stages of remineralization therapy in the patient at high caries risk but is not very attractive on the teeth. Many practitioners have dealt with this challenge by placing the

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CariFree®

WWW.carifree.com 866.928.4445

CARIES RISK ASSESSMENT

Adults/Children Over Age 6

Patient Name: _____ Date: _____

Instructions: Check all answers that apply.

If **1 or more Disease Indicators** *or* **2 or more Risk Factors** are circled, then this patient is at risk and therapeutic intervention is recommended.

1 ASSESS

DISEASE INDICATORS

	AT RISK	LOW RISK
Visible Cavitations	yes	no
Radiographic Lesions	yes	no
White Spot Lesions	yes	no
Cavity in Last 3 Years	yes	no

RISK FACTORS

Visible Plaque	yes	no
Inadequate Saliva Flow	yes	no
Hyposalivary Medications	yes	no
Acidic Beverages	yes	no
Frequent Snacking (1-3 times daily)	yes	no
Appliances Present	yes	no
Deep Pits and Fissures	yes	no
Other	yes	no

TESTING

CariScreen	9,999 – 1,501	1,500 – 0

2 DIAGNOSE

Risk Assessment	AT RISK	LOW RISK

3 PRESCRIBE

☐ Treatment Kit ☐ Maintenance Kit

I understand my risk for caries based on this assessment, as well as the benefits of the recommendations for therapeutic intervention.

Release Signature: _____

* Based on clinically proven Caries Risk Assessment Form in the Featherstone 2003-2005 study.
* Caries risk criteria as defined by the American Dental Association Council on Scientific Affairs, JADA August 2006.

FIGURE 1-2 Simplified caries risk assessment form. *(Courtesy Oral BioTech, Albany, Oregon.)*

fluoride varnish on the posterior teeth only, providing a ready reservoir of fluoride for sustained substantivity without compromising anterior esthetics.

TREATMENT PLANNING

Options

The design of the treatment plan should address the specific needs and risk factors identified for the patient. The various material options for the reparative sequence were discussed previously for both remineralization and restoration. The options for the therapeutic sequence must apply specifically to the needs of the patient. For example, a xerostomic senior patient may benefit from fluoride varnish treatment every 3 months plus daily use of fluoride rinse and pH-neutralizing products. This patient may also benefit from oral spray to moisten the mouth and boost pH between meals. An adolescent in orthodontic braces would benefit from daily use of fluoride rinse and home care instructions, diet counseling, and xylitol products. A patient who has had major restorative esthetic care would benefit from daily use of nonabrasive pH-neutralizing and xylitol-based products to maintain a healthy biofilm and reduce the risk for recurrent decay.

Sequence

The sequence in treating the patient at high caries risk is simple. Reparative needs are treated at the same time the therapeutic regimen is implemented. So the sequence would be fluoride varnish treatment first, then, as soon as possible, restoration of all carious lesions with glass ionomer and the application of antimicrobial agents, remineralization, xylitol, and pH strategies all at the same time. Patients should be placed on a 3-month recall schedule to evaluate their program. They can be given continued therapy as indicated and retested for their CariScreen score, with additional fluoride varnish and counseling as needed.

TREATMENT CONSIDERATIONS

Treatment considerations are straightforward. High–caries-risk patients should be initiated into therapy immediately and monitored as indicated. Low-risk patients should be screened annually.

Preparation

For the restorative or reparative phase, the primary goal is to remove all of the decay as soon as possible and place provisional restorative materials like glass ionomers. The preparations themselves need only remove the decay and are not intended to be definitive restorations. This can be accomplished with a high-speed or low-speed handpiece and carbide or diamond bur, air abrasion, or a hard tissue erbium-based laser. Remaining carious lesions act as a nidus of infection and continue to reinfect the mouth. It is important in the initial phase of treatment to eliminate these areas.

Procedure

The procedure is simple and not elegant. Local anesthesia is used where indicated, and the decay is removed and restored with glass ionomer as a provisional material.

Finishing

Finishing is simple as well. The restorations can be finished with a diamond bur or fluted carbide finishing bur once the glass ionomer has set, and then sealed with a resin to keep the moisture out while the material matures during the subsequent 24 hours.

EVIDENCE-BASED PRINCIPLES

Several basic principles of caries risk assessment and the medical model of caries treatment have been validated by scientific studies. Caries risk assessment was validated in a large-scale study of two insured populations totaling 45,683 individuals. The results demonstrated that patients diagnosed as being at high caries risk were four times as likely as patients diagnosed as being at low caries risk to have a decay event during the test period. Patients identified as being at moderate risk were twice as likely as low-risk patients to have a carious lesion. This large-scale study validates the usefulness of caries risk assessment in predicting caries risk among adult patients. The study also demonstrates the lack of benefit from fluoride treatment in adults when stratified by risk category. Caries risk assessment forms and risk factors have been validated and weighted in two clinical studies. Caries risk assessment combined with the medical management of caries (caries management by risk assessment [CAMBRA]) has been validated in a clinical study. Patients demonstrated significantly reduced levels of cariogenic bacteria and carious events during the test period. Additional scientific studies provide evidence of the efficacy of fluoride regimens in children, the correlation of cariogenic bacterial loads to dental caries, and the valid use of ATP levels to the cariogenic bacterial loads. Xylitol has numerous scientific studies proving its efficacy in reducing both cariogenic bacterial load levels and caries rate. Biofilm studies are providing a clearer picture of the diverse nature of biofilms and the complexity of the dental caries biofilm disease.

CLINICAL CONSERVATION CONCEPTS

The best dentistry is no dentistry. The conservation of healthy tooth structure and the routine use of minimally invasive procedures is the best care the profession can provide. The goal of CAMBRA is to identify patients at risk for dental disease and correct the situation before signs and symptoms of the disease develop, thereby conserving a patient's healthy tooth structure. The earliest expression of dental caries comes from net mineral loss of the teeth. These lesions begin as white spot lesions, which

can be remineralized without any operative treatment. Early and aggressive identification of the disease process leads to the most minimally invasive approaches.

MAINTENANCE

Once patients have had their dental caries treated and been diagnosed as caries free, healthy, and/or at low risk for disease, the next step is maintenance of their health and prevention of future disease. The best maintenance is provided by an annual risk assessment, bacterial screening metric, and routine daily maintenance of health with proper oral care.

CONTROVERSIES

Few controversies surround caries risk assessment or the materials and products used in the medical management approach to treating the disease. All of the CAMBRA philosophy is logical and has sound scientific evidence supporting the concept and materials. The only controversy is the concept of standard of care because the profession is slow to embrace these principles. Currently the concept of caries risk assessment is taught as the standard of care at most U.S. dental schools, is rapidly being incorporated into the curriculum, and is included in board examinations. The reality is that the benefits far outweigh any potential risks.

NEAR-FUTURE DEVELOPMENTS

Near-future developments look at several different ideas. Many novel remineralizing materials are currently being tested and developed. Other ideas involve the development of specifically targeted antimicrobial peptides that target a specific pathogen, such as *Mutans streptococci.* The extended ecological plaque hypothesis proposed Takahashi and Nyvad supports the mixed-bacteria ecologic approach that the proportion of acid- and base-producing bacteria is the core of caries activity. This undermines the view that dental caries is a classic infectious disease, and trying to treat the disease with elimination of one or two species such as *Mutans streptococci* with vaccination, gene therapy, or targeted antimicrobial treatment will be unwise and produce limited results. Ultimately, environmental control that reduces the acidification of the biofilm and trains healthy behavior of the bacteria is a better strategy. Additional products are being developed based on the pH selection pressure principle of the biofilm disease. These are designed to neutralize the biofilm for extended periods of time, resulting in a healthy oral biofilm, remineralization, and a net mineral gain.

CLINICAL TECHNIQUES

CASE 1 Adult with Low Caries Risk (Figure 1-3)

The patient is a 52-year-old woman with no medical issues. She is not taking any medications and has no allergies. She has not had any restorations in 13 years. No decay is present on examination, no radiographic lesions are present, the caries risk assessment form indicates she is at low risk and has no risk factors for dental caries, and her CariScreen score is 782, which also indicates low risk. She is diagnosed as caries free and at low risk for the disease. The patient has no immediate need for restorative dentistry, but she is provided instructions on home care, prevention products, dietary counseling, the concept of caries as a biofilm disease, caries risk factors, and the need for annual screening. If she has any elective dentistry she wants done, any appropriate esthetic material can be safely and predictably used.



FIGURE 1-3 A 52-year-old low–caries-risk patient.

CASE 2 Adult with High Caries Risk (Figure 1-4)

The patient is an ambulatory 47-year-old man. He has hypertension and is under the direct care of a physician. He is currently taking antihypertensive medication but has no allergies or other medical issues. He complains of a dry mouth and is concerned about losing his teeth. The patient has multiple missing teeth, visible plaque and carious lesions, multiple radiographic lesions, and a CariScreen score of 8756 (high risk). He is identified as at high risk on the risk assessment form. Among his multiple risk factors are dry mouth, poor oral hygiene, frequent snacking, medication-induced xerostomia, and suboptimal fluoride exposure. Treatment planning is broken into reparative processes and therapeutic processes. On the reparative side, remineralization is initiated with fluoride varnish and twice-daily use of fluoride rinses. Restoration consists of provisional restorations to repair all lesions with glass ionomer restorative material. The therapeutic regimen consists of antimicrobial rinses with sodium hypochlorite and fluoride twice a day for a month, followed by daily continued use of a pH-neutralizing fluoride and xylitol rinse and neutralizing xylitol gel twice a day until the 3-month recall interval. He is also given a pH-boosting oral spray to use between meals and immediately after any snacks. He is also given oral home care instructions and dietary counseling. He is placed on a 3-month recall schedule for review, reassessment, and retesting. This 3-month cycle of treatment and retesting is continued until health is achieved. Once the patient is determined to be caries free and at low risk for future disease, he is then scheduled for complete definitive restoration of his teeth, considering both function and esthetics.



FIGURE 1-4 A 47-year-old high–caries-risk patient.

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B SECTION

Cariology: Its Role in Esthetic Dentistry

Tomás Seif

RELEVANCE TO ESTHETIC DENTISTRY

Restorative dentistry is a rapidly evolving field. In the past, treatments depended solely on the opinion of the treating dentist. Today treatments are mainly "patient driven," which means that the people who receive dental services choose not only the dentist, but also the type of dentistry they want to receive.

We live in a beauty-conscious society. In fact, the advertising community has been pushing for many years the idea that "beautiful is better." A popular book, *Change Your Smile* by Dr. Ronald Goldstein (Quintessence Publishing), is geared toward patients and states, "Taking steps to improve our appearance today is considered an investment in our health and well being, it is socially acceptable as it is personally gratifying." If this is true, cosmetic dental services are socially acceptable and perfectly suitable for improving patients' appearance. However, dental professionals must be extremely careful to "really" gratify these patients not only with esthetically driven treatments but also with *long-lasting results,* as these patients invest time and money in their health and well-being. So, can we practice esthetic dentistry without proper knowledge of modern caries management (Figure 1-5)?*

GRATIFYING THE PATIENT WITH LONG-LASTING ESTHETICS

Patients will not be personally gratified solely with beautiful functional restorations that have been skillfully placed. Restorations must look good, feel good, and especially last for the longest time possible. For this to happen, the dentist who provides restorative treatments not only must be on the cutting edge of cosmetic and dental materials knowledge but also should understand the **longevity** of these restorations, considering the following three fundamental aspects:

1. *A healthy oral environment.* If any restoration is placed in an unhealthy oral environment, the majority of materials as well as the teeth that support them will not stand the test of time. *This is where the dental professional and clinical staff must have up-to-date knowledge about modern caries management, diagnosis, and treatment strategies.* This chapter focuses on these parameters. Periodontal and occlusal aspects are also important and are covered elsewhere in this book.
2. *A thorough understanding of the "restoration–dental pulp complex" relationships.* Restoring teeth with pulpal compromise that has not been properly identified and diagnosed before treatment (even in the absence of symptoms) poses a serious dental risk in the near future. This will make endodontic procedures necessary after the new restorations have been placed, requiring access to the pulpal chamber and affecting its integrity and esthetics while also affecting the perception of the patient about the quality of care.
3. *An effective maintenance regimen for the restored teeth.* Patients have long been instructed to practice good oral hygiene and return to the dental office for professional maintenance or recall visits. It is logical to also (a) educate patients who have received esthetic restorative treatments about how to maintain these restorations and (b) schedule regular visits for their maintenance.

If these fundamental steps are followed, the restorations will last longer in a healthy environment, patients will be happy, and their well-being will reflect on the dental office as well.

This chapter covers the fundamentals. The reader is encouraged to complete this information with further readings in these areas of knowledge.

A HEALTHY ORAL ENVIRONMENT

Brief History of the Clinical Development and Evolution of the Procedures

Almost a century ago, dental schools worldwide were attracted by the academic rigor of G.V. Black's approach to dental lesions. As a result, large departments of operative dentistry sprang up. Of course, operative techniques had (and still have) to be taught. However, they form the basis of teaching and not subsequent practice.

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FIGURE 1-5 **A, This patient had porcelain veneers placed in the anterior teeth only 14 months ago. Teeth were very sensitive to hot and cold stimuli; the patient was very dissatisfied with the dentist. Clinical intervention revealed secondary decay. B, If you were re-treating the case, would you expect to have a better outcome with only restorative dentistry?**

Operative departments often became the core centers where vast amounts of clinical time were invested and in which undergraduates strove to complete predetermined numbers of restorative treatments. However, in countries where such restorative dental treatment has dominated the scene, many shortcomings have now become apparent.

Practicing dentists and dental teachers have tended to see patients as people who have mechanical dental problems. These clinicians then become preoccupied with treatment procedures over prevention. A vivid example of this is the concept that proposes finishing margins of metal or metal ceramic restorations subgingivally to prevent recurrent caries in these areas. The overwhelming bias has been for dentists to focus on mechanical solutions to the problems posed by disorders (such as temporomandibular joint [TMJ] disorders) or bacterial diseases (such as dental caries and periodontal disease). This extends even to performing treatments (overtreating) even when reliable knowledge about the precise outcome of the procedures does not exist.

Firmly entrenched with this philosophy has been the erroneous belief that restored teeth equate with dental health. The vast majority of dental restorations are not as durable as is commonly believed by patients and dentists. Furthermore, most materials used for dental restorations have a weak link along the tooth-restoration interface and are therefore doomed to failure in the long term, even if executed to a reasonable technical standard using the latest adhesive materials, especially in the absence of proper maintenance (Figure 1-6).



FIGURE 1-6 **In the absence of proper maintenance, most materials used for dental restorations have a weak link along the tooth-restoration interface and are therefore doomed to failure in the long term, even if executed to a reasonable technical standard using the latest adhesive materials.**

Caries Management, Diagnosis and Treatment Strategies

Traditional caries management has consisted of detection of carious lesions followed by immediate restoration. In other words, caries was managed primarily by restorative dentistry. However, an irreversible process begins when the dentist takes the handpiece in hand. Placing a restoration does not guarantee a sound future for the tooth. On the contrary, it may be the start of a restorative cycle in which the restoration will be replaced several times.

The decision to initiate invasive treatments should be preceded by a number of questions, such as the following:

- Is caries present?
- If so, how far does it extend?
- Is a restoration required?
- Could the process be arrested by preventive treatment?

Sometimes the decision to restore may be based on questionable diagnostic criteria.

The introduction of adhesive restorative materials has allowed dentists to make smaller preparations, which has led to the preservation of hard dental tissues and, along with a decline in disease prevalence, has allowed the elimination of Black's principle of "extensions for prevention." Maximum tooth structure is preserved. However, this approach, sometimes described as the "dynamic treatment concept," cannot prevent repeated treatment procedures and the occurrence of iatrogenic damage. Lussi and Gygax showed that during the preparation of an interproximal lesion, the neighboring surface was damaged 100% of the time despite careful operating procedures.

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مهیار دندانسازان و دندانپزشکان

A Different Treatment Strategy

A different treatment strategy is recommended based on a proper diagnosis of caries, taking into account the dynamics of the caries process. The activity of caries should be determined, and causative factors evaluated. *Caries risk should be assessed in restorative dentistry before treatment is considered.* Treatment should include preventive regimens to arrest the caries process by addressing the imbalance between demineralization and remineralization.

The treatment goals in caries management should be to prevent new lesions from forming and to detect lesions sufficiently early in the process that they can be treated and arrested by nonoperative means. Such management requires skills, is time-consuming, and is worthy of appropriate payment. If these attempts have failed, high-quality restorative dentistry is required to restore the integrity of the tooth surface.

Etiology of Dental Caries

The factors involved in the caries process, which include the tooth, dental plaque, and diet, were presented in the 1960s in the model of overlapping circles. Since then, the model has been supplemented with the factors of time, fluoride, saliva, and social and demographic factors. At first glance, these circles constitute a simple model to explain caries risk, which is represented by the overlap of the three inner circles. When one of the risk factors increases, the respective circle becomes larger, as does the overlap of the circles, indicating increased caries risk. For instance, if there is hyposalivation, the saliva circle tightens and the three inner circles enlarge the overlap, again indicating a greater risk. Inversely, the model explains why reducing any risk factor decreases caries risk (Figure 1-7).

Dental Plaque

The prevalence of *mutans* streptococci *(Streptococcus mutans)* and lactobacilli is associated with dental caries. *S. mutans* is involved in caries formation from its initiation. Lactobacilli are so-called "secondary organisms" that flourish in a caries environment and contribute to caries progression (Figure 1-8). Dental plaque may be more cariogenic locally whereas *S. mutans* and lactobacilli are concentrated. In everyday practice, it is difficult for the dentist to identify cariogenic plaque to make this knowledge useful in treating individual patients. Plaque can be sampled and *S. mutans* and lactobacilli quantified, but the procedure is quite complicated and requires the support of a microbiology laboratory.

It is easier to count *mutans* streptococci and lactobacilli in saliva, and kits are commercially available for this purpose. These counts, however, do not give site-specific information and are poor predictors for high carious activities in general. Nevertheless, low counts and the absence of *S. mutans* are good predictors of low caries activity.

High numbers of *S. mutans* organisms and lactobacilli are probably the result of a high sugar intake and the resulting periods of lower pH levels in dental plaque. Inversely, the restriction of sugar intake reduces the number of *S. mutans* organisms and lactobacilli.

In one study of individuals complying with the Weight Watcher's diet, the number of *mutans* streptococci and lactobacilli was reduced by half. A comparable reduction was found in subjects who reduced their sugar intake frequency from 7.2 to 1.8 times a day. Interestingly, after a period of sugar restriction the pH response to glucose was reduced in buccal but not in interdental plaque. Apparently the reduced numbers of *mutans*

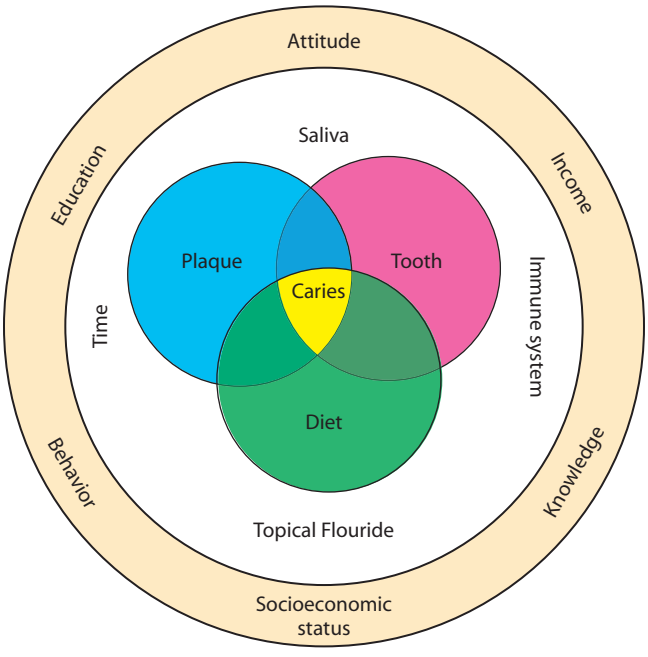


FIGURE 1-7 The factors involved in the caries process. When one of the risk factors increases, the respective circle becomes larger, as does the overlap of the circles, indicating increased caries risk.

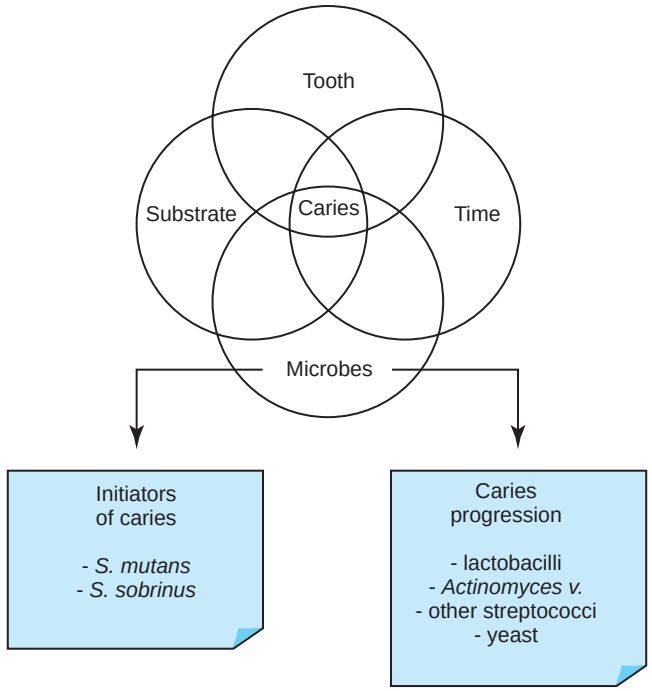


FIGURE 1-8 Current level of knowledge regarding involved bacteria essential for caries onset and progression.

streptococci and lactobacilli are insufficient to lower the acidogenicity of interdental plaque.

The oral flora colonizes on teeth continuously, but it takes up to several days before the dental plaque contains enough acidogenic bacteria to lower plaque pH to the level that causes demineralization. Theoretically, plaque removal every second day would be sufficient. If the dentition is professionally cleaned, an even lower frequency of cleaning has been demonstrated to prevent caries. However, we have only to consider the caries prevalence in the prefluoride era to realize that few people are capable of cleaning their teeth to a level adequate to prevent caries. Very few people even use dental floss.

Teeth

The calcium phosphate of teeth demineralizes when the environmental pH lowers. As the environmental pH recovers, dissolved calcium and phosphate can re-precipitate on the remaining mineral crystals in the process called *remineralization.* Remineralization is a slower process than demineralization. When remineralization is given enough time, it can eliminate the damage done during demineralization, but in the absence of this, the caries process will progress and a lesion will develop.

Dentin is more vulnerable than enamel because of structural differences and impurities in the lattice. For many years, much emphasis was given to the pre-eruptive effect of fluoride to improve the quality of the dental hard tissues. However, it is now clear that post-eruptively used fluoride is more protective against caries.

Diet

Dietary carbohydrates are necessary for the bacteria to produce the necessary acid demineralization. In general, dietary advice for caries prevention is based on three principles: (1) the drop in pH lasts for about 30 minutes, (2) the frequency of intake is more important than the quantity, and (3) stickiness is an important factor in the cariogenicity of foods. It is obvious, however, from many epidemiologic studies that when fluoride is used daily, sugar consumption and caries prevalence have become independent for many individuals. Even when there is a significant correlation between sugar consumption and caries prevalence, the caries-preventive effect of sugar restriction is small. With this evidence, the role of dietary counseling in caries prevention should be re-examined. This does not negate the value of diet analysis and advice for patients who have multiple caries lesions, but the importance of the proper use of fluorides should also be emphasized. Information gathered with the reliable pH-telemetry method has revealed that a pH drop induced by eating may last for hours if there is no stimulation of the salivary flow. Even the consumption of an apple can depress the pH for 2 hours or longer.

Long pH depressions are most prevalent in areas where saliva has little or no access. These are the most caries-prone areas. It is unknown how much additional harm is caused by a second sugar intake during such a period of low pH or how beneficial it is to omit a second sugar intake during that period. These considerations emphasize that at sites where caries lesions develop, advice based on the 30-minute duration of the pH drop is not necessarily effective for caries prevention. In addition, foods believed to be "good" for teeth may not be better than foods that are supposedly "bad." A chocolate and caramel bar might be considered bad because it feels sticky. In reality, the caramel dissolves and leaves the mouth relatively quickly, whereas potato chips, generally considered less harmful, take a longer time to clear the mouth. During this retention, the carbohydrate fraction may be hydrolyzed to simple sugars, providing a substrate for the acidogenic bacteria. All the uncertainties in determining the cariogenicity of foods make it difficult to provide strict dietary guidelines. To snack in moderation is the only wise recommendation. Sugar substitutes deserve special consideration, especially Xylitol, because it has shown to dramatically reduce caries incidence when used instead of sugary snacks between meals.

Time

Time affects the caries process in several ways. When caries was commonly considered to be a chronic disease, time was introduced to indicate that the substrate (dietary sugars) must be present for a sufficient length of time to cause demineralization. We now know that caries is not a chronic disease and that its effect can be arrested or completely repaired should enough time be given for remineralization. It is also clear that caries lesions do not develop overnight, but usually take time. In fact, it may take years for cavitations to occur. This potentially gives the dentist and the patient ample time for preventive treatment strategies.

Fluoride

Experiments have shown that fluoride protects enamel more effectively when it is present in the ambient solution during acid challenges than when it is incorporated into the enamel lattice. The mechanism by which fluoride inhibits demineralization is by re-precipitation of dissolved calcium and phosphate, thereby preventing these constituents from being leached out of the enamel into the plaque and saliva. Part of the re-precipitation takes place at the surface of the tooth. This narrows the pores in the enamel surface that provide diffusion pathways for the acids produced in the dental plaque to penetrate into the enamel. Acid penetration is thus hampered. In addition, during periods when the ambient pH is above 5.5, fluoride will facilitate remineralization, promoting lesion arrest and repair.

Lack of fluoride constitutes a caries risk. The retention of fluoride in the mouth is site specific. In plaque and saliva and in dentin samples fixed in dental splints, most fluoride was found on the labial surfaces of maxillary incisors, the buccal surface in the mandibular, and the molar region after rinsing with the fluoride solution. In addition, it was observed that fluoride from passively dissolving fluoride tablets remains highly concentrated only at the site of tablet dissolution. There was very little or no transport of fluoride between the right and left sides of the mouth and between the maxillary and mandibular arches. Because of this, localized caries lesions in the mouth may be related to an insufficient spread of fluoride when subjects use fluoride toothpaste. Patients who use fluoride toothpaste should

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be encouraged to spit out any excess rather than to rinse and dilute it vigorously with water.

Saliva

The important role of saliva is clearly demonstrated by the rampant caries that may occur in subjects with compromised salivary flow. These subjects lack the protective qualities of saliva, of which flow rate and buffering capacity may be the most important. Both help to neutralize and clear the acids and carbohydrates from dental plaque. Clearance, however, is not uniform throughout the mouth and may be slowest at the lateral aspects of the maxillary incisor and buccal aspects of the mandibular molars. Other sites in the dentition may not be easily accessible to saliva as a result of individual anatomy, including interproximal spaces and fissures. Dental plaque in a cavity may also be protected from salivary clearance. The sites that are difficult for saliva to reach may also be difficult to reach with mechanical cleaning devices, such as toothbrushes and dental floss. Plaque and food may adhere for a long time in these areas, making these sites more prone to caries. Furthermore, this caries risk factor may be easily overlooked in children whose teeth appear to be clean as judged from the sites that are easily cleaned. These children may even brush their teeth twice daily and have only a moderate sugar intake per day. The most feasible way to prevent caries at these sites is by thorough oral hygiene measures and use of fluoride-containing toothpaste, so that plaque is removed and fluoride is applied.

Social and Demographic Factors

Many studies have shown that, at least in the Western world, dental caries is more prevalent in the lower socioeconomic categories, in the less affluent areas, and among some ethnic minorities. Differences related to socioeconomic status are very clear for the primary dentition and less clear for the permanent dentition.

Although this pattern may differ in other parts of the world, studies have shown that prediction of caries development based on social and demographic factors in very young children without a long dental history may be successful. For older children, clinical parameters are more predictive. In the elderly population, however, root caries seems to be more prevalent in people from lower socioeconomic backgrounds.

Detection and Diagnosis of Carious Lesions

When a dentist identifies a carious lesion, it is a change in mineral content that is detected. The dentist must always determine whether a lesion is active or arrested before a logical management plan can be proposed. The dynamics of the case process must be recognized.

Detection

Teeth must be clean for clinical detection of carious lesions. Otherwise, reliable detection may be obstructed by the presence of plaque. The teeth are cleaned, and a water syringe is used so that the tooth surface may be dried. This drying performs two functions: it removes saliva, which can obscure the lesion, and it can also dry a white spot lesion. Removing water from the porous tissue in this way enables the dentist to gauge how far a lesion has progressed through the enamel. A white spot lesion visible on a wet tooth surface indicates that demineralization is over halfway through the enamel, possibly extending into dentin. A white spot lesion that becomes visible only after thorough air drying will be less than halfway through the enamel. Traditionally the dentist also requires bitewing radiographs to assist in the detection of proximal caries lesions, occlusal caries lesions, and recurrent caries.

Radiographs should be taken using a film holder and beaming device to take the guesswork out of tube alignment and allow comparable views to be taken on subsequent occasions. Lesions confined to enamel on radiographs should be managed by preventive treatment, and it is important to monitor them. Magnification is a great adjunct to caries detection.

For the clinician, the detection of a lesion, and whether it is confined to enamel (and therefore its potential to be reversed by remineralization), raises the question of appropriate treatment. In addition, different tooth surfaces present different problems for the correct diagnosis of the questionable lesion (Figure 1-9).



FIGURE 1-9 **A, A case involving multiple areas of demineralization. B, Preventive measures and remineralization therapy are of paramount importance before, during and after treatment. Same case after composite veneers.**

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Diagnostic Tools

According to Pitts (1997), the ideal method or tool for diagnosis of carious lesions would be noninvasive and provide simple, reliable, valid, sensitive, specific, and robust measurements of lesion size and activity and would be based on biologic processes directly related to the caries process. It would also be affordable, accessible to dentists and patients, and allow early implementation in both clinical practice and research settings. Its use would promote informed and appropriate preventive treatment decisions enhancing long-term oral health. Unfortunately, at present no single all-encompassing method fulfills these requirements.

Some decades ago, visual diagnostics with light and mirror and probing supplemented by bitewing radiographs were the only tools available for the clinical diagnosis of caries. For epidemiologic surveys and for the examination of most patients, these are still useful tools. However, in the last decade there has been a considerable increase in the assortment of diagnostic tools based on new technology. The accuracy (sensitivity and specificity), usefulness, and cost-effectiveness of these methods vary considerably. Some are very quick and inexpensive but subjective and are therefore useful for large-scale epidemiologic surveys. Others are objective and offer quantitative diagnosis but are time-consuming and require costly equipment. The detection methods and diagnostic tools discussed in the following sections are now available.

Visual Method The visual method is a combination of a light, mirror, and probe for detailed examination of every tooth surface. It is by far the most commonly applied method in general practice worldwide. Although sensitivity is low and specificity is high, it may be possible to detect (1) noncavitated lesions, enamel lesions (D1) on the free smooth surfaces (buccal and lingual), most anterior and proximal surfaces, and the opening of some fissures; (2) clinically detected "cavities" limited to the enamel (D1, D2); (3) dentin lesions (D3) with cavitation into the dentin and the buccal and lingual surfaces and the anterior and proximal surfaces, but with limited detection of posterior approximal and occlusal lesions; (4) secondary lesions with cavitation; and (5) active and inactive root lesions with or without cavitations. A major shortcoming is that this method is very limited for detecting noncavitated lesions in dentin on the posterior, approximal, and occlusal surfaces.

Clinical Visual Tactile Method The clinical visual tactile method is based on a combination of light, mirror, and gentle probing and is used in most epidemiologic surveys in the United States. Caries is diagnosed if the tooth meets the American Dental Association criteria of softened enamel that catches an explorer and resists its removal (the so-called sticky fissure) or allows the explorer to penetrate proximal surfaces on moderate to firm probing pressure. Lighting is usually adequate, but the teeth are neither cleaned nor dried.

The examination takes about 3 minutes per subject. The method is also used frequently in general practice in the United States. In the visual method used in European epidemiologic surveys, probing has been criticized for several reasons. It may allow the transmission of cariogenic bacteria from infected sites, it can irreversible traumatize potentially remineralizable noncavitated lesions of enamel and dentin, and it may provide no more accuracy in diagnosis than visual inspection alone, particularly in fissures and on posterior approximal surfaces.

Meticulous Clinical Visual Method Meticulous clinical examination after cleaning (including flossing) of all processes and thorough drying discloses more lesions that the aforementioned rapid clinical examinations.

Visual Method with Temporary Elective Tooth Separation The once popular technique of temporary elective tooth separation as an aid to the diagnosis of caries in approximal tooth surfaces is now regaining popularity, albeit with more humane and less traumatic methods that seem acceptable to most patients and dentists. This method permits a more definite assessment of whether radiographically detectable approximal enamel (D1, D2) and dentin lesions (D3) are cavitated. A regular orthodontic elastomeric separator is used for temporary tooth separation.

Visual Method with Temporary Elective Tooth Separation and Impression of the Approximal Lesion Temporary elective tooth separation complemented by a localized impression of the open interproximal space allows a more sensitive diagnosis of cavitation than the purely visual separating method. This also has the advantage of providing a replica as a reference for visual monitoring of changes in size of even a measurement of serial impressions.

Conventional Bitewing Radiographic Method Several factors have contributed to the general adoption of radiographic examination as an aid to the detection and subsequent treatment of caries. First, it discloses sites inaccessible to other diagnostic methods where geography facilitates the detection of carious lesions at an earlier, potentially reversible stage. Usually, more approximal and occlusal lesions are recorded when clinical examinations are supplemented by a full set of radiographs, especially coronal radiography (Figure 1-10). Second, the depth of the lesion can be evaluated and scored by different types on indexes. Third, because the radiograph provides a permanent record, recall examinations allow assessment of the progression or regression of lesions, the evaluation of disease activity, and the monitoring of the efficacy of preventive and therapeutic measures. Fourth, radiography is noninvasive, whereas gentle probing may cause high iatrogenic damage to the surface of noncavitated enamel and dentin lesions.

Radiographs, however, have some limitations. For accurate reproducibility, standardized geometric angulations, exposure time, processing procedures, and analyzing facilities are needed. A bitewing film holder fixed to a radiographic long cone facilitates standardized geometric angulation. Radiography does not disclose the earlier stages of lesion development. Radiography also does not unequivocally distinguish among approximal surfaces that are sound, have subsurface lesions, or are cavitated. To some degree radiographs underestimate the extent of demineralization, but overestimations may also appear as a result of projection errors. Radiographic diagnosis is subjective, and the interpretation of radiographic findings is subject to

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interobserver and intraobserver variations. Approximal secondary caries on the more apical part of a restoration may not be detected. Noncavitated carious lesions on the root are difficult to diagnose.

A wealth of data relate to conventional radiographic techniques that are used in general practice research and clinical trials, but studies predating the recent changes in the pattern of the disease process should be extrapolated with caution to present conditions.

Radiographic results are best considered by site for approximal surfaces. Recent studies show moderate levels of sensitivity at the D1 threshold (clinically detectable enamel lesions with noncavitated surfaces), disclosing many more relatively small approximal lesions that may be amenable to preventive care than are disclosed by most other techniques. Specificity is generally high, although not quite as high as for the clinical methods. At the D3 threshold (clinically detectable lesions in dentin, with and without cavitation of dentin), sensitivity is also moderate, and specificity is high. For occlusal surfaces, newer findings have changed perceptions of performance and the applicability of radiographic methods. Although the intrinsic image geometry of the bitewing projection with superimposition of large volumes of sound enamel precludes sensitive radiographic diagnosis of enamel lesions, the method is now highly applicable with moderate sensitivity for detecting extensive dental lesions that may be undetected on clinical examination.

Digital Radiographic Method Digital film techniques for intraoral radiography have been developed for several important reasons. First, conventional film absorbs only a few percent of the x-rays that reach it, using very little of the radiation to which the patient has been exposed. Second, poor darkroom technique can lead to both unnecessarily high doses of radiation and loss of diagnostic information. Third, the development of films is time-consuming, and the development and fixing solutions are hazardous to the environment.

For intraoral radiography, digital techniques with direct image acquisition have been available only since the end of the 1980s. Research and development and indirect digital radiography paved the way for direct digital filmless techniques.

The first to become available in 1989 was based on a charged couple device (CCD) chip similar to that found in digital video cameras. These systems have a relatively narrow dynamic range, which means that the best image quality can be attained only within a limited exposure range. Digital radiography linked to the dental unit offers an attractive design because the flat screen is adapted to the bracket table of the dental unit directly in front of the patient, facilitating discussion with the patient about findings from the radiograph as well as from an intraoral camera (Figure 1-11).

Lately there have been many developments in this area. In general the new digital systems are comparable to conventional radiography, although contrast enhancements may boost sensitivity at the expense of some loss of specificity.

Computer-Aided Radiographic Methods Computer-aided radiographic methods exploit the measurement potential of computers in assessing and recording lesion size. At both the D1

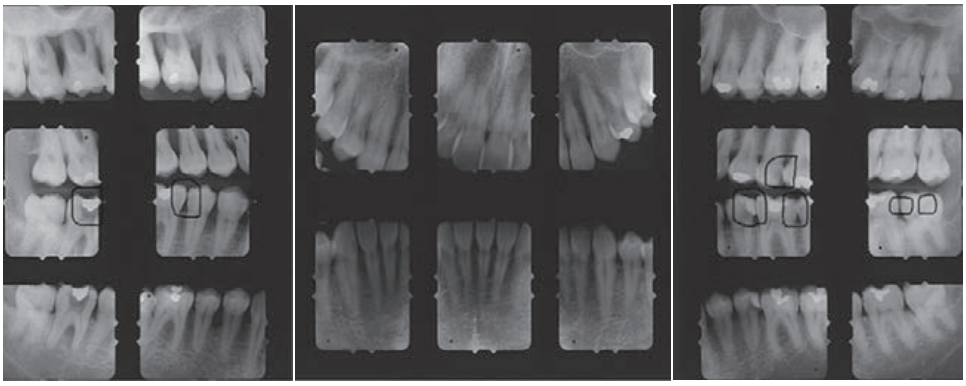


FIGURE 1-10 A full radiographic periapical set, particularly coronal radiographs, are mandatory for adequate caries detection (carious lesions marked in black).



FIGURE 1-11 A, Digital radiography is of widespread use in modern dental practices. B, It can be used with magnification directly in the dental unit, together with an intraoral camera.

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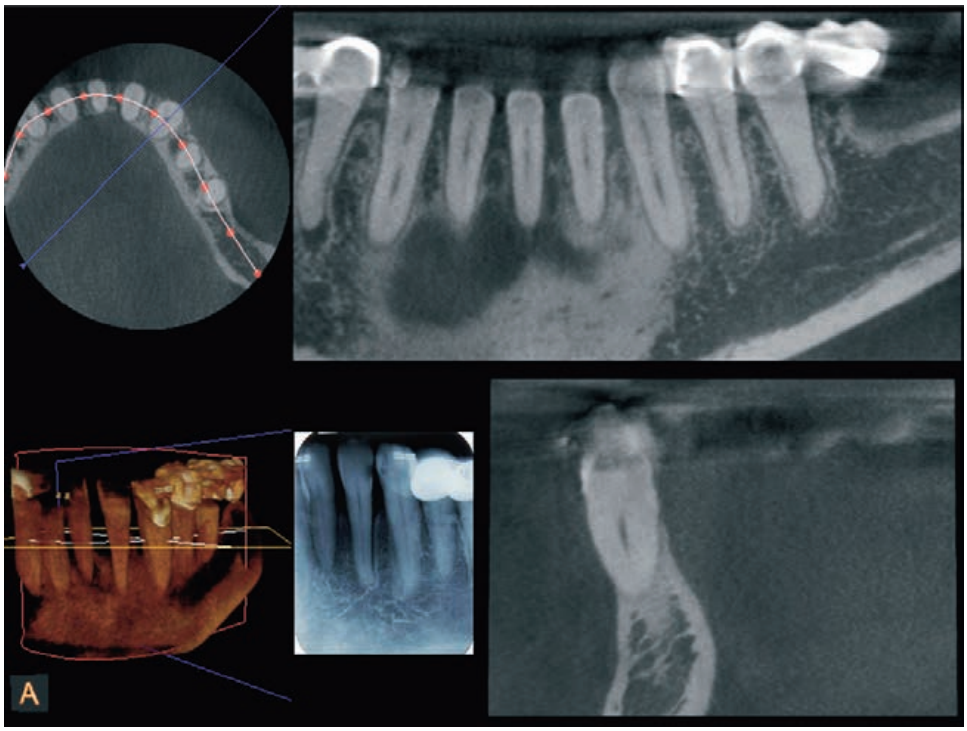


FIGURE 1-12 A very promising field for computer-aided caries diagnosis: cone beam 3D technology.

and D3 thresholds, computer-aided methods offer high levels of sensitivity for approximal lesions.

The trend is toward integrating several computer-aided tools and services in a local network with a powerful personal computer. Radiographs (conventional and digitized as well as computer aided) and clinical images can be transmitted for consultation and information.

Cone beam 3D technologies are also starting to be used for caries detection and interpretation. This is a very interesting and promising field for computer-aided caries diagnostics (Figure 1-12).

Fiberoptic Transillumination Method The fiberoptic transillumination method (FOTI) is a development of a classic diagnostic aid advocated some 30 years ago that never gained wide acceptance. However, transillumination should be a regularly used tool for diagnosing caries in the incisors and premolar regions, at least to supplement clinical examination and bitewing radiographs.

FOTI has enjoyed variable success in studies evaluating its performance, possibly because of failure to appreciate that the technique, like any other, requires an extended learning phase. FOTI cannot sensitively detect proximal lesions at the D1 level, but it is specific, and its success compared with that of clinical methods at the D3 level means that FOTI should be seriously considered as an agent and used in situations in which radiography is not appropriate or usable. Traditionally advocated for approximal lesions in dentin, FOTI may also have some applications in the diagnosis of occlusal lesions.

Digital Fiberoptic Transillumination Method The digital fiberoptic transillumination method (DIFOTI), a diagnostic method that gained importance in the early years of the twenty-first century, had the following advantages: (1) it used a light source that involved no radiation exposure for either dentists or patients, and (2) the user could amplify the images, replicate the images, and store the information in a computer, allowing the visualization of images for comparative purposes.

With this system, carious lesions adjacent to restorations and sealants could be detected. Other changes could be detected in the dentin of the coronal structure, such as fractures, fluorosis and decalcifications. Nevertheless, this method could not detect alterations subgingivally (Kavo Dental, Charlotte, North Carolina), and the cost of the equipment was an important factor. The Kavo Company bought this technology, and it is not commercially available at the time of this writing.

Electrical Conductance Method The electrical conductance method has been used since the mid-1950s. It is based on the fact that a healthy tooth is a poor conductor and therefore the electrical conductivity of the decayed tooth is favored by a substantial increment in the porosity of such teeth. This is because of the demineralization and the fact that saliva fills in the spaces left behind, making the tooth at this point a good electrical conductor. The different instruments fabricated based on this principle never gained much popularity.

The principal inconvenience was that the teeth had to be dried and then rehumidified with a saline solution to favor conductivity. Nevertheless, when the values of sensibility and occasionally the values of specificity were higher than those demonstrated for the visual inspection and the bitewing radiographs, a renewed interest in this type of system developed in the beginning of the twenty-first century.

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Laser Fluorescence and Quantified Laser Fluorescence Method A commercial laser fluorescence system, KaVo DIAGNOdent, has been introduced. This system seems to be efficient for the diagnosis of noncavitated enamel and dentin lesions on buccal, lingual, and occlusal surfaces. In particular, this system should be useful in longitudinal caries preventive studies. It is now available in both the original small tabletop unit and a new pen-type design (Figure 1-13).



FIGURE 1-13 The KaVo DIAGNOdent (A) and DIAGNOdent pen (B) laser fluorescence systems. C, Clinical view of occlusal tip positioning. *(A and B courtesy KaVo Dental, Charlotte, North Carolina.)*

A similar device, Midwest Caries I.D. (DENTSPLY Professional, York, Pennsylvania) uses a light-emitting diode (LED) instead of a laser to measure the caries reflection signature; it captures the resulting reflection and refraction of the light in the tooth. A specific optic signature identifies the presence of caries. A healthy dental structure is generally more translucent than a decalcified one; consequently, it has a different optic signature. Instead of a numeric readout like the DIAGNOdent's, the Caries I.D. offers red and green indicators (complicating the process of monitoring caries progression and remineralization).

SOPROLIFE (Acteon, Marseilles, France) enhances the ability to find caries by combining an intraoral camera for normal enhanced viewing through magnification with fluorescence technology to find caries. This device uses 450-nm light to cause the fluorescence. The device has both a diagnosis mode and a treatment mode. Diagnosis mode allows magnification from 30 to 100 times using white light. Turning a switch on the handpiece changes the lighting to diagnosis mode. This allows you to view healthy tooth structure versus caries (Figure 1-14, *A*). In treatment mode, caries shows up red. You can use this mode during caries excavation to determine if all the caries has been removed (Figure 1-14, *B* and *C*).

The Canary System (Quantum Dental Technologies, Toronto, Canada) uses a low-power, pulsating laser light to scan teeth for the presence of caries. The tooth absorbs the laser light, and two phenomena are observed: the laser light is converted into luminescence, and there is a release of heat (less than 1 degree Celsius). This heat does not harm the tooth but provides information about the tooth up to a depth of 5 mm below the surface. Simultaneous measurement of the reflected heat and light determines the presence and extent of tooth decay below the tooth surface (Figure 1-15).

Spectra (Air Techniques Melville, New York) is another caries detection device that uses fluorescence technology and real promise in the field of minimally invasive dentistry. LEDs of 405 nm inside the unit project blue light that causes cariogenic bacteria to glow less red while healthy tooth structure fluoresces green. The Spectra creates a graphic and a numeric display; the graphic can be saved to imaging software for monitoring caries over time. When used with preparatory software, a live image can be taken, and the severity of the caries on the different areas of the tooth can be graded on an easy-to-use 1-to-5 scale (Figure 1-16).

Another method that is attracting considerable interest, the Inspektor Biluminator, is a device for the assessment of oral hygiene at home or in the dental practice. It is based on Quantitative Light-Induced Fluorescence (QLF), developed by Inspektor Research Systems (Amsterdam, The Netherlands) and was first implemented in the Inspektor Pro system. The Inspektor Biluminator emits a harmless blue light that is used to disclose porphyrins (byproducts of the metabolic process of several strains of anaerobic bacteria) in the oral cavity, specifically inside or around tooth elements and the gingiva. These porphyrins are not visible with the naked eye. In the past 12 years, QLF has been used successfully to detect and quantify demineralization and remineralization of dental tissue and bacterial activity.

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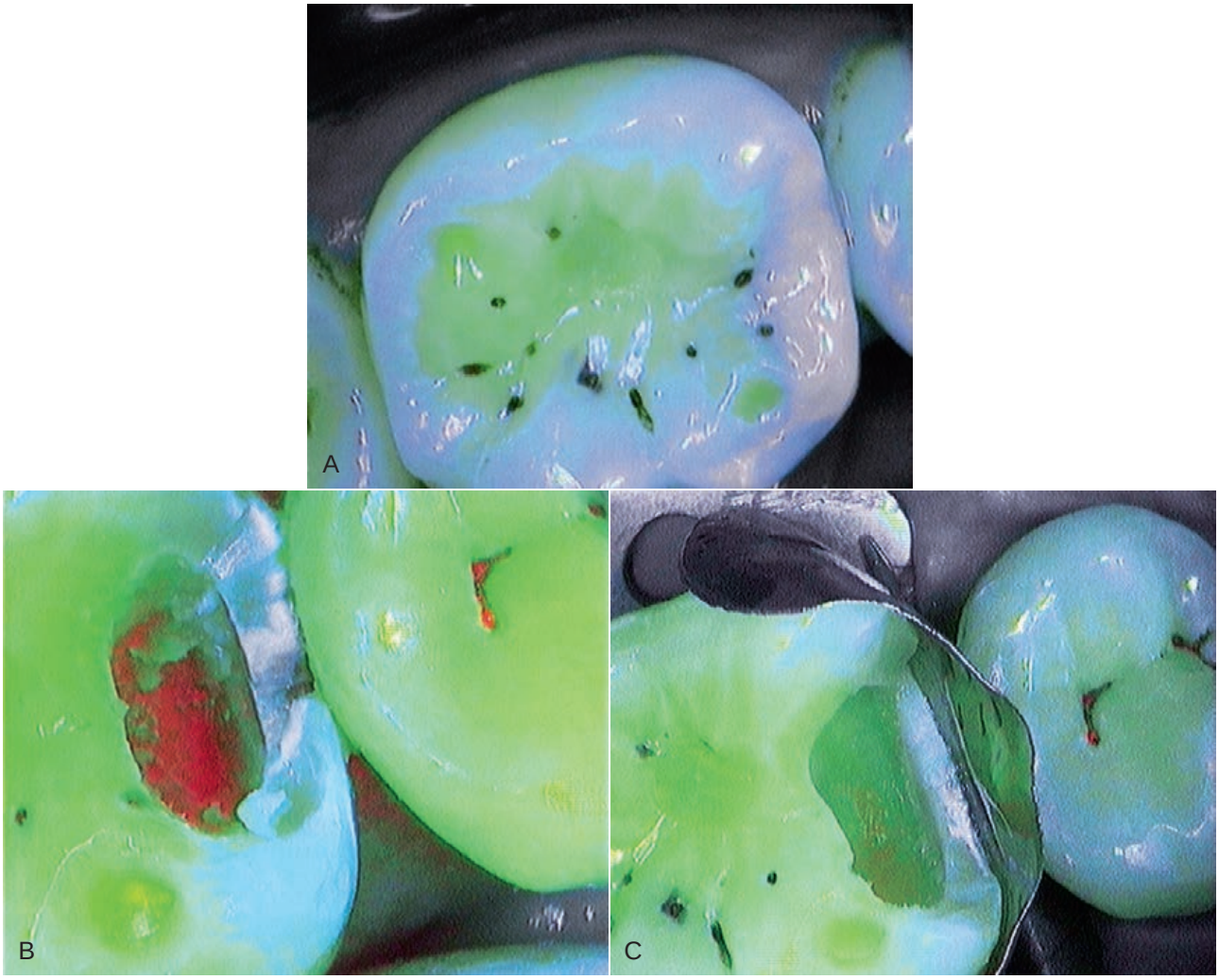


FIGURE 1-14 **A, SOPROLIFE in diagnostic mode. Healthy tooth appears white with green areas, whereas carious tissue appears darker (red). SOPROLIFE in treatment mode: at the opening of the cavity the fluorescence produces red reflection by infected dentine (B), and at the end of preparation the fluorescence produces green reflection return by conservable tissue (C).**



FIGURE 1-15 **The Canary System uses low-power pulsating light to scan teeth for the presence of caries.** *(Courtesy Quantum Dental Technologies, Toronto, Ontario, Canada.)*

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The Inspektor Biluminator enhances the detection of white spot lesions, approximal caries, occlusal caries, margin leakage and secondary caries, sealant integrity, calculus, and gingivitis with minimal investment in money or time (Figure 1-17).

Optical Coherence Tomography Another technology on the horizon for caries detection (and other diagnostic applications in dentistry) is optical coherence tomography (OCT). Capable of scanning both hard and soft tissues, OCT Dental Imaging System (Lantis Laser Inc., Denville, New Jersey) features a handheld scanner (still in design stage) that captures tomographic slices up to 3-mm deep. The cross-sectional images are displayed individually in real time and can be saved. This system can detect recurrent caries around restorations and can be used to examine marginal integrity of restorations bonded to tooth structure. This system should be commercially available in early 2012 (Figure 1-18).

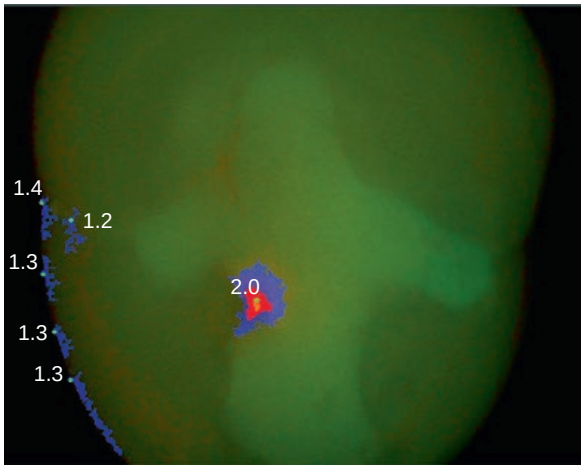


FIGURE 1-16 **A live image can be obtained with the Spectra system, grading the severity of caries on the different areas of the tooth.**

Electrochemical Impedance Spectroscopy (EIS) AC measurements, especially electrochemical impedance spectroscopy (EIS), can characterize all the electrical responses of matter whether materials or biological. A sinusoidal voltage is applied and the corresponding sinusoidal current measured, with the relationship being described by the impedance. By measuring the impedance over a range of frequencies, a wealth of diagnostic information is available in fields ranging from batteries to dentistry.

The CarieScan PRO (CarieScan Ltd, Dundee, Angus, United Kingdom) is a handheld device for dental caries detection implementing an impedance measurement system with multiple measurement channels that operate in the frequency domain.

This device applies a frequency sweep to the sample and analyzes each spectrum in <1s. A custom algorithm is then



FIGURE 1-17 **White spot lesions and margin leakage using the Inspektor Biluminator Quantitative Light-Induced Fluorescense (QLF) system.** *(Courtesy Inspektor Research Systems BV, Amsterdam, The Netherlands.)*

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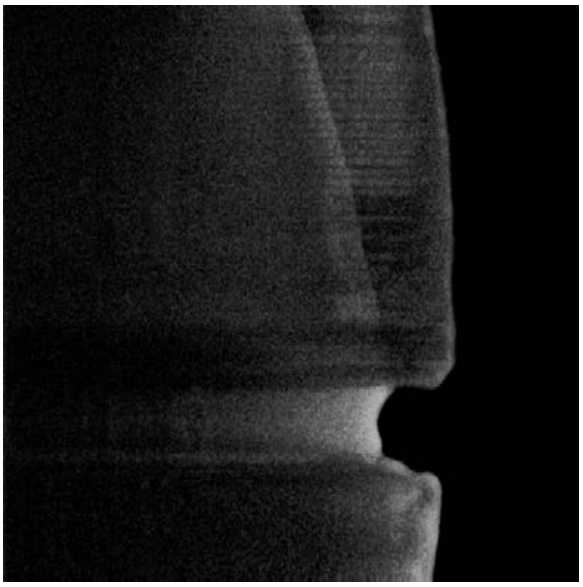


FIGURE 1-18 **Lantis Laser's optical coherence tomography (OCT) technology is used in a promising hand-held device. The image shows a tomographic slice of a cavitated tooth surface.**



FIGURE 1-19 **The CarieScan PRO is an electrochemical portable measurement system. The system is intended to be run autonomously or be linked wirelessly via Bluetooth to a supporting pc for data acquisition and embedded software maintenance.** *(Courtesy CarieScan Ltd, Dundee, Angus, United Kingdom.)*

implemented to extract the diagnostic score based on the recorded impedance values and mapped against a clinical reference. The system is intended to be run autonomously or be linked wirelessly via Bluetooth to a supporting personal computer for data acquisition and embedded software maintenance.

The CarieScan PRO impedance platform is an electrochemical measurement system that provides a portable, cost-effective alternative to existing benchmark equipment. It can collect, process, analyze, and output the results of multiple frequency measurements in less than 1 second. Although the first market-ready product clearly demonstrates its applicability to dental diagnostics, it could be considered a platform for a number of diverse applications. Its measurement accuracy of >95%—together with its small size, low-power consumption, and ultra-low applied current—makes it suitable for a wide range of medical and other applications (Figure 1-19).

Assessment of Caries Risk in Dental Restorative Patients

A patient "at risk" is a person with high potential to contract a disease because of genetic or environmental conditions. Actual "caries risk" describes to what extent a person at a particular time runs the risk of developing carious lesions.

In addition to differentiating active from inactive lesions, determining the overall caries risk for the patient is an important factor. If the patient has many cavitated lesions and the dentist skillfully restores the teeth, is the patient still at risk for caries? The answer is "yes" unless the biologic environment that caused the caries to occur changes. Preventive treatment is needed in addition to restorative care to help the patient remove plaque more effectively, to modify the diet if appropriate, to use fluoride to delay lesion progression, and to attempt to stimulate saliva if the mouth is dry.

The role of restorative procedures in caries control is to facilitate plaque control. *Restorations alone cannot be relied on to change the patient's caries risk status, particularly if the risk status is high.* Patients should be made aware of the caries risk status to encourage them to become involved in all preventive care, to keep appropriate hygiene appointments, and perhaps to help them budget for dental costs.

It is also important for patients to realize that caries risk status can change and the dentist can detect this change. Examples of a change in risk status may be addressing a dry mouth or changing the ability to remove plaque.

Assessment of caries risk is an important part of contemporary dental practice, and it is something that general practitioners do rather well. Indeed, research has shown that a dentist's best guess for a patient's caries risk may be as accurate as any combination of more objective factors, including (1) clinical evidence, (2) plaque control, (3) dietary habits, (4) saliva, (5) use of fluoride, (6) medical history, and (7) social history.

An experienced practitioner will be able to assess caries risk in less time than it takes the reader to read these descriptions. Risk assessment is an intellectual process demanding both clinical skill and experience.

Dentists should define the caries risk status of each patient. Whether the risk is high or low, they should also identify the reasons. Interestingly, it can be more difficult to explain low risk than high risk. However, it is with the high-risk patient that the definition becomes critical to patient management. It is

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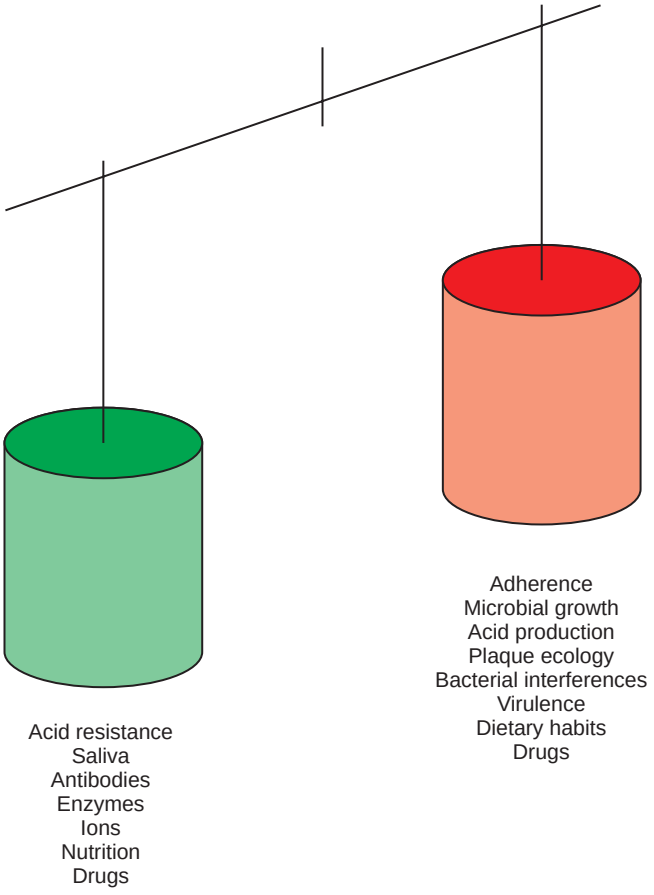


FIGURE 1-20 **Ecologic balance in the oral cavity. Aggressive and defensive factors balance each other and determine caries risk.**

important to determine whether or not the risk factors can be modified and, if so, how best this can be done (Figure 1-20).

Dental restorative treatments are "at risk for failure" if we do not take into account the factors discussed in the following paragraphs.

Clinical Evidence

Clinical evidence has been shown to be the best predictor of caries risk. The finding of many initial lesions or many restorations requiring frequent replacements provides evidence for a high risk of caries. There may also be a history of teeth having been extracted because "they were too carious to be restored." Clinical and radiographic examinations described earlier are very important. If the dentist reviews earlier radiographs, that were perhaps taken over years, the caries status of the patient may be graphically displayed.

It should also be remembered that adding a dental appliance to the environment, such as an orthodontic appliance or a partial denture, may tip the balance toward high risk. Because appliances favor plaque retention, they should be avoided in high-risk patients when possible.

Plaque Control

Dental plaque is a primary risk factor for dental caries. Not all patients with poor plaque control inevitably develop caries, but oral hygiene is the bedrock of a caries control program in high-risk patients. If for any reason plaque control becomes difficult, perhaps because of age or long-term illness, caries risk can change.

Dietary Habits

Sugar intake is considered an important factor in caries risk, but not all patients with high sugar intake develop caries. It is, however, unusual to find a patient with multiple active carious lesions who does not have a high sugar intake, especially between meals.

It is also important to remember that dietary habits can change. Changes in life circumstances such as unemployment or retirement can have profound implications. A vigilant dentist will take such changes into consideration.

Saliva

Low salivary secretion rate and low buffer capacity lead to reduced elimination of microorganisms and food remnants, to impaired neutralization of acids, and to reduced tendency of remineralization of early enamel lesions. A dry mouth is one of the most important factors predisposing to high caries risk. The four most common causes are as follows:

1. Many medications such as antidepressants, antipsychotics, tranquilizers, antihypertensives, and diuretics can cause dry mouth. Elderly patients take many of these at the same time.
2. Patients with rheumatoid arthritis may also have Sjögren syndrome, which affects the salivary and lachrymal glands, leading to a dry mouth and dry eyes.
3. People with eating disorders may experience hyposalivation, which, combined with a poor diet, can lead to extensive caries.
4. Patients who have received radiation therapy in the region of the salivary glands for head and neck malignancy often have very low salivary flow or even xerostomia.

Numerous studies have also shown that serial counts of *mutans* streptococci and lactobacilli help predict caries risk. This huge volume of work appears to show that for individual patients, low counts often predict low risk well, but the opposite is not necessarily true. The routine use of salivary counts as an "isolated method" for predicting risk status is therefore not recommended.

Use of Fluoride

Fluoride delays the progression of the carious process. Patients living in areas with fluoridated water will benefit, particularly in communities of social deprivation. Today most patients use toothpaste containing fluoride, but it is advisable to ascertain this in those who have multiple active lesions. Fluoride rinses, prescription home fluoride solutions, and gels are highly recommended in high-risk patients. Fluoride varnishes are effective in site-specific lesions.

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Medical History

Medically compromised and handicapped people may be at high risk for developing caries. For these patients, oral hygiene may be difficult, and the long-term use of certain medications can be problematic if the medicines are sugar based or cause reduced salivary flow.

The most important caries risk factor in the medical history is the complaint of dry mouth, discussed previously. It is important to realize that the medical history is one factor in the caries risk assessment that can change. The vigilant dentist will detect such changes and help the patient with the potential dental consequences.

Social History

Many studies have shown that social deprivation can be an indicator of caries risk. Other diseases such as coronary heart disease and some cancers also appear in socially deprived people. The dentist may notice a high number of carious lesions in siblings of the patient, or parents may possess little knowledge of the disease. Dental health may be a low concern and dental visits irregular.

Identifying Relevant Risk Factors

Although it is relatively easy for an experienced dentist to classify patients into high- or low-risk categories, determining the cause of the risk may take longer. However, this is time well spent and is an essential part of the diagnosis. An appropriate plan of action cannot be formulated until the factors that require modification have been defined. Identifying the reason the patient is at high risk is also relevant to the prognosis. Can the patient modify risk factors? For example, some causes for dry mouth are impossible to alter, and the patient may always be at high risk.

Other individuals may be able to change their status by modifying plaque control and/or diet, but this demands behavior modification. *The patient must take responsibility for the problem rather than transferring responsibility to the dentist. Unless the high-risk patient accepts responsibility for modifying behavior and improving his or her dental health, no restorative services, no matter how well executed, will prevent caries recurrence.*

Restorative Dentistry Treatment Strategy

Cosmetic restorative dental procedures have become possible and popular because of the evolution of certain materials and the understanding of adhesive technology. The process can be viewed as an evolution in the dental restorative arena in which, as a rule of thumb, the right restorative materials must be selected for each individual case. For example, a dental material to be used in a person with absence of parafunctional habits will most probably fail if used under heavy loads. Therefore, esthetics is sometimes overridden by function. As an example, metal occlusals may be chosen instead of porcelain occlusals. Fortunately, esthetic materials can be used in *almost* any case when properly selected.

Criteria for a Restorative Treatment

In 1987, the international symposium "Criteria for Placement and Replacement of Dental Restorations" held in Florida examined the details of certain basic criteria to which a restorative treatment should always be subject. The following are still currently valid:

- Compatibility with medical and other circumstances.
- Appropriateness of retaining the tooth (will the tooth have a long-term function?).
- A reasonable prognosis for the restored tooth.
- Agreement by the patient to undergo treatment.
- Carious lesions extend well into dentin (unless caries can be shown to be arrested) and/or are already showing sensitivity (e.g., to hot or cold).
- Pulpal symptoms are arising from the carious lesion.
- There is impaired occlusion or function (e.g., open contacts or tooth wear).
- *Appearance is unsatisfactory (cosmetic dental procedures per se).*
- Health of adjacent periodontal tissue can be improved significantly by restorative treatment (e.g., overhang of a restoration).
- A restoration appears to have caused a significant allergic response (e.g., acrylics, certain metals).

If one or more of these criteria have been met, restorative and cosmetic restorations can be executed. If none of these criteria are present, then only appropriate preventive care should be instituted (good oral hygiene, use of fluorides, and dietary control of carbohydrates).

The patient's selection becomes critical at this point.

The author strongly recommends interacting with various specialists during the treatment planning procedure and initial diagnosis of the patient to ensure a better final outcome. Some colleagues, including the dental technician, may offer different ideas that could enhance treatment results.

Before any restorative treatment is initiated, any sign of periodontal disease should be diagnosed and treated. Any pulpal infection should be evaluated and/or treated by an experienced endodontist, and any parafunctional habits recorded in the chart, including the use of a night guard at the end of the restorative treatment, especially with porcelain restorations.

When Should the Restorative Treatment Begin?

To begin the restorative process, the patient, with the guidance of the dentist, must meet some basic parameters. The following parameters should be continuously monitored during treatment, after insertion of the final restoration(s), and in recall visits in order to keep a healthy environment for restored and nonrestored teeth.

Adequate Oral Hygiene The daily removal of plaque maintains a healthy periodontal environment, removes leftover nutrients for cariogenic bacteria, and therefore reduces their number, which in turn affects the amount of acid produced.

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Dietary Control of Carbohydrates The frequent ingestion of carbohydrates, especially those in the form of sucrose, provides the nutrients for cariogenic bacteria and enhances their metabolic potential toward producing acids. Basically, the greater the frequency of sugar in the diet, the greater the amount of acids attacking the dental surfaces and the margins of the restorations.

A 5- or 7-day detailed diet history can be very helpful in finding hidden sugars in the patient's diet. Corrections should be attempted to reduce sugar consumption, especially between meals, or to find appropriate sugar substitutes.

Levels of Infection Caused by Cariogenic Microorganisms (*Streptococcus mutans* and Lactobacilli)

The specific plaque hypothesis (Loesche, 1976) states that only a limited number of organisms in dental plaque cause the caries disease process. *Caries is an infectious disease.* If this is so, this generates a very important set of assumptions:

1. Diagnosis is essential.
2. Only patients at risk for the clinical manifestation of the infection (caries) are treated.
3. Treatment is directed at reducing the dental pathogens (*S. mutans* and lactobacilli) and ceases at the therapeutic end point.
4. Failure is the dentist's responsibility, because it is a failure to diagnose the infection.

Cosmetic treatment that restores teeth that had become carious or that have recurrent decay will fail inevitably over time if the infection is not controlled before treatment, at placement of the final restorations, and at the maintenance (recall) phase. Again, patients with carious lesions have an infection and need preventive therapy; otherwise, the infection will prevail, and the beautiful restorations will fail in the near future (Figure 1-21).

Diagnosing Caries as a Bacterial Infection

The twenty-first century has brought forth an exciting new era of emerging science and technology, enabling minimally invasive dentistry to evolve. In fact, surgical intervention often can be avoided through the use of medical models of disease management. However, with so many options, instruments, and schools of thought, the predicament is choosing the right tools to do the job in a particular practice. One should consider tools that take an evidence-based approach, work with the current understanding of how oral diseases exist in the mouth, appeal to the logistic challenges of running a financially successful private practice, and align with a patient's desire for oral health and great dentistry. The question arises: how does the practitioner stay ahead of the curve of providing nearly the same dentistry one's patients could receive at the practice next door without jumping on the bandwagon of every shiny new piece of technology that enters the marketplace?

Caries management by risk assessment (CAMBRA) is a term one is hard pressed to avoid while reading a dental journal or attending a lecture. CAMBRA deals specifically with the management of dental caries in a fundamentally different way than the drill and fill focus of yesterday's practice. CAMBRA means moving to a medical model of disease management that involves the identification of risk factors for disease and the treatment of the bacterial biofilm infection that actually causes the disease. This approach mirrors the one medical doctors use most often and with which patients are already comfortable.

In-office salivary tests are available to detect and quantify the levels of *S. mutans* and lactobacilli infection (CRT bacteria), as well a test to measure the buffer capacity of saliva (CRT buffer) (Ivoclar, Vivadent Inc., Amherst, New York) (Figure 1-22). These tests discriminate at four levels of these microorganisms and therefore show the degree of infection of the patient. To use the test to best advantage, only patients with demonstrated caries



FIGURE 1-21 Carious abutment once a full porcelain crown was removed. Recurrent decay will appear inevitably over time if the infection is not controlled before treatment, at placement of the final restorations, and at the maintenance (recall) phase.



FIGURE 1-22 In-office salivary tests are available to detect and quantify the levels of Streptococcus mutans and lactobacilli infection (CRT bacteria) as well a test to measure the buffer capacity of saliva (CRT buffer). *(Courtesy Ivoclar Vivadent, Amherst, New York.)*



FIGURE 1-23 The CariScreen hand-held device shows changes in biofilm health specific to increasing populations of all acid-producing organisms. *(Courtesy Oral BioTech, Albany, Oregon.)*

risk should be tested. Caries risk has already been described in this text.

Diagnosis should also rest on a standard clinical examination. Patients with active caries have an infection. It probably makes little sense to test them bacteriologically while those lesions are open unless the dentist is looking for baseline data for record keeping or performing research. There is also a new chairside, real-time, handheld caries detection technology called the CariScreen meter (Oral BioTech, Albany, Oregon) (Figure 1-23). These diagnostic devices predictably show changes in biofilm health specific to increasing populations of all acid-producing organisms in a foolproof application. One simple swipe, a 15-second wait, and a highly accurate meter provide a relative light unit (RLU) number that is reliable and has statistically high sensitivity and specificity.

So in addition to new advances in adhesive technology, restorative dentistry can also rely on caries detection technology that provides the ability to diagnose and treat the most prevalent oral disease affecting children and also adults: dental caries.

Early detection and prevention efforts create the opportunity to have healthy, cavity-free patients and the ability to give patients a level of dentistry one would want for oneself and one's own family. These tools can provide reliable early detection. Once the system is in place, it is much easier to enroll patients in medical management programs and creates compliance for the available risk management recommendation and infection treatments, all while increasing the practice's profitability. Using these tools to detect and treat problems at the earlier stages can show patients that they are in the best possible hands and give them the confidence to refer friends and family.

Early detection allows a practice to provide expanded services that patients understand and accept, thus creating a very ethical revenue stream.

Treating the Infection in Restorative Dentistry

Six steps are proposed to treat the infection caused by cariogenic microorganisms, thus lowering the caries risk in a restorative patient:

- *Step one:* Restore all carious lesions that have penetrated the dentin. In cases with multiple restorations, placement of well-adapted temporary restorations is recommended until the levels of infection have been reduced.
- *Step two:* Simultaneously apply pit and fissure sealants to teeth with deep morphologic features (usually molars). Cariogenic microorganisms trapped below a sealant will decrease in number and remain metabolically inactive for the duration of their entombment.
- *Step three:* Chlorhexidine is an antimicrobial agent that is highly effective against *S. mutans* infections and should be applied, maintaining the concept of an intensive short-term treatment to a therapeutic end point. A 16-ounce bottle of chlorhexidine rinse should be prescribed for the patient for use in half-ounce increments for a 30-second rinse, morning and evening. There are two main drawbacks to the rinse: a bitter taste and a potential to reversibly stain teeth and composite restorations. For this reason, chlorhexidine in the form of a varnish can be used to paint the dentition or even specific areas of the teeth. This antimicrobial will suppress *S. mutans* for 12 to 26 weeks.
- *Step four:* Chewing gum that contains xylitol. This gum not only demonstrates noncariogenic properties, but also actually appears to be a very helpful adjunct to the remineralization therapy. Xylitol is a five-carbon sugar that is not fermentable by *S. mutans.* The gum causes increased salivary flow, and saliva is a wonderful remineralizing solution. This gum should be chewed three times a day for at least 5 minutes.
- *Step five:* Fluoride rinses. Patients should be instructed to use over-the-counter fluoride rinses in addition to fluoridated toothpaste at least twice a day at times separated from tooth brushing. The presence of the fluoride ion with the saturated solution of calcium and phosphate from the saliva stimulated by the Xylitol gum will remineralize early carious lesions.
- *Step six:* A first recall visit should be scheduled 3 months after the end of antimicrobial therapy. Bacteriologic testing should be performed, and the integrity of temporary restorations as well as pit and fissure sealants should be checked. If infection levels are low, final restorations can be performed (if possible, fluoride-leaching material should be used). If infection levels are still high, preventive re-treatment should be performed until there is a therapeutic effect. *Incorporating the precepts of a medical model for infection control into the routine practice of cosmetic dentistry is simple, practical, and tremendously beneficial to patients.*

The auxiliaries in the dental office can perform most preventive therapies. This also serves as a source of income. Dentists

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have the technology to diagnose and control dental caries in patients. It is possible to identify patients at risk and control their infection. We can become the healers that G.V. Black once envisioned, as well as superior artisans and technicians.

If you find these ideas stimulating, just imagine the face of your patients when they understand that you' are providing a superior cosmetic dental service and that you are not only a very professional artist, but also a caring professional interested in providing the longest-lasting treatment possible. In your office, the beauty never meets the beast.

A THOROUGH UNDERSTANDING OF THE RESTORATION–DENTAL PULP COMPLEX RELATIONSHIPS

Restoration and conservation of teeth constitute the bulk of treatment provided to patients in general practice. The term *conservative dentistry* covers the treatment of sequelae of dental caries in its widest sense and includes the techniques and procedures for the replacement of lost and defective dental tissues on individual teeth. It embraces everything from the prevention of caries and the procedures for remineralization of initial carious lesions, to complex restorative treatment.

In this context, cosmetic or esthetic restorations are in essence the most conservative restorative procedures in operative dentistry because of the constant evolution of adhesive technologies and dental materials. Traditionally, "conservative dentistry" curricula included endodontics and all types of restorations on single teeth. It retains this scope in many parts of the world. However, in many countries endodontics has been recognized as a specialty and is taught and practiced in several departments in dental schools. In private practice, it is also true that many endodontists and restorative dentists still practice at separate locations. The remaining area of conservative dentistry, after endodontics was removed, is usually referred to as "operative dentistry" or more rarely as "cariology." However, neither operative dentistry nor endodontics includes cariology per se. Pulp capping, an option usually performed by the operative clinician and sometimes by the endodontist, represents the clinical transition between operative dentistry and endodontics—for the purpose of this chapter, the transition between cosmetic restorations and endodontics.

Specialty training is advantageous to dentistry as a whole. It optimizes treatment of patients and increases the knowledge base. But what happened to the theoretical basis and the research area of conservative dentistry? When endodontics was divorced from conservative dentistry, it took with it the pulpal-dentin complex, its structure, ultrastructure, physiology, pathology, immunology, and reaction patterns. Concern for pulp reactions to operative procedures, to restorative materials, and to caries somehow ended up with the endodontist. Clearly, detailed knowledge of dentin and pulp is necessary for the endodontist in the diagnosis of pulpitis and in the differential diagnoses of various types of pain and sensations. The same holds true for the operative clinician. In fact, a thorough understanding of the pulp-dentin organ and its reaction patterns is essential for a biologic approach to restorative dentistry and to all procedures on vital teeth, be it inlays, onlays, or fixed prosthodontics.

The treatment of caries and the selection of the most appropriate techniques and materials for tooth restoration are the responsibility of operative dentistry, including pulp and dentin reactions to the procedures involved. Operative dentistry is preventive endodontics. The two fields complement each other. They are different but interconnected phases of dentistry. The dentist providing cosmetic restorative dentistry must be very aware of the importance of pulpal diagnosis before the placement of any restorations. Otherwise, pulpal symptoms may become evident in the near future, resulting in the perforation of the restoration in order to gain access to the infected pulpal tissues (Figure 1-24).

This of course will elicit a response from the patient ranging from surprise to anger. Patients may ask, "Why is this happening, Doctor? The tooth was okay, and since you did this beautiful restoration it started to bother me (or, even worse, hurt)." Does this situation sound familiar? Many restorations are placed on teeth already treated endodontically. These teeth also deserve special attention because many of them present subtle problems or pathologic conditions that can be regularly diagnosed by the endodontist, so a new root canal treatment can be performed before problems arise in the postrestorative phase.

We need to reassess with open minds, and based on clinical reality, where the theoretical basis and research activity of the pulp-dentin complex belong.

Modern restorative dentistry must cover biologic reactions to caries, all operative procedures, the treatment of primary and secondary caries, and all failed restorations. The physical, chemical, biologic, and clinical properties of all types of materials used to restore teeth, principles of cavity preparation for different materials, and the pulpal-periapical status of the teeth to be restored, either vital or endodontically treated, must be understood. Because most operative procedures are related to sequelae of caries, teaching and research related to dentin and pulp must be an integral part of modern operative dentistry. Research and clinical practice related to the pulp-dentin complex are the heart of dentistry. Dentin and pulp are multidisciplinary areas. Teaching programs may be developed and executed in many different ways, but it is imperative for the practice of modern restorative dentistry that they be presented in the right context. For the purposes of this chapter, that means the relationships between cosmetic dentistry and endodontics (Figure 1-25).

AN EFFECTIVE MAINTENANCE REGIMEN FOR RESTORED TEETH

The longevity and appearance of tooth-colored restorations can be adversely affected by improper care. Any practitioner providing these types of restorations should provide a maintenance service for the patients, although insurance will probably not pay for this treatment. Nevertheless, it must be explained to patients that this procedure is needed to keep their esthetic restorations looking their best for as long as possible.

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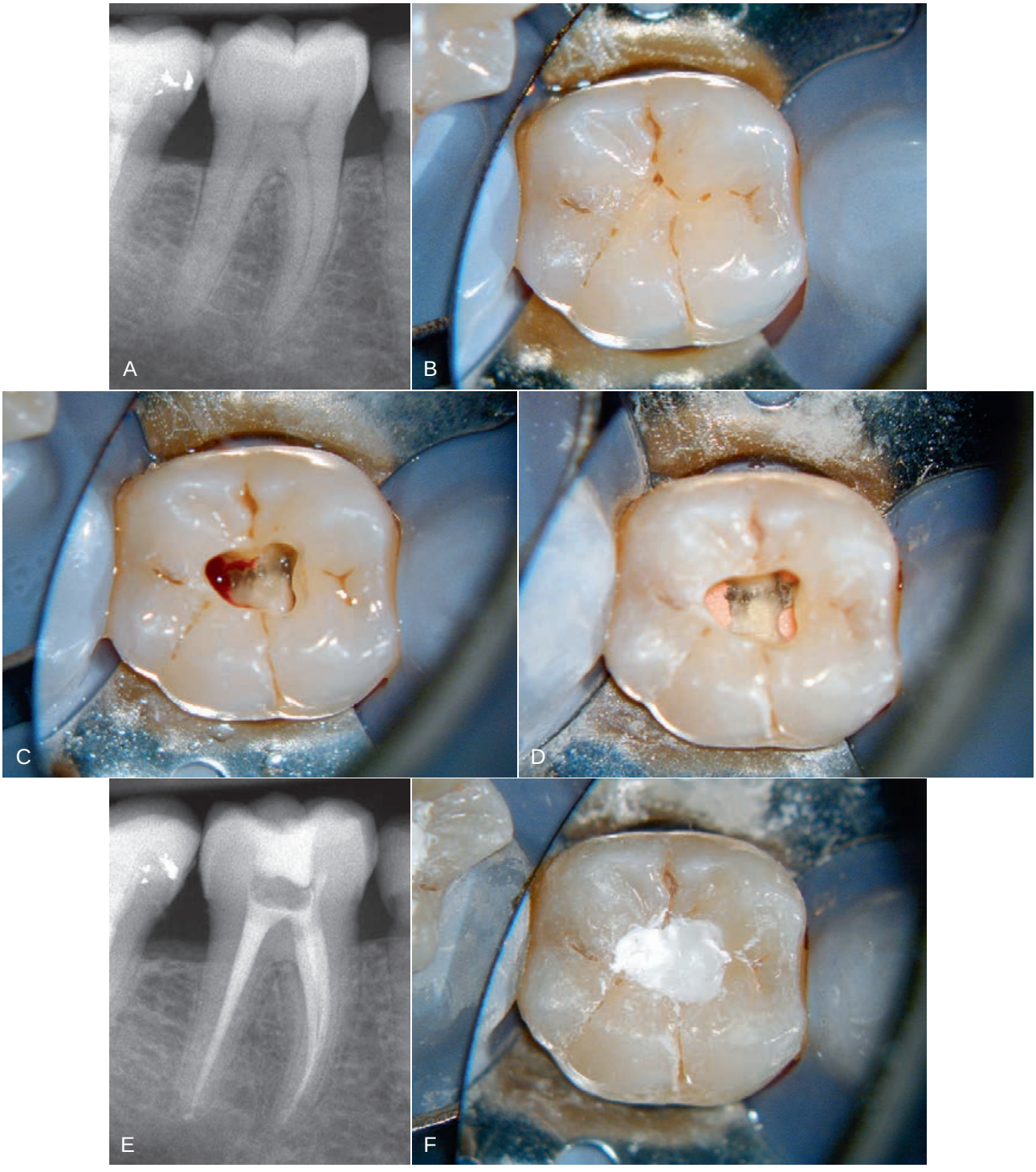


FIGURE 1-24 **A recently restored tooth (porcelain overlay) that has become symptomatic. A, Radiograph of restored tooth—changes in pulpal tissue suggest biologic degenerative changes. B, Preendodontic view. C, Profuse bleeding indicating pulpal inflammation. D, Finished endodontic treatment. E, Final radiograph of restored tooth. F, The restoration in need of repair. How does the patient feel about it? Could this situation be prevented by evaluating the pulpal status before restoring?** *(E Courtesy of Dr Carlos Bóveda)*

Patients must be aware of their role, both at home and in the dental office, in keeping the restorations looking great for as long as possible. After the cosmetic service has been provided, the patient is instructed on how to take care of the restoration(s) and is scheduled at once for the maintenance appointment.

Home Instructions for Patients

Eating

Patients must use common sense to avoid problems with their esthetic restorations. Some useful suggestions are as follows:

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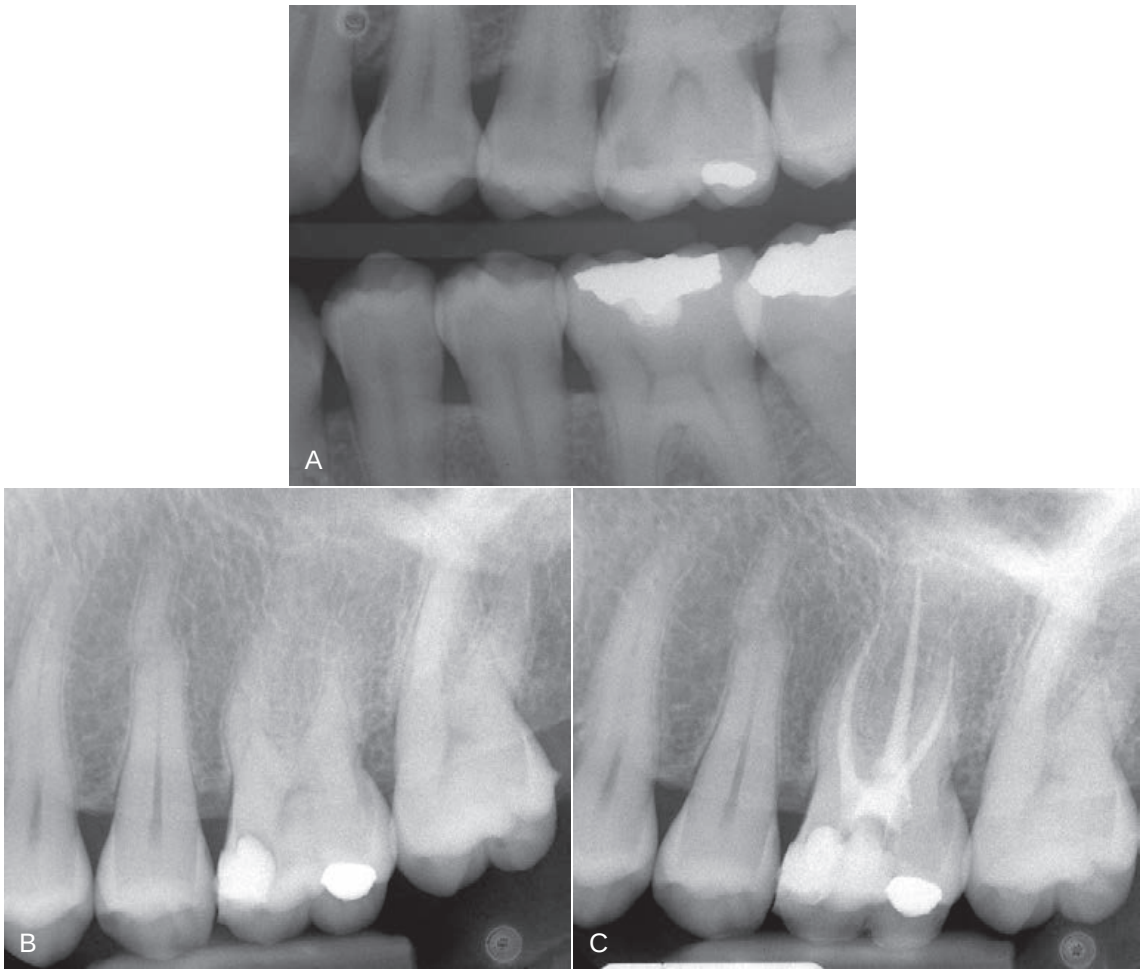


FIGURE 1-25 Combined restorative-endodontic case. A, Asymptomatic first upper left molar with radiographic mesial carious lesion. B, Preliminary temporary restoration. Endodontic treatment was decided because of caries depth. C, Finished endodontic treatment. *(Courtesy of Dr Carlos Bóveda.)*

- Do not chew hard or very sticky foods.
- Do not chew ice.
- Avoid foods with heavy natural or artificial colorants (e.g., berries, beets, carrot candies).
- Avoid scraping the meat off a bone with the teeth (e.g., chicken or spare ribs).
- Avoid biting on forks, spoons, or other eating utensils as well as pens, pencils, and eyeglass parts.

Drinking

Alcohol in drinks can damage bonded restorations. Dark drinks such as red wine, tea, and coffee are notorious stain producers as well as heavily colored artificial drinks. Soft drinks can also be detrimental to tooth-colored restorations because they contain sugar, which introduces the risk of recurrent decay. Some drinks have dark pigments, and the carbonated content can affect bonded surfaces over time.

Smoking

Smoking is highly deleterious to natural teeth and restorations, mainly because of its staining capacity.

Cleaning

Patients should be reassured that they can brush and floss their teeth in a normal manner. Soft toothbrushes are recommended with any available commercial fluoride-containing toothpaste. The brushing technique must be explained so that the amount of pressure and the position of the toothbrush bristles in relationship to the teeth are correct. Brushing and flossing twice or three times a day is enough. Patients with esthetic restorations should be advised about not using dental curettes and explorers, which are sometimes available over the counter in drugstores.

Mouthrinses

If a home fluoride regimen is necessary, *neutral sodium fluoride should be prescribed.* Alcohol in many mouthrinses has also been mentioned to have a negative effect on tooth-colored restorations. If the patient believes a mouthrinse is necessary, it is prudent to select one that does not contain alcohol. Chlorhexidine gluconate will definitely stain both the teeth and the tooth-colored restorations. Although these stains can usually be polished off, they might be difficult to remove from margins and small defects in restorations. If possible, a chlorhexidine varnish,

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FIGURE 1-25, cont'd D, Preparation for porcelain overlay–cuspal protection. E, Temporary restoration. F, Final porcelain overlay. G, Final radiograph of restored tooth. *(F Courtesy of Dr Tomás Seif)*

which does not stain teeth, can be used instead of chlorhexidine rinses.

Habits

Some habits, such as biting on pencils, pipes, and fingernails or opening objects (even envelopes) with the teeth, are potentially damaging and can even dislodge restorations. In addition, parafunctional habits such as bruxing should be detected and proper protection of the restored teeth should be prescribed by having the patient wear a night guard.

In-Office Maintenance

The maintenance visit should be scheduled two to four times a year, depending on the individual habits of the patient. Dentists should acquaint hygienists with the proper instruments and materials for cleaning and polishing these restorations. Hygienists should perform maintenance techniques with which they feel comfortable, assuming proper training has preceded this delegation.

- Before starting the actual prophylaxis ("prophy"), the hygienist should identify all the esthetic restorations by reviewing the patient's chart and by clinical examination. Tactile examination is important to differentiate between an esthetic restoration margin and calculus. If by mistake a margin is aggressively scaled, expensive replacement of the restoration will be needed. The use of ultrasonic and sonic scalers should be avoided on or around the tooth-colored restoration. This also holds true for abrasive units because they can damage the surface, making it more susceptible to staining.
- Calculus buildup should be managed carefully with hand instruments. There are specially designed hand instruments on the dental market that do not scratch esthetic restorations. If only plaque must be removed from the restoration, there are prophy pastes that come in different grits and are specially designed for this purpose. Toothpaste can also be used for this task.
- Although very important for caries prevention, *acidulated phosphoric fluoride (APF) and stannous fluoride (SF) should not be used on esthetic restorations.* APF acts as an etchant on porcelain and may affect the glass fillers in hybrid and microhybrid composites. SF can discolor and/or stain composites. *A neutral sodium fluoride should be used with these patients.*

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Special prophy paste should be used to avoid scratching the surface of esthetic materials. Composites can be polished with a wet aluminum oxide polishing paste. Porcelain should be polished with a diamond paste that is always used dry. Some extra tips on polishing composites and porcelain are as follows:

- To remove stain from composites, a combination of polishing, rubber polishing instruments, and different grits of polishing pastes can be used. If polishing pastes are used, the coarse grit should always be followed by the medium and fine grits. The same holds true when using polishing rubbers or disks. Always work from coarse to fine and from the margin to the tooth.
- Microfilled composites acquire a high shine after polishing with a rubber cup followed by an aluminum oxide paste.
- Hybrid and microhybrid composites can be polished very well, although it takes more effort than with microfilled composites. A stepwise procedure includes the use of a rubber polishing tip followed by Diacomp rubber instruments. Aluminum oxide paste on a regular wet prophy cup can be used afterward. Diamond pastes are effective but usually require the use of felt wheels or buff disks, which do not permit access to proximal or gingival restorations.
- To remove stain from glazed or polished porcelain, polishing paste can be used in the same manner as with composites. A final gloss can be attained with a Robinson brush or a prophy cup impregnated with diamond paste. Sometimes the use of the newest rubber polishing kits can also recreate a glazelike shine on porcelain.

The author encourages the use of composite sealants that are designed to penetrate any microcracks and defects that may have been created by finishing procedures. These sealants are specially formulated unfilled resins that cure in a very thin film and with a minimal air-inhibited layer. Sealing the margins of anterior restorations at recall visits may prevent or slow cement washout. Proper isolation and bonding protocols are advised.

CONCLUSION

Patients trust their dentists' clinical judgments and expertise. Dental professionals are, for many patients, "the ultimate experts" in esthetic dentistry and oral health. To keep patients' trust and to maintain their oral health for a long time, it is essential for any dental practice that offers restorative esthetic services to also provide up-to-date diagnostic services and preventive treatments. It is also very important to correctly diagnose the endodontic status of each tooth to be restored and to provide a maintenance (recall) service for the beautiful treatment rendered. It becomes an ethical issue as well as a moral responsibility with patients. It also results in dental professionals who can practice day after day with great peace of mind and many new referrals from happy patients. Esthetic dental treatments should look and feel good, but especially they should last for a long time.

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CHAPTER 2

Dental Materials

SECTION A

Evolution, Description, and Application of Dental Materials

Frederick C. Eichmiller

HISTORICAL PERSPECTIVE

The birthplace of many dental materials is the Paffenbarger Research Center (PRC) (Figure 2-1, *A*), the American Dental Association's (ADA's) Research Unit in Gaithersburg, Maryland. PRC was established in 1928 to collaborate with the National Bureau of Standards (now called the National Institute of Standards and Technology [NIST]) to develop science-based specifications for dental products. Familiarity with these institutions and pioneers gives a good historical perspective on materials development and the improvements made over the years. It also yields a good perspective on how the standards process of the ADA began and its vital role in defining what dental materials are and how they are used.

Silicate Replacements

Dr George Paffenbarger (Figure 2-1, *B*) joined the scientists at the Research Unit in 1929 and quickly became the unit's lead scientist. In 1985 the ADA renamed the Research Unit in Dr Paffenbarger's honor. Dr Paffenbarger did considerable research in silicates and was strongly interested specifically in silicate cements. In the 1950s and early 1960s, silicates were the only good anterior restorative materials available. Dr Rafael Bowen (Figure 2-2) (the primary developer of dental composites) was a dentist in private practice in Southern California who had a hobby interest in chemistry. A major frustration he faced in his practice was that every time he placed silicate cement he had to explain to the patient that it would last for only a short time and would eventually have to be replaced. Bowen's passion was to find a better material to replace the silicate cements. In his "back porch chemistry lab" he explored new technologies, such as other types of composites and other polymers such as epoxies. He made the first composites using porcelain by grinding up denture teeth with a mortar and pestle and mixing them into epoxy resins, forming the early prototype of dental composites. He tried these on a patient or two but quickly realized that the epoxy resin was not a good matrix material because the setting was slow, it was very difficult to work with, and the toxicity of some of its components was a concern. He then began synthesizing other types of restorative resins to use in place of epoxy. The first one he developed was bisphenol A glycidyl methacrylate (BIS-GMA). Paffenbarger took notice of this development through Bowen's presentations and publication of his work and invited him to PRC.

At that point Bowen began developing and perfecting the BIS-GMA–based composite, for which he is probably best known. He continued to work with the filler components of composite, even studying developments in other aggregate industries and how, for instance, concretes and asphalts were made. He viewed these as just a larger-scale composite and focused on how to make fillers efficiently compact together and bind to the matrix resins. He then applied his findings to dental materials. The materials further evolved through the development of a rapidly reacting catalyst and initiator system so these materials would be clinically convenient enough to use. The BIS-GMA matrix components have low toxicity as well as the necessary strength and toughness. The glass fillers and silane coupling systems that bind the filler to the matrix give the material its optical properties and additional strength and durability.

Evolution of the Components

Bowen's original research has been improved on through many subsequent developments. The resin matrix in composite is being replaced with more and more filler material packed even more closely together. This requires both the ability to densely pack fillers with a range of particle sizes and the ability to make very small filler particles.

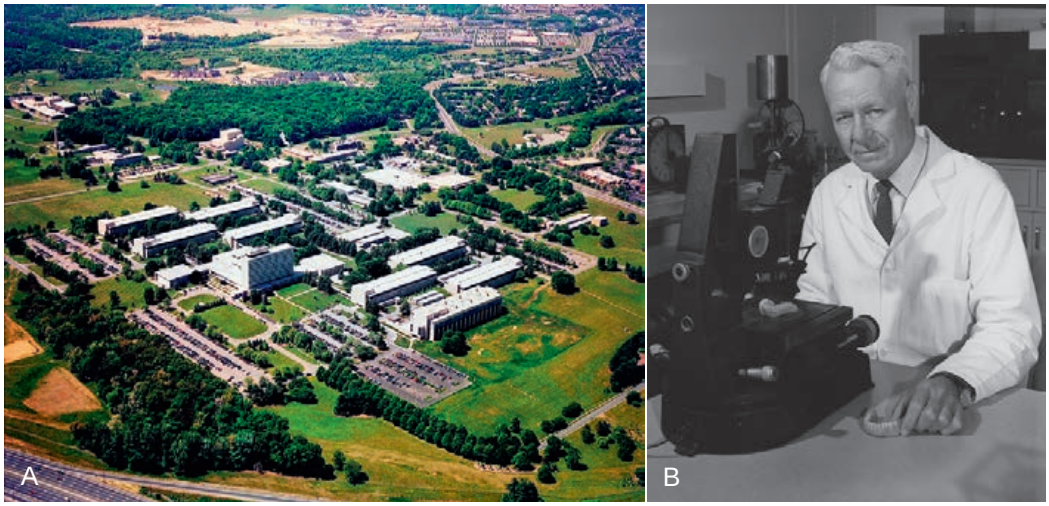


FIGURE 2-1 **A, American Dental Association Foundation's Paffenbarger Research Center. B, Dr George Paffenbarger.**



FIGURE 2-2 **Dr Rafael Bowen, best known for the development of dental composites based on dimethacrylate (BIS-GMA) resin chemistry. Dr Bowen's long career at the American Dental Association Foundation's Paffenbarger Research Center was entirely devoted to the development of improved resin-based adhesives and filling materials.**



FIGURE 2-3 **Examples of cordless curing lights. A, Radii Plus cordless curing light (SDI Limited, Victoria, Australia). B, Dentlight (Richardson, Texas).**

On the matrix side, less has changed until recent times, other than adding a few more resins to choose from in formulating. One major development related to initiators was the use of photoinitiators so that light-cured materials could be applied (Figure 2-3).

BASIC MATERIAL DESCRIPTIONS

The backbone of a dental composite is basically a liquid acrylic resin made up of bifunctional molecules. These bifunctional molecules have a methacrylate functional group on each end, and these are the groups that tie or link together during the curing process. During the curing process they link to form long molecular chains, which is what causes the material to thicken and eventually harden. They can also form *cross-links* between chains; the units on the ends of the molecules attach from one chain to another or attach to smaller resin molecules that bridge between the chains. This cross-linking process ties the chains together and stiffens the material, making it more rigid (Figure 2-4).

Most of the composite materials are based on similar matrix chemistry, and specifically the same methacrylate chain reactions. Each may have a slightly different base monomer, but the

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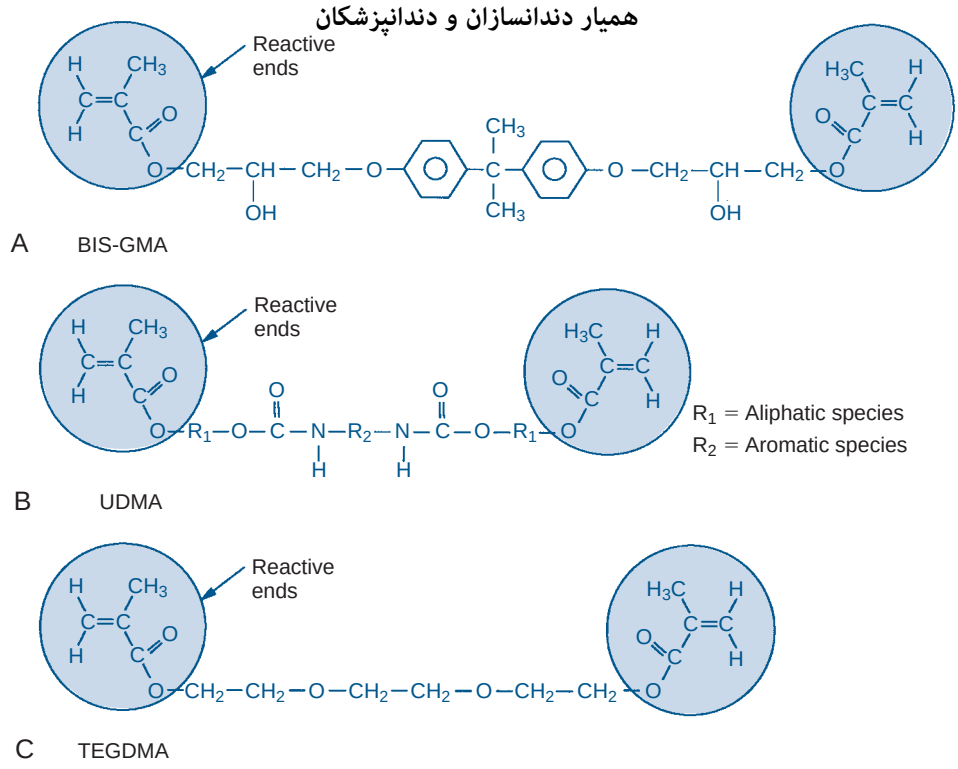


FIGURE 2-4 Chemical formulas of difunctional monomers commonly used in composites. A, BIS-GMA monomer. B, UDMA monomer. C, TEGDMA monomer. *(From Roberson TM, Heymann HO, Swift EJ:* Sturdevant's art and science of operative dentistry, *ed 5, St Louis, 2006, Mosby. Courtesy S.C. Bayne, School of Dentistry, University of North Carolina, Chapel Hill, North Carolina.)*

way they react, the coupling of the methacrylate groups, and the chain and cross-linking reactions occur in much the same way. This similarity in chemistry allows the mixing of different types of composites in a single restoration. An example would be placing a fairly large restoration on an anterior tooth that requires a significant buildup. The optimal choice for the body of the buildup would be a hybrid for strength. Yet when the need for translucency and light transmission at the incisal edge is considered, a microfill or nanofill material could be added to build this part of the restoration. Because most materials are completely compatible with similar matrix chemistry and can be laminated and cured together to make a single unit, this situation presents no difficulty.

The filler component (Figures 2-5 and 2-6) is largely made up of finely ground glasses, either ground from solid glass frit or manufactured through the sol-gel process, a chemical process that involves the precipitation of small particles out of liquid solutions. The composite includes particles in various size distributions so the smaller ones can fill the spaces between the larger ones, yielding a higher density of packing within a given volume.

Initiators come in various combinations. It is possible to use purely chemical initiator systems, photoinitiators, or dual-process initiators, depending on the application. If it is not possible to gain light access to a site for light-initiated products, chemical or dual-process initiators can be used. This may happen in a root canal, under a filling, or under a crown, where the light cannot penetrate. Chemical initiators are basically free-radical

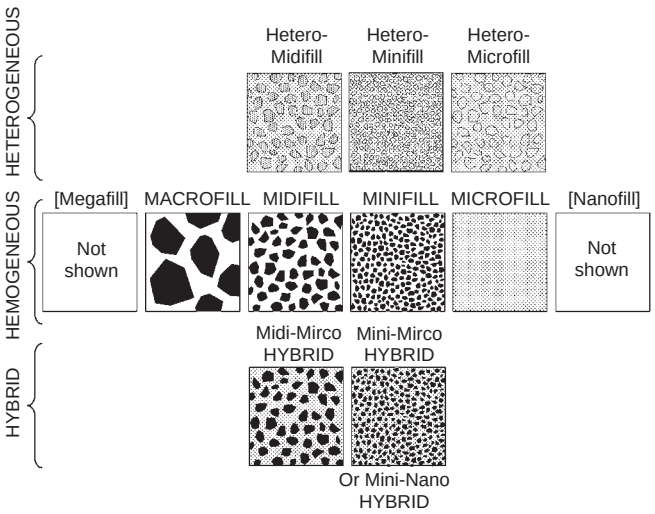


FIGURE 2-5 Examples of dental composite classification based on filler particle size. Composites are grouped on the basis of (1) primary particle size (homogeneous), (2) mixtures of precured with uncured composite (heterogeneous), (3) mixtures of major particle sizes (hybrids), and (4) other special modifications (e.g., chopped fiber is added) to the composite (not shown). Filler particles may be clusters or agglomerates as well. *(From Roberson TM, Heymann HO, Swift EJ:* Sturdevant's art and science of operative dentistry, *ed 5, St Louis, 2006, Mosby. Courtesy S.C. Bayne, School of Dentistry, University of North Carolina, Chapel Hill, North Carolina.)*

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generating combinations of a peroxide and an amine co-initiator. Benzoyl peroxide is the most common chemical initiator used. When the initiator and co-initiator combine they produce a radical that begins the chain-forming polymerization process.

Initiators known as photoactivators, the most common of which is camphorquinone, work in much the same way (Figure 2-7). The camphorquinone will form a radical when excited by a particular wavelength of light. The most common wavelength used today is the blue light with a wavelength of approximately 470 nm. This is what is used to start off the chain reaction of polymerization. The two other, less commonly used initiator wavelengths are 429 and 390 nm and are used to excite different photoinitiator molecules.

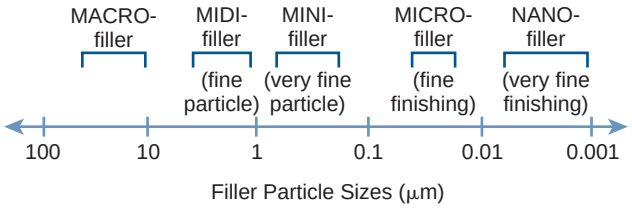


FIGURE 2-6 Composite filler ranges versus particle size (shown on a logarithmic scale). *(From Roberson TM, Heymann HO, Swift EJ:* Sturdevant's art and science of operative dentistry, *ed 5, St Louis, 2006, Mosby. Courtesy S.C. Bayne, School of Dentistry, University of North Carolina, Chapel Hill, North Carolina.)*

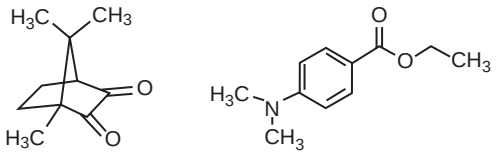


FIGURE 2-7 The camphorquinone will form a radical when excited by a particular wavelength of light.

Physical Properties of Importance

A number of physical properties are commonly measured in composites, some via the ISO Standards testing (Figures 2-8 and 2-9). Some of these properties have direct clinical relevance. The first one is *strength*. The most common strength measured is flexural strength (Figure 2-10), referring to how much the material will bend or flex before it breaks. It is probably the most relevant property clinically because, when considering how fillings support the forces of mastication, marginal ridges and occlusal tables must be able to support contact stresses. Flexural strength reflects the tensile strength of the material, and this refers to how much one can pull or bend a material before it will break. Most composites have flexural strengths in the 100- to 150-megapascal range. This appears to be the strength required for success from a clinical standpoint for composite restorations.

Another important property for polymers and other composites is how stiff they are—the *elastic modulus* (Figure 2-11). Stiffness measures indicate how much load a material will support before it starts to deform or how much it will resist deformation and bending. Restorations under loading should not flex significantly. All materials deform under load, but this deformation should not be great enough to break bonds and marginal seals. Ideally the restoration should be stiff enough to

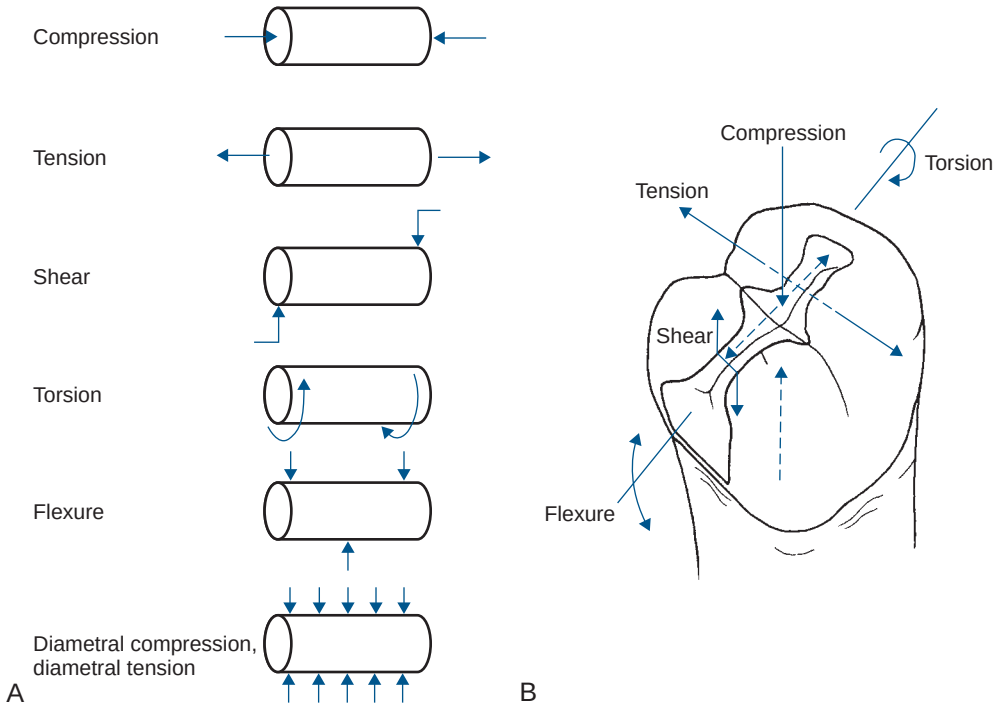


FIGURE 2-8 Examples of directions of loading. A, Uniaxial loading of cylinder. B, Uniaxial loading of a mesio-occlusal amalgam restoration. *(From Roberson TM, Heymann HO, Swift EJ:* Sturdevant's art and science of operative dentistry, *ed 5, St Louis, 2006, Mosby.)*

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FIGURE 2-9 Measuring hardness.

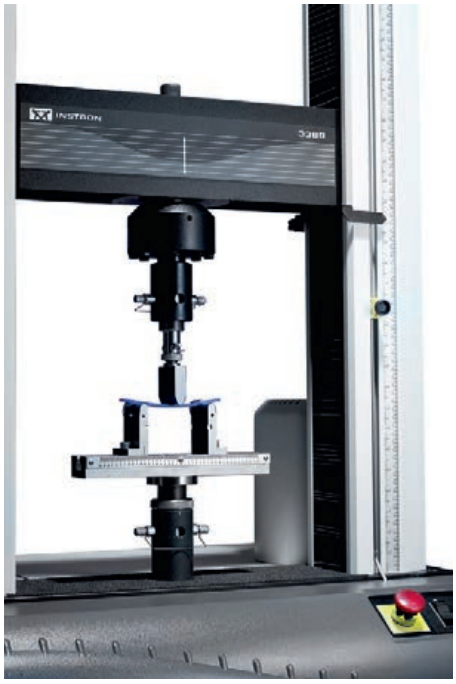


FIGURE 2-10 Flexural bend strength measurement. *(Courtesy Instron, Norwood, Massachusetts.)*



FIGURE 2-11 Measuring elastic modulus. *(Courtesy RTD, Saint Egreve, France.)*

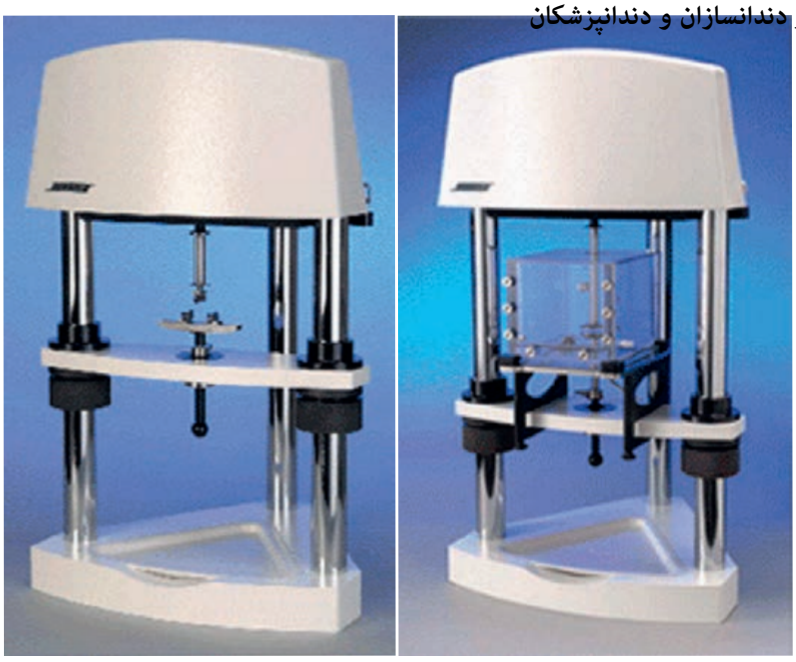
resist breaking the bond or the seal around the edges, a property that is also clinically relevant.

The third property measured in composites is *toughness* (Figure 2-12), which is really a measure of how well the material resists crack growth. All dental restorations sustain damage over time. They undergo loading with chewing, they fatigue, they form cracks, and they form surface defects. Toughness is the ability to resist the growth of those cracks or defects. Filling materials should have a fairly high degree of toughness. Most composites perform fairly well in this area, and all are much tougher than ceramics. If a ceramic has a small crack or defect, its lack of fracture toughness will allow that crack to grow quite easily, whereas a composite will better resist crack growth.

Another relevant property is *expansion* (Figure 2-13). This includes both thermal expansion and hydrolytic expansion. The thermal expansion values of composites are usually about three times those of tooth structure. With hot and cold, composites expand and contract more than the surrounding tooth structure, putting stress on the adhesive interface. This does not affect the composite material per se, but it does alter the bonded interfaces and result in breakdown of adhesion.

Another type of expansion to consider is what happens during hydrolysis, as the composite material absorbs water. Hydrolytic expansion can be especially detrimental if the composite is being used as a cement. In some of the early

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ElectroForce® 3200 with 3-Point Bend Fixtures

ElectroForce® 3200 Instrument Biomaterials Configuration

FIGURE 2-12 Measuring toughness using ElectroForce® 3200 test instruments. *(Courtesy Bose Corporation, ElectroForce Systems Group, Eden Prairie, Minnesota.)*



FIGURE 2-13 Thermohydraulic expansion measurement performed on an ElectroPuls™ E10000 linear motor test instrument. *(Courtesy Instron®, Norwood, Massachusetts.)*

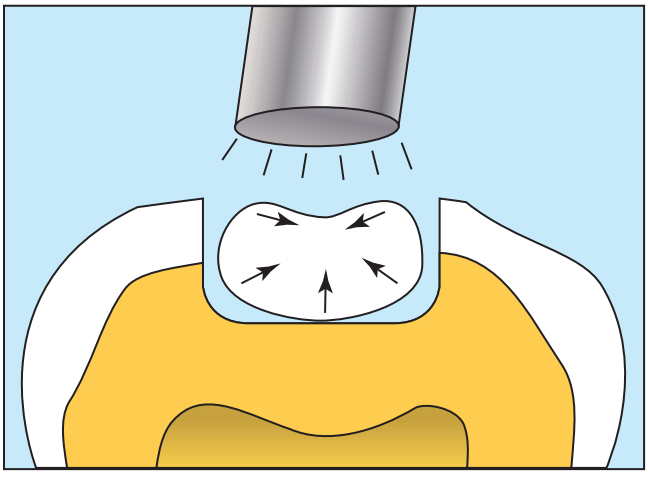


FIGURE 2-14 Polymerization shrinkage. *(Courtesy Dr Ray Bertolotti.)*

resin-improved glass ionomer cements, too much expansion fractured restorations such as ceramic crowns. This property is commonly measured in standards testing.

Another important composite property is *polymerization shrinkage* (Figure 2-14). One of the inherent properties of a composite that uses methacrylate-based resins that undergo chain polymerization is that they transform from what are called *van der Waals spacing* to covalent bonds between the molecules. During this polymerization process the molecules actually move closer together, so the material physically shrinks. Composites each have a characteristic curing shrinkage, but shrinkage of the pure matrix resin is 8% to 10%. Typically, by the time all the filler is packed in, much of that resin has been displaced, which brings the shrinkage down to about 2% to 2.5%. As the material shrinks, it puts stress on bonds or can open up margins. Over the years much effort has been expended trying to develop materials with lower and lower shrinkage. When more of the resin is displaced, less shrinkage can result. More filler and less resin results in a lower-shrinking material. Shrinkage and the stress produced during shrinkage are also affected by the volume of material, the shape of the cavity preparation, how fast the materials cure, and how much they cure. Considerable effort has also gone into reducing shrinkage stress by controlling the curing rate of composites. Many factors enter into the curing process,

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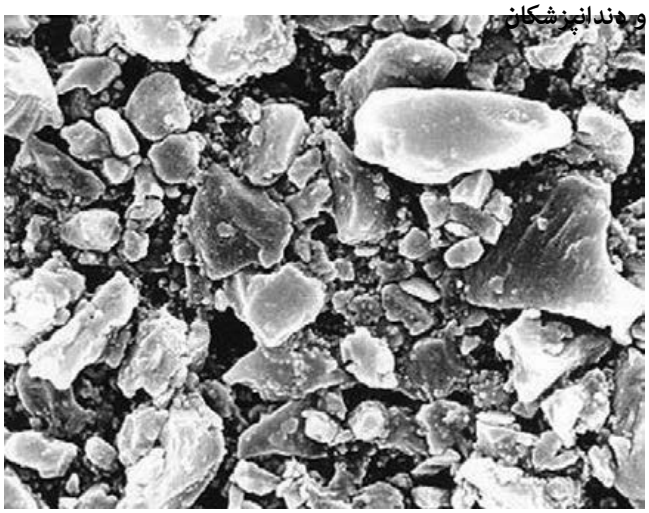


FIGURE 2-15 Macrofill material.

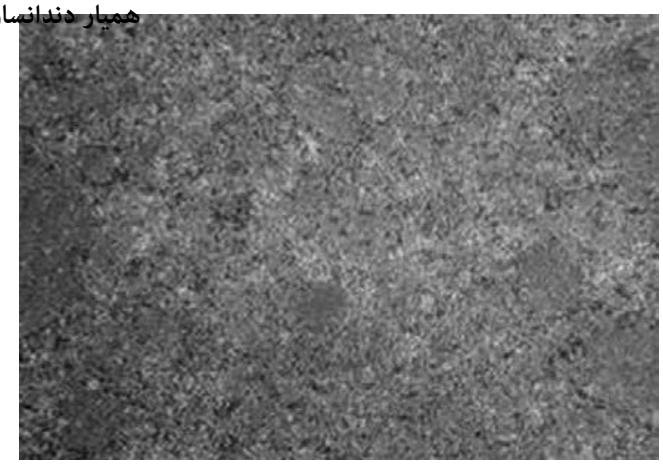


FIGURE 2-17 Microfill material.

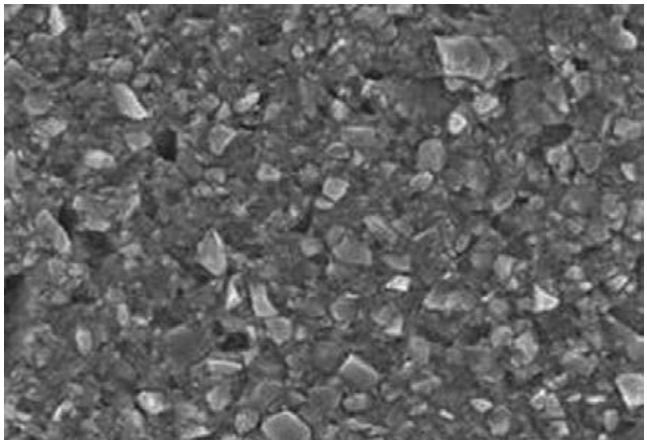


FIGURE 2-16 Hybrid material.

but the lowest shrinking materials are generally in the 1% shrinkage range. No resin matrix composite has yet been able to totally eliminate polymerization shrinkage.

Classes of Composite Materials

The classes of composites are generally based on the size of the filler particles. The earliest class of composites is referred to as *macrofilled materials* (Figure 2-15). These are not used much anymore and consist generally of composites made with large filler particles. Most of the early chemically cured macrofills used ground glass filler particles measuring up to 10 µm or more in average diameter.

Today *hybrid* or smaller-particle materials are most common (Figure 2-16). A hybrid contains different-sized filler particles ranging from very small submicron size to 2 or 3 µm in average diameter. This broad range of sizes allows hybrids to achieve extremely dense particle packing. Hybrids tend to be the most highly filled systems available today.

Microfill materials also have a mixture of particle sizes, but across a narrower range of diameters (Figure 2-17). The particles are 0.5 µm or less and can achieve a relatively high packing density. Because the particles are very small, it is also possible to finish and polish them very smoothly. They exhibit good optical characteristics, transmitting light quite well, and achieve the desirable enamel-like translucency.

The materials with the smallest particle size and the most recent appearance on the market are the *nanofills* (Figure 2-18, *A*). These materials are primarily made with fillers that are precipitated via the sol-gel process, which is capable of producing particles or agglomerates of particles that are down to the 100-nm range. Their optical characteristics are excellent, and they can achieve fairly high packing levels. They also exhibit good handling and excellent esthetic characteristics.

Some attempts have been made to use only individual nanoparticles in a composite, but this has proven difficult, as it is challenging to manufacturing individual nanosized particles. Theoretically, a pure nanocomposite would be possible if the manufacturing process could be developed, but that is not yet in place. What generally happens is that the nanoparticles agglomerate into clumps when going through the sol-gel process (Figure 2-18, *B*). 3M ESPE originally produced two classes of nanofilled materials—one in which there were larger agglomerates, and one with much smaller agglomerates.

Filler Level of the Various Classes

The most important material characteristic in a composite is the filler level by volume because that level will control or minimize the shrinkage, determine the strength and durability, and establish the handling and optical properties of the material. Generally, the higher the filler level, the higher the strength and the lower the shrinkage. Hybrids have the highest-volume filler fraction, followed by microfills and nanofills, which have comparable values. Percentage values in the high 70s are possible with some of the hybrid materials, whereas the microfills and nanofills generally have percentage values in the high 60s. The macrofills were not widely distributed, but they achieved around 65% in volume percent, so they were not as highly packed as a hybrid. They were able to achieve fairly good

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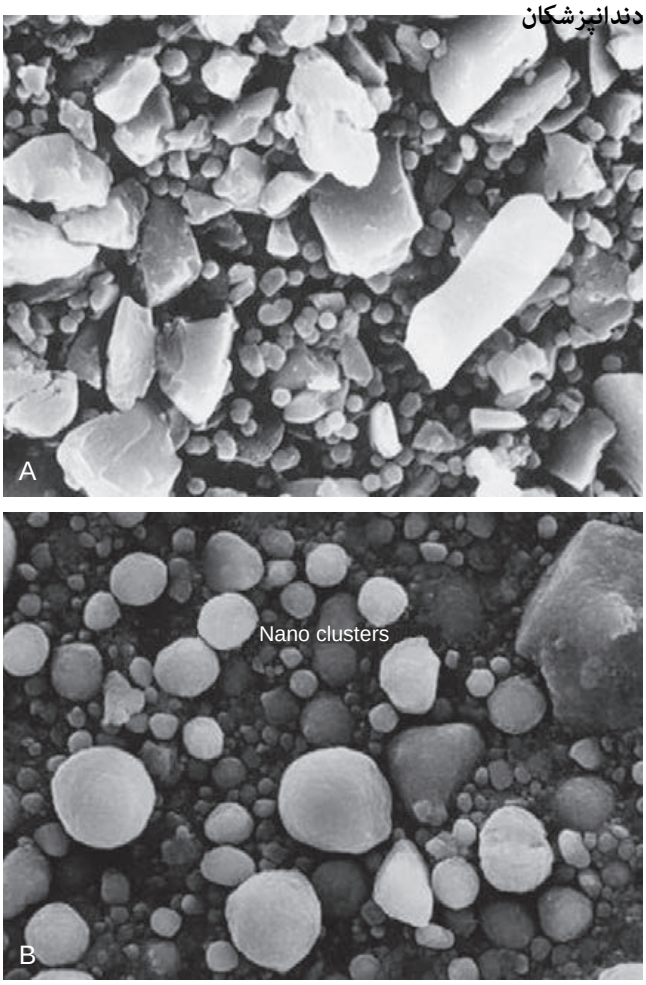


FIGURE 2-18 **A, Nanofill material. B, Nanofill distress.**

strength because of the large particles, but not the dense packing. Macrofills did not finish well because the particle sizes were so large, making them difficult to polish. Once the material was in place and subjected to wear or loss of the matrix material, particles protruded and gave the restoration a rough texture.

APPLICATION OF SPECIFIC COMPOSITES

Composites can consist of specialized compositions to best meet the requirements of their application. Changes can be made in shrinkage characteristics, curing method, optical properties, and handling characteristics. Filler level is often varied to change viscosity and handling characteristics. One material may be thin, whereas another one may be very heavy or very thick depending on the use. A good example is a flowable composite, which contains lower filler levels so that it has more of a flowing character and a lower viscosity. Very highly filled composites will have stiff handling characteristics, with better ability to be sculpted and shaped.

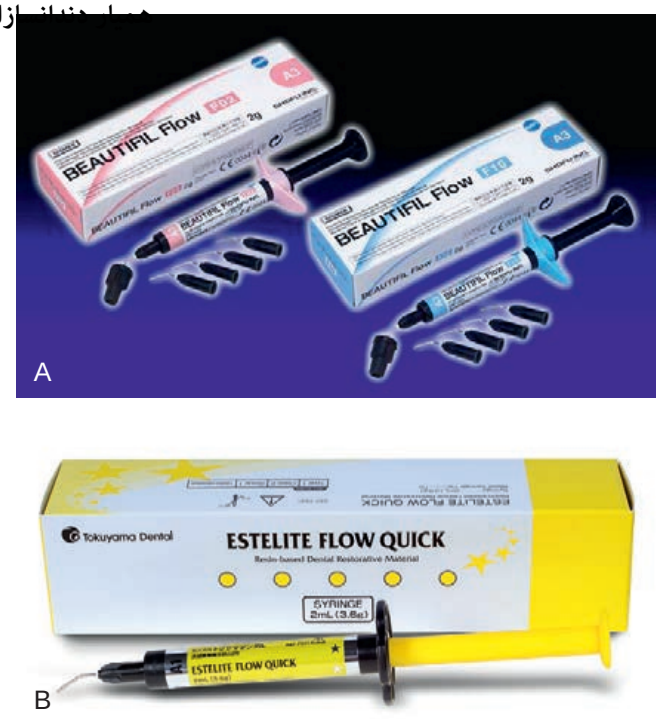


FIGURE 2-19 **Flowable composites. A, BEAUTIFIL Flow. B, Estelite Flow Quick.** *(**A,** Courtesy Shofu Dental Corporation, San Marcos, California. **B,** Courtesy Tokuyama Dental America, Encinitas, California.)*

Strength-Resistance Compromises

A *flowable composite,* because it has a less filler, has lower strength (Figure 2-19). It contains more resin so it will also have higher shrinkage values. As a result, this is not a good restorative material for stress-bearing conditions. It is used today more as a base and liner because of its flow characteristics, which allow it to adapt to tooth surfaces quite well. It is probably being used less and less as practitioners become more adept at handling the more heavily filled restorative composites.

One technique for adapting more heavily filled composites is using various ways of heating or warming them to lower their viscosity. When a more flowable form is needed, it can be obtained by just warming the high-viscosity composite. If a typical hybrid composite is heated to about 50° C, its viscosity will be drastically lowered, making it almost like a flowable material.

Another example of modifying the flow within a specific composite is the *packable composite* (Figure 2-20). These materials use very high filler levels and larger filler particles to give the material a very high viscosity. They are not used as much as they were in the past, but they can be handled somewhat like an amalgam and are condensable. These materials were designed to overcome one frustrating feature of placing posterior composite restorations, which is maintaining good proximal contact. It is impossible to force composite into a preparation and actually expand the space between the teeth with the material. The material is passive, so the dentist must establish adequate tooth separation before placing the restoration. The packable composites

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FIGURE 2-20 Packable composite: SureFil High Density Posterior Restorative. *(Courtesy DENTSPLY Caulk, Milford, Delaware.)*



FIGURE 2-21 Specialized composite material for core buildups: Spee-Dee Build-Up material. *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

behaved more like an amalgam by being viscous enough to provide some tooth separating forces as the material was pushed or packed into the cavity.

Specialized Formulations

An example of a specialized composite is a material used for core buildups (Figure 2-21). For this application a high degree of stiffness is desired. Because this material will not be used for adapting to small cavities, it does not require great flow or adaptability. It is possible to increase the filler level, make it stiffer, and maybe even add tints and colors that contrast with the surrounding tooth structure. This is useful for preparing a crown beyond the edge of the core buildup in order to visually determine that the finish line is ending on tooth structure and that an adequate ferrule of tooth structure is present beyond the buildup. Core material is often chemically cured rather than light cured because it is often placed under an opaque core matrix. Buildups are also often large enough in bulk that they cannot be adequately penetrated with a curing light.

Another good example of the variability of composites is the systems used for cementing posts and cores in endodontically

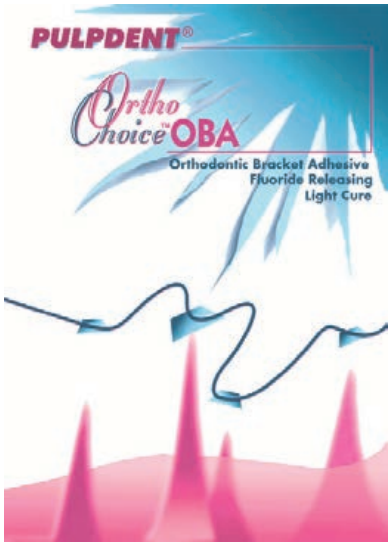


FIGURE 2-22 Orthodontic composite: Ortho-Choice No-Mix bracket adhesive. *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

treated teeth. Their viscosity is fairly low to allow for placement down the canal, but they also require a chemical or dual-cure initiating system because of the lack of access for light curing.

Some of the orthodontic composites are two-part systems with fairly high levels of chemical initiators in each of the components, so it is possible to add one component to the bracket and another on the tooth (Figure 2-22). When they come into contact, they rapidly cure and hold the bracket in place. If they are light cured as well, they will contain a very high level of photoinitiator so that again they cure very rapidly. Shrinkage is also less of a concern in these materials because they are not placed in cavity preparations.

Luting and Cementing Composites

Variations are made to luting and cementing composites to meet film thickness requirements. These materials must have very small particles and lower filler levels, so that viscosity is lower. These types of materials often have either a chemical (Figure 2-23) or a dual-cure curing (Figure 2-24) initiator system. In seating an all-ceramic crown, it may be possible to light cure through the ceramic and start the initiation reaction, but if light penetration is inadequate, a dual-cure material will still continue to chemically cure and achieve a sufficient final set. In placing a very thick or opaque ceramic or metallic restoration with no light access, dual-cure systems will still chemically cure under the crown or prosthesis.

Self-Adhesive Resin Cements

There are probably limits to how much one can alter the resin composition of cements and still maintain stable physical properties. However, the self-adhesive resin cements try to combine the adhesive functionality of the dentin adhesive monomers with the strengthening properties of the matrix resin (Figure 2-25).

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FIGURE 2-23 Cementing composite with chemical initiator system: ParaPost. *(Courtesy Coltène Whaledent, Cuyahoga Falls, Ohio.)*



FIGURE 2-24 Cementing composite with dual-cure curing initiator system: ResiLute. *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

In cementing metal or metal ceramic prostheses, these cements are probably appropriate, but the good, reliable adhesion necessary for bonding all-ceramic restorations may be somewhat compromised. When hydrophilic monomers are added to a resin cement system to make it self-adhesive, the level of hydrolysis also increases, causing it to absorb water more rapidly, and it may not maintain strength over long periods of time. Only time will tell if these materials are durable enough to become a permanent part of the armamentarium.

Temporary Restorations

The composites used for temporary restorations (Figure 2-26) have been modified by the addition of a plasticizer. These materials have a more flexible and resilient character, so the temporary restoration can be removed without damaging the tooth. Most use a combination of chemical or dual-cure initiators.



FIGURE 2-26 Rubberized urethane for temporary restorations: Tuff-Temp resin. *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*



FIGURE 2-25 Self-adhesive resin cements: A, Embrace WetBond Resin Cement. B, MonoCem Self-Adhesive Resin Cement. *(**A,** Courtesy Pulpdent Corporation, Watertown, Massachusetts. **B,** Courtesy Shofu Dental Corporation, San Marcos, California.)*

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FIGURE 2-27 **Pit and fissure sealant: Embrace WetBond Pit and Fissure Sealant.** *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

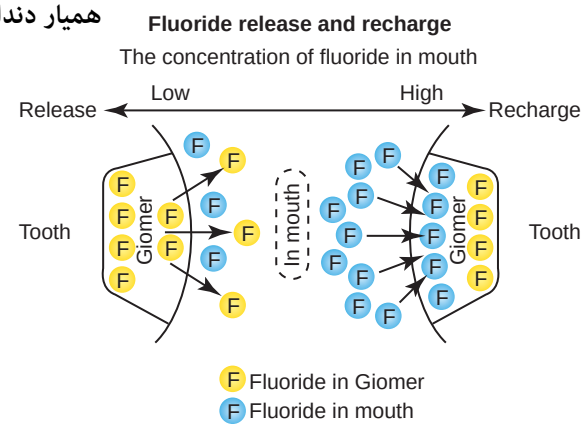


FIGURE 2-28 **Fluoride release and recharge in a giomer. These resins are much more effective absorbing oral fluorides and then releasing the ions at a later time.**

Pit and Fissure Sealants

Pit and fissure sealants (Figure 2-27) are another class of resin-based materials that are lightly filled and have a very small volume fraction of filler. The viscosity is low enough that they can penetrate deeply into the pits and fissures of the tooth. Early pit and fissure sealants did not have filler, but today most contain a small amount of filler to control the viscosity and increase the durability. Pit and fissure sealants also usually have a higher level of initiator, so they cure very rapidly.

Fluoride-Releasing Composites

The last class of materials consists of *fluoride-releasing composites* (Figure 2-28). Probably the most well known of these are compomers. One of the limitations of a composite is the hydrophobic or "water-disliking" quality of the matrix materials. Because these matrix materials do not absorb much water, it is hard to dissolve fluoride out of the composite. Most fluoride-releasing composites release a very low amount of fluoride when compared with glass-ionomers. Glass-ionomers have a much different polysalt matrix that can absorb water much more readily, providing a better exchange of the fluoride ions from within the glass-ionomer. The glass-ionomer also has a higher level of porosity than the typical composite material, making it more efficient at releasing and reabsorbing fluoride. It is very questionable whether the fluoride release from composite materials is great enough to be of any therapeutic benefit.

Comparison of Curing Systems

A *chemically cured* or *self-cured material* requires two components, two different pastes that must be mixed together (Figure 2-29). The two parts of the initiating system are physically separated until it is time to use them. The amine co-initiator is



FIGURE 2-29 **Chemical cured material: HardCore buildup material, dual cure.** *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

separated from the peroxide initiator used to form the radicals until they are mixed, either via dual-syringe mixing systems or manually. One drawback of this system is that once the materials have been mixed, there is a limited amount of time to work with them. The polymerization reaction begins at the start of mixing, so the working time is limited—generally 1 to 3 minutes. During this time the dentist must place and manipulate the material before it starts to harden and cure.

There are still a few applications for purely chemically cured systems. Resin cements used under metal prostheses need chemically cured systems because there is no way to penetrate the metal with a light and achieve photocuring. The chemical systems allow one to get a very high degree of conversion that will result in a very strong, durable cement once it has set. Buildup materials that are placed in a single bulk increment are often chemically initiated to ensure a complete cure throughout their thickness.

Photoinitiator systems have the advantage of not requiring the separation of the two components, the initiator and co-initiator (Figure 2-30). These components can be combined within the same composite formulation so no separate mixing step is required. As a result there is an almost unlimited working time.

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FIGURE 2-30 Photoinitiator system: Estelite Sigma Quick. *(Courtesy of Tokuyama America, Inc., Encinitas, California.)*



FIGURE 2-31 Dual-cure initiator system: Embrace WetBond Resin Cement. *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

The material does not begin to cure until it is exposed to the correct wavelength of light. The material may have some sensitivity to curing under the ambient light in the operatory, such as that from the overhead operating light. Generally, most composites are not terribly sensitive to ambient light, so the working time can be many minutes. The photoinitiator systems allow nearly unlimited time to manipulate the material and permit complete control over when it is cured. Their disadvantage is the inability to use them in situations where good light access is not possible. For example, light-cured resin cement is not appropriate under a metal restoration that cannot transmit the curing light. Light-cured composite may not be a good choice for large core buildups, where a large bulk of material thickness may need to be cured at one time. Light penetration sufficient to achieve an adequate cure may be only 2.0 to 2.5 mm within light-cured composites. Thicker situations require either a buildup of the restorations in multiple thinner increments or use of a chemically cured material.

The third type of initiator system is a *dual-cure system* (Figure 2-31). This system combines both chemical and light curing. Because it involves a chemically cured mechanism, it still consists of two separated components and requires mixing. The disadvantages are the need to mix the two components and the limited working time. However, with a dual-cure system the working time is longer than with a chemical cure. Typical working time is in the range of 6 to 8 minutes with a dual-cure material versus 2 to 3 minutes with the chemical cure. An advantage of dual curing is that once the material is adapted into place, the cure can be initiated more rapidly by shining the correct wavelength of light on the site, snap-setting or speeding the polymerization reaction. Today's dual-cure systems are used in multipurpose resin cements that, especially for all-ceramic restorations, allow one to shine the light through the restoration to achieve an initial set once the restoration is seated. Even with this quick photocure, the chemical reaction requires a certain period of time to polymerize to completion. If there is cement in an area where the light cannot penetrate, the material will still cure efficiently, giving a high degree of conversion and good physical properties.

FUTURE DEVELOPMENTS

In resin-based materials the holy grail of composites is the nearly nonshrinking or zero-shrinkage composite. Most of the basic research geared toward future composites has focused on developing lower-shrinkage systems. As this research has progressed, dentists have become much better at handling the materials available today, even with the existing shrinkage. Clinical techniques have improved to the point that zero shrinkage is probably not as important as previously thought. It is currently possible to influence many of the factors affecting shrinkage, such as incremental techniques, stress minimization, adaptation of materials, and contact achievement. Even so, some chemists are looking at everything from epoxide-type chemicals to ring-opening monomers to liquid crystal–type monomers, which all show some promise at being able to reduce or perhaps eliminate shrinkage.

Another focus for the future is on self-adhesive composites. This is an attempt to impart the adhesive properties of a dentin-enamel adhesive to the matrix system of the restorative composite so that it will adhere to structures more efficiently. Some progress has been made in the laboratory. Also, some studies have been done on self-adhesive pulp-capping liners, showing they are fairly effective. Whether it is possible to achieve adequate adhesion to make an interface strong enough to resist polymerization shrinkage and functional stresses, and maintain long-term durability is yet to be seen. Such a self-adhesive restorative composite is probably not as critical as once thought, as current adhesives have become more reliable and convenient to use.

Some work has been done in the development of *smart composites.* These are materials that have therapeutic or diagnostic functionality. For example, diagnostically a colorimetric marker could indicate a gap, a fracture line, loss of adhesion, or the beginning of acid production by adjacent bacteria. If there is a risk of recurrent caries, a colorimetric marker may show a leaking margin or presence of acids, so action can be taken before the caries process starts. Therapeutically composites may be equipped

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with antimicrobial or remineralizing capability. Some resin-based composites contain amorphous calcium phosphate. Currently they are being used for orthodontic adhesives and sealants, for which strength is not as critical as with restorative composites. The concept is based on adding a filler phase that is capable of releasing calcium and phosphate ions when there is an acid attack on or near the restoration, so it imparts a preventive or therapeutic effect.

Fluoride release has not proven as effective in composites as desired, but research into different fluoride compositions continues. Some clinical testing has involved the ability to formulate pulp-capping composites. One method for pulp capping is adding pulp repair–stimulating components directly into to the composite. These may include calcium phosphate, morphogenic proteins, or dentin-stimulating peptides. These formulations may stimulate the repair and deposition of secondary dentin under the pulp-capping composite. The concept is to have a material with good strength and durability that can stimulate the pulpal repair, but is also strong enough to support the overlying the restoration. Typically in the past, calcium hydroxide would be used for this purpose. Calcium hydroxide stimulates pulpal repair but tends to wash out from under restorations and has little strength to support an overlying restoration.

SUMMARY

Composites have evolved since Bowen's back porch experiments to become the mainstay of direct restorative dentistry. No other material in dentistry has the versatility to adapt to so many different clinical needs. Both the materials and the skills of the clinicians in using them have vastly improved over the past few decades. Research continues to improve on the properties, the handling, and the clinical uses for composite resins. It is to be expected that some day composite materials will be available that not only restore damage, but detect and prevent disease and perhaps even heal the damage done by disease.

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Impression Materials

Carlos A. Muñoz-Viveros

RELEVANCE TO ESTHETIC DENTISTRY

Impression materials are used to replicate the structures of the oral cavity. Using the impression it is possible to construct a model or cast so that functional or esthetic restorations can be fabricated (Figure 2-32).

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Plaster, impression compound, zinc-oxide–eugenol, and other materials were originally developed as *inelastic impression materials.* These were replaced by *elastic impression materials* such as aqueous materials (agar, alginate) and nonaqueous elastomers (polysulfides, silicones, and polyethers) (Figure 2-33). Impression materials are also classified as *reversible* (compounds and hydrocolloids) or *irreversible* (silicones, polyethers, and alginates).

Agar hydrocolloids have largely been replaced by rubber impression materials, but they are still used for full mouth impressions when severe undercuts are present. Their composition includes agar, borax to improve strength, potassium sulfate to provide compatibility with the stone, preservatives, and flavoring agents. The use of agar hydrocolloids is complicated by the need for a tempered water bath and prefabricated metal trays (Figure 2-34).

Alginates or *irreversible hydrocolloids* are the most widely used impression materials in dentistry. They are useful for making all types of impressions but not accurate enough for creating fixed cast restorations. They are composed of a powder containing sodium or potassium alginate, calcium sulfate as a reactant, sodium phosphate as a retarder, fillers such as diatomaceous earth, potassium sulfate for stone compatibility, and flavoring agents. The powder is mixed with water.

Polysulfide rubber is still used in many countries because it is inexpensive and has plenty of working time. It is supplied as a base and catalyst pastes. The base contains a polysulfide base polymer, fillers, and plasticizers. The fillers are mainly zinc oxide, titanium dioxide, or zinc sulfate. The catalyst or accelerator contains lead dioxide, hydrated copper oxide or organic peroxide as a catalyst, sulfur and dibutyl phthalate as a plasticizer, and other nonessential fillers. It is set by a condensation polymerization reaction. Because water is a byproduct of the reaction, the impression must be poured within 30 minutes.

Condensation silicone rubber is supplied as a base and catalyst and used for partial denture impressions and fabrication of small appliances. The base is composed of a polydimeththylsiloxane, orthoalkylsilicate for cross-linking, and inorganic fillers. The catalyst or accelerator contains a metal organic ester such as tin octoate and a thickening agent. It sets by condensation polymerization with alcohol as a byproduct. Because of its high polymerization shrinkage, manufacturers make a high-viscosity catalyst commonly referred as "putty." These putties are highly filled, so there is less polymerization shrinkage.

Addition silicones of *vinyl polysiloxane* (VPS) are currently the most used materials for making indirect restorations. They are available in many viscosities and a range of colors. These materials contain silicone prepolymers with vinyl and hydrogen side groups that polymerize via addition polymerization. They are sold as paste-paste, with one paste containing a vinyl-polysiloxane prepolymer and the other a siloxane prepolymer with hydrogen groups, a platinum catalyst, and a chloroplatinic acid that initiates the polymerization reaction. Oxygen is sometimes a byproduct of the reaction. These materials are highly hydrophobic.

Polyether rubber was developed in the late 1960s and is characterized by a relatively short working time but achieves great accuracy. The material is fairly stiff but very hydrophilic. There is a base paste that contains a low-molecular-weight polymer with ethyleneimine groups, fillers, plasticizers, and colloidal silica. The catalyst contains an aromatic sulfonic acid ester and thickening agents. When mixed, a polymerization reaction occurs by ring opening of the ethyleneimine groups.

CLINICAL CONSIDERATIONS

Indications

The indications for these materials vary depending on the intended clinical use. Some materials are used for diagnostic purposes, such as alginates. Others are used in fabricating complete dentures (modeling compounds). Still others are indicated

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FIGURE 2-32 **Examples of impressions. Here the impression material has extended cervical to the unprepared margin of the tooth.**



FIGURE 2-33 **Silicone impression materials with automixing machine.** *(Imprint 3 Impression Material, courtesy 3M ESPE Dental Products, St Paul, Minnesota.)*

for the fabrication of permanent prostheses such as restorations or appliances.

Contraindications

If the impression cannot be poured within a reasonable amount of time, alginates, polysulfides, and reversible hydrocolloids are not indicated. In addition, polysulfide and condensation silicones require a custom tray. Sometimes allergies limit the usefulness of these materials.

MATERIAL OPTIONS

The current material options are elastic impression materials such as irreversible and reversible hydrocolloids, addition silicones, and polyethers.

Advantages

Irreversible hydrocolloids are inexpensive and easy to manipulate, have a pleasant odor, displace blood and saliva, are hydrophilic, and can easily be poured in stone. No custom trays are needed.

Reversible hydrocolloids are also inexpensive, are nontoxic, and have a pleasant odor. Neither custom trays nor adhesives are needed and there is no mixing. These materials are highly hydrophilic.

Polysulfides are inexpensive and have a long working time, excellent tear strength, good flow, and good detail reproduction. They can readily be removed from undercuts.

Silicone rubber has a pleasant odor and good flowability. The setting time can be controlled by altering the amount of catalyst applied. Silicone rubber can be used as a paste-paste or in a putty-wash method, depending on the consistency.

Addition silicones are very accurate and offer many viscosities. They have excellent deformation recovery and low flow. Many have been considered hydrophobic, but newer materials are now available that are more hydrophilic. No custom tray is required.

Polyethers are easy to handle and mix. They also provide excellent detail reproduction and are hydrophilic.

Disadvantages

Irreversible hydrocolloids tear easily, are dimensionally unstable, and achieve limited detail reproduction. Reversible hydrocolloids require expensive equipment, tear easily, must be poured immediately, and are dimensionally unstable. Their use is primarily for single restorations. Polysulfides have an unpleasant odor and require a custom tray. These very-low-viscosity materials must be poured within a half hour. For silicone rubber, custom trays are needed. The material can be difficult to pour and must be poured immediately. Silicone rubber is also highly hydrophobic. Addition silicones are the most expensive of all the impression materials. They are very rigid and difficult to remove from undercuts. It is hard to pour them in stone, and their chemistry can be inhibited by the sulfur in latex gloves and rubber dams. Polyethers are very stiff, expensive, and sensitive to water moisture. They have a history of causing allergic reactions and are difficult to disinfect.

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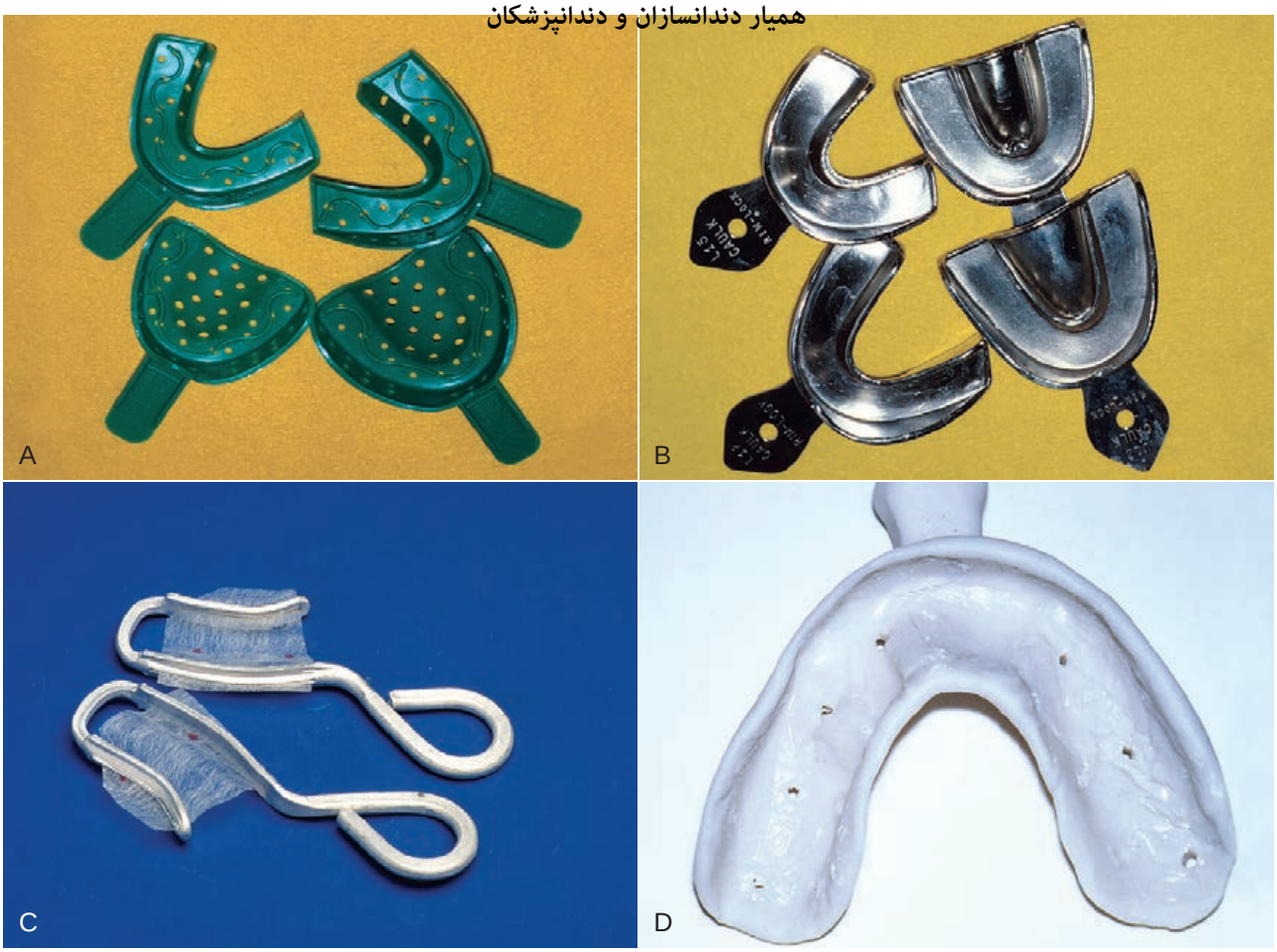


FIGURE 2-34 Selection of tray for impression procedures. **A,** Plastic stock trays. **B,** Metal stock trays. **C,** Closed mouth trays. **D,** Custom tray.

INNOVATIVE ELEMENTS

Surfactants have been added to the addition silicones to diminish their hydrophobicity. Hydrogen absorbers have been added to reduce their release of hydrogen gas. Bite registration materials have been introduced that are fairly stiff and offer fast setting times. Improvements in dispensing and mixing methods have also been made. Mechanical mixers are readily available. Most manufacturers offer impression materials in prepackaged 50- or 300-mL cartridges with disposable mixing tips. Unit dose impression systems are also available. Alginate substitutes have recently been introduced as inexpensive VPS materials.

Scientific

The biocompatibility of these materials has been improved, making them less toxic. Colorants have been added for easy identification in the oral cavity.

Technologic

In the future it may be possible to have materials that set on demand. Optical impressions may also be developed (Figure 2-35).

TREATMENT PLANNING

The type of impression material and technique chosen depends on the intended use. The dentist must first determine if he or she will use a closed or open mouth technique. The next choice is whether to use a heavy body–light body combination, a putty–light body combination, or a single mix technique.

TREATMENT CONSIDERATIONS

Preparation

If the preparation is subgingival, tissue displacement cord or an alternative method must be used. Any hemorrhage should be controlled before initiation of the impression procedure. The operating field should be isolated.

Procedure

The custom or prefabricated tray is evaluated intraorally, and then adhesive is applied. The cord is removed and the preparation gently dried with compressed air. Light-viscosity impression material is syringed around the margins of the preparation. The

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FIGURE 2-35 **Examples of chairside optical impressioning systems. A, Cerec 3D (Sirona Dental Systems, Charlotte, North Carolina). B, Lava Chairside Oral Scanner.** *(B Courtesy 3M ESPE Dental Products, St Paul, Minnesota.)*

TABLE 2-1 Selected Products Available for Impression Materials

IRREVERSIBLE HYDROCOLLOID (ALGINATE)	ALGINATE SUBSTITUTES	POLYSULFIDE	CONDENSATION SILICONES	POLYETHERS	ADDITION SILICONES (PVS)
Jeltrate Plus Jeltrate Dustless (DENTSPLY/ Caulk) Coe Alginate (GC America) Supergel (Harry Bosworth) Integra (Kerr Corporation)	Position Penta Quick (3M ESPE) AlgiNot AlgiNot FS (Kerr Corporation) Freealgin (Zhermack)	Permlastic (Kerr Corporation) Coe-Flex (GC America)	CutterSil Putty Plus (Heraeus Kulzer) ColtoFlax (Coltène/ Whaledent)	Impregum Impregum Penta Soft, Permadyne (3M ESPE) Polygel NF (DENTSPLY/ Caulk) P2 (Heraeus Kulzer)	Affinis President (Coltène/ Whaledent) Virtual (Ivoclar Vivadent) Extrude Take 1 Advanced (Kerr Corporation) Aquasil Ultra (DENTSPLY/ Caulk) Exaflex Examix (GC America) Flexitime (Heraeus Kulzer) Imprint3 Express (3M ESPE) KOPY (Dental Savings Club)

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impression material is thinned down using a stream of air to facilitate the placement and flow of the material into the sulcus. The tray is then seated. The manufacturer's recommendations for setting time are observed, then the tray is removed from the mouth.

Finishing

It is important to visually inspect the oral cavity for any loose material. The area is then rinsed and dried, and the impression is evaluated and disinfected.

CLINICAL CONSERVATION CONCEPTS

The use of custom trays permits a conservative approach.

MAINTENANCE

Very little maintenance is needed because these materials are used in the mouth for only a few minutes. They are usually poured once and are relatively accurate for several weeks.

CONTROVERSIES

The use of "triple trays" and the need for custom versus prefabricated trays are still lacking evidentiary support. Different viscosities are required for different preparations or techniques.

NEAR-FUTURE DEVELOPMENTS

Optical impressions will be an important contribution. With the development of these, other materials will simply disappear. Currently, some of these systems are available but are very expensive (Table 2-1).

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Photography: Digital and Analog

Clinical Photography Standards

Christopher Orr

RELEVANCE OF PHOTOGRAPHY TO ESTHETIC DENTISTRY

Good photography lies at the heart of absolutely every area of esthetic dentistry. The correct use of the clinical camera is an invaluable way for the practitioner not only to document what is being done in terms of pre-treatment and post-treatment photographs of cases, thereby maintaining excellent clinical records, but also to improve patient education and enhance his or her self-education.

Risks of Not Using Dental Photography

Patients easily forget what they looked like before they started treatment. When anything to do with the appearance is affected, not using a camera puts the practitioner at substantial legal risk.

Unfortunately, human memory is terribly short, and patients' recollection of how their teeth appeared before treatment is often quite hazy, which leads to the potential for dispute. Even for something as straightforward as tooth whitening, patients may feel that their teeth have not responded to treatment and thus may seek a refund of fees. If this occurs, showing them pre-treatment and post-treatment clinical photographs of how the teeth responded to the whitening process should clear things up. The patient has simply become accustomed to the new appearance of the teeth very quickly. Thus photography has a role in things as simple as bleaching and as complex as extensive rehabilitation; this makes the camera as essential an instrument as dental loupes, handpieces, and other basic tools in performing esthetic dentistry.

In addition, all practitioners learn by seeing clinical photographs in books and journals. Viewing their own patients in this same way frequently improves their diagnostic abilities and ensures that potentially important aspects of the treatment are not overlooked.

Need for Photography in Various Dental Areas

In general practice, dentists may not necessarily view all their patients as potential candidates for esthetic dentistry. However, the camera can show the patient his or her own mouth from the perspective of the dentist, dental staff, and other people. This allows the patient a better level of understanding of his or her situation, which may facilitate the process of consent to treatment and even increase the level of requested treatment. In general practice, dental charting has been used for over a century as a way of recording the condition of a patient's dentition. Digital photographs are an excellent supplement to traditional dental charting, as they allow the practitioner to record many details, such as wear or discoloration, which cannot be well represented with traditional charting.

Orthodontists have long been aware of the benefits of standardized clinical photographs for record keeping. This is particularly valuable in their area because of the inherently long-term nature of the treatment process.

The esthetic dentist is primarily interested in what the patients look like and what they *can* look like. In most cases, it is the patient who requests treatment. Esthetically motivated patients can use the photographs to help them communicate what they actually want, and practitioners can more accurately document what has been done.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

The major advance in dental photography centers on the shift from film-based to digital imaging. Film was a great step forward when introduced over a century ago. Clinically, however, it was

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not a useful or efficient tool, as it was impossible to analyse the images immediately and check whether the desired views had been obtained. Pictures were taken as slides because slide films were considered best for color reproduction. However, the film had to be sent out to commercial laboratories for processing. Due to the specialized processing needed, there was always a delay in return of the photographs, often 1 to 2 weeks. Showing patients their own teeth was inconvenient owing to the need to project the images. Copying images when required was an added inconvenience, as it was very difficult to achieve consistent quality and color accuracy in duplication.

It was very difficult to show the pictures to patients at the chairside; thus, for most practitioners, excepting those taking post-graduate examinations or clinicians on the lecture circuit, photography was not considered a routine practice.

Digital photography has been around for some time, but it was only in 2003-2004 that a good-quality digital single-lens reflex (SLR)–type camera become affordable for most practitioners. The mass marketability of consumer digital SLR cameras has revolutionized how clinical photography is done, how it is delivered, and its practicality and reliability. With digital photography, there is the advantage of immediately verifying that the desired image has been captured. It is very easy to look at the picture on the camera's screen, identify what is not right, and retake it immediately. There is no need for processing, so images can be viewed immediately, and they can be shared with patients right away.

Photography also improves the quality of referrals. If a general practitioner sees a suspicious red lesion under a patient's tongue, it is quite easy to take a picture of it, put that into a referral letter or attach it to an email, and send it to the oral medicine specialist. A complex restorative referral can be made much easier for the practitioner receiving the referral if photographs can be included along with radiographs and the referral letter as it allows the treatment planning process to begin even before the patient visits the prosthodontist's office. Not only does this allow the dentist to document what is being done, but it helps in caring for patients more comprehensively and more efficiently.

RELATING FUNCTION AND ESTHETICS

Digital photography is another example of how digital tools allow dentists to be better, more efficient, and more elegant in doing what used to be done by hand. Various people have described the technique of recording a patient's occlusal scheme, called the "occlusal sketch." In this, the dentist takes a drawing of the patient's teeth or a drawing of an idealized arch and marks the centric contacts or the excursive contacts with different colors of pencil. This is a very useful technique for recording the patient's pre-treatment occlusal scheme and occlusal problems, but it takes a long time. Much easier is doing the digital equivalent of an occlusal sketch. The dentist does a normal occlusal examination, asks the patient to functionally mark the contacts, and then simply puts an occlusal mirror into the mouth and takes a photograph. This entire process takes about 30 seconds, compared with the 10 minutes required for a good occlusal sketch. From this perspective, photography can be useful not only for documentation of static images but for functional occlusal considerations as well.



FIGURE 3-1 A typical "point-and-shoot" setup. *(Courtesy PhotoMed International, Van Nuys, California.)*



FIGURE 3-2 A typical single-lens reflex (SLR) setup. *(Courtesy PhotoMed International, Van Nuys, California.)*

EQUIPMENT OPTIONS

There are three levels of sophistication. Assuming that the 35-mm film camera is no longer in use, many dentists' entry point into clinical photography is a modified "point-and-shoot" camera (Figure 3-1) or an entry-level digital SLR camera (Figure 3-2). For the dentist who wants to improve their clinical photography, there is more sophisticated equipment that allows better images and greater clinical latitude.

The modified point-and-shoot cameras have an important place in clinical photography. The early consumer-level digital SLRs were more expensive than some practitioners could afford. The point-and-shoot cameras have the advantage of being compact, light, and (at that time) relatively less expensive. Their

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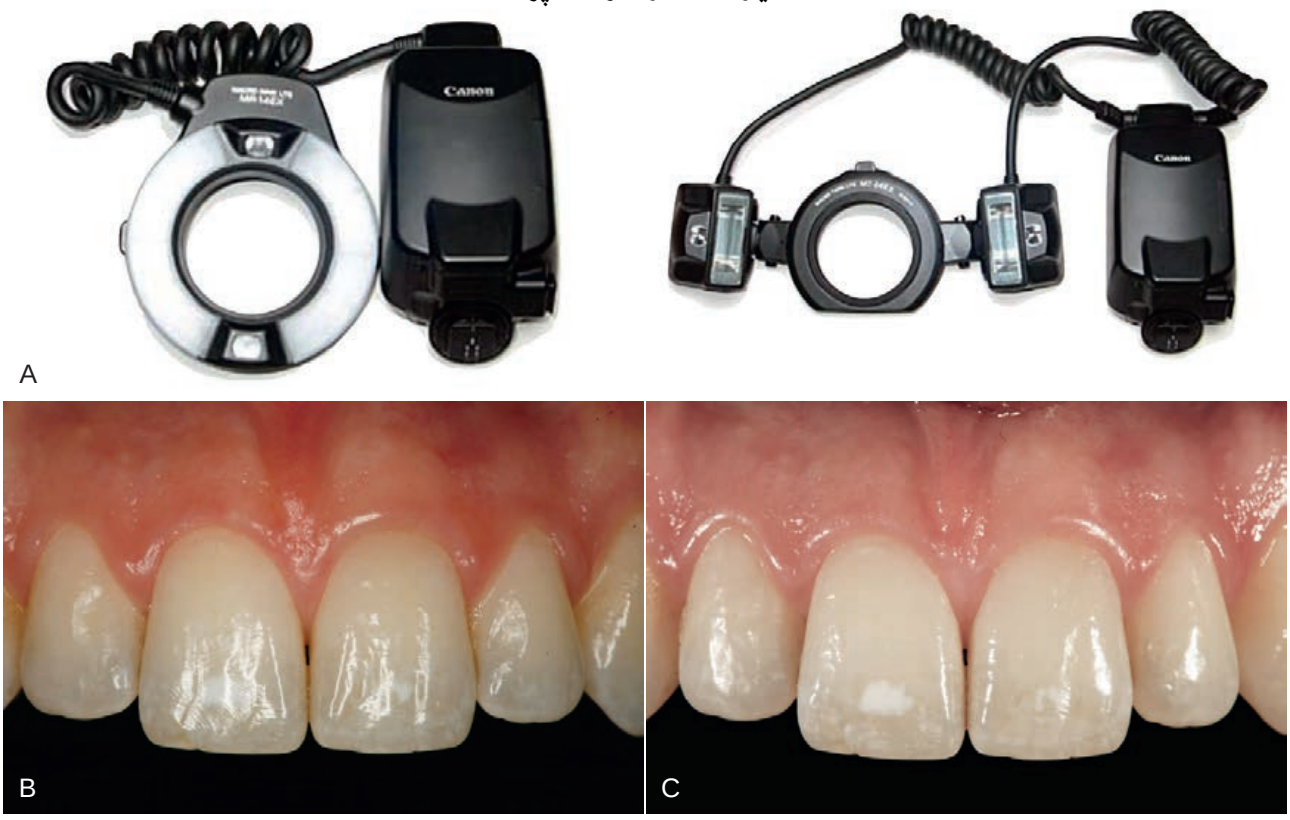


FIGURE 3-3 **A, Ring flash *(left)* and dual point flash *(right)*. B and C, Comparison of light reflection on mesial and distal line angles with different flashes. The ring flash (B) sometimes gives undesirable light reflection, whereas the line angles are better visualized with the dual point flash (C).** ***(A** Courtesy PhotoMed International, Van Nuys, California.)*

disadvantages relate to their distinct operational and a long learning curve, the need for a substantial degree of practice and familiarity with the setup to get the best images.

Often the dental practice has a second camera for the staff to use. When clinical photography is properly implemented in the practice, staff members and particularly hygienists become involved with patient picture taking as part of their educational process. Many staff members find the simpler, modified point-and-shoot cameras to be preferable to their SLR counterparts.

Current Best Approach

The best practice for most people begins with the purchase of the equivalent of a 35-mm–type digital SLR camera. Even today's entry-level digital SLR cameras have a pixel count that makes their digital images superior to film images. Their ease of use and efficiency in obtaining reproducible results are excellent.

The technical setup comprises a camera body and a macro lens, typically one with a focal length around 100 mm. The lens must be a specifically dedicated macro lens rather than a zoom lens that has a macro capability; for clinical photography dentists require easy access for close-ups of the teeth. This is another area in which SLR cameras are superior to modified point-and-shoot cameras. With point-and-shoot cameras it is more difficult to get close-up views and occlusal images that require the use of mirrors.

In addition to the body and the lens, a flash is required. In order to achieve images with all the teeth in sharp focus, the shutter speed is set to a fraction of a second to eliminate camera shake, the aperture is set to a very small opening size to maximize depth of field, and thus there is a need for an additional light source as ambient light will be far from sufficient. The most straightforward option for most practitioners is a ring flash. For a few practitioners who are very interested in taking the absolutely best-quality clinical pictures possible, more sophisticated flashes are available (Figure 3-3). These include a dual point flash, a twin light source that allows the alteration of the illuminations to show line angles and translucencies on teeth and restorations more accurately. This permits one to have more control over the final image. However, the requirement to adjust the flash heads individually for each shot makes it impractical for many dentists.

The best combination is therefore an SLR camera, a macro lens, and a ring flash. The camera sits assembled in the operatory, ready to be picked up and pointed at the patient. In addition, any practitioner taking photographs will need cheek retractors and mirrors. The more sophisticated practitioner may prefer visual contrast and can use black-out sticks in close-up shots to eliminate the out-of-focus background of the mouth. This is an issue of personal preference but improves the final picture significantly.

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Specific camera systems change so quickly that it is difficult to recommend a certain model. Generally, any SLR body made by either Nikon or Canon provides very good results. Other manufacturers' systems are available, but they may lack the full range of lenses or other accessories for optimal clinical usage. In terms of lenses, both Nikon (Nikon Inc., Melville, New York) and Canon (Canon USA, Inc., Lake Success, New York) make very good 100-mm focal length macro lenses. Sigma also makes good-quality macro lenses that are somewhat less expensive. Canon makes a very good ring flash, and a Sigma or Metz ring flash can be used with either Nikon or Canon products. Point-and-shoot setups vary greatly, so it is best to speak with one of the major suppliers such as PhotoMed (Van Nuys, California) or Clinipix (Wellington, Florida) to determine the latest products. If the dentist wants more sophisticated twin lights, Canon and Nikon both offer good choices. Clinical photography is a specialized area, so it is advisable to use one of the specialized clinical photography suppliers, as general photographic suppliers lack the technical knowledge of dentistry's specific requirements.

OTHER CONSIDERATIONS

Generally the best person to be taking the photographs is the dentist. However, in many practices well-trained staff members who understand the important issues of framing, focus, and correct exposure take the pictures on behalf of the dentist. Often for re-care appointments or new patient appointments, the person who takes the photos can be either a hygienist or a specifically trained dental assistant. The images are then ready for the dentist when he or she comes in to conduct the patient examination.

As part of the general consent process, consent for photography is implied by the patient sitting in the chair for the dental appointment. The photographs, however, are part of the clinical record and should be treated in the same way as radiographs and clinical notes. In terms of using clinical photographs in other settings, as with any clinical record items, if the patient is identifiable, one needs the patient's specific (usually written) permission. If the patient is not identifiable, then no specific consent outside of the general consent is required. If the dentist, for example, wants to use some before-and-after pictures for a portfolio on a website, many patients are delighted that their treatment turned out so well and will readily allow the doctor to show their cases. For most patients the main concern is a picture involving the full face where they are readily identifiable. Sometimes a very distinctive dentition is immediately identifiable. In those cases, permission is needed prior to use. Overall the use of pictures is perfectly acceptable, provided the patient cannot be identified.

INNOVATIVE ELEMENTS

In terms of clinical photography, there have been a a number of novel evolutions from general photography. First, the range of lighting conditions under which a typical digital camera can produce an acceptable image has expanded greatly. Second, the number of pixels that one can pack onto a camera sensor has increased while technology prices have fallen; pixel count is no longer the main determinant of cost.

The advent of the improved "through the lens" (TTL) light metering has had a major impact on the predictability of capturing good images. With film photography one had to make an educated guess and take multiple slightly different exposures (bracketing) in the hope of getting one perfect image. Today's electronic TTL (E-TTL) flashes decide exactly how much light should be generated to correctly illuminate the subject, leaving the dentist free to think about focusing the picture and correctly framing it. This eliminates yet another barrier for practitioners.

One area that remains the same is the differentiation between auto focus and manual focus. Auto focus is essentially the default setting on most consumer cameras, but it often does not work effectively when one is very close to the subject and doubly so when one is photographing a reflected image on a mirror. For that reason, manual focus is the best way to make sure that one achieves consistent framing and consistent exposure. It is best to choose a particular magnification ratio on the camera's lens barrel and then move the camera back and forth slightly to achieve the correct distance from the subject. This allows the dentist to take the same picture at a specified magnification consistently, without referring to previous photographs of the patient.

Light metering is essentially handled by the camera. That is a major reason for buying the E-TTL–capable ring flash. One can be tempted to buy cheaper ring flashes that do not communicate electronically with the camera body; these require guesswork for ideal illumination, and often result in many, many more pictures taken, wasting clinical time. In terms of chairside efficiency, the higher cost of the E-TTL flashes is more than justified by the amount of clinical time that one saves in use.

ARTISTIC ELEMENTS

There is a sharp distinction between pictures that are purely for clinical documentation value and pictures that are more artistic. The best example is the difference between shots taken purely as a record-keeping tool, which are pictures of the patient's full face or profile, smiling or not, and portrait photographs, for which the patient has been put into a studio environment, had their hair styled and makeup applied, and is wearing flattering clothing. There is a distinct line between a dentist and a studio photographer. Some dentists may wish to add that level of creativity and sophistication to their photography, so portrait photography may be another avenue for them to explore. Many who practice esthetic dentistry have their patients' outcomes nicely photographed at the end of treatment. If the dentist chooses to do a portrait photograph as well, it can be an enhanced service provided by the dental office.

The other artistic element is photographing one's ceramic restorations as beautifully as possible. With a bit of practice and the desire to experiment with the flash positions, one can

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produce very artistic pictures with light reflecting just the right way across the surface texture of anterior ceramic restorations. Those pictures have a degree of usefulness for clinical documentation, but they are taken more for artistic reasons. The people who tend to use that style of photography tend to write and give presentations extensively, as those pictures look very nice on the covers of journals or on a large screen in an auditorium.

TREATMENT PLANNING

A number of years ago the American Academy of Cosmetic Dentistry (AACD) recommended a standard set of 12 pictures for its accreditation examination (Figure 3-4, *A*), which represented a good starting point for planning and documentation over a wide range of situations. The views required were reflective of the limitations of film-based photography, in which it was very difficult to magnify selected parts of an image. With today's high-megapixel cameras, it is possible to zoom in and see similar amounts of detail to the film-based 1:1 photos, so these views are unnecessary for routine documentation. In addition, pictures of the patient's teeth in occlusion are useful for medicolegal purposes. Therefore a newer, simpler set of photographs is more appropriate reflecting today's equipment (Figure 3-4, *B*).

The first picture should be a full-face picture (Figure 3-5), taken with the patient looking straight into the camera, with the interpupillary line parallel to the lower border of the frame, and the facial midline parallel to the vertical border of the fame. Framing should include from just below the chin to just above the hairline.

All the other photographs are taken at a fixed magnification ratio of 1:3 (the equivalent of a 1:2 on 35-mm film and full-frame digital SLR cameras) and an aperture of f/22 or higher to provide acceptable depth of field.

The next pictures are a series of three pictures of the patient smiling (Figure 3-6). The frontal view has the central incisors in the middle of the picture parallel to the lower border of the frame and the facial midline parallel to the vertical border. It is



FIGURE 3-4 **A, The American Academy of Cosmetic Dentistry's accreditation views.**

Continued

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FIGURE 3-4, cont'd **B, A simpler but more comprehensive set of clinical photographs for general and esthetic documentation.**



FIGURE 3-5 **Full-face view taken at f/11. The photograph should show the patient's face from just below the chin to just above the hairline, with the facial midline parallel to the vertical border of the frame and the occlusal plane parallel to the lower border.**

important to note that it should be the facial midline, not the dental midline. Any discrepancy between the dental and the facial midline will be reproduced in the photograph and noted. After this, right and then left lateral smile views are taken, with the upper lateral incisor just above the middle of the picture and the occlusal view parallel to the lower border. The frontal view will allow the dentist to assess the lip line, the smile line, the midline, the relationship between the incisor levels, and the lips. The lateral views also show the teeth on their respective side plus the emergence profile of the teeth on the contralateral side.

At this point a set of cheek retractors is placed into the patient's mouth, and then frontal and left and right lateral photos are taken first with the teeth in occlusion (Figure 3-7, *A* to *C*) and then slightly parted (Figure 3-7, *D* to *F*). As with the frontal smile view, the central incisors are typically in the middle of the picture and the facial midline is parallel to the vertical border of the frame. The occlusal plane is parallel to the lower border of the frame. Lateral views also have the lateral incisor in the middle of the frame and the occlusal plane parallel to the lower border of the shot.

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FIGURE 3-6 **Smile views taken at f/22 and 1 : 3 magnification ratio on most cameras. The frontal view is framed with the central incisors in the middle of the frame, the facial midline parallel to the vertical border of the frame, and the occlusal plane parallel to the lower border. The lateral views are framed with the lateral incisor in the middle of the frame, and the occlusal plane parallel to the lower border.**

Finally, some occlusal images (Figure 3-8) are taken using an occlusal mirror. Patients should open very wide so the mirror can be inserted and the occlusal surface of all the teeth in an arch can be photographed, from second molars to incisors. The mouth should be opened wide enough that the interproximal embrasures of the anterior teeth are visible, but only a small area of the labial surfaces are shown. This can sometimes be difficult in the lower jaw. The assistant may need to position the retractors very precisely to allow the dentist to move the mirror for the perfect picture. For the lower picture it may also be helpful to have the patient curl their tongue to the back of the mouth.

These 12 images form a set of pictures that can be used almost universally for most treatment plans. It is wise to take them at an initial consultation; this permits the dentist to discuss the treatment plan with the patient immediately. Alternatively, if the treatment plan is complex and requires the dentist to further analyze the dentition before presenting treatment, the practitioner can see the patient's entire mouth without having to schedule an added appointment.

Additional photographs, such as close-up views of the anterior teeth or posterior quadrants and lateral images of the face, can be taken if appropriate to the patient's condition or if required for examination purposes.

CONSIDERATIONS FOR PHOTOGRAPHY DURING PREPARATION, PROCEDURE, AND FINISHING

In terms of specific patient preparation, very little needs to be done pertaining to photography. For full-face pictures, many practitioners prefer either to have the patient stand against a white or black wall or to position a colored card or cloth behind the patient's head in the chair to eliminate the distracting background of the treatment room. For the intraoral photographs, an air syringe blows saliva and water away from the teeth and tissues. Once the pictures have been taken, they can be viewed and stored using imaging or practice management software.

It is desirable (and legally required in some jurisdictions) to have the digital photographs backed up outside of the practice. Although there is software available to assist with this task, the large volume of data involved is best transferred to a pocket-sized hard drive. Each patient's folder (identified by the patient's last and first names), contains all the pictures for that individual, grouped into files by date or procedure. These are catalogued under a four-digit year, a two-digit month, and a two-digit

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FIGURE 3-7 Retracted views taken at f/22 and 1:3 magnification ratio on most cameras. Framing is similar to the smile views, but retractors are placed to hold lips and cheeks back. **A to C,** Teeth in occlusion. **D to F,** Teeth slightly parted.



FIGURE 3-8 Occlusal views taken at f/22 and 1:3 magnification ratio on most cameras. The dental midline is parallel to the vertical border of the frame. In addition to retractors, a mirror is essential to take these views correctly.

date—for example, 2011-09-10. If the program sequences the folders by name, the patient names will sort alphabetically by surname and the visits will sort chronologically, facilitating searches. Some practitioners who are very busy, or who use their cameras infrequently, take a photograph of their patient list for the day from either the appointment book or the computer screen; this list jogs the memory to identify which patients were seen on a particular day for later sorting.

EVIDENCE-BASED PRINCIPLES

It used to be said that the camera never lies. Unfortunately, today the potential for image manipulation is very great. One does not have to look too far to find examples of retouched photographs in show business and advertising. However, if the purpose of the clinical photograph is to serve as clinical documentation, then almost no post-processing is acceptable. The generally accepted yardstick is that global changes, such as altering the brightness or the contrast of the entire image or rescuing an underexposed or overexposed picture, are considered acceptable, as are cropping and rotating the image. These changes are applied to the whole image. Other types of edits—for example, altering the photographs to make things appear in places where they were not, making margins appear better than they were, or making colors brighter or perhaps darker than they really were—are considered localized edits and are not acceptable from any point of view in clinical dental photography.

Sometimes a practitioner who is documenting treatment wishes to have the equivalent of a digital negative. Many of

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the SLR cameras have a picture-taking mode referred to as RAW. Each camera manufacturer has its own format for the RAW file—for example, .nef (Nikon Electronic Format) or .cr2 (Canon Raw version 2). RAW essentially is a digital negative format: the RAW file can be opened up with suitable software, viewed or converted, but it cannot be resaved as a RAW file. The RAW file therefore acts as the secure digital negative and is used by many organizations in which clinical care submission is required as part of an examination. The RAW file must be submitted with photographs so that the examination process can be protected against the unscrupulous retouching and editing of pictures that make things look better than they are clinically.

MAINTENANCE

As with any kind of digital data, the best assumption to make is that at some point something or everything may fail. Therefore multiple backups across multiple media are probably the best means for ensuring that files are not lost or corrupted.

For smaller amounts of data, CDs or DVDs may be appropriate, but the size of even DVD storage capabilities is unfortunately small compared with the file sizes generated by today's typical digital SLR cameras. Tape backup solutions are expensive to purchase but cheap to maintain.

The increasingly low cost of hard drive storage makes it the easiest and most cost-effective method for storing large amounts of data. Even pocket-sized drives have the capacity to store hundreds of gigabytes or terabytes of data. It is very easy to store thousands of photographs on just one such drive. Backup software can be useful, but several hard drives on which one makes regular backup copies of the entire clinical archive are helpful.

Data backup experts usually recommend that three backups should be available at any moment. This means one that the dentist is working on, a previous backup, and the backup before that. The next backup, which would be the fourth in the series, overwrites the oldest one. Thus the dentist is as protected as is reasonably possible against data loss; multiple devices must fail simultaneously in order for all the data to be lost.

The amount of data that needs to be stored has become substantially larger in recent years. The best advice is that practitioners consult with information technology (IT) personnel or alternatively obtain a number of hard drives and make the sequential backups as described above.

NEAR-FUTURE DEVELOPMENTS

The marketplace now is geared toward consumer-level cameras, and no drastic price drops are anticipated. The price points within the markets are well established, and there is little to be gained by delaying a dental camera purchase. The number of pixels on standard sensors is likely to increase, but more pixels are unlikely to offer a clinical advantage. Near-future developments will see more practitioners becoming aware of the benefits of dental photography and more patients becoming more highly educated about dental esthetics through photography.

CONCLUSION

No single factor has had a greater impact on esthetic dentistry and clinical abilities than clinical photography. It gives practitioners a wonderful method for improving the quality of clinical record keeping, patient education, consent for treatment, and communication with colleagues. Far and away the greatest benefit is the advance in self-education. Developing clinical photography skills to the point where one can, consistently and reproducibly, take the same pictures at the same magnification time after time after time means that pre-treatment and post-treatment photographs can very readily be evaluated to determine whether treatment goals have been met. Case success can be justifiably celebrated. If treatment has not turned out as nicely as anticipated, one can learn how to do better next time. For anyone aspiring to be better at dentistry, it is essential to have a camera and to know how to use it.

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B SECTION

Digital and Analog Photography

Luca Lorenzo Dalloca, Carlo Alberto Piacquadio, George Freedman

RELEVANCE OF PHOTOGRAPHY TO ESTHETIC DENTISTRY

Photographs document the improvement that is achieved during treatment. Both good cameras and correct photographic techniques are needed so that dentists can communicate their clinical procedures and results to colleagues. With the help of images it is much easier to explain what has been done (Figure 3-9), particularly in esthetics in which there are many details that must be impressed on the minds of the viewers. Besides capturing color, form, and texture, which are all relevant to producing nicely crowned teeth, photographs help document the patient's face. It is possible to see the dental results in a facial context (Figure 3-10). Photographs show the difference that was created and the individual sequential steps that were involved in the technique. It is also possible to see how the final result blends with the patient's facial features.

Photographs can sometimes yield additional information and a better perspective on the dental treatment that has been done. It is important to take pictures before the treatment, at the time of the procedure, after, and later; very often the tissues demonstrate results best after a few weeks. A final picture some time after the insertion of crowns or veneers has different detail than would be seen at the time of cementation reflecting on the success of the restoration.

Fifty years ago when dentists did dental work, few if any photographs were taken. Today photographs are an essential part of the process. Photography offers the advantage of seeing one's diagnostic and clinical improvement over the years. Earlier image quality was not as good as what can be achieved now. Photographic advances have changed the dentist's life. Since the mid-1970s, conscientious dentists probably have taken at least two pictures of every case. The percentage of dentists using photography in the early 1970s was about 1% to 5%; today it has grown to 70% in some areas.

BRIEF HISTORY OF CLINICAL DEVELOPMENTS AND EVOLUTION OF PHOTOGRAPHIC PROCEDURES FROM CHEMICAL TO DIGITAL

Photographic documentation has made an important contribution to the clinical documentation of dental cases. Until the last century all scientific papers were illustrated by drawings. These were done as experts looked into their microscopes and reproduced on paper the details they saw under strong magnification. With the advent of photosensitive materials, both speed and visual clarity have undergone revolutionary improvements. Slides made it possible to project images, which created a milestone for presentations at conferences and lectures in universities, hospitals, and private clinics. Black-and-white film evolved into practical color film. The human eye is used to viewing in color, so colored images made everything look more real and details were much more understandable.

The advantages of using digital equipment are numerous, especially when compared with film. Immediate verification, higher resolution, lower cost, and practical storage and access are just some of the benefits. Digital *radiographic* systems emit less radiation than conventional chemical x-ray systems. Images acquired with digital cameras are recorded in real time and can be stored in digital files (on computer) immediately after being obtained. Digital images can be modified. Several programs are on the market to help improve pictures. Some cameras have built-in programs for basic photo retouching, such as red eye reduction and the ability to lighten or darken images, crop, modify colors, or shift directly into black and white. Images can be used to immediately discuss cases with patients or for referral to a colleague or specialist via email in real time. In addition to the ability to send images to a colleague for an instant response, the images can be used to train staff, present at conferences or for clinical teaching, or address medico-legal disputes. An image can be duplicated as many times as needed and the quality is always the same. With slides, the quality of a duplicate is always worse than that of the original. With digital technology it is possible to see the images on a computer or television, using a video projector, and so on. Slides were viewable only with a slide projector or via printed pictures. With digital photography, costs are reduced as well. The ecologic impact is also minimized compared with chemical systems.

Advantages in Moving from Chemical to Digital Photography

The main advantage for switching to digital photography is that dentists can now store their files on disk. Before the digital age, separate rooms were needed to store patient slides. Traveling to present cases at a conference required that the dentist carry a large bag. Now everything is on a computer, disk, or perhaps a memory stick. A few years ago, plans for presenting cases had

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FIGURE 3-9 Before (A) and after (B) photos of the teeth help to illustrate treatment results to the patient.

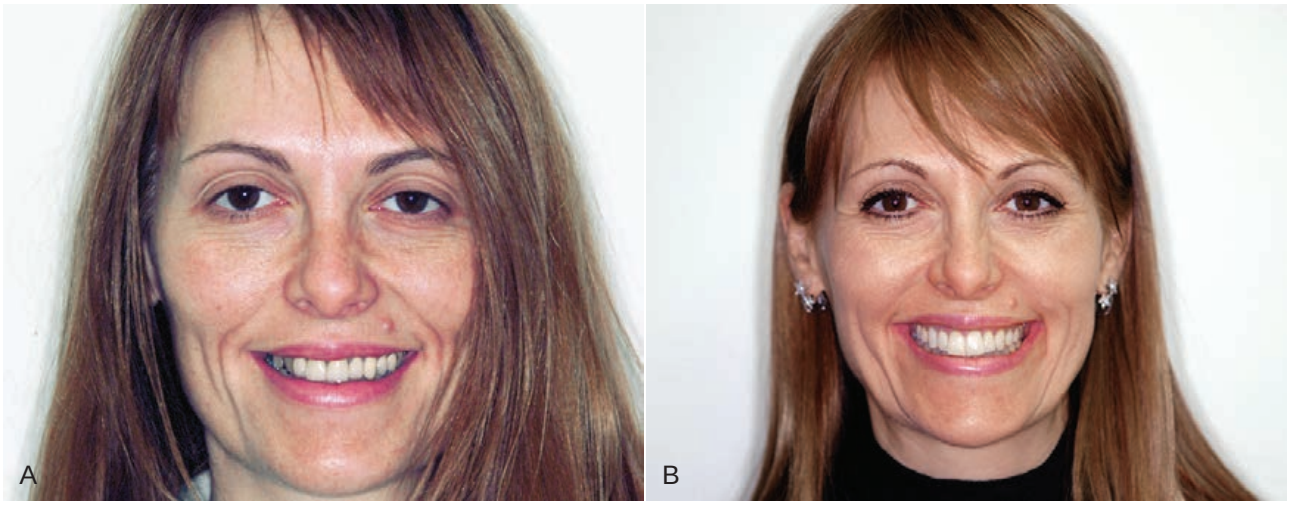


FIGURE 3-10 Before (A) and after (B) full-face photos show the dental results in a facial context.

to be made weeks or months in advance to allow development of new slides; now an image or a slide can be added to a presentation just minutes before it is given. Today image storage does not add appreciable cost, which is a huge advantage over slides or prints.

With chemical photography, dentists had to take two photographs after figuring out the best approach for each shot (calculation and bracketing). They kept one for the office and one as a backup. Sometimes the light bulb of old slide projectors would burn the slides, so the duplicate of each patient slide was essential. There was always at least one original that was stored and one used during treatment or case presentations. It actually was better to have at least two backups in case one was lost or stolen. Today it is easy to back up digital files. They can be automatically backed up on a computer in the office, although this can also be done manually, as long as the dentist or office manager remembers to do it. Multiple backups should also be kept at different geographic locations. There is little advantage to keeping multiple backups in the same office. In the case of theft, fire, or flood, for example, if the files are in multiple locations the chances of catastrophic events happening at all locales are extremely slim. It is possible to upload images to an off-site server over the Internet as well. Regardless of the method chosen, digital storage requires much less physical space than storing hundreds or thousands of patient slides.

Disadvantages in Moving from Chemical to Digital Photography

Unfortunately, retouching digital photographs is much easier than was possible with chemical slides. Anybody with a little skill in the use of graphics software can easily manipulate images. Such manipulation could be used to create situations and results that do not actually exist, perpetrating legal fraud.

Storage is secure if access is limited to the dental team responsible for the patient and the data; otherwise, patient privacy could be sacrificed. Computers and hard disks can be stolen more easily and are much more attractive to the thief than big boxes of slides.

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USE OF CAMERAS FOR ESTHETIC DOCUMENTATION

Esthetic documentation is one of the most important topics in the field of dental communication. The camera must accurately capture the smallest details and the quality of the colors. For these results to be achieved, both camera and lens are very important, along with type and quality of light. A dentist dedicated to good documentation must use a single-lens reflex (SLR) camera body (Figure 3-11). All companies that produce cameras have at least one SLR model in their catalogs; others have more SLR cameras, to be able to satisfy both the amateur photographer and the most demanding professional. The SLR cameras used by the authors are Nikon cameras (Nikon Inc., Melville, New York). Compact cameras are not recommended for documenting the typical maximum detail required for medical records, particularly for dentists and laboratory technicians documenting esthetic procedures.

The cameras considered here are the Nikon D5000, the D300, the D90, and the full-format SLR Nikon D700. The D5000 is the least expensive and newest in the Nikon line at the time of writing. The size of the sensor is the same for the D300, D90, and D5000. The SLR cameras give dentists the opportunity to set the focus through the classic viewfinder eyepiece (Figure 3-12, *A*) or through the liquid crystal display (LCD) screen or monitor (Figure 3-12, *B*). The Nikon D5000 is very similar to the D90 but has a larger monitor that can be detached from the camera body and rotated to various positions (Figure 3-13). This option may be useful for photos of objects or radiographs where the camera cannot always be placed in a comfortable position. Turning the screen achieves the best position and maintains patient and photographer comfort. The operation of Nikon cameras is similar regardless of the specific model. The complexity of the various menus differs, but the settings and functions are analogous.

SETTING THE CAMERA FOR PICTURES OF THE FACE MOUTH AND TEETH

Set the camera diaphragm priority to A (Figure 3-14, *A*) for all the pictures that will be taken. Set the focus to the minimum distance that corresponds to 0.314 cm visible on the window



FIGURE 3-11 **A single-lens reflex (SLR) camera body.**



FIGURE 3-13 **The Nikon D5100 has a larger monitor that can be detached from the camera body and rotated to various positions.** *(Courtesy Nikon Inc., Melville, New York).*



FIGURE 3-12 **A, The classic viewfinder eyepiece. B, Liquid crystal display (LCD) screen.**

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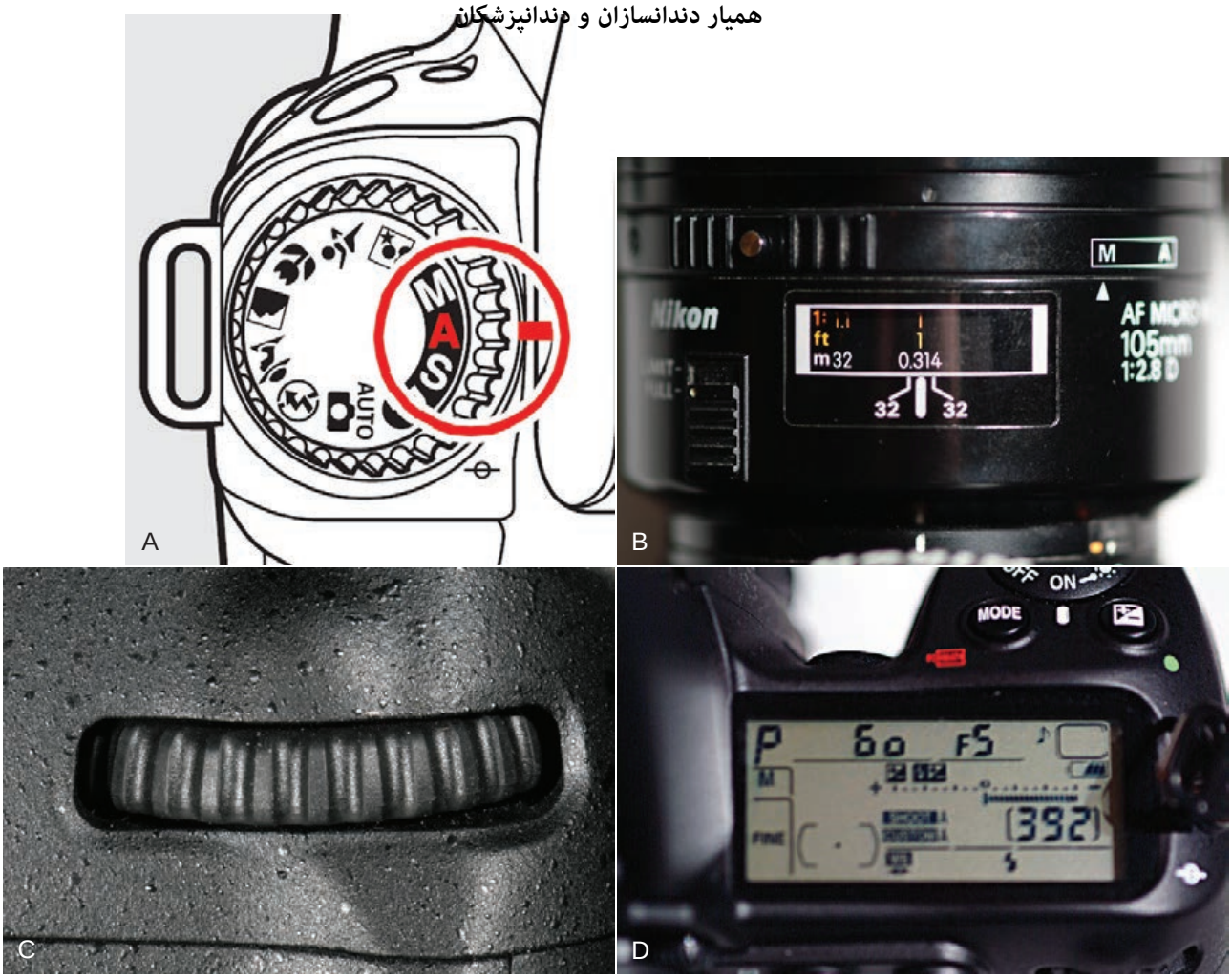


FIGURE 3-14 **A, Camera diaphragm set to priority A. B, The focus set to the minimum distance that corresponds to 0.314 cm visible on the window. C, The ring grained. D, The ring grained opens and closes the diaphragm to display the value corresponding to the most closed diaphragm: f/5.**

(Figure 3-14, *B*), then rotate the knurled ring (Figure 3-14, *C*) that opens and closes the diaphragm until the value f/5, representing the most closed diaphragm, is displayed (Figure 3-14, *D*). When this operation has been performed, the camera automatically adjusts the aperture with the change of focus. For example, after the aperture has been set to most closed (f/5), it is at its minimum focusing distance and the camera is ready.

Before one starts to take pictures, the menu of the camera is used to select one of the most important settings—that is, the "white balance" (Figure 3-15). The position is set on lightning flash or Speedlight. To obtain good chromatic results, it is necessary to use two flashes; white balancing communicates the light source(s) being used to the camera sensor. Doing so should result in colors that are as accurate as possible.

The first photos obtained should capture the patient's face. Set the lens to A (Figure 3-16) and the camera will adjust automatically to the best diaphragm and sharpness values. When taking pictures of the smile and mouth (Figure 3-17, *A*), set the lens to manual (Figure 3-17, *B*) and the focus to about 50 cm. If only the focus is adjusted, the aperture will automatically



FIGURE 3-15 **The position set on lightning flash or Speedlight.**

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adjust itself and match f/4 (Figure 3-18). The Nikon D7000 has a larger sensor, so the value may differ, but it will be decided automatically by the camera. After the smile photos, pictures of the front teeth are taken. For these the focus is moved from 50 cm to about 34 cm and the diaphragm will adjust automatically with the change of focus. If we see on the display in the photo of the smile that the diaphragm is f/4, then with the change of focus to 34 cm the diaphragm becomes f/5. This automation greatly simplifies the photographer's work. We have the certainty that the diaphragm is in its maximum closed position or highest f-stop for each photo, which allows pictures with the best sharpness.

Next, the following settings can be adjusted: contrast, sensitivity, color saturation, sharpness, and so on. Before being used, each camera should be tested with real-life images to verify that all the settings are positioned to match what is seen in the patient's mouth as accurately as possible.

Disputes with Patients

Some patients may be unhappy with their results. Sometimes things do not go as smoothly as planned. Photographic documentation is a guarantee of the quality of the work and the best way to present it. The images allow colleagues or legal reviewers to interpret precisely how the procedure was executed.

All digital pictures can be manipulated. Therefore legal doubt may arise, because it is possible to alter the images. Many cameras can authenticate the pictures that are taken through use of the authentication mode from the menu. Images recorded with this program cannot be manipulated, and in case of disputes with patients, no one can contest these photos. Cameras with this option include the Nikon D300 and more advanced versions.

Interaction between Clinician and Dental Technician

Communication between clinicians and technicians has relied on photographs for some time, but never before has there been such great opportunity for accurate communication without the dental technician actually seeing the patient. It is now possible to obtain images with accurate colors. To achieve this it is necessary to have the appropriate camera equipment, a professionally calibrated monitor, and a section of the office where the lighting is always consistent. The clinician should wear a



FIGURE 3-16 The lens set to A. The camera will adjust automatically to the best diaphragm and sharpness values.



FIGURE 3-18 If only the focus is adjusted, the aperture will automatically adjust itself and match f/4.



FIGURE 3-17 A, Taking a photo of the mouth and smile. B, The lens set to manual.

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neutral gray apron, and the patient should wear a neutral gray napkin. Using the Nikon Capture NX, it is possible to download data to a computer, take pictures of the patient, enter the photos on the computer, manipulate the images with the program until the colors match what is in the patient's mouth, and then record the data. The laboratory technician can recreate the exact same parameters in the dental lab for precise color matching. It is important to avoid making changes in the room, in the wall color, in the lighting, in the color of the lab coat, and so on.

INNOVATIVE ELEMENTS

Cameras can take movies in high-definition (HD) resolutions. The differences between a video camcorder and an SLR camera are that the sensor in the camera is much larger (compared to the standard video recorders), and the camera's macro lenses are of higher quality. The disadvantage is the lack of autofocusing in the SLR. If the photographer is well-trained in altering the focus during shooting, smoothly and slowly, this is not a major problem. A few simple settings can help obtain the best shots. One is to set the camera to a wide-open focus (live view) simply by pressing the button, then immediately press the "OK" button (Figure 3-19). To stop the movie, press the "OK" button again. This records video and sound with excellent quality. For those who do not have a monitor on the dental chair and want to see the images immediately, it is possible to use a radio-controlled receiver or a Nikon wireless product that allows the immediate transfer of images to the monitor even if it is located far from the dental chair. Another innovative feature is instant playback. The camera can record in black and white, which is good for radiographs and the final black-and-white pictures of the patient's face. It is also possible to change a colored image into black and white by selecting "retouch" from the menu (Figure 3-20, *A*), then choosing "monochrome" (Figure 3-20, *B*). Choose the photo to be converted and press the "OK" button. Immediately the picture will be recorded in black and white, so there will be two photos: one in color and one in black and white. From the menu it is possible to choose many other functions that until a few years ago were performable only by photo technicians or complex software programs.

Text continued on p. 71



FIGURE 3-19 **A, Camera set to wide-open focus (live view). B, The "OK" button is pushed after the live view is selected.**

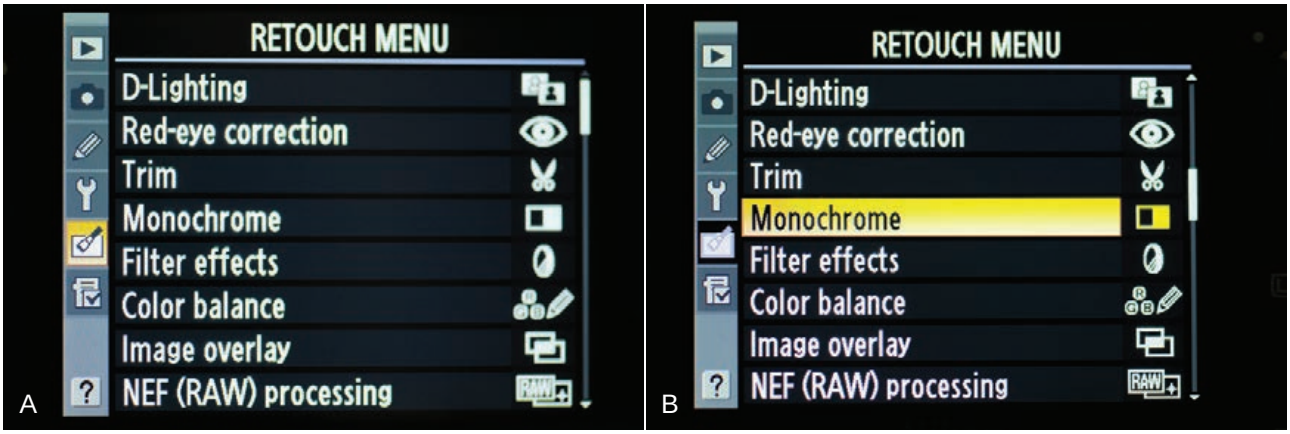


FIGURE 3-20 **A, "Retouch" selected on the menu. B, "Monochrome" selected.**

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FIGURE 3-21 A series of photos of an adult female patient showing both facial and intraoral views.

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FIGURE 3-21, cont'd

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FIGURE 3-21, cont'd



FIGURE 3-22 A series of photos of a teenage female patient showing both facial and intraoral views.



FIGURE 3-22, cont'd

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FIGURE 3-22, cont'd

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FIGURE 3-22, cont'd

ARTISTIC ELEMENTS

Health records have become much more precise and reliable. They allow dentists to view even the smallest defects or special details that are vissible in the teeth. The quality of the flash-emitted light that illuminates the teeth can help in obtaining three-dimensional pictures that show minute details. The pictures should not seem trivial but should represent the ability to build a clinical archive and document the art of dentistry in the best possible way. The series of photos that are shown are examples (Figures 3-21 and 3-22), but each practitioner must adapt the photographic process as appropriate.

NEAR-FUTURE DEVELOPMENTS

Digital cameras offer various opportunities to those who use such documentation for teaching, for personal archives, for training staff, for scientific publications, and for communications with the patient or the dental technician or in consultation with a colleague. Having cameras that can focus in automatic mode and produce a movie will allow dentists to run images that can be transmitted in real time via networks throughout the world. Thus anyone will be able to see the work in high-quality HD, whether it is a movie or still pictures. These recordings in real time can be viewed through accessories such as the Nikon Wireless Transmitter WT-4A. The photos or movies can then be viewed directly.

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Ultraconservative Dentistry

George Freedman

RELEVANCE TO ESTHETIC DENTISTRY

The establishment of porcelain veneer techniques as a basic treatment modality has been a rapid and welcome development (Figure 4-1). Many dentists offer this procedure as a routine service to their patients. In the continuing effort to deliver predictable, high-quality restorations, the dentist must be aware of the interplay between dental tissues and restorative materials (Figure 4-2). Today's patients are more involved and more knowledgeable, more keenly aware of their bodies, and less likely to accept invasive procedures than patients just a few years ago. Esthetic concerns are still very important, but not at the expense of tissue integrity. When porcelain veneers were introduced, one of the major underlying advantages was the conservative nature of the procedure. The minimal preparation advocated represented a significant advance over full-crown preparation techniques. Since then many practitioners have found it easier to correct color and shape by removing a 0.5-mm (or greater) thickness of healthy tooth structure, subsequently replacing natural tooth structure with opaques, bonding agents, and porcelain. The ultraconservative technique for porcelain veneers, involving minimal tooth structure removal, is respectful of healthy dental tissues and highly esthetic, making it potentially beneficial to both patient and dentist.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Dental ceramics have long been recognized for their similarity to dental enamel (Figure 4-3). They can be made to closely mimic the shades and textures of the natural tooth. Porcelain provides the practitioner with the clinical ability to restore a patient's dentition to its original appearance and function.

Developments in porcelain strength and consistency of manufacture have added to the popularity of veneers in modern dentistry. The biocompatibility and user friendliness of dental ceramics are unmatched in any other restorative material.

Over the past two decades the use of bonded porcelain has expanded exponentially. Previously, the weak link in ceramic procedures was the cement used to affix the restoration to the prepared tooth. Zinc oxyphosphate (Figure 4-4, *A*) cement and similar luting agents (Figure 4-4, *B*) were intended to simply occupy the space between the tooth and the crown that was inadvertently created during the manufacturing of the restoration. These materials did not impart any chemical or physical integration to the overall restorative treatment process.

The more recent composite resin cements not only take up the spaces that exist between the crown and abutment but also integrate the restoration and the tooth both micromechanically and chemically (Figure 4-5). As a result, all the components—tooth, resin cement, and restoration—act as a unit structure, or monobloc. Contributing to this trend are increased patient involvement in the dentistry process, better education, intraoral cameras, and a heightened sense of esthetics. Increased patient awareness has led to more active involvement by patients in selecting their own treatment modalities. Patients are less likely to readily accept invasive procedures. Although esthetics is a major motivator, to many the integrity of healthy tissue is paramount. The dentist is thus faced with the task of integrating the patient's dental needs with treatment options that are maximally conservative of healthy tooth structures and respectful of periodontal tissues while being highly esthetic. The dental armamentarium today offers both the techniques and the materials to accomplish these goals.

Rehabilitation of the dentition has been extensively described in the dental literature. Before currently available techniques and materials, these procedures routinely required aggressive preparation of all the teeth involved—not a tissue-conservative approach (Figure 4-6). This approach occasionally led to the extensive use of preprosthetic elective endodontic treatment because the remaining natural teeth demonstrated nonparallel angulation (Figure 4-7). Often, complex periodontal treatment was required to reestablish a stable soft tissue environment. These procedures could take months or years to complete, causing stress for both patient and dentist. Many patients, faced with a realistic description of the required treatment, declined to proceed. With the application of newer materials and techniques, minimally invasive, or ultraconservative, approaches have been developed to address these dental problems. Ultraconservative dentistry is respectful of the soft tissues, seeks to minimize the removal of healthy tooth structure, is highly esthetic, and uses the strengths of restorative materials to reinforce the remaining dentition.

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FIGURE 4-1 The visible benefit of porcelain veneers.



FIGURE 4-2 Close-up of veneers at the gingival margin.



FIGURE 4-3 Dental ceramics mimic dental enamel.





FIGURE 4-4 A, Zinc oxyphosphate cement. B, Polycarboxylate cement. *(Courtesy Shofu Dental Corporation, San Marcos, California.)*



FIGURE 4-5 Composite resin cement. *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*



FIGURE 4-6 Aggressive preparations of tooth structure.

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FIGURE 4-7 Nonparallel angulation of the maxillary anteriors.

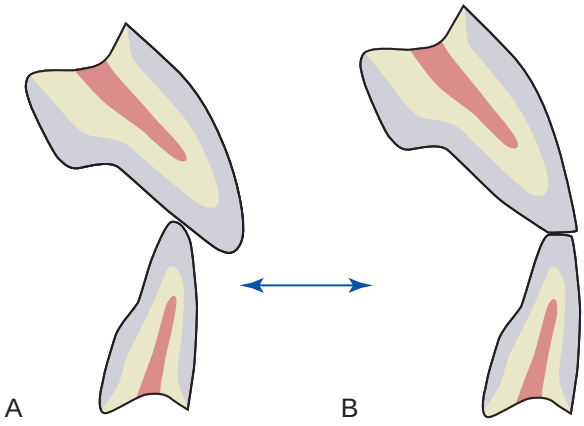




FIGURE 4-8 A and B, Loss of posterior vertical dimension causing excessive wear of the anteriors. C, Flat, older smile line. D, Younger, rounded smile line.

RELATING FUNCTION AND ESTHETICS

Occlusal Vertical Dimension

When rehabilitating an entire arch, the practitioner must consider esthetic restoration as well as functional restoration. The guidelines listed previously provide a more predictable periodontal prognosis. A debilitated dentition, however, often is accompanied by a compromised occlusal vertical dimension.

The posterior dental support present in the young (or ideal) occlusion can be lost to age, wear, function, fracture, and parafunction. The loss of posterior masticatory support can eventually cause excessive wear on the anterior teeth (Figure 4-8, *A* and *B*). The resulting flat or even smile line (Figure 4-8, *C*) is often associated with an older appearance, regardless of the patient's chronologic age. This is generally viewed as an undesirable esthetic condition, and many patients prefer a more youthful smile (Figure 4-8, *D*).

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An established method for treating this situation is the use of bonded porcelain veneers. Although veneers can be made long enough to make the resulting gingivo-incisal appearance acceptable, there may not be enough anterior interocclusal space to accommodate all the ceramic that is required for esthetics (Figure 4-9). A long unsupported incisal extension of ceramic veneers tends to interfere with the opposing incisors, causing extensive wear, fracturing, or both (Figure 4-10). One way to create adequate vertical extension space for worn anterior teeth is to recreate the posterior occlusal vertical dimension. In recent decades, posterior teeth have been more likely to be worn than missing, a result of the improved dental education and oral hygiene of the population in general.

When selecting the most conservative approach to restore these posterior teeth to their original (or ideal) occlusal vertical dimension, a bonded, all-ceramic onlay restoration best fits the required parameters (Figure 4-11). A ceramometal restoration has three components (metal, opaque, and ceramic) (Figure

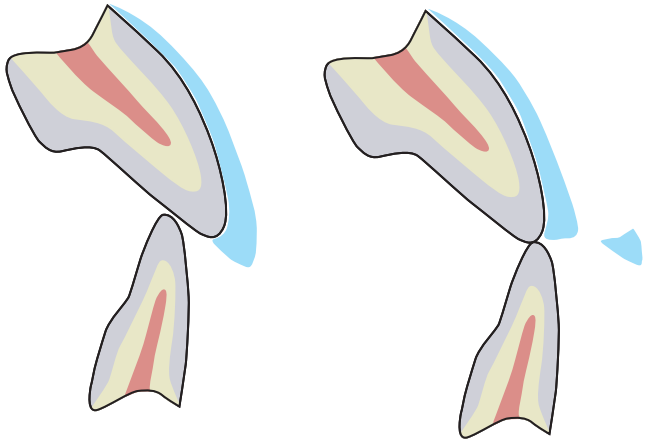


FIGURE 4-9 The ceramic extension required for ideal esthetics may be broken during function.

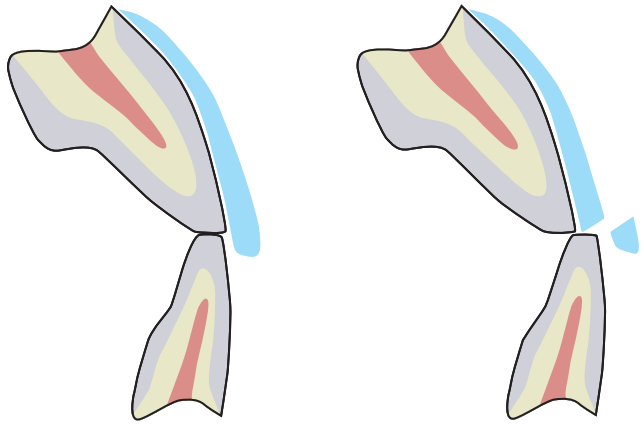


FIGURE 4-10 The unsupported ceramic extension may be broken during function.



FIGURE 4-11 Amalgams (A) being replaced with conservative ceramic onlays (B-D).

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4-12) and requires a prescribed thickness and thus greater tooth removal for each layer. An all-ceramic onlay (Figure 4-13) eliminates two of these layers—the metal and the opaque—and thus requires less thickness and consequently less removal of healthy tooth structure. Furthermore, the ceramic bond to tooth structure is stronger and more predictable than the bond of metal to tooth.

Several methods are used to develop and alter the patient's occlusal vertical dimension (Figure 4-14, *A*). Ultimately, the patient's function is the best guarantor of long-term stability. Through use of established guidelines for determining the vertical opening in complete denture patients, an initial interdental opening is estimated. An occlusal bite plate (Figure 4-14, *B*) is made that maintains this opening over a length of time to gauge the patient's comfort with the altered occlusal vertical dimension (Figure 4-14, *C*). The bite plate can be adjusted as required until the patient is completely comfortable. Typically, bite plates are white or translucent; for demonstration purposes, in the figure it is a strong orange color.

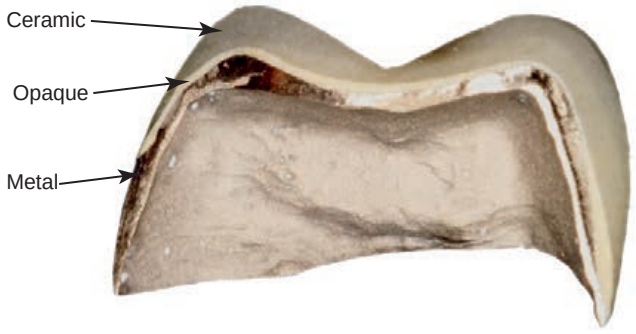


FIGURE 4-12 Cross-section of the ceramometal restoration shows three components—metal, opaque, and ceramic.



FIGURE 4-13 Cross-section of the ceramic restoration shows the ceramic component (the area painted red is the internal anatomy of the restoration).



FIGURE 4-14 A, The patient's original occlusal vertical dimension. B, The functionally developed occlusal bite plate. C, The patient's opened occlusal vertical dimension.

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FIGURE 4-14, cont'd **D and E, Facial demonstration of the effects of opening the occlusal vertical dimension. F and G, Note the effect of the open vertical dimension on the cheek support (*yellow circle*), labial support (*green circle*), and masseter support (*red circle*).**

Once the altered occlusal vertical dimension has been well tolerated for several weeks or months, depending on the age and oral condition of the patient, the final restorations that open the bite to the new position may be fabricated. Adding to the occlusal vertical dimension typically increases the anterior facial height, further enhancing the youthful appearance imparted by this dental procedure (Figure 4-14, *D* to *G*).

CLINICAL CONSIDERATIONS

Considerations in Ultraconservative Veneer Preparation

The primary concern is for healthy tooth structure. In the interest of maximizing bond strength, *all* the buccal enamel should be retained (Figure 4-15). Where some minimal preparation is necessary, however, the preparation must be left in the enamel layer if at all possible.

Almost any preparation, no matter how shallow, penetrates to the dentin at some point, usually toward the gingival portion of the tooth (Figure 4-16), where the enamel thickness flares down to a knife edge at the cemento-enamel junction. In the earlier days of porcelain veneers, only enamel bonding agents were available for securing laminates. Thus the area most prone to leakage (resulting in veneer failure) was the margin that terminated in dentin. The initial signs of subveneer staining were followed by percolation, then fracture of the gingival segment of the laminate (Figure 4-17). Even with the best of the newer dentin adhesive agents, the porcelain bond to enamel is still significantly greater than the adhesion to dentin, so it is advisable to minimize dentin exposure during preparation.

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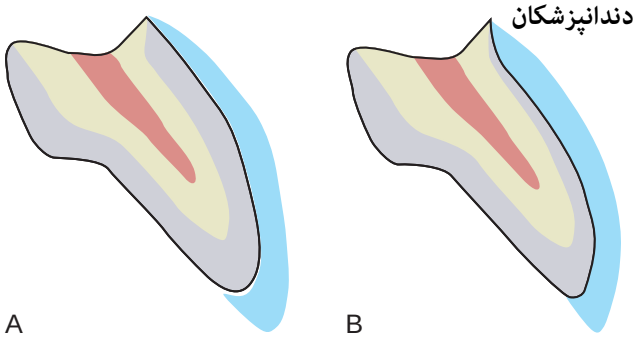


FIGURE 4-15 A, All the buccal enamel has been retained. B, Preparation for the veneer kept within enamel.

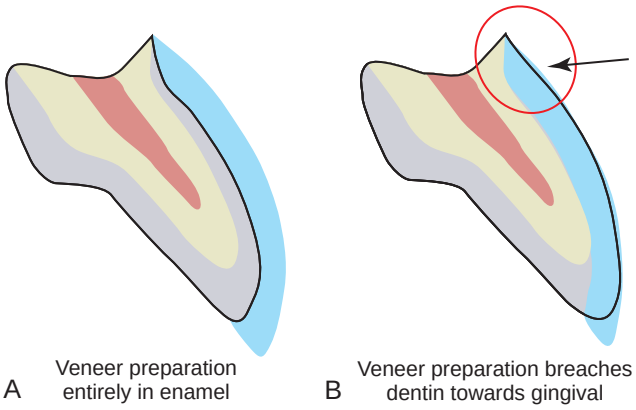


FIGURE 4-16 Although the preparation in part A is entirely within enamel, most clinical preparations will enter the dentin as seen in part B.



FIGURE 4-17 Initial subveneer staining followed by percolation, fracture, and repair of the veneer.

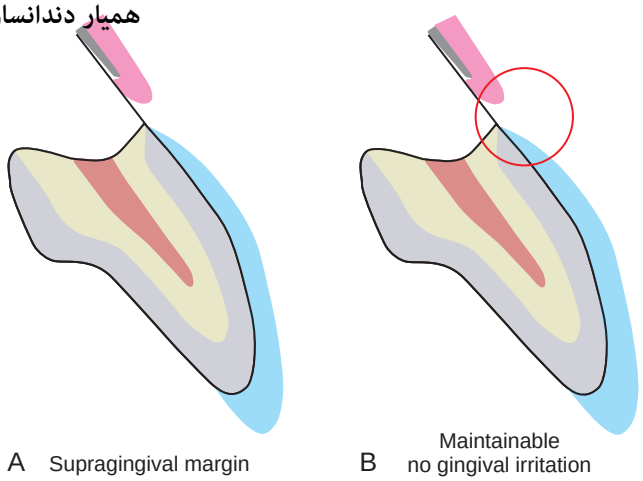


FIGURE 4-18 The supragingival margin (A) causes no gingival irritation and is maintainable (B).

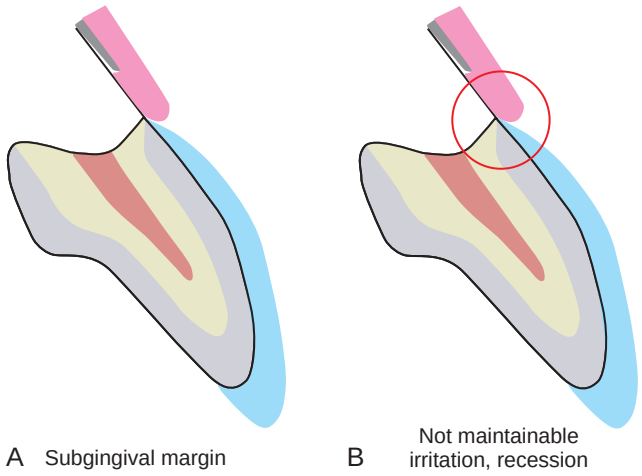


FIGURE 4-19 The porcelain subgingival margin (A), and in particular the luting cement, irritate the gingival margin and are not readily maintainable (B).

The margins of the porcelain veneer should be placed where the patient can readily access them for routine home maintenance. In particular, the gingival margin should be located supragingivally (Figure 4-18). The microenvironment of the veneer margin consists of a knife-edge silanated porcelain bonded onto enamel by a composite resin cement. The enamel and porcelain are both biocompatible with the gingiva and well tolerated. The composite, however, tends to cause irritation if it comes into intimate contact with the gingiva. When the margin is placed subgingivally, this luting material is in direct contact with the free gingival margin, eventually causing irritation and recession (Figure 4-19). With a supragingivally margined veneer, the composite is reasonably away from periodontal structures and is unlikely to cause tissue irritation.

All visually accessible areas of the tooth should be covered by porcelain (Figure 4-20). The area most often overlooked in this respect is the gingival portion of the proximofacial line angle (Figure 4-21). With gingival recession, these areas of slight concavity are uncovered. The dark underlying tooth structure is visibly unesthetic when the patient is viewed from the side. A slight reduction of the proximofacial line angle is usually all that is needed to permit an acceptable path of insertion for the proximally extended porcelain laminate (Figure 4-22).

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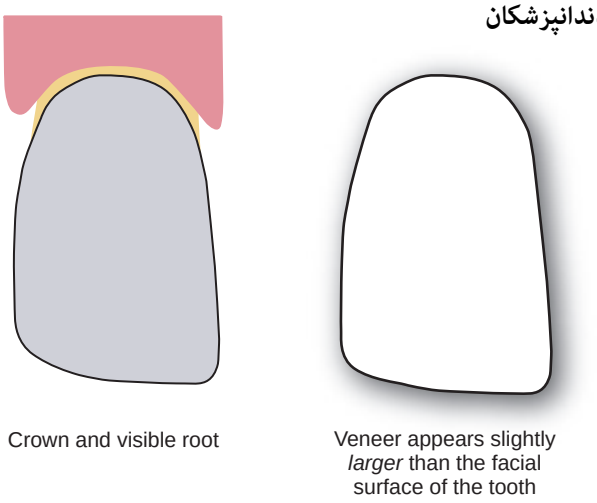
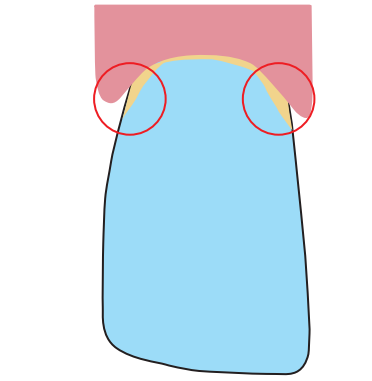


FIGURE 4-20 All visually accessible areas of the tooth should be covered by porcelain. Crown and visible root (*left*). Veneer is slightly larger than facial surface of tooth (*right*).



FIGURE 4-21 Proximofacial line angle not covered by porcelain.





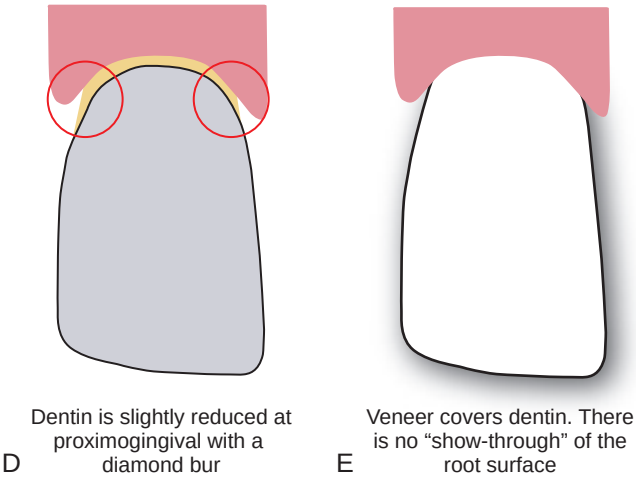


FIGURE 4-22 The dark show-through at the proximofacial line angle. A to C, The veneer allows show-through of darker dentin at proximogingival area. D, Dentin is slightly reduced at the proximogingival area with a diamond bur. E, The slight reduction of the proximofacial line angle eliminates dark show-through.

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FIGURE 4-23 **A, The maxillary anterior dentition requiring veneers. B, Occlusal view indicating less-than-ideal arch contour. C, The veneers correct the arch contour. D, The maxillary anterior dentition restored with veneers.**

All remaining sharp-angled areas of the enamel and existing restorations must be rounded; porcelain does not tolerate the stress of sharp internal angles well.

Indications

The indications for ultraconservative dentistry are perhaps best revealed by considering when ultraconservative dentistry is *not* indicated. All dentistry should be as conservative as possible. At this time in dentistry, the practitioner, and indeed the practitioner's philosophy, must be as conservative as possible in order to ensure that the maximum amount of natural healthy tooth structure is maintained. Natural tooth structure is by far the best dental material available today. With all the advances in material technology, the natural tooth still sets the standard and is the material that all others aspire to be. Therefore, when it can be conserved intact, that is a positive situation.

Ultraconservative dentistry usually involves several approaches. Rather than removing excessive tooth structure in order to create room for a veneer, veneers are placed with little or no surface preparation if possible. This is the ideal situation, but it may not always be achievable (Figure 4-23).

For posterior onlays, when the occlusal vertical dimension is to be opened, if the occlusal surface is intact and healthy, or restored with composite or ceramic, an onlay can be bonded onto the existing tooth surface, simply extending its vertical height, without necessarily preparing the tooth surface (Figure 4-24). This qualifies as ultraconservative dentistry. Minimal preparation is part of ultraconservative dentistry, but the ideal is always no preparation at all.

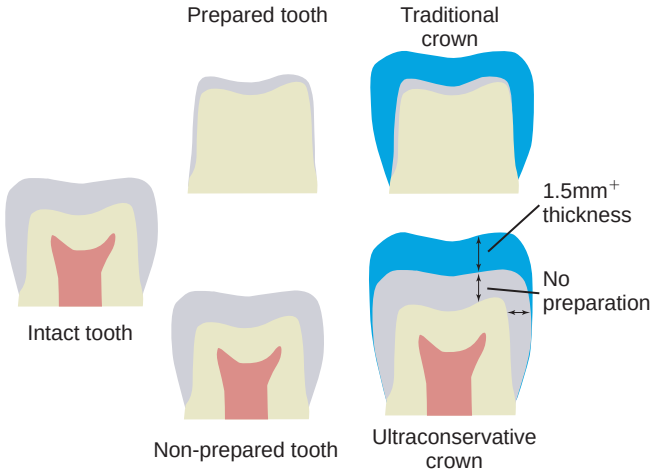


FIGURE 4-24 **Intact tooth to traditional ceramic crown and intact tooth to ultraconservative ceramic crown.**

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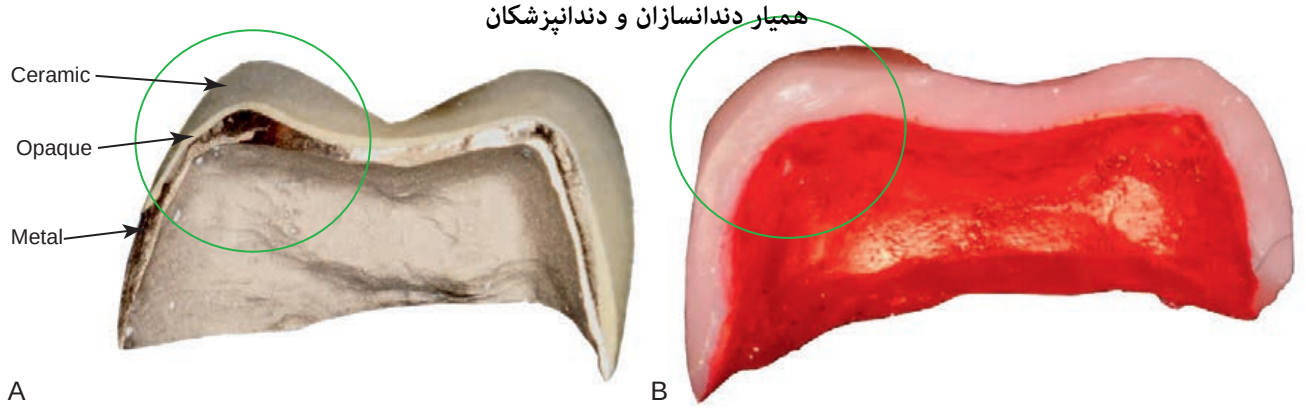


FIGURE 4-25 The thickness of the porcelain-fused-to-metal restoration (A) compared with the thickness of the all-ceramic restoration (B).

Contraindications

There are no contraindications to ultraconservative dentistry because it is so desirable in all its aspects.

MATERIAL OPTIONS

Material options in restorative dentistry are generally quite varied, including glass ionomers, amalgams, composites, ceramics, and metals. Generally, for ultraconservative dentistry, the materials of choice are composites and ceramics.

The advantage of glass ionomers, of course, is their release of fluoride. However, many products in this category do not stand up well to functional masticatory forces, and their surfaces become pitted and stained over time, unacceptable in esthetic situations.

Amalgams do not bond to the tooth surface and require far more aggressive preparation than desirable in ultraconservative approaches. Amalgam restorations require extension for prevention and extension for retention and therefore are far less conservative of tooth structure than most other restorative materials.

The crown and bridge metals used in dentistry are effective, but they require more extensive preparation of tooth structure to develop physical retention and/or leave space for the ceramic that can completely hide the color of the metal. In comparing a ceramic restoration with a porcelain-fused-to-metal restoration, the ceramic restoration must cover, change, or maintain the color of the underlying abutment. The porcelain-fused-to-metal restoration, on the other hand, is adapted to the underlying tooth structure, but then requires opaquers to hide the color of the metal and subsequently various layers and thicknesses of ceramics to hide the underlying color of both the metal and the opaquers to create a natural-looking, esthetic tooth. Thus the porcelain-fused-to-metal restoration tends to be much thicker than its all-ceramic or composite counterpart and is inherently less conservative than restorations accomplished with these materials (Figure 4-25). In addition, metals generally do not bond to tooth structure, enamel, and dentin as well as the composite and ceramic materials.



FIGURE 4-26 Stained and pitted anterior composite veneer.

The current best approaches to ultraconservative dentistry include composites, direct and indirect, and various types of ceramic. Direct composites are very effective, can be completed chairside, and have the time and cost advantage of not involving laboratory work. However, they are quite time consuming and require extensive chair time and skill with specific clinical techniques to create a lifelike appearance.

Laboratory-fabricated composites have the advantage of being manufactured by the technician, but require two dentist appointments rather than one chairside visit, and also have an associated lab cost. A major disadvantage is that the patient is often not seen directly by the lab technician who is fabricating the restoration. Therefore the final color may or may not be acceptable to the dentist and patient.

Both direct and indirect composites tend to absorb stains from foods, beverages, and habits (such as smoking) as they age (Figure 4-26). They are far more likely to discolor over time than ceramics. Many composites also color shift during polymerization, making it difficult to predict the final shade. The composite

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FIGURE 4-27 Stained composite veneer with percolation.



FIGURE 4-28 Esthetically pleasing anterior ceramic restoration.

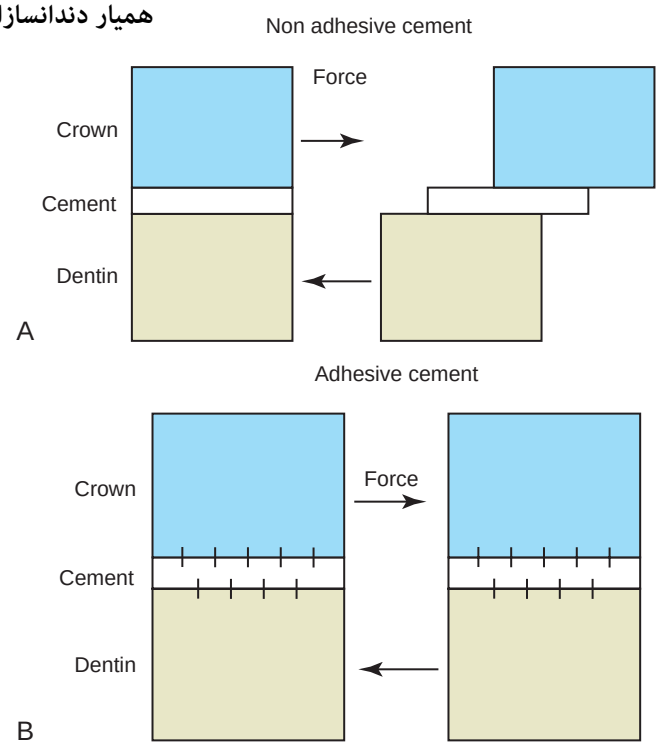


FIGURE 4-29 A, Nonadhesive cements create retention but not a monobloc. B, Adhesive cements create both retention and a monobloc.

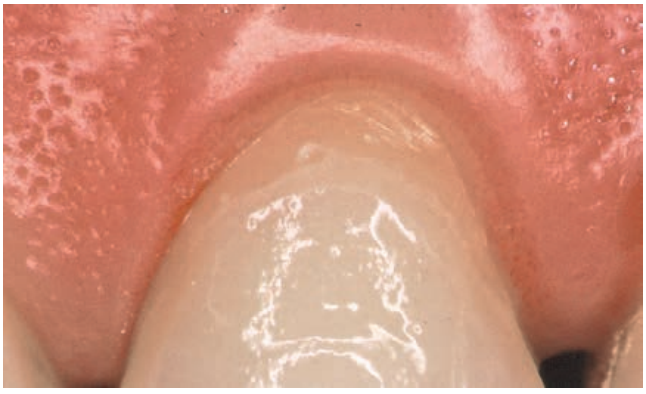


FIGURE 4-30 Gradual gradient of color at ceramic tooth interface.

placed on the tooth is the correct shade but undergoes a slight shift during polymerization. This change is not always predictable or consistent between batches or even within a given composite system. The advantages of composites for ultraconservative dentistry include minimal invasiveness, bonding to tooth structures, and esthetic results. Unfortunately these results tend to be much shorter term than for ceramics and may be difficult to achieve in the first place (Figure 4-27).

Ceramics, on the other hand, have been well established for many years. Bonded ceramics, in particular, are the treatment of choice and the current best approach to ultraconservative dentistry whenever possible. Many of these materials are quite strong, are very predictable, and can be fabricated with excellent levels of adaptation to the prepared or unprepared tooth structure. Ceramics offer excellent anatomy, excellent esthetics, and overall great functional strength (Figure 4-28). Traditional ceramics are not strong until they are bonded. Once they are bonded and have the substructure of the tooth supporting them, they become far stronger and are part of the monobloc of normal functioning dentition (Figure 4-29). They can be highly esthetic, their margins are easier to blend in to natural tooth structures, and the color change from the tooth does not have to be sudden or significant (Figure 4-30). If tooth coloration requires no alteration, the use of a translucent resin cement, such as Embrace Dual Cure for crowns and bridges (Figure 4-31, *A*) or Kleer-Veneer Light Cure for porcelain veneers (Figure 4-31, *B*), both from Pulpdent Corporation (Watertown, Massachusetts), allows a non–shade-shifting transition from the tooth to the

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FIGURE 4-31 **A, Embrace Dual Cure wet bond resin cement. B, Kleer-Veneer Light Cure Veneer Cement resin cement.** *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

restoration. Then it is just a matter of adapting the color of the restoration to the tooth itself. If the tooth shades must be altered, a somewhat opaque layer is blended into the ceramic to create the desired result without the technique-sensitive intermediate step of color modification with resin opaquers.

Restorative Margin

Defining the location of the restorative margin has long presented the dentist a technical and clinical dilemma. The ideal position of the tooth-restorative margin is supragingival (Figure 4-32), but in practice patient acceptance of a readily visible interface (such as the characteristic black line junction of porcelain, metal, and dentin) is limited. The supragingival restorative margin is technically superior: easier for the dentist to visualize and prepare the tooth, easier for the dentist to take an accurate impression without the interference of gingival tissues and crevicular fluid, easier for the lab technician to pour an accurate stone model, easier for the technician to fabricate a crown, easier for the dentist to cement (or bond) into place, and, most important, much easier for the patient to maintain at home in the long term (Figure 4-33). Many studies demonstrate histologically and clinically that even the best restorative margins are susceptible to plaque accumulation at the tooth-restoration interface. Supragingival margins are simply more accessible to plaque control, providing the patient with a better prognosis for the treatment. Subgingival margins, because they are harder for the patient to clean, are more susceptible to plaque accumulation and thus periodontal inflammation and recession, bone loss, and recurrent decay (Figure 4-34).

Bonded leucite ceramics provide the esthetic transition needed to blend in the tooth and restoration, even when the margins are located supragingivally. The establishment of a color gradient (as opposed to a monochromatic shade description) contributes to the natural appearance of these restorations (Figure 4-35). This resin-sealed interface provides an area that is readily visualized and accessible for patient cleansing. Because the status of the restorative margin can be continually observed,

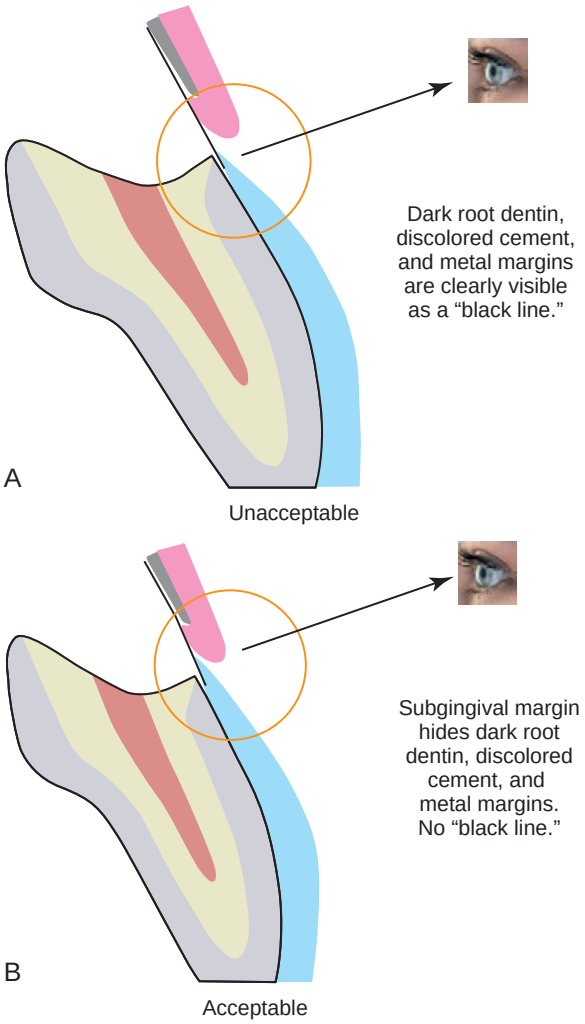


FIGURE 4-32 **A, Esthetically unacceptable discolored crown margin. B, Esthetically acceptable subgingival crown margin.**

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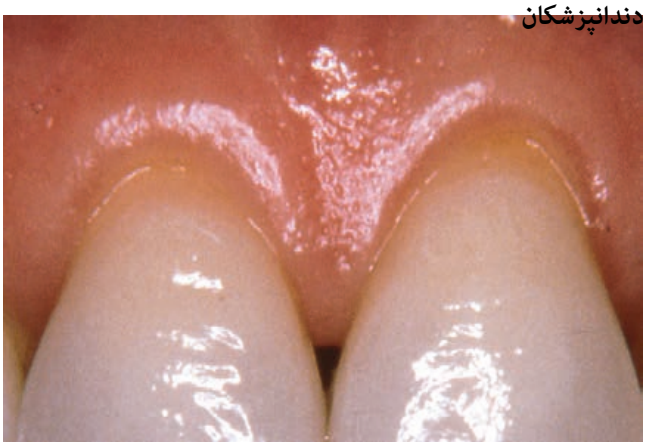


FIGURE 4-33 Supragingival margin that is both esthetic and maintainable.



FIGURE 4-35 The esthetic color gradient contributes to natural appearance of restoration.

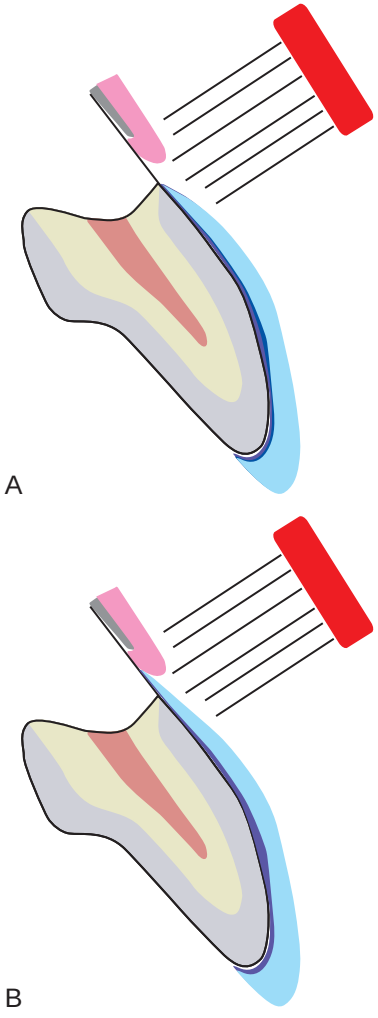


FIGURE 4-34 A, Home maintenance of the supragingival margin. B, Limited home maintenance of the subgingival margin.

the patient is more likely to be actively involved in its maintenance and health.

With supragingival margins, the positioning of the ceramic tooth interface is dictated by restorative requirements alone. Because the dentist can locate the margin esthetically anywhere on the tooth surface, whether the area is visible or not, additional tooth structure removal to hide the margin subgingivally is not necessary. This adds to the conservativeness of technique and to its popularity with patients.

INNOVATIVE ELEMENTS

Scientific Elements

A number of innovative developments contribute to ultraconservative dentistry, including scientific and technologic elements. The scientific elements are largely those associated with dental adhesive developments over the last 50 years. Adhesives originally bonded only to etched enamel but are now designed to bond to all surfaces, including enamel, dentin, existing composites, and ceramics. The current bonding systems, particularly seventh-generation materials, are very easy to use, very predictable, and not technique sensitive and give excellent bonds that are stronger than the cohesive bond of the underlying tooth structure to itself (Figure 4-36, *A* and *B*). Therefore the interface between the restorative material and the tooth is very strong and not at all at risk of fracturing under normal functional paramters. If sufficient force is transmitted to the tooth, of course, the entire tooth can break, but the fracture will be a cohesive one within the natural tooth structure rather than an interfacial fracture between the restoration and the tooth.

Scientific developments have also advanced feldspathic porcelains (Figure 4-36, *C*), which bond to tooth structure and are extremely esthetic and relatively easy for the lab technician to manipulate. The newer zirconium porcelains may have less bondability but certainly have tremendous strength and can provide wonderful esthetics either directly or when overlaid by conventional facing porcelain (Figure 4-36, *D*).

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FIGURE 4-36 **A, BeautiBond. B, Tokuyama Bond Force. C, Vintage Halo Metal Porcelain. D, Vintage ZR zirconia porcelain.** *(**A, C, D** courtesy Shofu Dental Corporation, San Marcos, California; **B** courtesy Tokuyama Dental America, Encinitas, California.)*

Technologic Elements

The technologic innovations involve techniques such as porcelain veneers, bonded inlays, onlays, and bonded crowns that have adapted available materials to clinical use in everyday practice. The use of cements that are effectively translucent allows supragingival and more cleansable, more predictable margins, which are much better for both dentist and patient (Figure 4-37). They benefit the dentist from the standpoint of preparation, fabrication, and cementation and the patient in the ability to maintain the restoration for extended periods of time.

ARTISTIC ELEMENTS

Ultraconservative dentistry involves many artistic elements. The primary element is that of smile design, in which the form of the anterior teeth is based on the patient's facial shape and facial proportions, as described in the chapters on smile design and the esthetic try-in (see Chapter 5). Once the appropriate sizes of the anterior teeth and the shapes thereof have been established based on the patient's own anatomic proportions and contours, the occlusal vertical dimension described earlier in this chapter is considered. When all of this information is entered, there is adequate information for the practitioner to assist in recreating the patient's natural smile and the natural function that was present before wear, injuries, and decay took their toll. Furthermore, each tooth, crown, veneer, and bridge can be artistically developed on its own, taking into account appropriate shade and color requirements including the translucence and fluorescence that all combine to create an overall esthetic result.

The artistic elements are really a combined effort among the dentist, the lab technician, and the patient with the assistance of the dental auxiliary, who can comment from still another perspective. All these players contribute much to achieving a

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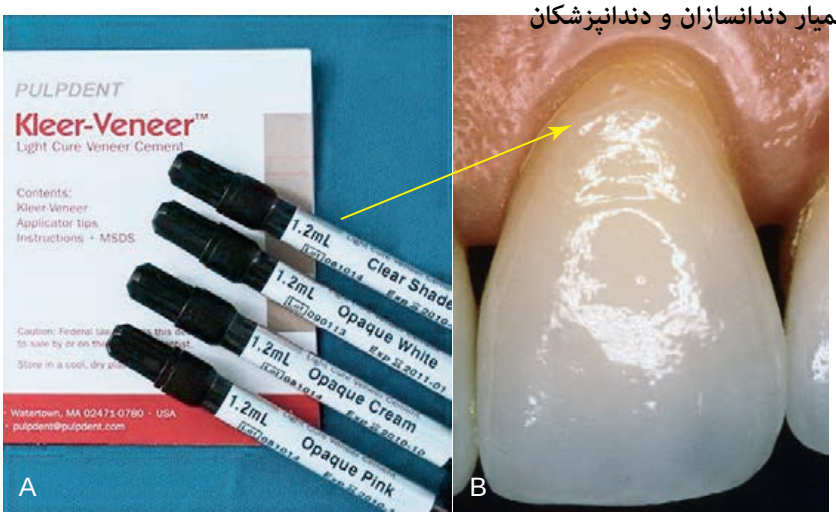


FIGURE 4-37 The use of translucent resin cement (A) allows supragingival cleansable and predictable margins (B). *(A courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

superior overall result. The discussion must be open and frank to ensure a positive result.

Dentists must refrain from imposing their concept of esthetics on the patient because it is the patient who will be wearing the smile for many years. Patients must be allowed to have extensive input into the final esthetics of the restoration. They must also accept the existing natural conditions that limit the dentist. The available materials and techniques and the inventive ingenuity of all the team participants can expand the clinical parameters to maximize both function and esthetics.

Some practitioners have more artistic ability or awareness than others. This does not necessarily mean that those without this knowledge base cannot accomplish ultraconservative procedures. It simply means that, as in all dental undertakings, the artistic elements of ultraconservative dentistry form part of a process of learning that begins in dental school and continues throughout life. It must be continually updated by continually learning and relearning concepts such as those discussed in other parts of this text. The practitioner can create the environment for success by learning the skills that are required. In fact, the reason for reading an article or textbook or attending a course or hands-on event is to build on the skills that the practitioner has, completing an educational process that leaves the practitioner more aware and more highly skilled than before.

TREATMENT PLANNING

A number of options are available to the dentist and patient. One is no treatment, which is usually the least effective. It essentially leaves the situation as it is and involves watching it deteriorate further. At the other end of the spectrum is the comprehensive approach, in which every tooth that requires treatment is addressed and the occlusal relationships that must be altered are improved. Everything that can be done is done. In reality, most ultraconservative dental procedures fall somewhere between the "no action, no treatment" side and "comprehensive complete treatment."

Generally most patients prefer to have more treatment, particularly in the anterior segment because this area is readily visible and has significant social impact. From the dentist's perspective it is often the posterior segment that is more important because this part of the dentition plays a supportive role without which anterior restorations cannot endure. It is the dentist's responsibility to simply refuse to provide unsupported anterior restorations until the posterior segments have been completed. This is a wise direction for the dentist, because if the supporting posterior restorations are not completed, the unsupported anterior restorations subsequently fracture, break, become dislodged, or come to other harm. It is typically the dentist's responsibility to make repairs, very often at no charge to the patient. Rather than getting into the situation in which the dentist is pressed by the patient who simply is not interested in the proven principles of dental restoration, it is better to not even begin treatment for patients who refuse to proceed according to a properly crafted protocol that follows sound practice.

Sequence

Consultation, Workup, and Treatment Plan

The sequence of treatment planning for ultraconservative dentistry begins with the initial consultation to gauge the interests and requirements of the patient and after a full diagnostic workup has been concluded. This includes radiographic study models, a full narrative on each tooth and segment, a full periodontal workup, an endodontic assessment, and orthodontic assessment (if required). Once these have been completed, the treatment plan can be established. The treatment plan is discussed and negotiated between patient and dentist until it is acceptable to both, manageable from clinical and technical perspectives, and affordable for the patient.

Esthetic Try-In

Once the treatment plan has been established, the esthetic try-in is prepared as the foundation for the treatment plan and the road map for the dentist and lab technician, developed in



FIGURE 4-38 Tuff-Temp Provisional Veneer, Crown and Bridge Resin. *(Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

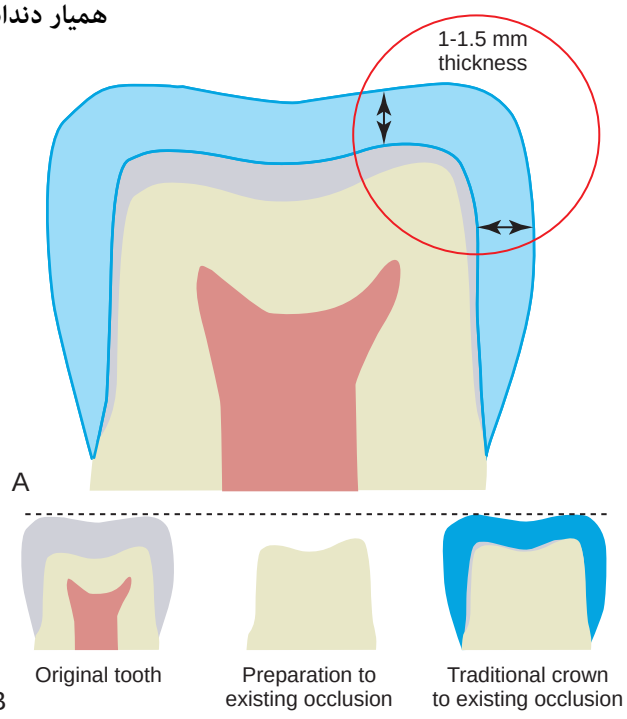


FIGURE 4-39 A, Ceramic thickness replaces an equal thickness of natural tooth structure that has been removed. B, Relative occlusal heights of the natural, prepared, and crowned tooth.

accordance with the patient's wishes. Once the esthetic try-in has been modified intraorally, the practitioner can readily determine where preparation is required and where it is not. Preparation and temporization (Figure 4-38) (if needed) are accomplished and the impressions are sent to the lab. The lab technician fabricates the appropriate prosthesis and returns it. The restoration is tried in, to ensure fit and esthetics. Then it is adjusted if necessary, polished, cemented, and repolished. The patient is given postoperative instructions and maintenance counseling.

Follow-Up

The patient should be followed up at several intervals: after several days, a week, and 1 to 2 months postoperatively, after which routine maintenance is instituted. If necessary, follow-ups can be repeated more frequently in the first year to ensure that any problems are addressed thoroughly and effectively.

TREATMENT CONSIDERATIONS

Tooth Preparation

If the posterior occlusal vertical dimension is to be altered, it must be altered on all of the posterior teeth, not just one tooth or one side. This process could be an invasive procedure were it not for the ultraconservative approach. For each tooth, the amount of tooth removal depends on the following:

1. Condition of the tooth
2. Strength of the ceramic
3. Minimal required ceramic thickness
4. Existing restorations

Because many younger patients today are relatively caries free, it is difficult to justify removing healthy tooth structures to accommodate weaker restorative materials that require thickness for strength. Porcelain-fused-to-metal crowns often require 2 mm of circumdental and occlusal preparation; jacket porcelain crowns require similar bulk to prevent fracture. Recently developed leucite porcelains are different in that they are bonded to tooth structure rather than cemented. Once bonded to the underlying tooth structure, they can be extremely strong even with minimal thickness. They may even be used in knife-edge marginal situations. Neither a broad shoulder nor heavy chamfer preparation is needed at the tooth-restorative interface. Leucite ceramics can accommodate circumdental preparations as thin as 1 to 1.25 mm. These preparations allow far more healthy tooth structure to be retained in the abutment and make for a far longer-lasting restoration.

When the occlusal vertical dimension is not altered, any thickness of ceramic placed on the occlusal of the tooth must be accompanied by the removal of an equal thickness of tooth structure (Figure 4-39); otherwise an occlusal imbalance (or prematurity) results. In rehabilitating an entire arch, however, the occlusal vertical dimension is often corrected to a more ideal, usually greater, opening. This correction means that a ceramic thickness exceeding the amount of tooth structure removed can be placed (Figure 4-40). The exact amount of tooth structure removal needed can be determined by considering the minimal thickness of the ceramic and the opening of the occlusal vertical dimension (Box 4-1). If the minimal thickness of the ceramic is 2.0 mm and the alteration of occlusal vertical dimension is 1.5 mm, the required removal of tooth structure is 0.5 mm. Where the increase of the occlusal vertical dimension is greater than 2.0 mm, no tooth preparation is required. Because bonded leucite porcelains can be used confidently in an occlusal bulk of 2.0 mm or less and the alteration of occlusal vertical dimension

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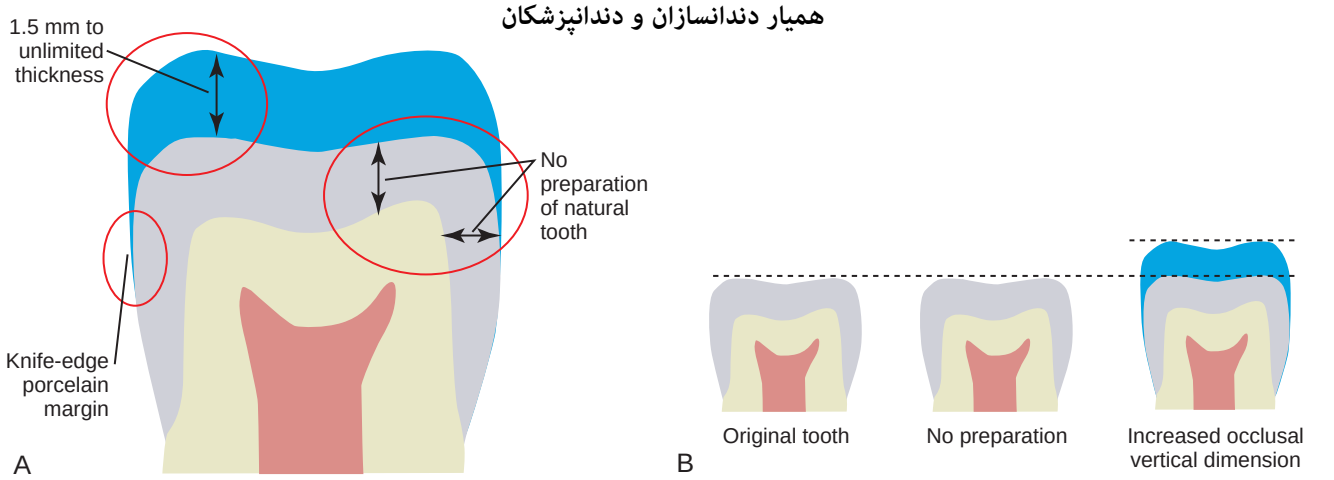


FIGURE 4-40 **A, Ceramic thickness exceeds the amount of tooth structure removed. B, Increased occlusal height of a ceramic crown placed on an unprepared natural tooth.**

BOX 4.1 CALCULATION FOR THE REQUIRED AMOUNT OF TOOTH STRUCTURE REMOVAL

Depth of Preparation

Preparation Guide

Desired occlusal position of crown or onlay –
Current occlusal position of the tooth surface =
Opening depth in millimeters

Porcelain Thickness = 2.0 mm

Preparation Depth Guide

Opening depth >2.0 mm → no prep
Opening depth <2.0 mm → guided prep



FIGURE 4-41 **PrepStart H_2O.** *(Courtesy Danville Engineering, Danville, California.)*

is often greater than 2.0 mm, often little or no tooth structure removal is necessary.

All existing restorations that will be covered by onlays should be examined for marginal integrity and recurrent decay. Generally, sound existing composite and ceramic restorations can be used as the substructure of the rehabilitation. Their surfaces can be made more adhesive by microetching (Figure 4-41) to increase the bondable area and chemical initiation: CompositRestore (All Dental ProdX, Ocean View, New Jersey) for composites and one of the numerous commercially available silanes for porcelain. Nonadhesive restorations, such as amalgams, should be replaced. Ultraconservative rehabilitation is a constructive augmentation process, in contrast to the destructive ameloclastic procedures that have characterized dentistry in the past (Figure 4-42).

Veneer Placement and Finishing

The major objective in placing veneers is esthetic. Often the ultraconservative veneer allows the underlying tooth color to contribute and modify the illusion being created, yielding a more natural appearance. In the gingival area, the saturation of the color of the porcelain decreases as the porcelain becomes thinner. This allows some of the natural dentin color to shine through the veneer. With the judicious use of composite color modifiers, the dentist can create a color gradient that masks the facial margin, hiding it in full view supragingivally (Figure 4-43).

The decreased enamel thickness toward the incisal edge of the tooth causes a natural tooth to appear somewhat translucent in this region. A very thin porcelain laminate recreates this translucence (Figure 4-44) but can fracture easily. Ultraconservative porcelain veneers permit both the natural reflections from the tooth surface and illusions created by modifying tints to be readily observable through the body of the ceramic. This lends an air of depth to the restoration (Figure 4-45).

Opaquers should be used with discretion and only in very thin layers. Otherwise, they impart a dense white coloration to

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FIGURE 4-42 Composite restorations (A) can be bonded to, but amalgam restorations (B) must be replaced completely.



FIGURE 4-43 Color modifiers develop color gradient using the underlying natural colors and masking the facial margin in full view.

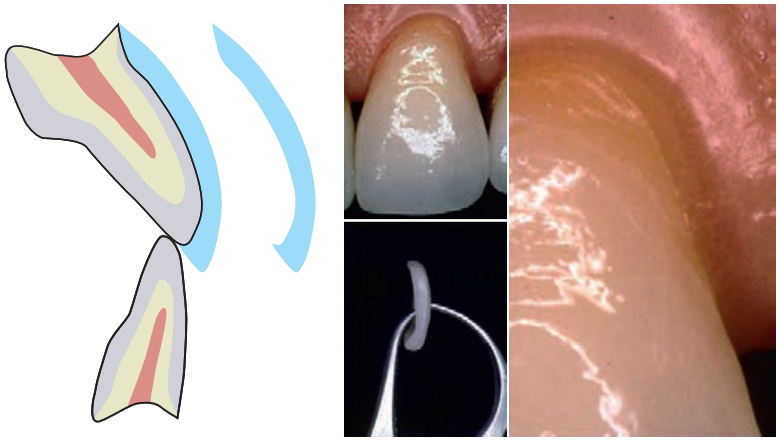


FIGURE 4-44 A very thin porcelain veneer permits translucence.

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the tooth that does not look natural. When a small dark area must be masked (Figure 4-46, *A*), it is best to slightly relieve the offending discoloration immediately before veneer placement (Figure 4-46, *B*). The increased thickness of the luting composite resin cement readily masks the offending area (Figure 4-46, *C*).

Finishing a supragingival margin is more predictable than attempting to polish subgingivally (Figure 4-47). The unhindered access ensures a smoother transition and hence less likelihood of plaque buildup and marginal breakdown. Occasionally, the interproximal gingival porcelain (or bonding material) is overcontoured interproximally. This leads to what is often described as the "Chiclets look" (Figure 4-48). This overcontouring can be eliminated with finishing or metal abrasive strips; interproximal recontouring can be accomplished more quickly (and more comfortably for the patient) with the Profin reciprocating handpiece (Figure 4-49). The proximogingival portions of the veneer are reduced until a natural appearance is restored (Figure 4-50). It is important to keep in mind that the tooth in this area is contoured, whereas most instruments are quite flat. Thus additional care must be taken to ensure an esthetically shaped tooth contour. Both the placement and finishing procedures can be accomplished without the need for local anesthesia.

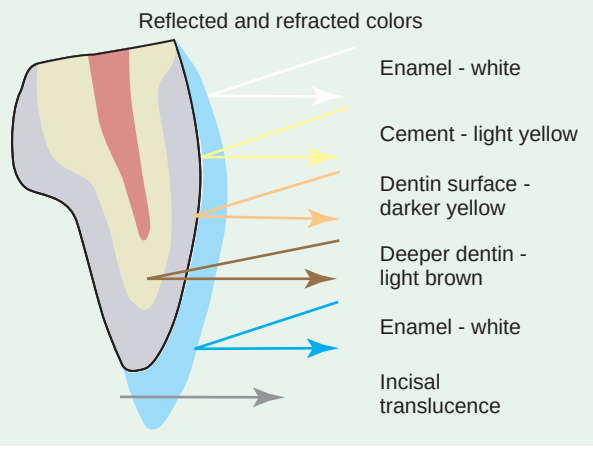


FIGURE 4-45 **Reflections from various layers of the veneered tooth.**

Factors Influencing Tooth Preparation

The extent of tooth preparation before veneering depends on three factors: (1) the condition of the tooth, (2) the reasons for veneering, and (3) the predisposition of the dentist.

It is much more acceptable to remove decayed enamel or restorative materials than sound tooth structure. However, with today's preventive procedures and dental health education, most patients have sound (if sometimes unesthetic) anterior teeth. The most common reasons for veneering teeth are discolorations



FIGURE 4-46 **A, Small, discolored areas of the tooth require masking. B, Discolorations should be relieved immediately before veneer placement. C, Increased thickness of composite resin cement masks discoloration.**

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FIGURE 4-47 The Jazz P3S Porcelain and Metal 3-Step Polishing System can be used to polish supragingivally. *(Courtesy SS White Burs, Lakewood, New Jersey.)*



FIGURE 4-50 Veneer contours reduced to natural gingival appearance.



FIGURE 4-48 Overcontoured gingival porcelain: "Chiclets look."



FIGURE 4-49 Profin reciprocating handpiece (Dentatus USA, New York, New York).

(Figure 4-51), diastemas (Figure 4-52), and size discrepancies (Figure 4-53). The latter two conditions can easily be resolved by very thin laminates. Even moderate tooth discolorations may be better masked by using more opaque luting agents in thin layers rather than increasing veneer thickness.

Ultimately, the final decision on preparation depth is the dentist's, based on both education and experience. Many dentists are reluctant to bond a restoration onto a tooth that has not been prepared; there are valid concerns about the emergence profile and overall tooth bulkiness. In actual fact, the emergence profile need not be compromised when the margin is placed supragingivally (Figure 4-54). Furthermore, the linguobuccal dimension of a central incisor is increased less than 5% by a well-fabricated and bonded veneer. Thus these concerns should not necessarily influence the dentist in favor of increased tooth preparation. If a tooth is positioned buccally to the arch contour, some elective reduction enameloplasty is needed to remove the protruded bulk that hinders an esthetic restoration (Figure 4-55). In certain cases with severe staining, the intensity of the color requires some enamel preparation for increased ceramic thickness and masking opacity.

Factors Influencing the Patient's Decision

The guiding principles of ultraconservative tooth preparation are also highly desirable from the patient's point of view. This aspect should not be underestimated. As porcelain veneers are generally an elective dental procedure, the patient must perceive that the treatment is desirable, comfortable, and of lasting value. Only then will the patient choose the procedure and pay to have it done. Minimal preparation (or none at all) is much easier for the patient to comprehend and accept. Patients tend to submit themselves more willingly to a constructive procedure than to a destructive one.

With ultraconservative preparation, there is usually no need for anesthesia or retraction cord. The dentist may find it

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FIGURE 4-51 **Examples of discolorations. Discolored dentition (A); veneers eliminate discoloration (B). Single discolored central (C); veneered anteriors eliminate discoloration (D). Patient smile before treatment (E) and after treatment (F).**

advantageous to point this out during case presentation. Medically compromised elderly patients may also benefit from not having to introduce a local anesthetic to their systems.

EVIDENCE-BASED PRINCIPLES

The evidence-based principles for ultraconservative dentistry begin with the periodontal demands for supragingival margins first indicated in the 1950s. It was shown repeatedly that subgingival margins cannot be maintained adequately. In the long term resin incompatibility with soft tissues causes bacterial breakdown along the marginal areas of any subgingivally finished restoration. The dilemma was that the tooth-colored materials of the day could not be finished supragingivally with any acceptably esthetic result. As patients became more attuned to the esthetic possibilities of restorative dental treatment, this marginal esthetic concern became a major issue. The practice for several decades was to hide the margins subgingivally (Figure 4-56); this went against contemporary scientific and clinical principles but was done in response to the demands that patients placed on dentists.

As bonding and adhesion came into more common use and could be applied to both dentin and enamel, it became easier to

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FIGURE 4-52 **Examples of diastemas. A, Central diastema; B, eight anterior veneers eliminate diastema. C, Central diastema and size discrepancy. D, Porcelain lengthens one central and widens the other central preferentially. E, Porcelain veneers placed. F, Patient smile after treatment.**

work supragingivally. Many cases in the literature show how effective and how clean the bonded margin can be (Figure 4-57). The surface at the margin of the adhered restoration is almost, but not quite, as smooth as that of the natural tooth. It is certainly better than the margin of a nonadhesively cemented restoration. Bonding makes it possible to restore a tooth and to create a margin that is clinically acceptable and can be maintained in the long term.

With the appearance of resin cements in the early 1990s it became apparent to restorative practitioners that placing margins supragingivally would be better for periodontal tissues and better for maintenance. Finally the restorative composites and ceramics that allowed an esthetic result in the marginal area became available. Ongoing research and development ultimately allowed dentists to address the requirements of the periodontal tissues, the needs of the restorative materials, and the esthetic demands of the patient with a single treatment modality, the supragingival margin. From the early 1990s on, the development and continual implementation of ultraconservative dentistry, translated as supragingivally margined and readily maintainable restorative or elective dentistry, increased.

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FIGURE 4-53 A, Severe size discrepancies and spacing. B, Size and spacing discrepancies corrected by veneers.

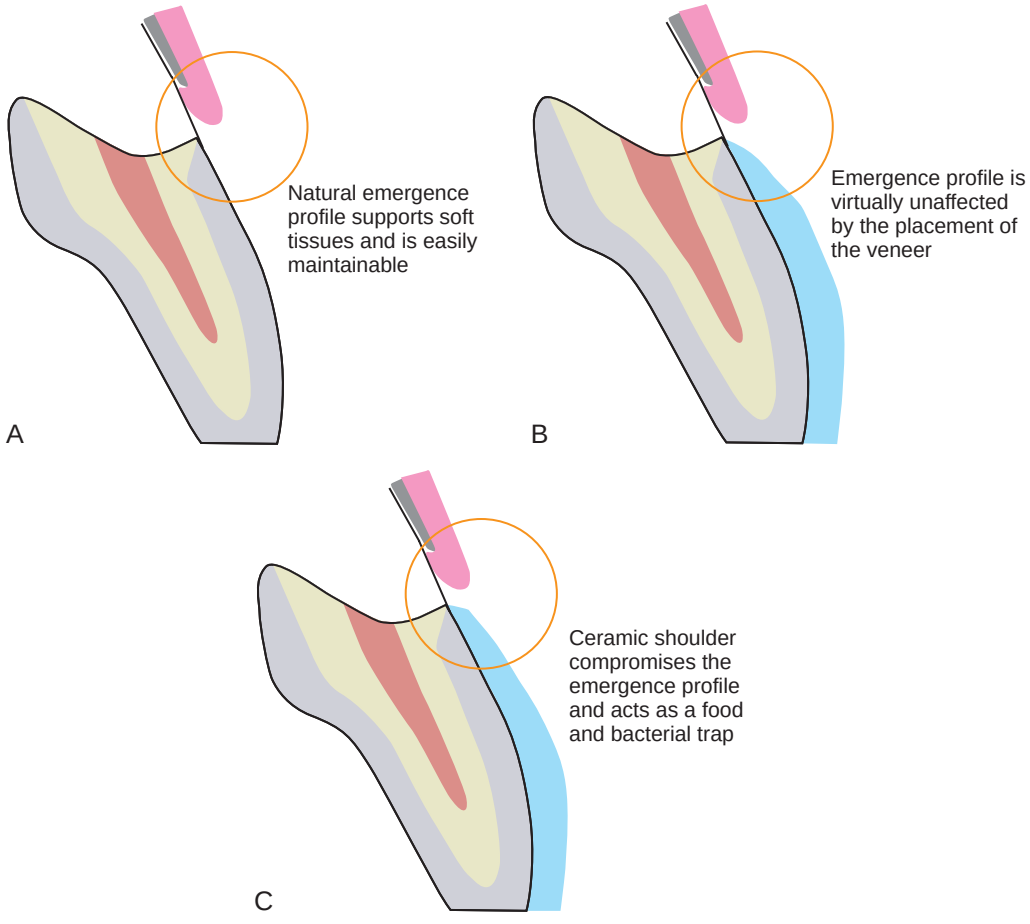


FIGURE 4-54 A, Unrestored emergence profile is tissue supportive and maintainable. B, Supragingival margin emergence profile is virtually unaffected by the placement of the veneer. C, A ceramic shoulder and exposed luting resin compromise emergence profile and create a food and bacterial trap.

MAINTENANCE

Although most patients who have had ultraconservative procedures do a relatively acceptable job of brushing their teeth at least once or twice a day, they often neglect the more involved procedures, such as flossing. Because this hygiene of the interproximal areas is generally not practiced by most patients, proactive dentists need a two-pronged approach to maintaining oral health. First, they must educate the patient as to the importance of the various tools available for oral hygiene maintenance and the significance of each, and the long-term necessity of these practices for maintaining natural or restored dentition in optimal health. Second, they must develop and

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FIGURE 4-55 Selective reduction enameloplasty removes protruded tooth portion that could hinder an esthetic restoration.



FIGURE 4-56 Subgingival margins irritate soft tissue.

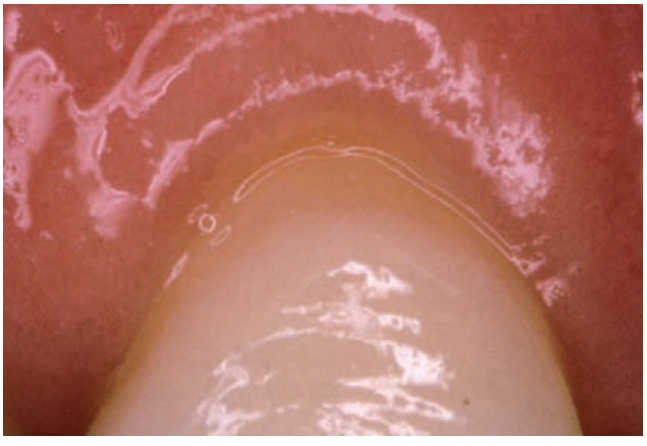


FIGURE 4-57 Supragingival margin in full view.

insert inherently more maintainable restorations into the patient's dentition, particularly in elective procedures where natural teeth are being modified primarily for esthetic reasons.

The dental team can assume that no matter how good the patient's oral hygiene motivation and techniques are, there will be little or no subgingival cleansing practiced by the patient. This area is visually inaccessible to the patient, it is difficult to access with tactile instruments, and conceptually most patients do not even realize it exists. It must be assumed that any margin placed subgingivally will not be maintained either in the short

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or the long term. No matter how close it is to the natural smoothness of the original tooth surface, it represents a weak area where plaque can accumulate, bacteria can congregate, and both acid production and hard and soft tissue breakdown will occur.

The most important principle of ultraconservative rehabilitation is that margins are placed supragingivally. After the restorations have been inserted, the patient is then in a position where routine brushing and occasional flossing tends to maintain these margins in a clean state, relatively free of the accumulation of plaque and bacteria.

The next concept in conservative terminology is that of tissue removal. When enamel or dentin is diseased or broken down, the decision to remove is easy. The unhealthy or compromised tissue should be reduced and replaced (although this concept is being modified by the innovations and developments in remineralization and hardening of previously diseased tooth structures). In any case the removal of compromised tissue poses less of a decision for the dentist. It is when the practitioner is dealing with healthy tissue that the real dilemma arises. The concept of removing healthy enamel or dentin for restoration by ceramic or composite materials is a difficult one. When healthy tissue is removed for various purposes, the dentist assumes a tremendous responsibility. This healthy tissue must be replaced with material that is at least as good as or preferably better than what was removed.

In certain situations, tooth structure must be removed for functional reasons to facilitate proper occlusion, to optimize cleansing, or simply to eliminate barriers to the path of insertion. In these instances conservation principles indicate that as little tooth structure as possible should be eliminated during the course of treatment. When tooth reduction is for esthetic reasons, particularly in elective treatment, the dentist assumes the responsibility for removing healthy tooth structure. Generally any materials used to replace tooth structure today are less effective, have less strength than the natural tooth structure, and provide an interface between the tooth structure and restorative material that can act as a weak link. In fact, restoring a perfectly healthy tooth often creates a weaker overall structure rather than strengthening the original. When procedures are done for elective reasons, particularly esthetic ones, the tooth structure should be considered inviolable if at all possible, and no healthy tooth structure removed if that is within the realm of treatment options. When no tooth structure has been removed during the procedure, the practitioner and patient always have the option of reversing the treatment by simply removing the restoration (although this can be difficult, tedious, and time-consuming, it is nevertheless possible if enough care is exercised) (Figure 4-58).



FIGURE 4-58 **A, Initial preparation through veneer must be careful in order to not damage underlying tooth structure. B, Undamaged underlying tooth structure revealed. C, Veneer completely removed without damaging underlying tooth structure. D, Four maxillary anterior veneers removed in preparation for reveneering.**

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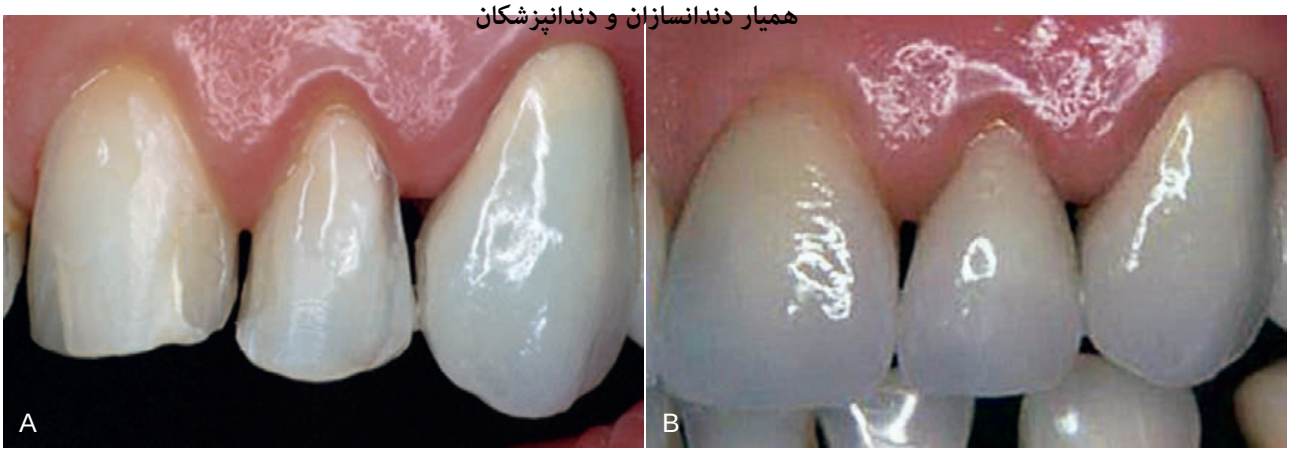


FIGURE 4-59 **A, Maximal veneer preparation eliminates interproximal contact. B, Veneers restoring form and function.**



FIGURE 4-60 **A, Anterior teeth not requiring preparation for veneers. B, Unprepared anterior teeth restored with veneers.**

It is possible to return to the original, unprepared tooth. Once the tooth has been prepared and healthy enamel and dentin have been removed, these natural tooth structures are gone forever and cannot be recreated. Any restoration placed thereafter consists of a material that is theoretically weaker than the original structure that once formed the natural tooth. Therefore it is with great trepidation that a dentist should even begin to consider the removal of healthy tooth structure unless every other possibility has been ruled out and no other course of treatment is possible. In certain situations the removal of healthy enamel and dentin is unavoidable during the course of elective treatment. However, these instances should be minimized as much as possible. The goal of every dentist undertaking esthetic procedures should be to remove no healthy tooth structure if at all possible and as little as possible in all circumstances (Figures 4-59 and 4-60).

One of the post-treatment realities is that patients are often less effective and/or less conscientious about maintaining their restored dentitions than they should be. Every additional tool that the practitioner can provide is likely to result in a healthier oral environment and an extended life cycle for the restorations. Tooth brushing is well accepted by the average patient and successfully practiced by most. String flossing is well understood but much less commonly practiced, as a rule. This is largely due to the manual dexterity that is required on the patient's part and the difficulty in making this process a part of routine, daily oral hygiene procedures. Water flossing (WP 100, Waterpik, Fort Collins, Colorado) is a much more patient friendly and less technique sensitive maintenance method that seems to encourage a higher rate of patient compliance (Figure 4-61). Water flossing is very effective in removing debris and biofilm both from accessible tooth surfaces *and* interproximally. As an added advantage, it leaves the patient's mouth feeling cleansed, thereby encouraging more frequent utilization. Thus, it is more likely to be incorporated by patients into their daily oral hygiene routine. A regularly practiced home regimen results in a longer lasting restoration.

CONTROVERSIES

The controversies that arise in rehabilitation dentistry are largely those of conservation verses maximal preparation. The science and art are firmly on the side of minimal preparation. However, some practitioners and some dental technicians prefer to remove more tooth structure to achieve more physical space wherein the

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FIGURE 4-61 **The WP-100, Waterpik® Ultra Water Flosser is effective in removing debris and biofilm both from accessible tooth surfaces *and* interproximally and encourages a higher rate of patient home care compliance.** *(Courtesy Water Pik, Inc., Fort Collins, Colorado.)*

desired esthetics can be developed. Although this facilitates the technician's work in some instances, there is no question that it compromises the long-term viability of the tooth and the prognosis that the restoration will be durable, esthetically effective, and maintainable in the long run. Thus, although there are some controversies, ongoing developments in restorative materials, ceramics, resins, and cements are quickly eliminating them. The profession as a whole is moving in the direction of more conservative dentistry with less preparation and less removal of healthy tooth structure. This benefits the patient and ultimately benefits the profession as well.

NEAR-FUTURE DEVELOPMENTS

Near-future developments in esthetic dentistry will likely continue to expand current directions; the momentum of the research in this segment of the profession has been strong for the last 30 or 40 years. Innovative ceramic materials that can be used in thinner layers to provide suitable esthetics and one-step resin cements for crowns and veneers that are totally translucent and provide no marginal color mismatch between the root and the crown or veneer are on the immediate horizon. More comprehensive at-home cleaning technologies that allow patients to keep their teeth cleaner and their restorative margins free of plaque, keeping eventual decay and breakdown at bay, appear regularly.

Although computer-aided design and manufacturing (CAD/CAM) technologies do not yet provide fully esthetic opportunities for very thin porcelain restorations in the anterior regions, it is likely that the ability to digitally color and stain these restorations in very natural shades and hues will enable the profession to provide chairside esthetic restorations that can be available in a matter of hours rather than days or weeks, as with lab-mediated procedures. Certainly the electronic shade-matching devices available today are much better at matching natural tooth shading and can assist in the creation of accurate reproductions even when the technicians are located remotely from patients.

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Smile Design

Smile Design

Elliot Mechanic

RELEVANCE OF SMILE DESIGN TO ESTHETIC DENTISTRY

It is extremely difficult for a dentist to achieve a pleasing esthetic result without having a clear picture of what the patient desires and what his or her expectations and esthetic goals are. For a dentist to enter into any esthetic procedure blindly not only can be frustrating and time-consuming but often leads to patient dissatisfaction with the course of treatment and its outcome. If during or after treatment patients choose to "switch dentists" and "close their chart," the dentist usually feels insulted and unappreciated, especially after all the hours of work that he or she put into the case. Sometimes the patient is so dissatisfied that he or she elects to redo the case with another practitioner. This is unpleasant for both the patient and the dentist as well as costly, painful, and inconvenient. One hopes that the patient will not pursue litigation, which would result in more aggravation for everyone.

On a daily basis dentists around the world try to achieve esthetic makeovers in a random manner with little or no preplanning or idea of what the final outcome will be. They simply take an impression of the patient's prepared teeth and send it to the dental lab technician with little instruction and few requirements for the restoration. They on the most part leave the fabrication of the restoration up to the ceramist, assuming that the ceramist will "magically" create a beautiful restoration. The lab technician with no exacting parameters to follow designs the restoration to the best of his or her ability and delivers it to the dentist. The dentist then tries the restoration in the patient's mouth and has the patient look in the mirror. If the patient responds, "I don't like it," the dentist then asks the patient, "What don't you like?" The patient might answer, "I don't know; maybe they're too long." The dentist then sends it back to the lab with instructions to make the restoration shorter. Sometimes there are not even specific details given on how much altering is desired. Often several appointments follow, with the restoration going back and forth to the lab. Eventually the patient gives in after becoming so tired of the process that he or she just accepts the outcome. But is the patient actually totally satisfied with the end result and how the smile and face appear? Does the patient regret undertaking treatment, or does he or she really wish to have the restoration removed and redone differently? If the dentist had provided the lab technician with an exact blueprint of what was desired, the ceramist would have had a guide to provide the patient with what he or she wanted, and the outcome would have been satisfactory.

The road map to all the clinical procedures to be done and the basis for treatment planning is the smile design. It is derived from a combination of what dentists know, the rules of esthetics, and listening to the patient's desires. These come together in a plan to achieve all the goals set. The limitations of the materials available, the positions of the teeth, and the finances of the patient are among the considerations in this process. The treatment plan agreed on by the dentist and patient is what is best suited to the situation at hand with what is available.

Smile design and the whole concept of being able to plan a smile makeover have had an impact on patients' perspective of dentistry. One must think of reconstructive dentistry as plastic surgery of the mouth with the aim of improving what currently exists. Modern smile design techniques and materials give dentists tools that do not exist in any other forms of plastic surgery. There is no other esthetic transformation procedure available in which patients can actually see and live with the changes they are obtaining before they commit to a permanent solution. For example, if someone wishes to have a procedure done to alter the shape of the nose or face, he or she must wait several weeks until the bandages and dressings are removed and even longer for the swelling to totally subside. In actuality it could take months before that person knows what he or she will finally look like. With dental temporization techniques, the key to modern smile design, the dentist can make changes to the patient's

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provisional restoration so that the patient can visualize and live with potential smile possibilities. The patient is then able to look at it, go home with it, and show it to his or her spouse and friends if desires. Once the patient approves the provisional restorations, the dentist simply takes photos and accurate impressions of them to serve as a template for the lab technician to duplicate in ceramic. By using provisional materials made of bis-acryl, dentists have the ability to add and subtract composite resin, allowing them to create exactly the shape, form, and appearance that will satisfy the patient.

BRIEF HISTORY OF THE SMILE DESIGN PROCEDURE

Looking back in time, little or no attention was placed on smile esthetics. Dental concerns placed very little importance on looking good, as if esthetics were for the vain and not within the realm of science and medicine. The past two decades have witnessed an esthetic revolution. Because of advances in materials, techniques, and the ever-growing demand of people to look and feel better about themselves, dentists have learned to "change a smile," which can sometimes "change a life." Incredibly, what is regarded today as "esthetic" or "cosmetic dentistry" is still not recognized and is frowned on by some dentists. They believe that it is unnecessary and that dentists who promote and offer these services are interested only in "making a quick buck." Admittedly there is significant charlatanism in dentistry, but isn't this true of many services and professions? The majority of our patients no longer accept "ugly" teeth—nor do they drive horse and buggies, live without computers, and desire amalgam restorations. A coordinated treatment plan yielding a healthy, balanced, easily maintainable restorative esthetic result is a beautiful thing.

When I attended dental schools in the 1970s, each student was given a mold guide of available denture teeth. Different manufacturers created their own guides for the teeth they designed. Common to all was the philosophy that tooth form was determined and should be selected based on the shape of a person's face and head. The teaching was that patients with round-shaped faces were given ovoid teeth (Figure 5-1), whereas tapering teeth went with a long face (Figure 5-2).

Written rules were used, and if students did not follow them, they would not receive a passing grade. Some students questioned what was being taught. If a dentist chose to place tapering



FIGURE 5-1 A round-shaped face calls for ovoid teeth.



FIGURE 5-2 A long narrow face calls for tapering teeth.

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FIGURE 5-3 India street merchant selling dentures on the street: "Choose your own teeth!" "Try before you buy!" Is this the ultimate smile design?



FIGURE 5-4 A diagnostic wax-up fabricated from mounted study models.

teeth in someone with a long skinny face, the face would look even longer. If round teeth were given to someone with a round face, the round face would appear even rounder. In actual fact, there was really no smile design or thought process regarding changing and improving a patient's overall appearance. There were set rules that everyone followed because that was the way it was.

Incredibly, and probably accidentally, some third-world countries demonstrated superior smile design to what was being done in North America. For instance, in India it is possible to purchase dentures from street merchants (Figure 5-3). The buyer can select a denture, try it in his or mouth, and then look at the appearance in a mirror. When the buyer finds a set of teeth he or she likes, the merchant (denturologist) relines the denture with acrylic, and the buyer leaves with new teeth. The buyer has immediate gratification from being able to see exactly what he or she is getting before approving the purchase.

The dentist performing removable prosthetic procedures has long been able to allow their patients to have a wax try-in so that they can preview the new smile before the denture is processed and finished. However, smile design for fixed prosthetics over the last 50 years in North America has often been haphazard. Dentists took an impression, sent it to a lab, and wrote the lab technician some basic instructions as to what they wanted. There was no real way of knowing exactly what the patient would be getting. As well, the standards and skills of lab technicians and the materials available to them were not sophisticated enough for them to be able to fabricate imperceptible, lifelike restorations.

RELATING FUNCTION AND ESTHETICS

The key to achieving a predictable smile design, eliminating guesswork and satisfying the patient's expectations on the first attempt without having to return the restoration to the lab for modifications, is to set the teeth up in a well-made provisional restoration. This temporary restoration provides a blueprint for both the desired function and esthetics. The dentist takes photos, bite records, and impressions of the patient's teeth, studies them, and decides what functional and esthetic changes are needed. The dentist then has the models mounted on an articulator and fabricates a diagnostic wax-up to act as a guide for the temporary restoration (Figure 5-4).

The dentist normally would choose to have the diagnostic wax-up fabricated in a cuspid-guided occlusion so that the canines can disclude the posterior teeth in lateral movements. Cuspid guidance allows the facial muscles to have the chance to not receive continuous stimulation, which can result in facial pain. This discomfort is often confused with temporomandibular joint (TMJ) disorder but actually is of purely muscular origin and not joint related. If the patient is comfortable in the temporary restoration, the dentist can then simply tell the lab to duplicate the temporary restoration when fabricating the permanent restoration. All the functional and esthetic requirements will have been worked out and tested in the temporary restoration.

It is not always possible that a smile that has been designed purely for ideal esthetics will work in the function or parafunction of a patient's mouth. If there are limitations, the dentist must point out the compromises to the patient. This is extremely important so that there are no false expectations or disappointments. There must be impeccable communication between dentist and patient. If the dentist knows that what the patient wants to achieve is not possible without considerable major changes to the patient's dentition, he or she must inform the person about the problems that can arise. It may be possible that orthodontics would be required to move the teeth or periodontics needed to augment or reduce the gingiva. If what the patient desires is totally impossible, the dentist must be totally honest instead of assuming that the patient would settle for a different result. The patient must be given realistic expectations and be guided to understand what is possible and by what alternative means he or she can achieve what is desired. If patients are presented with all the facts and options that are available to them, they usually make the right choice. On a daily basis patients electively undergo periodontal surgery to alter gingival

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levels to reduce a gummy smile or to increase their gingival width. Patients electively undergo maxillofacial surgery to alter their mandible and/or maxilla. For example, some people have chins that are too retracted, so they choose to have an oral surgeon advance their mandible surgically. All dentists should educate their patients about what is possible, what is not possible, and what may be possible.

CLINICAL CONSIDERATIONS

Any and all types of dental rehabilitation and reconstruction should be treated in exactly the same manner. For each and every single crown, and so on, the same principles should be applied. Even a simple one- or two-unit case is initially worked out and tested in provisional restorations to assess the desired function and esthetics of the permanent restoration. Impressions are taken of the temporary restoration, and photos are taken with a shade tab alongside the bis-acryl provisional restoration and the natural teeth (Figure 5-5).

This shows the lab technician the shade that is desired. Every single case has the same smile design protocol, even posterior molars. It is the author's process to work out the buccal position and the cusp heights of the teeth in the temporary, and then instruct the lab to duplicate it exactly.

Even a posterior lower or upper molar can have the cusp height, buccal position, and width of the tooth redesigned. The lab technician is given exact instructions so that when the restoration is returned it is exact. When the restoration arrives from the lab, it is compared with the models and photos of the provisional restoration—they should look identical (Figure 5-6).

If the extra few minutes are taken to design the temporary restoration properly with all the standards of smile design, the result from the lab will always be predictable. Today's superior lab technicians prefer working in this manner—that is, using photos and templates. They find that restorations are not returned to them as often for modification and correction.

THE DIAGNOSTIC WAX-UP

The key to achieve a pleasing smile design is having the dentist interview the patient and listen to exactly what the patient wants. Photos of the patient show what the teeth initially look like, and both the dentist and patient can study and assess the

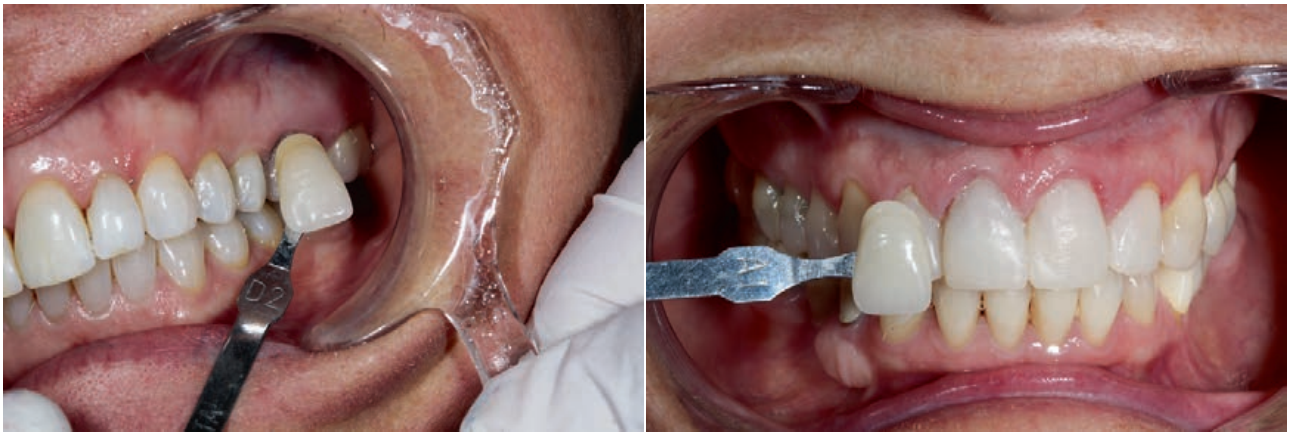


FIGURE 5-5 Shade tabs photographed for color illustration.

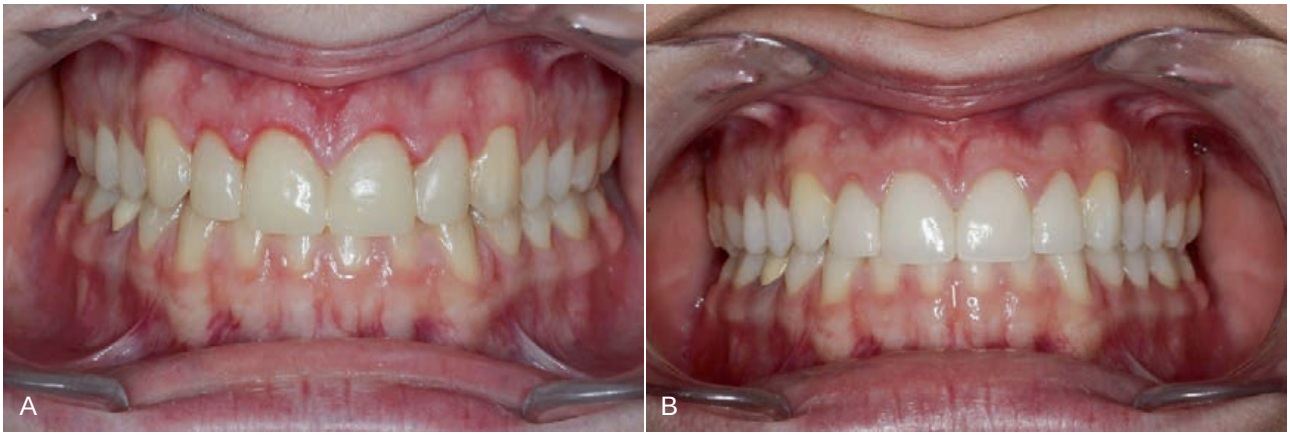


FIGURE 5-6 A, Provisional restoration. B, Porcelain restoration. The final porcelain restoration should follow the parameters set out by the temporary restoration.

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FIGURE 5-7 Planning the smile design by drawing on preoperative photos.

situation. It is possible to draw what is wanted, make the teeth longer or shorter, or change the midline or gingival position on the photos (Figure 5-7).

These basic tools help the team visualize what they want to achieve. This vision must then be communicated to the lab technician, who will create a diagnostic wax-up, which is basically a template or mock-up of what was discussed while looking at the photos.

The diagnostic wax-up is poured in high-quality, low expansion stone and mounted on a semi-adjustable articulator so that the teeth are oriented on the lab bench exactly as they are in the patient's mouth. An articulator is nothing more than a chewing simulator of the person's function. The lab technician will create preparations of the teeth on the model in a realistic fashion to accommodate the design of the desired restoration. The technician uses dental waxes in natural tooth colors to produce the anticipated result. The diagnostic wax-up should resemble the projected finished look of the patient's dentition. On the diagnostic wax-up the lab technician can make all the changes needed by correcting occlusion, changing the incisal or midline cant of the teeth, changing the dimensions of the teeth, expanding the arches, and so on. Every physical change can be made on the diagnostic wax-up. However, it is absolutely essential that the lab prepare the teeth in a realistic fashion. Once the diagnostic wax-up has been completed, the lab technician or dental assistant fabricates a silicon putty template that can be used to make the bis-acryl provisional restoration after the dentist similarly prepares the patient's actual teeth (Figure 5-8).



FIGURE 5-8 A silicone putty template is fabricated on a plaster model of the diagnostic wax-up.

BOX 5.1 Resin-Based Systems: Bis-Acrylic Composites

- Automix cartridges
- Quick set time
- Can be added to and modified easily with flowable, microfill or hybrid composite resin
- Easy to finish—glaze
- Natural looking esthetics—fluorescence

MAKING THE PROVISIONAL RESTORATION

Today's standard of fabricating a provisional restoration is to create a diagnostic wax-up of the desired result, fabricate a putty template of it, and flow a bis-acryl temporization material into it, which is then placed over the patient's prepared teeth and allowed to set. This technique yields provisional restorations that are a facsimile of the diagnostic wax-up. The introduction of bis-acryl materials dispensed from cartridge guns paved the way for dentists to be able to easily assess and to modify a proposed smile design (Box 5-1).

The advantages of these materials are several. **Bis-acryl** material is a liquid composite resin that sets hard, is lifelike, does not give off any heat, flexes so it does not break off the teeth easily, adheres to the teeth, and offers the teeth protection. However, the main advantage of this material is its easy

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FIGURE 5-9 **Bis-acryl provisional restorations can be easily modified by the subtraction or addition of composite restorative material.**

ability to be polished. It can achieve a polish similar to a composite resin, with a series of diamond points, carbide points, and disks. All that is required to finish it is to paint on a finishing glaze. If the dentist believes that it is necessary to change or modify this material, any type of composite resin can be added in the appropriate color. These additions can be remodified as well.

Before the introduction of bis-acryl materials, dentists mostly used methylmethacrylate acrylics created by mixing a tooth-colored acrylic powder with a liquid monomer. These materials are smelly, give off heat, take a lot of time to set, and are difficult to add to and modify. Bis-acryl changed the standard of dental temporization. It gives dentists a means to creatively do bonding additions to the provisional restorations and customize a look for each individual (Figure 5-9).

Bis-acryl provisional restorations can be easily remodified and repolished, and patients can wear them for long periods of time with few adverse effects on the gingival tissue. The main advantage of bis-acryl temporary restorations is that they allow the patient to live with the new look, evaluate it, and give the dentist feedback as to what they like or dislike. The dentist is then able to modify the provisional restoration to please the patient. Photos and an accurate impression are then taken of the final provisional restoration and are sent to the lab technician as a blueprint for creating the final ceramic restoration. This is the state of the art of predictable creative smile design.

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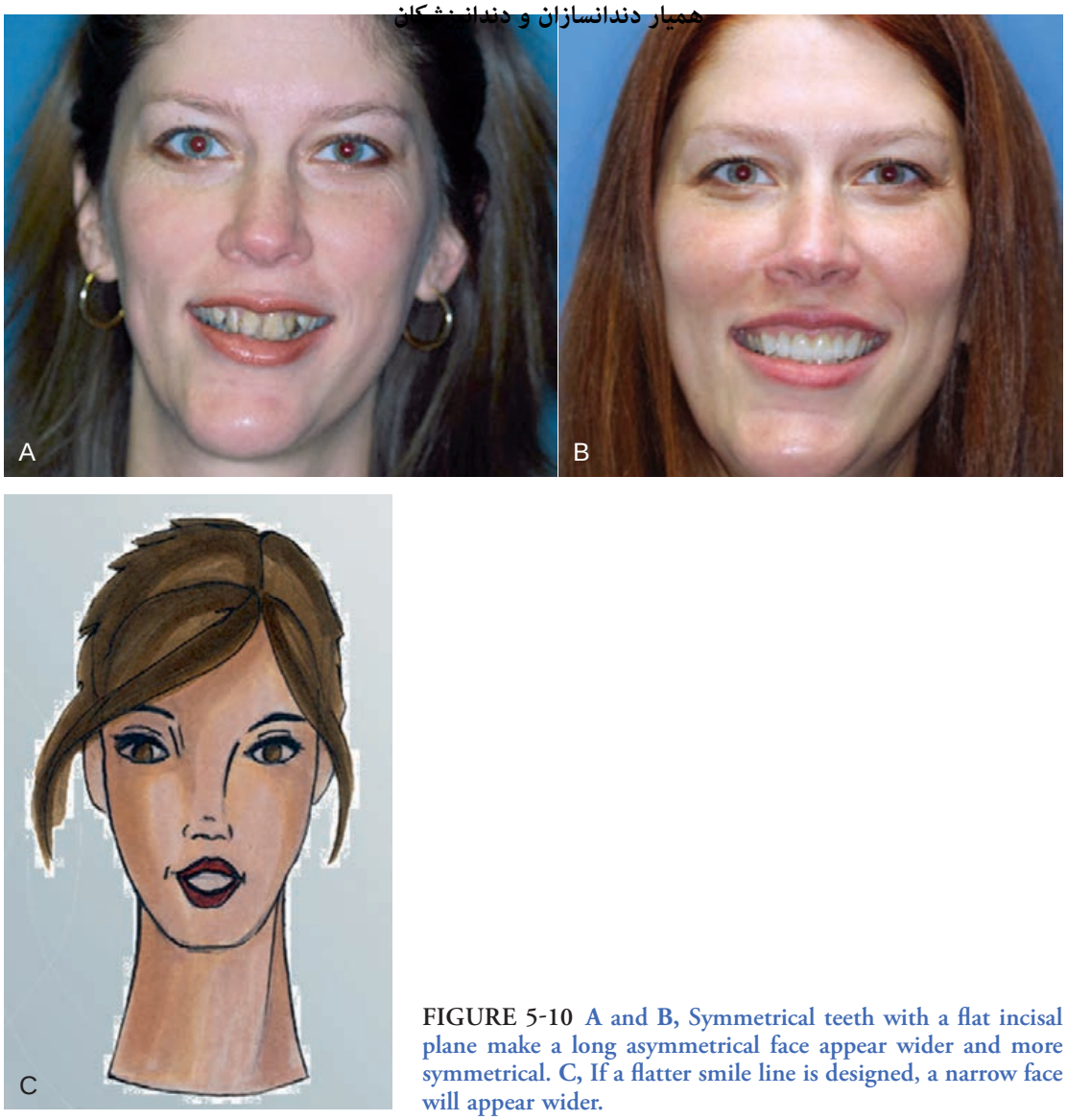


FIGURE 5-10 **A and B, Symmetrical teeth with a flat incisal plane make a long asymmetrical face appear wider and more symmetrical. C, If a flatter smile line is designed, a narrow face will appear wider.**

THINKING OUTSIDE THE BOX

Dentists have come to realize that the old rules of selecting a tooth shape that were taught in school may not apply in the real world. These protocols were created in order to select appropriate tooth molds to fabricate dentures. Formerly, a patient who had a long face was given long teeth. Today patients with long faces are often better off with square or more symmetrical flat teeth. These make a long face appear to be wider and more symmetrical (Figure 5-10). Similarly, someone with a round face can receive longer teeth to counteract the roundness (Figure 5-11).

From a technologic point of view, dentists stopped thinking like scientists, following the rules of science taught in school, and started taking an artistic approach to dentistry. This began in the 1990s. Dentists started thinking like designers of smiles and stopped thinking of just rules and formulas. Rules and formulas may be great on paper, but they do not always look good on people. Human beings exist in different variations—people come in different sizes, colors, and forms and have different personalities. Dentists began to think of technologic and artistic ways to create teeth to match and enhance personalities (Box 5-2). Dentists are today more than ever regarded as artists.

Standards in dental labs have also changed dramatically. For many years ceramists were limited by the materials available to them. However, these professionals now have access to lifelike new porcelains, pressed ceramics, zirconium, lithium disilicate, and other new technologies. Ceramists have become more and more artistic. Today's premiere technicians have raised the bar and distinguished themselves, pushing the barrier of what is possible. They are able to provide lifelike restorations that meet today's high esthetic standards.

An artistic approach and the coordination between laboratory and dentist continue to improve the ability to achieve a beautiful smile. Science and technology have changed every aspect of smile creation.

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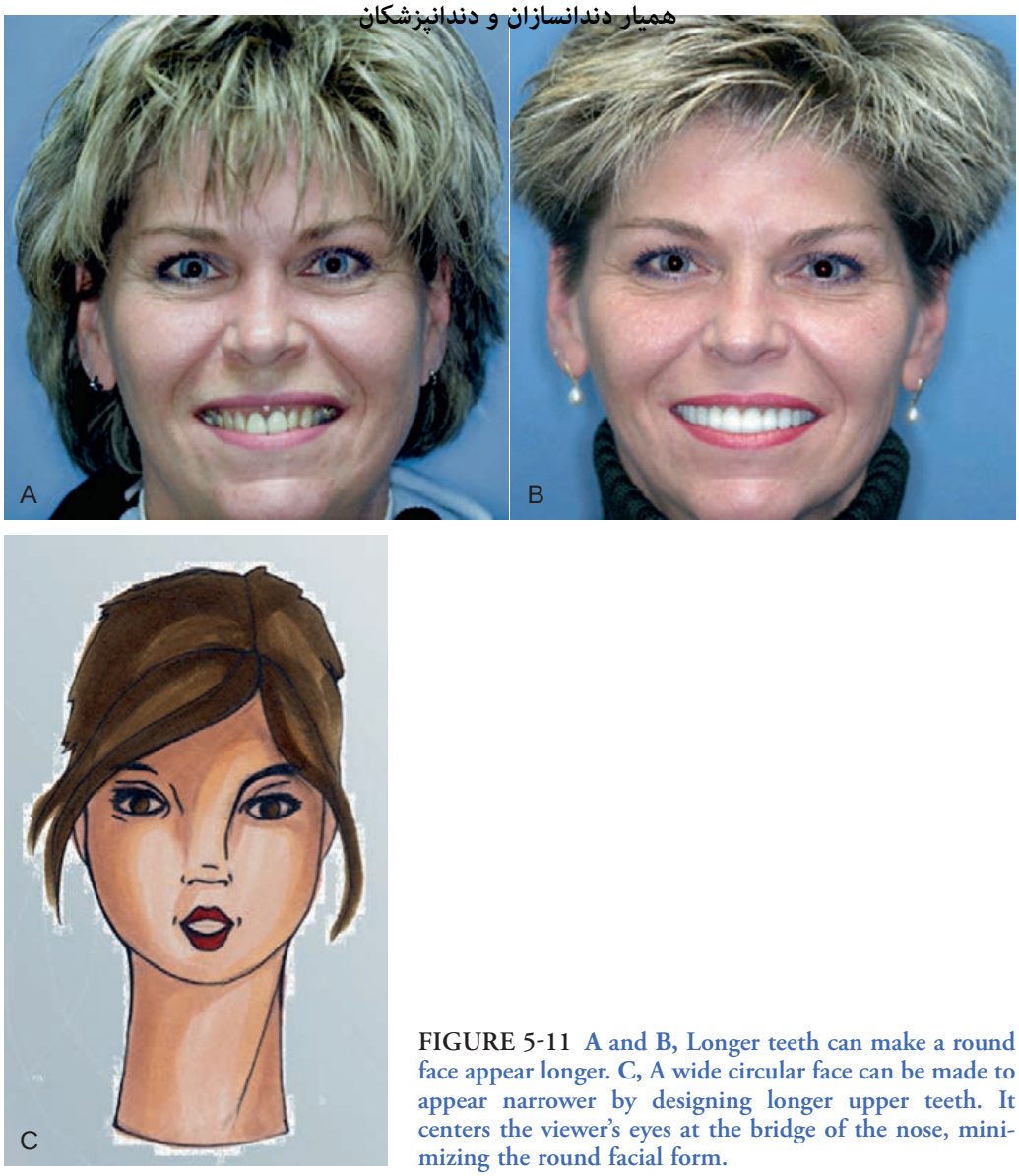


FIGURE 5-11 **A and B, Longer teeth can make a round face appear longer. C, A wide circular face can be made to appear narrower by designing longer upper teeth. It centers the viewer's eyes at the bridge of the nose, minimizing the round facial form.**

BOX 5.2 The Goal of Esthetic Dentistry: To Enhance What Mother Nature Has Given Us

- We are all human beings!
- We come in different sizes!
- We are different colors!
- We have different personalities!
- Our features and facial shapes differ!
- Our teeth have different shapes too!

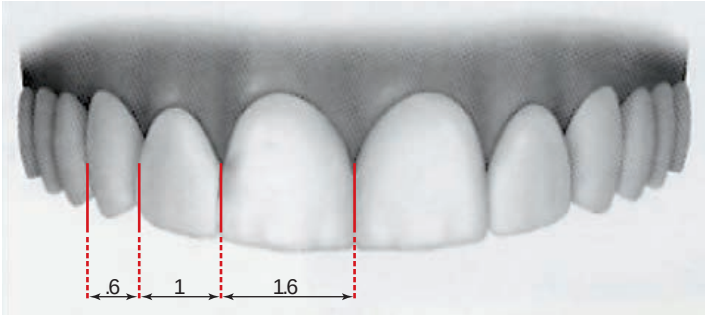


FIGURE 5-12 **The golden proportions.**

ARTISTIC ELEMENTS

Every dentist has been preached the **golden proportions**. The golden proportions state that if a person's teeth are viewed straight on and using the lateral incisor as the reference tooth, the adjacent central incisor should be 1.6 times the size of the lateral incisor, and the visible part of the canine 0.6 times the size of the lateral incisor (Figure 5-12).

These are the scientific principles of smile design. But science is one thing and art is another. Artistically, the central incisors must be totally symmetrical. Their incisal edges should be equal, and the incisal corners should be the same shape. If the mesial of

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one is square, the mesial of the other should be square. The gingival levels should also be equal. However, aside from the central incisors all the other teeth can have some form of variation. The lateral incisors should not be totally symmetric. The dentist can make one lateral incisor shorter than the other or turn one lateral incisor to give character and personality to the patient's smile. The lateral incisor is regarded as the personality tooth, so one can create a sexy or mischievous look by simply turning and playing with the angles of the these teeth. In a similar manner a canine can be made sharp or pointed to create a strong look, or it can be rounded for a softer appearance. It is also possible to expand and widen the dental arches and create a fuller buccal corridor. Even though there are scientific principles involved, it is really the dentist's eye and creativity that are the best tools for creating a beautiful smile. The dentist must think like an artist, study the patient's face, and try to enhance what is already present.

What is today being referred to as "pink esthetics" is fundamental in achieving a natural- and healthy-looking smile. The patient's gingival levels should be in the most natural-looking position. Usually as people age, their gingival levels change. The tissue may have receded because of disease, tooth abfraction, or overbrushing (Figure 5-13). Often with patients who are "long in the tooth," gingival grafting must be performed.

TREATMENT PLANNING

The new patient is the lifeblood of the dental office. Without new patients, dentists would have to rely on finding new work or redoing the dentistry of their existing clientele. The new patient experience begins when the patient first telephones the office. In our office we try to determine over the phone if the patient requires major or minor dental work. Dental offices that focus on and have a reputation for major restorative dentistry are more likely to receive patients with more serious needs than offices focused on family dentistry. The receptionist must carefully screen the new patient phone call to determine what type of new patient visit to schedule. The needs of a patient with full-mouth breakdown are far different from the needs of one who has a healthy dentition. Sometimes when patients call and say they require something major, it could actually be something very minor. Everyone has his or her own perspective.



FIGURE 5-13 **A, Gingival levels that are not harmonious make dentition look old. B, "Pink esthetics" and the ideal gingival height.**

In our office, when the receptionist believes that a major dental treatment is anticipated, an appointment for a screening consultation is made. The patient comes in on a lunch hour or at 5 o'clock for a consultation. At this time the dentist can sit with the new patient one on one with no distractions. Four photos are taken of the patient: (1) smiling full face, (2) at-rest full face, (3) smiling close up, and (4) smiling with a tissue retractor. The photos are printed, and the dentist sits with the patient at a consultation table and listens to what the patient desires. The dentist uses the photos to illustrate to the patient the situation that currently exists and possible changes that can be made. No treatment plan is established at this time, as this is not a formal examination. The dentist tries to open the patient's eyes to what can be done. There may be many things visible on the photos that the patient never actually recognized. In fact, they may be the things that actually bother the patient but that he or she could never pinpoint. It may be that the gingival tissue heights are not aligned, buccal corridors are not expanded enough, teeth are too short, and so on. The dentist must use a pen and draw on the photos to help the patient visualize some of the potential changes that are possible. On this initial consultation the patient is given an idea about what may be involved with respect to time, discomfort, and cost.

If the patient is still interested after the consultation, he or she then receives an appointment for a full new-patient examination, which is scheduled for 2 hours of time. At this appointment intraoral photographs of every single tooth are taken, as well as a full-mouth series and panoramic radiographs. Creation of a set of study models, bite registration, periodontal charting, occlusal evaluation, TMJ assessment, and a head and neck examination are also conducted. The majority of these records are gathered by a hygienist. The dentist usually enters the room only when all the information has been put together and is available, including the study models and photos. The dentist then performs the intraoral examination and tries to instill confidence in the patient. It is important to understand that a treatment plan is not usually proposed at this time, as the case has not actually been totally analyzed.

The patient's next appointment is made 1 to 2 weeks later for a review of the entire case. This is often referred to as the *case presentation.* In the meantime, the models, radiographs, and photos are studied and scientific principles applied to formulate a treatment plan. The dentist studies the photos first to see how much tooth is showing when the patient smiles. A study by Vig and Brundo in 1978 concluded that at age 30 years, people show

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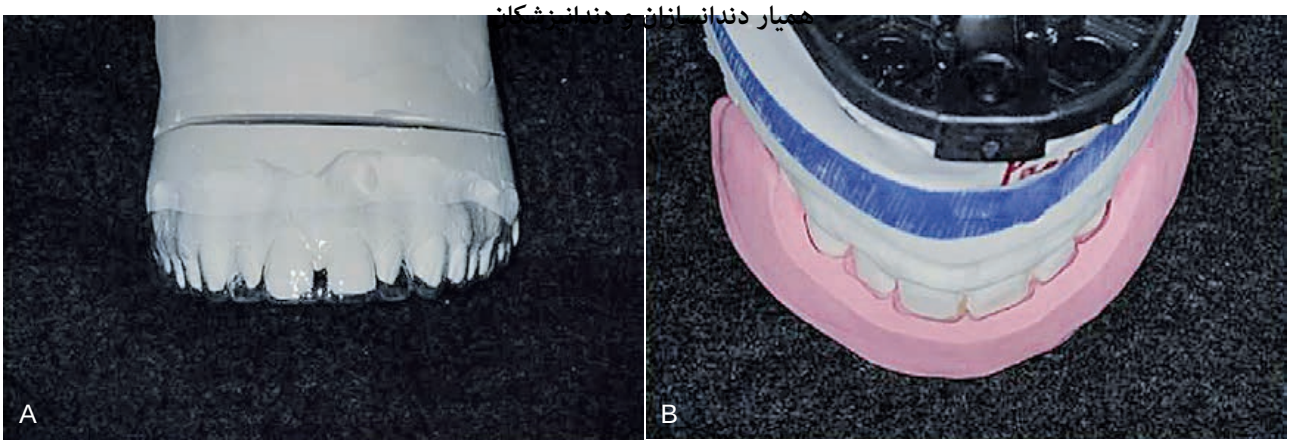


FIGURE 5-14 Acrylic (A) and silicone (B) preparation guides.

3 mm of upper tooth, and for every decade thereafter they start showing more molar teeth. At age 60 years they show virtually no upper teeth and 3 mm of lower teeth. Reviewing the photos, the dentist determines if sufficient maxillary teeth are displayed and if the patient's smile can be made more youthful in appearance. The planned changes can be drawn on the photos. It can also be determined if periodontal surgery, orthodontics, or other procedures are needed. The entire treatment plan is worked out by the time the dentist next meets with the patient.

Before presenting the case, the dentist must have a clear vision of what is required. Otherwise the dentist will look lost and incompetent. Once the treatment plan has been worked out, the dentist is ready for the case presentation.

The keys to a successful case presentation are (1) knowing what the final vision is, (2) having confidence that one can deliver the case as expected, and (3) having the ability to explain it to the patient in a manner that he or she can understand. When sitting and talking to the patient, the dentist should not use words that are too scientific, but rather should speak in terms to which the patient can relate. What dentists tend to do in case presentations is try to take the patients to dental school and educate them regarding the technicalities of the procedures they are suggesting. Patients do not care *how* their cases will be managed technically or how the actual teeth will be prepared. The dentist should explain what patients want to hear—how much it will cost, how much it will hurt, and what it will look like afterward. The patient really only cares about "What are the benefits for me?"

Once the patient has agreed to undergo treatment, the dentist determines how many teeth must be included in the diagnostic wax-up. Mounted study models and a detailed lab prescription are sent to the lab technician.

TREATMENT CONSIDERATIONS

When practicing reconstructive dentistry it is essential to follow a protocol to ensure that each and every case follows a consistent path. Errors and omissions are expensive, time-consuming, and inconvenient for all involved. In our office we try to break dentistry down into its simplest elements so that each case is set up the same way. When the wax-up returns from the dental lab, the dental assistant makes a plaster cast, and a preparation stent or "prep guide" from the plaster model. This guide might be fabricated from clear plastic, acrylic, or putty (Figure 5-14).

There are many prep guide options that achieve the same result. This template allows the dentist to visualize the desired preparation required and ensures that the dentist reduces enough tooth structure. Every case should have a prep guide.

For the actual preparation appointment with the patient in the chair, it is best to have a checklist to follow. The dental assistant's checklist has absolutely everything required and notes everything that has been done, such as how many photos were taken and how many models were made, what articulator was used, whether a prep guide was used, what type of bite registration, the dentin stump colors, and so on. Everything is written down and checked off so that nothing is forgotten. This protocol aids in preventing the dentist from receiving a telephone call from the dental lab informing him or her that an important record has been forgotten or asking that the case be re-prepared.

Technologically, it is extremely helpful to have electric handpieces in the operatories. In an adult restorative practice the dentist is often removing older dental work, which usually involves cutting through metal. With air-driven conventional handpieces, this can be very time-consuming and hard on the life of handpiece turbines, causing them to stall and ultimately blow out. With electric handpieces, taking off old crowns and bridges is much easier. It is wise to work efficiently using good tools, electric handpieces, sharp diamonds, and metal cutting carbides and always maintaining focus on what is to be achieved by having a clear mental vision of the desired result. The basic elements for success are the prep guide, great instrumentation, and a checklist so that nothing is forgotten.

EVIDENCE-BASED PRINCIPLES

Although the techniques and materials of restorative dentistry have dramatically changed, the scientific principles of function, maintainability and integrity have not. Dental principles are

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evidence based; much of this information was taught in dental school over 30 years ago. Sometimes dentists tend to forget what they were taught. The use of a semi-adjustable articulator is usually the first thing to be put aside after dental school, along with the principles of conservative tooth preparation. Dentists start taking short-cuts. It is extremely important to never forget or abandon what was taught in dental school. The innovation of today must be adapted to the accepted principles of sound dentistry. Every principle is put together in a consistent manner; a system from start to finish that produces predictable results. The dental lab technician appreciates working in this way, as it affords a clear picture of exactly what is required.

There is often not only one way to do things. Every dentist has a personal bag of tricks using techniques and materials that work best in his or her hands. The most important thing is the ability to achieve the results that have been planned. It helps to work within a team of specialists, which permits achievement of goals periodontally, orthodontically, and surgically. The dentist must be able to be in control of all aspects of treatment.

CLINICAL CONSERVATION CONCEPTS

A conservative approach to smile design helps to preserve healthy tooth structure. If the teeth are healthy to begin with, doing anything to them takes away some of their integrity. However, if the choice is made to alter them and the restoration is designed intelligently, it is possible to significantly strengthen the tooth. If a tooth has been weakened by having a large composite restoration, placing a veneer or a feldspathic crown around it will usually make it stronger. A lamination is created to encircle and bind the tooth. It is of extreme importance that at least 3 mm of sound tooth structure always be available on which to place the margins. This ferrule serves as a base for the strength of the restoration.

Using minor orthodontic movement also helps keep dentistry conservative. Teeth can be moved so that they can be centered within the restoration, avoiding overpreparation. The porcelain can then just wrap around the tooth rather than having to be overbuilt in an attempt to change the tooth position. Advances in ceramics have enabled the ceramist to achieve ultra-thin porcelain restorations, sometimes with a thickness of only 0.2 or 0.3 mm. The dentist then can reduce very little tooth structure to make significant esthetic changes to the tooth. Without using a prep guide, the dentist might cut too much or underprepare the tooth. Often the dentist overprepares the tooth, weakening it, or prepares teeth in the wrong direction as perspective and orientation have been lost. Prep guides allow dentists to be very conservative. With ultra-thin porcelain and new techniques, it is possible to be minimally invasive and not destroy the tooth structure. Remember, teeth have to last a long time—the less cutting is done, the better.

MAINTENANCE OF THE TEMPORARY RESTORATION

If a bis-acryl temporary restoration is made well, polished well, and finished well at the gingival margin, it requires very little maintenance. Staining is usually not a significant problem. However, certain foods can leave stains. Patients are advised not to eat yellow curry, drink red wine, or ingest other foods with staining potential. Most stains can be polished out easily with fine diamond or carbide polishers. Bis-acryl restorations seldom break, are very low maintenance, and are tissue friendly. The gingiva tends to look quite good around bis-acryl because it displays the same properties as highly polished composite. Simply normal brushing and flossing are advised.

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B SECTION

The Esthetic Try-In

George Freedman

RELEVANCE TO ESTHETIC DENTISTRY

Modern esthetic dentistry is by definition minimally invasive. However, to change the color and shape of the anterior teeth, a minimal thickness of restorative material, usually ceramic, is needed. Dentists are thus faced with the task of integrating the patient's dental needs with treatment options that are maximally conservative of healthy tooth structures and respect the periodontal tissues in addition to being highly esthetic. Dental science and art today offer both techniques and materials that allow these procedures to be accomplished successfully by the practitioner. Most notable in this area is the porcelain veneer, which effectively alters the visible face of the tooth (Figure 5-15).

Rehabilitating the dentition was successfully accomplished long before the current minimally invasive techniques were available. These modalities routinely required aggressive preparation of all teeth involved—not a tissue-conservative approach (Figure 5-16, *A*). Extensive preparation often required preprosthetic elective endodontic treatment because of the nonparallel angulation of the various teeth involved (Figure 5-16, *B*). In many cases, complex periodontal treatment was required to reestablish a stable soft tissue environment. These procedures could take months or years to complete, causing stress for both the patient and the dentist. Many patients, faced with a realistic description of the long-term and extensive treatment process, declined to proceed.

The availability of new materials and techniques has led to the development of minimally invasive or ultra-conservative approaches to manage dental problems. Ultra-conservative dentistry is respectful of soft tissues and seeks to minimize the removal of any tooth structure if at all possible. It is also, of course, highly concerned with esthetic outcomes and uses the physical properties of the restorative materials to reinforce the remaining dentition. The anterior dentition exhibits mismatched centrals and a diastema (Figure 5-17, *A*). The esthetic try-in (ETI) technique is used to predetermine esthetics and positioning (Figure 5-17, *B*) and to close the diastema esthetically (Figure 5-17, *C*). The veneers are bonded onto the *unprepared* anterior teeth (Figure 5-17, *D*), creating a much improved smile (Figure 5-17, *E*).

The most difficult pretreatment step for the dental practitioner is to understand and visualize the minimum amount of tooth structure that must be removed for a comprehensively successful end result. This is where the ETI can be used to predict minimal preparation and tissue disruption, guided by the desired posttreatment function and esthetics (Figure 5-18).

Although the concepts of porcelain veneers have been available to the dental profession for a number of decades, it was only in the mid-1980s that innovative clinical materials first became available, allowing the procedure to be successfully accomplished in the practice. The turning point in ceramic restorative dentistry was the development of a coupling agent in dentistry that could bond to both ceramic and tooth structure. In fact, these coupling agents work indirectly by attaching the porcelain to the bisphenol A glycidyl methacrylate (BIS-GMA) resins, and through the composite materials, whether adhesive or filler, to the tooth structure itself. Porcelain represents a particularly difficult surface for adhesion if the interfaces are to be submerged in water. Bond strengths of 1200 psi tensile are not unusual when resins are attached to porcelains in a dry environment, but typically these interfaces fall apart after only 48 hours of submersion in a wet environment.

Certain intermediary treatments of the surfaces involved can create extraordinary differences in outcome. For example, when the porcelain or ceramic is coated with a monomolecular layer of organophosphate silane such as Tokuso ceramic primer (Tokuyama, Encinitas, California) before resin adhesion, the bond strengths become formidable (Figure 5-19).

When suitable ceramics, silanes, and resin adhesives became available, dentists began to place porcelain veneers. The earliest veneers were envisioned and promoted as restorations that could be delivered without any preparation of the tooth structure. In fact, that was the major talking point for the veneer procedure. No preparation of tooth structure was recommended. As dentists began to tackle more and more difficult situations, it became apparent that some preparation (reduction of tooth structure) was required in many cases. Within a decade, though, veneer practice had shifted to a point at which the typical preparation for porcelain veneers involved a minimum of 0.5-mm reduction in the tooth surface from the buccal surface, effectively removing most, if not all, the facial enamel. The preparation also extended interproximally, eliminating contact areas (Figure 5-20). Although this often gave rise to very good esthetic results, considerable healthy tooth structure was sacrificed. For many dentists it became simpler to prepare all the teeth that were to be veneered without even preconsidering the final result. This approach created a blank slate; the dentist could abdicate esthetic responsibility to the laboratory technician.

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In recent years, increased emphasis has been placed on redeveloping the concepts of minimal preparation and porcelain veneers as a conservative rather than a destructive procedure. The preoperative dilemma, of course, is exactly how much tooth structure must be removed. Some dentists, equipped with **clinically skillful eyes** and artistic abilities, are able to visualize the final desired result in the patient's mouth even before commencing treatment. For most practitioners, however, it makes more sense to utilize a guided preparation approach. This approach provides previews of the intended final result even before commencement of the treatment.

Once the esthetics and the functionality of the veneers are established with an easily alterable material such as a composite resin, it is then simply a matter of measuring the thickness of the ETI to determine exactly where and how much tooth structure must be removed to allow for the required 0.5 mm of porcelain thickness (Figure 5-21). This brings porcelain veneers back to a minimal preparation directed by function and esthetics and offers guided preparation *before* initiation of the procedure.



FIGURE 5-15 The porcelain veneer changes the frontal appearance of the tooth.

RELATING FUNCTION AND ESTHETICS

Whereas esthetics drives dental consumers, intraoral function is preeminent for most dental professionals. Patients' involvement in their own dentistry has been increasing, however. Better education, intraoral cameras, and a heightened sense of esthetics all contribute to this trend. This increased awareness has produced patients who are more likely to be actively involved in selecting their own treatment modalities. Patients are also less likely to readily accept invasive procedures. Although esthetics is *the* major motivator for many if not most patients, it must be understood that the integrity of healthy tissues—both soft and hard—is paramount. For the professional, it is important to create a functional final result with the maximal esthetics that can be achieved, and preferably to be able to understand where these two sometimes conflicting requirements can ideally intersect for the patient's greatest benefit.

The ETI offers a preview for both the patient and the dentist (Figure 5-22). Typically, it is a laboratory-fabricated composite-acrylic mock-up that has been custom developed based on the individual facial measurements generated by the dental team for the patient's own facial size and shape (Figure 5-23). Typically, the coverage for 8 to 10 maxillary anterior teeth is created in one or two segments to fit over the unprepared maxillary anterior dentition (Figure 5-24, *A*), first on the right (Figure 5-24, *B*) and then on the left (Figure 5-24, *C*). The esthetics of the mock-up can then be esthetically and functionally evaluated and adjusted. The laboratory-fabricated ETI is made of composite and acrylic and has some resilience so that it can gently snap over the existing teeth and stay in place, tacked on temporarily with denture adhesive (Figure 5-25, *A*). The patient's smile is shown without the ETI (Figure 5-25, *B*) and with the ETI (Figure 5-25, *C*). The shapes and sizes of these ETI teeth are as

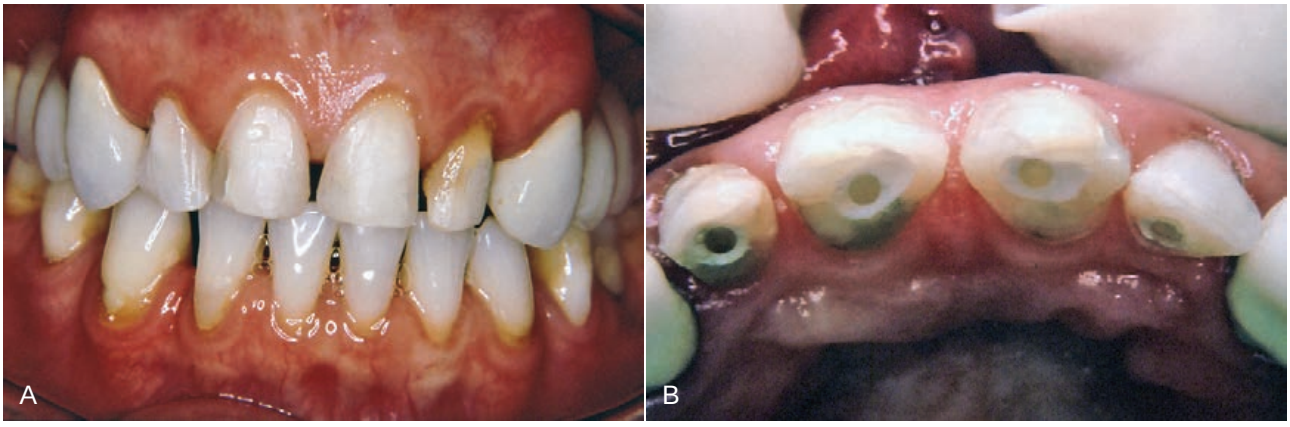


FIGURE 5-16 **A,** Aggressive preparation of the anterior teeth for veneer placement. **B,** Elective endodontic treatment to allow for aggressive tooth structure removal.

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FIGURE 5-17 **A, Mismatched centrals and diastema. B, Esthetic try-in (ETI) predetermines restorative dimensions and positioning. C, ETI determines diastema space allocation. D, Cemented porcelain veneers. E, Greatly enhanced smile.**

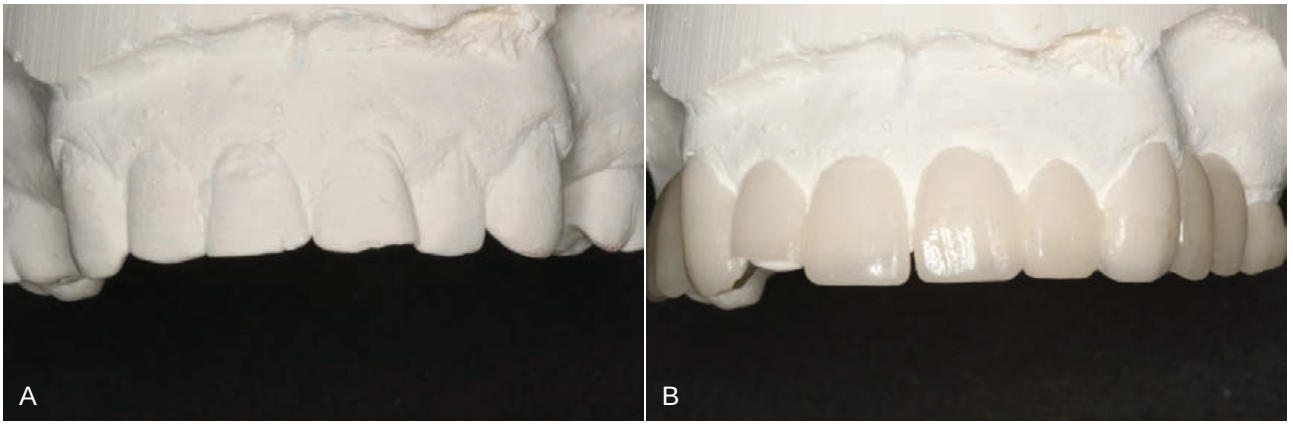


FIGURE 5-18 **A, Model of the pretreatment anterior teeth. B, ETI visualization of the esthetic results possible with veneers.**

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FIGURE 5-19 Tokuso Ceramic Primer. *(Courtesy Tokuyama Dental America, Encinitas, California, www.tokuyama-us.com.)*



FIGURE 5-20 Aggressive facial preparation of anterior teeth for veneers.

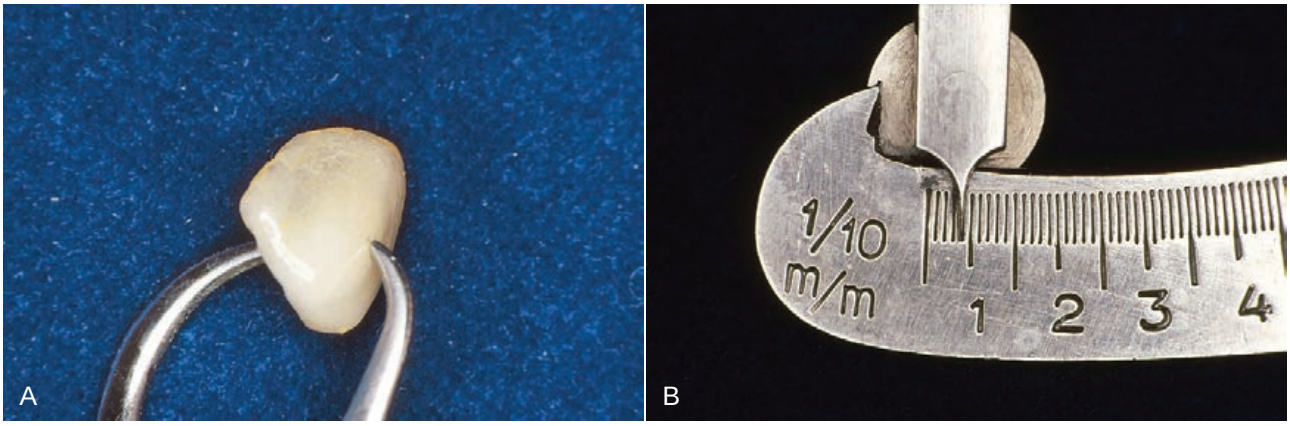


FIGURE 5-21 A, Caliper measurement of the thickness of the ETI. B, Required ½-mm thickness for veneer restoration.



FIGURE 5-22 The ETI is used as a visual aid when discussing the case with the patient.



FIGURE 5-23 Composite-acrylic ETI custom mock-up.

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FIGURE 5-24 **A, Unprepared maxillary dentition. B, ETI placed on the upper right quadrant. C, ETI placed on the upper left quadrant.**

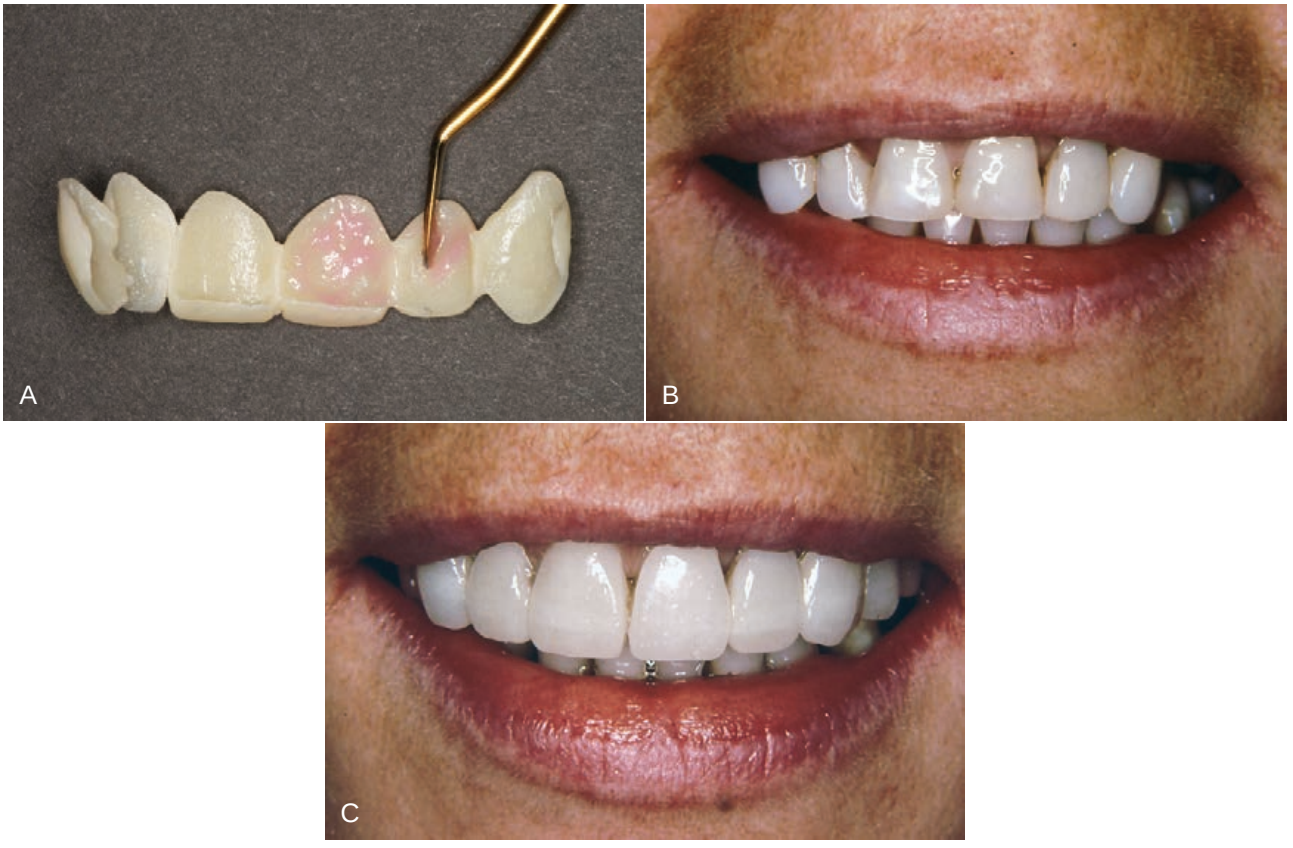


FIGURE 5-25 **A, ETI tacked with denture adhesive. B, Patient's smile without the ETI. C, Patient's smile with the ETI.**

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close as possible to the ideal developed using the patient's actual facial measurements. Some or all of these teeth are joined together for easier retention on the patient's natural teeth. Typically, the patient seeing the preview is astounded by the esthetic results that are achievable without any actual preparation of the natural tooth structure (Figure 5-26). This also serves a marketing purpose: many patients will not commit to a comprehensive treatment plan until they can actually see the potential results in their own mouth.

The ETI is not a functional restoration. It cannot be used for chewing, nor can it be worn outside of the dental practice. It is designed simply to be seen by the patient, patient's family and friends, and dental team and adjusted or modified chairside or intraorally as necessary (Figure 5-27). Practitioners claim that many patients, having seen the ETI on the dentition, are immediately motivated to proceed with treatment.

Once the marketing component is done, the preview is the next important step. The ETI not only provides a means of visualizing shape and size, but it also allows occlusal relationships to be previewed before the final ceramic restorations are fabricated. After all, it is much easier to adjust, reduce, or build up a resin material (Figure 5-28, *A*) than a ceramic (Figure 5-28, *B*). The occlusal relationships are checked for protrusive and lateral interferences and can then be reduced or built up as necessary for the ideal restoration. Subsequently, the size of the anterior teeth is reexamined. If the adjusted size is within the suitable height and length ratio required for predetermined esthetic parameters, the preview process can go on. At this stage the patient is asked for input. The patient can readily indicate whether from his or her perspective the proposed treatment offers teeth that are too long, too short, too wide, too narrow, too square, too rounded, and so on. The patient's natural smile (Figure 5-29, *A*) requires brightening and a lengthening of the maxillary incisors. The proposed restorations as shown by the ETI are far too large and square (Figure 5-29, *B*). This is no problem with the ETI. It is relatively straightforward for the dentist to make these adjustments in the ETI at this stage. If too much material is reduced, the ETI can be reconstituted simply by adding a flowable or hybrid resin, rebuilding the section that was inadvertently removed (Figure 5-30).

The sizes and shapes of the proposed restoration are reviewed and adjusted until there is concurrence between the patient and the dentist in terms of the final smile esthetic that is planned. This is the ultimate exercise in co-treatment planning. Then, it is simply a matter of measuring the thickness of the ETI in various locations. It is essential to remember that the restorative



FIGURE 5-26 Patient is able to see the esthetic potential with the ETI in place for the first time.



FIGURE 5-27 Chairside modification of the ETI.

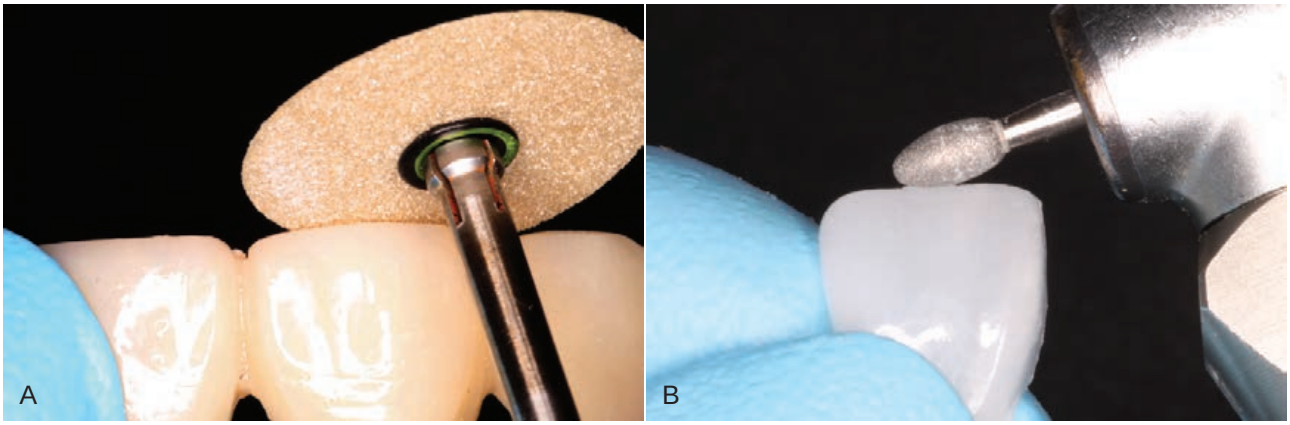


FIGURE 5-28 A, There is little risk of shattering when adjusting resin ETI with a slow-speed disk. B, There is a greater risk of shattering when adjusting ceramic with a high-speed diamond.

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FIGURE 5-29 **A, A patient whose smile requires brightening and lengthening of anterior teeth. B, ETI shows proposed restorations to be too large and too square. At this resin stage they can be readily modified.**



FIGURE 5-30 **Flowable or hybrid resin is added to the ETI.**

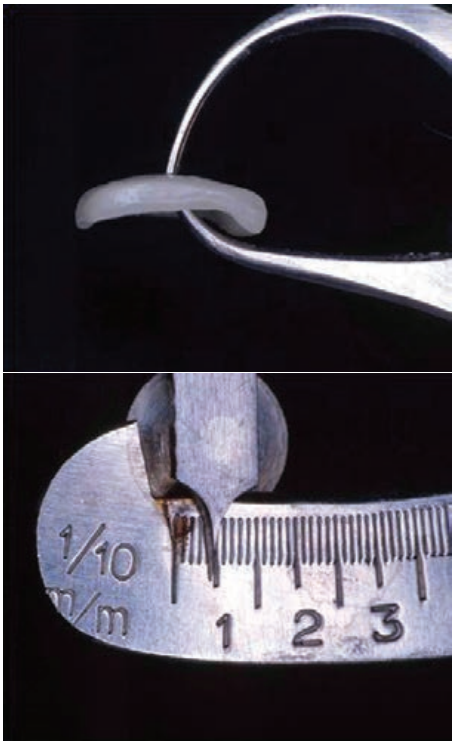


FIGURE 5-31 **Ideal ½-mm thickness of ETI is perfect veneer dimension.**

ceramic to be placed on the teeth in the form of veneers must be a minimum of 0.5 mm in thickness (Figure 5-31). Where the ETI is 0.5 mm or more in depth, no tooth reduction is required (Figure 5-32). Where the ETI is less than 0.5 mm (Figure 5-33), a minimal amount of natural tooth structure is reduced to give the required 0.5 mm restorative thickness. In this way, the ETI guides the practitioner to the most minimal preparation of tooth structure that is possible and realizes a restoration that is very precise because it is based directly on the intended esthetic and functional results. The ETI defines the ideal convergence of esthetics and function before any tooth preparation is undertaken.

CLINICAL CONSIDERATIONS

ETIs are indicated for all anterior veneer procedures regardless of the number of teeth involved. The technique provides not only the ideal convergence of the patient's and the dentist's desires, hopes, and abilities but also offers the best guide to an absolutely minimized preparation for these procedures. In fact, ETIs should be considered for all anterior indirect restorations, including crowns. There is no better method for protecting for the integrity of healthy tooth structure than determining the absolute minimum that must be removed from the healthy dentition to accommodate the intended final restoration.

The ETI is noninvasive and does not harm either the hard or the soft tissues of the oral cavity. Both time and cost factors are involved. However, given the benefits that this procedure provides, the laboratory fees and chairside time cost are relatively low. There are no contraindications to the ETI approach, and

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FIGURE 5-32 More than ½-mm ETI thickness means no tooth reduction is required.



FIGURE 5-33 Less than ½-mm ETI guides the practitioner to the precise location and amount of required tooth reduction.

the procedure is relatively straightforward, encompassing a very short learning curve. The fact that all the materials and technology needed already exist (and are likely to be available in the practice and at the laboratory) makes this a very attractive and significant part of the practice of advanced anterior restorative dentistry (Figure 5-34).



FIGURE 5-34 Armamentarium for the ETI procedure.



FIGURE 5-35 Flowable buildup resin (BEAUTIFIL Flow, Shofu Dental Corporation, San Marcos, California) can be added where and as needed.

MATERIAL OPTIONS

Fortunately all the materials and technologies needed to make an ETI are currently available. The only innovation is the concept of aligning the patient's expectations with the dentist's abilities and minimizing the amount of tooth structure condemned to surgical removal as part of the restorative procedure. Composites, acrylics, or a mixture of the two can be used to fabricate the ETI. The major requirement is that they be easy to shape and easy to build up with generally available flowable and composite materials, which can be bonded on as needed (Figure 5-35). Denture adhesive can be used to stabilize the ETI on the natural dentition, with any gel-like denture adhesive serving this purpose (Figure 5-36, *A*). Care must be taken to avoid any buildup of denture adhesive thickness between the tooth surface and the ETI, which could affect the position of the appliance and alter the shape or position of the ETI during the adjustment and esthetic alignment process (Figure 5-36, *B*).

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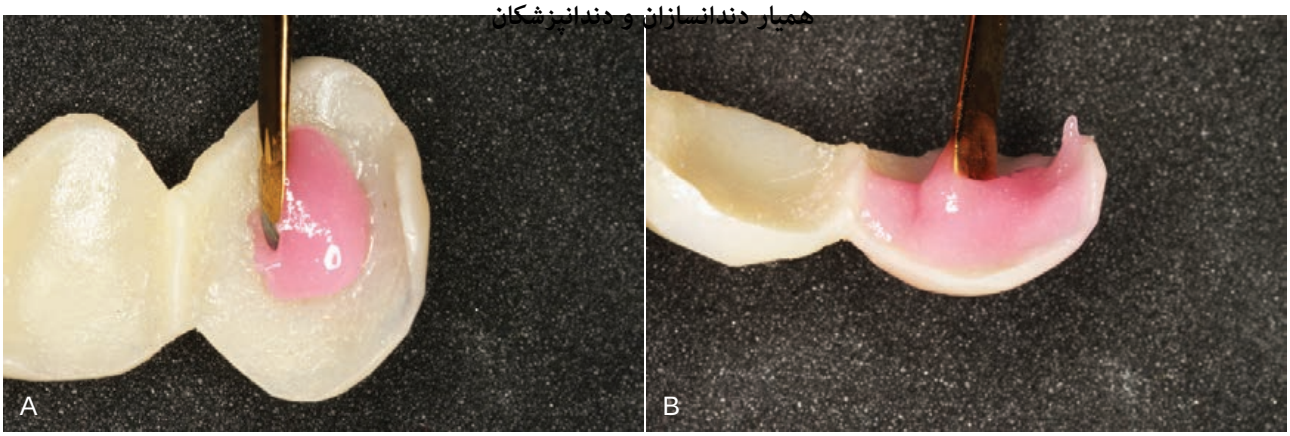


FIGURE 5-36 **A, Gel denture adhesive applied to lingual surface to stabilize ETI on dentition. B, Only a thin layer of gel is needed.**

Most dentists possess the skill to fabricate an ETI, but it makes far more sense to delegate this task to a laboratory technician who is more comfortable with building up teeth extraorally. The cost of having this done at the laboratory is significantly lower than when it is completed chairside by the dentist. Any bonding agent, flowable or hybrid composite, can be used to build up the ETI as required. Polishability and other properties are really not an issue. What the dentist hopes to achieve is an approximation of the final result, not a perfect simulacrum.

Advantages and Disadvantages

As already stated, all the materials and technologies required are currently available. Adding the ETI procedure to the restorative treatment adds time to the preparation appointment. Before the preparation, the dentist and patient may spend an hour or longer deciding the ideal shape, size, inclination, and other (functional and esthetic) particulars of the restoration. This time spent before preparation, however, minimizes the removal of healthy tooth structure and saves far more time during the seating appointment and thereafter. In addition, a good laboratory should be able to deliver a set of veneers or crowns that not only fits accurately on the abutment teeth but works perfectly from a functional and esthetic perspective because all the necessary parameters were previously determined. In effect, the ETI acts as the intraorally developed predictor of the exact shape, size, position, and so on of every aspect of the final restoration.

Current Best Approach

Once the ETI procedure has been completed, the dentist can provide a superior bonded ceramic restoration that requires little or no adjustment, fits well, and is esthetically sound. It is recognized that any ceramic that is adjusted intraorally or before cementation must also be polished afterwards (SS White Jazz Ceramic and Composite polishers; Figure 5-37). This, however, adds chairside time, cost, and effort to the procedure. The ETI process works for all existing ceramics, and all existing composites; there are no limitations on the process. Overall the ETI adds time before the preparation but saves far more time at the insertion, cementation, and polishing stages. In fact, most of the adjustment steps are minimized or eliminated.

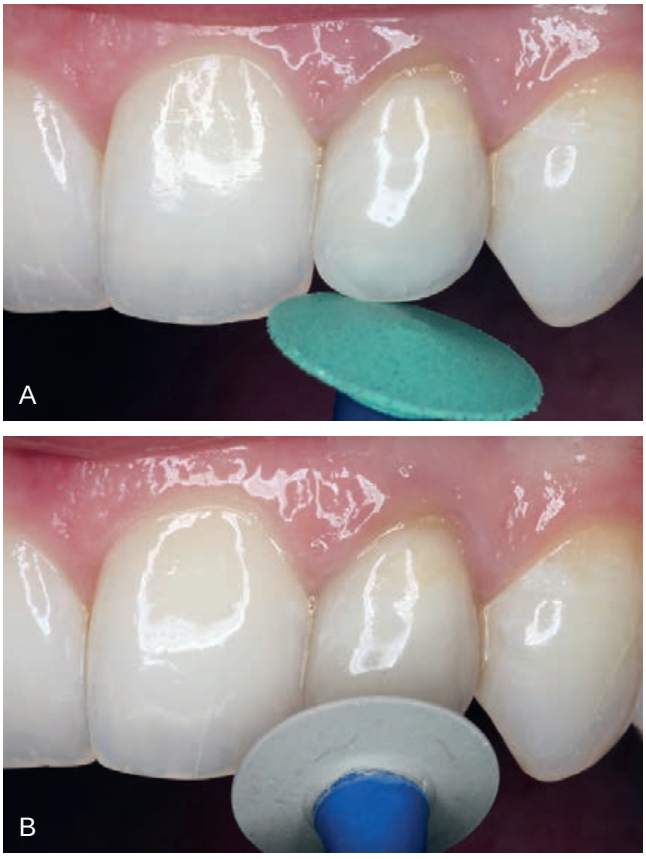


FIGURE 5-37 **Polishing the incisal (A) and buccal (B) ceramic of a veneer is time-consuming and may shatter the restoration.**

OTHER CONSIDERATIONS

A very important consideration of the ETI is its utility as a form of communication with the laboratory. Once the dentist and the patient have agreed on a particular set of objectives for treatment

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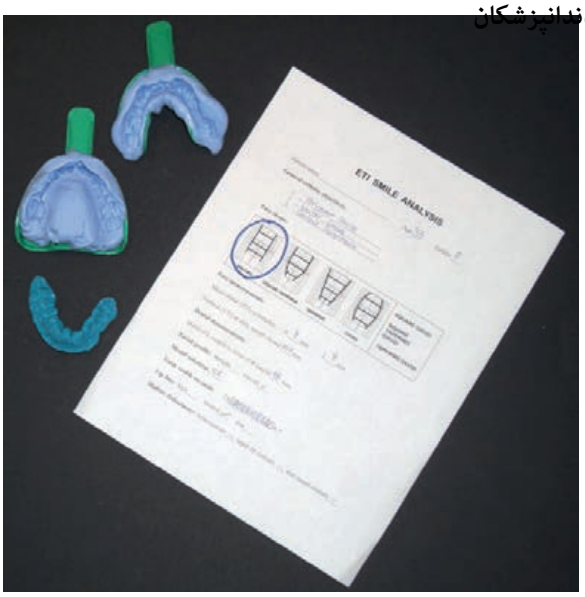


FIGURE 5-38 ETI prescription is sent to the laboratory as part of the lab communication.

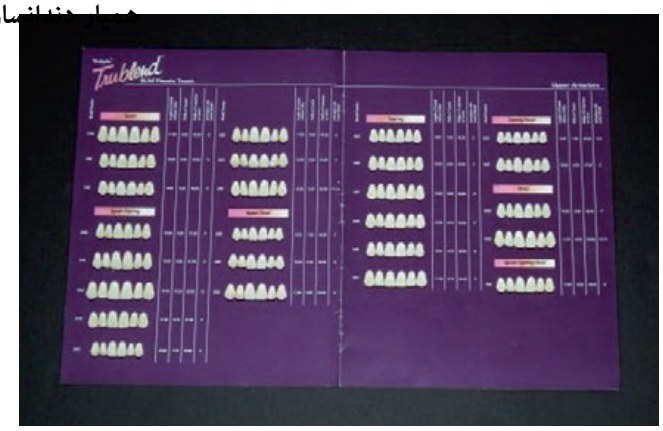


FIGURE 5-39 The Trubyte Tooth Indicator pictorial and numeric guide.



FIGURE 5-40 Auxiliary taking alginate impression of maxillary teeth.

at the ETI stage, in functional and esthetic harmony with the existing natural dentition, the ETI prescription is sent to the laboratory technician as part of the laboratory communication (Figure 5-38). When the ETI is placed over the prepared (or unprepared) teeth that have been captured by the impression and recreated by the laboratory in stone, it provides a 100% accurate template to the laboratory technician of what the needs and desires of the patient and dentist are in each particular case. Thus there is no guesswork on the part of the laboratory technician. Because of the three-dimensional communication offered by the ETI, every margin, every ridge, every height of contour, and every incisal edge can be placed exactly where it has been requested by the dentist. The ETI is the first three-dimensionally accurate and precise communication between the laboratory technician and the dentist. The laboratory technician is thus able to customize a perfectly fitting, functional, and esthetic ideal restoration. Given that the dentist has been able to calculate the exact clearance space required for the ceramic, the minimal ideal preparation depth should be guaranteed throughout the entire case as well.

INNOVATIVE ELEMENTS

The innovative scientific element is the tooth guide that is used to relate facial and dental sizes and shapes. This scientific data form is actually not new; it was established in the 1930s to provide a guide for dentists who were selecting denture teeth. The concept is to provide an objective numeric determination of tooth shape and size that is more accurate than the subjective one based on artistic ability (or lack thereof) (Figure 5-39). The system was intended to assist in the selection of properly proportioned anterior teeth for dentures, but it can also guide the choice of both shape and size in the veneer reconstruction of the smile or for anterior crowns. As an added benefit of the system, laboratory technicians are already familiar with denture tooth selection and can readily comprehend and duplicate the type of appearance that is prescribed by the dentist. The tooth guide provides an excellent starting point, which can be modified as required for function and esthetics. Using the tooth guide simply ensures that the dentist, with the patient's assistance, exercises artistic control during the try-in phase, the goal being to achieve the maximum esthetic improvement in the final restoration.

Technologically, this is a simple process to introduce into the practice. ETI data collection can be readily delegated to an auxiliary (Figure 5-40). Taking a measurement of the face shape and size is noninvasive and can be readily taught within a few minutes. Thus the innovative elements of the ETI are easy to learn, easy to apply, and easy to delegate.

ARTISTIC ELEMENTS

Although artistic elements and the whole concept of artistic ability are extremely important in designing anterior crowns and veneers, the ETI minimizes the always-difficult subjective

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input from the dentist and the patient. Instead it relies on specific measurements that can be quantitatively and objectively established without depending on innate or acquired artistic awareness, understanding, or capacity. The assembled data are numerically interpolated into real-life esthetics. Effectively, the ultimate esthetic result is created within the patient's own mouth through the collaboration between the patient and the dental team. Thus it is a cooperative process that involves the patient at every step. This is far better than having a surprised patient, unhappy with his or her smile despite treatment results that are scientifically and clinically ideal. The patient's input is available throughout the process. Therefore, as the esthetic objectives and results are developed throughout the course of the treatment, they evolve with an understanding of the opportunities *and* the limitations understood both by the patient and the dentist. When patients look at the end result of the ETI, they are in effect seeing the shape, size, and position of the end result of the ceramic treatment. It is much easier to express concerns at this stage, to ask for adjustments, and thus to arrive at ceramic restorations that are acceptable to both patient and dentist which are simply cemented into place at the insertion appointment.

TREATMENT PLANNING

Because the ETI is such an important element of treatment planning, there really is no option but to include it in every anterior esthetic procedure. All anterior procedures are, by definition, esthetic, which means every anterior procedure should include an ETI component.

Sequence

Once the patient has shown interest in the restorative procedure, the ETI is the first step that must be undertaken. The ETI must be completed before any tooth preparation is begun and, very often, even before commitment to treatment has been made. It therefore must be the very first step undertaken in any anterior treatment plan. It involves no invasive steps—simply an impression of the teeth (maxillary, mandibular, and a bite registration) (Figure 5-41, *A* and *B*) and measurement of the face, teeth, and size of the anterior segment of the maxillary arch (Figure 5-41, *C*). Patients who object to the additional cost of the ETI procedure (which is low compared with the overall cost of the esthetic restorative treatment) are perhaps not really ready to commit to a comprehensive treatment plan and may possibly not be good candidates for esthetic treatment.

TREATMENT CONSIDERATIONS

The following equipment is required to begin preparations for ETI information gathering: the **Trubyte Tooth Indicator** (DENTSPLY Caulk, Milford, Delaware) (Figure 5-42, *A*), a millimeter ruler (Figure 5-42, *B*), recording devices, and suitable

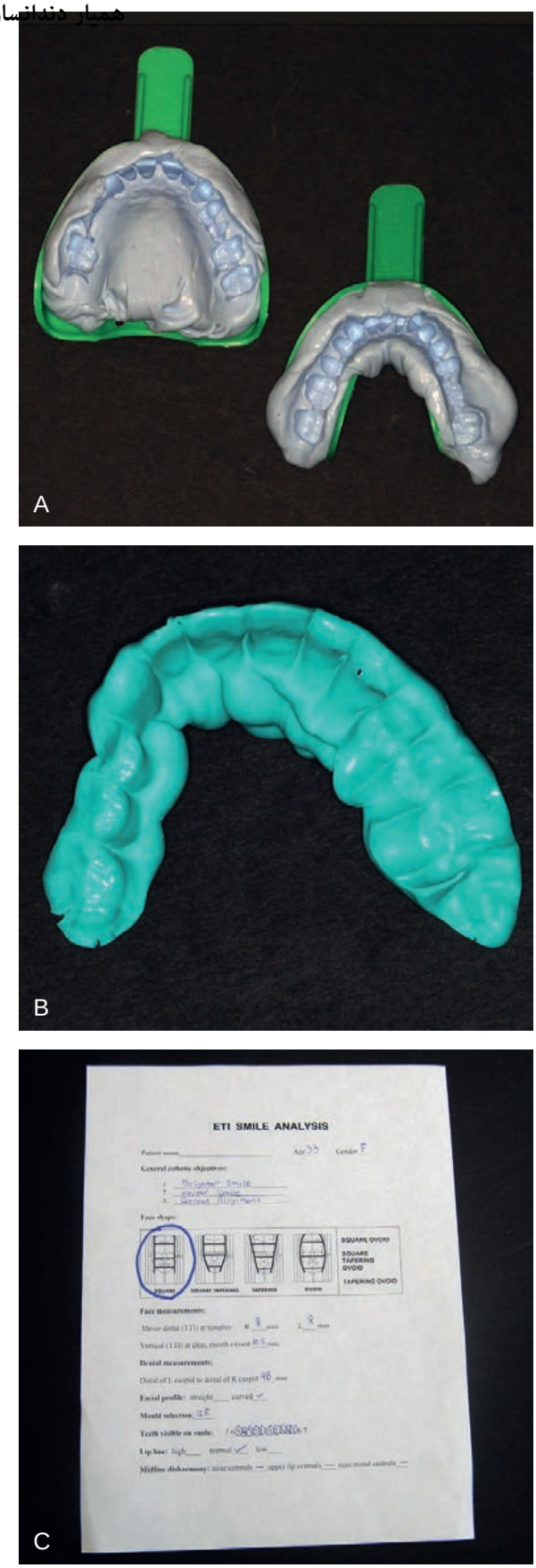


FIGURE 5-41 **A, Alginate maxillary and mandibular impressions. B, Polyvinyl bite registration. C, ETI prescription sheet.**

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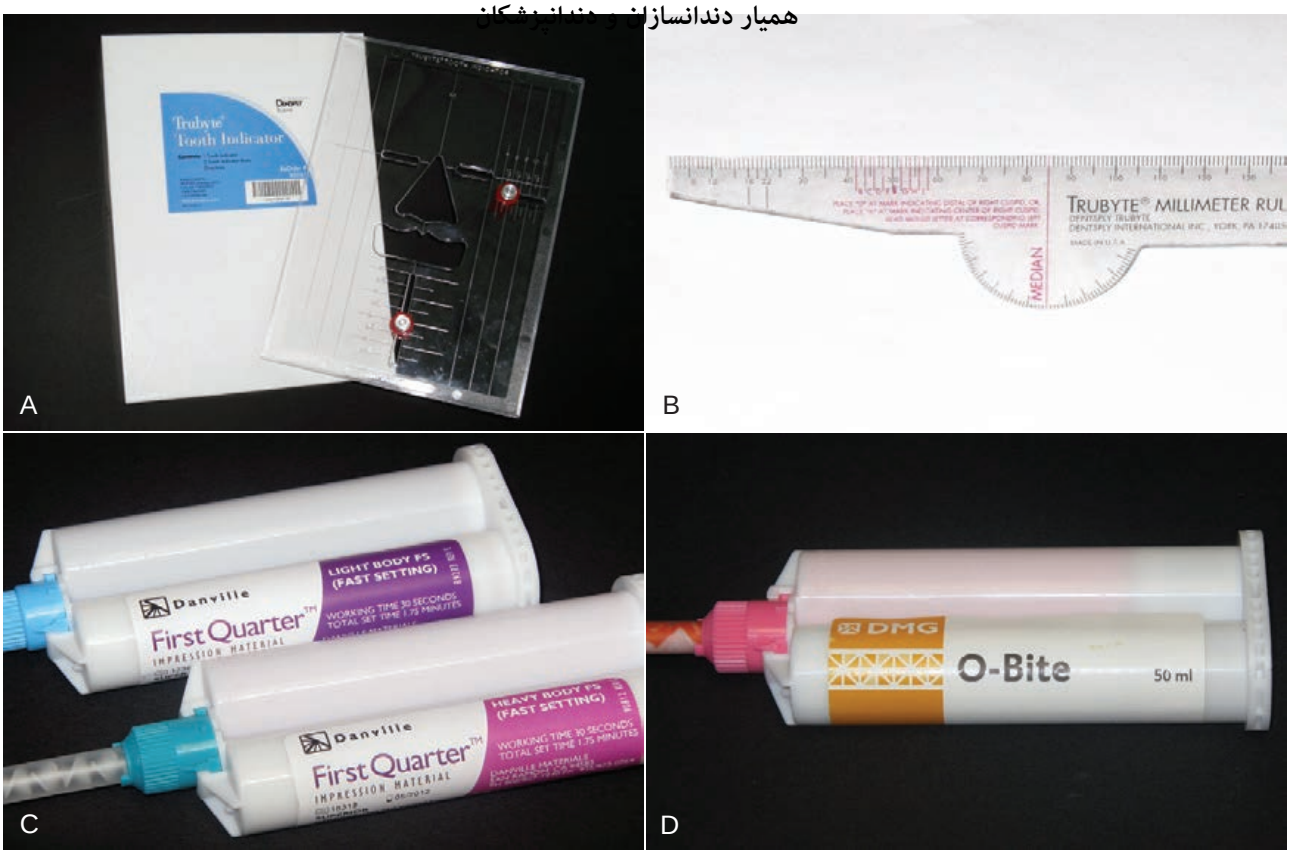


FIGURE 5-42 **A, Trubyte Tooth Indicator. B, Flexible millimeter ruler. C, Polyvinyl or alginate impression material. D, Polyvinyl bite registration material.**

materials for an impression (Figure 5-42, *C*) and a bite registration (Figure 5-42, *D*) (such as polyvinyl siloxane or alginate and disposable trays). It is difficult to analyze the facial shape and size simply by looking at the patient's face (Figure 5-43). The treatment procedure is as follows:

1. Place the plastic faceplate with the temple and chin platforms pointing toward the patient's face, with the nose centered in the triangular space in the center of the plastic plate (Figure 5-44, *A* and *B*).
2. Line the pupils up in the eye slits (Figure 5-44, *C*), and center the mouth (Figure 5-44, *D*).
3. Standing directly in front of the patient, determine the shape of the face (Figure 5-45, *A*). The shape may be square, square tapering, tapering, ovoid, or a combination of these options (Figure 5-45, *B*). The vertical and horizontal guide lines in the plastic faceplate assist in determining facial shape. These guide lines are particularly useful when trying to decide among various similar options and/or borderline cases (Figure 5-46). The faceplate helps to focus the dentist's attention on important details and eliminates much of the extraneous input that can confuse or complicate facial shape determination. It is much harder to determine a facial shape accurately with direct vision (Figure 5-47, *A*) than with the Trubyte Tooth Indicator (Figure 5-47, *B*).



FIGURE 5-43 **It is difficult to analyze facial shape and size simply by direct vision.**

4. Enter facial shape on the smile analysis sheet (Figure 5-48).
5. Facial shape also tends to influence the desired convexity or concavity of the maxillary central and lateral incisors. The patient is viewed from the side against a gray or black background (Figure 5-49, *A*). The curvature of the

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FIGURE 5-44 **A, Trubyte Tooth Indicator plastic faceplate is placed over the patient's face with the nose centered in the triangular space. B, Close-up of facial positioning. C, Line up the pupils in the eye slits. D, Center the mouth in the mouth space.**

face from the chin is recorded. (Figure 5-49, *B*). It may be convex, flat, or even somewhat concave (Figure 5-49, *C* and *D*). This is an area that is often overlooked by both the dentist and the laboratory technician. Although this is not a glaring omission, it can detract enough from the esthetics of porcelain veneers and crowns to make the results appear more flat and less lifelike. Enter facial curvature on the smile analysis sheet (Figure 5-50).

6. Next determine the approximate length and width of the maxillary central incisors (Figure 5-51, *A*). Position the chin platform at the chin with the patient's mouth closed in a relaxed position (Figure 5-51, *B* and *C*).
7. Read and record the number indicated by the position of the chin platform on the smile analysis sheet (Figure 5-52). This represents the **cervical to incisal** vertical height of the central incisor. The ideal length of the central incisor is in proportion to the length of the face (Figure 5-53).
8. Fix the temple guide bar of the Trubyte Tooth Indicator in position at the side of the face (Figure 5-54, *A* and *B*). Read and record the indicated number on the smile analysis sheet (Figure 5-54, *C*). This represents the mesial-distal width of the central incisor. The ideal width of the central incisor is in proportion to the width of the face (Figure 5-55). Because in most patients the left and right sides of the face are not equal in width, it is appropriate to take readings on both sides of the face when determining facial width (Figure 5-56).
9. These slightly different central widths may be recorded as is or averaged, depending on the esthetic demands of the particular case (Figure 5-57).
10. Measure the actual curved arch space available in the patient's maxillary anterior region from the distal of the cuspid on the left side to the distal of the cuspid on the right. First measure the distance from the distal of the maxillary right cuspid to the midline (Figure 5-58, *A*). Then measure the corresponding distance from the distal of the maxillary left cuspid to the midline (Figure 5-58, *B*). This total distance is typically in the range of 50 mm, representing the sum of the total amount of anterior space available within which the dentist must create the esthetics and the function of the six maxillary

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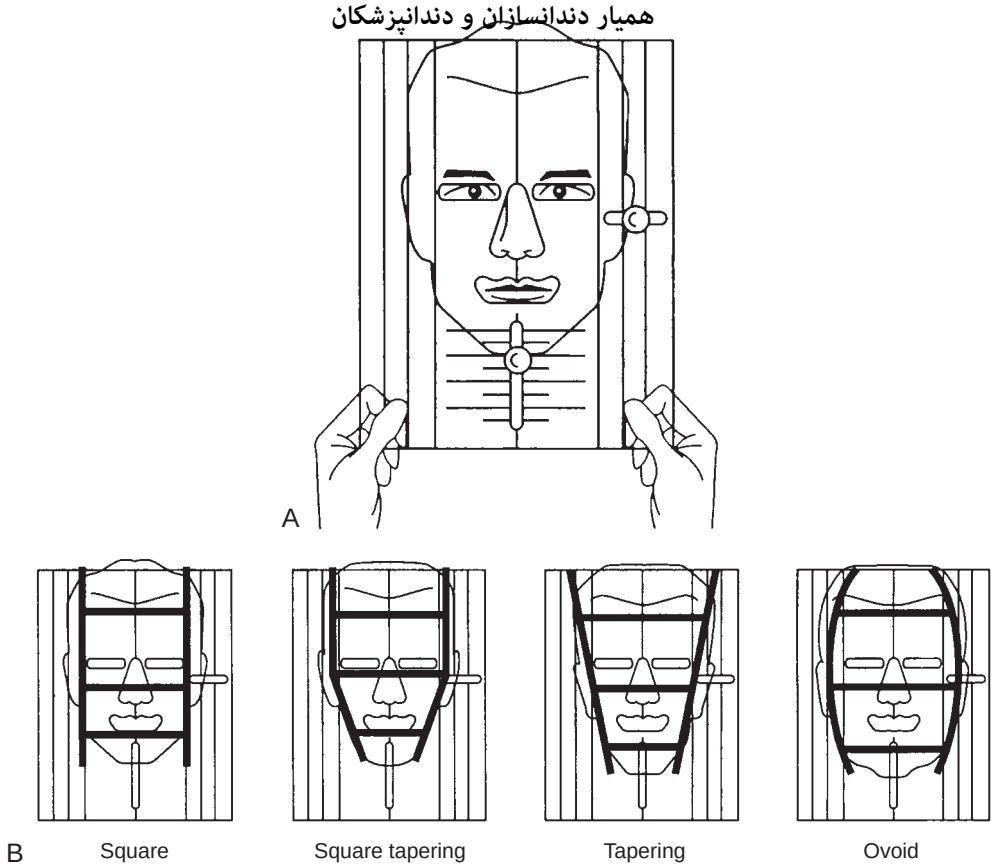


FIGURE 5-45 A, Standing directly in front of the patient, use the tooth guide to determine face shape. B, Facial shape may be square, square tapering, tapering, ovoid, or a combination of these.

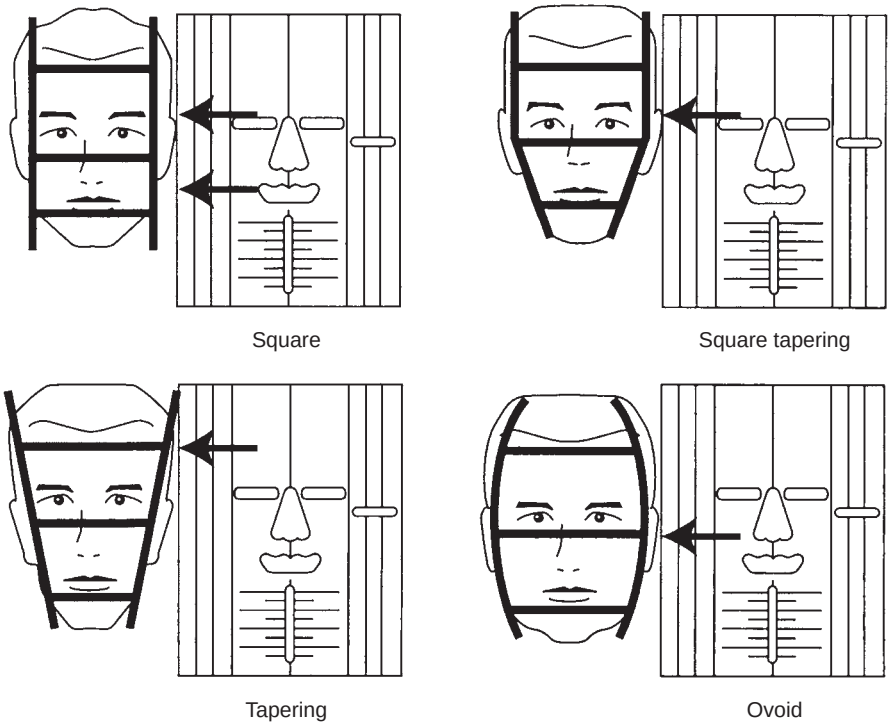


FIGURE 5-46 Shape guidelines are useful in deciding borderline shapes. Many factors can confuse facial shape and size analysis.

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anterior teeth. Verify these measurements on the model to eliminate the possibility of intraoral ruler slippage.

11. Compare in sequence the face shape, the total maxillary space available, and the widths and length of the central incisor with the Trubyte Bioform Mould Chart for face and tooth form harmony (Figure 5-59, *A*).
12. Select the most appropriate measurement or mould (Figure 5-59, *B*).
13. Transmit the mould guide reference to the laboratory technician (Figure 5-59, *C*).

It is important to remember that this system is only a guide. The dentist must always exercise artistic and professional decision making to achieve the maximum improvement in function and esthetics. Once these measurements have been taken, they are sent along with the impressions or the poured stone models and the bite registration to the laboratory technician (Figure 5-60, *A*), who constructs an idealized three-dimensional ETI that fits over the patient's unprepared teeth (Figure 5-60, *B*). The ETI can then be adjusted and modified by the dentist intraorally or chairside to bridge the gap from the ideal design to the functional and practical parameters that maximize restorative outcome.



FIGURE 5-47 Trubyte Tooth Indicator helps to focus the attention on important features.

EVIDENCE-BASED PRINCIPLES

The ETI's esthetic guidelines have been used successfully for almost a century in the dental field, initially with dentures and subsequently with crown and then veneer esthetics. The ultimate proof of the success of the ETI procedure is the harmony of the esthetic restoration with the anatomy, shape, and size of the face. Numerous studies over the years have indicated, however, that the ETI is an easier and more objective means of selecting tooth shape and size than trial-and-error subjectivity.

CLINICAL CONSERVATION CONCEPTS

Modern dentistry is based on minimal tooth preparation and the retention of as much healthy natural tooth structure as possible. Because the ETI allows the dentist to objectively determine the absolute minimum tooth preparation that is required, it is certainly an excellent means of achieving maximal conservation of the tooth structure. In fact, it is probably the best method of minimizing the tooth preparation required for both porcelain veneers and crowns. Ultimately the preparation is guided by the intended results (both esthetic and functional) and by the amount of space required for the restorative materials. Rather than forcing the removal of excess tooth structure just in case the space might be needed, the tooth preparation is based entirely on the actual spatial requirement (Figure 5-61).

The importance of clinical conservation of tooth structure is that if porcelain veneers are truly conservative then they can be removed and replaced at some point in the future. It has often been observed clinically that veneers tend to wear, darken and occasionally fracture with time. The discoloration is particularly evident at the margins and more specifically on margins placed within dentin rather than enamel. Since the primary objective of porcelain veneers and anterior ceramic crowns is esthetic, once their appearance is no longer acceptable to the patient,

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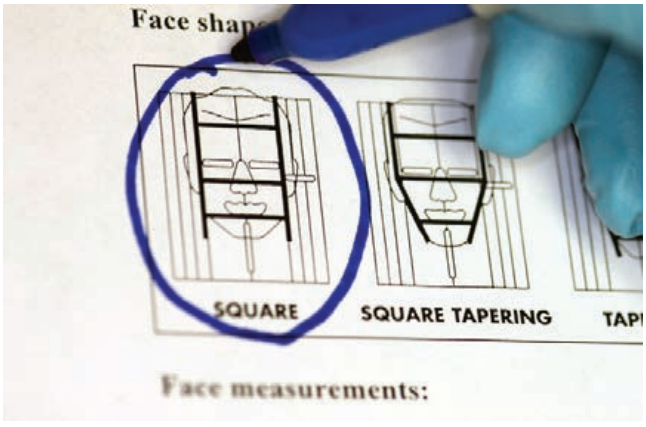


FIGURE 5-48 Note facial shape on the ETI Smile Analysis Sheet.

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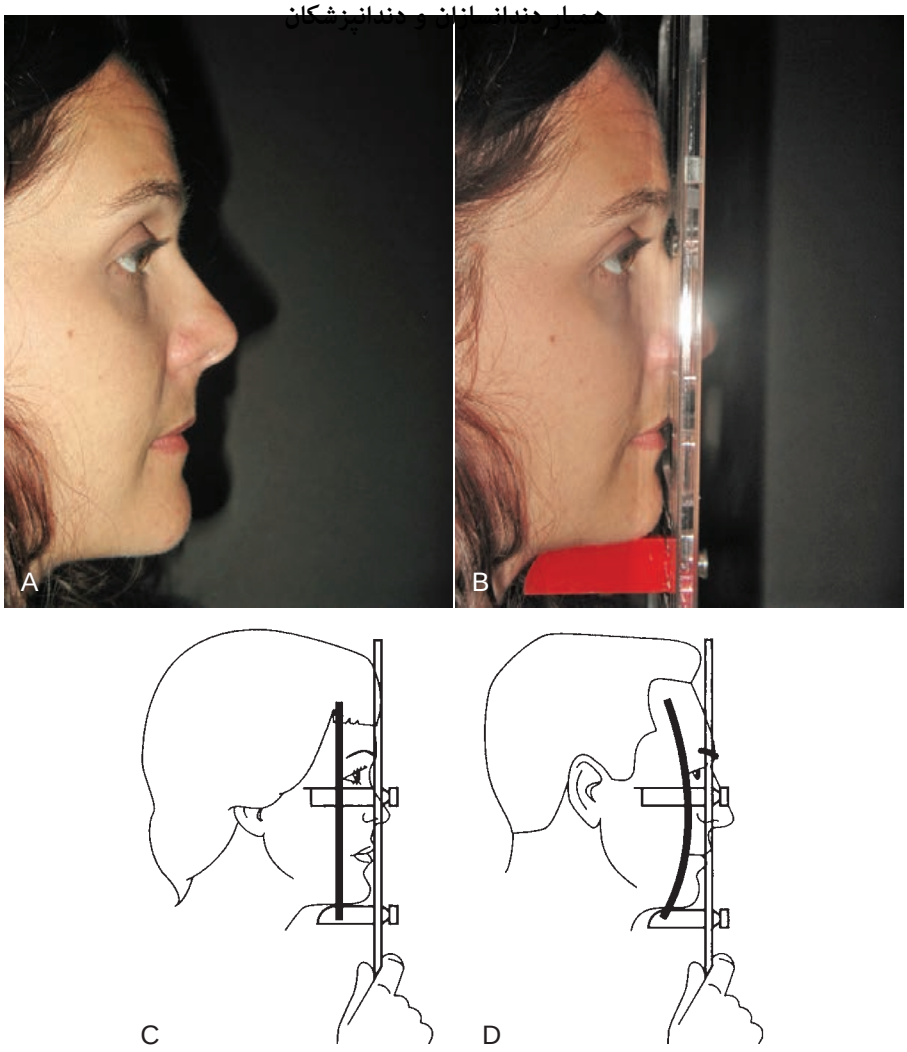


FIGURE 5-49 A, View patient from the side against a dark background to assess facial convexity. Using the Trubyte faceplate (B) helps to focus on flatness (C), convexity (D), or concavity.

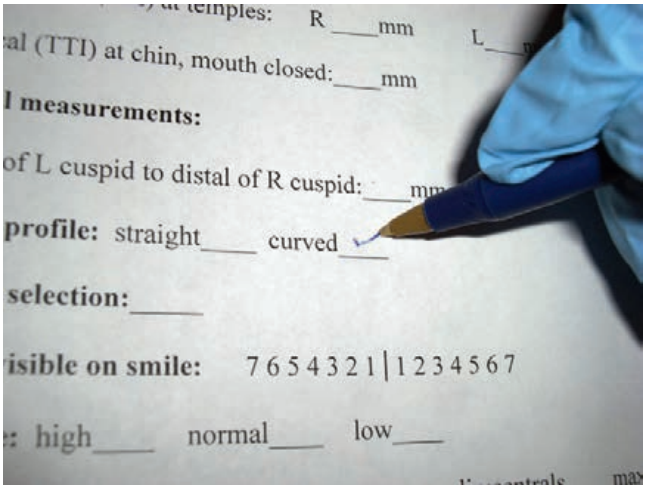


FIGURE 5-50 Enter facial curvature on the ETI Smile Analysis Sheet.

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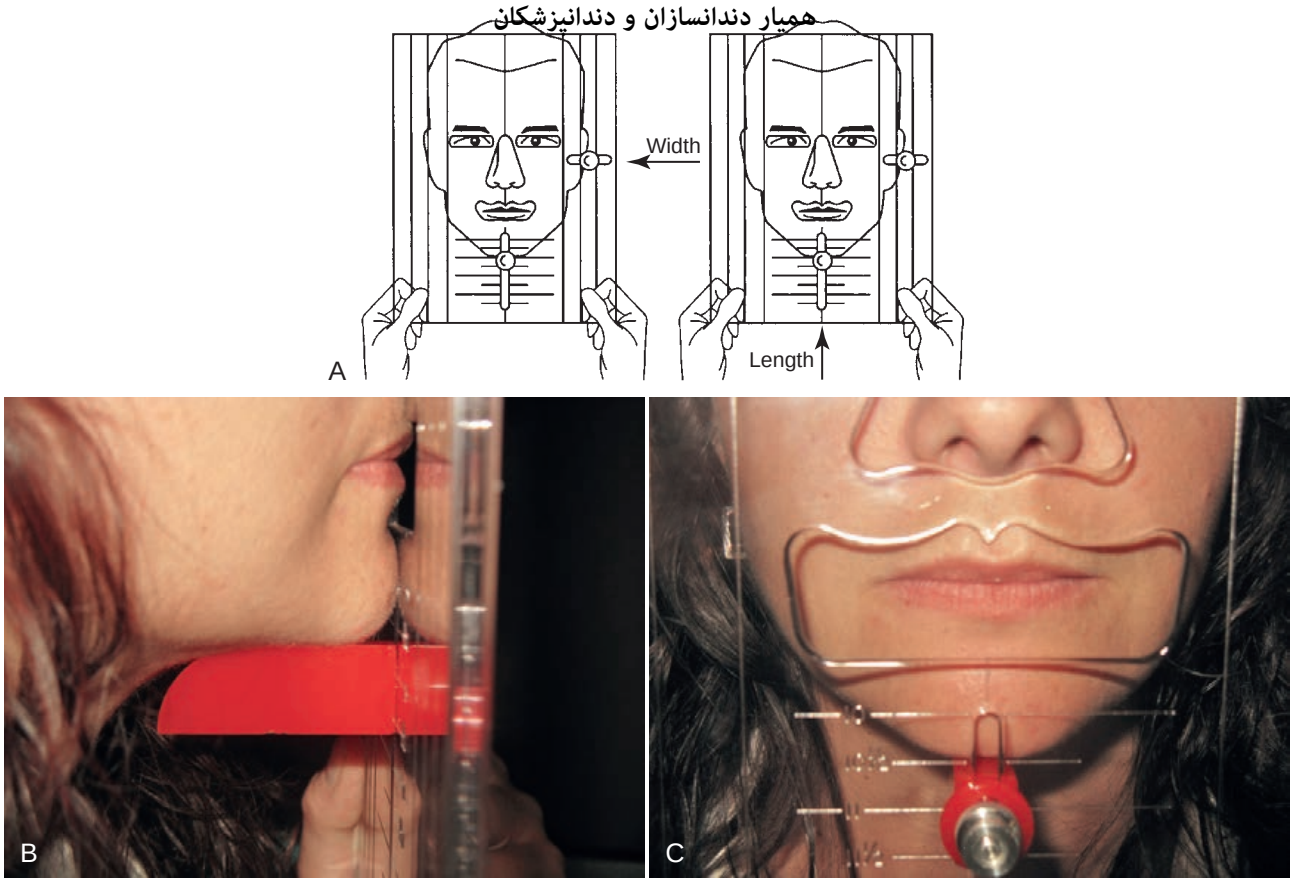


FIGURE 5-51 **A, Determine facial width and height. B, Position chin platform with patient's mouth closed and relaxed. C, Center the mouth in the mouth space of the faceplate, and tighten chin screw.**

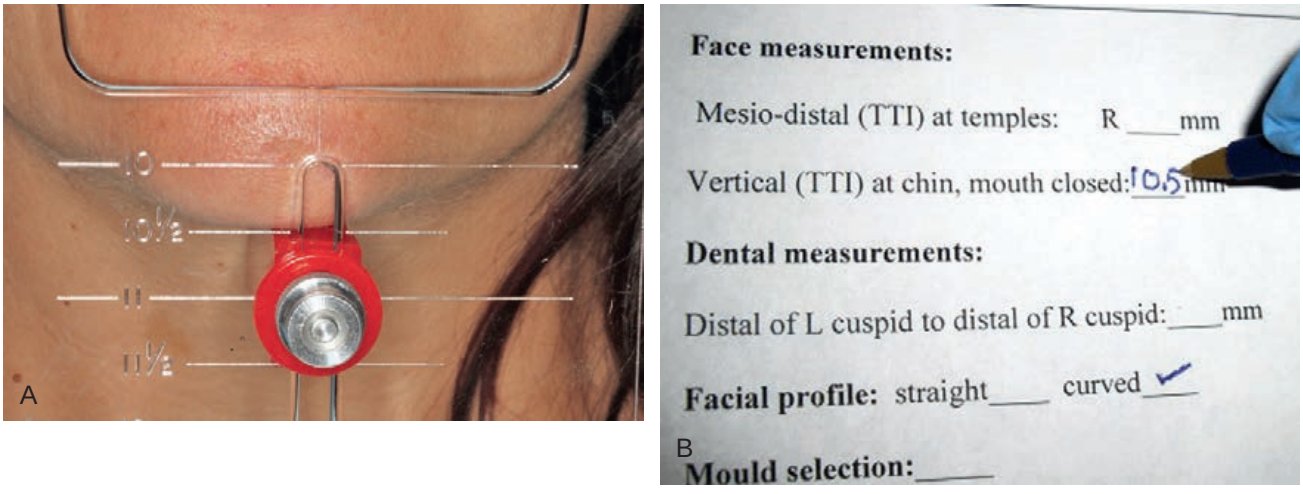


FIGURE 5-52 **A, Read the number at the fixed position of the chin screw. This represents the ideal vertical height of the central incisor. B, Record the length of the central incisor on the ETI Smile Analysis Sheet.**

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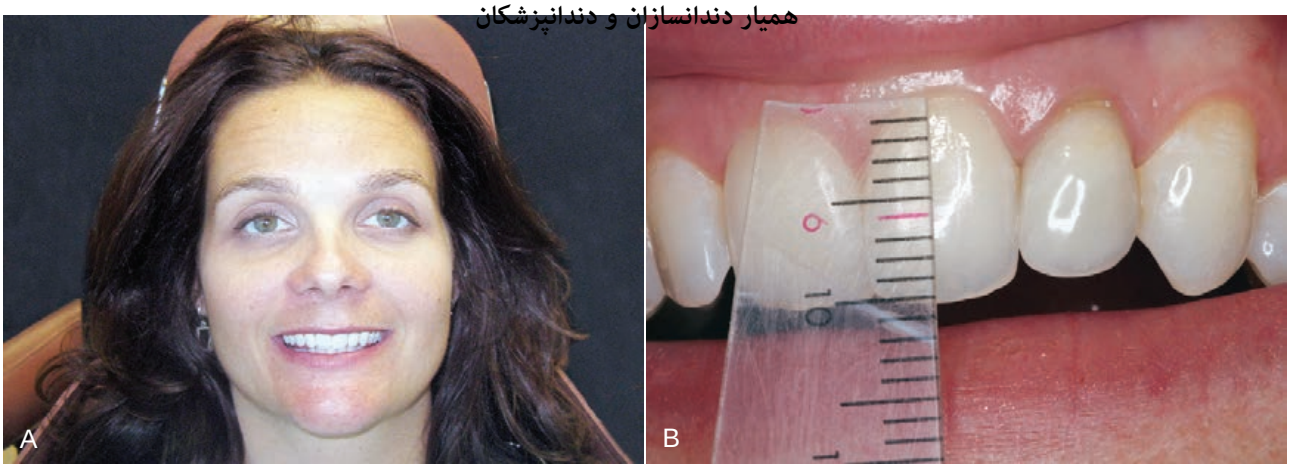


FIGURE 5-53 A, The number determined in Fig. 5-52 in millimeters relates to the vertical height of the face. B, The vertical height of the central incisor.

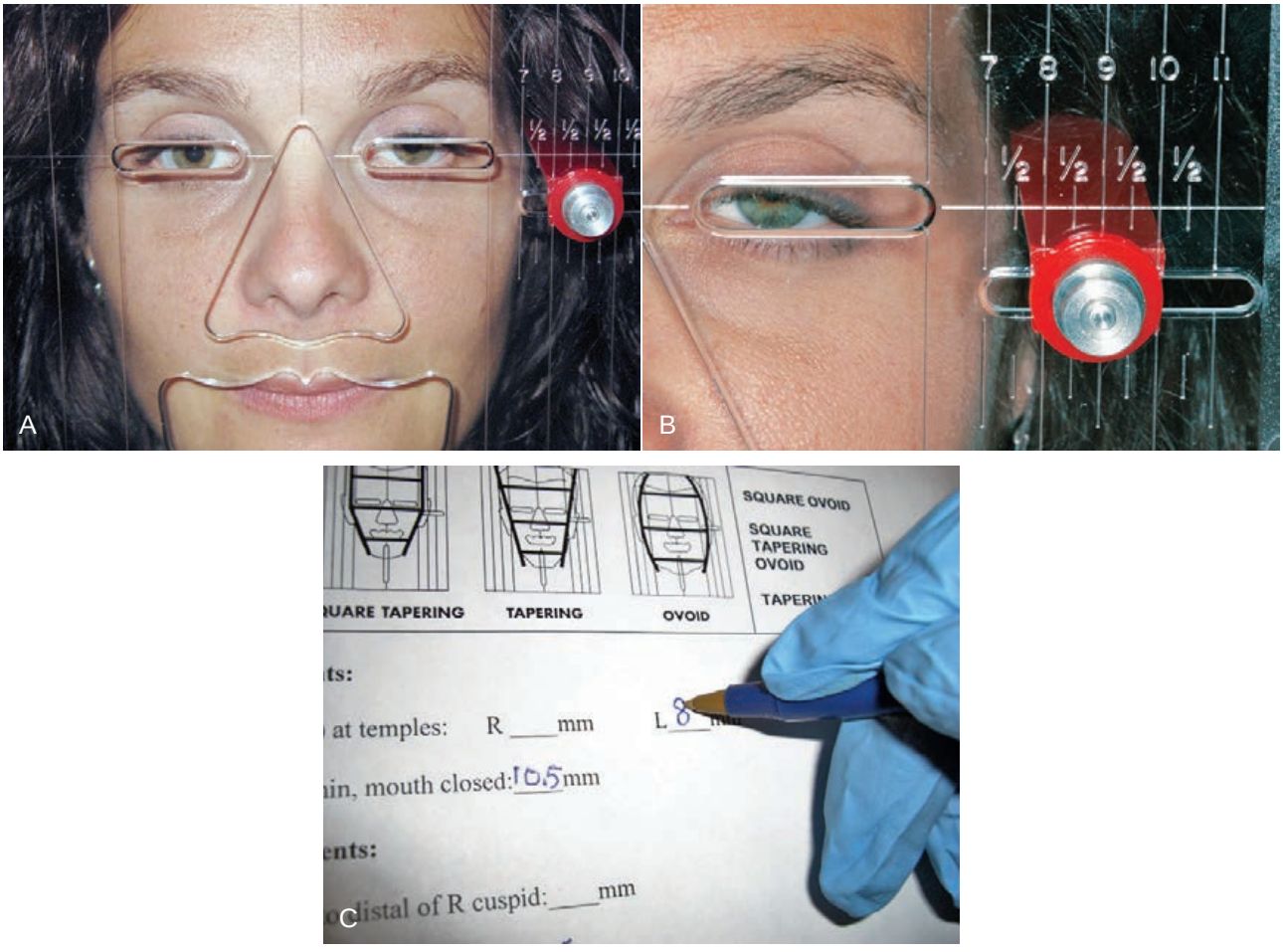


FIGURE 5-54 A, Fix the temple guide bar of the Trubyte Tooth Indicator at the side of the face. B, Read the number at the fixed position of the temple screw. This represents the ideal horizontal width of the central incisor. C, Record the width of the central incisor on the ETI Smile Analysis Sheet.

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FIGURE 5-55 **A, The number determined in Fig. 5-54 in millimeters relates to the horizontal width of the face. B, The horizontal width of the central incisor.**

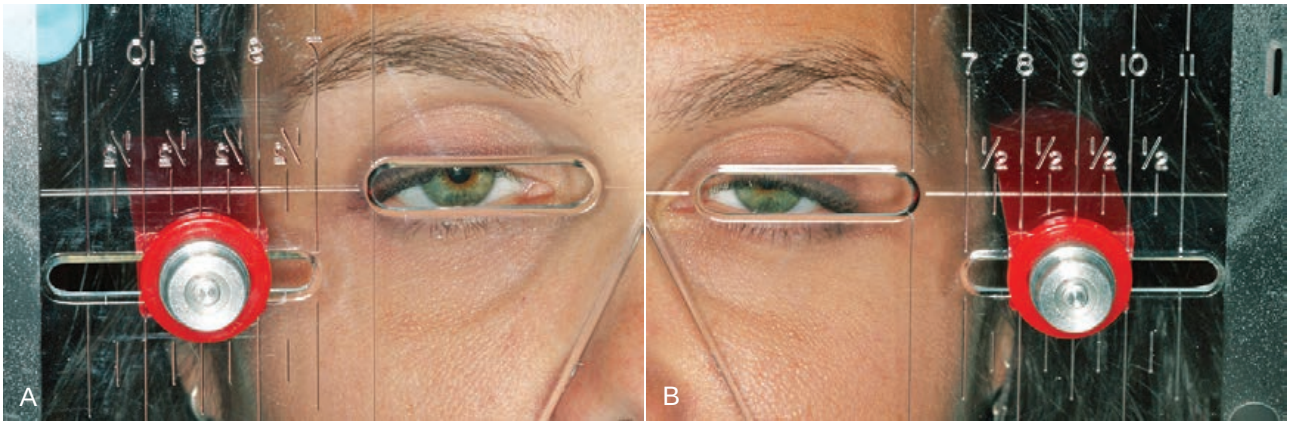


FIGURE 5-56 **A, Right side width analysis. B, Left side width analysis.**

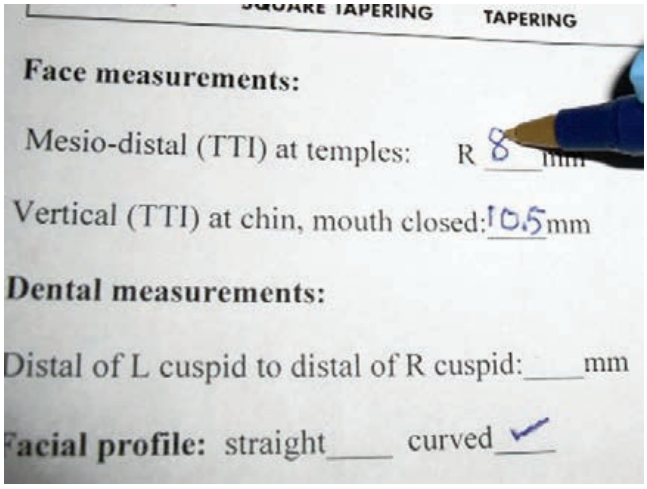


FIGURE 5-57 **Width analyses may be averaged or recorded separately, as appropriate.**

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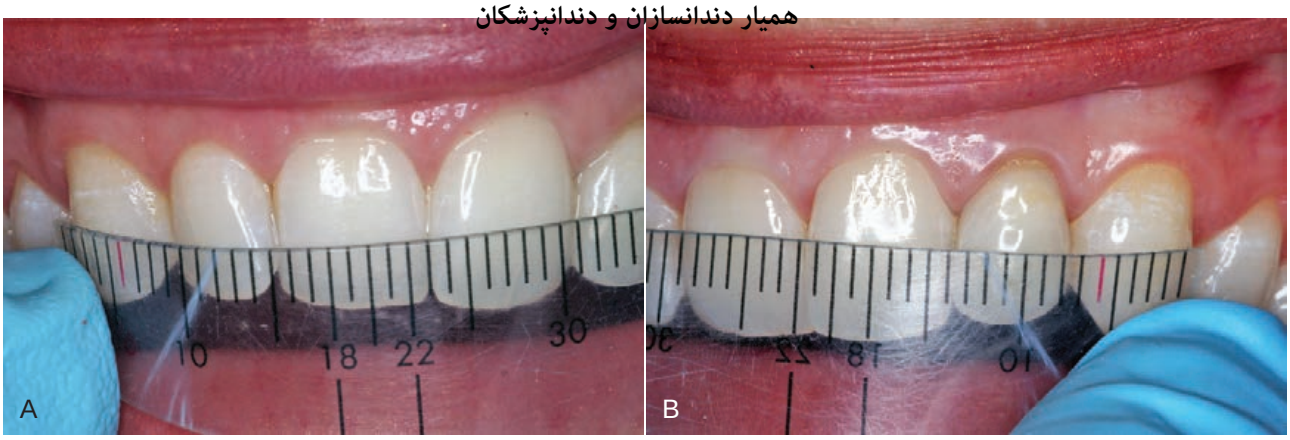
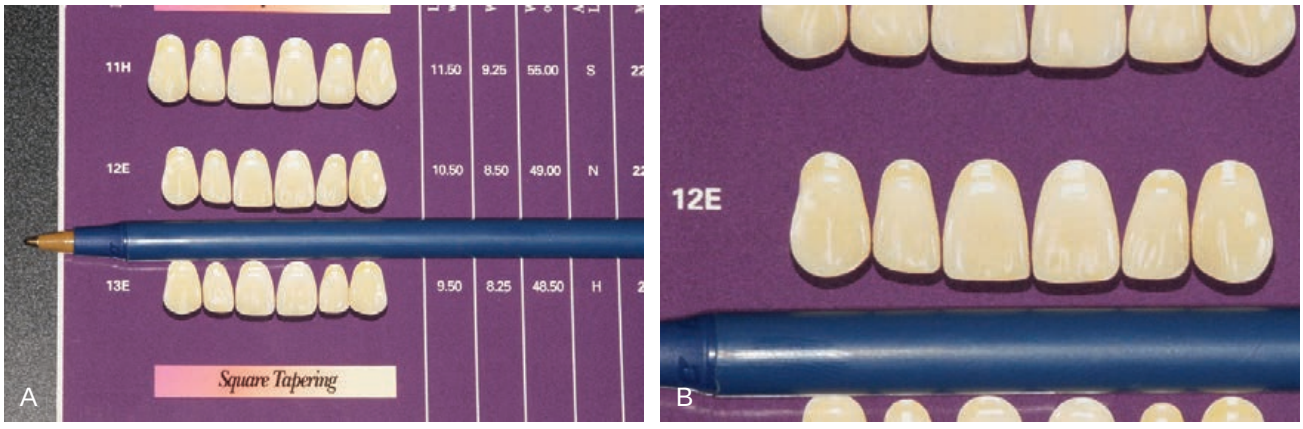


FIGURE 5-58 A, Measure distance from distal of cuspid to mesial of central (or the midline when a diastema is present) on the anterior right side. B, Measure distance from distal of cuspid to mesial of central (or the midline when a diastema is present) on the anterior left side.



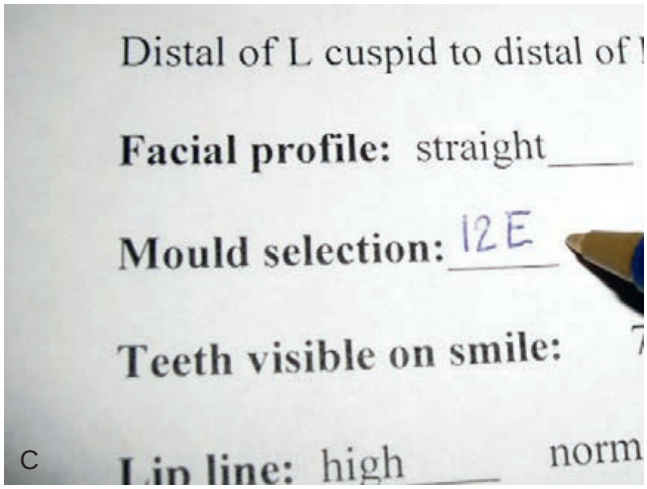


FIGURE 5-59 A, Compare the analysis, including face shape, arch space, and width and length of central incisors, with the list in the Trubyte Bioform Mould Chart. B, Select the closest matching mould. C, Note the mould selection on the ETI Smile Analysis Sheet.

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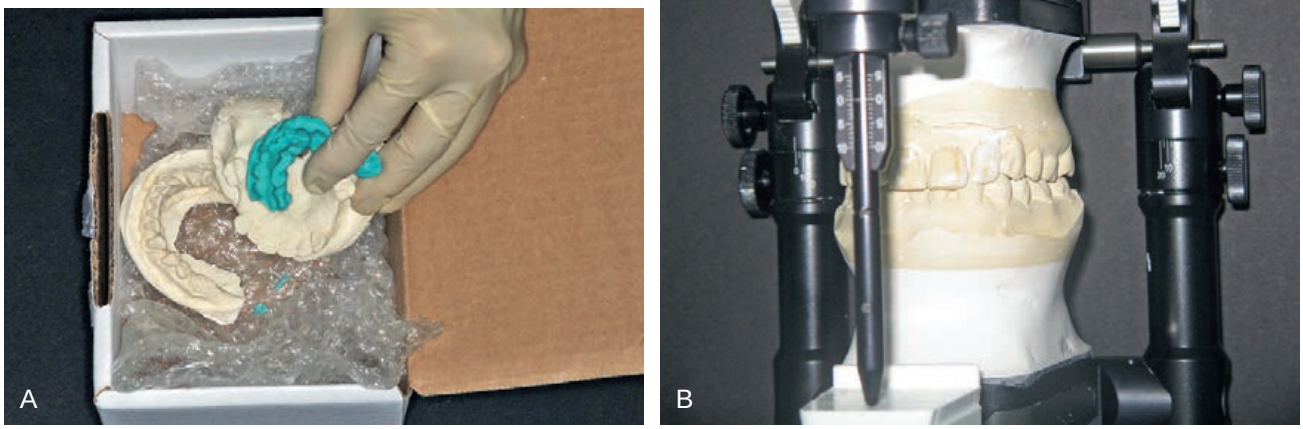


FIGURE 5-60 **A, The ETI Smile Analysis Sheet is sent to the laboratory technician with the impressions and the bite registration. B, The ideal three-dimensional ETI within functional limitations is fabricated on the stone models from the data transmitted by the dentist.**



FIGURE 5-61 **Ultra-conservative tooth preparation (or no preparation at all) is based on the amount of space required for the restoration.**

these restorations must be redone. If the ETI technique has been successfully utilized with minimal or no preparation of the natural tooth surface, then it is simply a matter of carefully removing the aged, chipped, and/or discolored veneer (Figure 5-62, *A* and *B*) and its resin luting material and then inserting a functional and esthetic replacement or repair (Figure 5-62, *C* and *D*). Where the tooth has not been extensively prepared, the marginal bonding is to enamel, a stronger substrate than dentin, and one that is much less likely to exhibit marginal leakage and discoloration. Thus minimal preparation not only is healthier for the tooth but also makes replacement of the restoration easier, more predictable, and more esthetic 10 or 20 years down the road.

CONTROVERSIES

In dealing with function and esthetics, dentists are often in a quandary with respect to art and science. Both art and science have major roles to play in the esthetic restoration of anterior teeth. However, the science must take precedence in developing the functionally based treatment approach. The ETI is a scientifically based procedure that determines maximal conservation, minimal preparation, and the limits to which esthetics can be stretched.

This last issue depends on both the laboratory technician and the dentist and involves the shape, coloration, and characterization of the restorations, which will give the natural appearance that patients desire. The ETI process allows for the contributions of both of these important aspects of dentistry in order to maximize patient benefit, optimize the objective approach to treatment planning and procedure, and provide functional esthetics of the highest quality to the patient.

NEAR-FUTURE DEVELOPMENTS

Much of what has been described for the ETI procedure is done manually. It is accomplished by visual measurement and notation and calculation with pen and paper. In the next 3 to 5 years it is expected that most of these tasks will be taken over by scanners and software, which will image the face and dentition from various angles, input the size and shape of the existing teeth, and electronically perform data collection and management, recommending suitable veneer shapes and sizes. Once this has been completed, it is a small step to where the actual three-dimensional ETI can be milled from a composite or an acrylic block by a computer-assisted milling unit expressly designed for the purpose. These units are currently available but for the moment are specifically oriented to ceramics and metals. It is easy to foresee how much of the process will be automated and made even better, easier, and faster than it is today.

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FIGURE 5-62 **A, An ETI minimal-preparation veneer fractured because of excessive occlusal forces. B, The ceramic was largely intact, and the underlying tooth enamel surface had not been reduced. C, It was a straightforward process to clean the surfaces, re-cement the veneer, and light cure the adhesive. D, The repair is polished to a very acceptable esthetic level.**

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The Nonsurgical Face Lift: Restoring a Youthful Appearance by Repositioning the Muscles of Facial Expression

Irwin Smigel

THE EVOLUTION OF ESTHETICS

In 45 years of dentistry, its image has evolved from one of pain relief (generally with extractions) and ungainly restorations (mostly amalgams) to the sophisticated esthetic perception the profession enjoys today.

The dental profession was mired in an esthetic quagmire for generations. In the 1950s, the main esthetic option was the acrylic veneer. Porcelain crowns, albeit available, were mostly for the very wealthy. They were referred to as "Hollywood crowns," implying that only movie stars or the affluent could afford them. Cementation was the only binding option, and the "give" of the cement between the tooth and crown often resulted in porcelain fracture. Fortunately porcelain fused to gold was perfected by the late 1950s.

In the early 1970s, a metamorphosis occurred that changed dentistry forever—the development of bonding. For the first time the dental profession could offer cosmetic improvement quickly, painlessly, and financially within reach. Bonding was revolutionary, and its success stimulated subsequent improvements and advances.

Porcelain veneers were a natural extension, and the Maryland bridge followed shortly after. Today, porcelain crowns that are bonded to the tooth structure are infinitely sturdier and far less prone to fracture. The newest concept in porcelain crowns, zirconia, is as durable as porcelain-fused-to-metal (PFM) crowns.

Esthetic changes in the profession also are influenced by demographics. In the 1950s and early 1960s, our nation experienced an extraordinary baby boom. To meet the demand of this proliferation, many dentists became orthodontists, and after the trend diminished and the baby boomers became young adults, "adult" orthodontics came into vogue.

Esthetic dentistry has similarly adjusted. In addition to the procedures previously mentioned, some form of tooth whitening is performed by 80% of dentists practicing today. Dentists are catering to the largest patient base, the aging baby boomers. The baby boomers are educated, are well-to-do, have a long life expectancy, and are anxious to enjoy it by looking youthful and attractive for as long as possible.

Plastic surgeons have benefitted considerably from desires for a youthful appearance, but today's esthetic dentistry offers options that are quicker, safer, and less invasive with results that are extraordinary. The revolution that occurred with the introduction of bonding in the 1970s has risen to a new plateau.

THE NONSURGICAL FACELIFT

Dentists often see people with tired, aged appearances in which their faces sag. There are, of course, many possible reasons for this condition, but the culprit is often the individual's teeth (or lack of them) causing an imbalance of the muscles of facial expression.

The muscles of facial expression are responsible for the appearance and function of our facial architecture. Ideally they are supported (held out) to their proper physiologic position by tooth and bone structure. When this is not the case, a sagging face and aged appearance are the result (see Figure 6-2, *A*). The muscles of facial expression consist of four groups (Figure 6-1) that intersect at the corners of the lips to form the intrinsic lip structure: the orbicularis oris, the triangularis, the zygomatic, and the buccinator. The muscles of facial expression also affect function. When they are not supported to their proper physiologic position, normal reactions such as smiling (see Figure 6-2, *B*) are distorted. The muscles of facial expression are responsible for the appearance and function of our facial architecture.

Treatment to reverse this condition varies with the cause. Dentures, fixed bridgework (with or without implants), crowns, bonding, and veneers are options that are overwhelmingly successful when properly designed. The case that follows demonstrates a particularly common dilemma.

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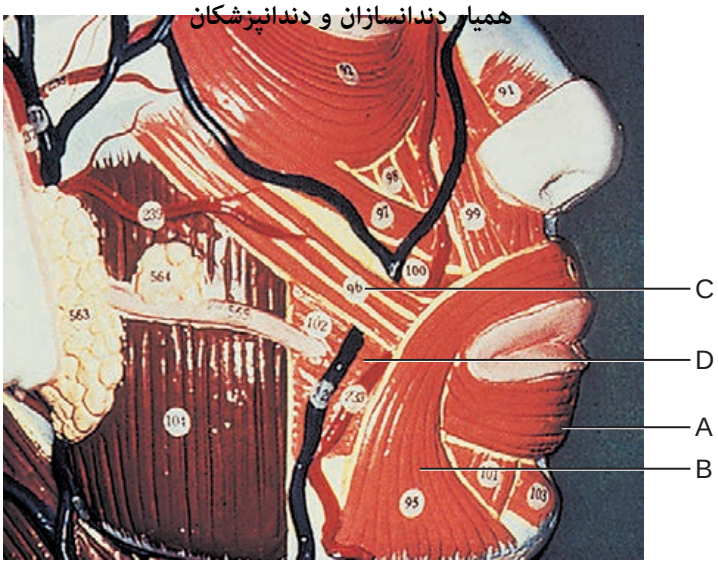


FIGURE 6-1 The main muscles of facial expression intertwine at the corners of the lip to form the intrinsic lip structure. The orbicularis oris *(A)*, the triangularis *(B)*, the zygomatic *(C)*, and the buccinators *(D)*.

CASE 1 Non-surgical Facelift

A 42-year-old female patient, Maria, sought treatment to improve the color and appearance of her smile, but it was apparent that she had more significant esthetic problems. She had a flaccid face, deep nasolabial lines, and thin lips that did not show her vermillion borders. Her face sagged, and she had jowls but no cheekbones (Figure 6-2, *A*). Maria appeared much more aged and tired than she should at 42 years of age. Maria was presented with a treatment plan to significantly improve the appearance and shape of her face, and it was explained to her how it would be accomplished. She confided that her appearance had bothered her for some time, but she had never even imagined this option before.

Her smile (Figure 6-2, *B*) was obviously weak and distorted. Maria was asked to smile as widely as she could, in the hope that she could overcome the slack causing the distortion. The stress of Maria smiling as hard as she could was evident in her eyes and the corners of her mouth. This attempt could not have been successful, because only when the muscles of facial expression are held to their proper physiologic position can a smile occur normally in response to an impulse from the central nervous system. Memory patterns in the neuromuscular system are reinforced, and the contraction (smile) is natural. When the muscles are not properly supported, the contraction is taken up in slack and a distorted smile is the result.

A closer look at Maria's dentition (Figure 6-2, *C*) provided a clue to the cause of her jowl problem. Her maxillary first premolars had been extracted before orthodontic treatment. In addition to losing important bone support, the extractions triggered a crucial loss of vertical dimension. Restoring her vertical loss was a priority. The first step in therapy was repositioning the mandible to produce an optimal neuromuscular balance and a normal bilateral jaw relationship. Impressions were taken and wax was tried in and corrected until the patient was able to appreciate both the facial change and a difference in comfort. At her next visit a Gelb appliance, constructed to cover the mandibular teeth only, was inserted. The Gelb appliance provides the patient with both functional and esthetic comfort and allows the clinician the opportunity to become familiar with the case and effect any changes deemed advisable. The new vertical was carefully measured and maintained throughout the treatment.

Continued

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CASE 1 Non-surgical Facelift—cont'd

After 8 months, with her new occlusion stable and Maria comfortable, we sustained the new vertical with veneers on 22 and 27 and crowns on 31, 30, 29 and 20, 19, 18.

The anterior veneers were carefully lengthened to better support her lower lip and overcontoured to build out the zygamatic and buccinators muscles. The treatment (Figure 6-2, *D* to *F*) was successful, and Maria was happy with the final results.

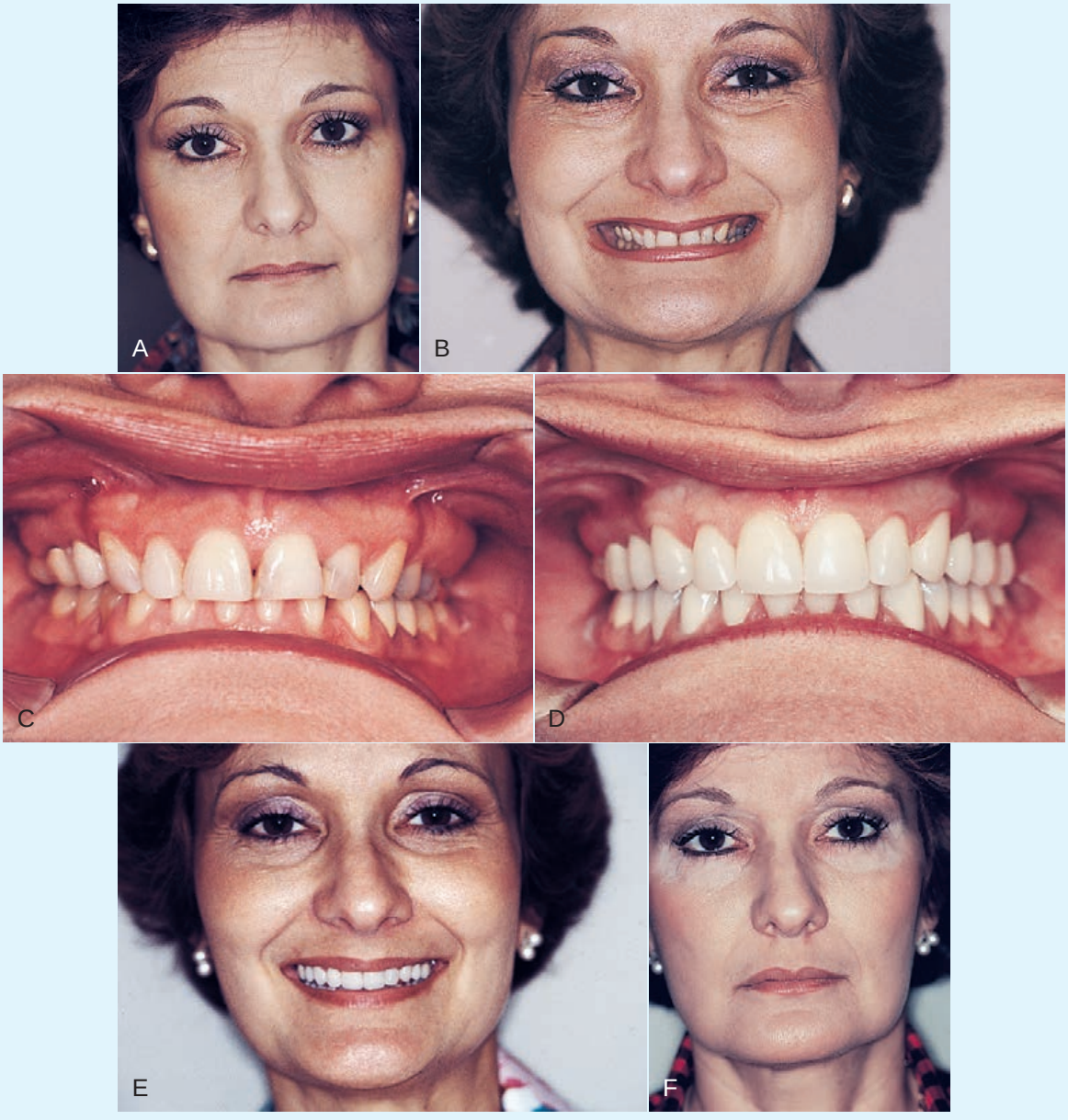


FIGURE 6-2 **A,** A classic sagging face. Deep nasolabial lines, jowls, loss of the vermillion border, and no cheekbone effect. **B,** When the muscles of facial structure are not held to their proper physiologic length, a typical weak smile results. **C,** A close-up view shows that the patient's maxillary first premolars have been extracted. Her arch has narrowed, and she has sustained a loss of vertical height. **D,** Maxillary veneers are bonded to teeth Nos. 6 through 11. The veneers are overcontoured to support the orbicularis and lengthened to hold out the lower lip. Zirconia crowns are placed on teeth Nos. 2, 3, and 5, and 13, 14, and 15. They are precisely aligned to best support the zygomatic and buccinator muscles. **E,** The new smile is wider, natural, and attractive. It is no longer weak and radiates energy and youthfulness. **F,** The most significant alteration is the normal lips. In the addition, she now has cheekbones, and her jowls have disappeared. The deep nasolabial lines have softened, and her formerly flaccid face is taut.

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CHAPTER 7

Color and Shade

SECTION A

Understanding and Manipulating Color

Fay Goldstep, George Freedman

RELEVANCE TO ESTHETIC DENTISTRY

The study of color can be extremely complex and involved. Although it is not the purpose of this chapter to be a complete report on the art and science of color, certain aspects of color have a direct impact on the clinical practice of porcelain laminate veneers. In fact, the understanding of color and its manipulation is fundamental to the ability to create esthetically pleasing restorations in the mouth. At first this may seem a formidable task. In fact, just describing a given color can be a heroic pursuit, because there are literally millions of discernible colors. By turning to the *Methuen Handbook of Colour* one can, if one has the time and inclination, learn the names of over 8000 of them. These include some of the less-than-classic colors, such as "fancy free," "wafted feather," and "heart's desire." These names may evoke poetic images, but they certainly do little to clearly communicate any of the dimensions of the shade they represent, particularly when they are communicated through linguistic translation. Clearly there is a need for some distillation of color science, and it is obvious that some sort of order is vitally necessary if one is to develop skill in the manipulation of color without having to spend a lifetime developing a "feel" for what seems to work.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

The search for such an understanding has been a preoccupation for centuries. In 1666 Isaac Newton discovered that white light can be broken down into a rainbow of color, but it was not until the nineteenth century that German physiologist Ewald Hering first described the now familiar color circle.

Although this created some organization of the color perception experience, it was only a beginning. At the time of its discovery, the color circle seemed to describe some basic law of physics, but it turns out that the organization of color into a color circle has more to do with the physiology of the eye and psychology of the observer. It does, however, form the basis for several present-day workable systems of color. In 1905, Albert Henry Munsell, an American artist and art teacher, further modified the color circle, devising a system of color organization that centered around three unique aspects of color: hue, chroma, and value (Figure 7-1). Using these three aspects, Munsell was able to construct a three-dimensional color wheel (Figure 7-2).

The Munsell system is not unique. Numerous other color wheels are available. Each is of different national origin, with versions from Britain, France, Germany, Argentina, and Sweden. Naturally enough, each system finds its greatest usage in its country of origin. Unfortunately, although such systems provide a good way to describe color, they actually do little to teach how to manipulate and control color in a clinical situation. In other words, rather than the Munsell system being a method used to control color, it merely serves as a relatively precise "language" to verbalize what is being done. In fact, it is even of limited value in describing tooth color, because it is primarily involved with surface reflection. It does not make any distinction between one color that is relatively translucent and one that is opaque.

Differences in surface texture also are not addressed by such a system. All dentists have seen the differing appearance of porcelain crowns and plastic temporaries of the same color. Subtle differences in appearance can even be discerned among various brands of porcelain, variations that can transcend the qualities of hue, chroma, and value. Obviously, then, there are dimensions to the appearance of tooth shade beyond mere color. This situation is not unique to dentistry.

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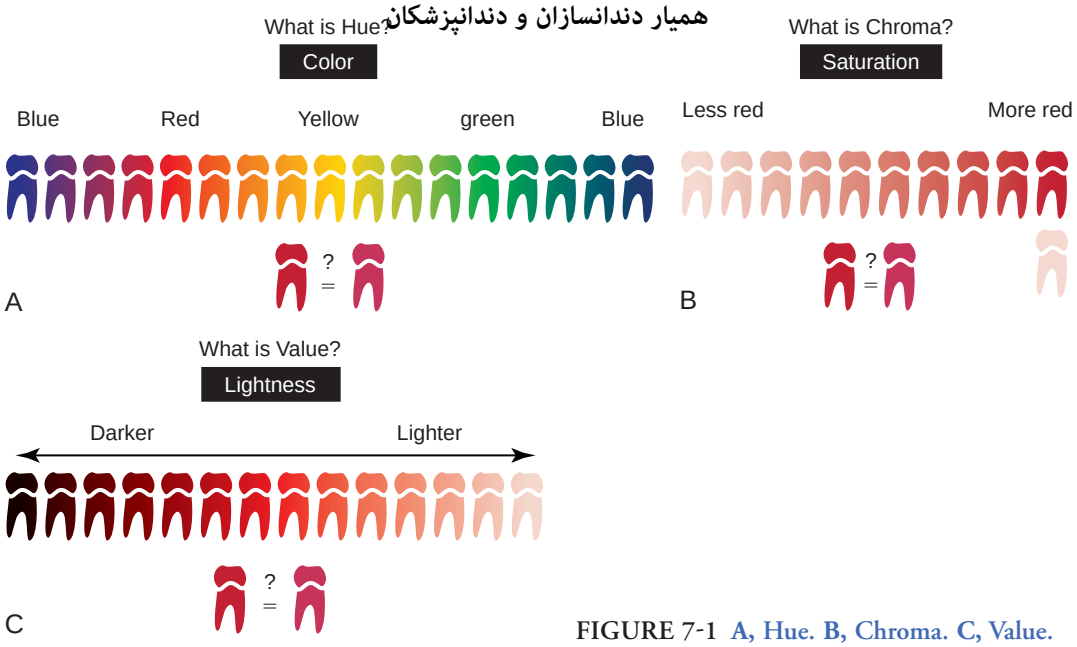


FIGURE 7-1 A, Hue. B, Chroma. C, Value.

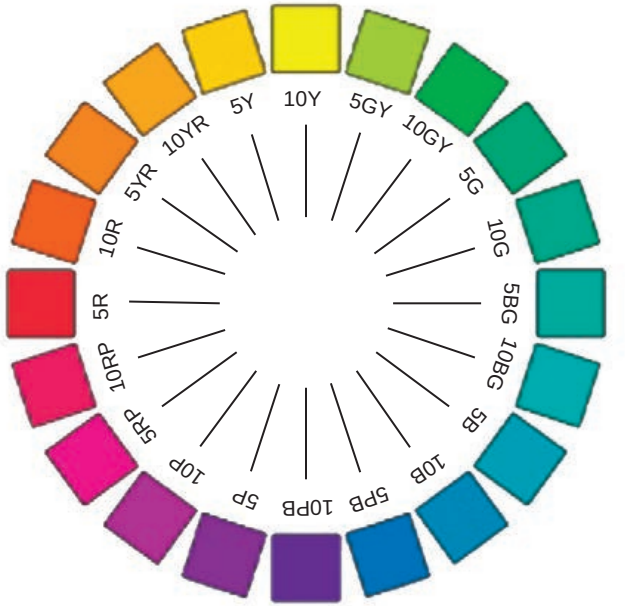


FIGURE 7-2 The Munsell color wheel.

In the fifteenth century, Flemish painters such as Jan van Eyck worked with a method of painting known as the "wet-on-wet" technique, in which layers of wet paint are applied to previous layers of wet paint (Figure 7-3). Different details of the paintings are placed in different strata over the canvas, and the layers of paint toward the outside are usually increasingly translucent, creating an illusion of depth and vitality that would be impossible if only opaque paints were used (Figure 7-4). In some paintings as many as 30 layers are used to create maximum effect. This is not that different from the technique a master dental technician uses when different shades of porcelain along with flecks of inlaid color are employed to imitate the dentinal and enamel layers.

Thus in some respects dentists are not much farther along than the artists of the Renaissance in the ability to control the chromatic appearance of their work. Nonetheless, there are several principles that guide practice. Today's dentist must understand that there are several completely unique systems for understanding and manipulating color, and although each of them provides a workable framework for understanding, they also may often seem to contradict the teachings of the other systems.

Over the last decade, computerized shade-matching systems have appeared on the market (Figure 7-5). This innovative technology offers better accuracy, improved efficiency, and esthetic benefits to patient, dentist, and technician. Based on technology imported from the painting industry, these systems analyze the color of the natural teeth; calculate the exact ratio of hue, chroma, and value for a multitude of points on the tooth surface; and display this information on the dentist's computer screen. The process illuminates the guesswork often associated with reading the shade tabs and greatly facilitates the communication of information to the lab technician. This improved flow of information encourages the fabrication of predictably accurate, highly esthetic restorations. From the lab's perspective, the frequency of remakes is reduced.

Computerized shade-matching systems are available in a variety of formats. Most include hardware and software that identifies the variously colored, translucent, reflective, and characterized areas of a tooth. This information provides a computerized shade map, one that offers significantly more information and detail than traditional shade matching and communication.

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FIGURE 7-3 Two examples of Jan van Eyck's work. A, *Portrait of a Man* (1433). B, *The Arnolfini Portrait* (1434). *(Copyright © The National Gallery, London.)*



FIGURE 7-4 Close-up view of the left bottom portion of *The Arnolfini Portrait*, demonstrating the translucency toward the edge of the painting. *(Copyright © The National Gallery, London.)*

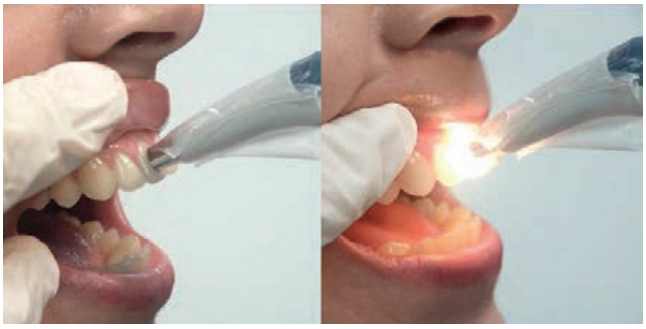


FIGURE 7-5 VITA Easyshade intraoral dental spectrophotometer in use. *(Courtesy Vident, Brea, California).*

Computerized shade matching eliminates the subjectivity and frequent perception errors associated with traditional shade taking. It improves the accuracy and predictability of restorative procedures, particularly those difficult situations in which a single anterior tooth is being replaced (Figure 7-6). There is no requirement for standardizing the light environment of the dental operatory, and thus accurate shades can be taken anywhere, anytime.

Although they offer many advantages, these systems can be expensive. The value of this technology to the individual practice must be determined not in terms of a single cash outlay, but as a purchase that saves time and improves the quality and predictability of treatment. The cost of the system should be amortized over the useful life of the product, and the daily cost determined. It is then a simple matter to compare the benefits of the system with the costs.

CLINICAL CONSIDERATIONS

Indications

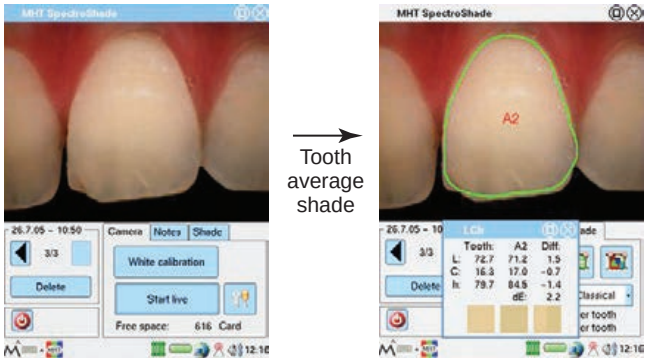
Importance of Color Matching

The major driving force in dentistry today is the demand for esthetic services. This has been the case for the last two decades, and this trend is likely to continue for at least a decade more (if not longer). For the first time in dental history, the patient is involved in diagnosis, treatment planning, and outcome evaluation. Much of the growth in dentistry is patient driven. Although this phenomenon has altered the traditional

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A



B C

FIGURE 7-6 **A, MHT SpectroShade Micro. B and C, Screenshots showing how the SpectroShade reads the color of the tooth and indicates the closest available chromatic standard. It calculates the numeric difference between the natural tooth and the selected color in terms of brightness, chroma, and hue.** *(A courtesy MHT Optic Research AG, Niederhasli, Switzerland.)*

patient-dentist relationship, it has also brought greater patient interest, cooperation, motivation, and compliance.

In today's dentistry, both composites and porcelains are expected to mimic not only the shade of natural dentition, but also the translucence, opacity, and shade distribution of a real tooth.

The public expects that the cosmetic or esthetic dentist can recreate nature accurately, repeatedly, and rapidly. The dentist is faced with the tasks of determining the shade, communicating it to the lab technician, and maintaining it through the cementation procedure to the final (and, one hopes, esthetic) result. These steps presume predictable shade determination and very clear and accurate communication between the dental office and lab. These requirements place tremendous pressure on eliminating the guesswork from color matching and communication in any treatment.

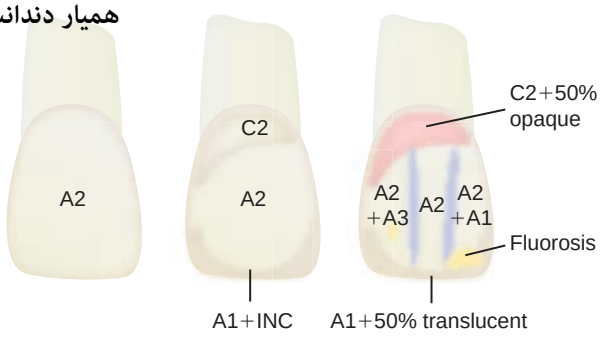


FIGURE 7-7 **Prescription showing the tooth color map, indicating the various shades within the tooth and their borders.**

Overall the indications for color and shade matching can encompass both the direct and the indirect procedures that are undertaken by the dentist on an everyday basis. Much of today's dentistry is esthetically related or expected to be esthetic by patients. Whether the restoration is a direct composite filling or an indirect ceramic or ceramic porcelain-fused-to-metal procedure, it is expected to match the coloration of all the existing teeth.

Contraindications

There are really no contraindications to shade matching because shade matching is not an invasive procedure. It does not affect the tooth structures that are being worked on. It does not change anything. It does not cause any discomfort unless the patient is subjected to a very long and tedious procedure. If the procedure is done incorrectly, then the resulting restoration will not match the teeth; and, of course, in that case the procedure will have failed even before the restoration is placed in the patient's mouth.

Clinical Options

Shade-Matching Techniques

There are two primary techniques for acquiring shade-matching data in dentistry. Both involve assigning ceramic and/or composite color analogs to the existing dentition shades to describe the natural colors as accurately and completely as possible. These analog (shade) maps enable the lab technician to create an esthetically compatible crown at a distance. The differences in the two techniques lie in the technology and the cost.

Traditional shade taking involves matching one or more selected colors from a range of shade tabs to the teeth adjacent or contralateral to the teeth to be restored. This serves as a guide to the lab technician fabricating the crown or the bridge. The more information (and accuracy) that the dentist can provide in the prescription, the more lifelike the technician's output can become. Thus the dentist who provides a drawing of a tooth color map, indicating the various shades within the tooth and their borders, is more likely to have a positive result than the dentist who describes the shade as a single generic color (Figure 7-7).

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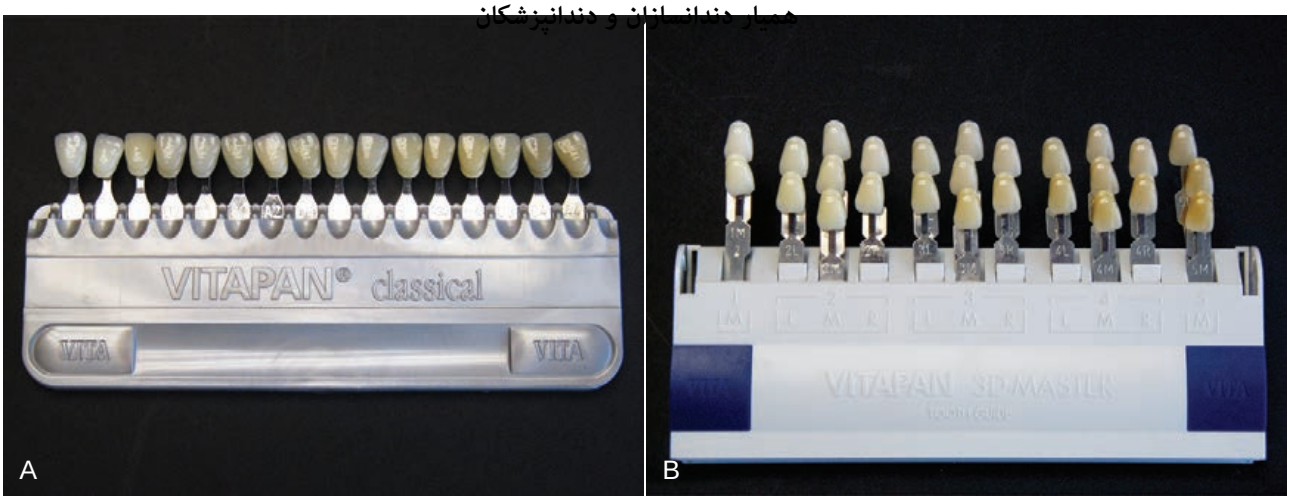


FIGURE 7-8 **A, VITAPAN Classical Shade Guide. B, VITAPAN 3D-Master Shade System (Vident, Brea, California).**

Earlier shade guides (Figure 7-8, *A*) were developed haphazardly, with no infrastructural relationship among the various shades. Today's advanced guides (Figure 7-8, *B*) have been developed logically, with incremental relationships among the various shade tabs, an organizationally structured series of family and color groupings, and a range that covers the entire tooth-visible color envelope. These modern guides are designed for ease of learning and ease of use. The entire shade guide system is available at less than $100.

These clinical options for shade matching include a variety of shade tabs that are used intraorally, with the dentist and/or one of the dental team members using his or her own visual perception to determine the color of the teeth relative to the system tabs predetermined color. The other major category is the electronic shade-taking devices.

The advantage of the shade tabs is generally that they are less expensive and can be used almost anywhere.

The disadvantages are many. The problems associated with perceiving color with the naked eye include first and foremost the environment. The environment of any color-taking procedure will affect the results. The coloration of the patient's clothing, the dental and operator chairs, the wall decorations, and even the color of the equipment may affect the perceived perception of the tooth color, as can sunlight or even snow reflections streaming in through an open window. Furthermore, sunlight at different times of the day will have different qualities and different underlying tones. Therefore it would seem that shade taking must be done in a room that has no windows and is totally color neutral. Another problem is metamerism—the same color appears different when viewed at various angles or reflecting off unlike surfaces.

Color perception can be unpredictable. The observer is instrumental in correct color evaluation or shade taking. Typically females see colors or hues better than males, but males see value or the grayness of an object better than females do. Younger individuals of both genders see color better than older individuals, and many people are affected by color blindness. In fact, up to 8% of all males (knowingly or unknowingly) may be affected by various levels of red-green color blindness. Fatigue can also affect the ability to take shades accurately, and there is little doubt that shades taken earlier in the day are more accurate than those attempted at the end of a long and difficult working day. Various medications also affect the ability to see color accurately, and although they may only affect color perception slightly, this still makes a major perceptive difference. Furthermore, eyes can be mistaken by illusions. Optical illusions and contrast effects often tend to hide the true nature of a color.

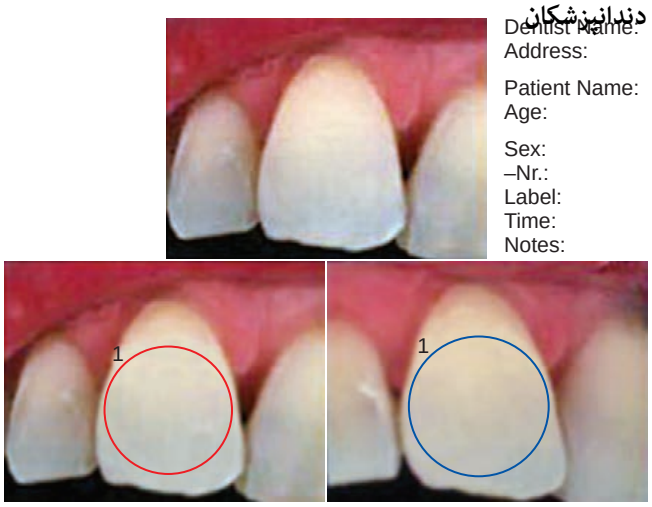
On the other hand, the advantages of a digital shade-matching system include objective readings and accuracy. There are two types of digital shade-matching devices commonly used in dentistry: the spectrophotometer and the colorimeter.

The spectrophotometer consistently and accurately measures natural tooth coloration in reference to any known specific color or can be based on any shading system. It measures the color characteristics of the natural tooth precisely and scientifically, indicating the deviations and gradations of value, chroma, and hue from a standard and provides all the information that is necessary to create an accurate restoration, or to modify an existing one such that it will accurately match the tooth. The spectrophotometer develops an accurate interpretation of the tooth shade on a given color system, which can then be related to an existing shade tab within dentistry or to a color that is interpolated between the shade tabs. In either case a lab technician is given all the color clues to recreate a shade that is very natural in appearance and very close to the target coloration.

The colorimeter analyzes the tooth coloration based on preloaded data that is related to a shade system. It determines the shade tab that is closest to the actual color of the tooth. The colorimeter is typically less accurate than the spectrophotometer but may suffice in most dental situations.

Because both spectrophotometers and colorimeters tend to eliminate ambient light by standardizing the immediate environs of the target tooth, the shade can be taken in any operatory with any kind of lighting streaming in through the window. Digital shade taking therefore is far easier, far more practical,

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1:	Left:	Right:	Diff.:
L:	69.93	72.61	2.68
C:	17.75	17.48	–0.28
h:	84.31	82.23	–0.64
		E:	2.77

FIGURE 7-9 The MHT SpectroShade can evaluate the coloration of the central incisor with respect to a selected shading system *(top)*, the entire tooth, or selected areas of tooth (as within the circles) before and after tooth whitening *(bottom)*.

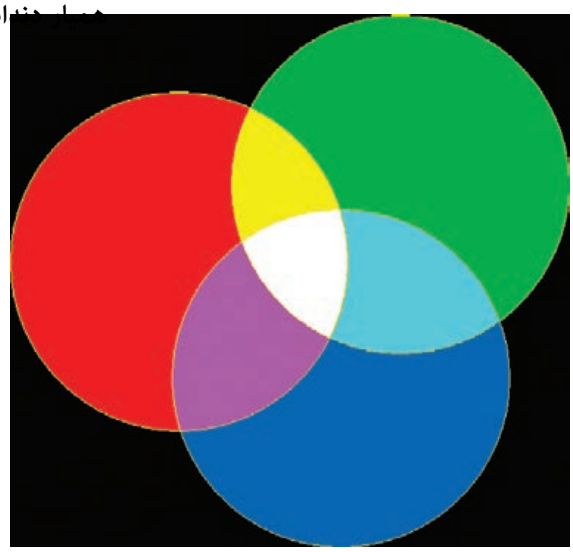


FIGURE 7-10 The additive system.

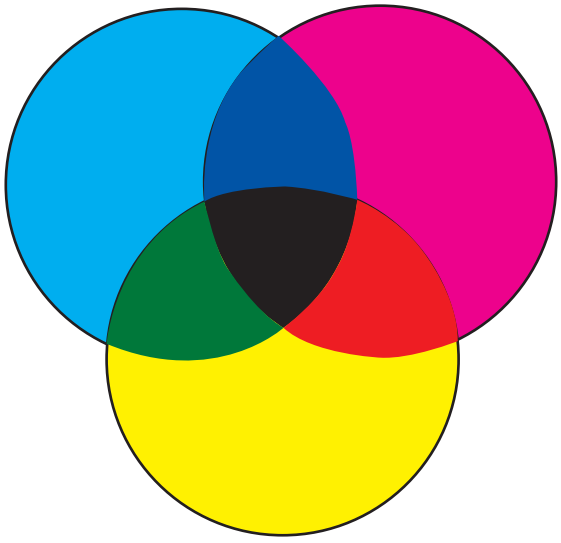


FIGURE 7-11 The subtractive system.

and far more accurate than shade taking using color tabs and the naked eye in a variable environment.

The current best approach to shade taking is the spectrophotometer. It provides the most accurate method for matching the coloration of the tooth. Some systems provide readings of translucence and reflectivity as well. Spectrophotometers provide consistent shade measurement regardless of the environment, lighting conditions, or other operatory variables including the dental team member who is conducting the shade-taking process. With some systems, a further comparative analysis can be undertaken on shade scans taken before and after treatment to provide the color difference between the two measurements. This is particularly useful for tooth-whitening procedures (Figure 7-9).

Other Considerations

The Additive System

The additive system consists of three primary colors: red, green, and blue. All other colors are made up of combinations of these three unique or "primary" colors.

Knowledge of this system (the so-called "additive" system of color) (Figure 7-10) has enabled the creation of such devices as the color television. Using only three phosphors, one each of the three primary colors, the color television is able to produce a seemingly unlimited range of shades. One such television monitor boasts a palette of 16,777,216 colors that are available on the screen. In the additive system, white is the balanced mixture of all the colors, and black is the absence of color. Yellow is a balanced mixture of red and green. Because the additive system of color does such a laudable job of organizing color, it may seem that there is no need for any other approach.

The Subtractive System

Those involved in art, however, tend to emphasize another arrangement. In this system, the so-called "subtractive" system, the three primary colors are red, yellow, and blue (Figure 7-11).

In the subtractive system, black is the result of a mixture of the three primaries, and white is the absence of color. This system is popular because it is perhaps the easiest to use when dealing with pigments (Figure 7-12).

There are other systems as well. Each color system has its own strengths and deficiencies. Yet despite the apparent contradictions in the various color schemes, each popular system of

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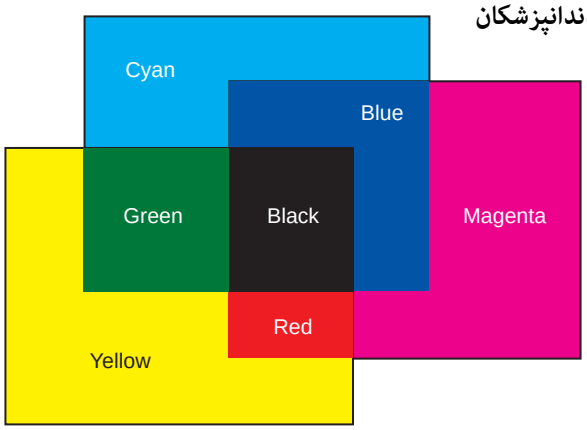


FIGURE 7-12 In the subtractive system, black is the result of a mixture of the three primary colors.

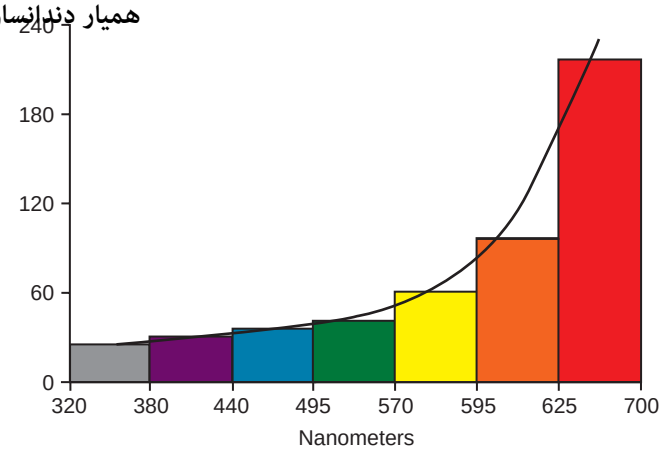


FIGURE 7-14 Reflectance curve of a red object.

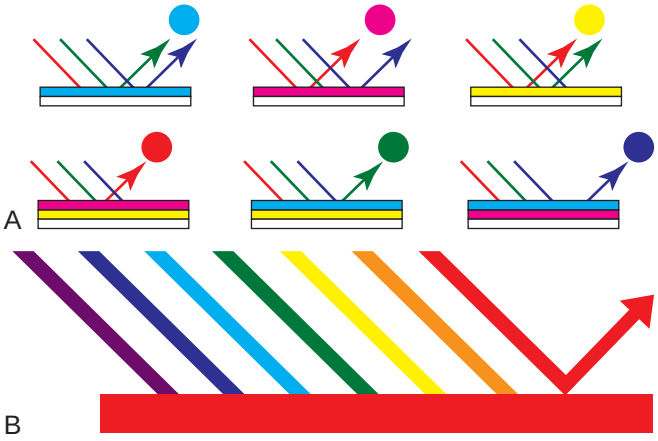


FIGURE 7-13 Examples of pigment light traps.

TABLE 7-1 Relating Color Absorption, Reflectance, and Appearance to the Eye

INK COLOR	ABSORBS	REFLECTS	APPEARS
C	Red light	Green and blue light	Cyan
M	Green light	Red and blue light	Magenta
Y	Blue light	Red and green light	Yellow
M + Y	Green and blue light	Red light	Red
C + Y	Red and blue light	Green light	Green
C + M	Red and green light	Blue light	Blue

analyzing color is correct within its own framework. Because dentists work with pigments when dealing with porcelain, the easiest system for clinicians to use is the subtractive system.

The subtractive system is not only the easiest to use, but also the one with which the dentist may be most familiar. The subtractive system is the one used in children's crayons; children learn at an early age that when they mix red and blue, for instance, violet is the result.

This system works the way it does because the pigments within the crayons absorb certain parts of the spectrum and reflect others. Thus the pigments are "light traps." Red pigment, for instance, absorbs all parts of the light spectrum except red (Figure 7-13 and Table 7-1).

If pigments displayed perfect efficiency, the mixture of any two primary colors would result in the production of black. If in the crayon example one crayon absorbed all the spectrum except red, and the other one absorbed everything except blue, there would be nothing left over. Normal pigment concentrations, however, are notoriously inefficient in this regard and are almost always thinned out to create a relatively low saturation. Thus a red crayon selectively absorbs certain wavelengths and reflects those centering around the 700-nm (red) range (Figure 7-14).

Because of the profession's familiarity with the rudiments of this system, and because of its easy applicability to the dental applications, all subsequent color discussions in this chapter take place within the framework of the subtractive system of color.

In the subtractive system, when the three primary colors are arranged in the traditional color wheel, diametrically opposed colors are called *complementary colors.* Yellow and violet, for instance, are complementary colors. The mixture of two highly saturated complementary colors results in the elimination of color and the production of black. Because the pigments used in dentistry are poorly saturated and imperfect, the mixture of the stains usually produces some shade of grey instead of black (Figure 7-15).

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FIGURE 7-15 Poorly saturated and imperfect pigments can produce a shade of grey instead of black.

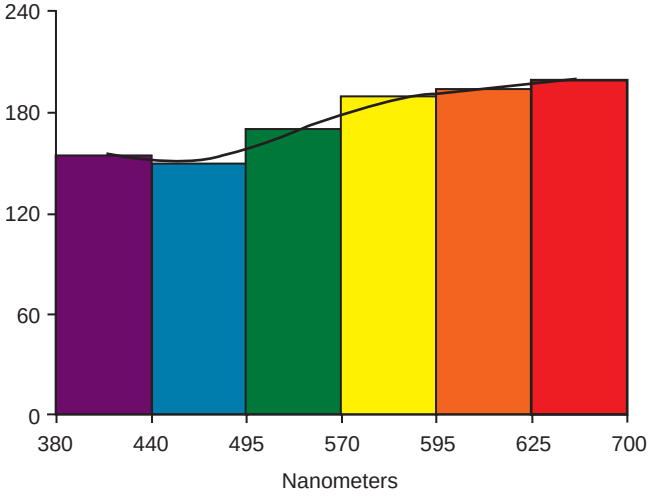


FIGURE 7-16 Reflectance curve of a typical tooth.

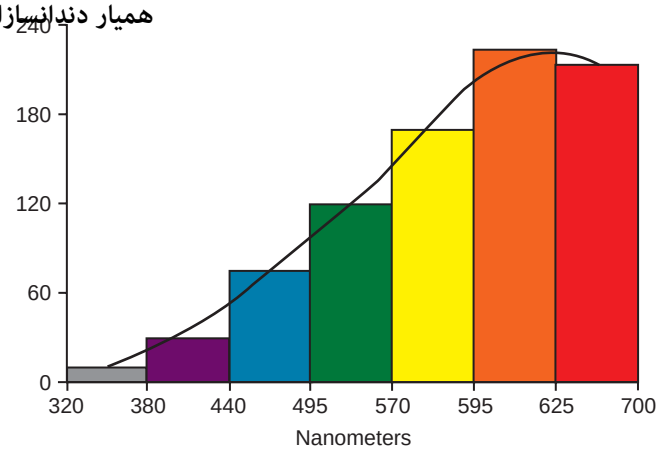


FIGURE 7-17 Transmission curve of incandescent light source.

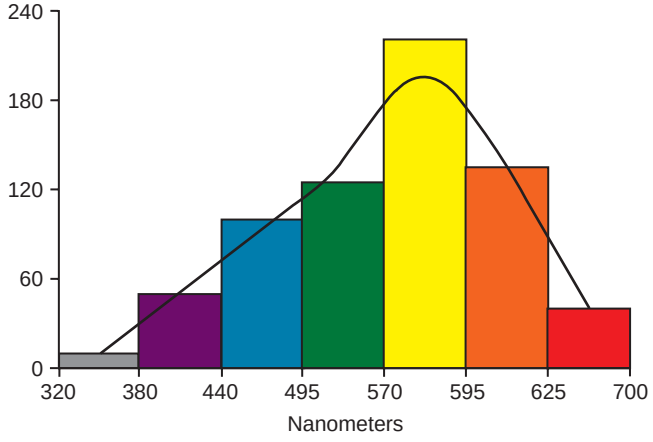


FIGURE 7-18 Transmission curve of fluorescent light source.

PROBLEMS INHERENT TO MATCHING THE SHADES OF TEETH

There is a list of difficulties the dentist must overcome when trying to make a perfect match of a tooth's color. Not the least of these problems is establishing the actual color of the tooth being matched. As every dentist knows, this is easier in theory than it is in practice.

The apparent color of a tooth is affected by the color of the incident light. For example, in full-spectrum light a tooth might normally have a reflectance curve such as that shown in Figure 7-16.

If the source of light changes, however, the apparent color can change dramatically. The normal transmission curve of a typical incandescent light bulb (Figure 7-17) contrasts with the normal transmission curve of a fluorescent light tube (Figure 7-18).

Figure 7-19 shows the two different reflectance curves a tooth would display under these two different sources of light. Even with a constant source of light, the light that actually reaches the tooth can be affected by the colors in the environment at the moment. A dark shade of lipstick or an intensely colored outfit can easily affect the available spectrum for reflection by the tooth.

In addition, there are variations in operator sensitivity. Color blindness is no small problem. It is a fact that nearly one in 10 dentists in the United States has some degree of color deficiency in the red and green areas. If other color deficiencies are also included, the percentage of visually deficient operators goes up even further. The likelihood of a male dentist being color deficient is more than 10 times that of his female counterpart (Table 7-2).

Fortunately, most of these operators are not color "blind" but only color deficient. Unfortunately, this means that most of them are not even aware of their problem. In most situations, such a deficiency is of little importance, but in the case of

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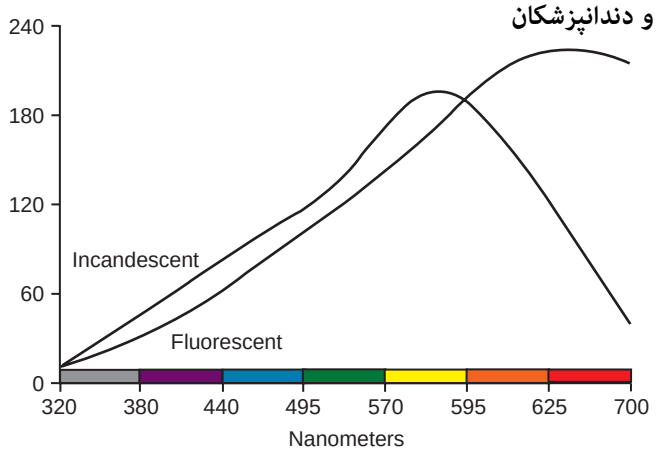


FIGURE 7-19 Reflectance curve of a tooth under two different sources of light, incandescent and fluorescent.



FIGURE 7-20 The color of the teeth has changed because of desiccation.

TABLE 7-2 Color Blindness Distribution in the General Population and Various Groups

	INCIDENCE IN MALES	INCIDENCE IN FEMALES
Caucasians	8.08 ± 0.26%	0.74 ± 0.11%
Northern European		
American		
Australian		
Asiatics	4.90 ± 0.18%	0.64 ± 0.08%
Japanese		
Chinese		
Others (e.g., Korean, Filipino)		
Other Racial Groups	3.12 ± 0.40%	0.69 ± 0.07%
American Indian		
Mexican		
African American		
Eskimo		

esthetic dentistry, even minor weaknesses in color perception can compromise the intended results.

Obviously, then, it is to each dentist's advantage to be tested for color sensitivity. Even if a minor deficiency is found, a simple solution may be to have a colleague or staff member who is not color deficient confirm all color choices.

Even when the dentist's innate visual color sensitivity is found to be optimal, however, there is still no guarantee of consistent color judgments. The eye can sustain a decrease in sensitivity from nerve fatigue, the same as any other sensory organ. For this reason, it is important to avoid staring at the tooth and shade guides when taking a shade. Instead, short glances should be employed, with the first reading considered the most accurate.

One other important point: during the cementation step for veneers, the area is often isolated. If many laminates are involved, the isolated teeth have time to desiccate during the extended procedure. After only a few minutes of drying, the appearance of the teeth begins to change. The dried teeth are markedly whiter, and their surfaces more opaque. To demonstrate this, a patient with perfectly matched anterior teeth had a rubber dam placed, exposing the maxillary teeth to air for 20 minutes. When the rubber dam was removed, the difference in appearance was clearly evident (Figure 7-20).

Obviously, any shade decisions must be made while the natural teeth are not desiccated. When laminates are placed in the mouth and the shade is perfect, the neighboring teeth may be slightly whiter at the completion of the procedure. If this is anticipated, the patient should be warned in advance that the laminated teeth will appear a bit dark for one day but that they will color match as soon as the unlaminated teeth rehydrate.

METAMERISM

Most evidence points to the fact that the eye is a tristimulus colorimeter. Like the color television, which is capable of producing thousands of colors from only three basic color phosphors, the eye can discern a nearly infinite range of color using receptors for only three wavelengths. Also like the color television, these three receptors seem to have their greatest sensitivity around the colors of red, green, and blue. Although this design may be conservative for the number of required receptors for color vision, it does lead directly to the problem of metamerism, the effect that is achieved when two samples of color appear to match in one type of light but do not match in another.

Simply put, the eye is incapable of distinguishing between certain combinations of light stimuli. Both of the spectral curves shown in Figure 7-21 are perceived as yellow-green. Under full-spectrum lighting, the surface that reflects light centered around 540 nm is indistinguishable in hue from one that reflects two loci of reflectance, one centered around 490 nm and the other around 650 nm.

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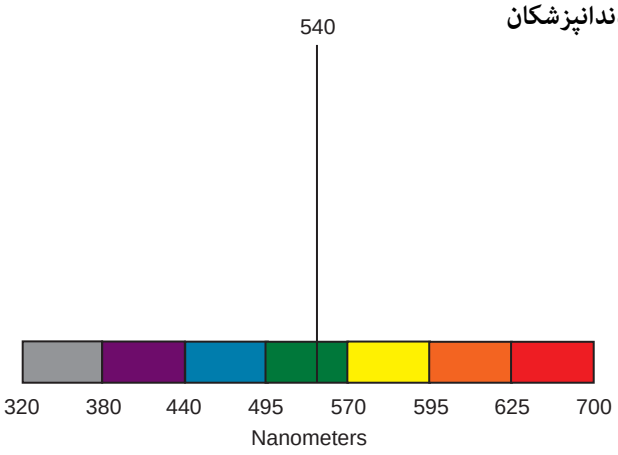


FIGURE 7-21 Two spectral curves, both of which are perceived as yellow-green.

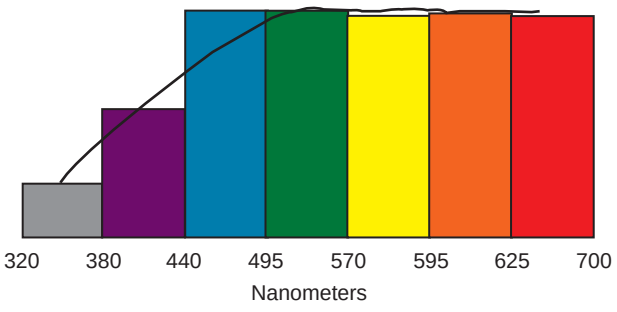


FIGURE 7-22 Transmission curve of natural daylight.

When the lighting source changes, however, the perceived color of the objects also changes. Sunlight on an average day produces a spectral distribution similar to that seen in Figure 7-22. Contrast this with the curve shown in Figure 7-17 for typical tungsten light. As can be seen, when a surface is illuminated by a tungsten source, there is very little light in the 490-nm range available for reflection. In this situation, the samples no longer match.

This example is by no means unique. A nearly infinite number of combinations can be computed that create metameric pairs.

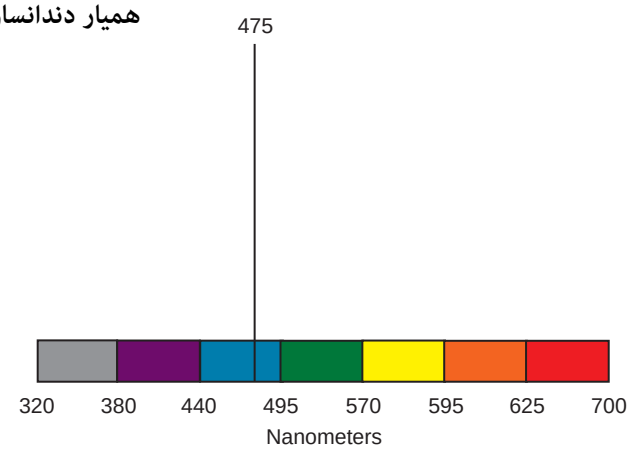


FIGURE 7-23 Representation of a metameric pair that would appear to be blue under full-spectrum light but that would not match under other light sources.

Figure 7-23 demonstrates one of the many pairs that would appear to be blue under full-spectrum light but that would not match under other light sources. The metameric pair in Figure 7-23 results from the fact that the eye cannot distinguish between a pure blue hue at 475 nm and the combination of 440 nm (reddish blue) and 490 nm (greenish blue), one of the many pairs that would appear to be blue under full-spectrum light.

The pair shown in Figure 7-24 would be seen as yellow. Unfortunately, metamerism is a common illusion in the dental field. A factor that complicates this even further is the fact that human vision is most acute in the yellow range—a color range of particular importance in dentistry. In other words, not only is it impossible to accurately determine a nonmetameric color match, but human eyes are uniquely most sensitive to this error in the yellow range.

Still another type of metameric pair can be created as a result of the fluorescent nature of teeth. It is well recognized that when natural teeth are exposed to ultraviolet light, they seem to glow. The apparent glow of the teeth is a result of their own natural fluorescence. Early attempts to achieve natural-looking fluorescence in porcelain involved the inclusion of small amounts of radium into the porcelain mixtures, a practice that is no longer used. Instead, certain fluorescing rare earths are incorporated into the porcelain.

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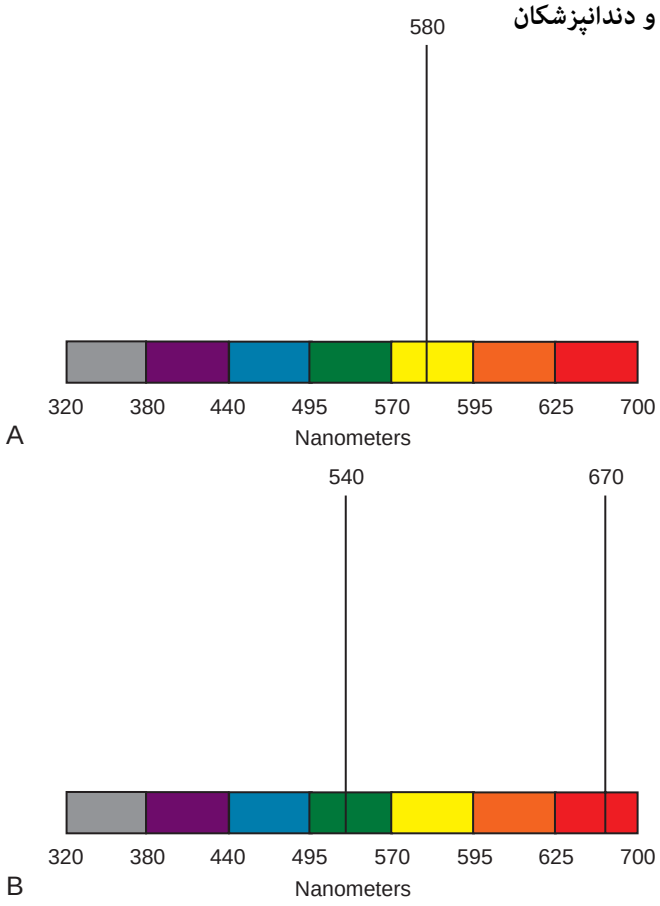


FIGURE 7-24 A metameric pair in which both A and B would be perceived as yellow. This is an example of a metameric illusion.

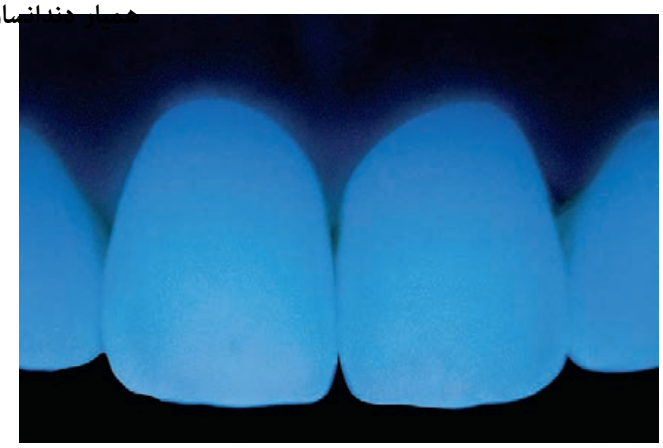


FIGURE 7-25 Teeth exposed to ultraviolet light appear to glow because of the natural fluorescence of the teeth.



FIGURE 7-26 VITA Easyshade. *(Courtesy Vident, Brea, California.)*

Tooth fluorescence is not uniform across all shades. Early this century, when several dentists made a careful study of the fluorescent properties of teeth, it was noted that certain teeth were more fluorescent than others. Usually teeth with the lighter shades were the most fluorescent. This led directly to the development of dental porcelains with variable fluorescing properties.

When a fluorescent porcelain is used in place of the nonfluorescent one, the shade match can even carry over to situations with intense ultraviolet light (Figure 7-25). Clearly there is a distinct advantage to creating the porcelain laminate veneer crown or bridge out of a variable fluorescing porcelain. There may be some advantage to using a luting agent that displays variable fluorescence as well.

INNOVATIVE ELEMENTS

Digital Shade-Scanning Devices

True-to-life shade matching is the key to creating both indirect and direct esthetic restorations. Obtaining the precise shade is always dependant on a number of factors that are less than objective, including the age, the gender, and the experience of the observer. To put it simply, not everyone is equally adept at taking accurate shades. This in itself need not prevent any dentist from doing very successful esthetic dentistry. After all, individuals on staff can assist in this part of the procedure as they assist in other aspects in overall treatment. Electronic shade matching, on the other hand, introduces an objective, readily reproducible and easily communicable data system that provides a predictable result every time.

VITA Easyshade

The VITA Easyshade (Vident, Brea, California) (Figure 7-26) is a hand-held spectrophotometer that has been designed for quick and accurate shade determination and is capable of accurately measuring a very varied range of VITAPAN Classical and VITAPAN 3D-Master shades. All that the dentist or the assistant is required to do is to select the tooth to be measured and then to place the tip of the spectrophotometer handpiece directly on the tooth (see Figure 7-5). A button is pressed, and the touch screen indicates the correct shade in both 3D-Master

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FIGURE 7-27 VITA Easyshade Compact (Vident). A, Handpiece and base with on-board calibration block. B, The interface screen found on the heel end of the handpiece. C, Probe tip with infection-control shield in place. *(Courtesy Vident, Brea, California.)*

and Classical values. This information is recorded, and the shade-taking process is done. Easyshade comes with USB and serial ports for expanded use with computers. Easyshade simplifies the shade-matching procedure, providing high-quality, predictable, dependable, totally objective shade determination, resulting in fewer reshades, fewer color alterations, and an overall superior esthetic product.

VITA Easyshade Compact

The VITA Easyshade Compact (Vident) is even more versatile (Figure 7-27). Electronic shade matching has replaced guesswork, estimation, and approximation in shade determination, for both indirect and direct restorations. Many practitioners limit electronic shade taking to indirect restorations. These very same units can, and should, be used for every esthetically critical anterior or posterior restoration, whether ceramic or composite. The Easyshade Compact is a spectrophotometer shade-matching device that assists the practitioner or auxiliary in evaluating the shade for indirect or direct restorations very quickly and effectively. It is also able to verify the shade of lab-produced work *before* the patient is brought in for cementation. The Easyshade Compact is cordless, portable, and lightweight enough for everyone. The technique is easily taught or learned. Its color readings are based on the VITAPAN Classical and VITAPAN 3D-Master shades. The Easyshade Compact self-illuminates the target area, making the results independent of lighting conditions, operatory colors, clothing, facial tones, and so on. The unit can store up to 25 shades at a time. Transferring the shade information to the technician is easy; the LabRx software prints out all the collected data, eliminating human transfer error. Easyshade Compact's convenient light-emitting diode (LED) technology offers extended use. The unit features step-by-step instructions and displays the tooth shade results within seconds: Simply press the handpiece switch to turn the unit on, calibrate right on the unit before each use, place the measuring probe on the tooth (make certain that the probe is flat on the tooth), and press the switch. Look on the bottom of the unit, and read the shade. Perfect shades every time, and anyone can do it!

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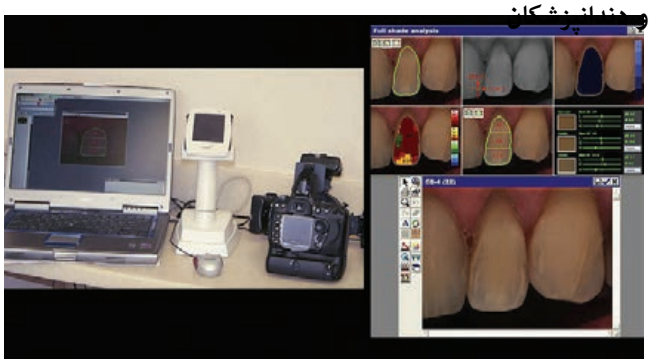


FIGURE 7-28 MHT SpectroShade system. *(From Chu SJ: Clinical steps to predictable color management in esthetic restorative dentistry,* Dent Clin North Am *51:473, 2007.)*

MHT SpectroShade

The Windows-based SpectroShade system (MHT Optic Research AG, Niederhasli, Switzerland) uses dual digital cameras linked through optic fibers to a fully functional spectrophotometer, allowing the system the ability to consistently and accurately measure natural tooth coloration in reference to any material or shading system (Figure 7-28). As the system measures the color characteristics of the natural tooth precisely and scientifically, it indicates the deviations in value, chroma, and hue from a standard that provides all the information necessary to modify the restoration and accurately match the tooth.

The multifocal dual lighting mechanism illuminates the tooth such that in addition to the colorimetric values, it is possible to take readings of surface translucency and reflectivity. This permits the SpectroShade to provide consistent shade measurements regardless of the environmental lighting conditions or other operatory variables.

Cynovad ShadeScan

The Cynovad ShadeScan (Cynovad, Montreal, Canada) employs innovative digital artificial vision technology to provide instant, accurate, and consistent shade measurements (Figure 7-29). The system is user friendly and is integrated with computed-aided design and manufacturing (CAD/CAM) technologies. The shade is measured by a handheld optical device from a single image of the whole tooth at the click of a button.

The dentist can instantly obtain a shade map of the whole tooth with various established and popular shade systems. The software in the ShadeScan generates a paint-by-numbers map of the tooth, keying various areas of the dental surface to the selected shade guide. Through use of different resolutions, translucent and opaque areas are identified for optimized characterization of the restoration. ShadeScan creates full-tooth translucency maps to facilitate fabrication of esthetic restorations.

For the lab technician, differences in value, chroma, and hue between the natural tooth and the shade guide ceramic are indicated, directing the small color modifications that will make the restoration look totally natural. The ShadeScan identifies and highlights markings on the tooth as well as indicating the surface texture.



FIGURE 7-29 Cynovad ShadeScan Shade-Selection Device. *(From Brewer JD, Wee A, Seghi R:* Advances in color matching, *Dent Clin North Am 48:341, 2004.)*



FIGURE 7-30 ShadeEye NCC. *(Courtesy Shofu Dental GmbH, Ratingen, Germany.)*

Shofu ShadeEye NCC*

The Shofu ShadeEye NCC (Shofu Dental GmbH, Ratingen, Germany) is a mobile, wireless measuring unit that analyzes the tooth shade digitally, and instantaneously transmits the information to the main unit through an infrared interface (Figure 7-30).

The software in the main unit then calculates the appropriate porcelain mixture that will provide the exact color that has been

*The ShadeEye NCC is no longer available.

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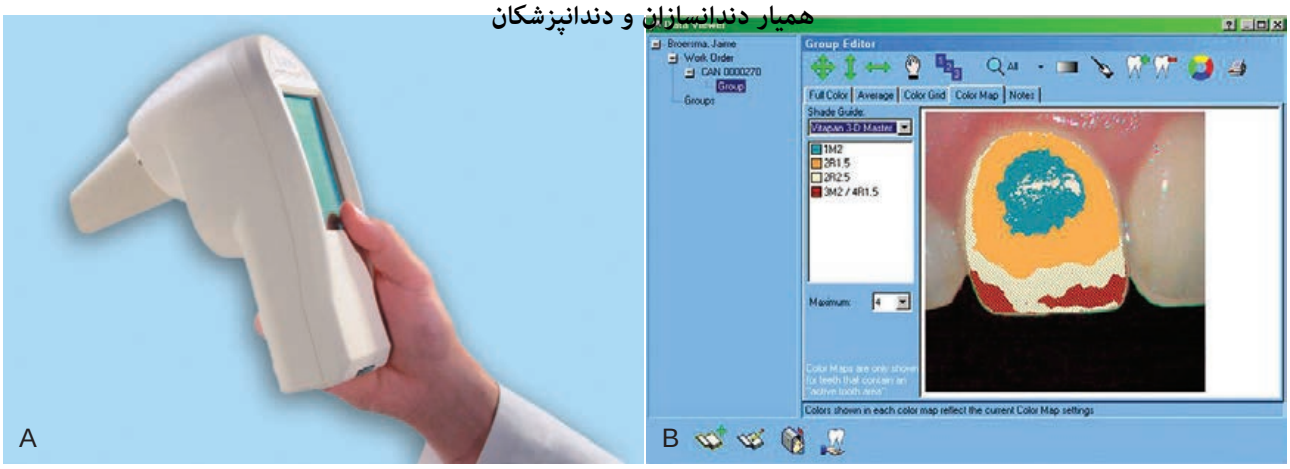


FIGURE 7-31 The X-Rite ShadeVision System (X-Rite, Grand Rapids, Michigan).

scanned by the mobile unit. The default on the ShadeEye NCC calculates the ceramic mixture requirements for Shofu's Vintage Halo porcelain, but the corresponding shade information for other color guides and ceramics is also available.

The ShadeEye NCC's xenon flash light source eliminates all ambient light that might interfere with obtaining a correct reading. It also eliminates visually disruptive factors such as the angle of viewing and the position of the patient or the dentist. The scan is fast and objective, providing information that facilitates data transfer between the dental practice and the dental laboratory.

METALOR Ikam Shade Analysis System

The METALOR Ikam shade Analysis System (METALOR Dental AG, Oesingen, Switzerland) combines digital photographic technology (Olympus) with color-analysis software. The system accurately records and transmits the color, shape, and contour of the natural teeth for use by both the dentist and the technician.

The color reference system of the Ikam is based on fired ceramic samples rather than on traditional shade tabs. This measurement of the undistorted color of the tooth eliminates subjective interpretation. Many of the leading ceramic systems' color data are included in the Ikam shade-analysis software. Reflections often appear on the tooth surface as a bright white glare, obscuring dental coloration. Ikam corrects this type of distortion by eliminating the reflections so that the color underneath can be analyzed. The dentist selects the level of detail to be acquired for each specific case: coarse (predominant shade), medium, or fine (detailed analysis). The selected image level produces a shade map of tooth that provides the technician with all the information necessary to create a naturally appearing restoration.

X-Rite ShadeVision System*

The X-Rite ShadeVision System is a handheld, portable measuring device that analyzes the shades of the tooth to be restored and the surrounding teeth with specialized imaging software.

*X-Rite ShadeVision System has been discontinued.

Note: The cone-shaped sensor (see Figure 7-31, *A*) of the Shade-Rite is pointed at the tooth to be replaced (and/or the adjacent teeth), and the images are acquired. Once the shade taking is done, the sensor is replaced in its cradle. As the unit clicks into the docking station, it initializes the system's software.

The shade data is uploaded, and the software selects the most appropriate shades from the designated ceramic system. The intuitive software leads the dentist through a step-by-step process that includes measurement, mapping, applying the shade guides, and creating a prescription for the lab (Figure 7-31, *B*). The files are readily accessible and easily transmitted via the Internet. The Shade-Rite software allows the dentist to easily and clearly organize patient files.

ARTISTIC ELEMENTS

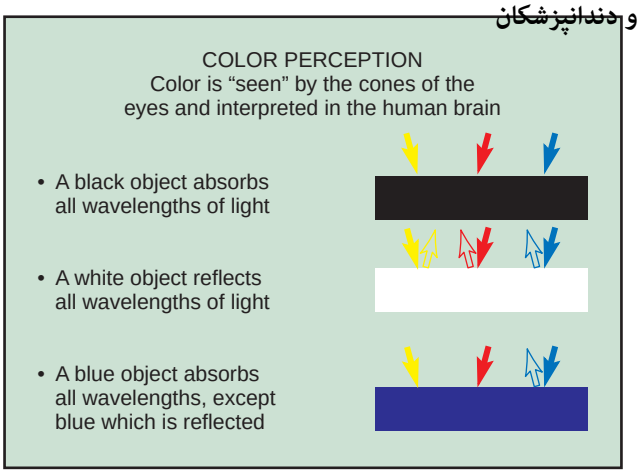
Chairside shade matching can be a difficult and demanding exercise. It is a process that can require many steps, each of which must be performed accurately under standardized environmental conditions. These parameters have been designed to ensure that the color information that appears in a tooth can be accurately documented. Electronic shade matching is less technique sensitive, and it is far easier and more predictable.

Alas, this is but the first step in the overall process. There is very great difficulty involved in accurately conveying a highly subjective collection of interpreted data (the shade match) to another individual, considering that the terminology and concepts of this science are barely standardized.

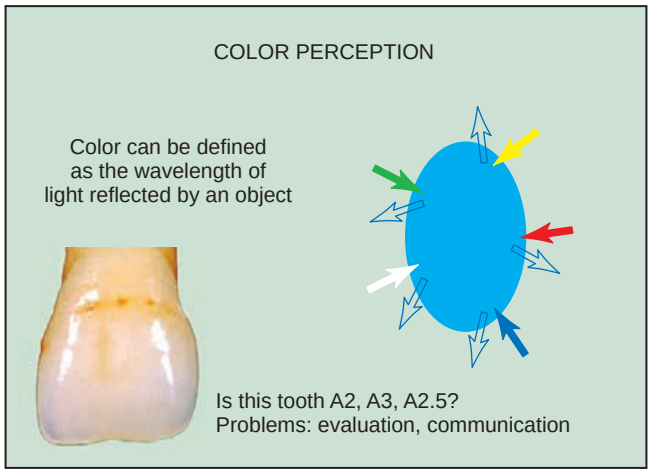
The second individual (the lab technician) then must reinterpret this information in terms of the lab approach to color, which is somewhat different from the clinical one, and must then build a tooth that recreates the esthetics of a patient whom he or she has never seen.

And the trek is not yet over. During the cementation process, the color and the opacity of the resin cement (not to mention the stump color of the underlying tooth) may affect the overall appearance of the final restoration. (Composite resin cements

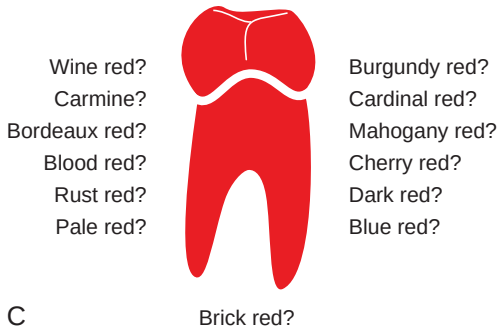
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A



B



C

FIGURE 7-32 **A, Color perception as it is interpreted by the brain. B, Color is subjective to each individual person, which is demonstrated when attempting to determine the color of the tooth. C, Although it can be agreed that this is a red tooth, people's opinions regarding the type of red will differ.**

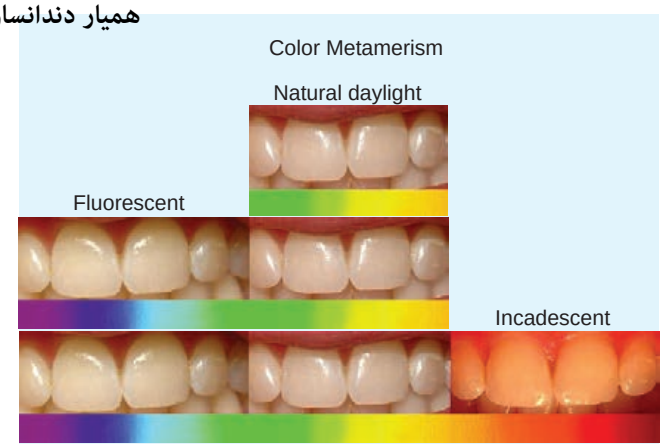


FIGURE 7-33 **The type of light can affect on the perceived color of teeth. When compared with the teeth seen in natural daylight, the fluorescent light gives the teeth a yellow-green cast, and the incandescent light a yellow-red cast.**

also tend to change color slightly during polymerization—just one of the many complicating factors.)

Indeed, it is a wonder, and a testament to the skills of dentists, their staffs, and lab technicians, that so many ceramic restorations look so good.

Color is seen by the cones of the eyes and interpreted in the human brain. A black object absorbs all wavelengths of light. A white object reflects all wavelengths of light. A blue object, for example, absorbs all wavelengths of light except blue, which are reflected; this is how the human eye determines what is blue (Figure 7-32, *A*).

Color can be defined as the wavelength of light reflected by an object. For the human eye, however, this is not an absolute definition (Figure 7-32, *B*). In looking at a tooth one can ask what color the tooth is and receive various responses from various people. For example, when looking at a particular tooth and in trying to define the coloration of the tooth, it may obviously be red (Figure 7-32, *C*). The question is what kind of red it is? And even though it may be defined correctly as "wine red," the unstated additional explanation of red *burgundy* or red *shiraz* can make a vast difference in the implied coloration. Of course, when dealing with teeth one is not dealing with reds but with very fine gradations of whitish yellow, which are perhaps even more difficult to describe than the various kinds of reds that are commonly seen. Just to complicate things even further for the trained shade evaluator, color metamerism can affect the perceived color of the teeth. Under natural daylight these teeth have a certain coloration; under fluorescent lighting these same teeth appear to be more yellowish or greenish (Figure 7-33). This is the fluorescent lighting that one often finds in office buildings and dental treatment rooms. Incandescent lights that comprise the majority of chair or unit-mounted dental operatory lighting make the teeth appear yellowish red. Thus, coloration under regular dental lights is very tilted to the reddish area of the spectrum. In fact, the ability to communicate color between two or more individuals based on an analysis of shade by each individual in differing locations under differing conditions is not only very difficult, it is virtually impossible.

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TREATMENT PLANNING OPTIONS

The light seen by humans is composed of wavelengths of energy (Figure 7-34), and the human eye sees the colors in the visible portions of light going from just under 400 to just under 800 nm. The visible light spectrum runs from 380 to 780 nm. In order for these colors to be interpreted, a number of techniques have been developed for separating the measurement of color into various components.

Shade selection, like occlusion, has historically been made overly complex. In dental school the student begins to wrestle with the concepts of value, chroma, and hue. The concepts are defined, analyzed, and promptly forgotten until the next lecture on shade selection, at which time they are relearned and then reforgotten. Why add all this complexity to a procedure that can be easily explained through an intuitive system?

First, throw out the words *value, chroma,* and *hue*. These are not intuitive terms. It is not intuitive for something with a low value to be dark. Why not simply say "lightness" level? The word *chroma* does not represent the intuitive concept of intensity or saturation level of color. Why not say "saturation" level of color? The word *hue* is just a fancy technical word for color. In the process of shade selection for teeth, hue usually indicates the redness or yellowness of a tooth. Why not call it "color"?

Digital color shade matching, on the other hand, is much more straightforward. Simply isolate the tooth to be shade matched, and remove all debris from the surface as well as all extrinsic discoloration. Move the lips or cheeks away from the tooth so that it is readily accessible to the shade-matching probe, and then place the probe as indicated to the tooth surface, fully flat against the surface and ensuring that no extraneous materials such as gingiva or the tongue are captured (see Figure 7-5). Press the capture button, and the shade distribution will typically appear on the screen within a matter of milliseconds.

The digital color map can be used to analyze the overall coloration of the tooth (Figure 7-35, *A*). It can also be used to analyze the coloration of thirds of the tooth in segments (Figure 7-35, *B*) or to map the entire tooth surface as indicated (Figure 7-35, *C*). Another shade-scanning device with a similar approach achieves the same result (Figure 7-36). Some spectrophotometers are even designed to demonstrate the translucence of various areas of the tooth (Figure 7-37). Most descriptors of translucence utilize an average reading that is assumed to apply to the majority of the tooth surface. A large part of the esthetics, however, involves translucence at the incisal third and into the mesial, distal, and interproximal regions. This is actually quite evident at first glance. What is not so readily evident is that the most incisal edge is not translucent but takes on the opacity of the rest of the tooth. If this is not reproduced in a restoration, the color match will seem to be somehow incorrect. The translucency map shows the opacity gradient that occurs toward, but not right at the incisal edge. Once the nontranslucence of the incisal edge is seen in this diagram, it is clearly evident in the tooth and helps both the dentist and the lab technician to create an accurate color match in the ceramic or composite restoration.

TREATMENT CONSIDERATIONS

During the preparations for electronic shade matching, the teeth should be clean of debris, food, dental materials, impression materials, and all other extraneous chromatic materials. The teeth should also be wet or moist; if dry they might exhibit a chalky appearance. In fact, commencing a procedure, such as cementation of crowns, bridges, or veneers, it is a good idea to take a shade measurement at the very beginning of the

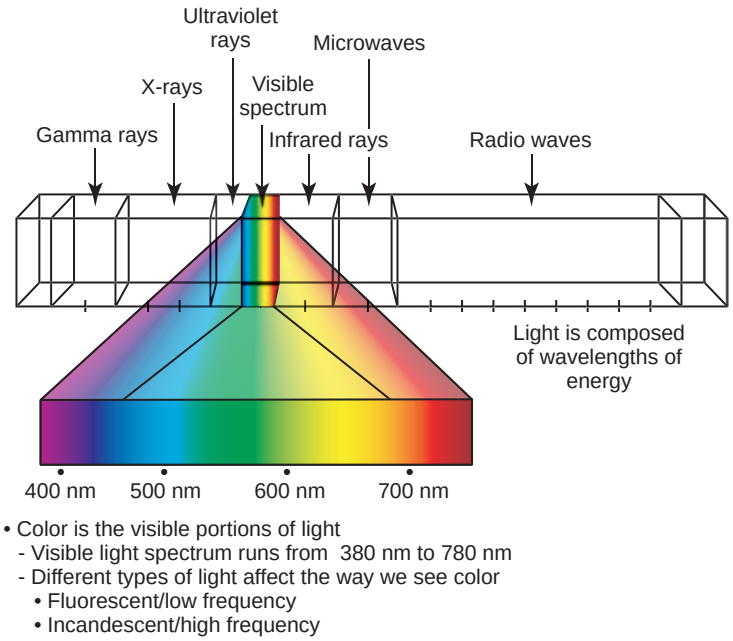


FIGURE 7-34 **The electromagnetic spectrum. Humans see colors in the visible portions of light going from just under 400 to just under 800 nm.**

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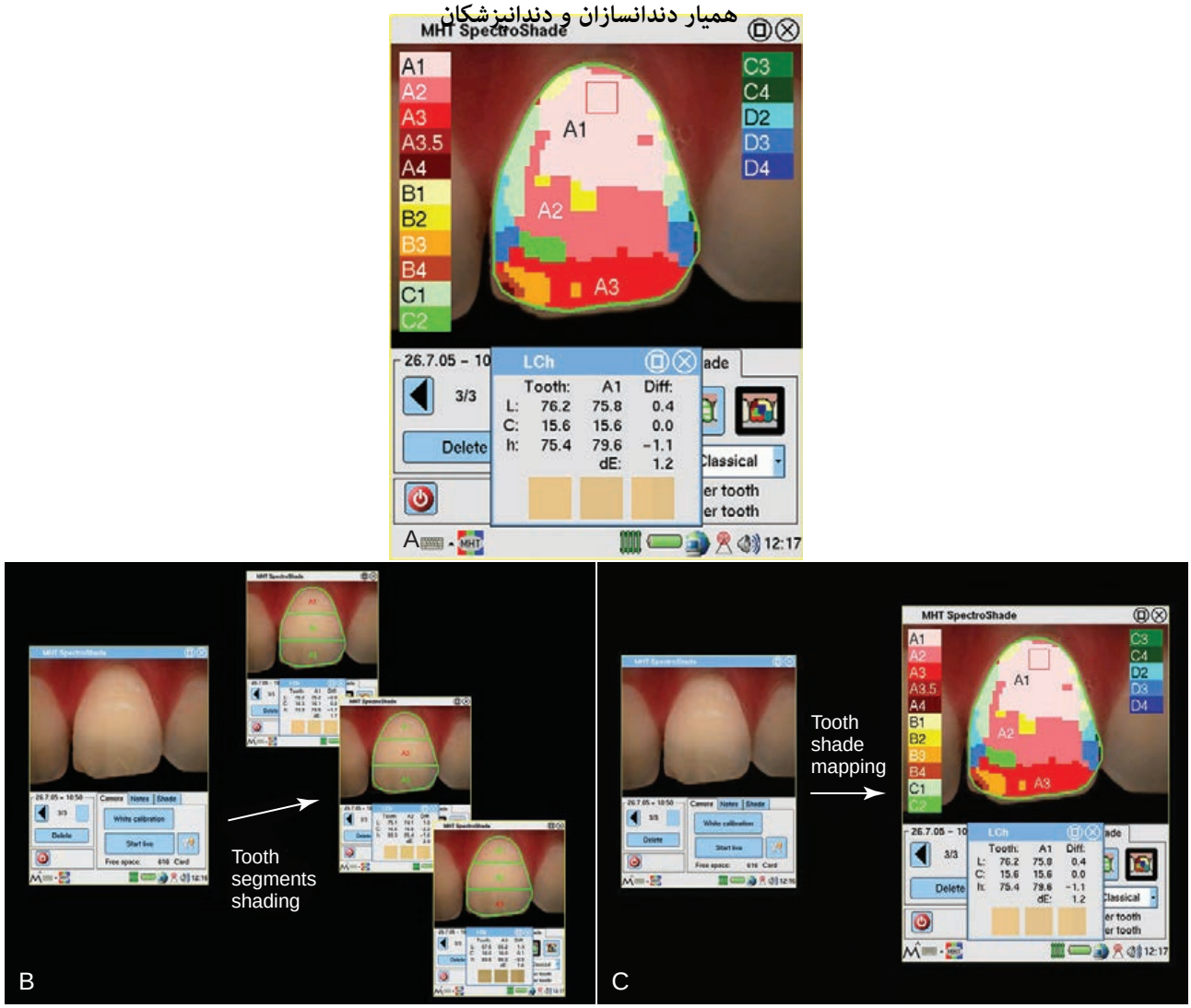


FIGURE 7-35 A, MHT SpectroShade analysis of the overall coloration of the tooth. B, Analysis of the coloration of thirds of the tooth in segments. C, Map of the entire tooth surface.

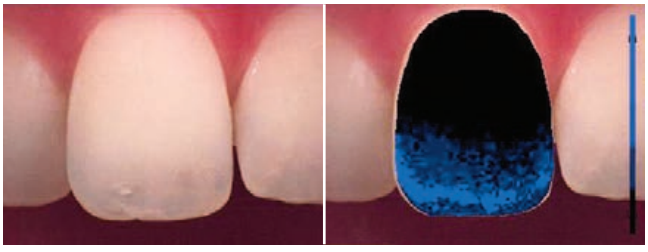


FIGURE 7-36 The SpectroShade can determine the relative translucency of the tooth regions. In this central incisor the gingival half is quite dark (opaque), whereas the incisal half becomes lighter (translucent) approaching the incisal edge. At the incisal edge there is a thin opaque layer that could easily be missed by the clinician not using electronic shade matching.



FIGURE 7-37 Translucency as detected by the Cynovad ShadeScan Shade-Selection Device.

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treatment. The teeth tend to be isolated and kept dry throughout lengthy dental treatments. As they dry, they become whiter and chalkier, a condition that is resolved once they rehydrate hours or days after the treatment. Therefore taking a shade at the beginning of the procedure will guarantee that the restorations—crowns, veneers, and such—will be the correct natural dental color rather than the desiccated white, which will not appear to match untreated adjacent teeth after insertion. The procedure for shade matching is actually very simple and straightforward. Simply follow the instructions for the particular electronic shade-matching system that is being used. Different systems and different units have different requirements, and it is important to be familiar with the requirements of each particular one. Most electronic shade-matching devices are rather simple to use: simply point the wand at the tooth and keep its glass fiber surface relatively flat in relation to the tooth surface that is to be measured. Then simply press the appropriate triggering mechanism to take the shade. Typically shade taking takes only moments, and therefore patient and operator fatigue and patient movement are unlikely. For some devices, patient or operator movement is problematic, and in these situations the patient must be urged to sit still, with the head and neck firmly supported. The lips, tongue, and cheeks must be retracted from the shading area.

The last part of the shade-taking procedure is the documentation. Documentation, in most cases, involves a simple printout or electronic transmission from the shade-matching device into the patient's chart and to the lab technician. Less sophisticated devices require a manual recording of the data onto a prescription sheet. It is important that all the information available be recorded accurately for ease of shade matching at the laboratory.

EVIDENCE-BASED PRINCIPLES

Shading or shade matching of restorations was an unpredictable part of dental procedures until about the mid-twentieth century. Then an empirical shading system using the colors that seemed to be most commonly required began to be employed. This empirical approach became the VITA System and has been used throughout the world ever since (see Figure 7-8, *A*). Its 16 shades (plus bleached shade tabs) provide a standardized, if not entirely accurate, approach to systematic shade matching. In the late 1990s the VITAPAN 3D-Master Shade system (see Figure 7-8, *B*) was developed. This is a much more accurate system that is based on value *first*, chroma *second*, and hue *third*. This is the procedural sequence that is used by the human eye to perceive color, and the VITAPAN 3D-Master system accomplishes the process in a relatively intuitive manner. It has 26 shades (plus bleach tabs), and the shades are all related and positioned within the defined system so that intermediate shades can be accurately interpolated. These shade-matching systems have been studied extensively, and within their limitations have proved very useful to the practitioner. Since the turn of the millennium, a number of spectrophotometric and colorimetric shade-matching devices have been developed. Generally the better shade-matching devices are more accurate, more predictable, more readily useable, and much faster than the older visually based shade-matching tab systems. There is extensive documentation that demonstrates that electronic shade matching is not only more accurate and more predictable than the visually based systems but more communicable and reproducible as well.

TROUBLESHOOTING

In spite of all the best intentions of both the practitioner and the lab technician, problems in shade taking, shade communication, and shade creation can still occur with tab-based systems. When these problems arise, it is helpful to ascertain the specific problem. For example, if shades are consistently incorrect, the source of the inaccuracy may well be the operatory lighting or the biased illumination conditions wherein the shade was taken. Standardized lighting may be the solution. Occasionally there are difficulties relating shade guides to porcelain or composite; the problem is that the shade tabs or the guides may be acrylic *or* ceramic. Of course, ceramic tabs will match the ceramic restorations, and the acrylic tabs the acrylics. It is inadvisable to use an acrylic shade guide for a ceramic restoration. Furthermore, when shade matching composites for direct restorations, it is very important that the shade tab be from the same batch of composite as the restorative material; different batches have slightly differing coloration. If shade matching is consistently thorny (and perhaps difficult to understand) for the practitioner, the cause might be partial or total red-green color blindness (predominantly in males). The problem could also lie with advancing age or could be a gender issue (women see color better than men). Sometimes observed colors are not correctly documented—either written down incorrectly or not noted at all. This implies lack of training and/or experience and is most easily corrected. Of course, the most predictable method to avoid the need for correction is the electronic shade-matching process, where the data are transmitted directly to the laboratory or printed out from the actual reading (Table 7-3).

Most shade instructions to dental laboratories are monochromatic: they consist of a single shade for one or more teeth. This is a practice that cannot realistically result in an esthetic restorative smile.

Teeth are not monochromatic. Therefore proper shade matching, although it takes time and effort, certainly yields a better result. Occasionally, in spite of correct matching in the dental practice and good lab work at the bench, shades still do not match. The reason in all likelihood is that, despite all the proper steps having been taken at each end of the information chain, the data transfer between the dentist and the lab technician is lacking, inappropriate, not readily comprehended, or otherwise miscommunicated. Sometimes the matching at the dental office is correct, yet the restorations are improperly colored. This may occur because the lab technician is not following the shading instructions or is not using the prescribed porcelain. Even though labels on various brands of porcelains may indicate the same color, they may actually differ somewhat; porcelains of a certain coloration from one manufacturer may

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TABLE 7-3 Steps That Can Go Wrong during Color Matching and Communication

STEP	PROBLEM	CAUSE	SOLUTION
Lighting	Consistently incorrect shades	Shades are being matched under light-biased conditions	Create a uniformly lit environment
Matching shades to natural teeth	Difficulty relating shade guides to porcelain and composite	Acrylic shade guides may not be color-corrected to porcelain and/or vice versa	Use shade guides that are specifically designed for specific procedures and materials
Perception	Consistent difficulty matching or actually seeing color differences	Operators: Partial or total red-green color blindness Age Gender	Shade-matching person(s) must have good vision, should be younger; women should be involved
Interpretation	Observed colors are not correctly documented	Lack of training and experience	Training of dentists and staff in shade matching
Mapping	Teeth are not monochromatic Most shade instructions to labs indicate a single shade?	Proper mapping takes *several* color readings of a tooth and more time to document	Appropriate prescription sheets that demand more color information
Communication	In spite of correct matching and good lab work, shades do not match	All the steps are done correctly, but communication between dentist and lab is lacking	Clear, complete, precise, comprehensible documentation that accompanies *every* case
Lab interpretation	Matching is correct, yet shades are off	Lab is not following shade instructions closely or is not using the prescribed porcelain	Labs must learn shade matching alongside dentists and use the prescribed ceramics, not substitutes
Lab ceramic selection	Colors slightly off	Dentist prescribed one ceramic, lab used a different material	Dentist and lab must coordinate ceramics
Lab ceramic application	Colors slightly to completely wrong	Lab technician training is not uniform, and ceramic results may vary	Choose lab and technicians carefully and make certain that they continue their education regularly
Cementation	All-ceramic crown looks great on try-in but loses appearance on cementation	Try-in pastes are often not closely matched to their cements Cement is too opaque Cement is too dark	Use less opaque (or nonopaque) cements that are matched to the tooth and restoration color

not correspond to the similarly-labelled shades of another. If restoration colors are consistently slightly off, the most likely scenario is that the dentist prescribed the ceramic of one manufacturer, and the lab used ceramic from a different provider. Occasionally the coloration of the restoration is completely wrong because the layered application of the ceramic at the laboratory was not uniform and the baking distorted the intended shade.

All-ceramic crowns often have a degree of translucence. This can contribute greatly to the "natural" appearance of the restoration, particularly if the laboratory has taken into account the shade of the remaining stump (abutment). If no accommodation is made for the underlying color, the show-through from the stump can compromise the overall appearance of the crown. Partially translucent all-ceramic crowns may look great on try-in, but the color match disappears with cementation. This is most likely caused by an opaque or colored cement. Try-in cements may or may not closely match their corresponding cements, or the cement may be too thick or too opaque. Generally it is best to use clear, translucent cements.

NEAR-FUTURE DEVELOPMENTS

The process of digital shade selection is relatively easy, predictable, and fast. It is difficult to imagine procedures that are even easier or more accurate. It is not likely that the electronic shade selection process, which takes a fraction of a second, can be made any faster. Many of the spectrophotometers today are so accurate that there is little clinical reason to make them more so. However, the real future of shade matching is likely to come from another direction: communication between the electronic shade-matching device and the composite or ceramic that is to be inserted in the mouth. New directions in research are

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developing techniques to create a film of esthetic coloration that is applied to the surface of a relatively monochromatic ceramic or composite restoration and then baked or cured, impregnating it directly into the surface of the restorative material. The digital or the electronic shade device thus creates a map or film that is, in effect, printed out and applied directly to the surface of the restoration, which is ready for insertion within moments. Another possibility is the development of color-reactive composites and ceramics that react to laser activation from a shading unit. The electronic shade match is captured with current technology, and then this coloration is laser holograмed in the restorative material at the lab bench or on the restoration in the mouth. Although these techniques may seem far-fetched today, it has to be remembered that a decade ago electronic shade matching was also the stuff of science fiction.

Clinical Shade Techniques

A number of clinical shade-taking techniques may be selected by the dental team. The classic shade-matching kits (such as the VITAPAN Classical Shade Guide [see Figure 7-8, *A*]) are based on more or less commonly occurring tooth colorations. However, each of these shades are based on their own individual color patterns and cannot be effectively interpolated into intermediate tints. The more recently introduced shade-matching systems (such as the VITAPAN 3D-Master Shade system [see Figure 7-8, *B*]) have been developed on a more scientifically based methodology that divides the visual envelope of tooth coloration into an organized system of intermediate steps. With these shade kits, intermediate shades can be accurately determined, specifically communicated, and confidently reproduced at the dental laboratory. By far the easiest and most predictable means of shade taking is the use of a digital spectrophotometer (such as the VITA Easyshade Compact [see Figure 7-27]) that is regularly calibrated and can be used effectively under all lighting conditions, both chairside and at the laboratory bench.

The dental operatory presents many obstacles to taking accurate shade matches of teeth. The metameric effects of strongly colored objects in the treatment room and the extreme variance of external and internal lighting confuse the issue even further. The color of the dental chair (Figure 7-38, *A*) and cabinetry may influence the perceived coloration of the teeth. Similarly, strongly colored clothing worn by the patient or the staff (Figure 7-38, *B*) contributes to a loss of perception that can throw visually obtained shades off. Even the color of the walls (Figure 7-38, *C*) and the flooring can confound the most astute observer. Many operatories are designed with extensive windows to the outside world (Figure 7-39, *A*). Although these features tend to contribute to a relaxing environment for the patient and the dental team, the light that enters from the outside varies from day to day, from season to season, and from morning to night. Thus the external available light that bathes the patient in the dental chair during shade taking not only is highly variable, but may contribute to metameric problems in the shading of restorations. The dental overhead light, a feature of every operatory, is typically an incandescent light source, and this throws the coloration of the teeth toward the red-yellow end of the spectrum. The

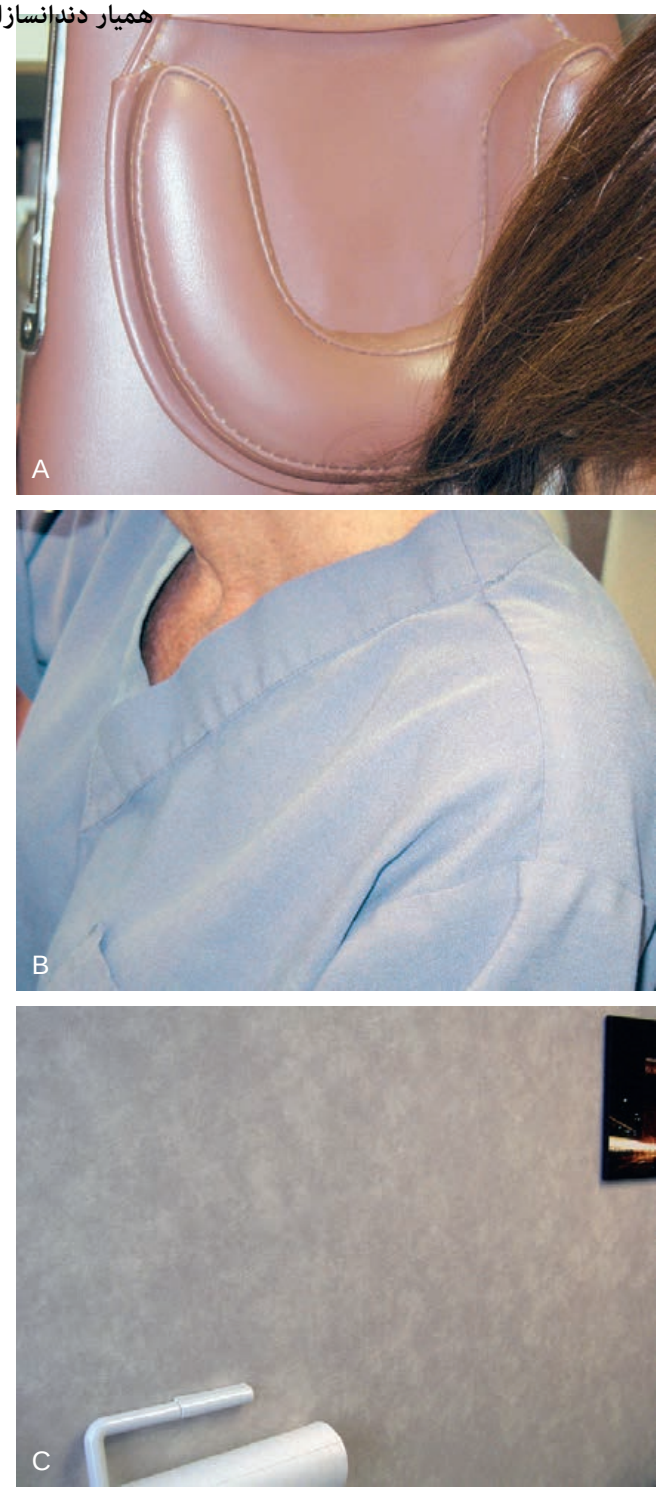


FIGURE 7-38 **Elements in the dental operatory that can affect the accuracy of shade matches of teeth include the color of the dental chair (A), the clothing worn by the operator and patient (B), and the color of the walls (C).**

weather outside the operatory window is highly unpredictable in any given location (Figure 7-39, *B*). A cloudy day will produce a different shading environment than a sunny day will, and, of course, shades taken in the evening bring still other color influences to bear. Last but not least are the ceiling light fixtures that

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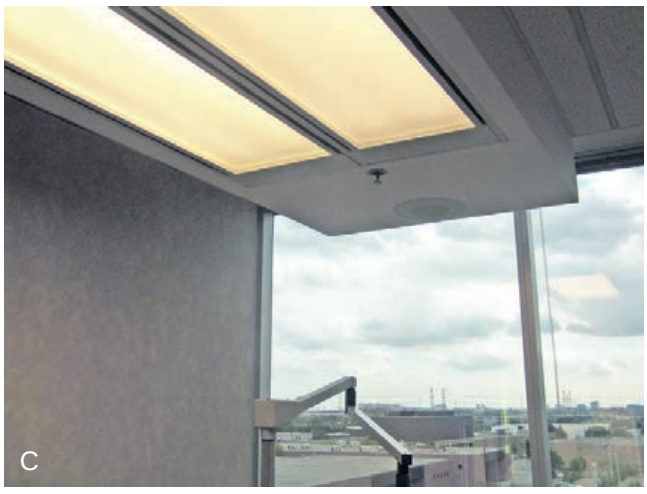


FIGURE 7-39 The source of light in the operatory can affect the accuracy of shade matching. Light from windows (A), weather conditions (B), and overhead lights (C) can all affect the perceived coloration of the teeth.

are found in most operatories (Figure 7-39, *C*). The fluorescent tubes tend to push the appearance of the teeth into the blue-green end of the spectrum.

Thus it makes sense to eliminate as much of the external variability during the shade taking as possible. Although the process of taking shades with prefabricated color tabs has been well established for more than a century, and is widely used throughout the world, the external color influences that affect the appearance of tooth coloration and that are present in every treatment room make this process highly unpredictable, unreliable and unsatisfactory. Digital spectrophotometric shade taking involves the isolation of the target tooth in a light envelope created by the device that neutralizes all outside influences and enables the measurement of tooth coloration under always-consistent and predictable conditions.



FIGURE 7-40 Color tabs rearranged from alphabetic order into the indicated value-based order, going from B1 to A4.

VITAPAN Classical Shade Guide System

The VITAPAN Classical Shade Guide system (see Figure 7-8, *A*) first appeared in the 1950s and was the standard in the dental profession until the development of the VITAPAN 3D-Master Shade Guide system. The Classical system is still the most commonly used shade-matching system worldwide. Given the environmental color variance in the dental operatory (discussed earlier), the dentist should do all that is possible to eliminate strongly influencing colors during the shade-taking procedure, including isolating the patient's head in a color-neutral environment, asking the patient to remove lipstick and makeup, and hiding the patient's clothing under a blue pastel bib. Before the VITAPAN Classical Shade Guide system is used for shade matching, the color tabs should be rearranged from their alphabetic order (which is how they are packaged) into the indicated value-based order that is included with every kit and goes from B1 to A4 (Figure 7-40).

The patient is asked to smile, and the VITAPAN Classical Shade Guide is passed in front of the teeth. For the patient in Figure 7-41, it is passed from the darker shades (see Figure 7-41, *A*) through the middle of the range (see Figure 7-41, *B*) to the lighter shades (see Figure 7-41, *C*). The first quick pass indicates that the patient's tooth shade is toward the lighter shades. The tabs of this shading group are brought edge to edge with the tooth in question in order to narrow down the actual color (see

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FIGURE 7-41 **Shade matching using the VITAPAN Classical Shade Guide system. The system is passed from darker shades (A) to middle shades (B) to lighter shades (C). The lighter shades are edged up to the tooth to narrow down to the actual color (D), and the appropriate color tab is pulled and compared (E). F, The color tab is rotated and positioned adjacent to the natural tooth to confirm the shade selection.**

Figure 7-41, *D*). The most appropriate color tab is pulled from the guide (see Figure 7-41, *E*) to further establish a suitable selection. For the final decision, the color tab is rotated and positioned adjacent to the natural tooth to confirm the shade selection (see Figure 7-41, *F*). Several readings are necessary to create a color map of a tooth. Typically at least three readings per tooth are suggested—one each for gingival, middle, and incisal segments.

VITAPAN 3D-Master Shade System

The VITAPAN 3D-Master Shade system was the first comprehensive, scientifically based shade tab guide to be introduced internationally. It has 26 color tabs versus the 16 tabs of the Classical system. The tooth shades are arranged into five families of equal value, with each value family subdivided into ranges of chroma and hue. Because the human eye sees value or "lightness" most easily, this is the first attribute of tooth coloration to be

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selected. Chroma, the intensity of color or "saturation," is the second feature to be noted by human eyes, and is selected next. Finally, the most difficult-to-see variations among yellow, intermediate, and reddish hues—or "color"—are selected. Thus the VITAPAN 3D-Master technique is a three-step shade selection system that makes maximal use of the visual capacities of the dental team. It is far easier to use than the Classical system and much more accurate. The learning curve is a very short one, hours versus the months or years needed for the Classical system.

The first step in using the VITAPAN 3D-Master system is to make sure the tabs are aligned vertically. Misaligned tabs can be distracting to the operator. The patient is asked to smile, and the VITAPAN 3D-Master guide is passed adjacent to the teeth, going from the darker colors (Figure 7-42, *A*) through the intermediate colors (Figure 7-42, *B*) to the lighter shades



FIGURE 7-42 **Shade matching using the VITAPAN 3D-Master Shade system. The shade guide is passed adjacent to the teeth from the darker colors (A) through the intermediate colors (B) to the lighter colors (C). The correct value family matched (D) and the center tab held to the dentition (E). Tabs in the chroma range are matched to the teeth in order to select the most appropriate: lower chroma (E), then the middle chroma (F), and the most intense chroma (G).** *Continued*

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FIGURE 7-42, cont'd **It is necessary to determine whether the natural tooth has a yellowish (H) or a reddish (I) hue. J, 2M1 is the most accurate shade match to the natural.**

(Figure 7-42, *C*). At this point the operator is simply looking to match the value or darkness-lightness of the teeth to the value of the shade tabs. There is no intent to match chroma or hue at this stage. The objective of this first step is very simply to select a value "family" and to narrow the shade option from 26 tabs to one of five possibilities.

Once the correct value family has been matched (Figure 7-42, *D*), the center tab is removed from the guide and held to the dentition. The group at the center of the lightness level spectrum has the most commonly occurring shades in nature. The groups on either side occur with decreasing frequency with movement away from the center. This center tab represents the chroma range of the family from lower intensity at the top to higher intensity toward the bottom. Each of the tabs in the chroma range is matched to the teeth in order to select the most appropriate—first the lowest chroma (Figure 7-42, *E*), then the middle chroma (Figure 7-42, *F*), and then the most intense chroma (Figure 7-42, *G*). In this case the lowest chroma represents the most accurate coloration. Because teeth are not monochromatic and saturation levels are variable within the tooth, several readings at different areas of the tooth are usually necessary.

In order to fine-tune the shade, it must be determined whether the natural tooth has a yellowish hue (Figure 7-42, *H*), intermediate, or a reddish hue (Figure 7-42, *I*). For this patient, the intermediate hue is the most appropriate, and thus 2M1 is selected as the most accurate overall shade match to the natural tooth (Figure 7-42, *J*).The shade 2M1 signifies lightness level 2, saturation level 1, and color level intermediate. Several readings are necessary to create a color map of a tooth. Typically at least three readings per tooth are suggested, one each for the gingival, middle, and incisal thirds. Shade selection has now become a simple three-step procedure. It is clear, accurate, and reproducible. With a simple change in semantics and reproducible numeric designations, it is now possible to solve one of the enigmas that have plagued many dentists since dental school.

VITA Easyshade Compact

In the early years of the millennium, the first clinically practical spectrophotometers and colorimeters became available to the dental profession. Instead of 16 or 26 color tabs, a virtually infinite number of tooth colorations could be measured, documented, and catalogued within the currently available range of composite restorative and ceramic shades. For the first time, it was no longer necessary to color-neutralize the operatory and the patient; the process became not only easier, but more objective, predictable, and accurate because of the digital and nonsubjective method of data collection, recording, and reporting of shade selection. The most recent electronic shade-taking device is the VITA Easyshade Compact (see Figure 7-27). The shade-taking handpiece is cordless and requires the base only

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for charging and calibration. The portability of the hand-held shade-taking handpiece makes it useful throughout the practice and for a variety of direct and indirect restorations and bleaching procedures. The calibration process is very straightforward but must be renewed before every shade-matching procedure. The handpiece is touched to the color-corrected calibrating tab, located in the base (Figure 7-43, *A* and *B*) and held there for several seconds until a series of beeps confirms that the calibration is complete. At this point the interface screen on the heel end of the handpiece offers four options: tooth single mode (a single tooth shade averaged over the buccal surface), tooth areas mode (a three segment mapping of the cervical, middle, and incisal shades), verify restoration mode for non-natural surfaces (a color check mode for crowns and other dental materials), and shade tab mode (a reference guide to verify the probe on VITA shade tabs) (Figure 7-43, *C*).

For this patient, the tooth areas mode is used to develop a comprehensive anterior shading map. Once this option is selected, the active dot appears in the cervical third of the tooth on the screen (Figure 7-44, *A*). The wand tip is placed flat on the buccal surface at the cervical third of the tooth (Figure 7-44, *B*). The nonslip infection-control shield has been omitted from this series for demonstration clarity. The button at the top of the wand is pressed and a light appears at the wand tip. It is important to not move the wand until the confirming beeps are heard. Then the wand tip can be removed from the surface of the tooth. The OK signal appears in the cervical third, and the active dot now appears in the middle third on the screen (Figure 7-44, *C*).

The wand tip is placed flat on the buccal surface at the middle third of the tooth (Figure 7-44, *D*). The button at the top of the wand is pressed and a light appears at the wand tip. It is important to not move the wand until the confirming beeps are heard. Then the wand tip can be removed from the surface of the tooth. The OK signal appears in the cervical and middle thirds and the active dot now appears in the incisal third on the screen (Figure 7-44, *E*).

The wand tip is placed flat on the buccal surface at the incisal third of the tooth (Figure 7-44, *F*). The button at the top of the wand is pressed and a light appears at the wand tip. It is important to not move the wand until the confirming beeps are heard. Then, the wand tip can be removed from the surface of the tooth. The OK signal appears in the cervical and middle and incisal thirds on the screen. Concurrently, the VITAPAN Classical and VITAPAN 3D-Master shades that are closest to the natural tooth structure coloration appear on the screen (Figure 7-44, *G*). These shade results can be noted manually on the laboratory prescription or transferred to the computer via a USB connection for electronic transfer directly to the laboratory technician.



FIGURE 7-43 **Calibration of VITA Easyshade Compact. A and B, Handpiece is touched to color-correcting calibrating tab in base and held there until calibration is finished. C, Interface screen shows the four measurement options available (see text for description).**

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FIGURE 7-44 Shade matching using the VITA Easyshade Compact. **A,** "Tooth areas" mode selected. Note the active dot appearing in the cervical third of the tooth on the screen. **B,** Wand tip on the buccal surface at the cervical third of the tooth. **C,** "OK" signal in the cervical third and active dot in the middle third on the screen. **D,** Wand tip on the buccal surface at the middle third of the tooth. **E,** OK signal in the cervical and middle thirds and active dot in the incisal third on the screen. **F,** Wand tip on the buccal surface at the incisal third of the tooth. **G,** OK signal in the cervical, middle, and incisal thirds on the screen. VITAPAN Classical *(left)* and VITAPAN 3D-Master *(right)* shades that are closest to the natural tooth structure coloration shown on screen. *Note:* The nonslip infection-control shield has been omitted from this series of photos for demonstration clarity.

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SECTION B

Using Color to Create Restorations

Sandesh M. Mayekar

RELEVANCE TO ESTHETIC DENTISTRY

Esthetic dentistry, using a combination of science and art, involves the use of colors to create a natural toothlike restoration. Basically, color and shade are very important because teeth are multichromatic with color variations from cervical to incisal. Similarly, every tooth in the mouth from the central incisors to molars, both upper and lower, varies in color. Hence, color and shading are absolutely necessary to make the restoration look like a natural tooth.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION

Color and shading are necessary for direct and indirect composite restorations and also for ceramic indirect restorations. For composites, universal shades were used for every tooth from cervical to incisal. These restorations looked monochromatic and seldom matched the multichromatic neighboring teeth. Subsequently, different shades of composites were developed that matched the VITA Shade Guide (Classical 3D-Master, see Figure 7-8). All these were dentin shades, and very few matched the translucency of the teeth, as there was no enamel shade. Then came the enamel shades, which had variations in accordance with the VITA Shade Guide—that is, Enamel A2, Enamel B3, and so on. There were few other shades such as Clear Enamel Shade (CE) and White Enamel Shade (WE) that matched the VITA Shade Guide. However, these dentin and enamel shades could not be used to mask underlying tooth color, so opaque shades in the Vita Shade Guide (such as AO2, AO3), and so on were developed. Subsequently companies came out with composites in the form of enamel, body, and dentin shades that can match the multichromatic nature of the tooth structure (for example, Filtex Supreme Ultra 3M ESPE, St Paul, Minnesota). An unfilled resin in the form of thin paint-on opaquers containing titanium dioxide came into use to mask the underlying tooth color in place of the existing thick opaque composites. Similarly, to characterize the restorative surface, unfilled resins in the form of tints also came into use that could give a natural look to the restoration by creating crack lines, hypocalcified spots, and so on.

To prepare a restoration with good shade and color that can match a multichromatic natural tooth, a combination of the dentin, body, and enamel shades and the opaque shades of the opaquers and tints can be used.

CLINICAL CONSIDERATIONS

The original color of a tooth is the color one sees as a result of the reflection, refraction, deflection, and absorption of light by the enamel, the dentin, and possibly the pulp. The color seen in a tooth is the result of combined optical effects of the layers of tooth structure—the translucency and thickness of the enamel and color of the underlying dentin.

The polychromatism of a restoration is vital to bring out the lifelike shade of a restoration. Enamel shades and dentin shades have to be analyzed and understood to bring about a well-integrated restoration with an invisible interface.

Indications

Color and Shade are indicated for all restorations: direct and indirect restorations, both anterior and posterior.

Contraindications

The contraindications to color and shade are none except when a patient wants bleached white teeth: with no color or shading, just plain, uniform, white monochromatic teeth.

MATERIAL OPTIONS

Different companies have come out with a wide variety of materials of different shades. Some companies have fewer shades of composites, which they claim will match the color of the neighboring teeth like a chameleon (e.g., Gradia DirectLoflo, GC America, Alsip, Illinois). There are some composites that have 26 shades or 16 shades in the form of dentin, body, enamel, and opaque shades. Most important is the classification of type and filler particle size—whether they are microfills, microhybrids, nanofills, and so on. The filler size and type differs in each case and has a bearing on the color of the restoration. The finishing and polishing also plays an important role in the color and shade of a restoration. A well-finished and polished restoration will give nice reflection and absorb no stains. All composite

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manufacturing companies make composites in accordance with the VITA Shade Guide, but these different guides do not match with one another. For example, A may represent the hue and 2 represent the chroma, but the value differs (grayness and whiteness, dullness and brightness) in composites of each company. Only VITA's composite matches the 3D-Master Shade Guide, which features hue, chroma, and value all in one.

For class III cavities and class IV fractures, an opaque composite can be used on the palatal side to prevent transmission of light. This opaque composite can then be covered with the body shade and finished with translucent shade up to the incisal edge to get a natural toothlike restoration.

Advantages

The material blends with the shade of the dentin and enamel and gives a natural multichromatic look to the restoration. Whether one uses a microfill, nanofill, or microhybrid does not matter for esthetics; what matters are the shade and color.

Disadvantages

If the correct shade and type of material are not used, the restoration might not be clinically acceptable. The final color of the composite depends on three very important things: the original color of the tooth, the thickness of the composite, and polymerization.

CURRENT BEST APPROACH

Determining the correct shade and color material is the best approach for a good esthetic restoration. To achieve this, it is important to understand color. This is done through comprehension of the *dimension* of the color (hue, chroma, and value and translucency) in relation to the manufacturer's shade guide or the universal shade guide (the VITA Shade Guide).

The best way to determine the shade and color is to do a mock-up in the patient's mouth and check it in different lights—natural, white, and yellow.

Sometimes, different company materials can be blended well to give an esthetic tooth color restoration. To get a good tooth color match, one must determine and reproduce the color, and between determining and reproducing, one must retain the color in the mind. For an indirect restoration, it is necessary to draw a tooth diagram with its color on the prescription form for the dental technician. It has been suggested that the best way to get the right color is to draw the tooth and draw the shade that one sees and wants to be reproduced in the restoration.

Other Considerations

Unless the accurate shade is determined and the correct shade materials are used, a technically good and natural-looking restoration cannot be produced. It is equally important to prepare the tooth for the right amount of material. For a laminate or a veneer, a mock-up of the composite on the prepared tooth can be used before the adhesive preparation to ascertain the varied shades in the different parts of the tooth.

Innovative Elements

The best improvised instrument to read a color is the eyes. Unless the tooth is read, the color cannot be reproduced. But, it cannot be true for all the people, as some might not be technically correct with their eyes and have a problem in reading colors. In short, what the eyes see can be subjective.

Today we have technology-based digital imaging and analysis. Several companies have come out with meters that can check the shade, not just of the total tooth, but also of the different areas of the tooth and the variations in the tooth color. This is the best objective and innovative method to determine color and shade.

It is important to understand the methodology to determine shade and color. Scientifically, the shade or color can be determined without relying on subjective observation by the human eye. The light source, whether yellow, natural, or white light and whether in an overcast or a sunny environment, is of consequence to determining the shade. The shade can be taken at any time of the day or night in any location in the objective methodology.

As far as technology goes, the meter is more consistent than human assessment and can determine the right shade and help reproduce it accurately. Although it is easy to determine the shade, it is difficult to reproduce the shade. The meter can help overcome this problem. However, it is expensive, and its use is time-consuming. For direct composite restorations, eyes are still the best guide.

Artistic Elements

A wide variety of available color materials makes it possible to mix and match the colors in creating the restoration that matches the multichromaticity of the tooth. To achieve the multichromatic effect, the cervical, body, and incisal shades are used in different areas according to the shade selection.

The artistic element comprises the ability to read the color and to reproduce it exactly, by mixing and matching the different shades with artistic finesse.

TREATMENT PLANNING

To determine the shade or color, a universal shade guide such as the VITA Shade Guide or a custom-made company shade guide may be used, or a mock-up may be done. The problem with the VITA Shade Guide is that there is no element of value or translucency. This guide shows only hue and chroma. The custom-made company shade guides appear to be very close to the color that one sees, but the effect of thickness and proportion of the composite needs to be assessed. The best method for determining the shade and color of the tooth to be restored is to prepare a mock-up in the patient's mouth, cure it with light, polish it, and check it in different lights. To determine the shade, a proper sequence is most important. First, the basic shade is considered, which means one looks at the tooth, but not for more than 7 seconds. The basic shade is thus

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determined—for example, A2. Next, a particular area, such as the cervical, body, or incisal, is concentrated on; thus one sees the basic shade variation in those areas. If the body is shade A2, the cervical could be A3 or A3.5. Then, the observer moves down to the incisal area, where the enamel shade and the translucent effect are checked—more transparency going toward transparent, and less translucency going toward opacity. The translucency is measured and the location is marked. Some incisal edges are in the form of a band, and some have "V"shaped translucency at the incisal edges. To communicate the variations in translucency, the translucencies are checked and are accordingly drawn. Lastly, regarding special effects, one looks at the tooth and draws the vertical crack lines, maverick colors near the root, or hypoplastic spots as one sees them. To understand the special effects, the tooth should be looked at uniformly and not haphazardly.

To determine the shade and color, it is advisable to follow a sequence: determine the basic shade, shade variations, enamel shades, and special effects; draw them; and reproduce them. The final result will be a good restoration.

Color and Shade Determination

The ability to reproduce a particular color largely depends on the dentist's ability to observe the condition as it appears naturally. Equally important is to understand what the patient expects and to have a good idea what shade the patient will accept before beginning the case.

The prerequisite to accurate shade determination is an understanding of natural tooth color. Shade determination is visual perception and is purely subjective. To the untrained eye, the color of the tooth is white or yellow. Under close examination, the tooth shows a range of hues and chroma over the surface. True shade or color is represented only in the middle third of the tooth. This is the principal area against which the shade guide is matched.

Options

- Using a universal shade guide such as the VITA Shade Guide
- Using custom-made shade guide from a company
- Doing a mock-up
- Using a colorimeter or spectrophotometer

Sequence

For optimal results, shade determination must follow the following logical sequence:

1. Basic shade
2. Basic shade variations
3. Enamel shade, translucency and location
4. Special effects

Treatment Considerations

Preparation

Depending on the restoration to be created—for example, laminates for misshaped teeth; veneers for discolored teeth; class III, class IV, or class I and class II restorations in the posteriors—the tooth is prepared. The preparation for laminates where there is no change in color should be minimal. The preparation for veneers where there is a change in color depends on the thickness of the material that is required to mask the inside color and get the right shade. For class III, class IV, and class V restorations, a bevel is necessary to blend the color coming from the natural tooth to the composite. In class III restorations, as the light strikes the labial surface of the tooth, the reflection is from the enamel and dentin. As one comes to the beveled area, the light strikes little composite and more of the tooth. As one goes toward more beveled (i.e., the 45-degree beveled area), there is a little more composite and less tooth color; and when one goes to the composite, what one gets is whole composite color, a blend of colors that is very important. So in preparation, an enamel bevel plays an important role in blending colors.

Procedure

Start with the laying of the cervical layer; adapt the body shade and then the incisal shade. When blending the colors from cervical to body, the cervical color is used and then mixed with the body color and then cured. While the body shade and the incisal shade are being adapted, the tints are used and cured to give a lifelike effect to the restoration.

Finishing

The attractive appearance of the restoration depends on the reflection, refraction, deflection and scattering of light on the tooth surface, which in turn depends on the surface texture and smoothness of the restoration. The effect of light gives color to the restoration. The finishing and polishing (to a large extent) are responsible for the color and natural lifelike effect of the restoration. If the restoration is not finished and polished properly, there will not be a definite reflection and absorption of light, which gives a dimension to the restoration. Therefore, finishing and polishing is very important to give color to the restoration. Deflection of light causes a shadow; creation of a direct reflection results in brightness. Playing with colors, one can create a deflection of light for a restoration to be of low value. Creating concavities and convexities that deflect and reflect give a three-dimensional appearance to the color. Creating a texture on the tooth surface scatters light and gives the restoration a three-dimensional appearance. All these factors are important and are achieved by finishing and polishing a restoration. In summary, finishing does not imply a smooth, shining finish and polish, which would not reflect the right color of the restoration. To give the right color and shade to a restoration, it should be textured, smoothed, polished, and finished.

Maintenance

To maintain the color of the restoration, the patient should be advised not to brush vigorously but to adopt the correct brushing technique. Vigorous brushing can result in a change in the surface texture, wearing of the material, and loss of enamel translucence in the restoration, which can alter the color and mar the appearance and look of the restoration. Professional finishing and polishing at regular intervals and in-dental office and home maintenance are advised.

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Near-Future Developments

A more varied range of colors of chameleon-like shade materials that match the surrounding tooth colors and easy shade guides will be future developments. How does one learn colors? One learns to understand colors as a child understands them: The child is shown colors and taught that they are red, yellow, blue, and so on. The child recognizes the colors in an instant, because the child has seen them and remembers them all. The same principle can be applied to the colors of the restorative material. If company "K" produces a box with 26 shades, one has to remember all the 26 shades. Initially, one has to understand what A2, B3, and A4 look like after curing. After achieving this understanding, one can remember these colors while determining the shade and color of a tooth in order to match them. Use of a mock-up with different colors is the alternative—a long and time-consuming process. To avoid these problems, a company could produce fewer tubes that matched a greater number of colors; this situation would be ideal. Also, more advanced meters or equipment should be developed to determine shades in multidirectional light.

CLINICAL TECHNIQUE

Patient History

A 20-year-old woman arrived for a smile makeover. She was Miss India in the Miss International Beauty pageant.

Relevant Conditions

Examination showed a healthy periodontal condition and good occlusion. The patient had a gummy smile, palatally inclined teeth because of orthodontic treatment, and a discolored upper left central incisor caused by root canal treatment (Figure 7-45).



FIGURE 7-45 Preoperative gummy smile inclining more toward the left and not in the golden proportion.

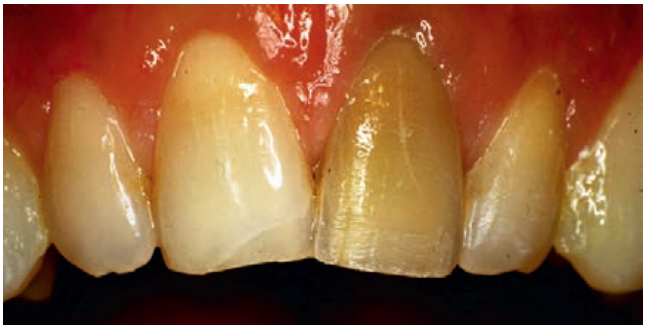


FIGURE 7-46 Healthy gingiva with proper contour after 3 weeks of healing after a crown lengthening procedure.

Treatment-Planning Process

It was determined that the gummy smile would be corrected by a crown-lengthening procedure (CLP)—that is, gingivectomy and alveoloplasty. For this CLP, two important factors were considered: the biologic width needed to be maintained, and the zenith and contour of the gingiva needed to be correct. After healing, ceramic composite laminate and veneers or ceramic laminate veneers could be prepared.

The patient opted for composite laminate veneers owing to financial constraints.

Clinical Step-by-Step

To correct the gummy smile, the CLP was done with the patient under local anesthesia, keeping in mind the biologic width, zenith and contour of the gingiva, and bilateral symmetry.

The restoration procedure was initiated 3 weeks after the CLP (Figure 7-46). The color and the shade were determined in a logical sequence and in consultation with the patient because all the anterior teeth (including the premolars) were to be laminated and veneered. The basic shade selected was A2. The basic shade variations were cervical shade A3, incisal V-shaped translucency, proximal enamel translucent shade A2, and incisal Clear Enamel (CE) shade. Not many special effects were necessary.

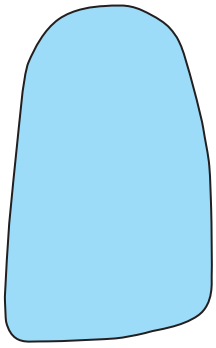
The mock-up was done to understand the depth of the preparation and to determine the extent of material that would be necessary to mask the discoloration.

Laminate and veneer preparation was done to a uniform depth of 0.5 mm, except for the upper left discolored central incisor, which was prepared to 0.75 mm depth. The discolored central incisor required additional preparation so that the final color would match the color of the neighboring teeth (Figure 7-47).

After cleaning, etching, priming, and bonding, paint-on opaquer was applied short of the incisal and proximal borders

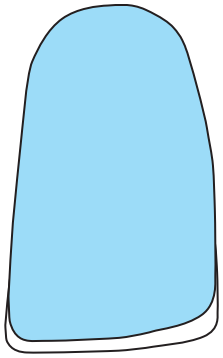
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B Laminate Veneer

FIGURE 7-47 **A, Teeth prepared for laminate veneer; discolored central incisor prepared more than the neighboring teeth. B, Representation of repaired laminate veneer.**

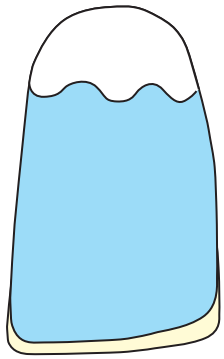


Opaquer

FIGURE 7-48 **Paint-on opaque on prepared tooth, short of the incisal and proximal borders.**

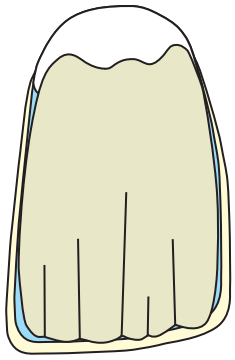
to mask the discoloration of the tooth (Figure 7-48) to give a translucent effect to the restoration. Paint-on opaquers should be applied on a smooth surface and as thinly as possible. The thicker the opaque layer, the less room for the translucent resin, and if the layer of the translucent resin is too thin, then the opaquer shines through and the tooth has a dead look.

The A3 shade of composite—the cervical shade—was placed from the gingival margin and reduced in thickness as it came onto the body of the tooth (Figure 7-49, *A*). Mammelons (irregularities in the form of convexities and concavities) were created on the surface of the restoration to facilitate merging of the overlapping cervical and body layers, so that no difference was



A Cervical





C Body - hybrid

FIGURE 7-49 **A, Adaptation of cervical layer in mammelan form. B, Cervical A3 shade showing convexities and concavities. C, Representation of combined effect of cervical and body shade.**

seen between the two layers (Figure 7-49, *B*). The next layer adapted was the body shade A2. This layer projected the overall view of the tooth. This layer was blended over the cervical layer, placed more on the labial body surface, and thinned down to the incisal margins (Figure 7-49, *C*). The shade in this region showed a combined effect of the cervical and body shades, and because of the merging of both the shades, there was no demarcation of cervical and body layers. To create transitional line angles and a mammelons-like effect, convexities and concavities were created on the labial surface.

Before the last layer of the body was cured, V-shaped notches were made at the incisal third (Figure 7-50, *A*), and subsequently the incisal enamel layer was adapted onto the last uncured body layer to give a translucent effect. Then both layers were cured. This gave a V-shaped enamel translucent effect to the incisal

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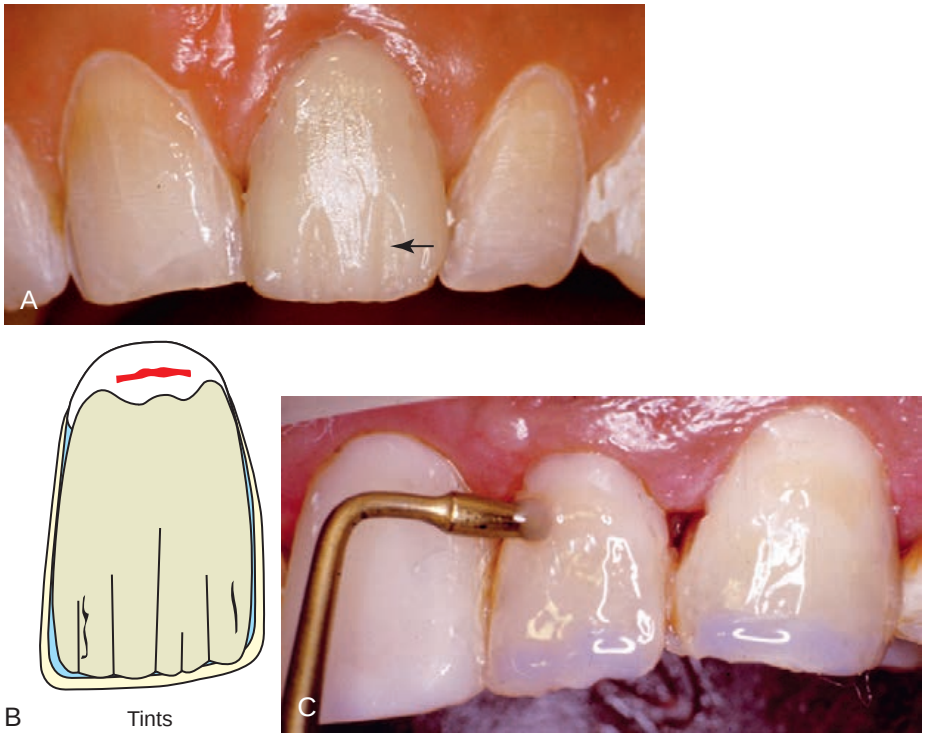


FIGURE 7-50 A, V-shaped notches on uncured A2 body layer. B, Representation of tint application. C, Tints applied.

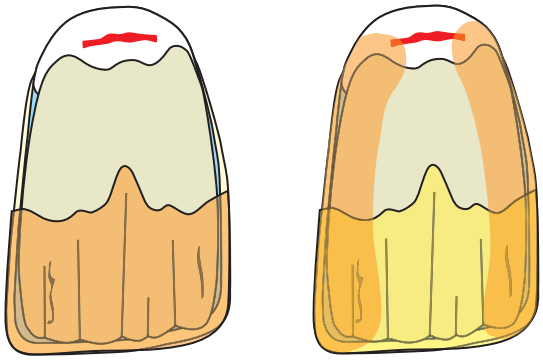


FIGURE 7-51 A, Representation of application of tints at incisal and cervical areas. B, Representation of adaptation of initial enamel layer at incisal third.

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FIGURE 7-52 Before (A and B) and after (C and D) views of patient's smile.

third. To create character—a halo or translucent effect in some part of incisal area—blue tint was applied, and orange and brown tints were applied in the cervical area to create maverick or rootlike colors (Figures 7-50, *B* and *C*).

After the tints were applied and cured, the initial enamel layer (shade CE enamel) was adapted onto the cured tints (Figure 7-51, *A*). The proximal enamel shade, A2, was adapted on both the mesial and distal sides, running from cervical to incisal in such a way as to highlight the transitional line angles (Figure 7-51, *B*). This layering technique for shade and color gave a lifelike appearance to the restorations (Figure 7-52).

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8 CHAPTER

Adhesion

A SECTION

The Evolution of Adhesive Techniques

George Freedman

RELEVANCE TO ESTHETIC DENTISTRY

Over the past two decades the evolution of adhesive techniques has transformed the scope of dental practice. Today, most direct and indirect restorations are bonded to natural tooth structures rather than cemented or mechanically retained. Extensive research and product development have consistently improved the adhesive armamentarium available to the dentist, broadening its applications and range. Patient interests and demands reflect a new-found interest in oral appearance and health, most commonly associated with adhesive procedures.

The widespread demand for, and use of, dental adhesives has fueled an intensive development of better and easier-to-use dental adhesives in rapid succession; dentists have literally been inundated with successive "generations" of adhesive materials. Although the term *generation* has no scientific basis in the realm of dental adhesives and is to a great extent arbitrary, it has served a useful purpose in organizing the myriad materials into more comprehensible categories.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

The "generational" definitions help to identify the chemistries involved, the strengths of the dentinal bond, and the ease of use for the practitioner (Box 8-1). Ultimately this type of classification benefits the dentist and patient by simplifying the clinician's chairside choices.

The Generational Development of Adhesive Systems (see Box 8-1)

The *first-generation* adhesives in the late 1970s were really rather ineffective. Although their bonding strength to enamel was high (generally, adhesives of all generations except for the sixth bond well to the microcrystalline structure of enamel), the strength of their bond to the semi-organic dentin was the major problem facing dentists. Their adhesion to dentin was pitifully low, typically no higher than 2 MPa. Bonding was achieved through the chelation of the bonding agent to the calcium component of the dentin. Although tubular penetration did occur, it contributed little to restoration retention. It was common to see debonding at the dentinal interface within several months. These bonding agents were recommended primarily for small, retentive class III and class V cavities. Post-operative sensitivity was common when these bonding agents were used for posterior occlusal restorations.

In the early 1980s a distinct *second generation* of adhesives was developed. The enamel was etched and rinsed prior to bonding, keeping the acid away from the dentin. This generation targeted the smear layer on the dentin (a post cavity preparation layer composed of dentinal debris, dead and live bacteria) as a bonding substrate. The smear layer is typically bonded to the underlying dentin at a negligible level of 2 to 3 MPa. The weak bonding strengths of these second-generation agents—2 to 8 MPa to dentin—meant that a mechanical retention form in cavity preparations was still required. Restorations with margins in dentin saw extensive microleakage, and posterior occlusal restorations were likely to exhibit significant post-operative sensitivity. The long-term stability of second-generation adhesives was problematic. For direct restorations, 1-year retention rates were as low as 70%.

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BOX 8.1 Generations of Dental Adhesives

First Generation (1970s)
- 1 to 3 MPa adhesion to dentin
- Bonded well to enamel through resin tags into enamel
- 50% failure at 6 months
- Examples: N-phenylglycine and glycidyl methacrylate, NPG-GMA

Second Generation (Early 1980s)
- 2 to 8 MPa adhesion to dentin
- Phosphate-ester bonding agents
- Bonded to smear layer (organic debris)
- Weak ionic bond to calcium undergoes hydrolysis
- Examples: Scotchbond, DentinAdhesit, Bondlite

Third Generation (Late 1980s)
- 8 to 15 MPa adhesion to dentin
- Etching of dentin removed or modified smear layer
- Spaghetti-like projections of resin into dentinal tubules
- Examples: Scotchbond 2, Gluma, Tenure, XR Bond

Fourth Generation (Early 1990s)
- 17 to 25 MPa adhesion to dentin
- Total etch; complete removal of smear layer and collapse of exposed callagen fibers
- Bonds to enamel, "moist" dentin, metal, porcelain
- Multibottle, multistep
- Examples: Scotchbond MP, Imperva, Gluma 2000, Syntac, All-Bond 2, Permagen

Fifth Generation (Mid-1990s)
- 20 to 25 MPa adhesion to dentin
- Single component in a single bottle
- Bonds to enamel, moist dentin, metal, porcelain
- Etching required
- Moist surface required (wet or moist bonding)
- Examples: Pulpdent UNO-DUO, Prime & Bond NT, Gluma Comfort Bond, Single Bond, One Step, Bond 1, Excite

Sixth Generation (2000)
- 17 to 22 MPa adhesion to dentin
- No separate etching step
- Multibottle, multistep
- Bonds to dentin, metal, porcelain
- High incidence of enamel interface fractures
- Examples: AdheSE, SE Bond, Tyrian, Prompt L-Pop, Xeno III

Seventh Generation (2003)
- 20 to 30+ MPa adhesion to dentin
- Single bottle—no mixing
- Bonds to enamel, dentin, porcelain, metal
- Moisture independent
- No technique sensitivity
- Examples: BeautiBond, Bond Force

In the late 1980s, two-component primer-adhesive systems were introduced. The marked improvement that these bonding agents represented warranted their classification as *third-generation* adhesives. Significant increases in bonding strength to dentin, 8 to 15 MPa, decreased the need for a retention form in the cavity preparation. Erosion, abrasion, and abfraction lesions were treatable with minimal tooth preparation, hence the introduction of ultraconservative dentistry. A noticeable decrease in post-operative sensitivity observed with posterior occlusal restorations was very welcome. Enamel etching was routine but it was feared that etching the dentin would cause pulpal necrosis and necessitate endodontic treatment. The third-generation adhesives were the first agents that bonded not only to tooth structure but also to dental metals and ceramics. The downside to these bonding agents was their limited longevity. Various studies demonstrated that adhesive retention with these materials started to diminish after 3 years intraorally. However, patient demands for tooth-colored restorations convinced some dentists to begin routinely providing posterior composite fillings.

In the early 1990s *fourth-generation* bonding agents transformed dentistry. Their high bonding strength to dentin, 17 to 25 MPa, and decreased post-operative sensitivity in posterior occlusal restorations encouraged many dentists to begin the tectonic switch from amalgam to direct posterior composite restorations. Both the enamel and the dentin are etched and then rinsed simultaneously with the "total etch" technique. This generation is characterized by the hybridization process at the dentin-composite interface.

Hybridization is the replacement of the hydroxyapatite and water in the surface dentin by resin material. This resin, cured with the remaining collagen fibers, constitutes the hybrid layer. Hybridization involves both the dentinal tubules and the intratubular dentin, dramatically improving bonding strength to dentin. Total etching (both enamel and dentin) and moist dentin bonding, concepts developed by Fusayama and Nakabayashi in Japan in the 1980s and introduced in North America by Dr. Raymond Bertollotti, are innovative hallmarks of the fourth-generation adhesives.

The fourth generation adhesives are distinguished by their components; there are two or more ingredients that must be mixed, preferably in precise ratios, or utilized in a specific sequence. This is easy enough to accomplish at the research laboratory but much more complicated, and perhaps impossible, chairside. The number of mixing steps involved and the requirement for precise component measurements tend to confuse the process; imprecise procedures and inaccurate ratios reduce or eliminate the bonding strengths to dentin.

This led to the development and the great popularity of the *fifth-generation* dental adhesives. These materials adhere well to enamel, dentin, ceramics, and metal, but, most important, they

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are characterized by a single component in a single bottle (in addition to the etching gel). There is no mixing involved in the adhesion process, and hence less opportunity for error. Bonding strengths to dentin are in the 20- to 25-MPa range, suitable for all dental procedures (except self-curing resin cements and self-curing composites).

Dental procedures tend to be both technique sensitive and stressful. Where some of this stress can be eliminated, dentists, staff, and patients all benefit. There is little technique sensitivity in a material that can be applied directly from the bottle to the prepared tooth surface. Post-operative sensitivity was reduced appreciably. The fifth-generation bonding agents, easy to use and predictable, were the most popular adhesives of their day.

Over the years, dentists and researchers have sought to eliminate the etching step or to include the surface conditioning process chemically as part of another component. The *sixth-generation* adhesives require no *separate* etching step, at least at the dentinal surface. Since 2000, a number of dental adhesives specifically designed to eliminate the etching step have been introduced. These products have a dentin-conditioning liquid as part of one of their components; the acid treatment of the dentin is self-limiting, and the etch byproducts are permanently incorporated into the dental-restorative interface.

Significant questions were raised by researchers concerning the quality of the bond after aging in the mouth, typically at the 3-year milestone. Interestingly, the bond to the dentin (17 to 22 MPa) remains strong; it is the bond to the unetched, unprepared enamel that tends to fail in 30% or more of cases. In addition, the multiple components and multiple steps required for the various sixth-generation agents can be confusing and lead to clinical error. In practice, it is possible to eliminate bond failure at the enamel interface simply by etching or roughening the enamel before placing the adhesive. This, however, introduces a separate etching step to a supposedly non-etching generation.

A novel, simplified *seventh-generation* adhesive system overcomes all previous objections. Just as the fifth-generation bonding agents made the leap from multi-component systems to a rational and easy-to-use single bottle adhesive the seventh-generation simplifies the multi-component, multi-step sixth-generation materials into a single-component, single-bottle system. The seventh-generation adhesives are typically more acidic (1.0 pH lower) than their sixth-generation counterparts. This adequately etches all exposed enamel for effective bonding strengths. The etch is self-limiting immediately after its application to the tooth surface, and the byproducts are ultimately incorporated into the adhesive interface during the light-curing step. Because the conditioning materials are never rinsed off the tooth surface before polymerization, there is far less likelihood that any vital dentinal tubules are left open, and thus made more prone to after-treatment discomfort. Thus, postoperative sensitivity is virtually never observed after the deployment of seventh-generation adhesives.

Both the sixth- and seventh-generation adhesives are available for self-etching, self-priming adhesion for improved procedures with minimal technique sensitivity and little or no post-operative sensitivity. Seventh generation adhesives are easier to use, less technique sensitive, and do not require a "moist" surface.

RELATING FUNCTION AND ESTHETICS

Conservative dentistry, a treatment process whereby a minimum of healthy tooth structure is removed during the restorative process, is inherently a desirable dental objective. Natural enamel and natural dentin are still the best dental materials in existence, and thus, minimally invasive procedures that conserve more of the original, healthy tooth structure are preferable.

Minimally invasive dental procedures are beneficial from a patient's point of view as well. There is less discomfort, less need for local anesthesia, and a real prospect that the repaired natural tooth will last a lifetime. The replacement of existing amalgam restorations with newer amalgam involves ever larger restorations that have shorter life spans than their predecessors. The replacement procedures may nick or otherwise damage adjacent healthy teeth.

In many parts of the world, restorative dentistry has been described and taught as "conservative dentistry." It has hardly been conservative of tooth structures, however; traditional methods and materials have been aggressive and highly invasive, requiring the removal of otherwise healthy enamel and dentin for various reasons, including extending the cavity for the retention of the final restoration and extending a preparation for the prevention of recurrent decay. Thus, healthy tooth structures were condemned to removal by the demands of non-adhesive restorative materials (Figure 8-1).

Fortunately, the current era of dentistry has witnessed the development of new materials, new techniques, and new instruments that make conservative dentistry practical and ultraconservative dentistry a reality. Adhesive restorations eliminate the need for more extensive retentive preparations (Figure 8-2). Enamel-mimicking composites (both hybrid and flowable) offer long-lasting tooth structure replacement with minimum requirements for restorative bulk. Little or no healthy tooth material must be removed simply to allow for adequate thickness of the filling material. Innovative materials, particularly when combined with early detection and conservative treatment make the development of esthetics possible within every dental practice.

CLINICAL CONSIDERATIONS

Early Detection and Treatment

Routine diagnosis and treatment of large, visible dental decay is relatively easy. Its presence and location are readily accessible. Over the past several decades, however, there have been major changes in the pattern of dental decay. Owing largely to the advances in the dental education of the public, there is a greatly increased dental awareness among many population groups. Combined with more frequent and more thorough preventive care by dentists, this has led to fewer and smaller cavities, particularly among the younger age groups.

Although this represents great progress for the dental profession (as well as the general population), this trend toward fewer and smaller cavities has raised some new questions:

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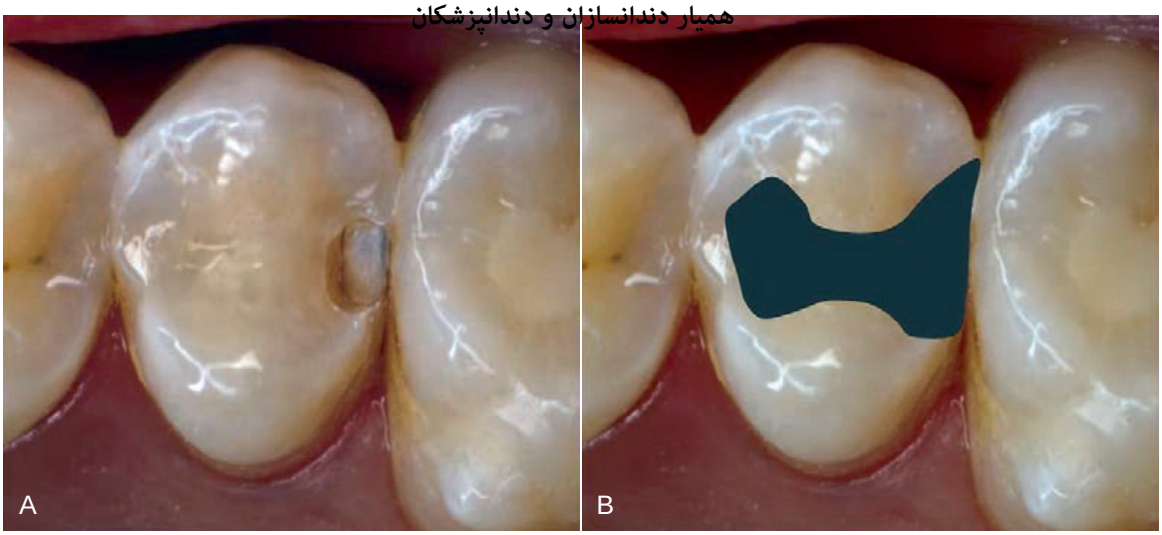


FIGURE 8-1 A, Small interproximal decay. B, Nonadhesive amalgam extended for retention and prevention.



FIGURE 8-2 Composite resin restoration without extension for retention and prevention.

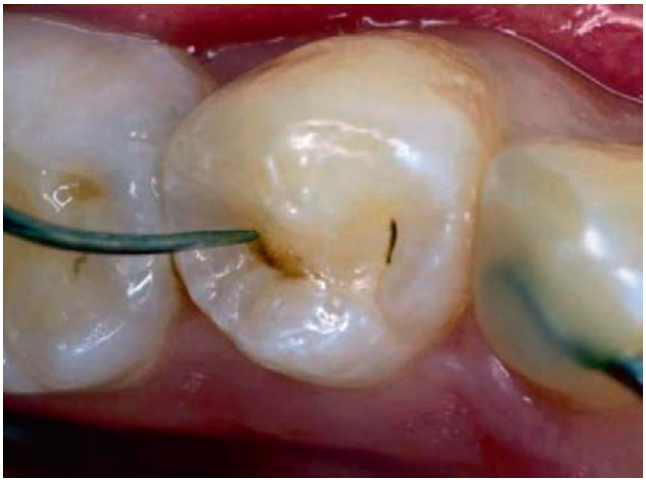


FIGURE 8-3 Explorer used on tooth to diagnosis decay.

- How does one effectively diagnose these much smaller lesions in the teeth?
- Should these smaller lesions be left to grow larger for easier diagnosis and access or should they be intercepted while they are still small?

The accurate diagnosis of minute lesions may be quite difficult with traditionally accepted techniques. The shape of pit and fissure lesions tends to mask the size and extent of the defect when the dentist is using an explorer. Forty-two percent of these fissures have a narrow occlusal opening and vary in shape as they progress inward in the tooth. Caries is initiated in the lateral walls of the fissure and progresses downward toward the dentino-enamel junction (DEJ). The narrow occlusal opening tends to prevent the entry of the explorer into the larger chambers of the lesion. Often only a stickiness of the instrument in the tooth surface is reported. In fact, histologic cross-section has confirmed a ratio of only 25% accuracy in diagnosing decay underlying the occlusal surface using the traditional explorer method (Figure 8-3). This is hardly an impressive rate of success.

Radiographic diagnosis is an important tool for the practicing dentist. Radiographs can detect caries when none are observed clinically. However, negative radiographic results can be misleading. All too often the tooth has caries that the radiographic process will not reveal. This is known as the phenomenon of hidden caries, a condition in which the tooth appears caries free clinically and/or radiographically but is found to be carious by other diagnostic means (Figure 8-4, *A*). Subsequent cross-sectioning of the tooth clearly reveals caries that has originated at the base of a fissure and is now spreading along the DEJ (Figure 8-4, *B*).

The dilemma of clinically diagnosing small caries at an early stage is a very real problem that cannot easily be solved by

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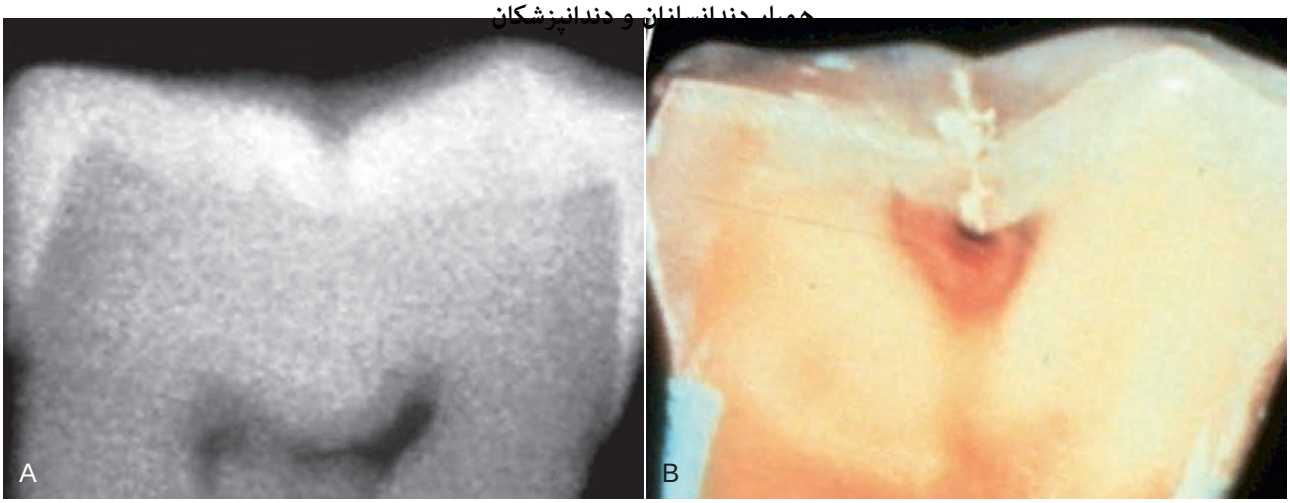


FIGURE 8-4 **A, Radiograph showing an apparently healthy tooth. B, Cross-section of tooth showing hidden caries spreading along the dentino-enamel junction.**

existing diagnostic techniques. Explorers and radiographs are simply not adequate tools for this common type of dental lesion. A further complication is the aggressive use of fluoride on a regular basis in fluoridated communities. A study in the Netherlands determined that the entire Dutch population (among others) may be overdosing on fluoride. This may have resulted in an undiagnosed hidden caries level of approximately 15% in the younger population. The surface-hardening effect of fluoride on the enamel makes the tooth surface more impenetrable to exploration, while at the same time masking the carious activity occurring just below the tooth surface and along the DEJ.

The clinical dentist is faced with the option of (1) watching and waiting until the early caries, which may be far more active just under the enamel surface, becomes larger and destroys more healthy tooth structure, or (2) aggressively eliminating these early lesions and restoring the cavities with ultraconservative restorations. The older tradition of "watching" incipient decay is no longer tenable. Extensive recent research has clearly indicated that incipient surface decay may, particularly in fluoridated communities, mask much greater subsurface carious activity within the tooth. Incipient decay must therefore be intercepted at the earliest possible opportunity to prevent the spread and growth of caries and to permit the most conservative restoration possible.

The practice of sealing pits and fissures has enjoyed widespread acceptance. There is continued concern, however, about the placement of sealants over undiagnosed caries. Because it is often difficult to determine the status of caries activity in fissures, an exploratory technique, or excisional biopsy, offers the best access and the best diagnostic and conservative technique for the maximum retention of healthy tooth structures combined with the assured removal of all decay. The excisional Fissurotomy bur (SS White Burs, Inc., Lakewood, New Jersey) remodels the anatomy of the fissure, facilitating the access, the acid etching, and the bonding of composite resin into the cavity preparation. If this can be accomplished with minimal patient discomfort, preferably without any anesthetic, patient acceptance will be high, and the dentist's conservationist goals can be attained (Figure 8-5).

Contraindications

There are no contraindications to adhesion in clinical dentistry. There have been no reports of allergy to the materials. Restorations that failed have done so only when the adhesion was improperly implemented, or early in the adhesive era when bond strengths were simply too weak. It is very important that adhesion be accomplished rigorously, following the instructions and the requirements of the materials involved.

There are many different adhesive procedures. Specific composite materials may require specific adhesive components. Some composite materials are not compatible with all adhesive components. Thus it is essential that the adhesives used be appropriate to the procedure and the restorative material and that the entire system be used according to the manufacturer's instructions. Certain restorative materials, bases, cements, and ionomers do not require separate adhesives because the bonding chemistry is incorporated into the restorative material itself. In these situations, the adhesive may be superfluous. It may even compromise the restorative to tooth bond strength and the overall success of the bonding procedure.

MATERIAL OPTIONS

The dental practitioner has many options in the area of adhesives. As described earlier, there are seven distinct generations of adhesives. Each generation has its own advantages and disadvantages; some of the earlier generations are currently not in widespread use because better methods have superseded them quite effectively. Only generations four through seven are commonly used at this time (Table 8-1).

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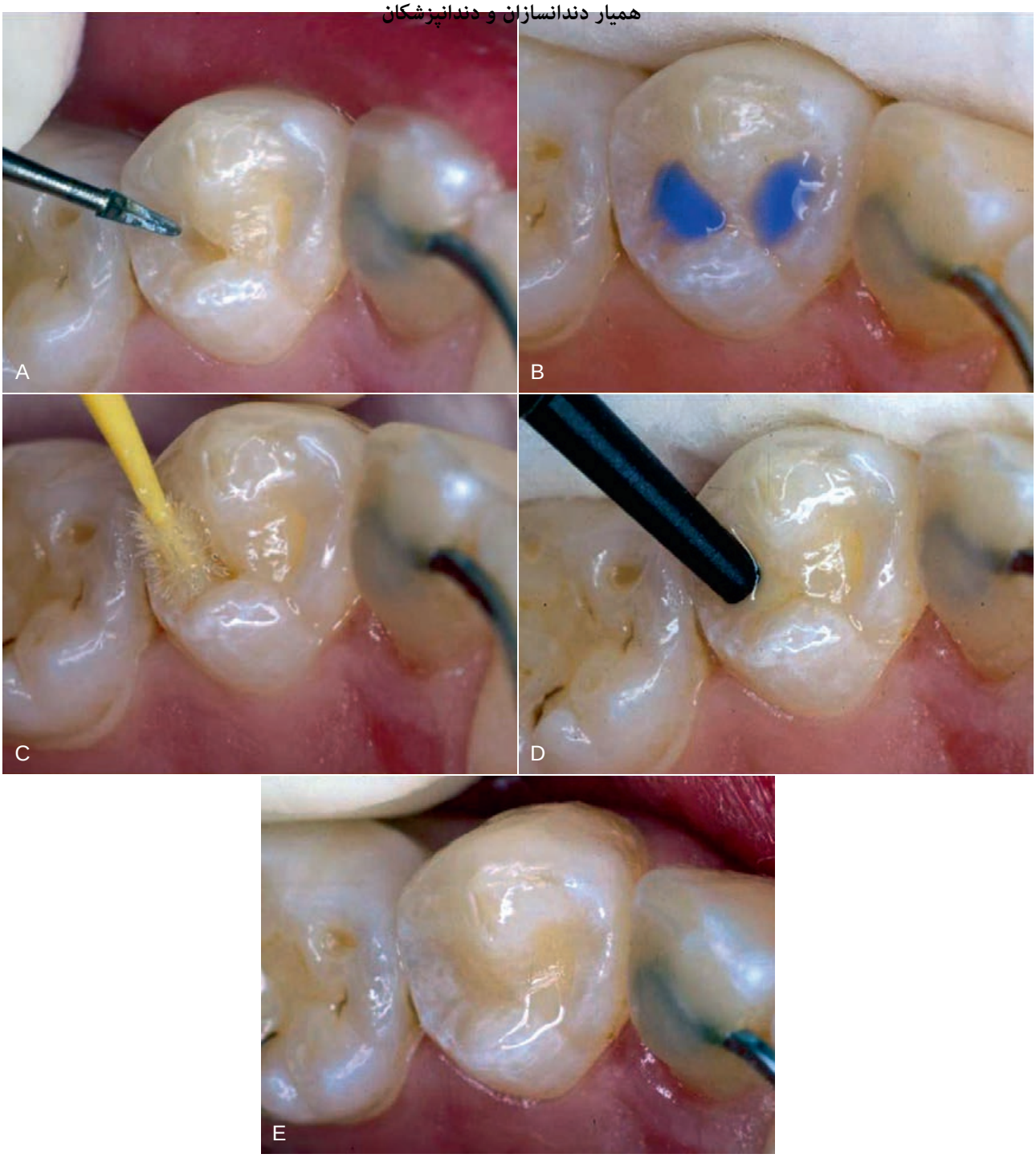


FIGURE 8-5 **A, Fissurotomy bur is used to excise early decay to the depth of the dentino-enamel junction or just beyond without need for local anesthetic. B, Acid etching of the prepared cavities. C, Fifth-generation adhesive applied to etched surfaces. D, Flowable composite inserted into the small occlusal preparations. E, Completed ultraconservative restorations.**

The **first-generation** adhesives bonded quite well to enamel through resin-infiltration of the enamel microcrystals but did not bond to dentin. Etching was not yet well established as a technique; in fact, there were numerous controversies about whether etching should precede bonding. Later on, etching, performed either directly or as part of one of the adhesive components, became an essential part of the bonding process.

First-generation materials did not include dentin conditioners, and it is questionable whether they were capable of removing the smear layer at the dentin surface. It can be assumed that the etching step would have eliminated the smear layer of the dentin; however, if no etching was done, the smear layer was essentially left intact. Therefore no hybrid layer could be created and moist bonding was not required. Typically, the number of bottles in

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TABLE 8-1 Dental Adhesives: Generational Comparison

	Generation						
PROPERTY	1st	2nd	3rd	4th	5th	6th	7th
Etch as a separate step	?	Yes, E	Yes, E, D	Yes, E, D	Yes	No?	No
Condition	No	No	Yes	Yes	Yes	Yes	No
Remove smear layer	?	No!	Yes	Yes	Yes	No	No
Hybrid layer	No	No	No	Yes	Yes	Yes	Yes
Moist dentin required	No	No	No	Yes	Yes	No?	No!
Number of bottles	1-2	2	2-4	3-5	2	2-3	1
Number of steps	2-3	3	3-4	3-7	Etch +1	2-3	1
Post-operative sensitivity	?	?	Some	10%+	1%-5%	None	None
Dentin bond (MPa)	1-3	2-8	8-15	17?-25	20-25	17-22	23-30+

D, Dentin; *E,* enamel.

the first-generation kit was one or two, and two or three steps were needed to complete the procedure. Because the dentinal tubules were not opened by acid etching, there was little if any postoperative sensitivity. The enamel bond was significantly strong, typically 20 to 30 MPa, but the dentin bond at 1 to 3 MPa was essentially nonexistent. This made bonding to exposed dentinal surfaces such as Class V abfractions impossible.

The **second-generation** adhesives were also effective in bonding to enamel. With respect to the dentin, they bonded to the smear layer, the organic debris that is found on the surface of the prepared tooth. These adhesive bonds at the dentin interface were weak, ionic bonds that were generated by the hydrolysis of calcium. Etching was a routine part of the bonding procedure, but dentin conditioning had not yet been introduced. The second-generation adhesives bonded to the smear layer but did not remove it and did not develop a hybrid layer. Moist bonding was not a requirement. Typically, second-generation techniques involved two bottles and three steps. There were few reports of postoperative hypersensitivity unless the dentin was over-etched. Dentinal bonding reached levels of 2 to 8 MPa, whereas enamel bonding remained in the 20- to 30-MPa range.

The **third-generation** adhesives were the first ones specifically designed to remove and/or modify the smear layer. Adhesion to enamel was as with earlier generations, but there was a major focus on the dentinal surfaces. When this interface was examined under the electron microscope, the polymerized intratubular resin had the appearance of spaghetti-like projections that acted as anchors inside the tubules and provided increased dentinal adhesion. Both the enamel and the dentin required etching, and for the first time a conditioner was used on the prepared dentinal surface, which removed the smear layer to allow the adhesive to enter into the dentinal tubules. No hybrid layer was created, and moist bonding was not yet a requirement. Most third generation kits had two to four components and three or four distinct clinical steps. The smear plugs were partially or completely removed by the etching and conditioning, unblocking the dentinal tubules. Because not all of the vital dentinal tubules were effectively resealed by the adhesive, there was some postoperative sensitivity observed with third-generation bonding agents. Dentinal bonding of 8 to 15 MPa was achieved, along with the expected 20 to 30 MPa for enamel surfaces.

The **fourth-generation** adhesives were the first to require a total etch of all prepared tooth surfaces. Dentin bonding to *moist* dentin was 17 to 25 MPa, at least theoretically, whereas enamel bonding remained fairly constant at 20 to 30 MPa. The fourth-generation bonding protocol involved etching both enamel and dentin and conditioning the dentin. The elimination of the smear layer was a key part of the procedure. A hybrid layer was created at the adhesive-tooth interface through the interaction of the adhesive material with the moistened tooth surface. Moist bonding became a clinical requirement.

This generation was the first wherein the bonding strength to dentin was greater than the polymerization shrinkage of the composite. As a result, the composite did not shrink away from the tooth-resin interface during polymerization, thereby leaving a gap that could develop into a collector for oral fluids and bacteria. The drawback of fourth-generation systems was the need for multiple components. Kits had three to five components and required three to seven distinct steps in their protocol, a very time-consuming and technique-sensitive exercise. Certain components had to be mixed equally, and in a specific order, chairside. This is rather difficult to accomplish predictably on a regular basis, as evidenced by the common situation in which one of the "equal mix" components was always used up more quickly than the other. The unequal amounts of the components often compromised the adhesive strength of the bonding agent. Although the final bonding strength to dentin was theoretically 25 MPa, in actual fact it was often less than 17 MPa, the minimum adhesion needed to avoid marginal gaps caused by polymerization shrinkage of the composite. Clinically, the greater the number of steps, the greater the likelihood of inadvertent procedural error (Figure 8-6).

Postoperative sensitivity was observed in 10% to 30% of posterior restorations (far less with anterior restorations). This

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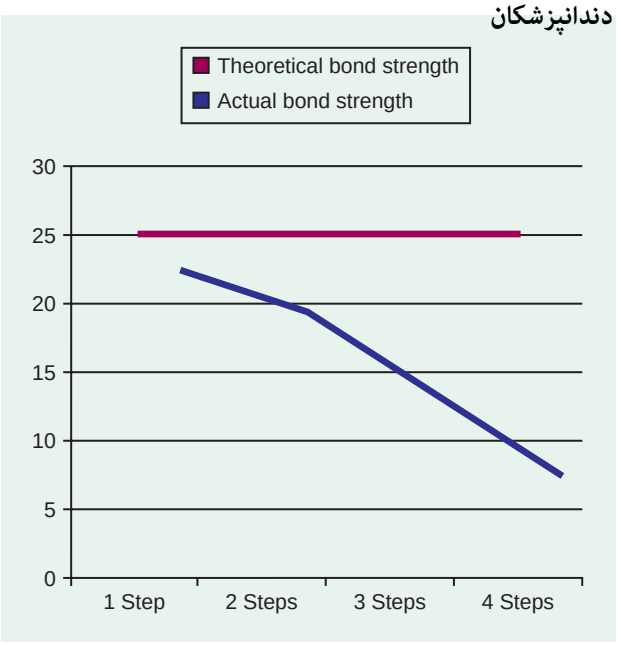


FIGURE 8-6 **Clinically, the greater the number of steps, the greater the decrease in bond strength from theoretical to actual.**

may have been a result of the prescribed technique that effectively eliminated the entire smear layer as well as the smear plugs in all the exposed dentinal tubules. In order for post-treatment sensitivity to be prevented, the bonding agent had to infiltrate and seal *every single one* of the opened dentinal tubules to plug them. Any open dentinal tubules allowed the outflow of intratubular moisture, creating hypersensitivity that could cause the patient pain for days, weeks, or even longer. The sensitivity was much more acute and more likely to occur in posterior teeth, possibly because of the higher C factors in these preparations. Postoperative sensitivity was often observed even when technically precise procedures were performed with great clinical care.

Fourth-generation adhesives are dual cure; this means that after mixing they can be polymerized within seconds with a curing light. In the absence of a photo-catalyst, these adhesives will cure within 60 to 90 seconds after mixing. Thus they polymerize both in the presence and the absence of a curing light.

The **fifth-generation** adhesives combined all the necessary bonding components into a single bottle, not including the etchant. They had somewhat lower bonding strength to dentin than the fourth-generation products, at least in theory. However, as there were no components to mix chairside, the formulation having been completed under controlled factory conditions, the adhesive was more likely to always be at its optimal chemistry. The single-component fifth-generation adhesives bond to both enamel and dentin; they require total etching however (a 15- to 25-second process).

Etching is very predictable and is easily accomplished by practitioners. The most common fifth-generation problems relate to the moist bonding surface requirement. Although it generally has been accepted that a "moist" bonding surface is a must, the definition of "wet" or "moist" surfaces can be rather controversial and confusing. Some academics and practitioners assume that a very slight moistness is enough; others maintain that a liquid sheen must be visible on the surface to be bonded. Because there has been little research to quantify or specify the correct level of moisture for optimal adhesion, there is little consensus within the profession on this topic.

The fifth-generation adhesives are specifically designed to remove the smear layer and to generate a hybrid layer created through moist bonding. There is one etchant bottle and one adhesive bottle. The number of indicated steps is two: a relatively simple and rapid etching step, and a second, adhesive step that varies in complexity and technique sensitivity from product to product. There is less post-operative sensitivity observed with fifth-generation bonding agents—typically 5% or less in posterior teeth and quite rare in anteriors. This benefit may be a result of the more consistent manufacturer premix of the adhesive components and the reduction of the recommended etching time from the earlier 60 to the more sensible 15 seconds. The dentin bond is a more predictable 20 to 25 MPa (the premix eliminates mixing errors and variability), and the enamel bond range is 20 to 30 MPa.

The chemistry of fifth (as well as sixth and seventh) generation adhesives is not compatible with dual cure restorative materials such as cements and core buildups. Thus, an accessory dual-cure additive was introduced by many manufacturers to make the strictly light-cured fifth-generation adhesives compatible with dual-cure restorative materials. Theoretically, the dual-cure fifth-generation adhesives were light initiated but would polymerize within 5 minutes in the absence of light, as well. According to a number of published reports based on clinical testing, only Pulpdent's DenTASTIC UNO-DUO system (Figure 8-7, *A*) and Bisco's One-Step Plus system (Figure 8-7, *B*) were shown to truly have dual-cure properties. Many practitioners who attempted the use of fifth-generation dual-cure products other than the two noted above were very disappointed with their cementation results.

The **sixth-generation** adhesives were designed to eliminate the separate etching step. (In fact, there is no *separate* etching step with sixth- or seventh-generation products; the surface conditioning is accomplished by the chemistry of the bonding agent.) The sixth-generation adhesive materials bond to both enamel and dentin. The dentin bond is 17 to 22 MPa, which is relatively acceptable. The bond to enamel, however, particularly at the enamel interface, all too often fails within the first 3 years. Thus most sixth-generation adhesives cannot be indicated for enamel bonding without an additional enamel etching or enamel roughening step.

The sixth-generation adhesives are placed on the tooth surfaces at a very low initial pH, immediately etching all the surfaces that they contact until the adhesive-tooth complex is titrated (approximately 1 to 2 seconds). The etching of the tooth surfaces is accomplished as part of the overall adhesive process, not as a separate step. The sixth-generation adhesives were the first to incorporate the etching chemistry into the adhesive components, but unfortunately reverted to the multibottle, multistep application. This reintroduced the drawbacks of unpredictable chairside mixing, incorrect component ratios, and

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FIGURE 8-7 A, DenTASTIC UNO-DUO system. B, One-Step Plus system. *(**A** courtesy Pulpdent Corporation, Watertown, Massachusetts. **B** courtesy Bisco, Schaumburg, Illinois.)*

possibly an inappropriate application sequence. Some sixth-generation adhesives such as ExciTE F (Ivoclar Vivadent, Schaan, Liechtenstein) use innovative chemistries to overcome the problem of inadequate enamel etching

The clinical concern is that the acidity of the pH and the tooth application time of most sixth-generation adhesives are simply inadequate to etch the enamel sufficiently. Therefore, enamel interfaces have a tendency to break down. Whereas the dentinal interfaces are likely to stay intact in the long term, enamel interfaces may not. There are two very simple solutions to this problem: the practitioner must chemically etch or mechanically roughen the enamel surfaces of the preparation before sixth-generation adhesion. This additional step, however, creates a paradox: it makes the sixth-generation a non-etching adhesive that still requires etching materials to be used on the enamel—not a truly practical solution.

Most sixth-generation adhesives are supplied in two or three components and require two or three clinical steps. This generation uses dentin conditioners to chemically alter but not to remove the smear layer. The adhesion is to the etched enamel and conditioned dentin surfaces. The chemistry of the conditioned dentin and the hybridized layer raises the question of whether a moist surface is required. The jury is still out on this point.

The **seventh-generation** adhesives are furnished in a single bottle or ampule that includes all the required components for self-etching, surface conditioning, hybridization, desensitization, adhesion, and often fluoride release, as well. All the necessary adhesive steps are accomplished chemically by the simple application of the adhesive to the tooth surface. No additional clinical steps are required, no mixing is needed, and the bond to the enamel, unlike with sixth-generation adhesives, is very acceptable. The seventh-generation bond to dentin is the highest among all the adhesive groups, in the range of 23 to 30 MPa and higher. The enamel bond developed with seventh-generation agents is successful simply because of the lowered application pH (1.0 pH lower or 10 times more acidic than sixth-generation adhesives at the enamel surface on application). The enamel surface is etched quickly and effectively.

The most important innovation of seventh-generation adhesives is the added advantage of *moisture independence*. The acid-base reaction of the seventh-generation adhesive on the dentin surface is that of an acid acting on an organic base. This chemical reaction generates organic salt and water. Thus, seventh-generation adhesive procedures effectively *create their own moisture.* They can be applied to a "moist surface" (however that may be defined) or a dried surface (much more easily described). Because seventh-generation systems are supplied in a single premixed container and require a single application step, and no moist or wet surface, few mistakes are possible and there is *no* technique sensitivity. The process is simple: apply the adhesive to the tooth surface, agitate or scrub if required, and then, after a brief wait, simply air dry the surface. Once the bonded surface is dry (no longer moist with bonding), it is light cured. There are no separate etching or conditioning steps, and the smear layer is not removed. There has been virtually no post-operative sensitivity reported with seventh-generation bonding agents. The hybrid layer is created by the chemistry of the adhesive. The number of bottles is one; the number of steps is one. There is no post-operative sensitivity, and dentin bonds of 23 to 30 MPa and higher have been reported.

Of the seven bonding agent generations available to the dentist, the first-, second-, and third-generation agents are rarely used. The main reason for this is that their adhesion to dentin is less than the minimum force required to resist the forces of polymerization contraction of composite (17 MPa). When adhesives of these generations are used to bond composite restorations, a marginal gap often develops at the interface between the composite and the tooth surfaces. This gap attracts plaque and bacteria, resulting in acid formation that causes soft and hard tissue breakdown. Current dental practice essentially focuses on fourth-, fifth-, sixth-, and seventh-generation

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adhesives. Although all of these adhesives can be used successfully (it is crucial to follow instructions and to proceed in a logical step-by-step in sequence), the newer-generation products are clinically easier and far more predictable than the earlier ones.

Current Best Approach

The best choice for restorative dentistry today is a seventh-generation adhesive. With a single-component, single-step process, the bonding process is straightforward and predictable, and no clinical mistakes can be made. The practitioner simply takes the bonding agent from the bottle or the individual dispenser compule and applies it to the tooth surfaces. There the adhesive is agitated or left to infiltrate the tooth structure, according to the instructions. The excess adhesive is air dried until no droplets remain on the surface. Then it is light cured. There is virtually no post-operative sensitivity with seventh-generation adhesives. (The sixth-generation adhesives also cause little sensitivity, but fourth- and fifth-generation bonding agents are associated with significant post-operative sensitivity. These earlier adhesives can be useful but are more problematic clinically.)

Clinically, the most efficient procedures use the fifth- and seventh-generation adhesives; there are fewer components and fewer steps. The time required for bonding may not seem relevant for the practitioner at first glance; 30 seconds per restoration for a fifth or seventh generation compares very favorably to the far longer application times of fourth-generation adhesives at up to 180 seconds. A difference of 1 to 2 minutes in chairside time bonding time has a significant impact on productivity when it is considered that the average practice day comprises more than 20 adhesive procedures. Patients who must keep their mouths wide open for the entire procedure, might be uncomfortable with extended procedures, and will certainly appreciate a more streamlined treatment.

Often the fourth generation is referred to as the gold standard. Although this adhesive category is definitely the most researched over the years, fourth-generation adhesives are also the most difficult, most technique sensitive, and often the most time-consuming to use. They are known to cause more post-operative sensitivity in posterior teeth than adhesives of the other generations, even when used exactly according to instructions. This group of bonding agents requires the development of a hard-to-define moist surface prior to the application of the adhesive.

Sixth-generation products are easier to use than fourth-generation products, but despite having eliminated the acid etching step, sixth-generation procedures still involve numerous components. The most significant problem with sixth-generation agents, however, is their unpredictable adhesion to unprepared, unetched enamel. Hence the need to separately etch or roughen the enamel surfaces to increase adhesion predictability.

The remaining options are the fifth- and seventh-generation adhesives. Both are fairly rapid and easy to use, but fifth-generation agents involve a separate acid etching step, more components, and more steps. The seventh-generation bonding agents are better, faster, and easier, as well as more predictable. They offer the patient-pleasing bonus of eliminating virtually all post-operative sensitivity.

OTHER CONSIDERATIONS

One of the most important clinical considerations for the selection of adhesive products is the bonding strength required at the adhesive interface. This question first arose with the development of adhesive materials in the 1950s, and it is still a somewhat controversial topic. Certain basic principles have been conclusively established and are well accepted. In the 1980s and 1990s, a number of studies, including Munksgaard in 1985 and Retief in 1994, found that a minimum of 17 MPa of adhesion to tooth structure was required for successful adhesion. The 17 MPa represents the force of the polymerization contraction of the composite resin restorative material. If there is less than 17 MPa of adhesion to *either* the enamel or the dentin, the polymerization force of the composite resin is greater than the force adhering the material to the enamel, dentin, or both. The forces of polymerization cause the resin to contract toward the center of the composite, pulling the restorative material away from the walls of the cavity (Figure 8-8). A small gap is created, which then allows micro-infiltration of bacteria and plaque that eventually causes marginal breakdown. The fluid inflow and outflow at the restorative interface carries bacteria and sugars deep into the tooth-restorative interface and eventually causes decay. In time, a dark line appears at the margin of the restoration.

Where the bonding agent's adhesive strength to the dentin and the enamel exceed the 17 MPa of polymerization contraction, the shrinkage of the composite is toward the walls of the cavity (Figure 8-9). The laws of entropy dictate that the polymerization contraction process always tends to go in the direction of least resistance (or higher attraction). The composite is thus more attracted to the dentin and to enamel surfaces than it is to itself. Because the shrinkage is toward the walls and away from the center, no marginal gap develops. This makes marginal infiltration of bacteria and oral fluids far less likely, and thus prevents decay and eventual breakdown. The meniscus developed in the center of the restorative material is simply filled in by the next

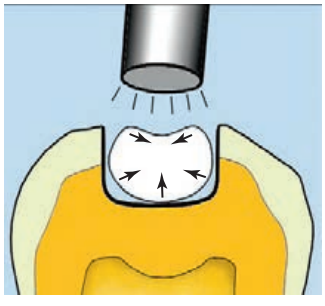


FIGURE 8-8 **Less than 17 MPa of adhesion results in the polymerization forces, causing the resin to contract toward the center of the composite, which pulls the restorative material away from the walls of the cavity.** *(Courtesy Dr Ray Bertolotti.)*

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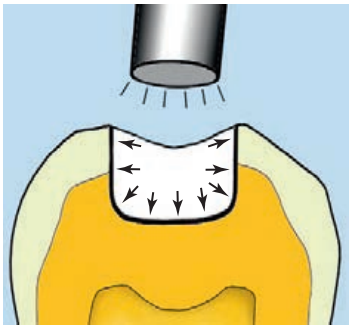


FIGURE 8-9 When there is more than 17 MPa of adhesion, the polymerization contraction causes shrinkage of the composite toward the walls of the cavity. *(Courtesy Dr Ray Bertolotti.)*

layer of composite resin. This is why an adhesive must have bonding strengths both to enamel and to dentin of more than 17 MPa to be clinically acceptable. Ideally, the bond strengths to enamel and dentin should be relatively equal. If, for example, the adhesion to the enamel is far greater than the bond to the dentin, the stronger force at the enamel interface will tend to pull the composite away from the dentinal margin during the polymerization process, weakening the dentin interface.

INNOVATIVE ELEMENTS

Chemistry of Dentin Bonding Agents

Although the currently available dentin bonding agents effectively adhere composites to the dentinal surface, there is still room for improvement. Assuming application as prescribed by the instructions under carefully controlled conditions, the clinical longevity of the bonded resin is comparable to that of any other material currently used by the restorative dentist. Unfortunately, some bonding systems are more technique sensitive than originally presumed. In a study that examined fourth-generation dental adhesives (and with findings that may apply to fifth-generation products as well), Hashimoto demonstrated that gradual debonding at the dentinal surface can occur over time. The bond strength of posterior composite resin restorations adhered with fourth-generation materials decreased by *nearly 75%* over a 3-year period. In addition, scanning electron microscopy demonstrated that some of the collagen fibers beneath the hybrid zone had undergone various levels of degradation. Although this study was conducted on primary posterior teeth, the same conclusion could be extrapolated to restored permanent teeth. This rationale is based on the fact that the mechanism of bonding to collagen and the formation of the hybrid zone are similar for both deciduous and permanent dentition.

Although the specific reasons for these findings have not been determined, the most probable cause can be attributed to the manipulative procedures associated with the bonding process itself. Specifically, it is probable that once the decalcification (acid etching) process is completed, the bonding agent primer fails to penetrate completely into all of the evacuated dentinal tubules and spaces among the peritubular collagen fibers. Without the protection of either the naturally occurring hydroxyapatite or the resin component of the dentin bonding agent, the exposed collagen fibers simply undergo a process of biologic degradation.

This problem can be related in part to the manner in which either the fourth- or fifth-generation bonding agents are used. In both procedures, the acid etching agent is first used to demineralize the dentin. Once this step has been completed and the etchant rinsed, the clinician applies the dentin bonding agent to the prepared surface to effectively reverse the etching process; all the open dentinal tubules and intracollagenous spaces created by the demineralization must be completely filled with resin adhesive. Unless the dentist is very careful to follow instructions precisely, apply the correct number of primer layers, and allow the time required for the complete diffusion of the adhesive into the denatured dentin, adequate resin penetration may not be achieved. Other factors may influence the level of penetration as well; overdrying the preparation and thus failing to leave some water on the surface (for the mandated moist bonding) may prevent the primer from penetrating the dentin. Excess water on the surface may also prevent the infusion of the bonding agent. Premature vaporization of the alcohol or acetone solvent of the bonding agent (a problem that occurs when the adhesive is dispensed too early and the solvent allowed to evaporate in the well) may also cause inadequate diffusion and bond failure.

The recent introduction of self-etching dentin bonding agents (sixth and seventh generations) has been met with great enthusiasm. The most important reason for this is the relative ease of use of these products. Many practitioners view self-etching adhesives as materials that can etch both dentin and enamel in a single step. They also perceive these bonding agents as systems that can simultaneously apply the primer and/or adhesive in the same step. A second reason for the rapid acceptance of these materials is related to the virtual absence of post-operative sensitivity associated with their use. Together, these two factors have convinced many practitioners to abandon earlier adhesive systems for a process that they perceive to offer better, faster, easier, and more predictable bonding to tooth structure.

The inherent advantage of the self-etching dentin bonding agents is that they etch and deposit the primer simultaneously. This procedural sequence makes it far less likely that underfilling (incomplete replacement by resin of the etched minerals in the dentinal tubules and intracollagenous areas) will occur. Consequently, the possibility of both long-term bond strength degradation and short-term post-operative sensitivity is significantly diminished. Furthermore, the number of steps needed for bonding composites to the dentin surface is reduced, minimizing technique sensitivity. The latest-generation adhesives make bonded dental procedures easier, better, and more predictable.

Technologic Elements

The technologic advances that have played a role in the process of dental adhesion are very important. The earliest bonding agents were supplied in one or more bottles. The components

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were dispensed and mixed as required and then were picked up by a brush or synthetic foam stick to be applied to the tooth structure. If the applicator was inserted into the bottle, the remaining adhesive was immediately contaminated.

There were certain bonding chemistries and bottle materials that were not entirely compatible, which greatly decreased the shelf life of the adhesive.

It is important that the adhesive be at its optimal chemistry when it is applied to the tooth surface. Because the most common dental solvents—acetone and alcohol—are highly volatile at room temperatures, the practice of anticipating a procedure by dispensing the material into a well 2 to 3 minutes before application allows excessive solvent evaporation, an altered chemistry, and premature bond failure.

One of the first major innovations was the development of individual dispenser containers, or disposable wells wherein the components were quickly premixed, eliminating the possibility of cross-contamination. Each cap or individual dispenser was designated for a single patient use, for one or more teeth; they certainly could not be shared among patients.

The issue of chemical contamination of the adhesive by the plastic bottle material was solved, initially by using glass containers and then by adjusting the chemistries of either the adhesive or the bottle plastic, or both.

Many of the earlier applicators could not transport sufficient volumes of adhesive to the tooth surface effectively or quickly. Manufacturers began to provide innovative reservoir mechanisms to overcome this problem. Tooth applicators went from simple brushes to foam carriers and then advanced to foam-brush carriers that were capable of incorporating significant amounts of adhesive to be brought to the tooth in a single carry. With current adhesives, it is imperative that the adhesive be carried to the tooth as quickly as possible in sufficient quantity, applied to the tooth, agitated on the surface, and then, once completely air dried, light cured.

Another technologic innovation has been the factory-level mixing of components. In a clinical situation when two materials must be mixed freehand, one material may be used in a greater proportion than the other. This is often demonstrated by dentists finishing one component of a two-bottle system well before the other, indicating that too much of one component (or too little of the other) was used. The resulting decrease in the adhesive's chemical properties can damage the functionality and decrease the longevity of the restoration.

Over the past decade, the individual-dose adhesive dispenser has become very sophisticated; it is stable on the practice tray, can be resealed for optimal chemistry over a long procedure, and maintains its mix without shaking or agitation for extended periods. These technologic innovations have made adhesive dentistry easier and more predictable.

TREATMENT PLANNING

The process of treatment planning for adhesive procedures is often complicated by the dentist's confusion regarding which adhesives to use in specific clinical situations. Owing to the conflicting claims of manufacturers and the unclear descriptions of these products in promotional and packaging materials, dentists are often at a disadvantage when selecting adhesives. Although they understand the general concept, the chemistry of each generational classification may be too complex for those who are not experienced organic chemists. Therefore it is important to have a means for clearly differentiating bonding agents with respect to their generations. Two questions should be asked:

1. **Is there a distinctly separate etching component and step?** Etching is a required step in the modern adhesive process. In some generations of materials, the etching material and step are distinct from the other components (fourth and fifth). In other generations (sixth and seventh), the etching process has been chemically incorporated into one of the other components.
2. **How many components are involved in addition to the etching material?** The various chemistries of the different generations require one or more components. The number of components (bottles) in the adhesive kit has a direct bearing on the generational classification.

Having asked these two questions, the practitioner can set up a simple table (Figures 8-10 and 8-11) to make it very easy to classify adhesive materials. Any one of the bonding agents—fourth, fifth, sixth, and seventh generations—can, when used properly and under the right circumstances, work well in the short and long term. It is important to remember that adhesives must be selected for appropriate indications and used according to the manufacturer's instructions, with *all* the specific steps outlined. Omitting any of the steps may compromise long-term clinical success and possibly even the short-term result.

The sequence of using adhesive materials is very straightforward. Typically, once the preparation of the tooth is completed, it is simply a matter of cleansing the dental surfaces of all debris. There should be an effort to eliminate bacteria from, and below, the prepared enamel and dentin surfaces using ozone or photoactivated disinfection technologies. These systems actually kill bacteria on the tooth and the prepared surfaces to a depth of 2 to 3 mm and offer an improved restorative substrate that is less

Adhesives Generational Selector

Etch step → # of components ↓↓↓↓↓↓↓	Separate	Not separate
Single component		
Multiple components		

FIGURE 8-10 Table used to classify adhesive materials.

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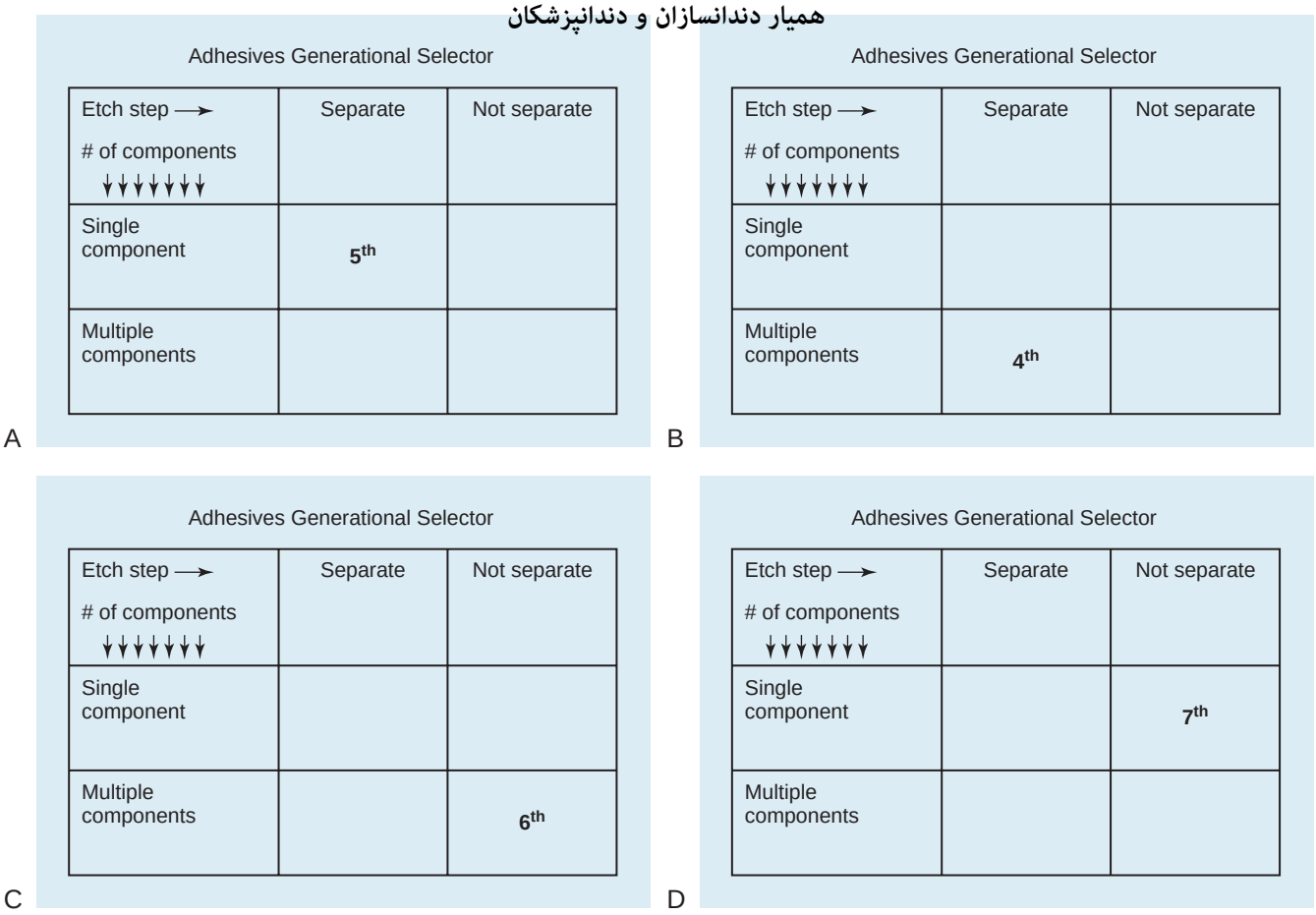


FIGURE 8-11 **A, If the procedure involves a single adhesive liquid with a separate etching component, the product is a fifth-generation adhesive. B, When multiple adhesive components follow a separate etching step, the agent is of the fourth generation. C, Systems that require no separate etching agent but use multiple adhesive components, mixed or applied in sequence, are by definition sixth-generation adhesives. D, The simplest and easiest to use are the single-component adhesives that require *no* separate etching step; these are the seventh-generation adhesives.**

likely to redecay. The surfaces may then be desensitized as required with the clinician's selection of preadhesive and adhesive materials. Many adhesives have desensitizers incorporated into their chemistry, and no additional desensitizers need be used. Most desensitizers do not affect the adhesive capacity of the bonding agent, and their components do not adversely affect polymerization.

Once the adhesive bottles or compules have been opened and the components dispensed (and mixed, for fourth- and sixth-generation products), it is important to carry the adhesive to the tooth quickly to avoid the volatilization of the acetone or alcohol solvents.

The adhesive is then applied to the tooth as per the instructions. Some materials require several applications and adequate time in between to complete the **hybridization** process. Agitation on the prepared surface may be recommended, depending on the chemistries involved. It is essential to follow the instructions to the letter with regard to applying, agitation, leaving liquid on the surface, or observing the recommended waiting times. The hybridization process requires no more than 20 to 30 seconds in most cases. Once hybridization is complete, it is important, with adhesive agents of all generations, to eliminate the remaining solvent from the surface with a stream of oil-free air. This step is crucial; it has been suggested that bonding liquid that has pooled and polymerized near the margins is responsible for the brown lines that are occasionally observed at marginal areas but are *not* accompanied by marginal breakdown. Bonding agents are less filled and more soluble than composite restorative materials and more likely to stain and discolor. Discolored restorative margins may be present even if no marginal discrepancies are discernible.

It is essential to air dry the adhesive completely; the ideal prepolymerization state of the bonding agent is a surface on which the continued application of air causes no adhesive droplets to run across the surface. The ideal air-dried, bonded surface has a very characteristic dull gloss. The adhesive is now ready for photopolymerization. The adhesive layer is typically 10 to 15 μm in thickness and requires very little polymerization time; 10 seconds or less with a light-emitting diode (LED) curing light should be more than adequate to polymerize the adhesive layer completely. Because the polymerization beam does not pass through solid dental structures, it is a good idea to move the light around somewhat during polymerization to ensure that no areas of adhesive are left uncured.

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TREATMENT CONSIDERATIONS

During the adhesion procedure, several points must be remembered. For most procedures involving fourth- and fifth-generation adhesives, a moist tooth surface is mandatory. For sixth-generation products this moist surface is not generally required. These concerns are totally eliminated for seventh-generation materials; the chemistry of the adhesive is such that the required moisture is created as soon as the bonding agent is applied to the tooth surfaces. Very specifically with seventh-generation agents, either a dry or a moist tooth surface is acceptable.

Theoretically, prebonding moistness is a well-established concept, but a reliable clinical definition is much more difficult to find. The most critical concern with non–seventh-generation adhesives is that the tooth surfaces must be moist immediately prior to bonding—there is little clinical concurrence in the description of this state and it tends to vary greatly in definition.

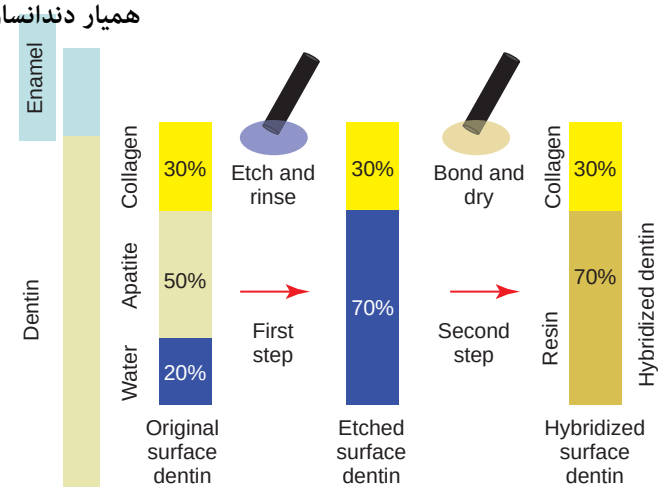


FIGURE 8-12 Fifth-generation hybridization.

Need for Moist or Wet Bonding

Two types of adhesion are associated with dentin: adhesion inside the dentinal tubules and adhesion at the peritubular surface. The intertubular or peritubular dentin is seen at the preparation surface between the tubules. In each case the objective of post-preparation dentin treatment is hybridization.

The **chemical composition** of the surface dentin (to a depth of 20 to 30 µm) changes significantly during the bonding process. The original surface dentin has 50% hydroxyapatite, 30% collagen, 20% water, and no resin (Figure 8-12). The 20 to 30 µm of dentin nearest the surface, whether inside the dentinal tubule or at the peritubular surface, is the target for the adhesive treatment.

Etching and rinsing this region (fourth- and fifth-generation adhesives) demineralize the layer, effectively eliminating the apatite. The fifth-generation adhesion approach is a two-step hybridization process. When the dentinal surface is acid-etched and rinsed, the surface dentin is demineralized, eliminating the apatite. Its composition is now 30% collagen (unchanged) and 70% water (see Figure 8-12). The next step is the application of the adhesive. The adhesive does not restore any of the apatite but ideally displaces all the water with resin. Thus, at the completion of the fifth-generation adhesive process, the surface dentin is a hybrid layer composed of 30% organic collagen (unchanged) and 70% inorganic resin (see Figure 8-12). The original 20- to 30-µm organic layer of the dentin is now infused, or hybridized with resin; hence it is called the *hybrid layer.*

After polymerization, the hybrid layer forms the dual-natured interface between the organic dental structures and the inorganic composite resin restorative materials. The purpose of the hybridization procedure is simply to replace the apatite and water in the surface dentin with resin.

The seventh-generation procedure has the same start and end points, but the separate processes are combined into a single step.

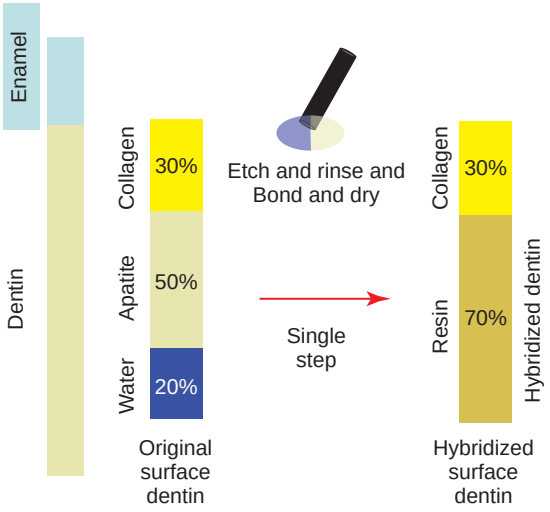


FIGURE 8-13 Seventh-generation hybridization.

The original dentinal surface composition is 50% hydroxyapatite, 30% collagen, 20% water, and no resin. After adhesion the surface dentin hybrid layer is composed of 30% organic collagen and 70% inorganic resin. The significant difference is that the process is accomplished in a single step that is *not* technique sensitive (Figure 8-13).

In summary, hybridization, which is often considered a difficult process to describe, is simply the replacement of the apatite and water in the surface dentin with bonded resin, which in turn, is the substrate to which the overlying composite layers bond.

The treatment considerations for adhesive procedures are fairly straightforward. Certain conditions must be met during the preparation, the procedure, and the finishing to ensure an optimal adhesive interface. Most published and advertised studies that mention adhesive values indicate maximal values. Real clinical practice values may be lower—in fact, significantly

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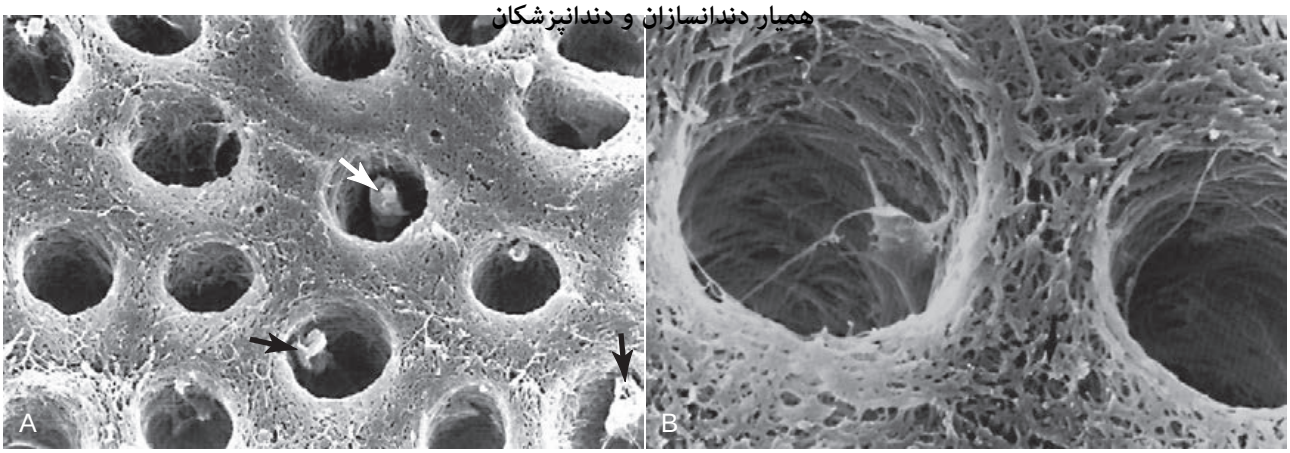


FIGURE 8-14 **A, Open tubules seen on prepared, acid-etched, and dried dentinal surface. B, Close-up of dentinal tubules shows highly porous surface and collagen fibers surrounded by empty spaces.**

lower. For this reason, it is essential that every practitioner optimize the conditions under which the adhesion is performed to ensure that the clinical values approach the theoretical or published values as closely as possible—knowing full well that clinical factors such as speed, time, and chairside imprecision will reduce theoretical values by a significant amount no matter how much care is used.

Preparation

During preparation, it is important to remember that in the earlier generations enamel exhibits stronger bonds to resin than does dentin. This is true for generations up to and including the fifth generation. Most sixth-generation products bond well to dentin but do not exhibit the same adhesive strength to unetched or unprepared enamel. The seventh-generation adhesives bond well and relatively equally, to both enamel and dentin. Knowing this in advance makes it possible for the dentist to (1) prepare the tooth effectively in anticipation of projected adhesive parameters and limitations and (2) understand the bonding requirements that will present during the restorative phase.

Theoretically, leaving the restoration on enamel surfaces with enamel margins provides the highest adhesive values and allows the most conservative preparation possible. In most cases, however, preparation is driven by decay, wear or fracture. In these situations, the dentist must adapt the restorative technique to the actual clinical situation. Most often, dentinal surfaces are extensively exposed. Because the marginal areas are critical for the effective sealing of the restorative interface, they should be located on a suitable width of enamel surface. If only very narrow areas of enamel are available, they may be inadequate to ensure a completely effective marginal seal. In these situations, beveling the enamel surface creates a wider enamel surface near the margin.

The exposed external adhesive interface where the restoration abuts the natural tooth structure is likely to be weaker and more susceptible to plaque breakdown, bacterial infiltration, and secondary decay than most other areas of the dentition or the restoration. Therefore, whenever possible, the margins should be located such that they are readily cleansable by both the dental team at regular maintenance visits and (most important) by the patient during routine at-home maintenance. A margin that is located subgingivally or at another location that is not readily accessed by simple at-home patient techniques will sustain breakdown much more readily than margins located in cleansable areas that can be readily maintained by the patient with routine oral care.

Figure 8-14, *A* presents a view of a prepared, acid-etched, and dried dentinal surface with open tubules. The close-up view in Figure 8-14, *B* reveals the highly porous surface, collagen fibers surrounded by empty spaces.

Figure 8-15 demonstrates the rationale and scientific basis for and clinical importance of **moist bonding.** The stylized dentinal tubule is approximately 15 to 20 μm in depth (see Figure 8-15, *A*). The blue circles represent the water molecules, the red triangles represent the adhesive resin, and the black squares represent the acetone molecules, which function as a solvent for the adhesive resin. The objective of the bonding process is to get the red triangles of resin to fill the dentinal tubule very quickly (15 to 30 seconds) and very completely. It must be remembered that there are thousands of open dentinal tubules in a prepared tooth, and they must *all* be filled by adhesive resin in order to prevent post-operative sensitivity. The resin-acetone solution must be drawn into every tubule and into every porous surface as quickly and effectively as possible.

Water moisture has a very low surface tension on the tooth surface and tends to spread in an even thin film throughout the dentin, into every dentinal tubule (see Figure 8-15, *B*) and into all the intracollagenous spaces in the peritubular dentin. The acetone molecule (black square) has a very strong affinity for water—much stronger, in fact, than its bonding strength to the resin (see Figure 8-15, *C*). Thus when the weakly attached resin-acetone solution (delivered to the tooth as the bonding agent), represented by the red triangle attached to the black square, is applied to the tooth surface (see Figure 8-15, *D*), its molecules are attracted by the surface and subsurface moisture on the tooth, spreading the bonding agent thinly but completely over the entire exposed dental surface (see Figure 8-15, *E*). Once the

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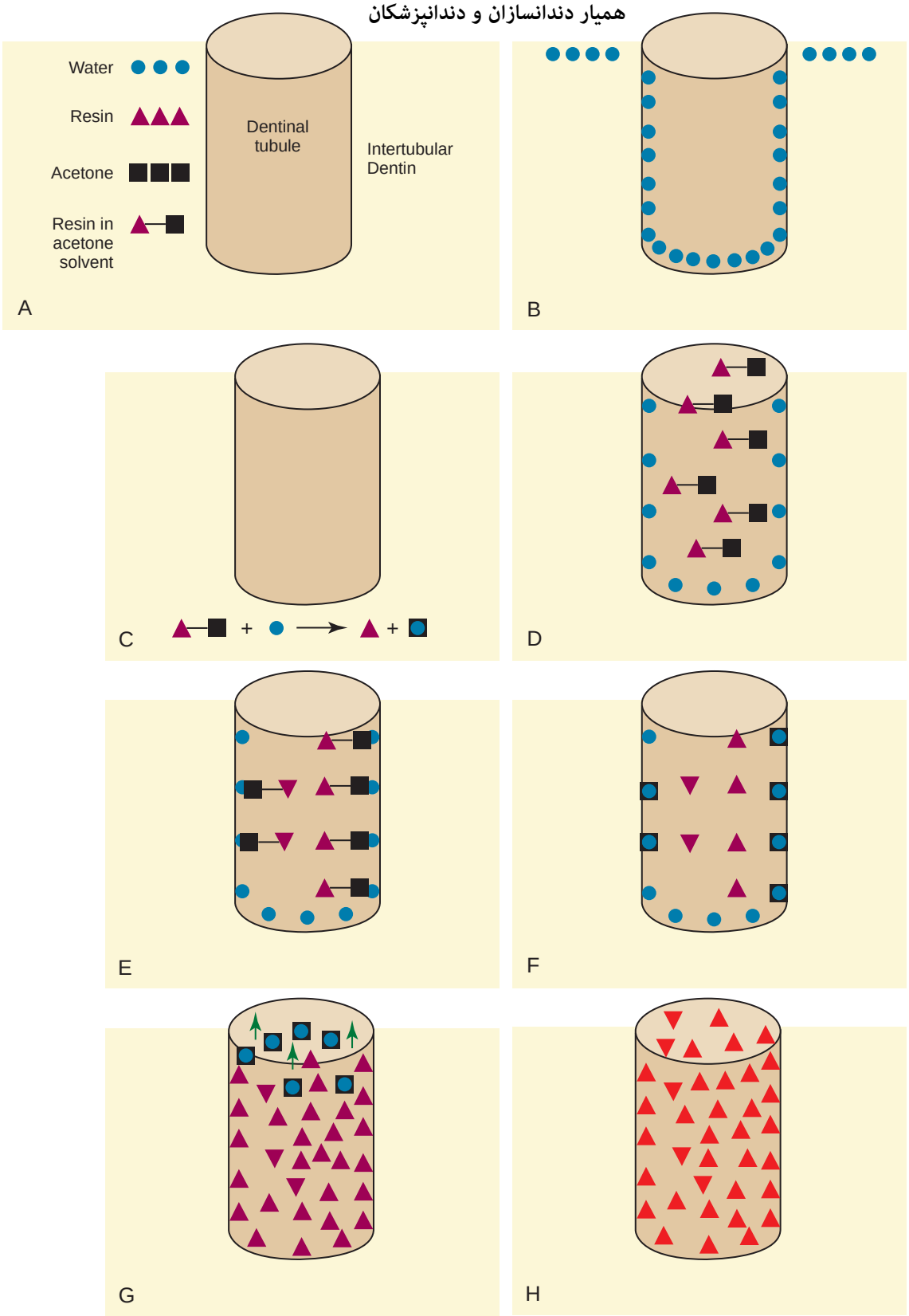


FIGURE 8-15 Representation of moist bonding. See text for detailed description.

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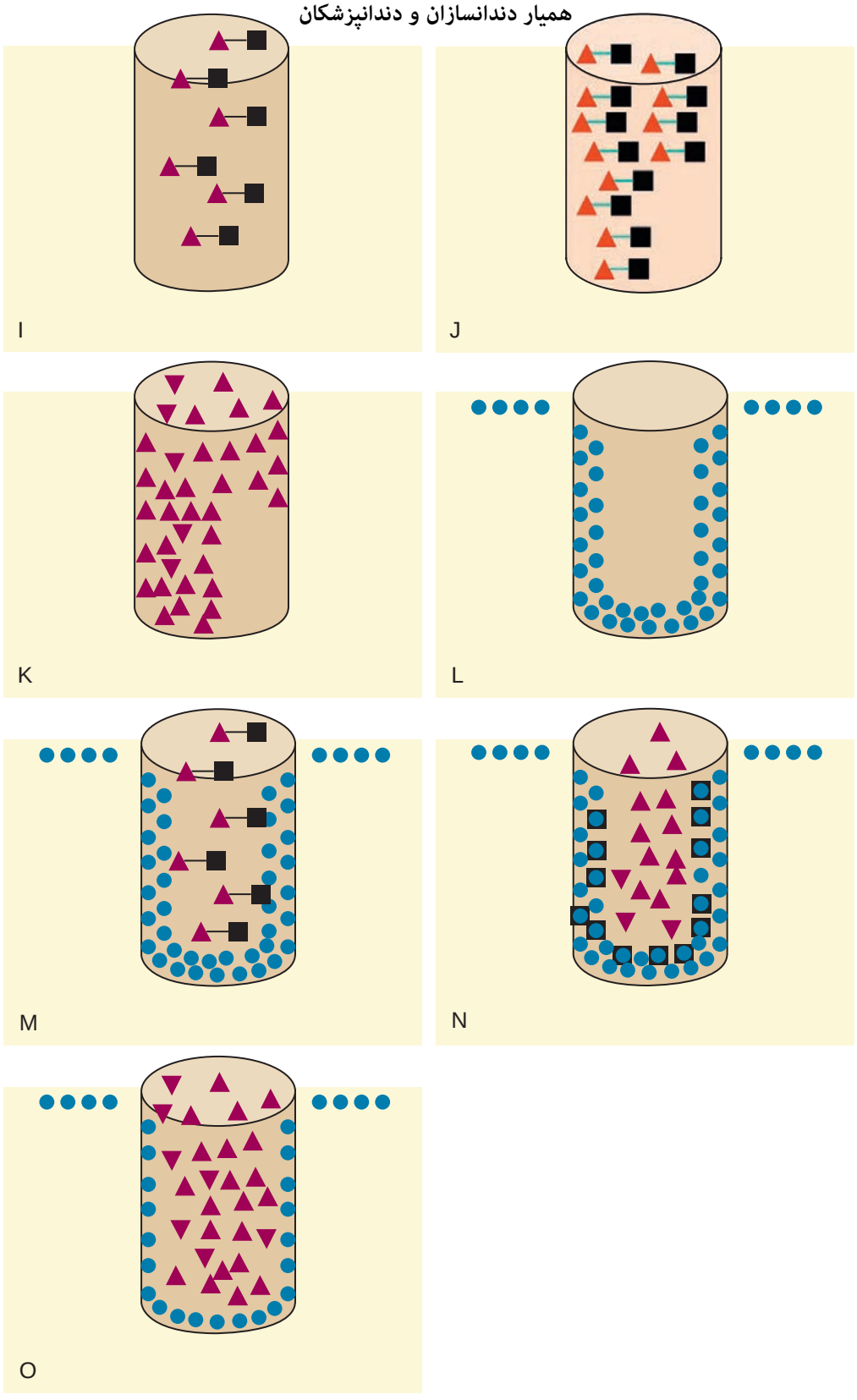


FIGURE 8-15, cont'd I and J, Bonding to a too-dry tubule. L and K, Bonding to a too-wet tubule.

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resin-acetone (red triangle–black square) is in close proximity to the moisture (blue circle), the acetone (black square) exhibits its greater affinity for the water molecules (blue circles) by detaching from the resin (red triangle) and creating an acetone-water complex (black square–blue circle) (see Figure 8-15, *F*). The acetone-water complex volatilizes (see Figure 8-15, *G*), leaving the resin (red triangle) behind inside the dentinal tubules and at the dentinal surfaces (see Figure 8-15, *H*). Overall, this is a very efficient, effective, rapid, and predictable method for developing a thin, relatively even layer of resin over the entire prepared surface that also fills the etched dentinal tubules. The process typically takes 20 to 30 seconds when performed according to the instructions and tends to fill every single open dentinal tubule. Because even one unfilled tubule can cause mild to moderate post-operative sensitivity, the relatively low incidence of after-treatment discomfort is a testament to the effectiveness of this technique. Once this layer of resin has been air dried, it is ready for light polymerization.

In situations where the tooth surface is dry (see Figure 8-15, *I*); there is no moisture to attract the resin-acetone solution to the tooth surface (see Figure 8-15, *J*), and the bonding agent may pool (see Figure 8-15, *K*), spread unevenly, and possibly miss certain surface areas entirely, creating an uneven adhesive interface that is more prone to microleakage and is weaker. Furthermore, any remaining open dentinal tubules can be the cause of post-operative sensitivity.

Too much water inside the dentinal tubules can play havoc with adhesion as well (see Figure 8-15, *L*). An excess of water means that not all the water molecules will attach to acetone molecules (see Figure 8-15, *M*) and be volatilized. The acetone cannot remove ALL the moisture from the tubule or the dentinal surface (see Figure 8-15, *N*). This leaves excess moisture at the tooth-adhesive interface as a lubricant between the tooth and the restoration (see Figure 8-15, *O*), permitting microleakage and resulting in a weaker bond and restoration failure. The same problem is also observed at the intertubular dentin surface. Both resin and moisture are present, preventing complete polymerization and weakening the bond because the resin tags inside the intertubular dentin surface are less patent.

Thus it is clear that the ideal amount of moisture is critical to an effective adhesion process, specifically for fourth- and fifth-generation adhesives. The major problem from the practitioner's perspective is that there is no clinically accurate definition or even a commonly accepted description of exactly how wet is "wet" or how moist is "moist."

Adhesion Process at the Intertubule Level

The **physical nature** of the surface dentin also changes significantly during the process of hybridization. The original surface dentin (depth 20 to 30 µm) is covered by a smear layer consisting of organic and inorganic debris left after the preparation, including live and dead bacteria (Figure 8-16, *A*). Etching (Figure 8-16, *B*) and rinsing (Figure 8-16, *C*) this surface remove the smear layer and eliminate the apatite (demineralize) from between the collagen fibers. The underlying dentin beyond 30 µm is not demineralized. Drying the surface collapses the remaining collagen fiber network on itself, creating a surface that is very dense and highly impenetrable to adhesive liquids (Figure 8-16, *D*). Any attempts to bond to this dry collagenous surface ultimately fail. Fortunately, the collapsed collagen network can be fully restored by rehydration, the application of water (Figure 8-16, *E*). As the collagen fibers spread out, they are surrounded by moisture. They can then be treated by hydrophilic primers (Figure 8-16, *F*) as part of the adhesive process. Once the resin has totally replaced the water (which had previously replaced the apatite) in this layer, the bonded preparation surface is light polymerized resulting in a hybrid layer. Again, it is critical that the exactly appropriate amount of moisture be present; over-moist and over-dry areas can significantly reduce the predictability of the entire process.

- The intertubular dentin before etching. The collagen fibers are visible, surrounded by apatite (Figure 8-17, *A*)
- The intertubular dentin after etching. The collagen is present but the apatite in the surface dentin layer is demineralized. On the right is the collapsed intertubular dentin after drying (Figure 8-17, *B*).
- The collagen fibers have been moistened in order to decollapse them.
- The resin has replaced the missing apatite and water. This collagen and resin layer is a hybridized layer of two materials—organic collagen fibers and inorganic resin (Figure 8-17, *C*).

Surface Contamination

The importance of oil-free water and air cannot be overstated. Oil of any sort, whether from dental materials or compressor/dental vacuum system lubricants, can contaminate the tooth or adhered surface to weaken or destroy adhesion. Therefore it is critical for both the water and air delivery systems to be totally free of contamination, particularly oil contamination.

When moistening dentinal surfaces, it is essential (and assumed) that the water or moisture is oil free, saliva free, and debris free. Saliva contains proteins and other contaminants that are not compatible with adhesion. Any dentinal or enamel surface that has been contaminated by saliva must be re-treated, beginning at the very first step. Because seventh-generation adhesives involve just one step, re-treating is easier and faster.

Finishing and Curing

With the adhesives that do not require an additional, separate etching procedure, the finishing of the adhesive protocol is straightforward. The adhesive surface is dried until it exhibits a matte appearance. It is very important that all the solvent moisture—the water-containing acetone (or water-containing alcohol) droplets that persist on the bonded surface—be totally air dispersed, leaving only resin behind. The elimination of moisture yields the optimal adhesive strength that is so critical to the subsequent restorative procedures.

A good clinical method for determining whether moisture is present on the surface is to look at the isolated bonded surface under magnification as a stream of uncontaminated air is blown

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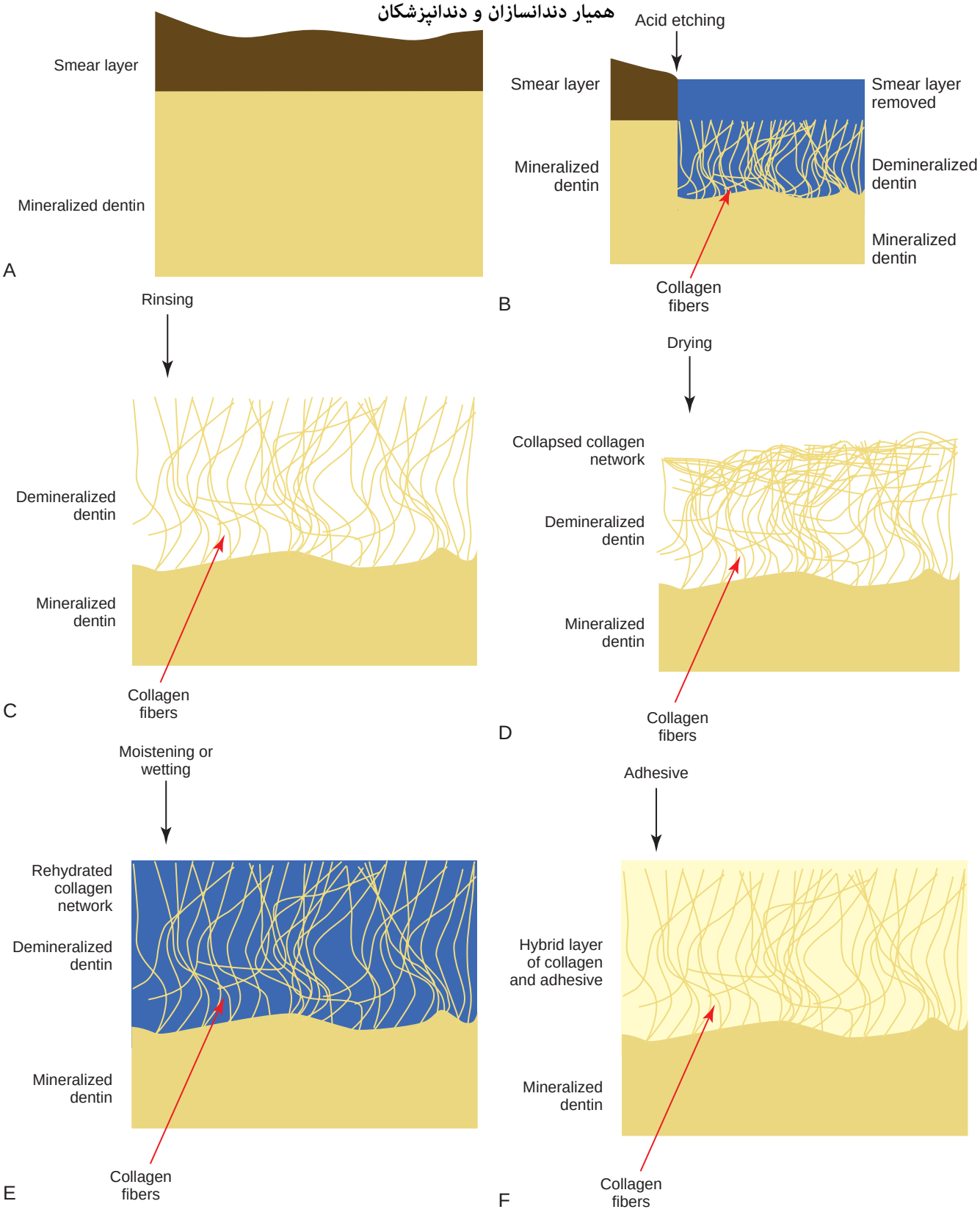


FIGURE 8-16 Changes in the physical appearance of surface dentin caused by the hybridization. See text for detailed description.

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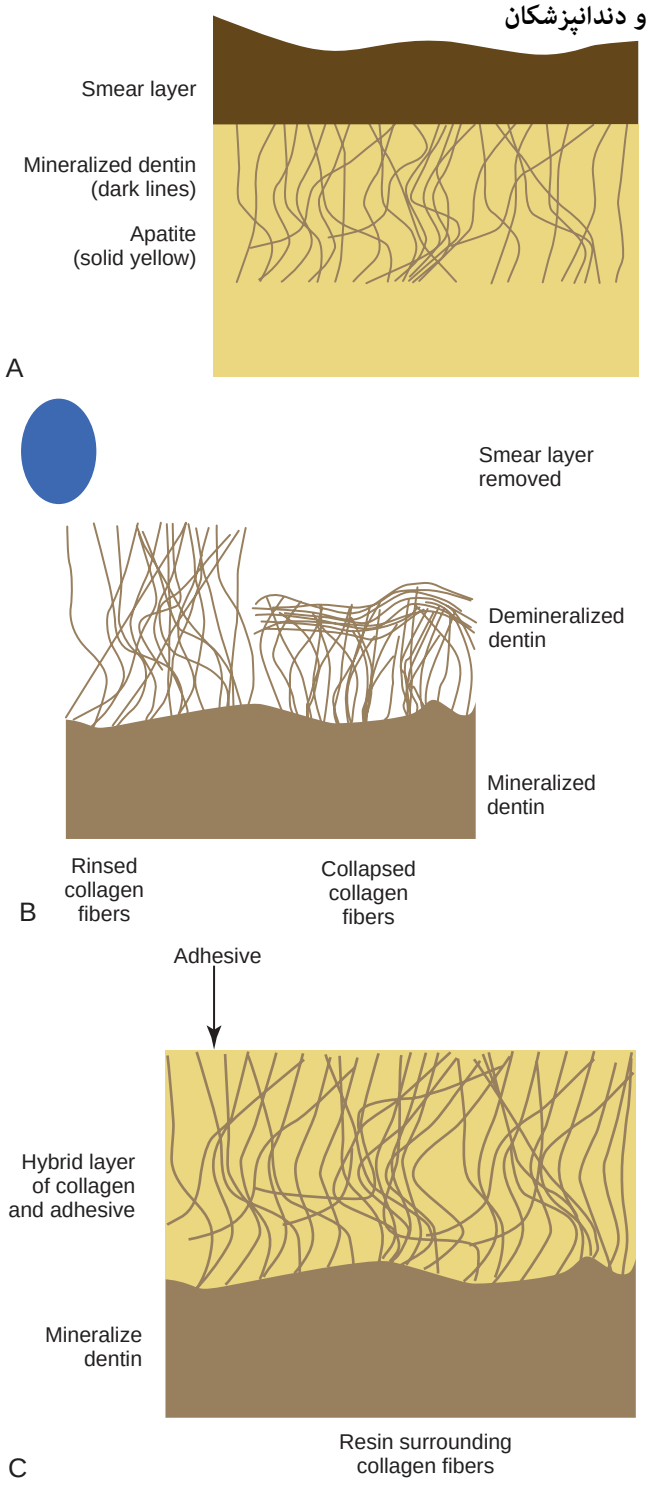


FIGURE 8-17 **Intertubular dentin before (A) and after (B) etching. C, Resin has replaced the apatite and water.**

over the tooth. If little droplets are seen scurrying across the bonded surface, this indicates that there are still beads of solvent moisture. Once these mini-droplets are no longer present, the clinician can be confident that the bonded surface is dry and ready for light polymerization.

The curing process is straightforward. The resin layer is very thin, and thus only a very short polymerization time is required with an LED, plasma, or halogen curing lamp. The minimum recommended time for each adhesive and each unit should be utilized. After curing, the dull matte finish that is characteristic of most uncured bonding agents will have turned into a somewhat shinier surface. This surface must not be contaminated by saliva, moisture, oil, or blood. Restorative composite must be placed immediately if the surface is to have the maximum reactivity to the overlying resin materials.

EVIDENCE-BASED PRINCIPLES

The scientific evidence for adhesion in dentistry has been documented for more than 50 years. The principle of adhesion to crystallized enamel structures was first described by Buonocore. In the 1970s and 1980s, the research and development extended to dentin bonding. Since then, both enamel and dentin bonding have been used extensively to restore teeth worldwide and have served as the foundations of modern-day dentistry. Thousands of studies have examined short- and long-term risks, benefits, and potentials. Their conclusions have been resoundingly positive. A short list of suggested readings is available in the reference section at the end of this chapter.

CLINICAL CONSERVATION CONCEPTS

The clinical conservation concept is also straightforward. Because adhesives allow a wide range of restorative materials to be bonded to both enamel and dentin (in other words, natural tooth structures), there is no longer a need to use the more invasive and aggressive principles that were necessary for amalgam restorations at the beginning of the twentieth century. These principles include "extension for prevention" and "extension for retention." These older concepts essentially describe the removal of otherwise healthy tooth structures to:

- Retain a restoration within tooth structures
- Ensure that vulnerable surfaces are protected from recurrent decay
- Compensate for the shortcomings of the available restorative materials

With bonded materials that adhere successfully to both enamel and dentin, there is no need for "extension for prevention." The fundamental concept of the adhesive approach is to remove only those structures that are diseased and/or significantly weakened, while retaining the maximum amount of tooth structure possible. Clinically, bonding allows far more of the natural tooth to be retained. Conservative approaches such as Proactive Intervention Dentistry (Dr Fay Goldstep) and minimally invasive dentistry have been made possible by the advent of bonded dentistry.

Clinical conservation also has a great impact at the tooth-restoration marginal interface. With non-bonded procedures, the margin is the weak link, particularly susceptible to acid weakening, bacterial attack, bacterial infiltration along

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the interface, and subsequent recurrent decay and marginal breakdown. Because earlier restorative materials were placed non-adhesively within the prepared tooth cavity, the interface was a wide-open portal for bacteria. With successfully bonded restorations, this interface is sealed and no longer presents an area where bacteria can deposit, infiltrate, or attack the restored or natural tooth structures. A further suggestion that margins be located where they are readily cleansable results in less extensive tooth preparation and therefore even greater tooth conservation.

MAINTENANCE

Because the bonded surfaces are mostly covered with restorative materials, no ongoing maintenance is required other than brushing or flossing. The only at-risk area is at the exposed margin where the natural tooth and the restoration meet. This area is most susceptible to microleakage, bacterial infiltration, and subsequent breakdown. Thus, the restorative margin should be located where the patient can readily access it to perform daily brushing and/or flossing. Routine maintenance with brushing or flossing of the bonded interface should be adequate to ensure years or decades of continued service without breakdown.

Regular professional maintenance is also important in removing any bacteria that have deposited in this area and are threatening to weaken the interface by acid dissolution of the remaining tooth structure. Bonding agents, particularly earlier versions, were more susceptible to staining than the composite restorative materials. If the bonding agent discolors, it can be polished to restore the original color match of the tooth, restoration, and interface. In cases where the bonding agent was insufficiently air-dried before light curing, the entire thickness of the bonding layer can stain. In these situations the entire restoration must be replaced. Attempting to clean out the marginal interface to any depth may undermine the restoration and cause further damage.

CONTROVERSIES

The first major adhesion controversy (1970s) centered on whether etching the preparation prior to adhesion was appropriate. This issue was settled very clearly long ago in favor of routine etching of enamel surfaces.

The second major issue surfaced in the 1990s. There were concerns that etching dentin would damage the pulp and lead to an explosive rise in endodontic procedures. It turned out that etching dentin for 15 seconds (versus the earlier 60-second surface demineralization) was very safe and well tolerated by vital dental structures. The current recommended etching time of the dentinal surface is exceedingly short (1 to 2 seconds), making it very unlikely that this step can be responsible for creating post-operative hypersensitivity or damaging the surface.

The latest major adhesive controversy is whether self-etching is acceptable. In fact, self-etching is preferable in many respects because the dentinal tubules are actually never opened up by the removal of their smear plugs, and the patient is far less susceptible to post-operative sensitivity. The seventh-generation adhesives have been used for about a decade with virtually no cases of post-operative sensitivity reported. When applied as instructed, seventh-generation products are just as effective in terms of etching as the other generations (except sixth-generation products that do not etch the unprepared enamel surfaces adequately).

Another controversy, based on semantic classification, has also surfaced. The issue was whether the new group of self-etch, single-bottle adhesives should be designated sixth-generation single-bottle or seventh-generation materials. Historically, the differentiation between the fourth and fifth generations was that of a multi-component versus a single-bottle system. The differentiation between sixth and seventh generations is similarly one of chemistry—a multi-bottle versus a single-bottle system. In both cases, the controlled factory mixing of the components of the later generation (fifth and seventh) offers significant clinical advantages, predictability, and chairside efficiency over the earlier generations (fourth and sixth). The generational step has always represented a major advance in chemistry, clinical effectiveness, ease of use, and patient benefits. Because the seventh-generation products clearly fulfill all these criteria, it is difficult to see why they should not be recognized as belonging to a distinct generation.

NEAR-FUTURE DEVELOPMENTS

The process of tooth restorations bonded with seventh-generation adhesive materials is so simple and so predictable that there is little pressure to advance the technique or the technology. It is difficult to imagine what improvements can be developed in this area. It is certain, however, that dental materials will continue to become more predictable, and even easier to apply, making them less technique sensitive. These evolutionary steps are likely to occur with the next 5 to 10 years. A game-changing revolutionary leap forward is also likely within the next decade: adhesives will be incorporated chemically within restorative materials, and no separate adhesive (or etching) steps will be required at all.

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Dentin Bonding

*Karl F. Leinfelder, George Freedman**

RELEVANCE TO ESTHETIC DENTISTRY

In the past, retention of the direct restoration was accomplished by means of mechanical undercutting. In addition to converging the walls of the preparation to the facial or occlusal surfaces, the preparations (by today's standards) were considerably larger. The relatively large preparation was advocated for a number of reasons. First, the preparation was extended into areas prone to future caries. Second, the preparation was extended to include defective enamel regardless of the depth of the imperfection. Third, applying particularly to dental amalgam, adequate bulk was provided to prevent future fractures of the restoration.

The rationale for the smaller preparation can be related to the potential for bonding the restorative agent to the walls of the prepared cavity. Bonding eliminates the need for converging the walls of the preparation and can enhance the fracture resistance of the tooth, especially in multisurfaced posterior restorations.

The ability to bond to tooth surface (enamel) was developed over 50 years ago. Dr. Michael Buonocore (Figure 8-18) demonstrated that by pre-treating the enamel with phosphoric acid, acrylic resin could then be made to adhere to its surface. This historic achievement took more than 10 years to be accepted clinically. The first clinical application of bonding to enamel was the pit and fissure sealant. Rather than acrylic resin, which lacks wear resistance, the resin of choice was a formulation of dimethacrylate (BIS-GMA). This development was so successful that it is still widely used today.

Enamel bonding was followed by dentin bonding. This bonding to both the organic and inorganic tooth components led to the substitution of composite resin for dental amalgam, both in anterior and posterior teeth. Clinical acceptance was far easier for anterior than for posterior teeth. For posterior teeth the composite resin had to be modified to offer greater compressive strength and wear resistance. Furthermore, the cavity preparation best suited for composite resin bonding evolved over several years. Today composite resin is used as a total substitute for amalgam in most practices (Figure 8-19). This combination of enamel and dentin bonding has also changed how the clinician restores anterior teeth (Figure 8-20).

In horizontal fractures, for example, pins of various types were needed to retain the restoration. These pins were either cemented or threaded into the dentin. Today a minimal amount of tooth structure is removed, along with simple beveling of the enamel margins.

Undoubtedly the marriage of dentin bonding agents with various composite resins has dramatically changed how the dentition is restored. Research will continue to improve dentinal adhesives and simplify how they are used.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF ADHESION

A serious attempt to find an agent to bond to dentin began over 30 years ago. It was not until the early 1980s that the first successful dentinal adhesive was generated. Although Buonocore is generally credited with developing the ability to bond to enamel, recognition for the first dentinal adhesive belongs to Swiss chemist Oskar Hagger. His efforts led to the development of the first commercially available adhesive resin system. Marketed in the early 1950s, it was designed for use in anterior resin restorations.

The Four Popular Generations

Fourth Generation

Fourth-generation materials made their appearance in 1990 and mark a major departure from their predecessors; this is the first in a series of generations that have been clinically successful. For the first time in the history of dentin bonding agents, the bond strength was great enough to prevent microleakage, debonding, and pulling away from the tooth preparation (because of polymerization shrinkage at the dental interface). Bond strengths ranged from about 18 to 25 MPa. Interestingly, bond strength values of this nature had been predicted by Dr. Erik Asmussen (University of Copenhagen) to be necessary to avoid gap formation between the restoration and the walls of the cavity preparation.

The fourth generation of dentin bonding agents is characterized by having at least three components or bottles, which contain (1) acid etching agent, (2) primer, and (3) adhesive. In effect, a minimum of three components must be mixed and applied according to a variety of protocols. Each is applied in a sequential pattern. As with bonding systems of all generations,

*Clinical photography.

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the directions should be followed very carefully. The acid-etching component prepares the enamel and dentin surface; the primer is responsible for developing the hybrid layer at the dentin interface and sealing the dentinal tubules. The adhesive is needed to bond composite resin to the surface and functions as a link between the hybridized dentin and the overlying composite resin (Figure 8-21).

Fifth Generation

Fifth-generation dentin adhesives, a modification of fourth-generation products, consist of two bottles, an etching agent and a single-bottle conditioner. These adhesives were designed to make application of the bonding agent simpler and less time-consuming. The dental profession rapidly converted to this newer system (which appeared in 1995), but the fifth-generation dentin bonding agents had problems related to significant post-operative sensitivity—less than with fourth-generation agents but still appreciably serious (Figure 8-22).

Sixth Generation

Sixth-generation dentin adhesives, like fourth-generation materials, use a two-bottle system. The acid and primer are contained in the first bottle, and the adhesive in the second. The adhesive



FIGURE 8-18 Dr. Michael Buonocore (Eastman Dental Center), a pioneer in adhesive dentistry. *(Courtesy Basil G. Bibby Library, Eastman Institute for Oral Health, University of Rochester Medical Center, Rochester, New York.)*

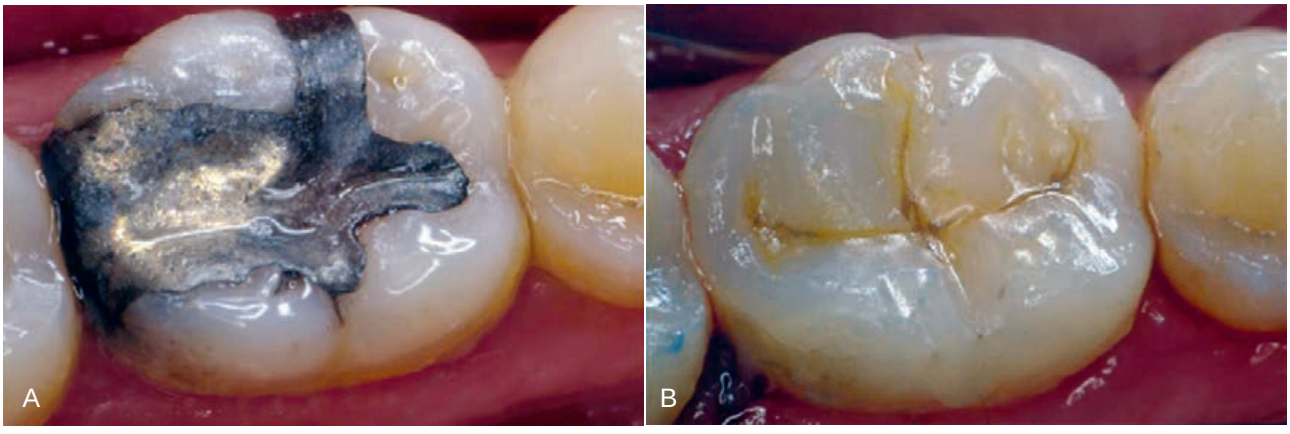


FIGURE 8-19 A, Amalgam restoration. B, Composite restoration. For the practitioner the transition from amalgam to composite may take only 15 to 20 minutes. For the patient, it makes all the difference in the world.

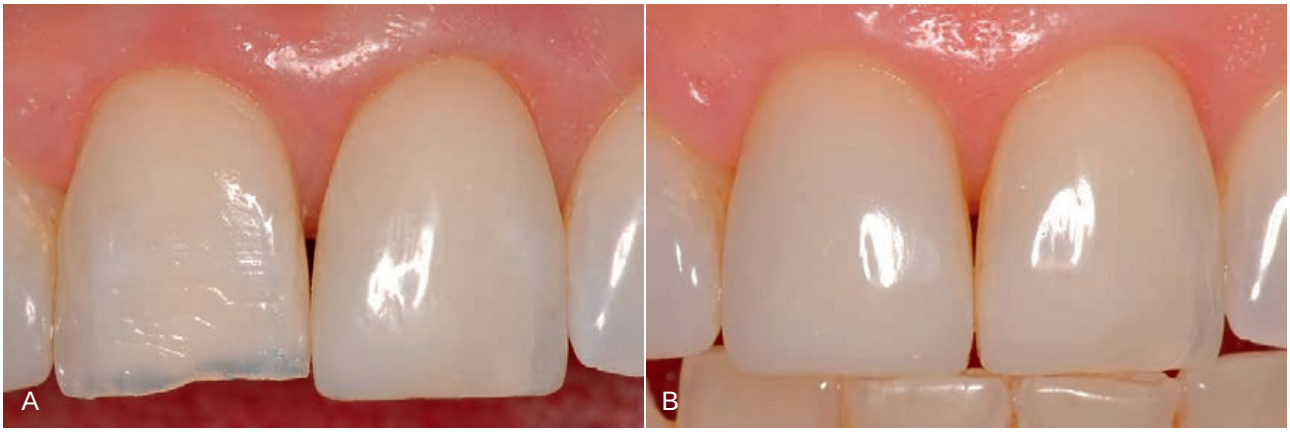


FIGURE 8-20 A, Chipped central incisor. B, Esthetically restored central incisor. Unesthetic anterior teeth are no longer acceptable to the public or the profession.

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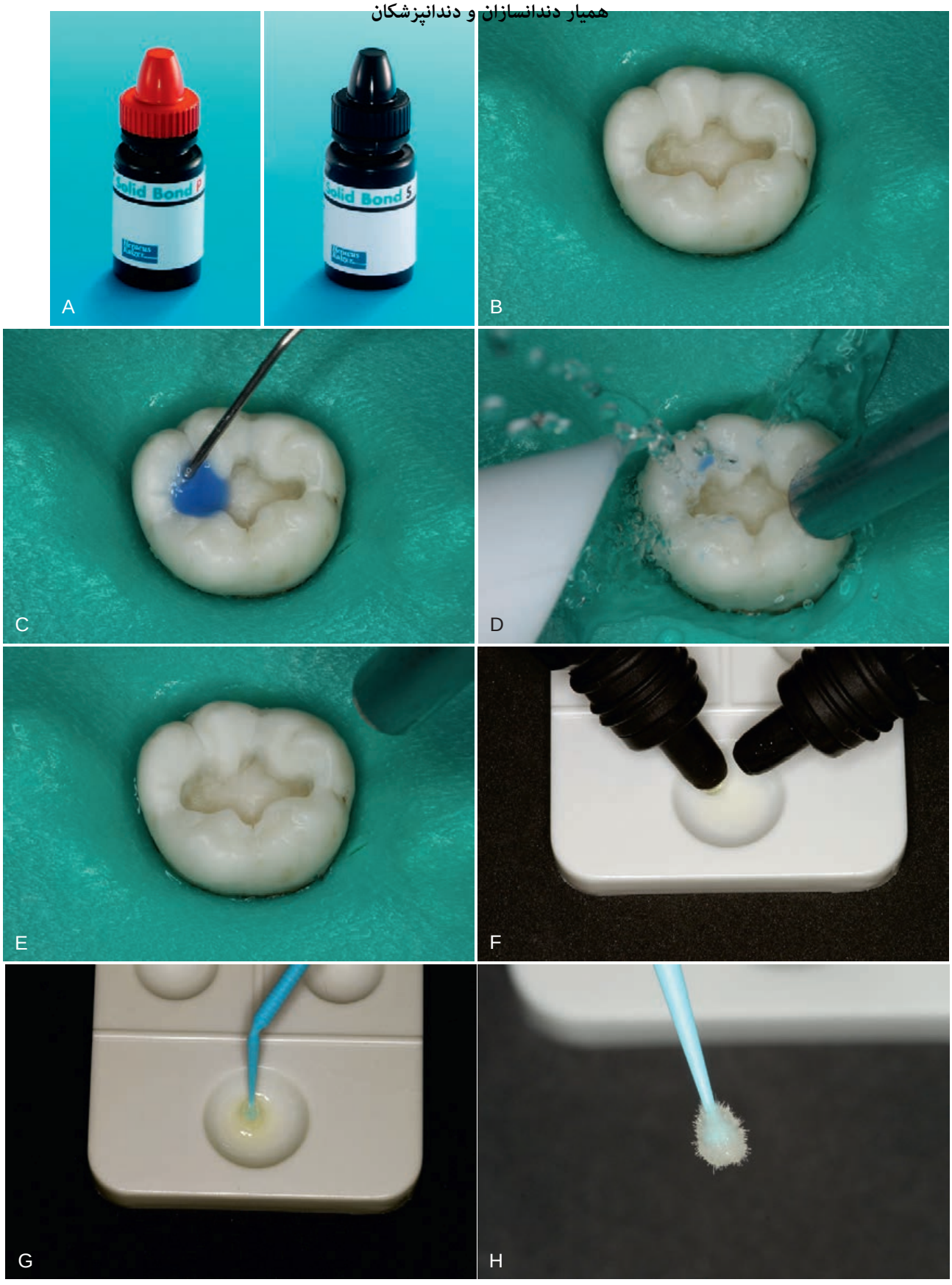


FIGURE 8-21 **A,** Fourth-generation bonding agent (also known as a *total-etch system*). (Pictured: Gluma Solid Bond.) The preparation (B) is ready for etching. The etching solution is applied to the enamel and dentin simultaneously (C). After washing (D) and lightly drying (E), the components of the primer are mixed (F), carried to the preparation (G and H), placed in the cavity (I), and air dried (J). *(A courtesy Heraeus Kulzer GmbH, Hanau, Germany.)*

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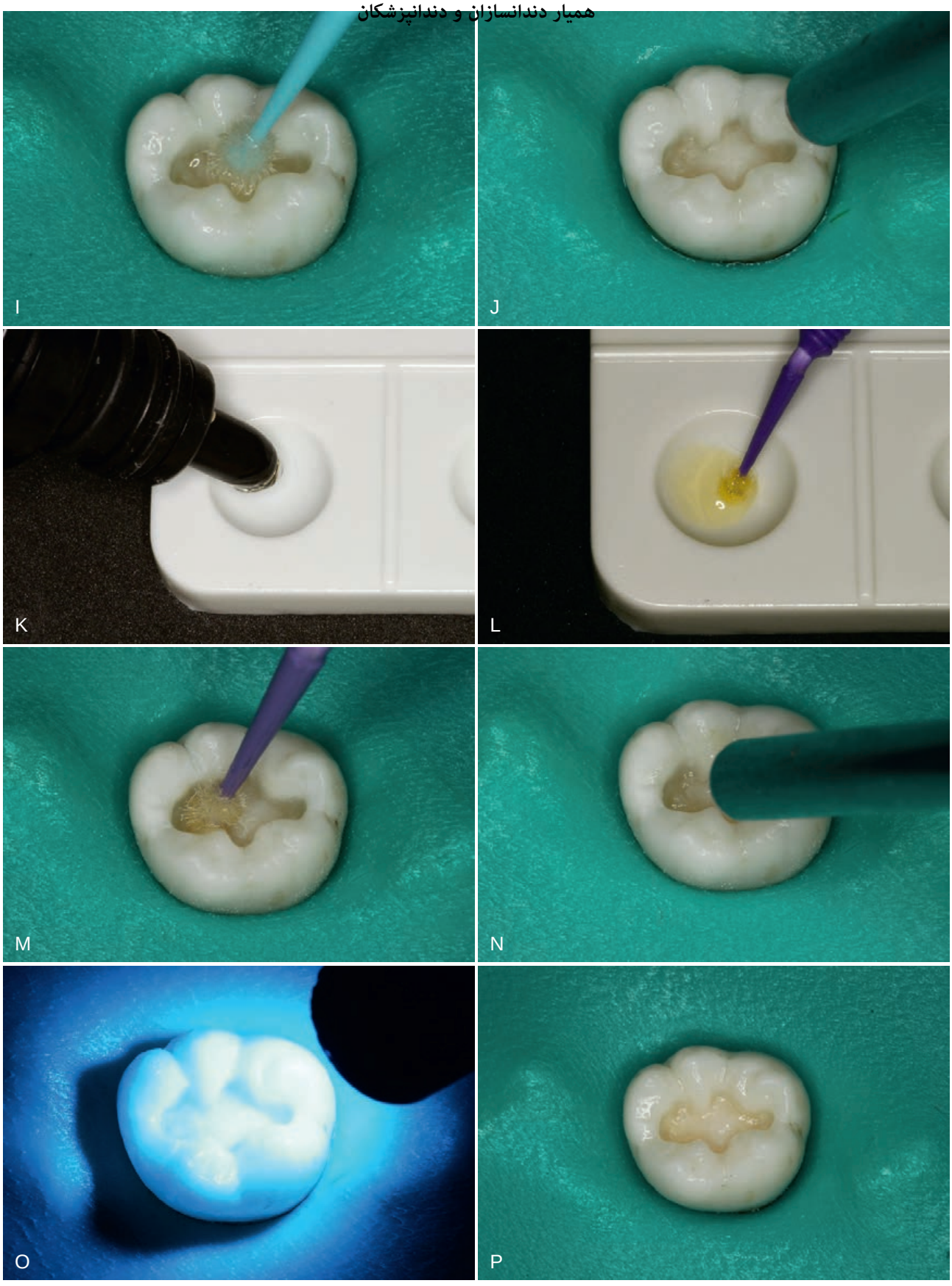


FIGURE 8-21, cont'd Then the adhesive (K) is picked up on the applicator brush (L), scrubbed into the preparation (M), and air dried (N). The adhesive is then light cured (O). When the directions for use are followed carefully, the glossy surface of the adhesive ready for composite placement (P) is acceptable. The fourth-generation system is considered by some to be the standard by which all others are compared.

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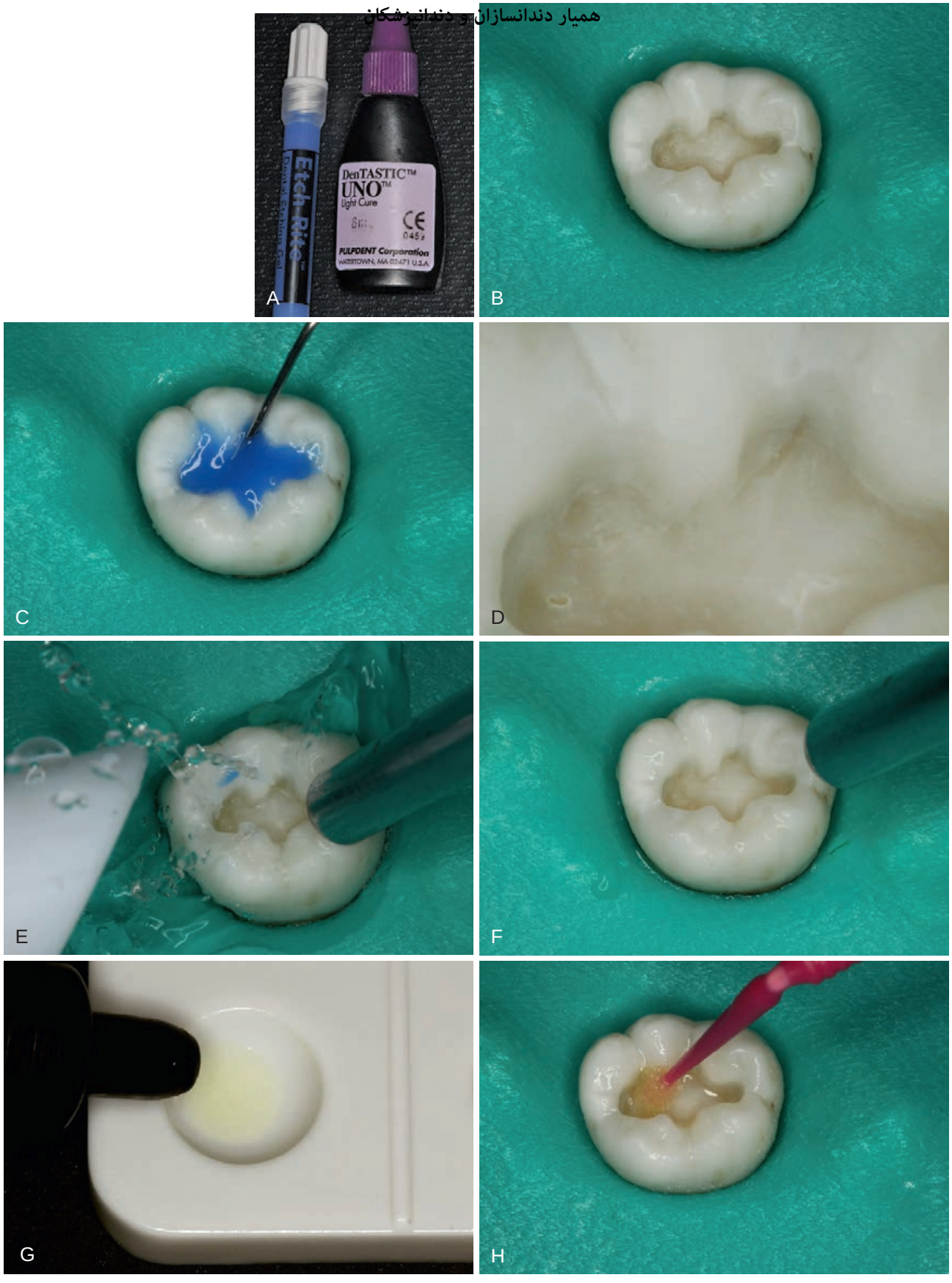


FIGURE 8-22 **A,** Fifth-generation dentin bonding agents include only two components or bottles: the acid etching agent and the bonding agent. (Pictured: Etch-Rite and DenTASTIC UNO, Pulpdent Corporation, Watertown, Massachusetts.) The single-bottle bonding component consists of a factory-controlled mixture of primer and adhesive. The preparation **(B)** is acid etched **(C)**, which decalcifies the dentin by removing the hydroxyapatite from around the collagenous structures **(D)**. The preparation is washed **(E)** and air dried **(F)**. The premixed primer and adhesive **(G)** are applied to the preparation **(H)**.

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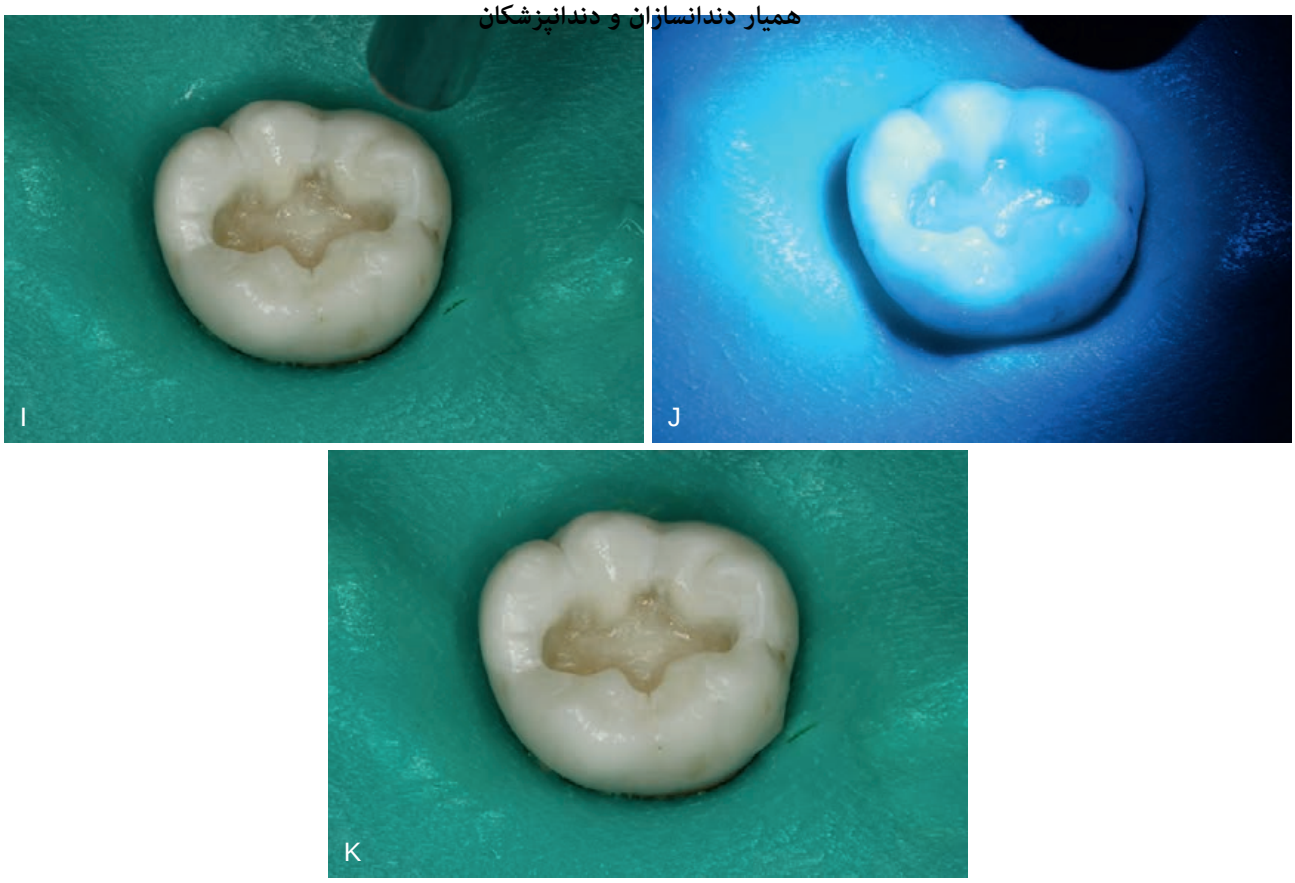


FIGURE 8-22, cont'd **This not only hybridizes the preparation but also provides a chemical link between the surface of the preparation and the resin restoration. Through elimination of one of the components from fourth-generation products, the application time for the system is shortened and simplified. Air drying (I) is followed by light curing (J), leaving the bonded preparation ready for restoration (K).**

is needed for bonding of the resin restoration to the wall of the cavity preparation (Figure 8-23).

Seventh Generation

Seventh-generation dentin adhesives, like the fifth-generation systems, are contained in a single bottle, which offers the clinician less complexity and a faster operation. These agents are essentially an all-in-one approach. As with dentin adhesives of all the other generations, it is necessary to follow the directions carefully (Figure 8-24).

Problems with Each Generation

Each generation of dentin bonding agents was designed to resolve specific problems associated with its predecessor. For example, the fifth-generation (one-bottle plus etching agent) systems were developed to offset the complexities associated with the mixing protocol of the fourth-generation bonding agents. When the primer is combined with the adhesive, the application time is reduced by one third. Unfortunately, however, the newer system faced various problems, the most prominent of which was the potential for incompatibility between the bonded surface and self- and dual-curing luting and cementing materials. It is now known that the increased acidity associated with products of this generation tended to create incompatibility between the adhesive and resin-based self-cured cements. When this problem occurs with a bonding system, it is necessary to add equal amounts of an amine derivative to the bonding agent. Failure to do so results in partially or totally unbonded restorations. With current self-adhesive cements, this is no longer an issue. Efforts to eliminate these problems brought about the sixth-generation bonding systems.

The sixth generation of dentin bonding agents was quickly accepted because of its virtual elimination of post-operative sensitivity. As with the fifth-generation bonding agents, problems were observed after several years because of the incomplete etching of enamel surfaces. Unprepared or unetched enamel interfaces tended to debond with relatively high frequency within several years. This led to seventh-generation bonding systems, which have all the necessary components in one bottle, including an acceptable level of etching, and prevent post-operative sensitivity. They are also incompatible with self- and dual-curing adhesives.

The fourth generation of dentinal adhesives—the most researched category—is considered by many scientists, academicians, and clinicians to be the gold standard for dentin bonding

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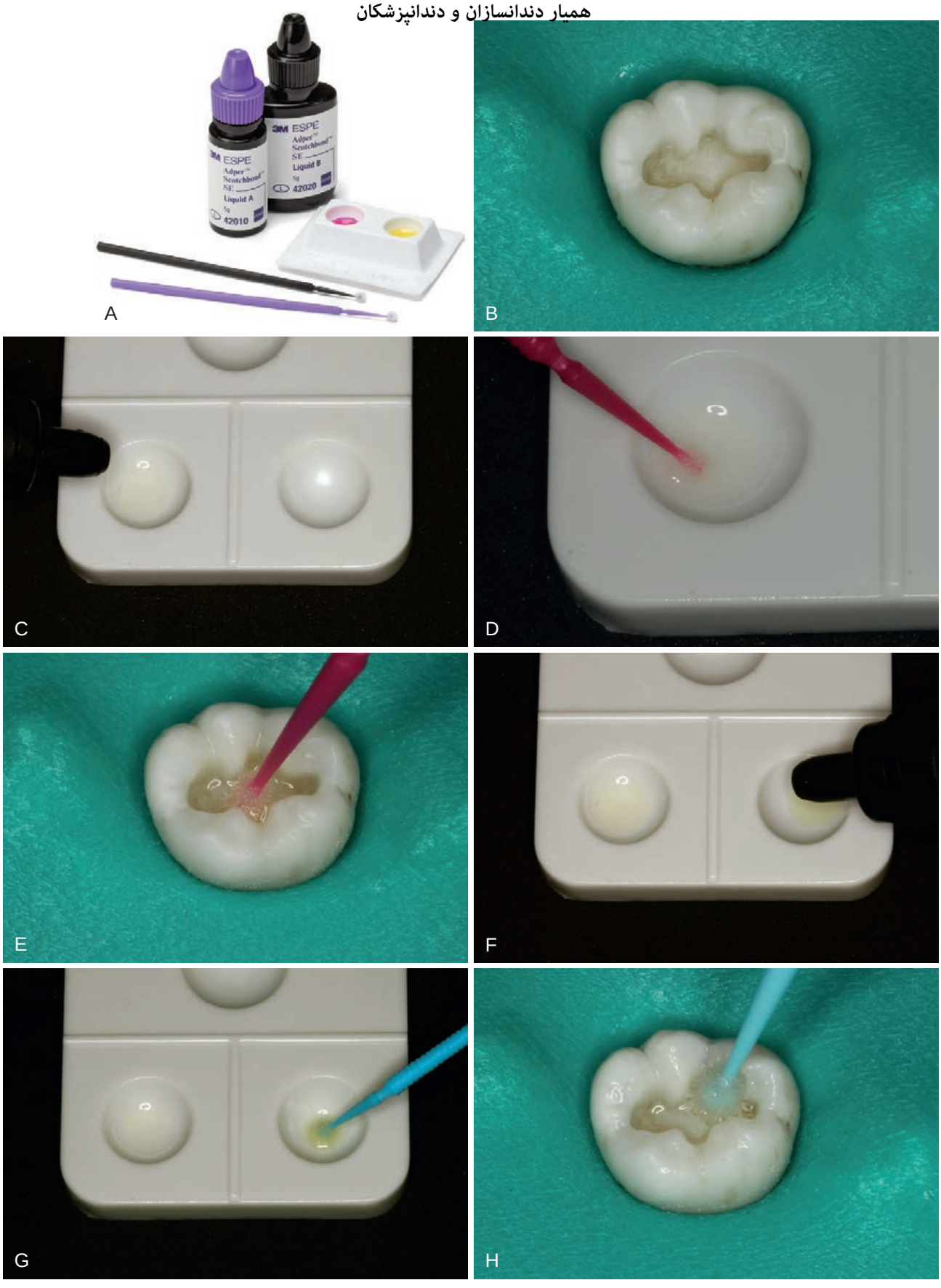


FIGURE 8-23 **A, Sixth-generation bonding agent. (Pictured: Adper Scotchbond SE.) After the preparation is washed and lightly dried (B), each component is applied in sequence. First the acidic primer is dispensed (C), picked up onto the applicator (D), and applied to the tooth surface (E). Then the adhesive is dispensed (F), picked up on the applicator (G), and applied to the tooth surface (H).** *(A courtesy 3M ESPE, St Paul, Minnesota.)*

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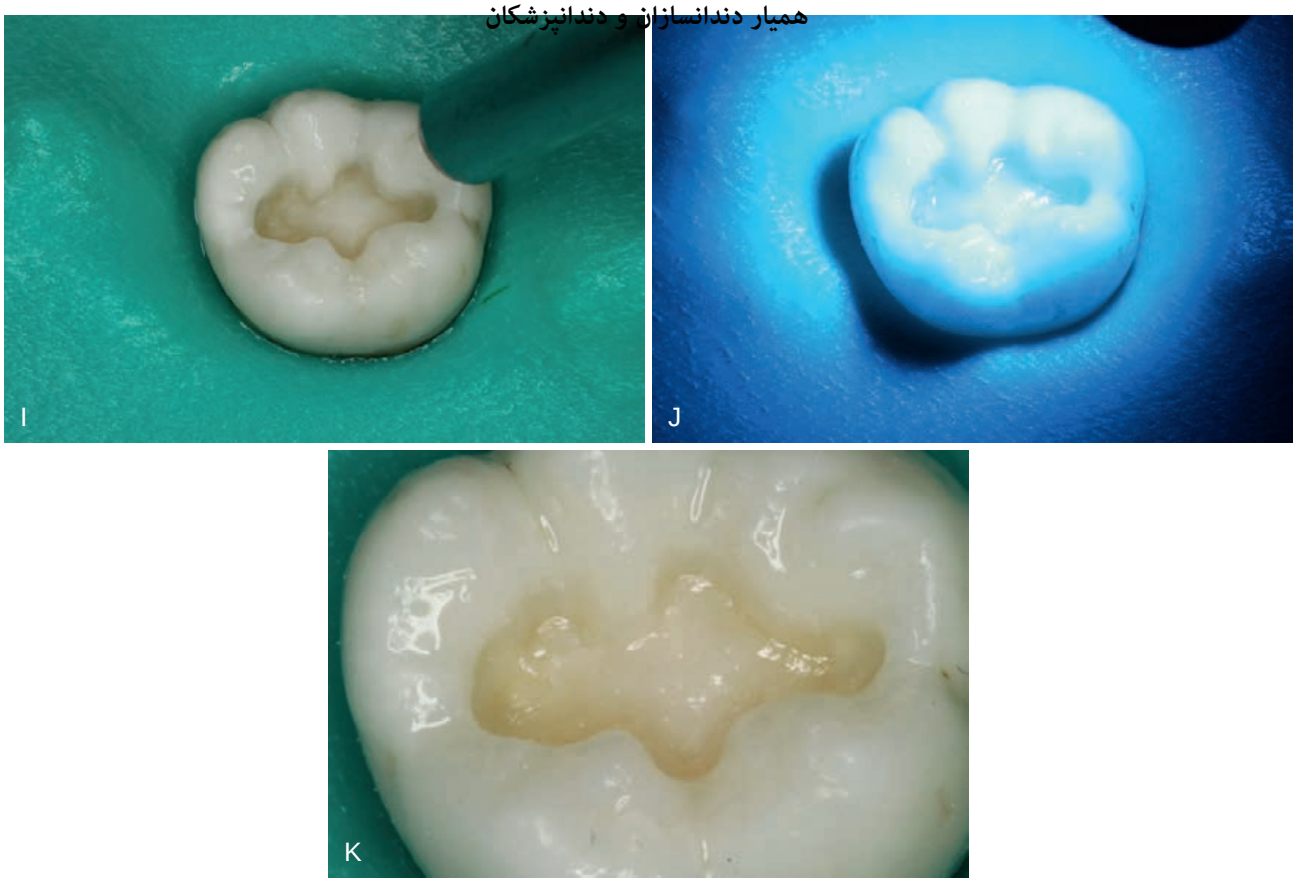


FIGURE 8-23, cont'd **Neither solution is rinsed off the tooth surface. After the liquids have been air dried (I), the bonded surface is light cured (J). The resulting surface is smooth and glossy (K). Because acid etching of the dentin and resin deposition into the evacuated spaces occur almost simultaneously, post-operative sensitivity is reduced dramatically.**

agents. It is also the most complex and time-consuming to use. Assuming one follows the directions for use carefully, adhesives of this generation provide excellent bonding and complete compatibility with all dual-cured or self-cured luting agents and composite resin core and buildup materials. Furthermore, the fourth-generation products are very versatile. As a result, some clinicians have returned to using this earlier generation of adhesives.

MATERIAL OPTIONS

Total-Etch versus Self-Etch Dentin Bonding Agents

The first clinically successful dentin bonding agents were developed nearly two decades ago. Many clinicians were pleased with the introduction, but a substantial number had concerns with the concept of placing acid on the dentin surface (Figure 8-25). In accordance with earlier concepts it was believed that placing acid on dentin would result in the transmission of acid through the dentinal tubules and into the pulp, causing pulp necrosis. Subsequent clinical experience, however, demonstrated this was not true, so this procedure is routinely part of the required steps for the adhesion of resin restorative materials to both dentin and enamel.

The four currently used generations of dentin bonding agents (fourth through seventh) can be subdivided into "total-etch" and "self-etch" categories. The differences between the two different types relate to the individual step of placing phosphoric acid on the preparation surface as a separated step (fourth and fifth generations) or as a step integrated with other components (sixth and seventh generations).

In **total-etch** (fourth- and fifth-generation) dentinal adhesives, a 37% solution of phosphoric acid is placed on the entire preparation, including both dentin and enamel. The acid removes the smear layer (Figure 8-26, *A*), exposing the dentinal tubules (Figure 8-26, *B*), and effectively etches the ends of the enamel rod prisms and etches out the hydroxyapatite surrounding the collagenous structure of the dentin (Figure 8-26, *C*). Once the hydroxyapatite has been removed, the dentin bonding agent is applied and rapidly fills in all of the evacuated spaces created by the acid etching agent. In fourth-generation bonding agents, the system consists of the phosphoric acid, a primer, and

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FIGURE 8-24 **A and B, Seventh-generation bonding agents. (Pictured: BeautiBond [A] and Tokuyama Bond Force [B].) The preparation surface (C) is washed (D) and lightly dried (E). The single-component seventh-generation adhesive is picked up from the unit-dose dispenser (F) and applied onto the preparation and the margins (G to I).** *(**A** courtesy Shofu Dental Corporation., San Marcos, California. **B** courtesy Tokuyama Dental America, Encinitas, California.)*

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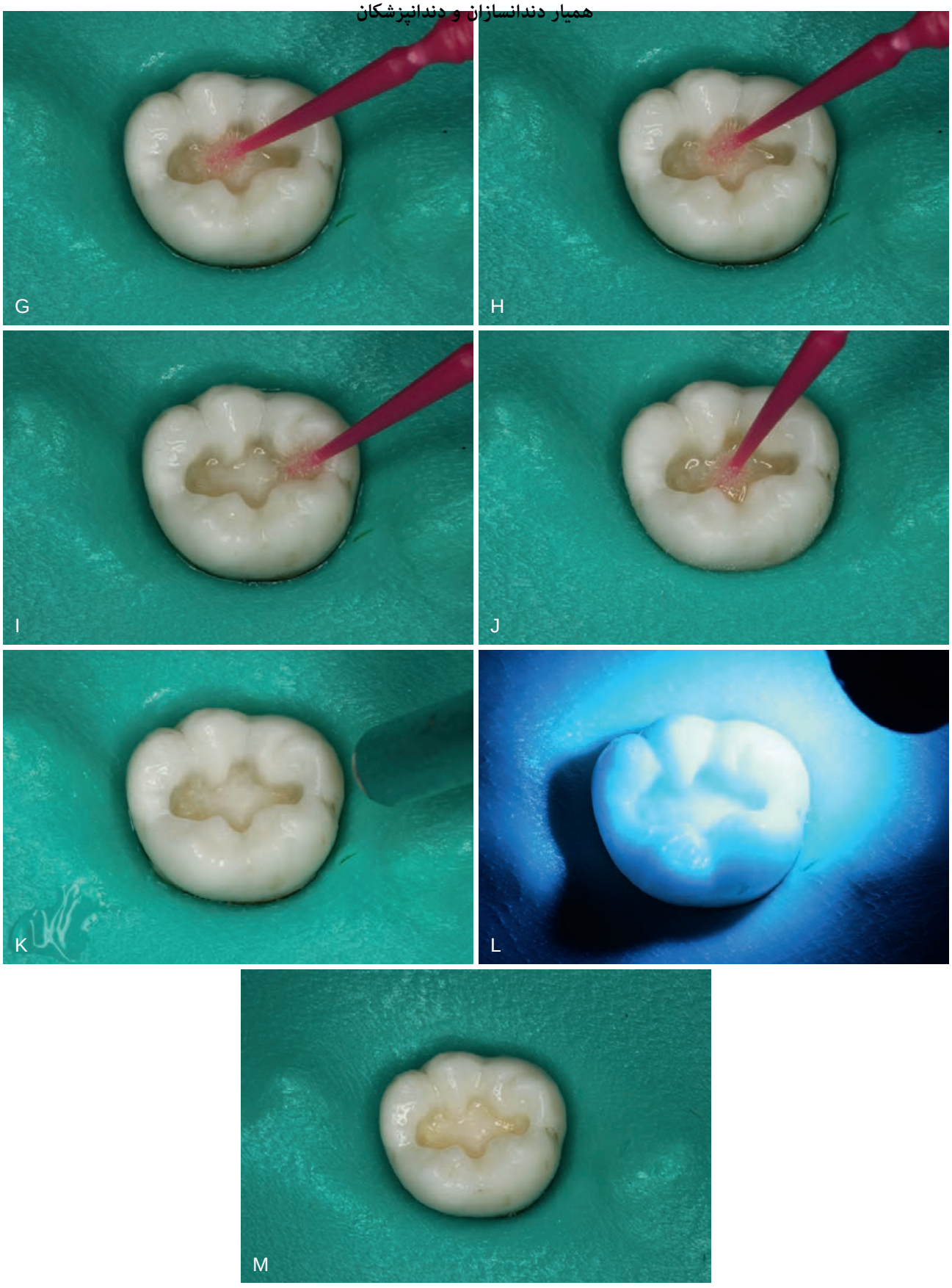


FIGURE 8-24, cont'd Some manufacturers suggest scrubbing the surface as well (J). After air drying (K), the adhesive is light cured (L), leaving a hard glossy surface (M). The concept is relatively new but growing rapidly in popularity. Today many different seventh-generation systems are on the market.

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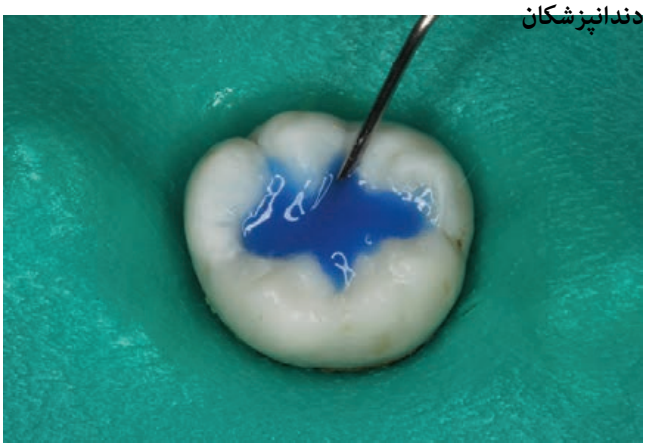


FIGURE 8-25 Acid placed on the dentin surface of a tooth.

an adhesive. In fifth-generation bonding agents the first bottle contains the acid etching agent, and the primer and adhesive are premixed in the second bottle.

In a **self-etching** dentin bonding agent (sixth and seventh generations), the preparation is not treated by applying phosphoric acid. Instead the bonding agent is applied to the entire preparation. In sixth-generation dentinal adhesives the adhesive is placed after the application of the primer. In seventh-generation bonding agents everything is accomplished in a single step.

In both cases etching of the dentin and enamel is achieved. The etching potential of enamel is not as easily attained with the self-etching agent as it is with the total-etch process. For this reason the agent can be applied to the enamel surface for twice as long as to the dentin surface, or the initial acidity of the agent must be at a relatively low pH. If the adhesive is not sufficiently thin or dry on the dentin, adhesion may fail and a visible band of brown coloration along the tooth-restoration interface may appear within months or years. The brown discoloration is attributable to food or drink stains that have penetrated between unbonded composite resin and the enamel tooth structure.

Advantages and Disadvantages of Total-Etch Dentinal Adhesive

The total-etch dentin bonding agent is well regarded by practitioners. There are two types of total-etch bonding agents. The first (fourth-generation) agent consists of three components: an acid etch gel, a primer, and an adhesive. The technique is somewhat complex but well documented. The acid gel is applied for 15 seconds, followed by thorough washing and air dispersion, leaving a "wet" or moist surface. The primer is applied and air dried, followed by the adhesive application and air drying. (Some fourth-generation bonding agents require the mixing of the primer and the adhesive before their application.) Then the surface is light cured for 15 seconds. Failure to scrupulously follow this procedure commonly results in clinical failures. The patient will exhibit post-operative sensitivity regardless of the size of the preparation, and secondary debonding of restorations placed in preparations without mechanical retention occurs. Staining along the restoration-enamel interface may be common

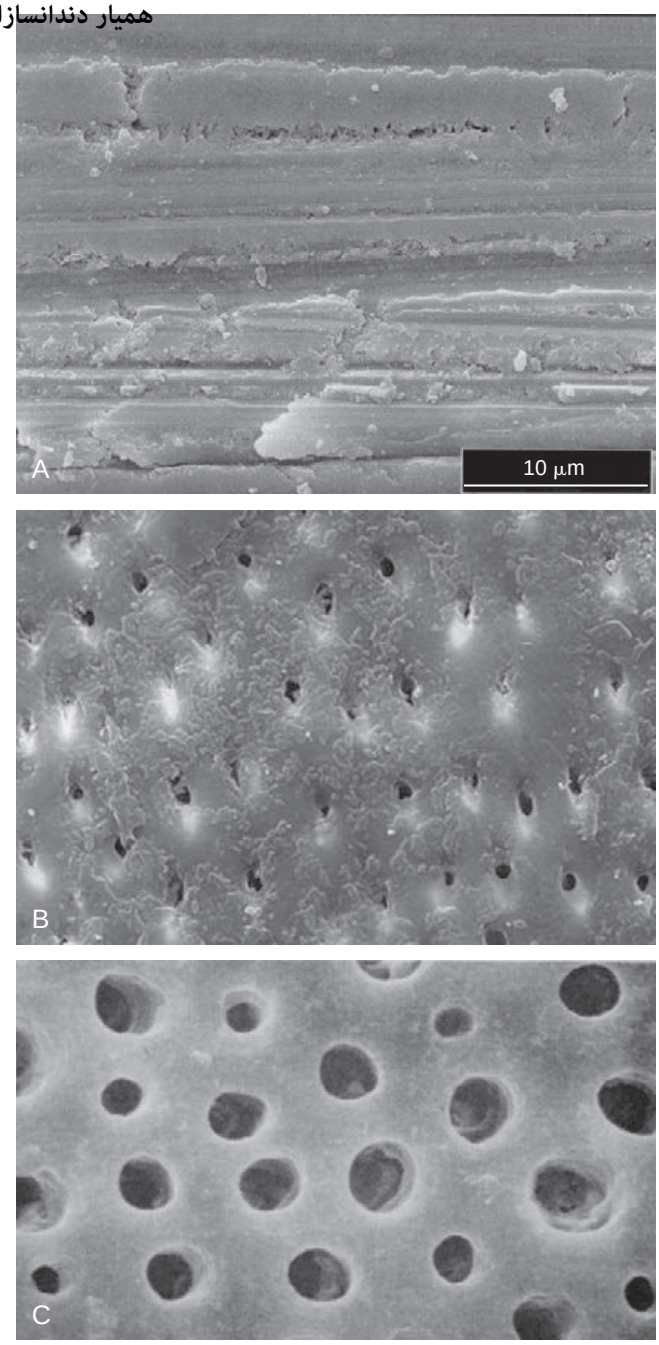


FIGURE 8-26 A, Smear layer on the dentinal surface. B, Acid etch has removed the smear layer, exposing the dentinal tubules. C, Magnification of the hydroxyapatite surrounding the collagenous structure of the dentin.

and is directly related to inadequate bond and seal of the margins after the failure to adequately air thin the adhesive layer.

An advantage of the total-etch system is its longer time in service than the self-etch systems. Total-etch systems can be used for many procedures, including crowns (ceramic, polymer, and metallic), inlays and onlays, posts, and veneers. Interestingly, the primer component can be used with amalgam restorations. After etching, the primer is applied and the amalgam margins are photocured. Not only does the technique seal the dentinal

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tubules, but it also reduces the potential for post-operative sensitivity. The potential for reducing or eliminating post-operative sensitivity comes about through the sealing of the dentinal tubules. The sealing process also eliminates the potential for microorganisms to travel into the tubule, preventing pulpal necrosis. Another disadvantage of the fourth-generation total-etch system is time required to complete the procedure. Fifth-generation bonding systems appreciably reduce the time required for the hybridizing process.

There are some disadvantages to fifth-generation dentinal adhesives. For the components of fifth-generation agents to be placed in a single bottle, their pH must be lowered (the acidity increased). This neutralizes the amine component of self-curing resin cements as well as composite resin core material and prevents the cement or core materials from curing at the adhesive restorative interface. Thus, many crowns and posts in the patient population were inadvertently improperly cemented. Because the pH of fourth-generation dentin bonding agents is higher, they have no similar problem with incompatibility.

Fifth-generation dentinal adhesive systems are generally more expensive than fourth-generation systems.

Advantages and Disadvantages of Self-Etch Dentinal Adhesive

The greatest advantage of the self-etching dentin bonding system is a substantial reduction in the observed post-operative sensitivity. However, there are a number of disadvantages, with the primary one being the incompatibility between the dentin bonding agent and dual- and self-cured resins, including luting agents and core materials. The chemical problem is caused by the neutralization of the amine in the dual-cure cement of the core material. Reducing or eliminating the amine prevents the core or luting agent from curing. Compatibility between the bonding and luting agents can be determined by simply placing the dentin bonding agent on a glass slab, then placing the luting agent over it and curing with a light. If incompatibility is present, the luting agent separates completely from the adhesive. Realizing this potential for incompatibility, numerous manufacturers include a small bottle of tertiary amine (dual-cure initiation) with the fifth-generation dentin bonding agents. If setting incompatibility is of concern, a drop of tertiary amine is added to the dentin adhesive. However, not all so-called "dual-cure initiators" are equally effective in creating setting compatibility with self- and dual-curing composites.

Another disadvantage of some self-etch agents relates to enamel bonding. In general the bond strength is less than that obtained with most fourth- and fifth-generation (total-etch) systems. In addition, bond strength tends to decrease with time. The problem can be resolved by increasing the amount of time the bonding agent rests on the enamel surface. Procedurally, the self-etch bonding agent is first lightly rubbed or swabbed over the enamel aspect of the preparation for 15 seconds. Then the bonding agent is applied to the dentin surface for 15 seconds. This allows the agent to be in contact with the enamel for 30 seconds or twice as long as it is on the dentin. However, this may be somewhat impractical clinically. Another approach is to etch the enamel surfaces of the preparation with a 37% solution of phosphoric acid for 15 seconds followed by washing and light drying for 2 seconds. Then the dentin adhesive is applied to the entire preparation for the recommended period of time. After air dispersing the surface is light-cured for 15 seconds.

The literature indicates that the hydrophilicity of the newer generations of dentin bonding agents may cause water to become trapped in the hybridized form of the adhesive. The resulting "water trees" may be of concern because they may permit water transfer through the hybrid zone.

BONDING PROCEDURE

The procedures for the two systems are appreciably different. However, regardless of which bonding system is employed, it is vital to seal the bottles of the dentin bonding agent to prevent volatilization of the ingredients.

Total-Etch Procedure

In total-etch systems the finalized cavity preparation is treated with phosphoric acid gel, which is applied and left in place for 15 seconds. The acid gel is then vigorously washed away, followed by air-dispersal drying for 2 seconds. An alternate method for removing the water consists of wiping the preparation with a dry cotton pledget. When the wiping is finished, the surface should exhibit a slight sheen.

Once the etching process has been completed, the dentin primer is applied. An applicator is saturated with the primer and then rubbed or swabbed onto the surface of the preparation continuously for 15 seconds. After air dispersing, the process may be repeated if called for in the manufacturer instructions, then the surface of the preparation is light cured for 15 seconds. The preparation surface is now hybridized and ready for application of the composite resin restorative material.

It is not always easy to determine if the preparation has been properly treated with the dentin bonding agent. Figure 8-27 demonstrates a rather simple test for determining effectiveness.

During the adhesive procedure the bonding agent diffuses below the dentinal surface. At first the surface appears shiny, but if the dentin is not saturated with the bonding agent, the surface becomes dull (see Figure 8-27, *I* and *J*). This test should be carried out whenever the clinician uses a new bonding agent or if the bottle of bonding agent has been opened for more than a couple of months.

Self-Etch Procedure

Figure 8-28 details the steps for the self-etch procedure.

HYBRIDIZATION

Hybridization is a process by which the hydroxyapatite of the dentin is chemically removed and a low-viscosity resin is infiltrated into all the evacuated spaces. The process of generating a

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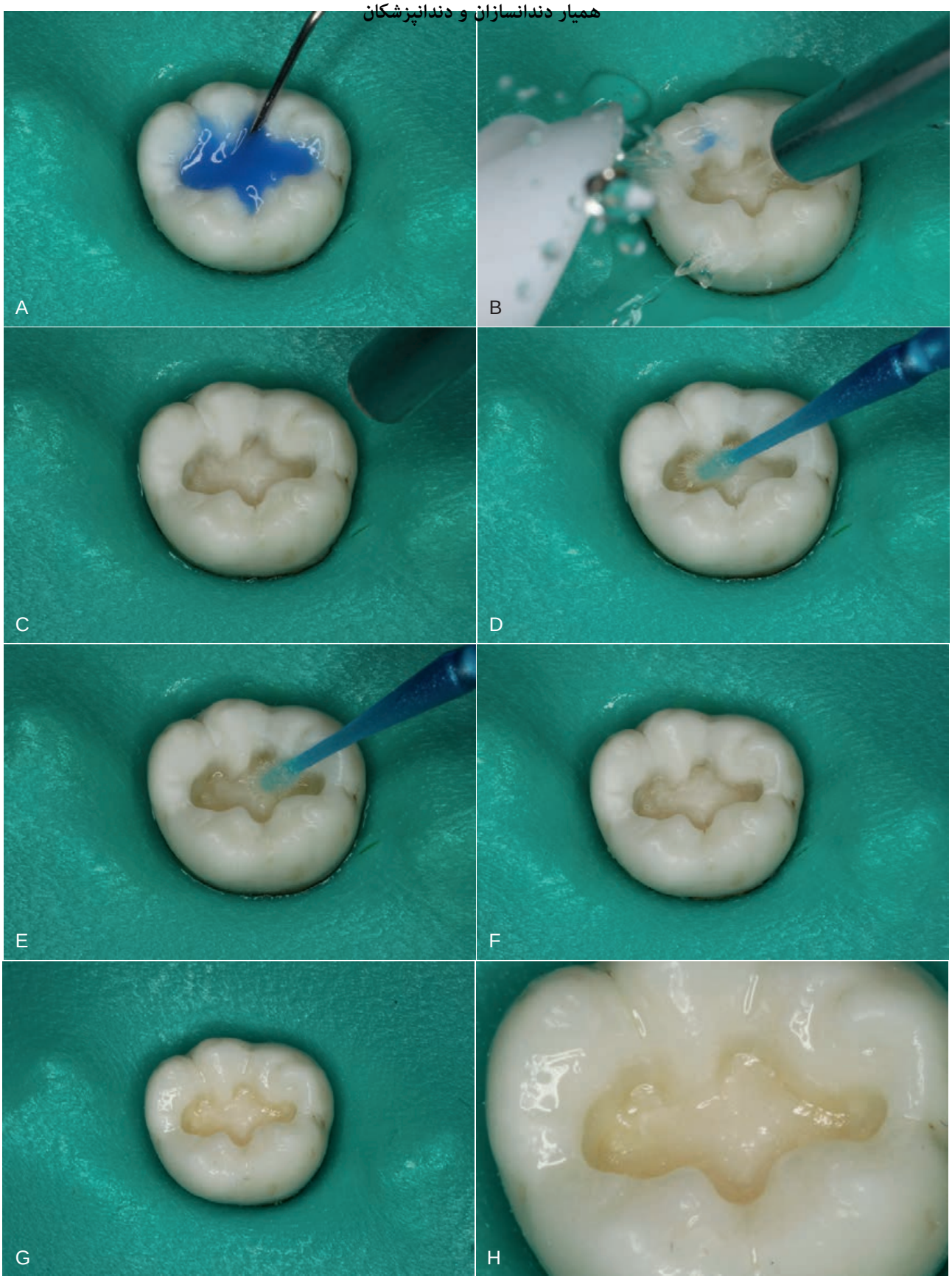


FIGURE 8-27 Steps to determine if the preparation has been properly treated with the dentin bonding agent. **A,** Step 1: Acid etch the preparation. Step 2: Rinse (**B**) and then dry (**C**) with the air syringe for a few seconds. **D,** Step 3: Apply the dentin bonding agent. **E,** Step 4: Repeat the process if required. **F,** Step 5: Instead of using the light to cure the material, wait an additional 15 seconds. **G** and **H,** Step 6: If the surface of the preparation continues to be highly light reflective, the amount of dentin bonding agent applied is sufficient.

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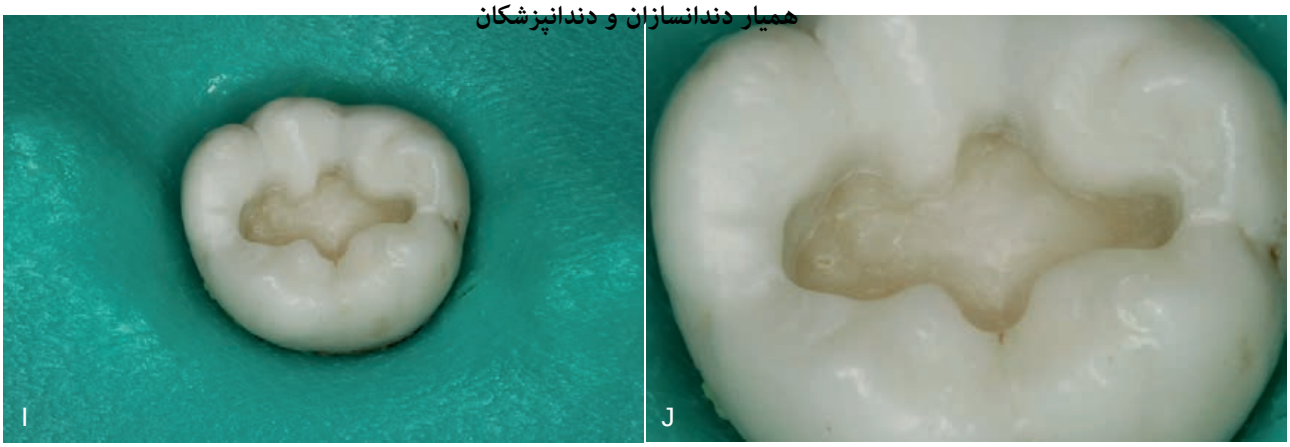


FIGURE 8-27, cont'd **I and J, Step 7: If the surface begins to lose its luster and takes on a dull appearance, the amount of dentin bonding agent applied to the preparation is insufficient and the dentin bonding agent should be reapplied.**

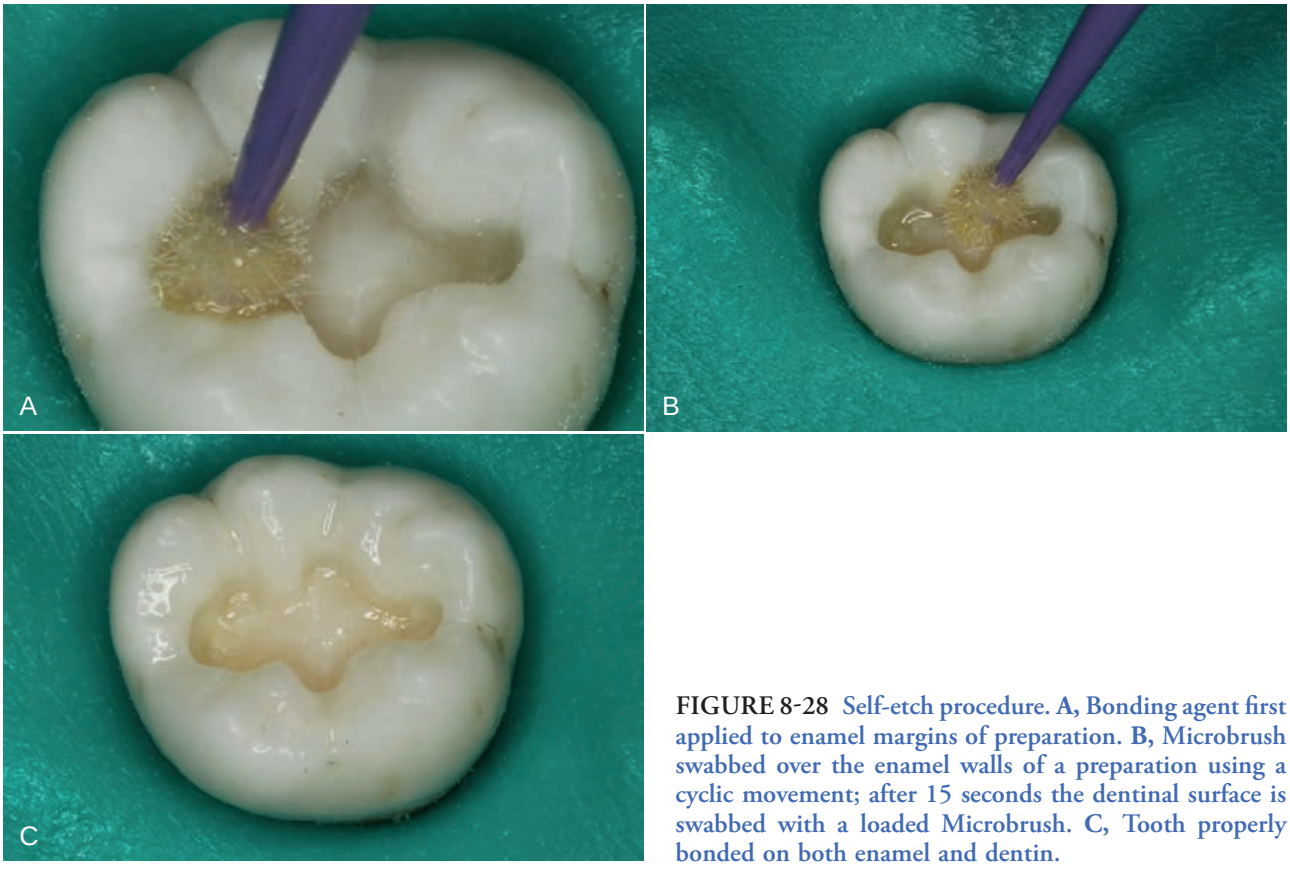


FIGURE 8-28 **Self-etch procedure. A, Bonding agent first applied to enamel margins of preparation. B, Microbrush swabbed over the enamel walls of a preparation using a cyclic movement; after 15 seconds the dentinal surface is swabbed with a loaded Microbrush. C, Tooth properly bonded on both enamel and dentin.**

hybrid layer or hybrid zone is relatively simple clinically. The process of hybridization is initiated by applying an acid medium (as in the fourth- and fifth-generation etching agents) to the dentin surface. Almost immediately, the acid begins to react with the calcium hydroxyapatite of the intertubular dentin. The process continues to a depth of about 10 µm. (For the sake of comparison, the average width of a human hair is about 40 µm, so the depth of acid penetration is less than 25% of the width of a human hair.) Concurrently the acid begins to penetrate into the orifice of the dentinal tubules to a depth of up to 100 µm.

At the end point (approximately 15 seconds later) the acid etch is vigorously washed away, leaving behind microscopic vacancies surrounding the collagenous structure. Care must be taken to avoid overdrying the etched and washed surface (the need for moist bonding). Overdrying by as little as an additional 15 seconds may reduce bond strength by 50%.

The surface is then ready to receive the dentin bonding agent, which infiltrates into the evacuated spaces. The bonding agent accomplishes this task through its relatively high level of hydrophilicity. Infusion into the evacuated spaces is a function of time

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as well as availability of the bonding agent. It is sometimes necessary to use two or more applications of low-viscosity bonding agent. One coat penetrates to the base of the evacuated spaces, eventually leaving the superficial layer relatively free of bonding agent. The second coat effectively leaves enough bonding agent at the surface to adhere to the restorative material, thereby avoiding post-operative sensitivity from unsealed dentinal tubules containing vital odontoblastic processes.

The formation of a hybrid layer using the sixth- and seventh-generation dentin bonding agents is essentially the same as for the total-etch or fourth- and fifth-generation dentin adhesives. The acid-containing components of the primer (sixth-generation agents) or all-inclusive seventh-generation bonding agent simultaneously etch and introduce the bonding agent. This ensures an adequate level of isolation of the odontoblastic processes and minimizes the potential for post-operative sensitivity. Although etching of the enamel rod prisms is also based on the same basic concept, the degree of effectiveness is somewhat less. Etching with self-etching bonding agents for a mere 15 seconds may be insufficient. For this reason a pre-etch of the enamel with phosphoric acid may be needed, particularly with some sixth-generation materials. An alternate method for achieving adequate etching of the enamel rods with the self-etching bonding agents involves leaving the bonding agent on the surface for 30 seconds.

Hybridizing the cavity preparation accomplishes several clinical goals. First, the dentinal tubules and intertubular dentin are sealed, appreciably reducing or eliminating the potential for invasion of microorganisms into the pulp via the dentinal tubules. Before dentin bonding agents were introduced, leakage and pulpal necrosis associated with composite resin restorations were a much greater concern.

Second, hybridization affords the opportunity for bonding the restoration to the preparation. Although this approach is obvious with composite resin, it is also possible with amalgam and ceramic materials. Bonding of the dentinal surface at the amalgam interface can be accomplished through the adhesive layer. Bonding preparations before amalgam placement has been advocated to eliminate post-operative sensitivity and to seal against bacterial invasion into the interface between the restoration and prepared cavity.

Third, hybridization and associated bonding to both dentin and enamel allows the opportunity to reduce the size of the cavity preparation. There is no need for mechanical undercutting to attain long-term retention of the restoration. This means the dimensions of the preparation for posterior composites can be minimized both at the occlusal isthmus and in the width and depth of the gingival box. Clinical experience teaches that smaller posterior composite resin preparations exhibit restorative longevity far better than larger-sized traditional preparations.

Determining Proper Hybridization

One of the greatest problems associated with any of the dentin bonding agents is the possibility that total hybridization will not be completely achieved. For the purpose of illustration there are three main principles associated with the etching process: (1) acid etching (demineralization), (2) air dispersal, and (3) diffusion.

Acid Etching of the Preparation

As already mentioned, the generally accepted time for etching with phosphoric acid for most if not all clinical conditions is 15 seconds. Although it was once recommended that etching time for primary teeth should be extended, this has not been proved by research. Nor should highly sclerosed dentin associated with class V cavity preparations or abfracted lesions be etched twice as long. This extended etching may actually reduce bonding potential.

Air Dispersal

The dispersal of the water used to wash away the acid gel is a necessary step. However, it is important to retain the water in the evacuated spaces surrounding the collagenous structures. Drying time extended beyond the recommended 2 seconds may cause the collagenous structures to collapse on themselves, reducing the intercollagenous structures substantially, thereby limiting the potential for infiltration of the dentin bonding agent.

Diffusion

Diffusion of the low-viscosity dentin bonding agent into the dentin surface is a concern. Regardless of the generation of bonding agent, the surface should appear highly reflective of light. If there is a relatively dull appearance, the bonding agent has diffused downward, leaving the prepared surface relatively free of the bonding agent. Should this occur, the dentin bonding agent should be reapplied.

Figure 8-29 demonstrates the procedure for applying a fourth-generation adhesive.

The technique for applying a fifth-generation dentin bonding agent is essentially the same. The sixth- and seventh-generation dentin bonding agents are applied first to the enamel surface, then to the dentin surface. The bottom line in dentin bonding is that the clinician must follow manufacturer's recommendations very carefully in conjunction with the guidelines noted previously.

Water Trees in Hybrid Zone

Early dentin bonding agents were relatively hydrophobic, so the dentin surface had to be dry to achieve bonding. The most current generations of dentin bonding agents are appreciably more hydrophilic than any of their predecessors. The increase in hydrophilicity encourages better diffusion of the low-viscosity dentin bonding agent into the evacuated spaces created by the acid etching process. As a result, water is incorporated in the shape of trees in the hybrid zone. This creates a condition by which fluids can be transferred between the dentin and the outside surface—in effect, microleakage. The water sorption by hydrophilic resin monomers within the hybrid layer may unfortunately contribute to deterioration of the bond between resin and dentin. Some seventh-generation dentin adhesives may be more hydrophilic than their predecessors and therefore more

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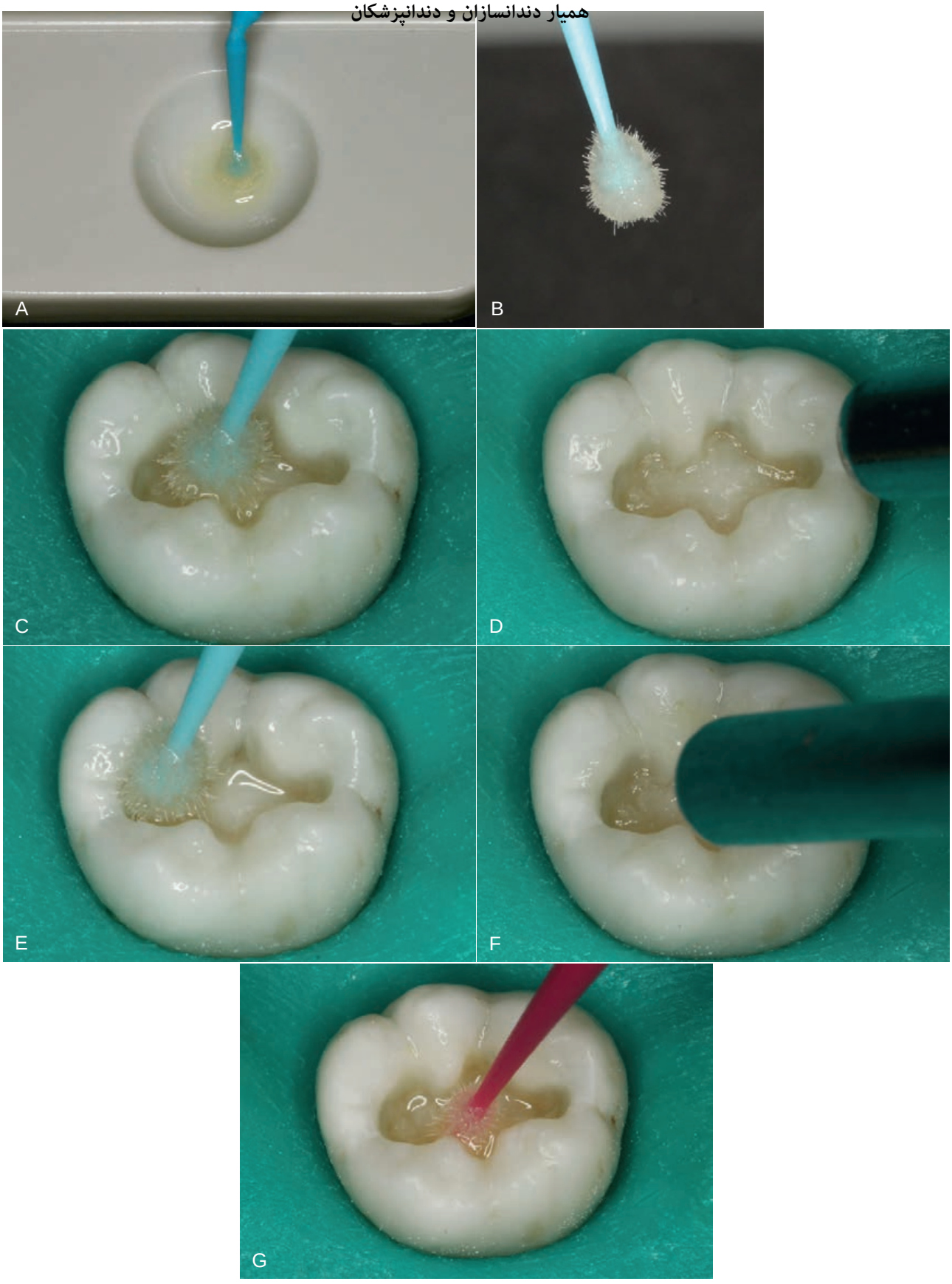


FIGURE 8-29 The procedure for applying a fourth-generation adhesive. **A** and **B**, Saturate the Microbrush with the dentin conditioning agent. **C**, Thoroughly swab the surface with light pressure continuously for 15 seconds. **D**, Air disperse lightly to thin the layer of the conditioning agent. **E**, Apply the second coat of bonding agent and lightly air disperse (**F**). **G**, Apply the dentin adhesive by swabbing the surface with the saturated Microbrush.

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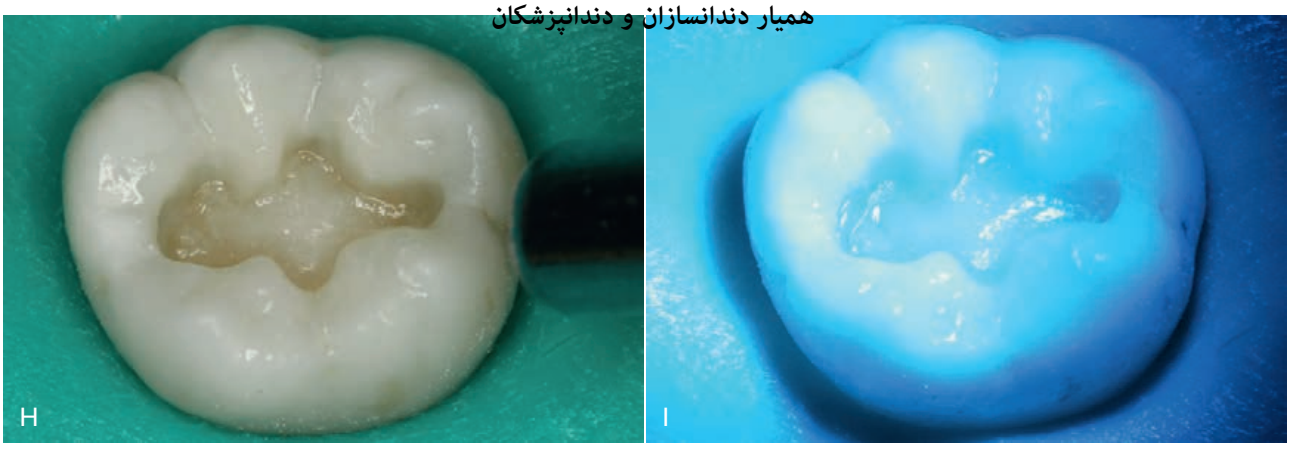


FIGURE 8-29, cont'd Air disperse for a several seconds (H) and then light cure (I).

permeable to water. Although the clinical significance has yet to be demonstrated, the potential for microleakage and eventual deterioration of the resin-dentin interface may be enhanced.

Recent publications have demonstrated that hybridized preparations degrade over time, whether in a laboratory or a clinical environment. The exact cause has yet to be determined, but degradation may be associated with microleakage, water transmission across the hybridized zone, or a less-than-ideal approach in the initial application of the dentin bonding agent.

Recent studies by Pashley and Tay show that applying Hemaseal and Cide Desensitizer (Advantage Dental Products, Lake Orion, Michigan) may actively prevent degradation of the resin and hybridized zone. The application technique is quite simple and straightforward. The cavity preparation is etched, washed, then dried. The Hemaseal is applied with a brush, followed by air suction to remove the excess. The final step is to apply the adhesive, then the restorative material.

SENSITIVITY

Post-operative sensitivity used to go hand in hand with the restoration of teeth. This sensitivity is associated with the odontoblastic process and is most commonly caused by inappropriate use of the dentin bonding agent. The pain ranges from slight to acute. With amalgam, for example, sensitivity commonly occurs immediately after placement and lasts for a week to 10 days. During the first several days after restoration a definite gap of several microns exists between the walls of the preparation and the amalgam restoration, thereby allowing the transfer of fluids.

The sensitivity associated with posterior composites can last considerably longer and demonstrate appreciably greater intensity. The mechanism of sensitivity undoubtedly is somewhat complex. Regardless of the cause, the pain can be directly related to the odontoblast itself. Whatever creates a negative pressure on the odontoblastic process creates a pain response. Positive pressure has no effect; only negative pressure creates a response.

Several situations contribute to post-operative sensitivity. First is the application of cold temperatures. When an ice cube is placed near the gingival crest, especially in mature and older adults, a sharp pain is commonly experienced. In effect the cold temperature of the ice is transferred to the exposed cementum, which creates a contraction of the odontoblastic process. The result is a pain response. Interestingly, the sharp pain retreats when the ice is removed and the temperature of the tooth returns to the normal physiologic state.

Second is the presence of salts and sugars. As the salt or sugar goes into solution, the ions will contact exposed odontoblasts, causing a negative pressure and resultant sharp pain. The pain lasts until the pressure on the odontoblastic process is neutralized.

Sensitivity often can be avoided or eliminated by proper use of a dentin bonding agent. The agent either seals the surface of the dentinal tubules or actually penetrates the individual tubules and isolates the odontoblastic process from the external environment. This can be accomplished by proper use of a dentin bonding agent or a dentin desensitizing agent.

Causes

Although the exact cause of the "cracked tooth" (Figure 8-30) or "cracked cusp" was not always known, it is now clear that the pain associated with this clinical condition is attributable to the odontoblastic process. The technique for determining whether or not a fracture exists consists of having the patient bite down on a rubber "Burlew Wheel" or a wooden stick (Figure 8-31). During the test the rubber wheel is placed over one cusp at a time. The patient is instructed to bite down slowly and as much as possible. Then the patient opens the mouth as rapidly as possible. If a small crack extends from the enamel into the dentin, a sharp pain can be anticipated. If no crack is present, there will be no sensation. If a crack does exist, any fluids present will be forced inward to the odontoblastic process. Such a condition causes positive pressure on the odontoblastic process. Because the odontoblastic processes do not respond to positive pressure, no pain response will occur on biting down. However, the rapid release of pressure will create a negative pressure on the odontoblastic processes and pain will occur.

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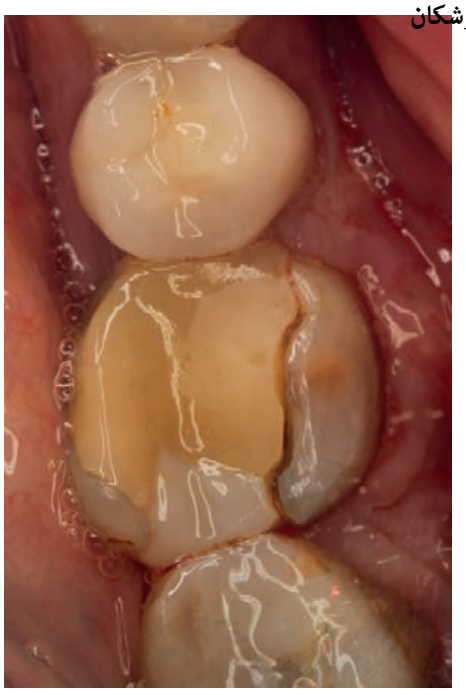


FIGURE 8-30 Fractured lingual ridge of a maxillary first molar.



FIGURE 8-31 Patient biting down on a wooden stick to diagnoses and locate fracture.

The painful response also occurs when air is forced across the surface of the prepared tooth in the absence of anesthesia. Under these conditions, fluid evaporation from the dentinal tubule results in negative pressure on the odontoblastic process. The pain response generally lasts for several seconds, until the evaporated fluids are replaced.

Role of the Odontoblasts

Odontoblasts constitute a single layer of cells on the surface of the pulpal tissue just below the predentin. At the end of the cell is the odontoblastic process. This process extends into the dentinal tubules and generally terminates at about one third the distance between the pulpal chamber and the dentino-enamel junction. Sometimes these processes can extend into the enamel.

The odontoblastic processes are responsible for maintaining and repairing dentin after the caries process and dental restorative procedures. Interestingly, the intrinsic capacity to repair dentin depends on the vitality of the odontoblast, so the clinician must be aware of the components of the materials used to treat the surface of the cavity preparation. For example, eugenol-containing agents should not be considered when temporizing the preparation. Even very small amounts of eugenol may kill the odontoblasts with which they come into contact. If eugenol-based materials are to be used, the preparation should first be hybridized. It is better if the clinician selects a temporary restorative material containing no eugenol. Eugenol-containing materials also appreciably decrease the polymerizing potential of composite resins, including restorative materials, resin cements and any other dental monomers.

Avoiding Post-operative Sensitivity

Several techniques or materials influence the occurrence of post-operative sensitivity. The first is the dentin bonding agent. It is necessary to follow the manufacturer's directions carefully. The second is the use of a flowable composite resin, particularly in class I and II cavity preparation. This material, properly used after the dentin bonding agent, provides significant protection from post-operative sensitivity. Sometimes the dentin bonding agent may not completely seal the open dentinal tubules. The overlying composite, particularly if it is a universal composite, may not optimally wet the surface, so some of the odontoblasts may be exposed to the outside environment, leading to post-operative sensitivity. Because of the excellent wetting ability of flowable composites, the tubules will be more completely covered and sealed against leakage.

Another agent useful in avoiding post-operative sensitivity is glass ionomer. Success has been achieved with both the standard self-cure glass ionomers and the light cure varieties. The material may be used in conjunction with the flowable composite resin or by itself. The glass ionomer, because of its matched coefficient of thermal expansion with tooth structure, is an excellent agent for preventing microleakage. In other words, because the glass ionomer and the tooth structure have matching expansion coefficients, there is no differential in pressures at the interface when the bonded structures are heated or cooled. Consequently, leakage is commonly not a factor. Incidentally, the glass ionomer is very effective in preventing post-operative sensitivity. Many clinicians have substituted glass ionomer for flowable composite resin and have had excellent results in terms of minimizing post-operative sensitivity.

Glass ionomer is recommended as a liner because it releases fluoride ions of the tooth surface. Also, the glass ionomer constantly releases fluoride ions into its immediate environment, which in turn kills microorganisms that may be present and therefore aids in the fight against secondary caries.

Another way of avoiding post-operative sensitivity is to use desensitizing agents. In essence there are two different types. The first simply seals the orifice of the tubule. The second actually

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FIGURE 8-32 Gluma Desensitizer. *(Courtesy Heraeus Kulzer, Hanau, Germany.)*

penetrates the tubule and forms a series of bridges across the tubule itself. A number of products are available for sealing the tubules. The ones that penetrate the tubule, such as Gluma Desensitizer (Heraeus Kulzer, Hanau, Germany) (Figure 8-32), are perhaps the more effective. The desensitizer essentially penetrates the tube as far as 200 µm and then forms a series of bridges across the dentinal tubule. These bridges are impermeable to the odontoblastic fluids. When the cooling temperatures of ionic solutions are applied, fluid movement in the tubules is restricted, with no potential for sensitivity.

This type of sealing offers a definite advantage for both clinician and patient. It provides the clinician a great way of eliminating sensitivity relatively permanently. The procedure is demonstrated in Figure 8-33.



FIGURE 8-33 Procedure for using a desensitizing agent. A, Immediately after the completion of a full crown or inlay or onlay preparation, wash and slightly dry the surface. B, Place the Gluma Desensitizer on the preparation using a 15-second continuous swabbing technique. C, Air dry the surface. D, Take the impression. E, Place a temporary restoration.

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At the cementation appointment, the clinician removes the temporary restoration and washes and dries the site. Because the desensitizer was applied just before the impression was taken, there generally is no need for desensitizing again. The tooth remains desensitized, thereby eliminating the need for anesthesia during cementation. At the time of cementation the operator can select any method, including standard cementing with resin, glass ionomer, zinc phosphate cement, or polycarboxylate. It is even possible to hybridize and bond porcelain, resin, or metal to the preparation.

CLINICAL EFFECT OF PLACING ACID ON CUT DENTIN SURFACE

Regardless of the generation of dentin bonding agent used by the clinician when restoring teeth with composite resin, there is definitely an attack on the dentin by the acid or the self-etch bonding agent. Although this is currently a widely accepted technique (the technique of acid etching dentin has been common for more than two decades), it was difficult at first to get clinicians to accept the concept. The acid etching, whether a separate or an integrated step, opens dentinal tubules for the subsequent penetration of adhesive resins, which advance into the vacated spaces and are light polymerized. Once cured, they provide a micromechanical attachment of the resin to the dentin, as the non-parallel resin tags physically anchor the restoration to the dentinal surface. A dentin surface that has not been etched demonstrates far less resin tag penetration (Figure 8-34, *A*) than one that has undergone routine acid etching (Figure 8-34, *B*).

Perhaps the greatest force against placing acid on the dentin came about by observing that silicate cements killed the pulp. However, it probably was not the acid from the glass silicate cement but the leakage that occurred because the smear layer on the surface of the dentin was eliminated. Silicate cements exhibited a low pH and removed the smear layer, thereby opening the dentinal tubules. Because the silicate cement was not bonded to the walls of the preparation, a gap was established between the preparation and the restorative material itself, making it possible for microorganisms to enter into the opened tubules and eventually the pulpal tissue.

Effects of Overdrying Etched Dentin

Before the advent of the currently available dentin bonding agents, it generally was recommended that the tooth surface be as dry as possible in preparation for cementation. This guideline was based on the potential dilution of the then-existing cement with water, which was shown to be detrimental to the long-term properties of the luting process. The same concept was true for all the nonpolymer types of cements. Because the mechanism of retention associated with the resin cements is appreciably different from any of its predecessors, it should be no surprise that the rules of engagement are different.

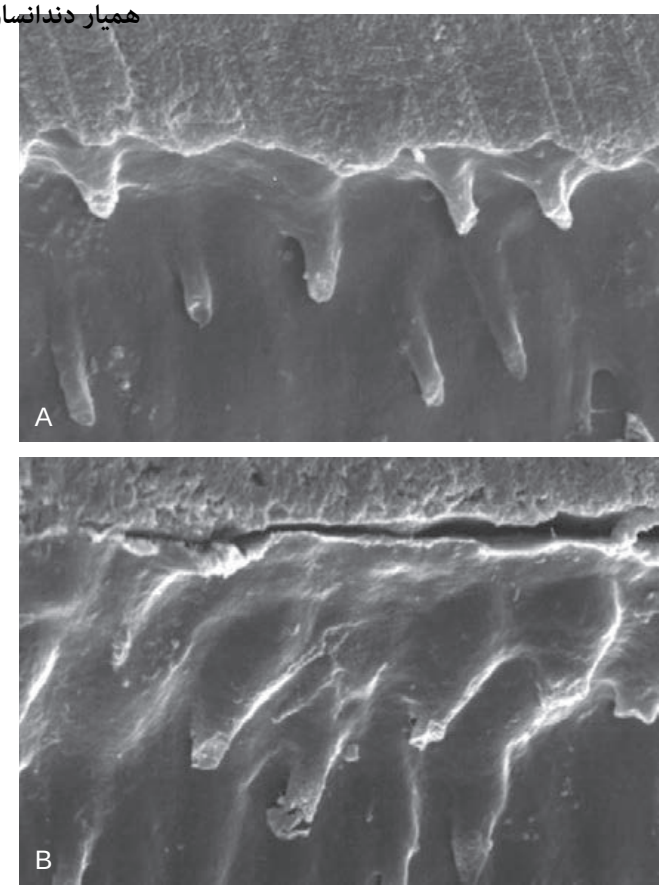


FIGURE 8-34 **A, Minimal depth of resin-tag penetration of dentinal tubules without acid etching. B, Normal depth of resin-tag penetration of dentinal tubules with acid etching.**

After acid etching, followed by washing and drying, the calcium component of dentin has been eliminated. When subsurface moisture or water is allowed to remain, the now unprotected collagen fibers are buoyed up. When this moisture is removed by vigorous air drying, the exposed fibers of collagen begin to collapse on themselves. This in turn significantly reduces the evacuated space between the fibers, thereby decreasing the amount of resin that can be infiltrated. The end result is a reduction in shear bond strength by as much as 50%.

Should the clinician overdry the preparation after acid etching and washing, the problem can be corrected simply by rewetting the dentin surface. This in turn results in the water penetrating between the collagen fibers and spreading them apart. Air drying time should be no longer than 2 seconds.

SPECIFIC APPLICATIONS

Posterior Composite Situations

All four latter generations of dentin bonding agents (fourth through seventh) can be used successfully in conjunction with posterior composite resins. If post-operative sensitivity has been

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an issue, then a sixth-generation (Clearfil SE Bond Kuraray Co., Ltd., Osaka, Japan) or seventh-generation (BeautiBond, Bond Force) dentinal adhesive is recommended. The recommendation is based on reports from many clinicians who have reported little or no post-operative sensitivity with these types of adhesive. With fourth- or fifth-generation bonding agents the etching process is done as a separate procedure. When this process has been completed, the infusion of the dentin bonding monomer is initiated. The degree of bonding success depends on how well the monomer diffuses into the evacuated spaces. Unless strict adherence to the process is followed, full and complete diffusion into all open dentinal tubules is not attained. All this can create substantially decreased bond strength, leakage, degradation of the collagen, deterioration of the adhesive zone, and debonding of the restoration. Furthermore, even with a single unsealed tubule, the risk of post-operative sensitivity is increased.

The use of self-etch dentin bonding agents has risen rapidly because of the lack of post-operative sensitivity.



FIGURE 8-35 Abfracted buccal gingival area of lower first bicuspid.

Ceramic Veneers

The type of cement chosen for bonding ceramic or resin veneers generally depends on the biologic makeup of the prepared tooth surface. The prepared surface consists of enamel, dentin, or a combination of the two. The type of surface structure remaining depends on the degree of discoloration and the degree of imperfection in the tooth structure. Although the chemical makeup of the tooth surface cannot always be controlled, the most ideal is an enamel surface. Bonding agents can be successfully bonded to either dentin or enamel, but the one best in terms of longevity is enamel. A considerable number of recent papers compare the degradation of bond strength at the dentin and enamel resin interfaces. Degradation of the enamel-resin interface is significantly less, and the interface could actually outlast the restoration itself.

Most clinicians use a fifth-generation dentin bonding agent in conjunction with veneering agents. The fifth-generation dentin bonding agent should provide the same lasting results as a fourth-generation bonding agent but involves fewer steps and is less prone to technique sensitivity.

Abfracted Lesions

Thanks to the information generated by Lee and Eakle, considerably more is known about the cause of the abfracted lesion. It previously was assumed that the concave or V-shaped cavities appearing in the cervical regions were attributable to excessive toothbrush abrasion. It had been assumed that the V-shaped defects were created by brushing the surface of the tooth in a mesial-distal direction. This made sense because the defect was in the cementum or dentin and not in the enamel. Because the cementum or radicular dentin is less resistant to toothbrush wear than enamel, the argument was quite convincing.

According to Lee and Eakle the defect is created by bending the tooth beyond its physiologic limit. At this point small cracks begin to appear in the cervical region. As they progress, small pieces of tooth structure actually begin to break away from the surface of the tooth. The word *abfraction* therefore is appropriate, as it is derived from Latin, meaning "to break away" (Figure 8-35).

Before the lesion is restored, it is important to evaluate the occlusion for prematurities (Figure 8-36, *A* and *B*), particularly on those teeth that exhibit abfracted lesions. Once the prematurities have been eliminated (Figure 8-36, *C*), the surface of the defect is treated with air abrasion, pumice, and/or a finishing bur (Figure 8-36, *D*). Next, retentive grooves may be placed on both the incisal or occlusal and the gingival surfaces. If the morphology of the lesion resembles a V-shaped groove, it is best to modify the defect with a number 4 round bur. This will then put the restoration in the state of compressions. The V-shaped groove puts the restoration in a state of tension, which will then increase the potential for debonding.

The actual material used to restore the defect depends on the age of the patient. For younger patients it is recommended that the next procedure be to hybridize the preparation (Figure 8-36, *E*) with either a fourth- or a fifth-generation dentin bonding agent (Figure 8-36, *F* and *G*). The restoration is then placed using a restorative resin that exhibits a lower modulus of elasticity (Figure 8-36, *H*). This ensures that when the tooth bends during mastication, the restoration bends or deflects to a certain degree. Flowable and microfilled composite resins are the materials of choice (Figure 8-36, *I*).

For elderly patients a glass ionomer such as Fuji IX (Figure 8-37, *A*) or "giomer" such as BEAUTIFIL, a composite resin (Figure 8-37, *B*), is the recommended restorative agent. The glass ionomer or giomer is used because there is greater potential for caries to occur in the cervical region than in the proximal region. The glass ionomer has a relatively high release of fluoride ion. As with younger patients, incisal and gingival retentive grooves are placed. This is even more important for the glass ionomer restoration, because the bond strength for the glass ionomer restoration is appreciably less than it is for composite resin.

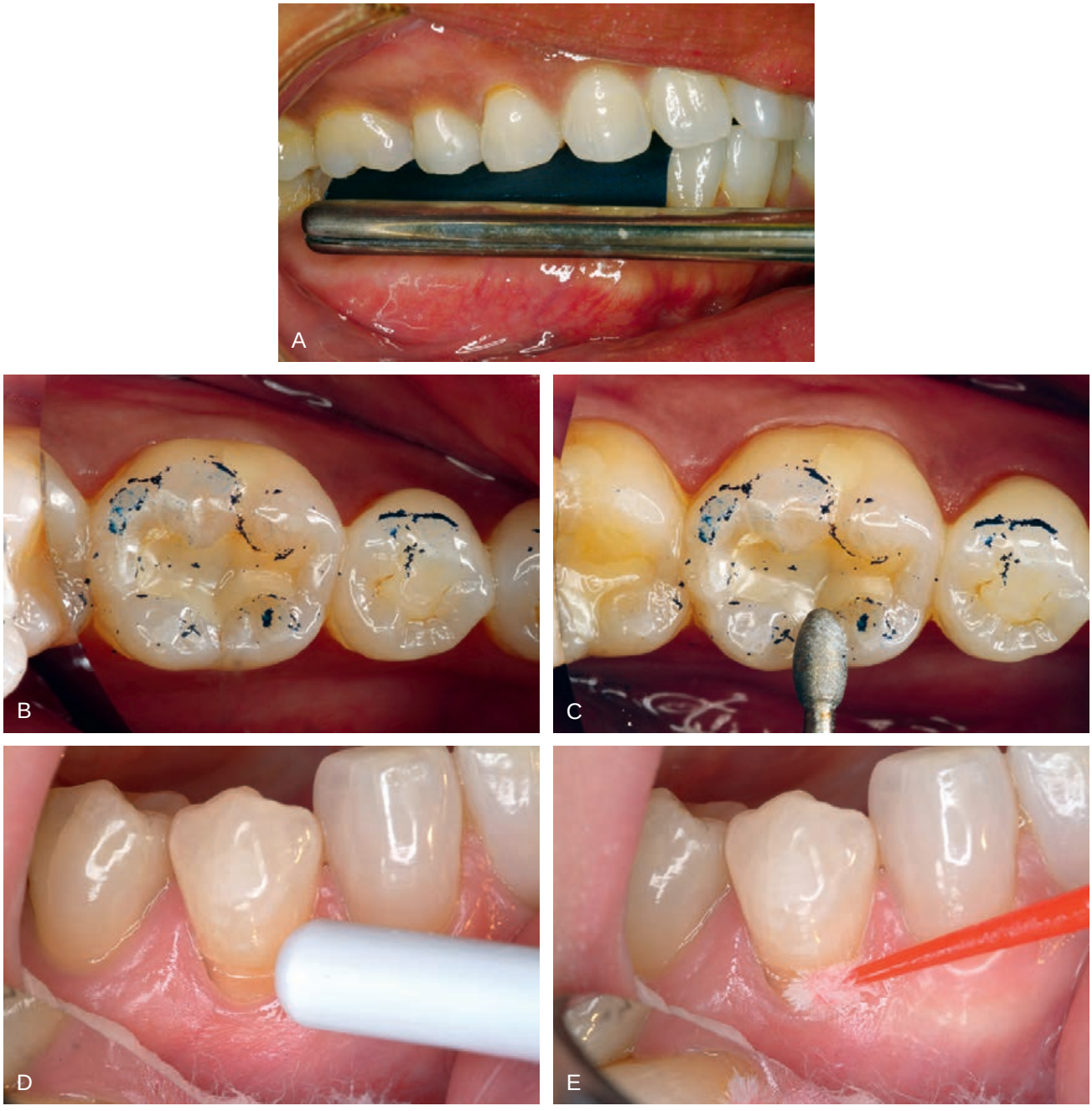


FIGURE 8-36 **A, Occlusal relationships determined with articulating paper. B, Contacts and prematurities clearly indicated on occlusal surfaces. C, Occlusal prematurities eliminated with a diamond bur. D, Abfraction defect is cleansed with air abrasion. E, Dentinal surface is hybridized.**

Continued

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FIGURE 8-36, cont'd Gluma Solid Bond (fourth-generation adhesive) (F) and DenTASTIC UNO (fifth-generation adhesive) (G). H, BEAUTIFIL Flow. I, Completed restoration. *(**F** courtesy Heraeus Kulzer GmbH, Hanau, Germany. **G** courtesy Pulpdent Corporation, Watertown, Massachusetts. **H** courtesy Shofu Dental Corporation, San Marcos, California.)*

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FIGURE 8-37 A, GC Fuji IX GP EXTRA Packable Glass Ionomer restorative. B, BEAUTIFIL II giomer restorative. *(A courtesy GC America, Alsip, Illinois. B courtesy Shofu Dental Corporation, San Marcos, California.)*

CONTROVERSIES

The mechanism of bonding was well described by Nakabayashi. In total-etch bonding systems the acid superficially removes the inorganic component (hydroxyapatite) surrounding the collagenous structure. The depth of dissolution on the cut surface of dentin is about 10 µm. The acid then penetrates into the individual dentinal tubules to a depth of about 100 µm. The low-viscosity dentin bonding agent is then applied, followed by rapid diffusion into the decalcified regions. The mechanism of bonding is micromechanical. Very little true bonding of the resin to the collagenous structure takes place.

One of the greatest problems associated with the bonding process is inadequate diffusion of the dentin bonding agent into the decalcified dentin. Failure to attain complete filling of the small vacancies created by the acid etching agent will result in unprotected collagenous structure. Such a condition can lead a biologic degradation of the now exposed collagenous structure. This in turn leads to microleakage or nanoleakage, post-operative sensitivity, and possible debonding of the restoration.

Even when carried out properly, there can eventually be collagenous degradation. Hashimoto demonstrated that biologic deterioration of the dentin may occur even when bonding is carefully carried out. Researchers restored a number of primary teeth using a dentin bonding agent and a composite resin. Before exfoliation the teeth were extracted. After preparation of the teeth, tensile test measurements were obtained. Surprisingly, the investigators found a 75% reduction in bond strength from baseline values. Furthermore, evaluation with scanning electron microscopy (SEM) revealed biologic degradation of the hybridized dentin.

Since this investigation was published, numerous other investigators have also found evidence that bond strength decreases over time. They also found degradation of the collagenous structure. In light of this information, it is highly recommended that the clinician follow the manufacturer's recommendations for use and monitor bonded restorations on a regular basis.

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9 CHAPTER

Anterior Direct Composites

A SECTION

Direct Anterior Bonding: Minimally Invasive Dentistry at Its Best

K. William Mopper

Modern resin materials have opened a huge door of opportunity for both dentists and patients by offering an esthetic and minimally invasive alternative for restoring the dentition that can be accomplished in just one office visit. Direct composite restorations make it possible to restore defects, repair tooth structure invisibly (Figures 9-1 to 9-3), and change tooth shape and alignment (Figures 9-4 and 9-5) without the use of a dental laboratory. This chapter section explores the influence of composites on modern dentistry and guides dentists through the art and science of restoring the anterior dentition with composites.

For consistent esthetic results to be achieved, proper technique and the choice of materials are of paramount importance. Physical and handling properties, opacity, translucency, color stability, and polishability greatly affect the esthetic outcome of the restoration. Each material is unique and has its own place in achieving a beautiful result. When proper technique and the proper choice of materials are combined, the result will leave the dentist and patient more than satisfied. The author has chosen the specific materials in the cases discussed in this chapter to achieve these results.

For many years, anterior direct composites were believed to be inadequate restorations that were not strong enough to hold up in the mouth long term. The consensus was that composite procedures were inferior, time-consuming, and stressful, making it difficult for dentists to obtain predictable results.

In truth, however, composite procedures are actually less stressful for dentists because tooth preparation is kept to a minimum, no impressions are necessary, no temporization is required, the results are instantaneous, and there is no lag time because the laboratory is eliminated. Because the procedure is under the dentist's complete control, he or she never has to worry about cementation or marginal integrity. If something must be corrected, it can be corrected chairside. If something must be repaired, it can be repaired in the office. Dentists can also use composite to quickly mock up the final results for their patients. Having patients see what their dentist can do for them is excellent advertising, showing creativity and the resultant beautiful work—a great practice builder!

Throughout the past 50 years, the materials and procedures for anterior direct composites have evolved immensely. Decades ago different types of plastic and composite materials were in use (such as Sevritron and Adaptic). In 1955, Dr Michael Buonocore revolutionized dentistry with his breakthrough research on acid etching of the enamel, which enabled plastic materials to adhere to tooth surfaces. He found that acid etching enamel before applying different materials greatly enhanced adhesion to tooth structure. As a result of these findings, composites were the breakthrough of the late 1960s as an anterior restorative. Ultraviolet-light curing in the 1970s and finally visible light curing in the early 1980s superseded earlier systems.

Over time, many different bonding agents have been developed with varying adhesive qualities. This is important because bonding agents allowed the dentist to have complete control in placing, shaping, and sculpting composite material. The new adhesive qualities permitted higher bond strengths to enamel and dentin and yielded a better bond to metal, porcelain, and other materials.

Great advancements have been made in composite materials over the years. Macrofill materials such as Nuva-Fil (DENTSPLY Research and Development Corporation, Los Angeles, California) were the first composites used in direct anterior dentistry. Macrofill composites were highly filled, large-particle-sized materials exhibiting great strength and low esthetic properties. In 1978 the first microfill material was developed and has since been the premier material for simulating the enamel surface.

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FIGURE 9-1 A, Decalcification after orthodontic treatment. B, Tooth preparation. C, Invisible restorations created using Renamel Nanofill with Renamel Microfill overlay.



FIGURE 9-2 A, Hypoplasia (white spots). B, Defect eliminated invisibly by white spot removal and the use of Renamel Microhybrid overlaid with Renamel Microfill.



FIGURE 9-3 A, Worn incisal edges. B, Repaired incisal edges. Note the complete invisibility of the restorations.

Microfill composites are the best material for simulating the enamel surface both esthetically and biologically. Owing to their small-sized, uniform, spherical particles, microfills exhibit the greatest long-term polish and the best wear resistance; they are the most plaque resistant and exhibit a refractive and reflective index closest to that of the enamel surface. Microfills also most closely simulate the enamel surface in color density, polishability, light refraction, and reflection, in both the short and long terms, and give the natural vitality of a finished enamel surface. Microfills have a translucence that most closely resembles enamel, thus allowing tints to shine through. When microfill composites are used, fracture toughness must be addressed. The single contraindication for a microfill is use in high-stress areas because of its lowered fracture toughness.

Microhybrids were first developed to compete with microfill materials owing to their higher strength properties. Although microhybrids are not as polishable or as compatible with the tissues as microfill composites, their strength and opacity are extremely helpful in simulating the strength and support characteristics of the dentin. These composites work well for posterior restorations and, because of their increased opacity, for masking of dark or discolored areas. Their esthetic properties are not as good as those of a microfill or a nanofill composite; however, their physical properties include strength and fracture

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FIGURE 9-4 **A, Old composite veneers. B, Patient after color change with Renamel Nanofill and Renamel Microfill combination.**

toughness. The mean particle size range of microhybrids is 0.4 to 0.7 micron. The larger particles are agglomerated up to 35 microns to give the material workability and strength. Because of their larger particle size, microhybrids are not as polishable, do not hold their polish long term, and are not as wear resistant as nanofills or microfills. The esthetic qualities of microhybrid composites do not compare with those of a microfill in any way.

The most recently developed composite materials are nanofills. Nanofills are considered today's universal material, exhibiting qualities of immediate polishability and great surface smoothness. In addition, nanofill materials are strong, demonstrate low shrinkage, and offer good opaquing qualities. They are recommended for use on their own or underneath a microfill, except in areas where extreme color changes are needed. Their translucent quality allows the vitality of the tooth to be apparent when the light reflects through them. When used as a universal anterior material, nanofills exhibit excellent surface smoothness and ease of handling and good color. However, when compared with microfills, they will not maintain their polish long term and do not have the same translucent qualities of enamel. Although not yet proven clinically, nanofill composites are unlikely to be as biologically compatible with the gingival tissues over time as their microfill counterparts.

To summarize, microhybrids exhibit great strength and opacity; therefore they are great for dentin replacement. Nanohybrids exhibit good strength and better esthetics then microhybrids and thus are more suited for a universal material. Microfill composites are the most esthetic of the three composite types and are the only materials that closely simulate the enamel surface. (Microhybrids and nanofills simulate dentin in strength and opacity, whereas microfill simulates enamel.) When there is enamel involvement, especially in anterior sites, microfill is still the most appropriate choice. If the dentin's physical properties are an issue, either nanofill or microhybrids are more appropriate.

Opaquers help dentists achieve complete invisibility of the restoration with composite by blocking unwanted color and



FIGURE 9-5 **A, Dentition before realignment. B, Patient after realignment, along with tooth reshaping, gingival recontouring, and color change. Note the translucency achieved, with gray tint shining through the overlaying microfill.**

raising the value of the final restoration. Unfortunately opaquers are underused in the profession because of a lack of knowledge of their importance and insufficient training in their application. For consistently reliable restorative results with complete invisibility to be achieved, opaquers are a necessary adjunct to the practitioner's armamentarium. Opaquers are primarily used to block out the unwanted shine-though from a dark under-color, to block metal, to cover a tetracycline stain, or to eliminate unesthetic translucent shine-through. Truly invisible restorations require the use of a sophisticated opaquer that works in relationship with the composite system that is used.

The best example for the value of a reliable opaquing system is when repairing a fractured incisor. Often clinicians try to replicate the dentin color and then overlay this layer with a compensating shade of enamel to achieve the right surface color. This involves considerable guesswork and offers inconsistent results. An alternate approach is to consider only the surface color. For example, if a fractured tooth is A1, then an A1 hybrid or nanofill can be added to recreate the incisal dentin portion of the tooth to help achieve opacity and strength. To eliminate translucent shine-through, an A1 opaquer can be placed over the top of the nanofill or microhybrid (Figure 9-6) to block and blend. Once the shine-through has been eliminated, there should be no difference between the tooth surface and the restoration. The addition of A1 microfill will create a perfect match of material to tooth structure and completely simulate the entire enamel surface once finished and polished. In this type of system, the colors of the opaquers, microhybrids, nanofills, and microfills should match one another and the corresponding shade guide exactly; only their values are different. (The Renamel

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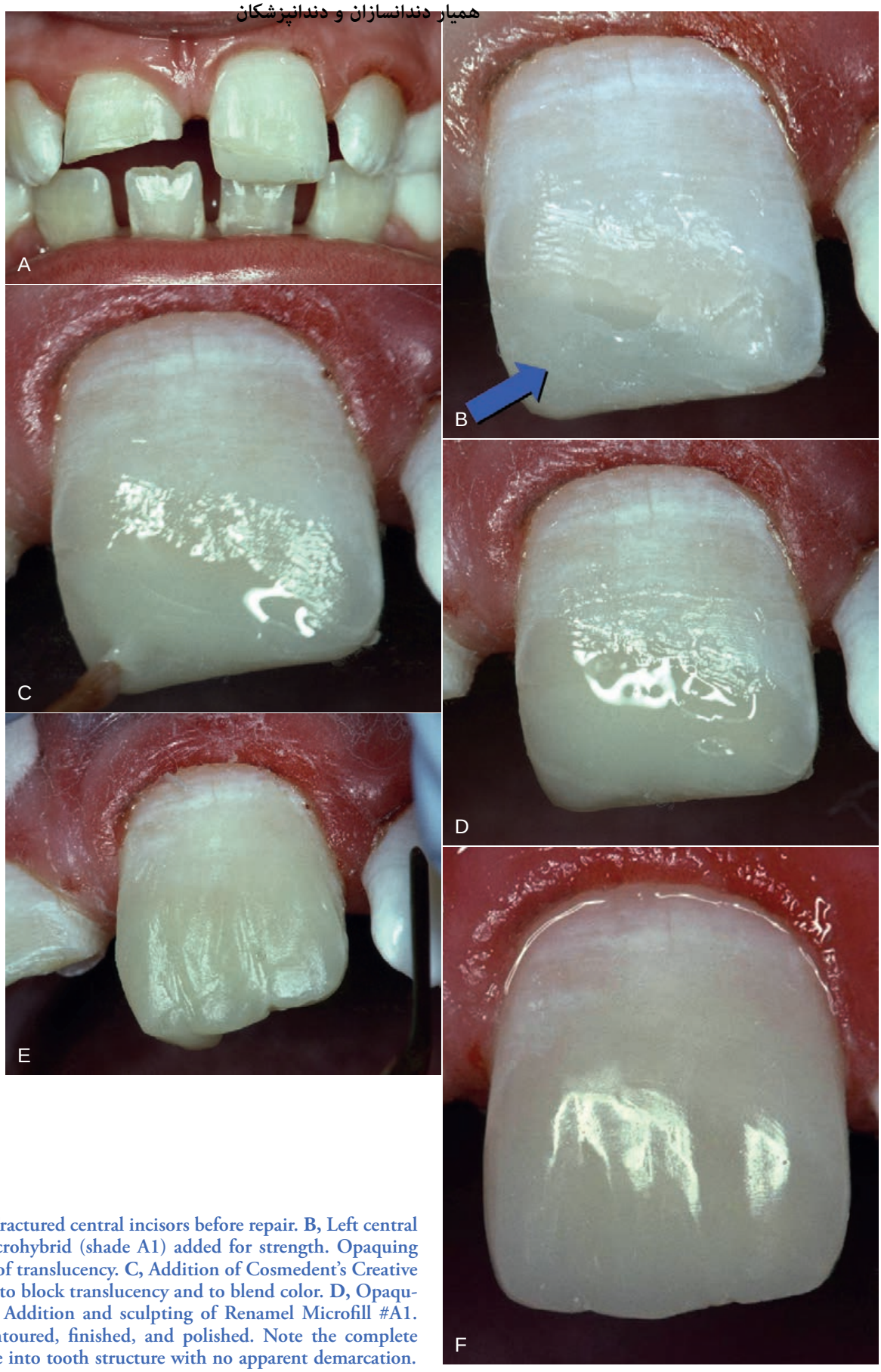


FIGURE 9-6 A, Fractured central incisors before repair. B, Left central with Renamel Microhybrid (shade A1) added for strength. Opaquing necessary because of translucency. C, Addition of Cosmedent's Creative Color opaquer A1 to block translucency and to blend color. D, Opaquing completed. E, Addition and sculpting of Renamel Microfill #A1. F, Restoration contoured, finished, and polished. Note the complete blend of composite into tooth structure with no apparent demarcation.

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Restorative System by Cosmedent [Chicago, Illinois] is the best example of this.)

Tints are yet another underutilized material that if used properly can greatly enhance the esthetics of anterior composite restorations. As with opaquers, lack of knowledge and lack of training in the application of tints is common. Tints are used to enhance incisal translucency as well as gingival hue and chroma. A good tint must be transparent to allow the light to shine through and carry the color into the overlying composite layer. Because of its translucency, microfill is the only composite material that truly allows this phenomenon of color shine-through to take place, creating the color realism from within (Figure 9-7).



FIGURE 9-7 **A, Tint application using Cosmedent's Creative Color gray tint with a Cosmedent #1 brush at the incisal. Note that the tip of the brush aids in placement control. B, Tinted area complete and outlined. A thin incisal edge is left devoid of tint in an attempt to develop a halo. C, Renamel B1 Microfill placed over hybrid and tinted layer. D, Completed veneer. Note incisal translucency, incisal halo, and characterization. E, Completed case 1 year postoperatively. Note the exceptional polish retention.**

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FIGURE 9-8 **A, Class III preparations. B, Restorations 6½ years postperatively. They are virtually invisible when a Renamel Microhybrid with a Renamel Microfill overlay is used.**



FIGURE 9-9 **A, Fractured left central and lateral incisors. B, Immediate postoperative smile after fracture repairs with Renamel Microhybrid, Creative Color Opaque, and Renamel Microfill as the enamel layer.**

This is yet another reason for using microfill as the prime enamel layer.

CLINICAL CONSIDERATIONS

Composite Indications

Composite materials are indicated for almost all types of anterior restorations, from surface and incisal defects to routine restorations such as class III (Figure 9-8), class IV (Figure 9-9), and class V (Figure 9-10). They are ideally suited for other situations such as diastema closures, anterior veneering for color change, tooth reshaping, and tooth realignment to obtain a desired smile design (Figure 9-11). In addition, composites can be used for any type of treatment; such as full-bonded crowns (Figure 9-12), short-span anterior bridges, and porcelain repairs (Figure 9-13) which can all be constructed with direct composite resin. The indications for the use of anterior composite materials depend on how skilled the operator is, how comfortable the procedure feels, and how well the operator can develop the desired restoration. Although these restorations have the undeserved reputation of not holding up, when done properly they generally last at least 20 years (Figure 9-14).

Misconceptions pertaining to this type of restorative dentistry are the increased time required and the considerable effort needed, which may both cause added stress to the practitioner. However, consider these important advantages of composites:

1. These types of restorations require minimal or no preparation.
2. Patient comfort is increased (often no anesthesia is required).



FIGURE 9-10 **A, Old cervical restorations. B, Cervical restorations immediately postoperatively, using Renamel Microfill only.**

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FIGURE 9-11 **A, Diastemas to be closed after orthodontics. B, Invisible diastema closures completed with no preparation and using Renamel Microfill only. Note the beautiful architecture of the gingival tissue.**

3. No temporization is necessary.
4. Dentists have complete control over the final result because a laboratory technician is not involved.
5. If something does break, it is easily repairable.

The use of direct anterior composites can create beautiful and long-lasting esthetic results, from routine restorations to complete veneering, and is minimally invasive dentistry at its best.

Whereas many dentists now accept the benefits of composite, to do anterior direct composite procedures well requires a desire for perfection. For restorative procedures it is important to properly estimate the value of the procedure and reflect that value in how much is charged. Most often the practitioner underestimates the value of his or her technical expertise, thus resulting in undercharging for these types of restorations. If a minimally invasive technique can be used to save a person's tooth and restore it beautifully (perhaps even better than a technician could), this procedure deserves to be priced at an appropriate value. These techniques take added time, which should also be reflected in the additional charge.

Contraindications

Anterior direct composite restorations should not be done by a dentist who does not feel sufficiently skilled. They are also contraindicated in patients who have areas of extremely high stress, such as severe bruxers or clenchers who refuse to wear nighttime appliances, in overly aggressive eaters (e.g., those who chew hard candy), and in fingernail biters. In cases with long-span spaces to be restored, these restorations are generally not successful.

TREATMENT PLANNING

Treatment planning is driven by the characteristics of each individual case. For patients who have no problems with their centric occlusion, centric relation or vertical dimension, treatment planning can be done in segments. Anterior restorations can be accomplished without restoring the posterior, but the practitioner should always remember to look at tooth size, inclination, rotation, or position and then visualize what needs to be done to create the illusion of perfection. For patients whose teeth are over-closed and those with decreased vertical dimension, it is necessary to treat the posterior occlusion first before addressing the anterior problems. Once the correct vertical dimension and centric occlusion have been established, then the proper anterior length and incisal guidance can be achieved with ease (Figure 9-15).

Sequence of Treatment

When planning a case, dentists must first look at the patient's occlusion and all of the excursive and protrusive movements. If a person has either lateral or protrusive interferences, these must be addressed before tooth lengthening. For example, establishing proper canine rise with the use of composite is an excellent way to allow dentists the space necessary for tooth lengthening and proper disclusion (Figure 9-16). In wear cases, the patient's mouth is treated according to the lip line. Often it is necessary to restore the cusp tips of the bicuspids and at least the first molar to achieve the ideal look and the uniform curve of Spee.

In planning a case, it is wise to look at the patient's smile to make sure that the arch form is broadened. There is nothing quite as unsightly as six restored anterior teeth and negative space in the bicuspid area. If the negative space is not addressed, then the "floating" six anterior teeth detract from a beautiful smile and the patient will not be happy with the result. Before treatment, it is wise to demonstrate to the patient through a mock-up. Bringing the bicuspids into the negative space and filling out the facial aspect will show exactly what can be accomplished.

Treatment Considerations

The treatment considerations depend on what the patient wants. It is important to get the patient's input on the proposed treatment, particularly when creating a complete color change, when color matching is not necessary. During a patient consultation, let the patient do the talking, then offer him or her advice and discuss the options available. Often the patient does not see exactly what all the problems are. Doing just half the case will never make a patient happy. In treatment considerations, a thorough functional and esthetic diagnosis is essential to get the best result. After treatment, patient input is also welcome. Patients

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FIGURE 9-12 **A,** Undersized right peg lateral incisor and missing left lateral incisor. **B,** Preoperative close-up of peg lateral. **C,** Preparation of peg lateral. **D,** Immediate postoperative view of full bonded crown. **E,** Full-bonded crown and resin retained bridge 4½ years postoperatively. Note the diastema closure between the two centrals, the papillae completely intact after 4½ years. No wear and no color change is seen due to the use of the microfill material.

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FIGURE 9-13 **A, Exposed cervical margin with gingival recession before repair. B, Repair completed using Cosmedent's Pink Opaque, Renamel A2 Microhybrid, and Renamel A2 Microfill. C, Access area before porcelain repair. D, Completed porcelain repair, using the same technique and materials.** *(Dentistry and photos courtesy of Dr. Dennis Hartlieb.)*



FIGURE 9-14 **A, Nine-year postoperative view of VITA shade C1 (maxillary laterals and centrals) full composite veneers blended to existing dentition. B, Fourteen-year postoperative view of VITA shade A1 (maxillary right cuspid to maxillary left cuspid) full composite veneers blended to match existing dentition.**

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FIGURE 9-15 **A and B, Worn dentition on 23-year-old patient. C, Mounting of case to determine how much the vertical dimension should be increased. D and E, Stent made over wax-up used to lengthen lower centrals and establish desired incisal guidance. F, Lower arch completed using Renamel Nanofill. Note all cusps rebuilt in composite and the improved curve of Spee. G, Patient in centric occlusion with vertical dimension increased by 2.5 mm. H, The upper arch was rebuilt to the lower arch using Renamel Nanofill and Renamel Microfill. Then the teeth in the lower arch were reduced slightly and re-veneered with Renamel Microfill. The completed case demonstrates freeway space, curve of Spee, and increased tooth length. I and J, Retracted views showing inter-cuspation.** *(**A to G,** Dentistry and photos courtesy of Dr. Dennis Hartlieb. **H to J,** Dentistry and photos courtesy of Dr. K. William Mopper.)*

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FIGURE 9-16 **A, Absence of canine disclusion places disclusion on laterals and centrals, which causes wear and possible fracture of composite veneers. B, Canine disclusion after cuspid rise has been added. C, Retracted view before treatment showing discoloration of original composite and canine wear. D, Full view in centric occlusion after the development of canine disclusion and re-veneering on centrals and lateral incisors with nanofill and a microfill overlay.**

can help find interferences and identify any discrepancies that may have inadvertently been overlooked.

The author's first treatment choice would be a layered technique, which would simulate both the enamel and the dentin layers. In the procedure, a material that simulates the dentin—a hybrid or nanofill—is used first, followed by a material that simulates the enamel—typically a microfill placed on the outermost surface. Knowledge of opaquing and tinting principles helps in achieving invisibility and overall consistency in the final restoration.

CLINICAL CONSERVATION CONCEPTS

The object of minimally invasive dentistry with the use of direct resin bonding is the preservation of tooth structure. In preparation, dentists should consider how conservative the approach can be, what the plan is, and how minimally invasively the results can be achieved. The hard tissues should be preserved whenever possible because excessive destruction of these tissues can cause many long-term problems. The amount of preparation depends on the procedure to be done. For example, if a tooth is in labial version, the preparation may extend into the dentin, whereas if the tooth is in lingual version, no preparation may be necessary. It is desirable in any preparation to maintain as much enamel as possible for the best adhesion of the composite.

MORPHOLOGY

It is often difficult for dentists to shape anterior teeth properly. To establish proper morphology, the dentist must recognize the relationship of tooth size and form to the facial structure and understand the relationship of lip line to tooth size. A completed smile should follow the curvature of the lip line.

To make a tooth more realistic is the real art of anterior composite dentistry. The art form of creating correct morphology is sculpting. In order for the dentist to achieve proper sculpting of the tooth form and to be able to manipulate the material beneath the gingiva, the dentist must have proper instrumentation, such as Cosmedent's anterior instruments. These titanium-coated instruments make it easier to apply and refine morphological aspects of tooth formation (Figure 9-17).

SMILE RELATIONSHIPS

After observation of the occlusion in relationship to the lip line and an exploration of the patient's needs and wants, the occlusal relationship and the relationship in phonetics must be considered. It is important that the patient be able to pronounce the

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FIGURE 9-17 **A and B, Cosmedent's titanium-coated anterior composite placement and shaping instruments. C, 8A application of Renamel nanofill from lingual. D, IPCT short blade to define interproximal. E, 8AL to apply microfill. F, IPCL to refine material beneath free margin and interproximally. G, Multipurpose to interlobe and sculpt incisal edge for incisal material placement.**

sounds needed for communication. The relationship of one tooth to another is explored because not all teeth are the same length. The central incisors are more prominent, the laterals are less prominent and perhaps a millimeter shorter, and the canines are longer, about the same length as the central incisors. It is desirable to have a nice smile line and a good curve of Spee, plus well-defined contact areas with good proximal contact, although sometimes some spacing may be desirable. The dental arches should conform to the relationship of the buccal mucosa over the dentition so that no negative space and no narrowing of the

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FIGURE 9-18 **A, Smile needs change in color, tooth length, shape, canine rise, and embrasure spaces. B, Results of smile change. Note the color and shape of the lateral incisors. Now the curvature of the upper arch follows the lip contour perfectly; all restorations are a perfect color match; and canines, laterals, and centrals have been reshaped.**



FIGURE 9-19 **A, A 22½-year-old case showing original Renamel Microfill A2. Note the perfect color match to the VITA shade guide. The color stability of Renamel Microfill shows the material's ability to stand the test of time. B, Case redone in A2 Renamel Nanofill overlaid with A2 Renamel Microfill. Note the perfect color match to the VITA A2 shade tab. The laterals and centrals were done with A2 Renamel Nanofill overlaid with A2 Renamel Microfill, and the canines were restored with A2 Renamel Nanofill.**

arch form are present. The smile line should follow the lip line, giving a good curve of Spee and avoiding a negative smile (Figure 9-18).

HANDLING PROPERTIES

In selecting a composite, not only is it important how closely the color matches the shade guide, but how well the material handles is essential for the practitioner. Currently most materials have excellent handling properties. Working environments are crucial to the overall handling properties of the materials. It is impossible to work with materials in an environment where it is too hot or too cold. The temperature in the office should be maintained at 20° to 22° C (68° to 72° F). If the material is too stiff, the use of a composite warmer can greatly enhance its workability. It is also important to understand different lighting systems. Although it is not possible to over-polymerize, one can under-polymerize, which is a common mistake dentists make.

THE IMPORTANCE OF COLOR

There are many techniques for color management. Shade taking has always been a problematic area for dentists. Some materials do, in fact, match existing porcelain shades guides exactly (Figure 9-19). Some manufacturers make shade guides from polymerized and polished materials to work with their system. Electronic or computerized instruments are now available to help match shade. Whatever method used, it is absolutely essential to have a good shade guide that accurately matches the composite system of choice. Dentists must train their eyes to select accurate color. It is common knowledge that, on average, a highly trained female has higher color acuity than her male counterpart of similar age.

There are three different aspects of color in the tooth structure: hue, chroma, and value. Hue is the actual color of the tooth; the color one can see. Chroma is the density of that color. This correlates to the depth of intensity or how much color is present. Third, the value is the relative lightness and darkness of the tooth. In trying to take a shade, overall hue is seen in the center of the tooth or the center of the shade guide.

Looking at the tooth from the front will help determine the density of the gingival color and whether there is a deeper chroma or more color at the gingival margin or the tooth has a straight flat color gingival to incisal. The incisal edge will show the amount and color of translucency. This may be subtle or intense, on the blue side, violet side, or gray side. Taking all

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FIGURE 9-20 **A, A long bevel on the facial surface of a class III restoration. B, A long bevel on the facial surface of class IV restoration. C, The necessity for restoration on the cervical eroded areas on the bicuspids and first molar. D, Extent of bevels on buccal surfaces. E, Completed restorations immediately postoperatively after use of Renamel Microfill only.**

of this into consideration will yield overall color. When the case is being referred to a laboratory, it is possible to use a color map. If one tooth is to be matched to an arch, it is best to color map an existing tooth before any preparation.

Taking a shade should always be done in a moist environment. Drying the area desiccates the tooth, and it loses its color. Shade reading is best taken under fluorescent light; the whiter the better. Shades can be taken in colored light, but not in sunlight because sunlight contains all shades, which will influence the appearance of the tooth.

Translucency is different for every patient and every tooth. Dentists tend to consider translucency as uniform, but some patients have no translucency in their teeth. The translucency is very important because in a vital tooth there is subtlety of transfer. People like subtle translucency; it is something they can see. Generally people do not like hyper-translucent incisal edges. Teeth that are so thin that they can be seen through are not esthetically pleasing.

Beveling

In preparing the facial aspect of a class III or IV or the buccal aspect of a class V restoration, beveling is important for making the margin of the restoration disappear into the tooth structure. The preferred method is a feather-edged bevel blended into the enamel surface (Figure 9-20). Neither butt joints nor chamfers are desirable. Once composite material is placed past the bevel, it should be finished and polished into the enamel surface, following its contours past the long bevel. One should never polish to the beveled margin because this will create an area of visible demarcation between the restoration and the tooth surface. If the described procedure is followed, it will

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FIGURE 9-21 **Left canine veneer before finishing and polishing. Note that the shape and form have been properly presculpted, making finishing, polishing, and the final result much more predictable.**

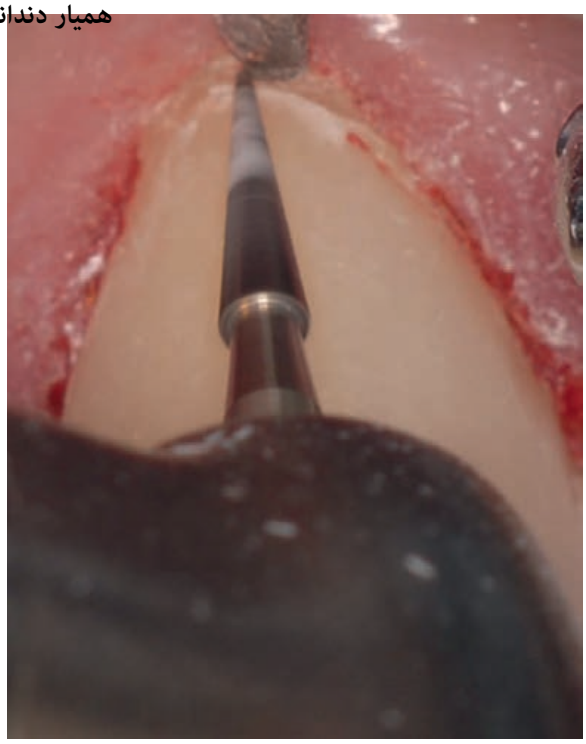


FIGURE 9-22 **The use of a Brasseler ET-9 bur for contouring.**

greatly enhance the predictability of invisible results, assuming the color is right.

CONTOURING, FINISHING, AND POLISHING ANTERIOR COMPOSITES

A common mistake made by most practitioners is trying to polish without properly contouring the restoration first. Proper contouring can be accomplished only if one sculpts the material to correct morphological shape before polymerization (Figure 9-21). Precontouring is accomplished through the use of reliable instruments such as fine diamonds, esthetic trimming carbides, or coarse disks (Figure 9-22). Once the proper contour has been achieved with these instruments, then the finishing and polishing process can be started.

Most manufacturers are attempting to develop a single instrument that will finish and polish all materials completely. It is extremely doubtful that this will ever happen. It takes a series of different systems to obtain the best finish and polish. Each practitioner must learn how and when to use various finishing and polishing materials. Composite materials cannot be marginated with the use of silicone or rubber-impregnated material alone. The only way to properly marginate composite material is with the use of a series of different aluminum oxide disks with various grits ranging from coarse to superfine (Figure 9-23). A rubber-impregnated system or aluminum oxide– or diamond-impregnated instruments will characterize composite restorations very nicely (Figure 9-24). Diamond-impregnated rubber instruments are also extremely helpful in polishing hybrids and nanofills, but they will not polish a microfill as well as the aluminum oxide cups and points.

Given all the finishing and polishing instruments that are available, it is a matter of finding the ones that work best for each material. The final step of polishing should include the use of an aluminum oxide polishing paste on microfill and the use of a fine diamond polishing paste followed by an aluminum oxide polishing paste on a microhybrid or a nanohybrid. Using these pastes under pressure, with a felt wheel, point, or felt disk will highly enhance the final polish (Figure 9-25).

MAINTENANCE

Proper home care instructions should always be given after composite bonding procedures have been completed. The patient should be instructed not to use tartar control toothpastes because of their extreme abrasiveness and to avoid using toothpicks, Stim-U-Dent plaque removers, Proxabrush tips, or any other device used for cleaning between the teeth, as this process will ultimately destroy the papilla and can create black triangles. Hand brushing is the best way to maintain these restorations, and it is best to floss gently beneath the free margin and up against the tooth. Wrapping the floss around the tooth or placing it deeply beneath the cervical marginal can lead to clefting or violation of the gingival attachment.

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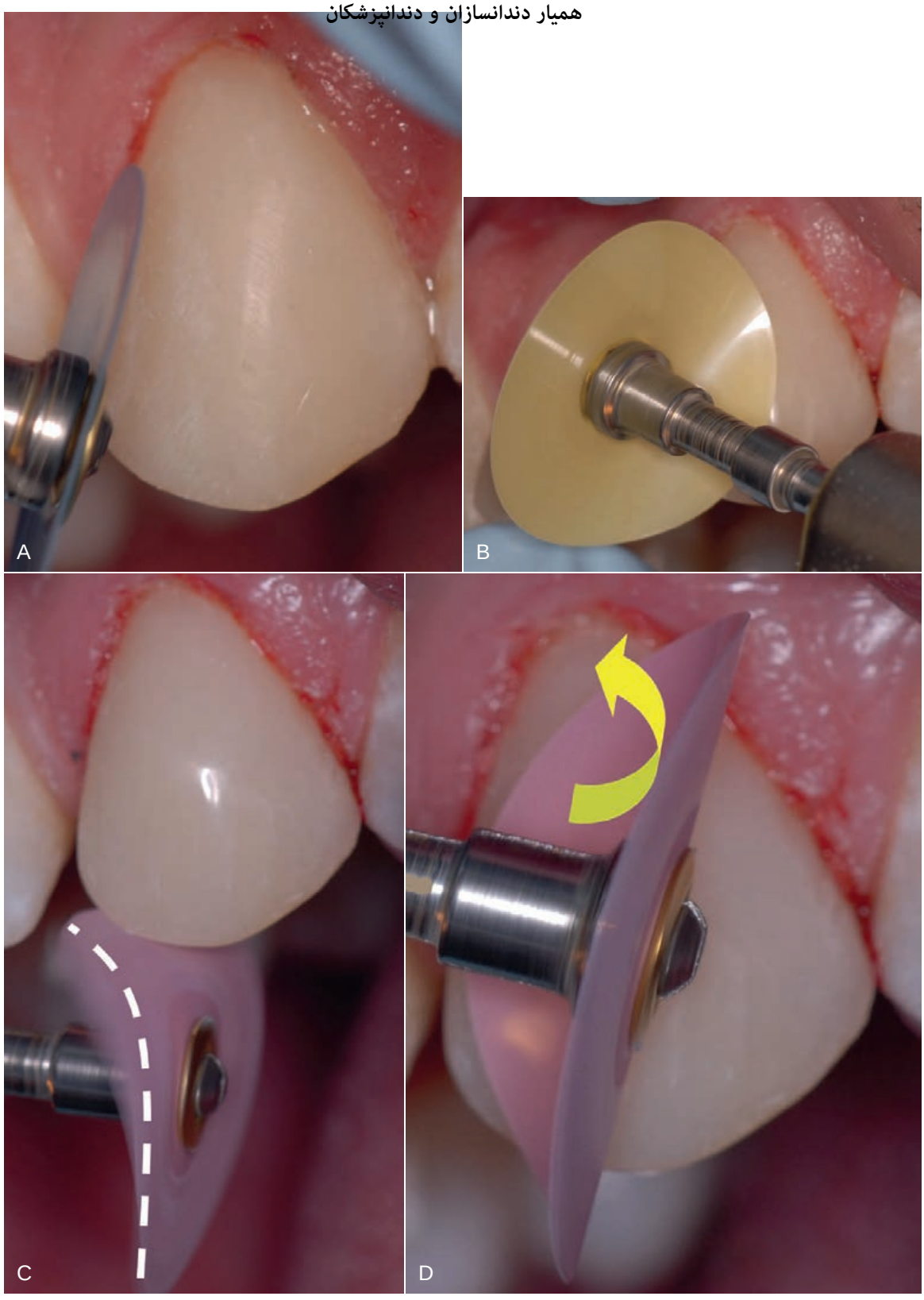


FIGURE 9-23 The use of Cosmedent's FlexiDiscs of different grit sizes (ranging from course to superfine) to achieve excellent contours, surface smoothness, and polish. Notice the flex of the discs in use.

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FIGURE 9-24 The use of impregnated rubber instruments (can be impregnated with diamond or aluminum oxide.)

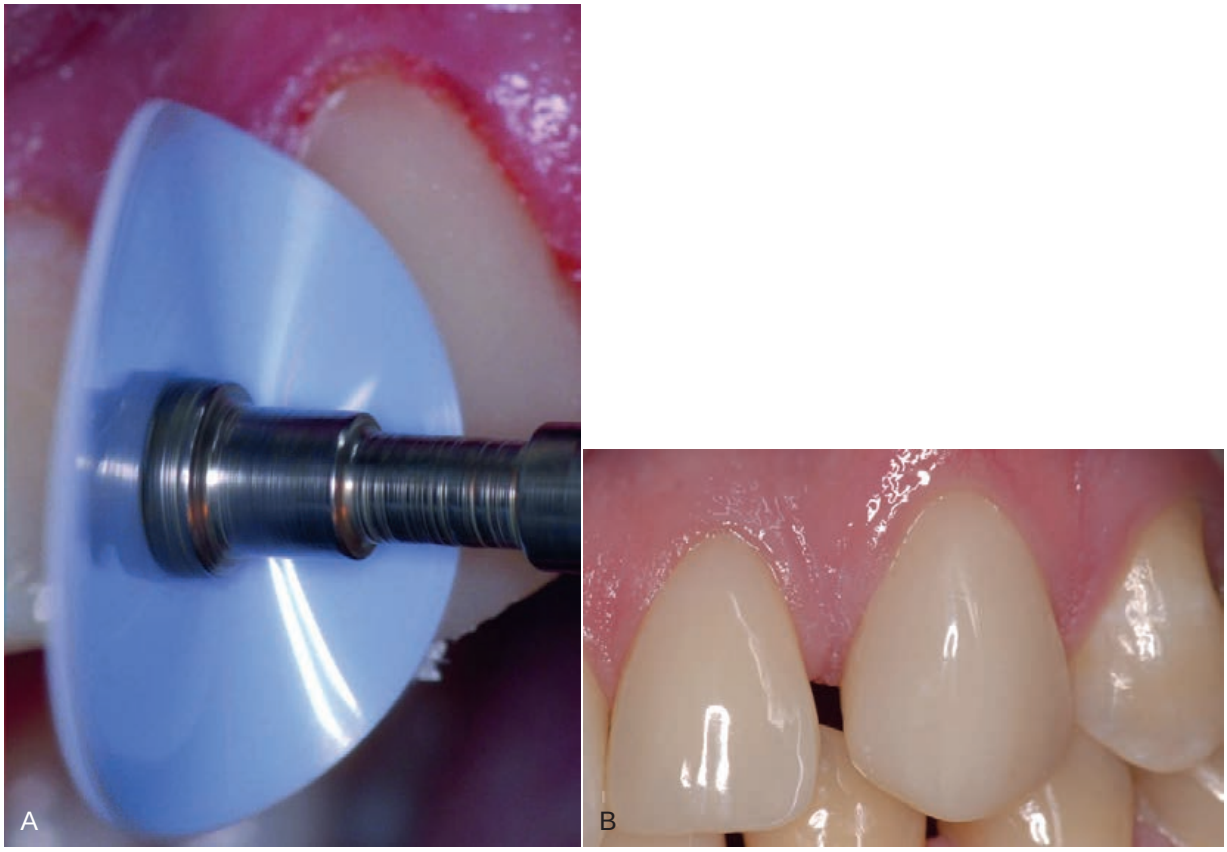


FIGURE 9-25 A, Final polishing using Cosmedent's FlexiBuff and Enamelize polishing paste. Note the flex of the disk. B, Final polish achieved. The left lateral features Renamel Microfill overlaid over Renamel Nanofill, and the canine features Renamel Nanofill alone.

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FIGURE 9-26 **A, Cosmedent's FlexiBuff with Enamelize used in the final polish to create the final glossy surface. B, Cosmedent's FlexiStrip with Enamelize used to polish interproximally. C and D, Fourteen years postoperatively, after final polish. Notice the healthy condition of the papillae after 14 years.**

In addition to maintaining proper brushing and flossing, the patient should also see the dentist at least three or four times a year. Hand scaling of the teeth and mild prophylaxis paste are sufficient. Aluminum oxide polishing paste used with a felt buffing instrument, such as FlexiBuff will give the highest gloss attainable. Interproximal stains can be easily removed with aluminum oxide paste used in conjunction with super-fine aluminum oxide strips (Figure 9-26).

NEAR-FUTURE DEVELOPMENTS

Composites offer dentists and patients a great restorative option for esthetic, minimally invasive procedures that can often be accomplished in just one office visit. Although manufacturers have made many attempts to create a composite that can "do it all," the only material that truly simulates enamel is a microfill. Nanofills are closer to a true universal material than microfills and can be used for posterior or anterior restorations. Microhybrids are stronger than either nanofills or microfills and are considerably more opaque; therefore they are excellent composites for the initial layer of major color change cases.

It is important to understand the different types of composite materials available and how each can benefit one's practice. In order to achieve consistent esthetic results, proper technique and the choice of materials is of paramount importance. Physical and handling properties, opacity, translucency, color stability, and the polishability greatly affect the esthetic outcome of the restoration. Each material is unique and has its own place in achieving a beautiful result. When technique and the proper choice of materials are combined, the result will leave you and your patient more than satisfied. For the above reasons, I have chosen these materials.

Composite materials have come a long way over the years, and they are here to stay. The benefits of composite are remarkable, and the future of composite dentistry is extremely exciting. Who knows where the composite revolution will lead? Only time will tell!

Disclaimer

Dr Mopper is a co-founder and co-owner of Cosmedent, Inc., where he has been responsible for product design for over 30 years. Many of the materials described in Chapter 9, Section A, were developed by Dr Mopper and a leading team of polymer chemists. He is also director of the Center for Esthetic Excellence, which is devoted to teaching the methods of direct resin bonding.

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Predictable Customized Class IV Restorations

Sunil Bhoolabhai

RELEVANCE OF CLASS IV RESTORATIONS TO ESTHETIC DENTISTRY

In today's world of extreme sports and high-impact pastimes, there are increasing numbers of younger people who have fractured or chipped teeth. The dental professional must be prepared to restore these teeth conservatively and in a minimally invasive manner and give the patient optimal function. What the class IV restorations offer is something that is both predictably strong and esthetically good-looking. Composite bondings for class IV restorations allow practitioners to achieve just this in one office visit—great fee-for-value dentistry.

Importance of Class IV Restorations to the Business of Dentistry

A fractured tooth, especially in the anterior segment of the mouth, is an eyesore that can create painful self-consciousness depending on the individual's personality. The patient could shy away from regular activities because of his or her appearance. For a dentist it is a great advertisement for the practice if these fractures can be fixed quickly with minimal trauma, and the patient can be sent home gratified. These circumstances allow the dentist to charge a suitable fee as well. If the dentist sees a new patient for a class IV fracture repair and does a good job, it is more likely that the patient will become a regular at the practice. The author treated a movie star once who had opened the cellophane of her new Cartier watch using her teeth and ripped the entire embrasure space between the central incisors. She had to be on camera the next morning. There was a miniscule chip on both teeth that the author fixed with enamel bonding. She could not believe it could be done so quickly and so beautifully. That sort of situation creates a good rapport with patients, who often will remember it and never leave the practice in the future. It is a great practice builder.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT OF CLASS IV RESTORATIONS

Class IV restorations have become predictably successful. With such restorations, one adds material directly onto the tooth, unlike with a veneer or crown. The rise of these restorations was a result of the evolution of composite materials with regard to strength and optical properties, allowing dentists to recreate beautiful, natural esthetics and durability. The silicate materials are inappropriate to use in a situation like this because they do not have predictable properties or appropriate optical properties, nor do they achieve the strength of the natural teeth along the incisal edge. In addition, after 1 or 2 years they would look like small chalky pieces of material on the corner of the tooth that had been fractured. They are soluble in oral fluids, and have poor surface characteristics (e.g., pitting), so they collect plaque and may discolor.

Adhesive and Restorative Developments

The direct bonded resin, bonding systems, and bonding materials have advanced to the point where they achieve predictable strong bonds between resin and tooth. In addition, the materials' chemistry has been altered over the years so that they can replicate the optical and physical properties of natural teeth. It is possible to have a translucent material on the incisal edge and opaque material on the body of the tooth so there is no shine-through where the material was added. These materials have great strength so the patient can bite into apples or other hard foods without causing damage, although this is not a recommended practice. The combined resin chemistry and bonding system chemistry, regardless of the thin edge, can match the physical compressive strength and the flexural modular strength of human teeth, making these materials quite appropriate for class IV cases. The upper third bonding generation achieved this level of performance through the use of a primer, adhesive, and

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unfilled resins along with a good durable and esthetic resin system.

Effect of Microfills and Nanofills

Nanofill resin and the nanometric-sized range of materials have given most dentists a "universal material" that can be maintained and removed as needed. The resins allow a more than adequate finish and luster, reasonably extended wear on the tooth, and shine and surface qualities that last for a long time. If the case demands a more exacting result, the dentist may want to overlay a microhybrid or a nanofill with a microfill, and the microfill will remain serviceable for a much longer time.

RELATING FUNCTION AND ESTHETICS

In relating function to esthetics with a class IV restoration, an important aspect is the overall impact of the incisal edges compared with the other teeth. Some people have excessive wear on their teeth. They have disocclusion on one of the incisal edges in protrusion. Others may have parafunctional habits. It is necessary to map out all these things and provide a restoration with predictable longevity and outcome. The contributing factors besides individual preference include biologic status, which relates to the longevity of the work.

With a closed bite or slight protrusion, there may be a huge slope on the lingual surface of a fractured central incisor. The dentist may want to add additional fortification in the form of a bevel on the lingual surface to achieve extra durability in the restoration. Even after completing the restoration the practitioner may want to ensure that the sliding contact is across three, four, or five teeth and not just on the restoration and that the restoration has been adjusted accordingly.

MATERIAL OPTIONS

Function, Strength, and Material Choice

Material choice should always be based on strength. One should complete a class IV restoration using a nanofill or a microhybrid that is sufficiently strong for the situation. At the most it may be necessary to overlay with microfill for better extended wear resistance and a lasting surface luster. It is wise to overdesign the restoration by using a nanofill or a microhybrid, which will function through a cross-section of different occlusion patterns and functional envelopes in varied clinical situations. To fortify the individual preparation, one can add design features such as a lingual bevel and then again adjust the occlusion as needed.

Material Shades

Material shades are more related to esthetics than to function. Looking at the color of the tooth, there is an inner core of dentinal materials that are more opaque than the translucent enamel material. A body shade is used within the core of the fractured portion and then an overlay is placed on the proximal, the incisal, and maybe the labial with a relatively more translucent material. This yields a better shade and more natural color without shine-through. The dentinal core prevents shine-through as the light reflects from the back of the mouth and highlights the built-up restoration. The translucent enamel shade gives an excellent luster and a rich-looking restoration.

CLINICAL CONSIDERATIONS

Indication

The indication for a class IV restoration is anyone with a fracture caused by a sports injury, incidental trauma, or accident. All of these could certainly be restored using a bonded class IV restoration. The class IV restoration is considered a minimally invasive approach to restorative dentistry and is done by lightly adding material onto existing tooth.

Contraindications

Among the contraindications are parafunctional habits. If the patient has habits such as biting on bones or using the teeth to open bags, he or she must be warned that the restoration may not be successful. Patients who want bonded or cosmetic procedures done for anterior teeth should (1) avoid tearing into hard foods such as whole apples directly with the anterior teeth and (2) refrain from parafunctional habits.

OTHER CONSIDERATIONS

Occlusion

When doing a class IV restoration the dentist should check the bite and centric relationship to make sure that there is adequate clearance and no protrusion that could cause additional trauma to the restoration. It is also necessary to ensure that the material chosen has adequate strength and flexural modulus and that the patient's occlusion will not cause fractures in that area thereafter. In addition, the dentist must examine the occlusion afterward to verify that there are no immaturities or interferences created by the restoration.

The dentist adjusts the occlusion after completing the restoration to ensure that the lingual surfaces and incisal edges are free of interferences. *The occlusion in sliding, lateral, or protrusive movements should not load the restoration.* That will allow the restoration to last much longer and make the outcome much better.

If the patient is wearing a night guard and the dentist has created a class IV restoration on a tooth that was chipped after the night guard was made, it is necessary to check the fit of the night guard for interferences. If it cannot be ensured that there is no additional interference, a new night guard should be fabricated to match the new occlusion.

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INNOVATIVE ELEMENTS

The evolution of bonding materials has produced exceptional materials. Materials now offer fantastic bond strength, so it is possible to achieve securely bonded resins on properly prepared teeth. After the tooth is prepared, the bonding resin is added. Resin chemistry has evolved, and a large part of that evolution has involved the filler chemistry of resins; microhybrid and nanofilled resins are very strong and come in a diversity of opacities and translucencies that allow matching of the optical properties of the tooth along with a predictable prognosis. These resins permit the dentist to add onto the opaque body of the tooth to keep the restoration from being visible, as in a shine-through. In the proximal and incisal areas, translucency is possible, giving an extremely lifelike restoration. For those not very comfortable doing a class IV restoration freehand, it can be waxed up and a silicon stent made using polyvinyl siloxane putty on the lingual surfaces of the tooth; it is then locked in place with a resin or impression compound. Application of the resin is done slowly from proximal to lingual and up to the labial. Of course one must examine the occlusion first before doing the restoration with the stent at the stage of the wax-up.

ARTISTIC ELEMENTS

The first thing the author does in a fractured tooth scenario is make a shade reference. This is done right at the beginning of the procedure because the tooth will lighten with dehydration during isolation, offering an inaccurate shade for matching. Also, the shades of most resins will shift during polymerization. Microfills will lighten and microhybrids will darken. Therefore it is wise to make a shade reference, take a digital photograph of it, and examine the characterization present on the approximal teeth. The dentist then duplicates that appearance and stays with the shades selected and not the shade of the resins seen during layering before curing.

Once the practitioner starts preparing the tooth and isolates it for 5 to 7 minutes, it will be dehydrated, making the shade lighter than it should be. When the shade reference is made at the outset, marks are made indicating the body shade, incisal shade, and so on. As the tooth is being built up with resin, it is necessary to keep in mind that the core of the tooth, or the body, is generally of dentinal opacity—and an overlay with translucent material. Right before adding the final increment on the labial surface of the tooth, it is necessary to add characterization—a feature resembling a streak of hypocalcification, a tiny patch of stain, or something similar. To do this, one generally takes references from the approximal or adjacent teeth; a single tooth so prepared would "stick out like a sore thumb." The shape of the incisal edge must also be synchronized with the appearance of the surrounding teeth. Most people like to make straight incisal edges. This can look very ugly and out of place.

These are some of the factors one must consider and orchestrate when creating a class IV restoration. The fragment could have two or three different shades; the position of the line angle should not be too far out or in but "in sync" with the remainder of the tooth; the shape of the incisal edge must be considered; any stains or characterization must be included; and so on. This is a small piece of tooth but involves a lot of hard work for the clinician to make it blend with the remainder of the intact natural tooth.

TREATMENT PLANNING

When restoring a vital fractured anterior tooth, in most situations it is wise to build up the fragment using a bonded restoration.

If a large portion of the tooth—for instance, two thirds—is missing, then the dentist may consider creating a ceramic crown, fortifying it, and establishing a good ferrule around the margins. To build this compromises the durability of the restoration, as there is just a little bit of tooth structure and a very large restoration.

Between these modalities—that is, a bonded restoration and a crown—is the veneer. The decision to do a crown or a veneer is based on clinical judgment. A veneer could be considered in certain situations if the occlusion is not traumatic, because it is much more conservative than a crown.

Sequence

When a patient comes in with a fractured anterior tooth, the first step is the shade selection. The dentist matches what he or she sees and selects the appropriate shade. It is also important to note the shape of the incisal edge and the characterization to know what should be used to duplicate the original. Having done that, the dentist checks the occlusion. The next step is to make sure there is adequate space to insert and complete the restoration. Once that has been done, the tooth preparation begins, creating the bevel such that most of the structure, durability, and enhanced bonding are set up. Next the tooth is etched. The bonding resin is applied, beginning with the opaque end and moving to the center and the body of the tooth. Bleaching may also be required. Having done all this, the dentist starts the final increment to achieve the desired thickness of the restoration. At about 0.2 to 0.3 mm down from the final intended labial position it is possible to see what needs to be done to finish. That is when the stains are applied, using tints and opaquers on the tooth to make it more lifelike. The dentist then applies the final layer of restorative material—a microhybrid, nanofilled, or microfilled material. Finishing and polishing are then done. As far as the insertion is concerned, these are the steps generally taken.

To document the case for patient records, it is best to obtain the smile shot—intercuspal shot—at the beginning before isolating the area so that it is possible to see what the tooth looked like before dehydration. A close-up shot is also taken right after finishing the procedure and polishing it. Finally, the dentist should take a close-up shot 24 hours or so after finishing the

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restoration, when it is rehydrated and has achieved its final finish, color, and appearance.

TREATMENT CONSIDERATIONS

Preparation

In most class IV restorations, the preparation involves a wide labial bevel. A bevel allows the restoration to feather with the tooth so that it primarily blends with the remaining tooth structure. To be very exacting, one could create a wave bevel that undulates vertically; this enhances the natural appearance during the blending of the shade as the material gets thinner and blends with the natural tooth and recreates the ups and downs along the fractured fragment, thus camouflaging even better. If clearance on the lingual is inadequate because of the occlusion, then the creation of a short lingual bevel will add more structural durability.

Procedure

Adequate isolation is an imperative step in composite bonding. It would be ideal to use the rubber dam, but the author does not advocate this. Any surviving humidity is detrimental to resin bonding, so isolation is paramount. The resin is then added in small increments—it is stratified onto the tooth. It is a misconception among dentists that polychromatization as seen in natural teeth is created by choosing a multiplicity of stains to replicate the effect. Characterization is created by stain. There is a big difference between the two. For example, a tiny degree of translucency may be created by staining, but not the overall effect. Looking at the labio-lingual thickness of what is being created, stains and characterization must be added just 0.2 to 0.3 mm before the final thickness of the restoration. This will ensure that they are visible and not submerged and obscured by an excessive thickness of material.

Finishing

Finishing must be done meticulously because in a class IV restoration one proximal side is going into the embrasure, going right into the contact and beyond. With such a restoration, plaque may accumulate on margins if floss snags therein. Interproximal finishing strips and a No. 12 Bard-Parker blade and handle can be used to finish and smooth the margins. The line angles and facial embrasures can be shaped and polished to look like those of the approximal tooth using finishing points and disks. Facets and prominences can be imparted to make the restoration look more natural, along with perikymata and undulations to make the anatomy appear more natural.

EVIDENCE-BASED PRINCIPLES

Plenty of data support the insertion, stratification, handling of occlusion, functions, and finishing and polishing of such restorations. In the last few years dentistry has reached an age of strength in esthetics.

CLINICAL CONSERVATION CONCEPTS

A class IV restoration using a bonded resin is one of the most minimally invasive dental procedures being done. The material is bonded onto the tooth after creation of something as mundane as a bevel. The bite and occlusion are checked, the restoration is finished and polished, and the patient is done.

From the patient's perspective, he or she comes in with a fractured tooth, largely not expecting that the tooth will be repaired immediately and perhaps even thinking that the fracture is a big problem that could affect the rest of his or her life. Then the magician called a dentist fixes it in 45 minutes to 1 hour.

MAINTENANCE

Maintenance of the class IV restoration is basically the same as for natural teeth in terms of brushing and flossing. A gentle reminder is always made to the patient not to use that restoration in a parafunctional manner, which could cause damage. It is possible to break a natural tooth, as he or she has already seen, so the patient should be aware that caution is needed with the reconstructed tooth.

CONTROVERSIES

Certain dentists may insist that these restorations are conditional. Resins will change color, probably becoming a bit darker over the next 5 to 7 years. However, the procedure is so minimally invasive and conservative, can be done so quickly, and is so customized and gratifying for both clinician and the patient, that it is worthwhile. If need be, 5 or 7 years later it can be changed quite easily.

NEAR-FUTURE DEVELOPMENTS

Near-future developments will probably include resins that are self-etching. The dentist simply applies these to the tooth, and they stay there. Resins that attempt to naturally match the existing tooth color on their own without any input from the dentist might also be developed.

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Clinical Case for Class IV Restorations

A 35-year-old bank clerk came to the dental office to do some banking work, and the dentist noticed that the clerk had a broken incisor (Figure 9-27). On questioning, the clerk admitted it had been broken for years because he was afraid to have a cap or crown put on it. The dentist offered to fix it by simply adding material to it and promised there would be no down time. The patient's previous dentist had not offered this option. In the final results of the case, the left and right central incisors look similar in terms of texture, shine, demineralization, incisal edge shape, and natural appearance and not artificial compared with the other adjacent teeth. The restored tooth looked as though it had been there for years.



FIGURE 9-27 **A,** Full smile. Note the right central incisor tooth. The dentist looks at the whole picture to obtain perspective. The picture shows a fractured segment on the left central incisor and a bit of wear on the left lateral incisor on the incisal edge. The incisal edge on the right central incisor has a bit of up and down and a whitish streak of demineralization. The surface texture on the teeth is reduced in general, suggesting that the patient may have been using a hard toothbrush or an abrasive brushing technique. Here is where the dentist begins to make a shade check and evaluates the occlusion. **B,** Note the three different shades that work together in the appearance of this tooth. There is a body shade, transcribed within the red line, which actually consists of two shades, and an incisal shade, which is under the white line and between the red and white lines against the incisal edge. **C,** There are two shades for the body. The material being used is Vitalescence (Ultradent Products, South Jordan, Utah), which has a multiplicity of shades including characterization shades. The characterization shades are called Trans-Gray and Pearl Frost. The gray area between the body and the incisal edge has the Trans-Gray, and the whitish incisal edge is the Pearl Frost. **D,** The dentist has made a long flat bevel and created a wave double or one up and down and tried to create undulations to achieve better shade matching overall. The long flat wave bevel gives better esthetics and better blending of the material as it feathers onto the tooth and as one moves from proximal to proximal and mesial to distal.

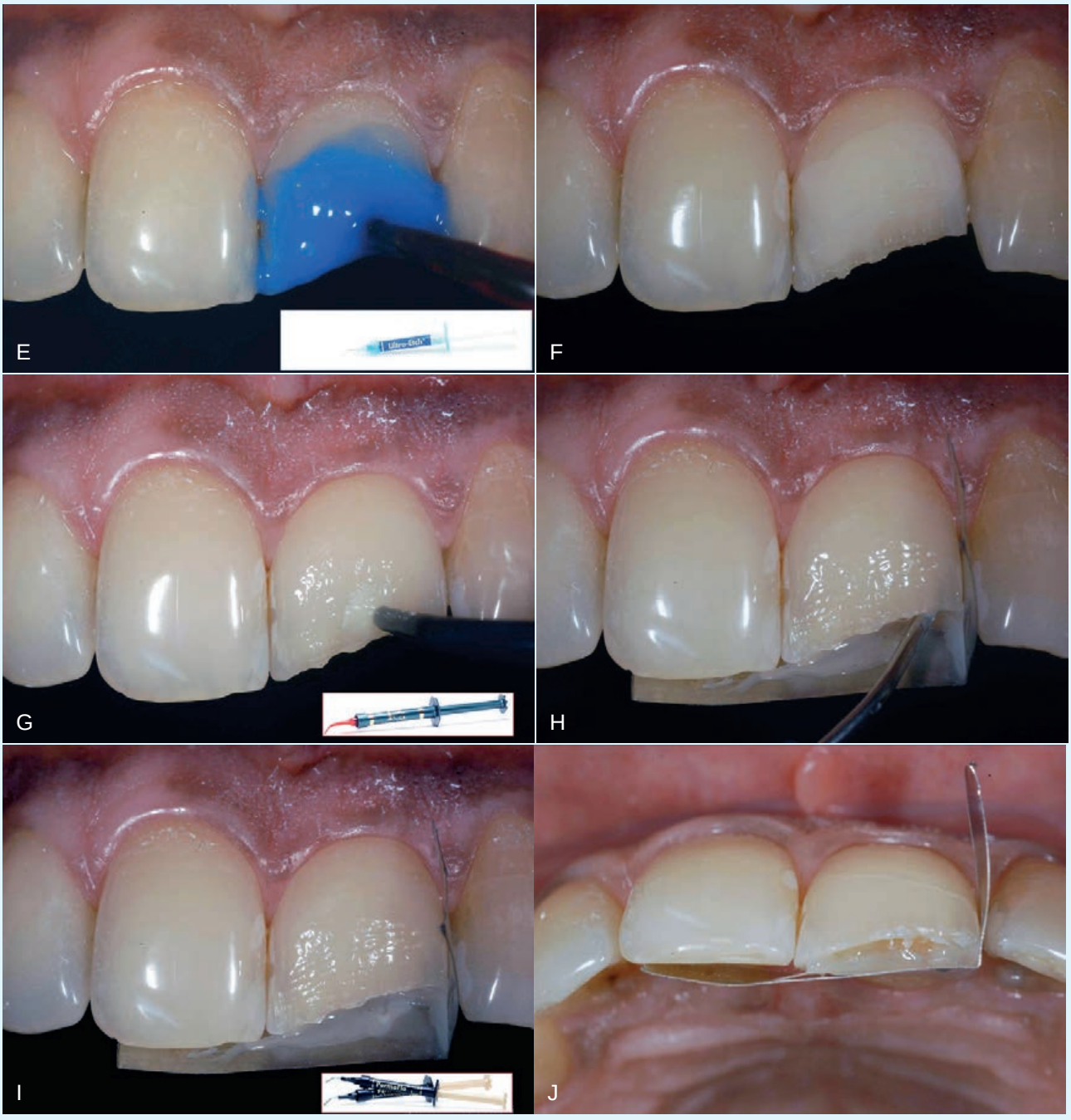


FIGURE 9-27, cont'd **E,** The etching gel used is Ultra-Etch (Ultradent Products), which is very visible and does not slump. It is applied to the tooth for 20 seconds and then washed off with a generous blast of air and water. **F,** The chalky opaque area suggests that the tooth has been etched adequately. **G,** The ethanol-based bonding agent called PQ1 (Ultradent Products) requires agitation with an Inspiral Brush tip (Ultradent Products) before being applied to the etched tooth surface. A glossy sheen is created as the material is applied with the brush tip. After blowing it thin with an air blast, it is cured. The tooth is ready to be restored with resin. **H,** The dentist has taken a matrix band and inserted it gently into the distal contact area, bent it at 90 degrees, and respected the sanctity of the gingiva without creating trauma. The dentist then adds a small amount of flowable material (Permaflo [Ultradent Products]) on the fractured portion of the tooth and creates a "bandage" that will adapt intimately with the tooth and minimize the possibility of hypersensitivity. **I,** The band is extremely stable, and the flowable material has been cured. **J,** Occlusally there is little flowable material used, so it has no clinical significance for the restoration's strength. This very thin increment seals incidental niches and voids and provides a beautifully sealed area through capillary action and the viscosity of the material.

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Clinical Case for Class IV Restorations (cont'd)

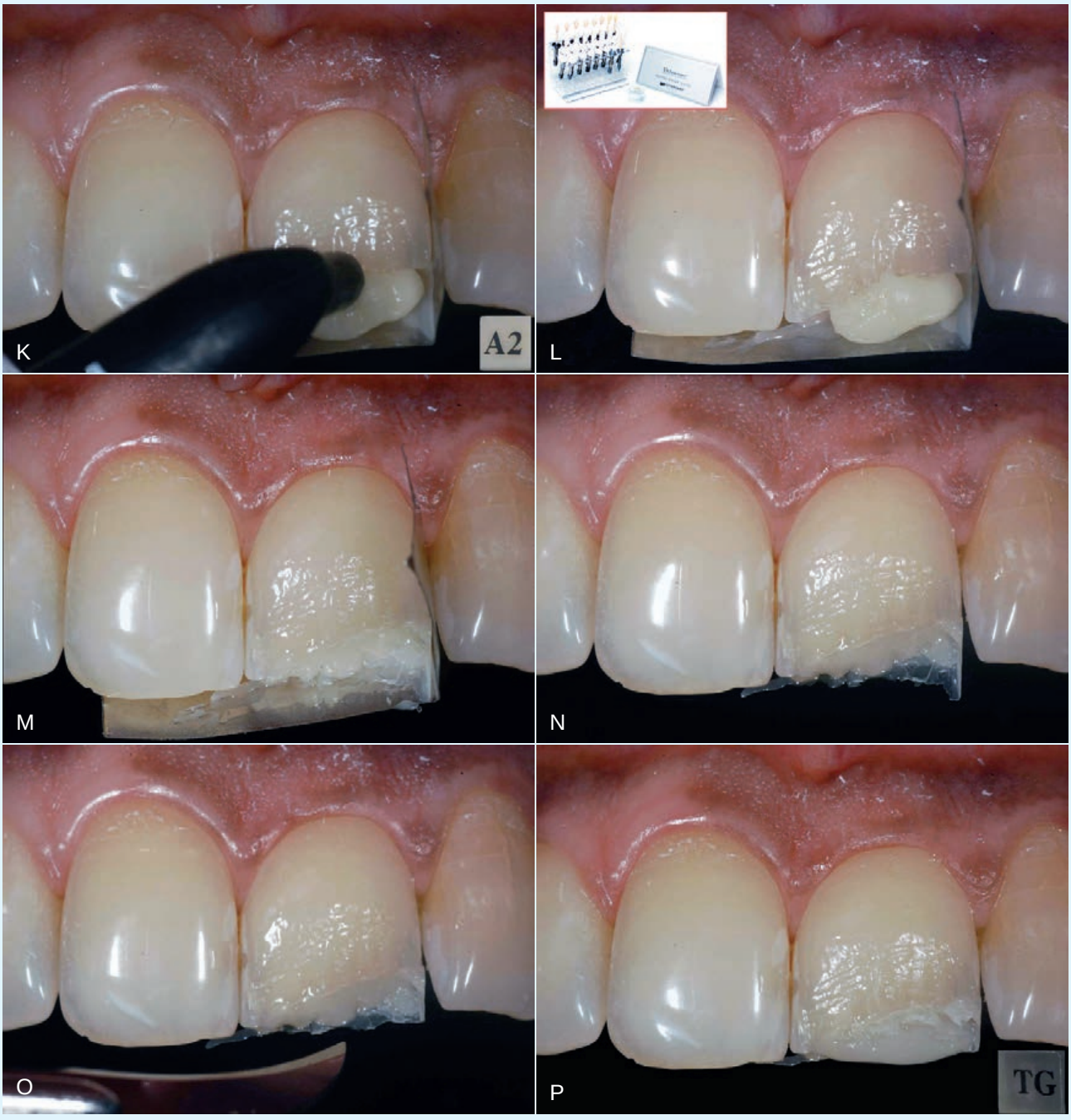


FIGURE 9-27, cont'd **K,** After the flowable material has been cured, the opaque A2 body shade Vitalescence is used. The dentist uses a Cavifil tip at an angle to the tooth to control the increment better and to allow the application of controlled, tiny increments at a time. **L,** The increment is being added before modeling. The instrument is placed against the fractured incisal edge of the left central incisor tooth. The dentist then takes a spatula or a Goldstein instrument (formerly sold by Almore in the United States) and with it makes a few grooves or mamelons to create a realistic-looking restoration from within. The shape of the body material is dictated by what is adjacent to it before the tooth dehydrates. If there are projections, then the dentist attempts to recreate projections. **M,** Body material after curing. **N,** The resin shade before and after polymerization. The dentist has taken great care to ensure that in the interproximal area on the distal of the tooth it extends past the contact points. This creates a shell-like veneer. **O,** Using a No. 12 blade the dentist trims the incisal edge a bit and can freehand the rest of the tooth with resin. The dentist has very strong scaffolding and an outline form to work on. The No. 12 blade comes across the incisal edge because the dentist is working dry. A very sharp No. 12 blade will cut resin and will not chip it. **P,** Note Vitalescence, Trans-Gray (Ultradent Products) material in the bottom right. The dentist has added the Trans-Gray and slowly builds the incisal edge shape of the right central incisor without labio-lingually violating the dimension and extrudes too far labially. The dentist is always considering at the occlusal relationship while doing this.

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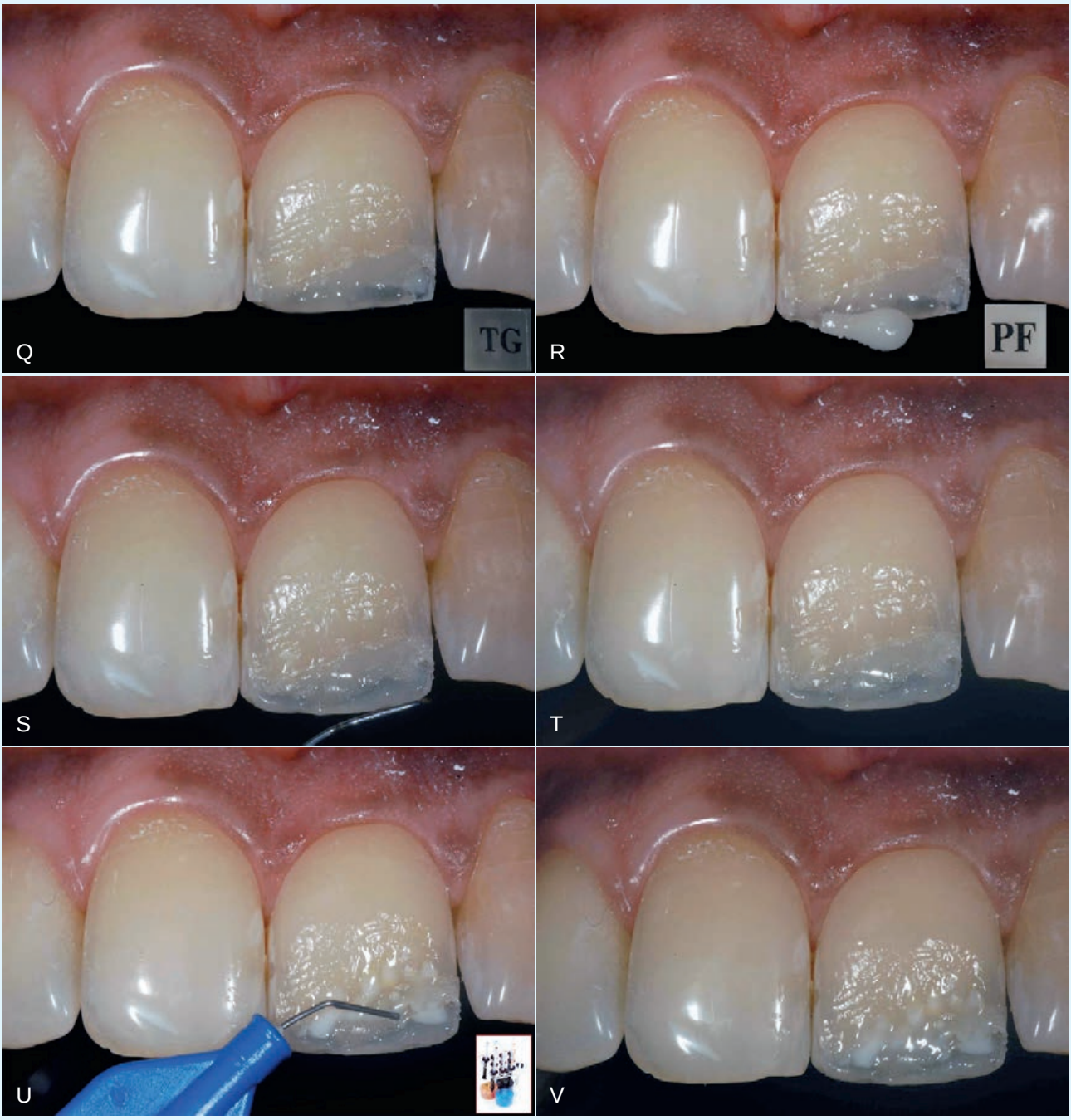


FIGURE 9-27, cont'd **Q,** Trans-Gray material becomes translucent after curing; it is impossible to judge the shade before the resin has cured. Once the Trans-Gray material has cured, the dentist layers on the second color, Pearl Frost (Vitalescence). The Pearl Frost material is added onto the incisal edge. It is then modeled with the end of a Goldstein instrument. The restoration has an incisal edge that mimics that of the right central incisor in its outline form. The restoration is made up of three shades—a body opaque A2, Trans-Gray, and Pearl Frost. The dentist has extended the restoration beyond the interproximal contact point on the distal, creating an outline shell-form. **R,** Applying the increment of Pearl Frost onto the incisal edge. **S,** Modeling the incisal edge shape with the rear spoon-shaped end of a Greenstein instrument. **T,** After the incisal edge has been modeled, the similarity between the two central incisor teeth becomes apparent. Note how the left central incisor looks at this stage of stratification. The labio-lingual dimension is still less than the final intended restoration. **U,** Many practitioners use the stains from Ultradent with ease. The stains come in penlike syringes with very fine 30-gauge tips. It can be used for painting by dentists who are not used to a brush technique. The dentist has taken a bit of whitish stain and, like diffused clouds and cloudy patches, has spread it on both sides of the fracture line so that it is not possible to discern where the fracture line is in the final restoration. **V,** Note the cloudy stain on the teeth.

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Clinical Case for Class IV Restorations (cont'd)



FIGURE 9-27, cont'd **W,** The dentist has taken the flat end of the Goldstein instrument and added another increment of body material A2 over this. The restoration does not come to the final labio-lingual thickness. **X,** The dentist is still about 0.2 mm inside the final labio-lingual edge and has taken a flat-end G2 brush (Ivoclar Vivadent, Amherst, New York) to gently pack the material into place. This approach, rather than squishing resin in place, gives the correct anatomy. Patting it down minimizes the incorporation of air and gives a much more solid restoration. The goal is to re-create the esthetics of the right central incisor. **Y,** White stain added. The tone is subdued compared with the right central incisor because the right central incisor has dehydrated at this stage. The newly added composite is not dehydrated. The stain in the right central will be attenuated. The stain must be a bit more subdued than the natural tooth so that when the tooth rehydrates the stains will look similar. **Z,** A thin layer of body material Vitalescence A2 is applied and flattened or smoothed down. The restoration is now ready to be finished. **AA,** The occlusion is correct, the embrasures look good, and there is a good contour overall along the teeth. **BB,** A No. 12 blade is used to remove excess flash from the gingival embrasure. The blade is well tucked in so that no trauma to the gingiva occurs. This can be done in the gingival embrasure.

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FIGURE 9-27, cont'd **CC,** Very gently with an interproximal finishing strip (Cosmedent, Chicago, Illinois) excessive flash is removed to ensure a smooth interproximal surface. One must be careful when using a finishing strip because if it is used very aggressively, the result can be an open or shy contact. **DD,** If it is necessary to have a flattened labial surface, a disk can be used on the central portion (Super-Snap disk Shofu Dental Corporation, San Marcos, California). This is a coarse black disk. A nice flat surface is desirable here, based on the anatomy of the contralateral tooth. **EE,** This disk is a smaller-diameter, ⅜-inch disk used to go into the embrasure spaces. The embrasure spaces are contoured and smoothed, and thereby accumulate less plaque. **FF,** A silicon carbide polishing point made by Ultradent is used to finish and polish the tooth. **GG,** In the gingival area the dentist has already used the green point and now uses the yellow; the finest one is the white. This will give an increasingly smoother surface. **HH,** Placing Taub Insta-Glaze (George Taub Products & Fusion Company, Jersey City, New Jersey) diamond polish on the tooth.

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Clinical Case for Class IV Restorations (cont'd)



FIGURE 9-27, cont'd **II,** A silicon carbide brush (Jiffy Brush, Ultradent Products), at low revolutions per minute (rpm)—(4000 to 5000 rpm) is used at high pressure and low speed to polish the tooth to a nice glaze. **JJ,** There is spatter on the lateral and the adjacent central incisor tooth. The case is now ready for final buffing. **KK,** A goat hair brush (Ultradent Products) is used at 15,000 rpm. The speed must not be too high because it is possible to burn the resin. **LL,** The tooth is buffed using the goat hair brush to achieve a high shine. The photo shows the adjacent tooth, the shine, the line angles, the reflective areas, and the hypocalcification or demineralization created. The adjacent tooth will rehydrate by the next morning. There will then be more parity between the teeth. **MM,** An incisal view of the completed restoration. **NN,** Pre-operative intercuspal view showing the fractured tooth—the left central incisor—and right central incisor side by side.

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FIGURE 9-27, cont'd **OO,** The completed restorations showing the two teeth looking fairly similar in terms of texture, shine, demineralization, incisal edge shape, and natural appearance. Note notching in the middle and other nuances. **PP,** One-to-one view before restoration. **QQ,** The fracture has been restored adequately with no shine-through. There is a little gray around the incisal edge. Also apparent are the demineralization, the high-gloss area, an embrasure space curling in as it is supposed to, and an incisal edge that looks as though it belongs in the patient's mouth. **RR,** Full smile shot before treatment. **SS,** The actual finished restoration. ***(E, G, I, L, U, FF** [insets] courtesy Ultradent Products, South Jordan, Utah.)*

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10 CHAPTER

Posterior Direct Composites

A SECTION

Posterior Composites

David Clark

RELEVANCE OF POSTERIOR COMPOSITES TO ESTHETIC DENTISTRY

When esthetic dentistry began its evolution, the posterior teeth were considered unimportant. As patient expectations have increased, more focus has been placed on the esthetic contribution of posterior teeth (Figure 10-1). With the mechanics of mandibular function, as humans speak, laugh, and exhibit the behaviors considered human, the incisal edges of the lower anterior teeth and the occlusal surfaces of the posterior teeth are critical (Figure 10-2).

Many patients inhibit behaviors and develop a lack of confidence from a lack of pride in the anterior teeth. The same problems occur with the patient's quality of life with regard to the posterior dentition. Many practitioners have seen these behaviors in patients with unacceptable anterior teeth. It is a valid exercise to examine the psychology of what happens when posterior tooth esthetics are not ideal. These problems have an impact on both quality of life and self-esteem (Box 10-1). Interestingly, habits such as pursing of lips and raising the hand to cover the mouth are the same regardless of whether patients dislike the appearance of their anterior or their posterior teeth.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF THE POSTERIOR COMPOSITE PROCEDURE

For anterior composites, North American dental schools rapidly integrated both materials and updates. Cavity preparations were adapted to the material very early on. In terms of longevity, anterior composites have been deemed acceptable by both practicing dentists and dental schools. It is important to talk about perception of success with teaching institutions and outcome studies because often they are unrelated. Two factors were key in the success of anterior composites and their early integration. First was the clear Mylar matrix—the simple, single-space filling technique. Second was an early recognition by dentists and dental schools that the cavity preparation benefits from significant changes in the preparations done for silicate restoration or gold foil restorations, which the composites replaced. Thirty years later, after constant evolution, the modern anterior cavity preparation that has little or no mechanical undercuts and long infinity edge margins bears little resemblance to the silicate and gold foil preparations that anterior composite has replaced.

Unlike with anterior composites, the integration of posterior composites has had a tumultuous journey because of the lack of a regimented cavity shape and filling technique. Posterior composites have a somewhat dysfunctional relationship with dental schools. Many dental schools have discouraged the placement of posterior composites, knowing full well that on graduation most dentists would place posterior composites on a wholesale basis. In the schools' defense, the outcome studies referenced, combined with the instructors' personal observations of the parade of failing, leaking composite fillings, validated schools' resistance to embracing the use of posterior composite on a wide-scale basis. It should be noted, though, that the posterior composite can be the most minimally invasive, biomimetic, and esthetically pleasing of all posterior restorations.

THE FIVE Cs

Cracks and Fractures

Cracks and fractures are now the third leading cause of tooth loss in industrialized nations. The original hope was that because composite restorations are adhesive, the composite would be

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FIGURE 10-1 **A and B, Amalgams placed 20 years previously in the patient. The teeth were asymptomatic but were treated because of incomplete fractures and recurrent decay. C and D, Postoperative results at 3 days, occlusal (C) and lingual (D) views. Patient experienced no sensitivity afterward. E, High-magnification palatal view of the upper first molar.**

able to repair or splint the tooth together after the cavity preparation has weakened the tooth. Unfortunately, this is not the case, as recent outcome studies have shown the same number of cuspal fractures in amalgam-restored and composite-restored posterior teeth. Some immediate strengthening of the tooth can occur after placement of a composite, but two important factors must be borne in mind. First, crack initiation and propagation in the human dentition take years or even decades to accomplish. Today dentists are seeing cracks and fractures in teeth with posterior composites because enough time has elapsed. Much of the immediate strengthening of the tooth lessens dramatically over time. Many teeth that had posterior composites placed 15, 20, or 30 years ago are now fracturing. Second, it is not possible to predictably rely on composite to keep the tooth splinted long term. That challenges the dental profession to rethink the entire posterior composite approach. Unless the cavity design is changed dramatically, clinicians should consider posterior composites to act as "white amalgam" in terms of tooth fracturing.

Dental practitioners also worry about cracks and fractures in the material itself. A full explanation of composite's characteristics is beyond the scope of this text. The most important

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FIGURE 10-2 The occlusal surface of the lower posteriors can have a dramatic impact on the esthetics of dynamic human faces.

characteristics in preventive dentistry for cracks and fractures can be divided into two different camps: characteristics during placement and polymerization, and characteristics of the composite once it is in the tooth and functional. Radiopacity, flexural strength, modulus of elasticity, fracture toughness, and total fracture work all contribute, but the most important factor from a clinician standpoint is fracture toughness. Catastrophic problems occur with posterior composites lacking fracture toughness. The fracture toughness of composite materials in general is inferior to that of gold—one of the liabilities of composite. These concerns must be overcome.

Crack initiation must be carefully evaluated and managed during cavity preparation and placement of composite and finishing. This addresses both crack initiation in the tooth and crack initiation or propagation in the composite material.

The C-Factor

The **C-factor** is a concept that is bandied about by many in the dental community. Although the concept has never been proven scientifically, it is the best guide to the management of polymerization shrinkage in various cavity preparations. *C-factor* stands for *configuration factor* and expresses the ratio of internal walls versus external surfaces. A second way to describe C-factor is internal surface area versus external surface area. C-factor is a fundamental flaw in traditional cavity preparations because the parallel walls for resistance and retention work *against* the dentist during polymerization shrinkage (Figure 10-3).

As the curing light hits the composite, it will shrink toward the center (Figure 10-4). The shrinkage can be measured as either volume or linearly. On a linear basis, most direct composites shrink 2% to 5%. All composites shrink on polymerization at this point, but the way the composite shrinks is critical and is based on the C-factor. The shape of the cavity preparation, the number of opposing walls, how they oppose one another, and the angle at which they oppose one another are extremely critical to the behavior of composite shrinkage.

BOX 10.1 Posterior Dentition's Impact on Self-Image and Quality of Life

A senior partner at a large, powerful accounting firm commented that she would arrange the seating for business meetings so that her colleagues were seated directly in front of her rather than to the side. Why? So that they would not see her maxillary bicuspid, which had a small interproximal display of gold. The culprit was a gold onlay placed by her previous dentist 20 years earlier. Over time a dinginess often occurs with interproximal metal restorations (see Figure 10-1, *A* and *B*).

This conversation was initiated when the patient was shown buccal corridor photographs. A traditional anterior photograph or "lips" picture does not really show the side view. Photographs where people are looking either obliquely or laterally allow the dentist and patient to discuss problems seen only from these perspectives.

This patient referred herself to the practice because she distrusted self proclaimed "cosmetic dentists"who aggressively promote their procedures. Yet a routine use of intraoral photography allowed her to enter into a course of self-discovery and served as the basis for an honest exchange of ideas and concerns. Such a course can lead to esthetic dentistry procedures without the ethical dilemma of "pushing" esthetics on the patient.

Happily, this patient chose a comprehensive esthetic reconstruction (see Figure 10-1, *C* to *E*). She now smiles and laughs and conducts meetings without rearranging the chairs in the room.

The C-factor is a ratio of the internal walls divided by the external walls, or it can be expressed in terms of surface area of the external surface. For C-factor a high number is unfavorable. Realistically a number of 2 or above is a problem when it comes to performance of the composite. Stress that is put onto the tooth and or composite can compromise the bond, cause microfracturing of the enamel, and lead to lack of adhesion in certain areas of the composite. The higher the C-factor, the worse for the situation. To simplify things, basically everything that dental school taught students about making a good preparation for amalgam with retention and resistance form are problematic for composite because of the C-factor (Figure 10-5).

Contamination

Contamination during posterior composite use occurs realistically in three ways:

1. Residual bacteria. Caries present on the tooth must be completely removed, although deep in the tooth some residual caries can be acceptable. The modern method of pulp capping is to avoid pulpal exposure if at all possible. Follow-up of teeth with indirect pulp caps has demonstrated that when small amounts of carious dentin are left

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FIGURE 10-3 As the light hits the composite, it will shrink toward the center. Most direct composites shrink 2% to 5%, determined linearly. The linear number is usually a higher number. The way the composite shrinks is very critical and is based on the shape of the cavity preparation, the number of opposing walls, how they oppose each other, and the angle at which they oppose each other. These variables are critical to the behavior of the shrinkage of composites.

over the pulp, after a few months this infected dentin heals and becomes hardened and sterile. However, this should not be misconstrued to assume that sloppy caries removal is acceptable. Within 1.0 to 1.5 mm of the margin, residual contamination in the tooth or as caries often results in recurrent decay.

2. Contamination of the infinity edge margin, or slight extension of the composite past the finish line. The long bevel or infinity edge margin combined with acid etching and bonding the composite a little *past* the margin is done with great success in anterior sites but has never been fully recognized with posterior placements. For the infinity edge or "Margeas margin," the composite tends to go slightly past the finish line. Although this can be a strength in anterior restorations and achieves great esthetics, it is more difficult to clean posterior teeth. Compounding the problem is the problem that dentists unfortunately abandon protocols used on anterior teeth when preparing and filling posterior teeth, such as aggressively de-plaquing the teeth with rubber cup and coarse pumice. When the margin is not on enamel but on biofilm, no technique can provide an adequate seal.
3. Contamination that occurs during the restorative process. If fluid—water, saliva, or blood—is incorporated into the composite material, problems result. With amalgam, contamination is less detrimental.

Circulatory Insult

Circulatory insult can be broken into two different types. First, there are about 10,000 dentin tubules per square millimeter that are exposed whenever the dentin is cut. It is quite possible to insult the pulp with these cuts. In reality this is a circulatory insult to the osmotic pressures on the dentin tubules. Second, a circulatory insult can occur with poorly polymerized resin, overhangs, or rough composite. These irritate the attachment apparatus (surrounding gingiva and bone).

The result of both types of circulatory insult is often postoperative tooth sensitivity. This tooth sensitivity can linger for months or years, unlike amalgam sensitivity. Also, circulatory insult as far as the attachment is concerned can result in poor esthetics of the tissue, with lack of stippling and a cyanotic color. Dentistry's focus is often on white esthetics (porcelain, composites, and bleaching), but in reality dentists must focus on both white and pink esthetics (gingival health and contour) and properly achieve both.

Contacts

Contact problems can be classified as either esthetic problems or function and health problems. A major problem with composite is the lack of "swell" when it is placed into the matrix. This creates a very pointed contact. If the embrasure space is not filled like a natural rounded tooth, the point contact creates unsupported composite. This leads to problems with cracks and fractures. Often those margin ridges can break. Point contacts can also create food impaction into the gingival tissues, or the contact may be positioned too far occlusally. The contact should be placed farther gingivally, as it is with natural teeth.

The *height of curvature* must occur more toward the middle of the tooth as opposed to on top of the occlusal table. An esthetic problem with contacts occurs when the interproximal area of a tooth is large. The Bioclear matrix system (Bioclear Matrix Systems, Tacoma, Washington) has rounded, anatomic matrices and non-deforming wedging systems that form biomimetic embrasure shapes, as opposed to creating the black triangles so common with most conventional matrixing and wedging techniques. Very large embrasure spaces become black triangles, which are quite un-esthetic. The contact and embrasure area either buttresses or disengages the papilla. The shape of the filling material in the embrasure area is of paramount importance.

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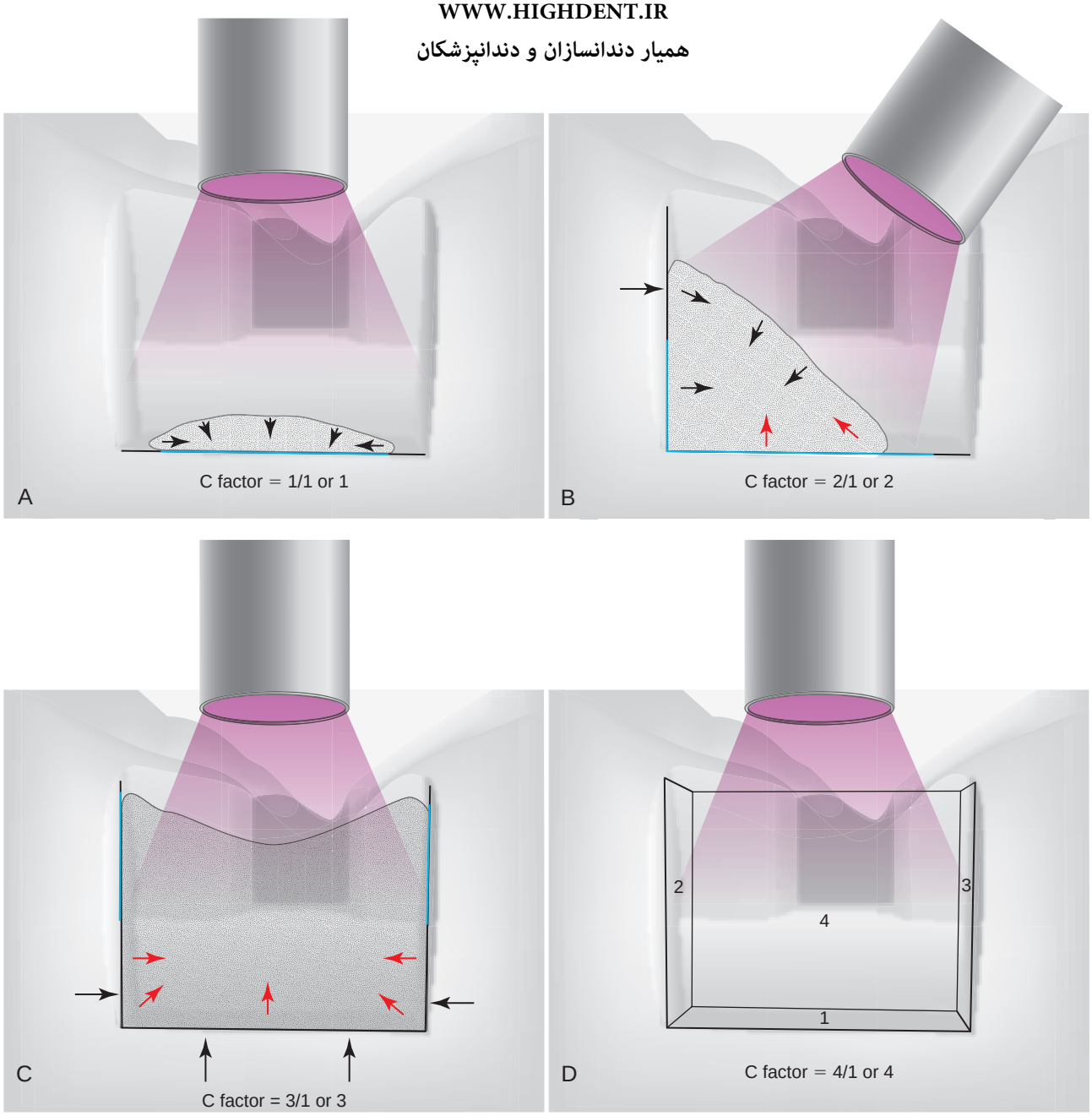
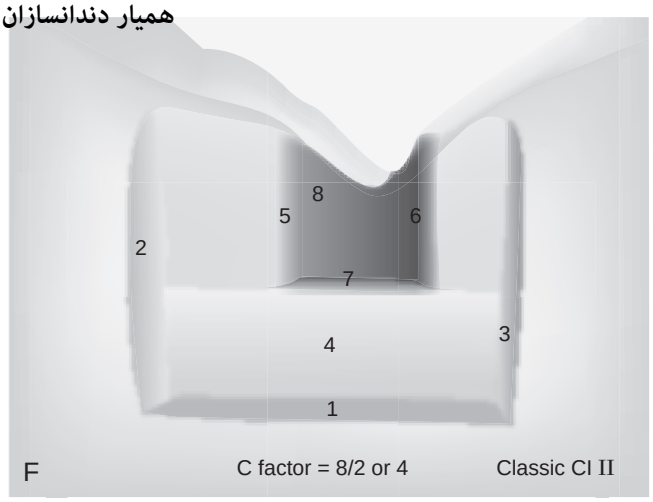


FIGURE 10-4 **A,** The curing light in the box area where the composite has been selectively placed on the gingival floor. The composite shrinks toward the single wall to which it has been applied. The C-factor is 1 because there is one internal wall that is being touched by the composite and one surface of the composite. A C-factor of one is very favorable. **B,** The light angled in. The C-factor is 2 because there are two cavity walls that the composite is touching at the same time and only one external surface to the composite, yielding a C-factor of 2. The *red arrows* shows where the composite is pulling toward the occlusal margin because of the shrinkage. In this example, the C-factor is 2 over 1 or 2. **C,** Filling the box area. The composite is engaging three walls of the cavity preparation—buccal, lingual, and gingival margin—simultaneously. The curing light is applied and shrinkage develops. The C-factor is 3. What typically happens in situations such as this is the shrinkage develops away from the gingival margin, the gingival dentin. This is extremely problematic both in post-operative sensitivity and microleakage on the gingival margin. There are three walls to the tooth cavity in this section of the box, and only one external surface of composite. This is an extremely unfavorable C-factor. The *red arrows* show the area where the composite pulls away from the tooth. **D,** When the actual wall of the cavity preparation is added to the buccal, lingual, and gingival walls, there are four cavity walls and realistically only one external surface area, which would be the interproximal area of the composite. The C-factor of 4 occurs in the classics. **E,** The new slot preparation, which has a C-factor of 4 for that box area. **F,** Classic G. V. Black class II preparation with an occlusal element. The C-factor is actually about the same as it was in the slot preparation because one traditional external surface has been added to the composite, the occlusal portion of the external surface of the composite. The ratio becomes eight internal walls over two external surfaces of composite, yielding a C-factor of 4, which is still unfavorable. **G,** Clark Class II preparation. Note the saucer shape. The C-factor on this is calculated at 1.4, significantly less than the 2 that was problematic. As composite is placed in this flattened cavity preparation, the C-factor is favorable enough that it is possible to injection mold the entire restoration as one without worrying about mitigating a C-factor with exotic layering techniques.

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E C factor = 4



F C factor = 8/2 or 4 Classic CI II



G C factor = 1.4 Classic CI II

FIGURE 10-4, cont'd

RELATING FUNCTION AND ESTHETICS OF POSTERIOR COMPOSITES

Molars are under significantly higher forces than are anterior teeth. Studies have shown that the first molar can have the highest occlusal forces. Intraoral observation shows the lower second molar is the worst candidate for porcelain or composite material, but surprisingly the lower second molar is also at highest risk for cuspal and whole tooth fractures. The forces on a maxillary first bicuspid are several magnitudes less than those on the lower second molar. The dentist must carefully consider this in treatment planning. A doctor and patient can have high confidence in a posterior composite in the first bicuspid. As one moves posteriorly toward the second molar the potential for excess wear and fracture with a composite increases. The dentist should inform the patient of the risk and overengineer the restoration.

CLINICAL CONSIDERATIONS

Indications

Posterior composites can now be recommended for nearly all patients. This includes class I, class II, class V, and cuspal restorations. For a tooth that is 50% or more destroyed by decay or fracture, the use of composite bonding must make sense both

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FIGURE 10-5 **A to C, What's wrong with this picture? These recently placed posterior composites demonstrate the often woeful state of direct composite restorative dentistry. *Black arrow:* A carious fissure was missed; insufficient magnification was the likely cause. *Blue arrow:* "Minimally invasive" class II cavity shape creates impossible C-factor problems. *Red arrow:* Incremental loading leaves seams and voids that allow subsequent fracture. *Green arrow:* Proximal tooth was iatrogenically gouged and now has a carious lesion penetrating into dentin. D, The gingival margin in this class II composite demonstrates the pervasive problem of microleakage. There was unfavorable C-factor at the margin, creating "suck back." Uncured and contaminated flashing results from a metal matrix that blocks light curing and visualization. E, Re-treatment with Clark class II filling techniques and instruments overcomes the multiple problems.**

from a structural standpoint and from a practice management standpoint. If there are deep caries on both mesial and distal aspects of the tooth and the tooth has the potential to fracture, the situation exceeds the logistics of a posterior composite. Although it is possible to do major tooth reconstruction with composite, in the average traditional practice, it does not make sense and an indirect restoration is indicated.

Contraindications

The most important contraindications to posterior composites are based on individual tooth considerations. For example, when both the mesial and the distal surfaces were previously restored with either composite or amalgam and fracture is suspected, that is not the best indication for posterior composite. When large

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areas of the margin are on dentin or cementum or when cast restorations are relying on dentin cementation, then an indirect restoration is more predictable than with large areas of dentin bonding on the margins. Dentin cementation is more predictable than dentin bonding when there are large areas of the margins exposed. For a severely caries-prone patient, a patient with salivary disorders, or a patient undergoing cancer or radiation therapy, amalgam or glass ionomer may be preferred. Composite has not been shown to release therapeutic levels of fluoride, and the current composites have no ability to act as a fluoride bank or to be rechargeable unless they are glass ionomers. Although research shows that significant caries resistance for therapeutic restoratives such as glass ionomer is absent, it is generally recognized that the valid approach is to use a glass ionomer. Amalgam is more bactericidal than composite and tends to accumulate less decay. If there is biofilm underneath a composite restoration, that can lead to recurrent decay. In addition, amalgam is more inert than all of the resins and will not degrade. The key here is that composite resins that are turning brown are actually degrading as if the bacteria were consuming the composite. This is most common at the gingival margin.

MATERIAL OPTIONS

The chemistry in the composite really has been unchanged for the past 25 years, but recently composites have been broken into two categories: pastes and flowable composites. Each of these can be subcategorized as a microfill, a preconglomerated microfill, or a microhybrid. The new, popular term "nanofill" is more marketing than science. Furthermore, those camps can be broken down into light cured materials, chemical cured materials, or those that have both light and chemical cures. In the paste camp, a new organic chemistry has finally been introduced to achieve low shrinkage. With this, the material actually expands as it contracts during polymerization shrinkage.

The paste composites have better polishability, but more important, as already discussed, they have the ability to maintain polish and surface integrity. Many of the studies show polishability as an asset. Many flowables allow a good polish, but that polish is very temporary. One of the problems with the literature is that studies do not look at long-term ability to retain a polish, which is more important for esthetics. In general the pastes are far superior in maintaining the polish compared with the flowables. The flowables in general tend to lose luster much more quickly than does a well-polished paste.

The advantages of flowable composite are superior handling and wetting of the cavity preparation. The research on using a flowable composite as the first layer to fill in the nooks and crannies and seal to the gingival margin reveals that it is not superior to putting paste composite directly into the cavity preparation. There is a perception that when the dentist places a flowable composite, it will fit into the nooks and crannies better in a class I or a class II preparation. Recently the American Dental Association analyzed the two composite types. One thing that research does not consider is the microgap versus the macrogap. If the dentist, during handling of a paste composite, leaves large voids in the restoration, then there will be microleakage. Flowable composite may not show a better result in research studies, but in practicality, most dentists feel they can get a better result using flowable composite.

Nearly all the physical characteristics of flowable composites are inferior to those of the paste composites. The advantages of the flowable materials are nearly all focused on ease of application as an aid to the paste composite and avoidance of mistakes. Flowable composite should never be considered as a replacement for paste composite.

In comparing a microfill and a microhybrid, microfills tend to have less wear but inferior strength. Microhybrids, conversely, have greater tendency for wearing and marginal ditching because of the clumping phenomenon as the larger particles fall out of the matrix. On the other hand, they tend to have higher compressive strength.

Current Best Approach

The traditional metal matrix and the translucent systems are completely different. For metal matrix the current best approach is layering at 2-mm increments. For the first layer a flowable composite is popular but has not been proved scientifically to be better. The goal is to use as little flowable composite as possible to avoid fracturing and weakening from the nexus of the flowable composite. The reason 2-mm increments are needed is because currently that is the deepest one can guarantee that the curing light will penetrate. The problem with the 2-mm layering, especially in a taller preparation, is that it is quite difficult and highly susceptible to developing seams and gaps between layers. The best approach using a non-metal matrix or translucent system is either the "snow plow" or the "injection-molded" technique. The former involves using a flowable and then a paste injection using the bulk loader. The author's preferred technique is the injection-molded technique, which is a total-etch technique, with placement of resin, then flowable composite, then paste in sequence with no curing between applications.

The current best approach for large cavities or teeth with early incomplete fractures is a direct composite onlay. The best environment for posterior composite in class I or class II cavities is when all the margins can be placed and maintained on the enamel. Therefore great care should be taken during tooth preparation to preserve residual enamel along the finish line. Even if it is a tiny sliver of enamel, it should be carefully maintained.

Many dentists are going away from the total-etch technique and using self-etching resin. The author's recommendation is still a total-etch technique because it allows the dentist to create a good bond on the infinity edge portion of the margin, which is the part of a composite that extends slightly past the finish line on the enamel. However, the self-etching resins do not provide as strong a bond on uncut (un-abraded) enamel. To obtain that last purchase, the last seal at the marginal extreme, a total-etch technique allows a light feather etch that the self-etch technique does not. The total-etch technique can be done with either a one-bottle or a two-bottle formulation. When a total-etch one-bottle technique is used, some clinicians have reported problems with sensitivity. The recommendation for the

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total-etch one-bottle technique is to place and dry two coats, then air thin and cure two coats of resin over the dentin before binding to the enamel to increase the dentin bond and to decrease sensitivity. Many clinicians have adapted the technique and achieved significant reduction in postoperative activity. A few new self-etching resins can be used after etching with phosphoric acid, Easy Bond (3M ESPE, St Paul, Minnesota) being the best known. Most other self-etching resins have poor dentinal bonds if the dentin is etched first.

The current best approach as far as adhesives and adhesion to enamel is still the total-etch technique. The current best approach for restorative materials for all posteriors is to use a microfill or agglomerated microfill (nanofill). Extremely small particles are needed to impart good polishability and good wear resistance with posterior teeth. The only agglomerated microfill currently available is the Filtek Supreme by 3M ESPE.

Flowable composite can be used as a dentin replacement. The goal with flowable composite is to use as little as possible in the restoration of the tooth to maximize its handling ability and to minimize the volume of flowable composite because of its physical limitation. The best method for maximizing the effect of flowable composite and minimizing the volume of flowable composite is the injection-molded technique.

INNOVATIVE ELEMENTS

Technological Elements

Caries removal has traditionally been done with carbide burs, both high speed and low speed. This is still the most accepted modality, but there are now other options for caries removal. It can be performed with air abrasion and laser ablation. The Caridex chemical dissolution system worked nicely but very slowly and has been defunct for about 20 years. A new possibility is the Icon technique, which uses hydrochloric acid. Other techniques also permit chemical removal of caries.

Changes in how caries is removed demand different ways of restoring the tooth because the cavity shapes should be organic, nontraditional, and non–G. V. Black–like. As a result it becomes even more critical to work creatively with the new matrix and the use of flowable composites. These make it possible to treat in a more minimally invasive manner that addresses nontraditional cavity shapes created with the new cutting modalities.

Introducing the Clark Class II

At first glance, non-retentive cavity preparations seem to be a problem, but in reality, the inverse is true. The non-retentive cavity preparations typically have a higher percentage of enamel that has been prepared and a smaller percentage of dentin that has been exposed, so there is a better enamel-to-dentin ratio, yielding a stronger enamel bond (see Figure 10-1, *D*). The C-factor is also improved because the cavity shapes are generally flatter and the disconnected occlusal portion more of a fissurotomy shape versus a parallel-sided preparation. The lack of mechanical retention tends to be a problem at first glance but is actually a benefit once reliance on mechanical retention is replaced by reliance on the strength of time-tested adhesive dentistry, which is bonding to large surfaces of acid-etched enamel.

ARTISTIC ELEMENTS

Many textbooks and articles addressing direct composites are focused on rather exotic techniques for layering, staining, and mixing opaque composites to achieve the most artistic and lifelike posterior restorations. This well-meaning emphasis is certainly an enjoyable art form. The author's analysis after nearly 20 years of microscope-based dentistry casts more aspersions on this issue. There are problems with the stains and voids and the structural flaws or lack of durability. There is a practicality issue with posterior composites, which are difficult to access in the back of the mouth. The esthetic value of molars is important, as they frame the anterior teeth for beauty, but in reality there are higher patient expectations for anteriors than for posteriors. For posteriors, it is preferable to compromise esthetics rather than compromise functionality and longevity; the difficult access and unforgiving nature of the posterior composite will sometimes require a clinician to choose one over the other.

The translucent nature of composite combined with the contact lens effect makes esthetics easier to achieve when compared with porcelain restorations. The fact that the composites must be placed in the back of the mouth creates generous and lenient judgment of esthetic success. Artistry in posterior composites is important, but the primary focus should always be on longevity.

TREATMENT PLANNING

Options

With posterior composite there are two options for cavity preparations as well as options for materials. Non-retentive, minimally invasive cavity preparations are clearly more successful when the tooth is younger, when it is not heavily restored, and when there is sufficient occlusal and cervical interproximal enamel to engage. Once a tooth becomes more mutilated and more reliant on dentin adhesion, the procedure may benefit from more traditional cavity preparations. The other option to consider is whether to attempt to provide intracoronal splinting during treatment. A decision must be made early concerning the creation of intracoronal splinting of the compromised tooth. These teeth must be treated with composite onlays or "calla lily" type preparations (see Figures 10-6 and 10-8). Those options must be considered early because they will have a bearing on occlusion.

Sequence

Typically the first task is to undertake disease control. Next will come whitening of the dentition, if desired. Whitening is done before the posterior or anterior composites are placed. The desired color outcome for the dentition is then verified and the

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direct tooth restoration placed before the indirect restorations. With the modern cavity preparations it is easy to purposely or inadvertently alter the vertical dimension with direct composite. If the vertical dimension requires opening, this can be handled very nicely with the posterior composite restoration.

TREATMENT CONSIDERATIONS

Rather than break posterior composites into class I or class II rigid categories, the determination is treated more organically. Basically the facial, lingual, interproximal, and occlusal surfaces should each be addressed individually. As far as the occlusal portion of the preparation goes, the design will preferably not be affected whether it involves the interproximal or the facial aspect. The best outcomes will be achieved when cavity preparations are *not* connected to one another. The goal is to break the approach down into a thought process that is more consistent with the modern view of the five Cs. The final case to be presented is the retrieval of some failing class II amalgams in a very different approach. Planning involves thinking about the occlusal portion and whether or not the interproximal area is involved. The occlusal portion of the modern posterior composite is a fissurotomy shaped, calla lily–shaped, cusp-tip-to-cusp-tip composite or a composite onlay. The interproximal modern shape is a "saucer" shape, whether small or large.

Preparation for Re-Treatment of Old Amalgams or Failed Composites

The preparation of old composite or failed amalgams becomes significantly more complicated because of the five Cs. The goal with restorations is to reduce the problems of C-factor and crack initiation by modifying the cavity preparation significantly. The other thing that is required is to amend the problems associated with previously cut G. V. Black–style preparations by using exotic layering and filling techniques. The C-factor is so unfavorable in old fashioned "boxy" preparations that these cases cannot be remedied 100% by modifying the cavity preparation alone. Work is done on both ends, modifying the cavity preparation, addressing problems that were inherited, and removing the old amalgam metal composite using corrective and a few defensive filling techniques.

The author no longer does traditional G. V. Black–style posterior cavity preparations unless an amalgam restoration is being done. There is no place for traditional parallel-sided cavity preparation in the posterior dentition except in extenuating circumstances such as when there is almost no enamel present.

When doing first-time treatment of the tooth for class I and class II caries, the ultimate goal of the tooth preparation is to not connect the interproximal to the occlusal preparation (Figure 10-6). The ideal preparation is a fissurotomy preparation of the occlusal grooves and removal of any occlusal caries, then the interproximal portion is done separately so they are as disconnected as possible.

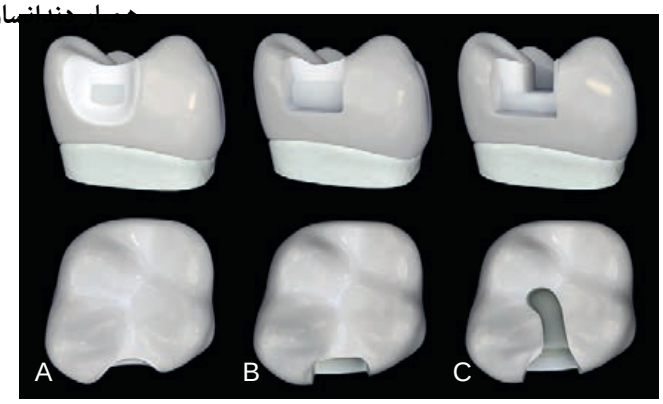


FIGURE 10-6 **A, Examples of the Clark class II preparation. B, The slot preparation created by Simonson and others. C, The original G. V. Black class II preparation.**

Once the cavity preparation has been cut, the interproximal area should be aggressively sanded with the lightning strip to remove biofilm on that infinity edge margin. The enamel is lightly abraded slightly past the finish line.

The following procedure produces a seamless, durable, strong, and leak-resistant composite filling. The prepared cavity is restored as follows:

1. *Pre-wedge the teeth to be restored.* Prepare a "saucer" style class II preparation as outlined under Clark Class II or Injection-Molded Composite Technique, making sure to pre-wedge the teeth to be restored. The process will be predictable and enjoyable only after this preparatory step is performed. There must be slight clearance between teeth when the preparations are finished. It is acceptable to break the contact with a lightning strip to avoid gouging the neighboring tooth.
2. *Cover dentin with glass ionomer or two coats of bonding resin, then flowable composite.* Cure each layer individually. The choice depends on personal preference and the need to leave less than 2 mm of axial space (distance between depth of cavity and the projected cavosurface of the composite). If there is minimal exposed dentin, skip this step.
3. *Remove wedge.* Interproximal areas should be aggressively "sanded" with a lightning strip and cleaned with pumice and rubber cup. This is followed with sodium bicarbonate spray (Bioclear ProphyPlus Cavitron Prophy Jet [DENTSPLY Professional, York, Pennsylvania).
4. *Place the appropriate Bioclear anatomical sectional matrix band around the tooth, maintaining the anatomic crown and root adaptation.* Wetting the matrix with a drop of water before placement makes it much easier to work with. Start with the 6.5-mm AFM (average flat molar); it is the "go-to" matrix for most posteriors.
5. *Stretch and "floss in" the appropriate interproximator or place an anatomic wedge such as the Bioclear SABRE Wedge.* The interproximator can be applied with fingertips or with delicate hemostats. A little soap on the isthmus is extremely helpful. The dental assistant can

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hold the matrix in place as the dentist seesaws the interproximator into place.

6. *Use of a metallic bi-tine separator ring in the interproximal embrasure is sometimes needed.* When needed, it creates additional tooth separation and additional adaptation pressure on the matrix. However, the softer-faced separators by Bioclear, Triodent Corp (Los Alamitos California) or Garrison Dental Solutions (Spring Lake, Michigan) provide ideal adaptation of the matrix to the tooth and predictably snug contacts.
7. *Etch with both liquids and immediately chase with gel phosphoric acid 1.5 mm past margins for 20 seconds, then rinse and dry.* This may have occurred in step 2 in the choice of resin and dentin bonding over that of glass ionomer.
8. *Place Adper Single Bond Plus (3M), Optibond Solo Plus (Kerr Corp., Orange, California), or other total-etch compatible resin to cover the entire cavity preparation and 1 mm past the margins.* Air thin the resin except in gingival sites, where a small pool is maintained. Do not light cure at this point.
9. *Inject Filtek Supreme Ultra Flowable Restorative flowable composite (or similar microfill) directly into the pool of bonding resin (under magnification if possible) without incorporating bubbles.* Fill the interproximal area no more than one third full. Express a tiny amount of the flowable composite before placement to ensure that there is no air in the cannula. Do not light cure.
10. *Inject Filtek Supreme Ultra Universal paste composite (or similar microfill) into the pool of flowable composite without creating air bubbles.* Allow the paste to displace most of the lesser filled resins (under magnification if possible). Apply injection pressure as the syringe is pulled away to avoid "pull-back" and voids.
11. *Burnish, carve anatomy, and carve excess composite.* Avoid the use of a condenser or plugger. Cure the occlusal surface, then cure the interproximal area with two curing lights, one from the buccal and one from the lingual, while applying air cooling from an air syringe. Use high-intensity light-emitting diode (LED) or arc curing lights.
12. *Remove matrix or matrices and interproximator, then polish with disks, strips, and rubber-tipped and carbide burs.* Pre-polish with coarse pumice. Finish with the SS White Jazz (SS White Burs, Inc., Lakewood, New Jersey) (or similar diamond-impregnated) rubber polishing cup.

Note that the liquid etch is applied deep in the interproximal areas, then in the deep fissurotomy areas. Gel etch is applied by injecting it into the liquid etch so all the enamel area is engaged. After the area is rinsed and dried, two coats of adhesive are placed over the dentin area, air drying between each step. Bonding resin is placed on the occlusal and interproximal areas. The bonding resin is air thinned aggressively on the occlusal but only lightly in the interproximal. The flowable composite is then injected into the fissurotomy area and deep into the interproximal saucer area. The paste composite material is then injected into the reservoir of flowable composite and bonding resin in the interproximal area, then in any large areas on the occlusal. The interproximal area is quickly shaped with appropriate explorers and burnishers before photopolymerization. (Because the bonding agent is polymerized separately over the dentin, the bonding resin in the remainder of the technique serves only as a wetting agent.) Finally, the photopolymerization is begun with two curing lights—a buccal and a lingual—and working from the gingiva so there is a favorable cure toward the weakest margin. The advantage is that it is possible to initiate the photopolymerization at the gingival margin, which is more favorable to resisting the opening of the gingival margin, then the occlusal portion is cured last.

A more complex treatment, a large re-treatment restoration, is generally broken into the restoration of the occlusal and the restoration of the interproximal to control C-factor and simplify the process. On the occlusal aspect, once the cavity preparation has been modified to a more open preparation (Figure 10-7), which is the calla lily (Figure 10-8) or onlay shape, select areas of the dentin are noted. A total-etch technique is done on the occlusal portion of the tooth with at least 20 seconds of etch on the enamel and less than 20 seconds of etch on the dentin. Two coats of bonding resin are applied, each one air thinned and then

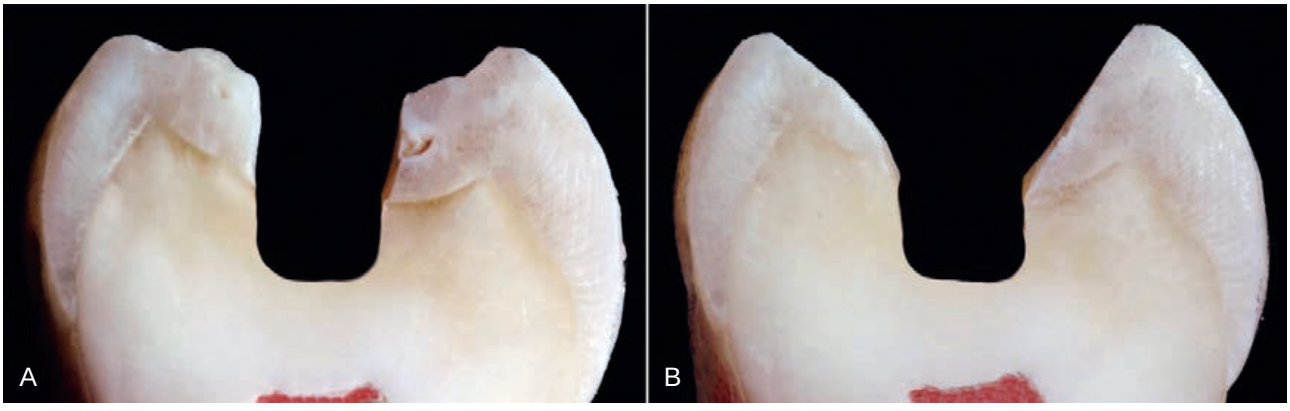


FIGURE 10-7 **A, A boxy class I preparation is shown in cross-section. B, A 45-degree cut through enamel gradually diminishes to a tangential or infinity edge margin near the cusp tips. However, undermined dentin should never be removed for the sake of splinting the tooth or improving C-factor.**

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FIGURE 10-8 The graceful calla lily mimics ideal shape for class I cavity preparations. It allows tooth splinting when composite is placed, maximizes enamel rod engagement, allows ideal visualization of the cavity, and minimizes the potential for crack initiation.

cured on the dentin. Dentin replacement is done with care to block out undercuts and to control C-factor to keep it from touching all four walls at the same time. This can be accomplished if several small spots of flowable composite are placed, and then light cured so that they will not touch one another or more than 2 walls of the cavity preparation at the same time. Once the dentin has been replaced, it is possible to apply adhesive to the enamel and place paste composite in one, two, or three increments to control cross-tooth and cusp-to-cusp curing. The next step is to re-prepare the interproximal area and then do injection molding of the interproximal as described in the section on conservative preparation. New low stress flowable composites claim to eliminate the need for controlling C Factor, but have not been shown to reduce micro-leakage. In addition, the manufacturer's recommended techniques with self leveling low stress flowable composites leave the tooth with far too much flowable composite and far too little of the paste component.

Finishing

The three steps in finishing are shaping, pre-polishing, and final polishing. Shaping can be done with a high-speed carbide or diamond bur, taking great care to try to not cut into the enamel. The esthetic advantages of the infinity etch margin are maintained, so it demonstrates a slight infinity or feather etch onto the enamel, both in the interproximal area and on the occlusal area. The next step is to pre-polish. The pre-polish is performed best with the coarse pumice in a rubber cup. The use of disks is advantageous interproximally.

For the final polish, it is possible to go from the pre-polished state to the final polish with either the Jazz polisher (SS White Burs, Inc.) or the D Fine Shape & Shine (Clinician's Choice Dental Products, Inc., New Milford, Connecticut). Coolants are needed when doing significant polishing from these cups because they can generate heat and overheat the pulp and/or the composite material.

EVIDENCE-BASED PRINCIPLES

A significant problem mentioned previously is the resistance of the schools to teach posterior composites on a widespread basis. One of the problems has been the outcome studies on amalgam versus posterior composite. Most of these studies show that amalgam has a better outcome than the posterior composites. That has been one of the limiting factors in regard to posterior composite. Following the steps outlined here should help the profession move ahead with posterior composites and change the outcome of composites once problems have been properly addressed.

The evidence on paste composite shows that it is vastly superior to flowable composite in almost every aspect—longevity, strength, and wear resistance.

Most studies on heated composite show that it is a benefit. It shows more rapid polymerization or a higher percentage of polymerization and better strength. One problem with heated composite is that if it is allowed to cool completely before curing, it loses all of its benefits. In addition, although it can be heated and cooled multiple times without losing its good characteristics, it can be overheated and it can deteriorate if heated for too long over too many instances. If a composite is placed while heated and then is allowed to cool down to mouth temperature, it is no longer superior to a composite not placed in the heated fashion. At that point its performance is equal to that of a traditional composite.

Glass ionomers, compomers, resin-modified composites, and flowable composites have all been used as liners. For an extremely long period in dentistry there have been efforts to place liners underneath both composites and amalgams. Glass ionomer has a long and successful history in this area. Even though the bond is bit weaker typically than dentin bonding, the bond tends to have significantly less deterioration over time than dentin bonding with resins. Glass ionomers are especially popular in Europe.

The compomers, which are really a mixture of resin and glass ionomer, in most instances have the disadvantages of both. Compomer has fallen out of favor except for some pediatric applications where its use is more temporary and the physical limitations over time are less of a concern.

Resin-modified glass ionomers continue to grow in popularity. They are less proven as far as long-term bonding to dentin, but because of their ability to be placed easily, to be light cured immediately, and to achieve an immediate set, they are popular.

Flowable composite has been increasingly popular as a liner. Its disadvantage is that no evidence shows there is a therapeutic

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release of fluoride from those that contain fluoride, whereas glass ionomer does have a therapeutic long-term release of fluoride. The flowable composite, because of its lessened filler content, has a significant amount of shrinkage, so C-factor and other shrinkage problems occur when it is used as a liner. Despite the liabilities, it has some advantages as a liner.

An incredible amount of research is currently going on as well as debate regarding self-etch versus acid-etch products. Originally the manufacturers of the self-etch materials did not indicate that the enamel needed a separate self-etching step. However, some manufacturers are now recommending that even with the self-etch the enamel should be etched briefly before the self-etching is applied. Most studies show that acid etch is superior on uncut enamel. A key concept is to create an infinity edge margin in which the composite goes slightly past the cavity margin. The enamel there is uncut. In most cases acid-etch materials will give a superior bond to that enamel. The author tends to prefer acid etching over self-etching. If the tooth being treated is severely broken down, self-etching resin that allows the dentin to be exposed to rinse etching, such as the new Adper Easy Bond (3M ESPE) is an acceptable choice.

Besides dentin bonding with typical self-etching or acid etching, other concepts must be considered. One is the use of glass ionomer to bond with the dentin. This can be used either in the open sandwich technique—the gingival margin, a small area of the dentin, and a small area of the glass ionomer will be exposed—or the closed sandwich technique—the entire external surface of the restoration is covered with composite and the glass ionomer is not exposed. The third adhesive concept is being advanced as the Embrace technology (Pulpdent Corporation, Watertown, Massachusetts), which does not have a typical dentin bonding.

CLINICAL CONSERVATION CONCEPTS

There is a new hierarchy of tooth needs because the current model of minimally invasive and conservative dentistry weighs out differently—tooth structures have varying values. The goal is not just preserving tooth structure, but preserving the most important tooth structure, sometimes at the expense of a less important tooth structure. The overall concept of trying to be conservative and preserving tooth structure must now be modified so that certain areas of the tooth have higher value. In other words, the dentino-enamel junction, where the enamel is interfacing to the dentin, is extremely important for the posterior composites. If that zone can be more carefully maintained at the expense of a less important area, such as external enamel, then that is a good trade-off.

The Hierarchy of Tooth Needs

Table 10-1 represents the hierarchy of needs to maintain optimal strength, fracture resistance, and several other characteristics needed for long-term full function of the posterior and anterior tooth. This chapter is designed to simply introduce the reader to the reshuffling of the values assigned to different tooth structures and of the nuanced role of the importance of regional tissues.

TABLE 10-1 The Hierarchy of Tooth Needs for Posterior Teeth

VALUE TO THE TOOTH	TISSUE TYPE
Extremely high	Axial wall zone dentino-enamel junction (DEJ) Cervical enamel Pulp in immature teeth
High	Coronal zone DEJ Coronal dentin
Medium	Coronal enamel
Low	Secondary dentin
No value or liability	Tertiary dentin Inflamed pulp in mature teeth Exposed dentin (common in cusp tip areas)

MAINTENANCE

One of the new protocols developed is the use of diamond-impregnated polishers. Both the Jazz polisher and the Shape & Shine polisher can be used in a 10-second application to return a mirror finish to some of the composites that have lost some of their brilliance and shine over time (Figure 10-9).

Many toothpastes are extremely abrasive, and these should be avoided for patients who have significant areas of posterior composite on the cavosurface. Smoking is definitely an issue for composite restorations because these margins are exposed and even a well-sealed margin can accumulate tobacco stain.

CONTROVERSIES

Even though amalgam continues its decline in popularity, there is still significant debate on the use of amalgam versus composite for the posterior dentition. This debate will probably continue for at least another decade.

For other controversies, attention has been directed recently toward some of the possible negative health effects of composites. These are typically attributed to the organic binding with bisphenlol-A glycidyl dimethacrylate (BIS-GMAs) and other binding resins. Research shows possible teratogenic, carcinogenic, and mutagenic effects from composite.

3M ESPE offers a new composite that actually expands as it shrinks, the Filtek LS Low Shrink Posterior Restorative System. Whether it will truly compensate for polymerization shrinkage will have to be seen over time. Other composites now claim to have 1% or less shrinkage. Further research and studies will be

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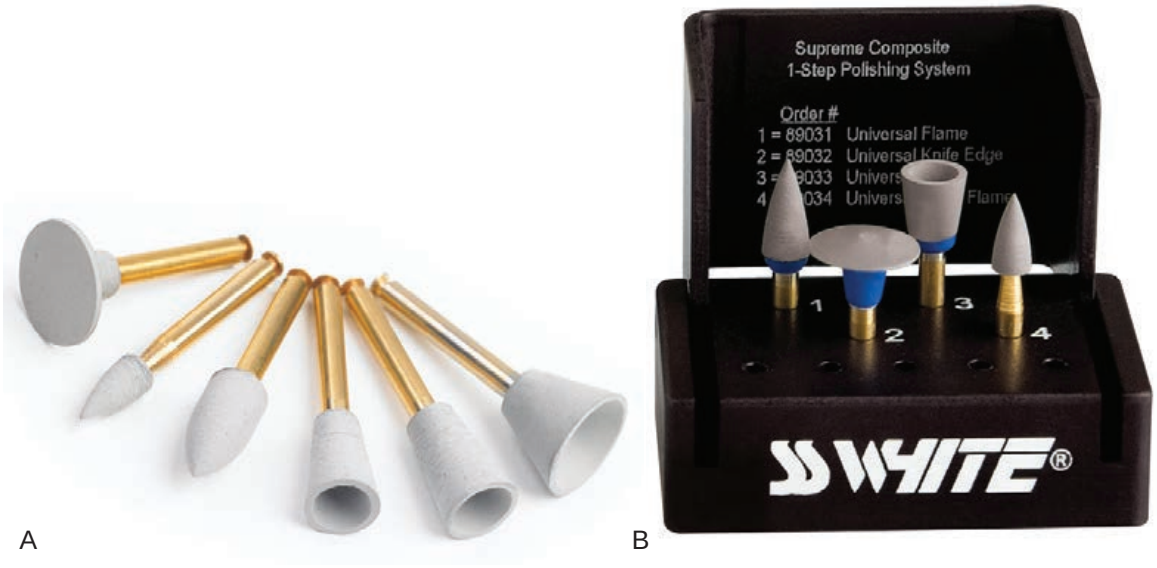


FIGURE 10-9 A, D-Fine Shape & Shine polishers. B, Jazz Supreme Polishing System for composites. *(A Courtesy Clinician's Choice Dental Products, New Milford, Connecticut. B Courtesy SS White Burs, Inc., Lakewood, New Jersey.)*

needed on these low-shrink composites and also to determine at what point the shrinkage becomes a non-factor. It may be possible that if products can achieve 0.5% shrinkage, the C-factor will no longer matter. These controversies have not been resolved and will continue to be debated and researched.

Many are concerned about some of the weaknesses of flowable composite. Certain experts in dentistry recommend that flowable composites be used extremely sparingly. Others are using flowable composite for significant portions of their restorative protocols, and new flowables that have high shrinkage but low stress are being aggressively marketed to be used to fill most of the tooth (SureFil, DENTSPLY Caulk, Milford, Delaware). There is no evidenced-based support for this approach. That controversy will continue. In the author's practice, flowable composite is extremely important but must be used in moderation at all times, understanding its weaknesses but also recognizing that the physical characteristics of flowable composite allow for some extremely helpful clinical steps that are simply impossible without this material.

NEAR-FUTURE DEVELOPMENTS

There will probably be more low-shrink composites coming onto the market. Another development might be the elimination of dentin bonding. Although there is tremendous focus on dentin bonding, the hybrid zone of dentin bonding—where the composite and the dentin tubules interface—is the liability of dentin bonding. A replacement for dentin bonding, for example, Embrace technology, or the increased use of glass ionomer or future developments may eliminate dentin bonding altogether.

Another potential development is that some composites will try to offer a deeper depth of cure. This would exceed the recommended 2 mm and allow potentially 3 to 5 mm of curing.

CASE 1

A 35-year-old woman had a composite in the distal of the upper first molar that has fallen out of the tooth (Figure 10-10, *A*). The patient was concerned about the esthetics in this area, as she did not want to have the silver coloration in the teeth. In addition, the patient is congenitally missing a bicuspid and the tooth had drifted (Figure 10-10, *B*). This is an extremely difficult contact area that was causing food impaction, not only along the unfavorable marginal ridge in the mesial, but also where the restoration was missing (Figure 10-10, *C* and *D*).

It should be noted that despite the esthetic liabilities of the amalgams on the teeth, these amalgams had served well for 25 years. The composites placed by another dentist had lasted only 3 years and were already deteriorating.

The goals in this case were to improve the marginal ridge situation, to have an esthetic result that was acceptable to the patient and dentist, and, most important, to have a result that would last for decades instead of just a few years.

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CASE 1 (CONT'D)



FIGURE 10-10 A, Preoperative radiograph showing the upper first molar. B, Radiograph showing the difficult contact area on the mesial of the upper first molar. The patient had been congenitally missing a bicuspid and the tooth had drifted. C, Preoperative condition of the teeth. D, High magnification showing the contact area where the composite has fallen out of the restoration. E, Rubber dam and pre-wedges placed. F, Old restorations and majority of caries removed.

CASE 1 (CONT'D)



FIGURE 10-10, cont'd G, Application of sodium hypochlorite removes the last of the stains. H, Occlusal portion completed without restoring the interproximal area, as that area will be re-prepared to control the C-factor. I, Teeth re-prepared with the saucer preparation. J, The biomatrices positioned, and one interproximator in place. The first molar (the problem area) does not have an interproximator in position. K, A Universal Posterior Bioclear Matrix. L, High magnification view of the Universal Posterior Bioclear Matrix.

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CASE 1 (CONT'D)

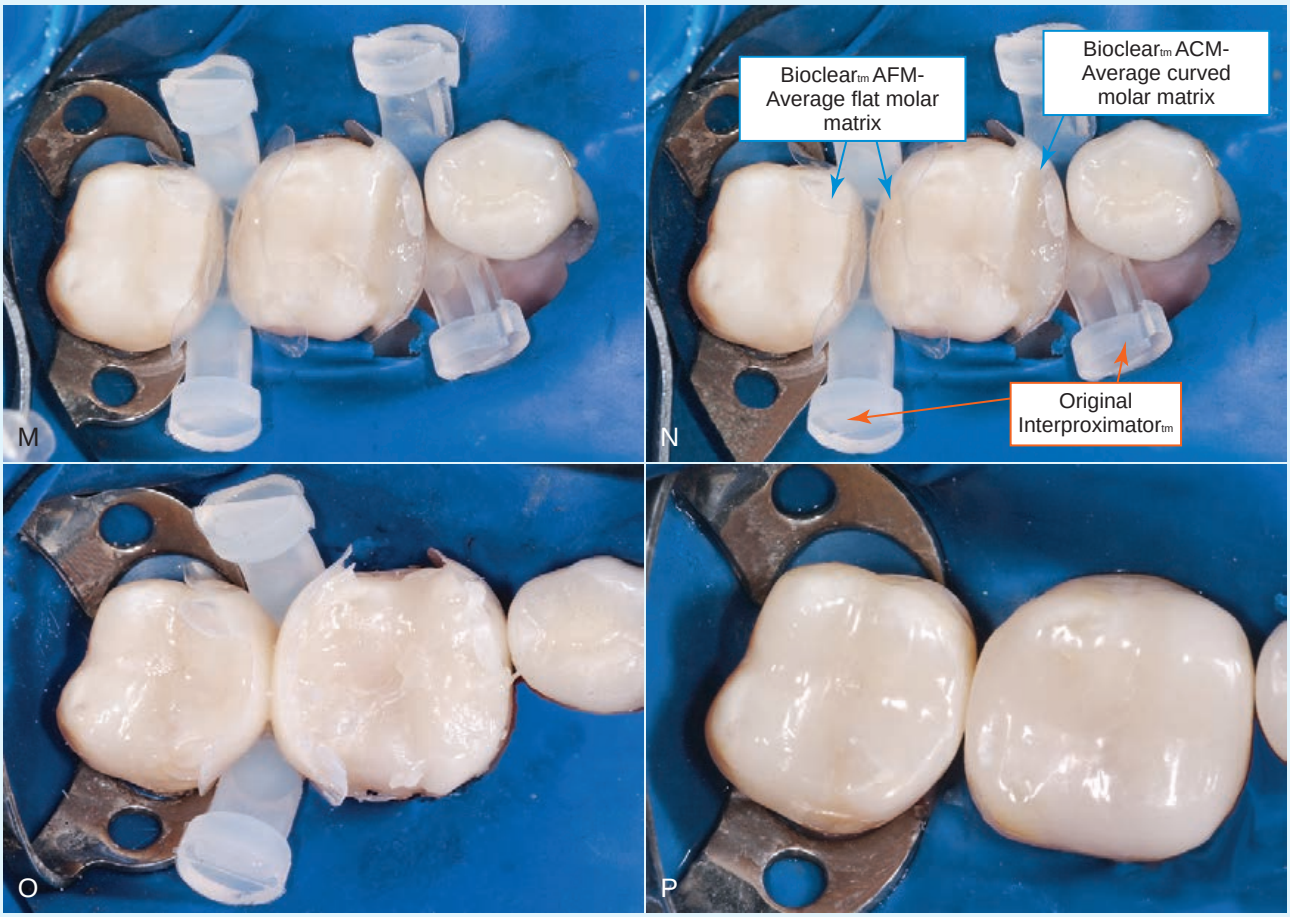


FIGURE 10-10, cont'd **M, Both Interproximators positioned, and the first layer of composites placed on the mesial of the first molar. N, Actual instruments and matrices and Interproximators used. O, The Interproximator removed from the mesial of the first molar to allow the contact and to allow the tooth to drift slightly to permit tight contacts on the distal of the first molar and the mesial of the second molar. P, The post-treatment result. The infinity edge margin, rounded embrasures, and large surface area on the contact both bucco-lingually and occluso-gingivally serve as both functional and esthetic assets.**

The early text outlines the unfavorable characteristics of a retentive cavity preparation. This is the classic slot preparation that was cut for the composite by the previous dentist. Although the restoration had mechanical retention, the composite debonded and fell out anyway. This is in contrast to amalgam, which had served well for 25 years.

The rubber dam and pre-wedges were placed (Figure 10-10, *E*). Pre-wedging is an important aid in creating ideal interproximal areas. Pre-wedging performs three important functions: it compresses the papilla so the restoration becomes a supragingival restoration, it creates better light and visibility and the ability to thoroughly clean the surfaces in preparation for the composite, and it protects the rubber dam and the gingiva from laceration.

The old restorations and most of the caries were removed (Figure 10-10, *F*). The calla lily or cusp-to-cusp tip type of preparation discussed previously was created. All of the interproximal amalgams were removed, and the procedure would be staged. The occlusal area was prepared so the C-factor was controlled; this interproximal area would be re-prepared so that it could be injection molded in a single phase. The combination of caries removal and the application of sodium hypochlorite was done to remove the last of the stains (Figure 10-10, *G*). Some of the stained dentin was sound and could be retained, but because of the color problems, the author's preference was to apply full-strength sodium hypochlorite for 1 to 3 minutes to reduce the amount of stain. This is a more conservative approach to obtain an ideal esthetic outcome rather than just removing the discolored dentin.

The occlusal portion was completed without restoring the interproximal area because that area would be re-prepared and to control the C-factor (Figure 10-10, *H*). The cusps were built one or two at a time and not all at the same time because of concerns about cross-tooth polymerization and C-factor issues. The teeth were re-prepared with the saucer preparation (Figure 10-10, *I*).

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CASE 1 (CONT'D)

The Bioclear matrices are positioned, and one of the Interproximators is put in place. As the mesial of the first molar was the problem area, it does not have an Interproximator in position. This demonstrates how difficult the closure of this contact area is.

Figure 10-10, *K* and *L*, shows an average curve molar. This is a patented diastema closure matrix, ideal for a difficult contact such as this one. It has a very pronounced and exaggerated curvature.

Both Interproximators are positioned (Figure 10-10, *M* and *N*). The dentist will not restore all of the contacts simultaneously to avoid trouble with open contacts. Figure 10-10, *M*, shows the first layer of composites being placed on the mesial of the first molar. In contrast to the recommended single-phase loading, this is a difficult contact, a diastema closure, and it is attempted in two steps. This step shows the first layer of composite being placed, and then the matrix is teased away from the tooth slightly to close the contact. The Interproximator is removed from the mesial of the first molar to allow the contact, to allow the tooth to drift slightly to permit tight contacts on the distal of the first molar and the mesial of the second molar (Figure 10-10, *O*). Figure 10-10, *P*, shows the post-treatment result.

Note: The author does not spend a lot of time carving deep occlusal anatomy and addressing stain in the occlusal views of these teeth. Until the failure rate of composites improves, it is best to focus on durability of the restoration, and only then possibly budget time for artistic occlusal anatomy. Patients are nearly always satisfied with the esthetics of even very utilitarian posterior composites and would prefer that over food impaction, post-operative sensitivity, and floss snagging on overhangs and open margins. A last reason to question the carving of deep anatomy in the composite is the potential for crack initiation in the composite material.

CASE 2

In a case similar to Case 1, the ideal round emersion profile is combined with a contact that has been shifted into a more natural position toward the mid-portion of the tooth as opposed to the "point" contacts that are often centered in the occlusal one fifth of the tooth. "Point" contacts often lead to marginal fractures and other food impaction problems (Figure 10-11).



FIGURE 10-11

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Anatomical Posterior Contacts

Simon McDonald

RELEVANCE TO ESTHETIC DENTISTRY OF POSTERIOR CONTACTS WITH COMPOSITE RESTORATIONS

There has been a strong move away from amalgam in tooth restorations; now class II composite restorations are placed routinely. Unfortunately, the instrumentation that worked well for amalgams does not work well with composite resins. A new set of instruments was needed, and this brought with it a new set of problems to overcome.

Poor anatomical contacts between posterior teeth with proximal restorations are potentially quite serious. If there is a gap between the new restoration and the neighboring tooth measuring approximately 0.1 to 1 mm, then food packing acts like an orthodontic separator. The gap increases and traps more food, leading to periodontal disease and secondary caries to either side of that contact. This is fairly disastrous, particularly because root caries is difficult to diagnose, often causing no symptoms until it is quite advanced, at which point the patient requires endodontic treatment or even an extraction.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT OF INSTRUMENTS FOR POSTERIOR RESTORATION CONTACTS

Initially, circumferential bands were used, but it is difficult to obtain correct contacts with these. This type of band tends to create "tin-can" restorations in which the contact point is too close to the marginal ridge. The contact is often light or nonexistent because the matrix band has to pass through the interproximal area of both sides of the tooth. The band on the un-restored side of the tooth pushes the tooth in the wrong direction so that when the band is finally removed the tooth springs back into its original position and the newly established contact point on the other side of the tooth opens up, much to the dismay of the clinician! The Palodent system (DENTSPLY Caulk, Milford, Delaware), invented by Buddy Meyers, was the first separating ring and sectional matrix and worked quite well on smaller cavities. However, the separating rings often get in the way of the wedge, and the tines tend to collapse in on wide cavities. There are also difficulties in placing the matrix, which is hard to hold with tweezers or pliers. Frustratingly, the matrix tends to move when the wedge is pushed into position. In the author's experience, the Palodent retainer ring can be awkward to seat properly and has on occasions jumped off; once, memorably, the ring flew across the room. Many dentists became so frustrated with sectional matrix systems that they returned to using amalgam.

In 2003 the Triodent Corporation (Los Alamitos, California) launched itself with development of the Tri-Clip, which was a device that enabled the dentist to place a matrix, a wedge, and a separating ring simultaneously. This product had limited success, probably because the approach was a bit too different from the traditional method. Around this time several other products came on the market, particularly from Garrison Dental Solutions (Spring Lake, Michigan). The Triodent system was also improved. The Garrison ring effectively addressed the problem of the rings jumping off. However, problems remained with the rings collapsing into wider cavities, the matrices were still difficult to hold, and the ring competed with the wedge for in the interproximal space.

A huge problem with these single-tine rings was that the dentist did not know whether to place the ring in front or behind the wedge. The first version of Triodent's V-ring was a nickel-titanium and stainless ring with a V-shaped gap between tines. With this development there was no longer difficulty in finding where to place the separating ring—it always sat over the wedge. The original V-ring was very successful and Triodent won numerous clinical and business awards.

In 2008 Triodent launched the V3 ring, an all nickel-titanium ring with plastic tines. The improved tine shape led to better spring tension and excellent retention. The mechanics also changed so that the spring pushes directly into the interproximal area rather than above it, also improving retention. The V3 ring comes in two different colors, green and yellow. The yellow one is for premolars. In general, springs follow Hooke's law, which means that the force applied is proportional to the expansion of the ring. However, nickel-titanium does not follow Hooke's law. Even though the spring has been opened farther and farther, the amount of force flattens off so that the spring maintains a clinically appropriate separating force of around 3 to 4 kg. With a

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small tooth such as a lower premolar, a conventional separating ring does not open far, and consequentially the force applied is only 1 or 2 kg. This is insufficient to cause separation. Clinically we notice this because the ring is loose on the lower premolars. The yellow V3 ring achieves a tight fit with a balanced, ideal 4-kg force even for small teeth. The shape of the V3 ring also allows it to be placed over the wedge or the wedge to be placed after the ring is in place.

RELATING CLINICAL FUNCTION AND ESTHETICS

The Triodent V3 system gives consistently tight contacts, and the matrix creates an anatomically correct marginal ridge. The contact point is of the correct height rather than being too near the marginal ridge, which is a common problem with sectional matrix systems. There is also minimal flash and therefore minimal finishing.

The periodontal membrane surrounding teeth allows them to have their own "independent suspension," and a separating ring with 3 to 4 kg of force will cause the teeth drift apart. The teeth separate more than the thickness of the matrix, so when the retainer ring or the separating ring is removed, the teeth spring back to their original position and establish a tight contact.

With a circumferential band, the band goes completely around the tooth in a class II restoration and through the intact contact. In a mesio-occlusal (MO) restoration, for example, the matrix goes through the distal contact and tends to push the tooth in a mesial direction, which is the wrong direction; the goal is to push the tooth into a distal direction. The dentist then completes the restoration and even presses hard against the matrix to achieve a tight contact. The matrix is removed from both the mesial and the distal contact and the tooth springs back in a distal direction, thereby opening the contact.

The V3 ring system helps create a marginal ridge, always a major finishing concern for the dentist, because the matrix is designed with a marginal ridge built into it. Much work has been done to develop the curvature so that it is as tooth shaped as possible. A related issue is getting the contact to the right points. That is the key because the curvature of the matrix is S shaped. This shape can be seen on some of the clinical radiographs and closely approximates the natural cervical shape of the tooth and the emergence profile of the tooth in that area. The system minimizes flash and the finishing needed after the composite is in place because the tines on the V3 ring hug the buccal and lingual surfaces nicely.

When discussing finishing of composites, a good analogy is the laying down of concrete. Imagine we have two builders and the first builder is in a hurry to lay down the plywood and timber framing and does not do a very good job. The concrete is poured and the timber framing moves. When the concrete sets, the builder has to come back with a concrete saw. In the end, the job takes longer and the result is not very good. In contrast, the second builder spends a little more time getting the concrete boxing properly established. When the concrete is poured and the timber framing removed, very little finishing is necessary. When this analogy is applied to class II composites, it is easy to see that a little extra effort obtaining an anatomically accurate matrix system results in less time overall and a much more satisfying result.

CLINICAL CONSIDERATIONS

The V3 ring system is suitable for all class II restorations in both primary and permanent teeth. For mesio-occlusal-distal (MOD) restorations, The author prefers to use a circumferential matrix band, with the V3 ring as a tooth separator. There are no contraindications. Although some post-operative sensitivity has been related to the bonding agent used for composites, none has been linked to the sectional matrix.

OPTIONS FOR MATRIX SYSTEMS

The options for matrix systems are the circumferential band such as the Tofflemire; the sectional matrix from manufacturers such as Garrison Dental Solutions (Spring Lake, Michigan) and Danville Materials (San Ramon, California), and the Triodent system. The Triodent system has a number of advantages in that it is easy to use, it overcomes the difficulties associated with the wedge, the ring has very good retention, and the final outcome produces a very lifelike, natural restoration with minimal finishing.

In contrast, full circumferential bands can produce an adequate contact, but to achieve this the operator must wedge extremely hard. For this to be accomplished, rigid wedges, such as wooden wedges, are needed. Sometimes the wedges create dents in the matrix that show as a marked depression or notch on post-operative radiographs.

When considering wedging, many clinicians want the wedge to have two contrary functions: first, separate the teeth, and second, make the matrix conform to the cavity and seal the margins. Since the V3 rings separates the teeth so effectively, the function of the Wave-Wedge is primarily to seal the matrix on the cavity margins. Therefore it is a more flexible shape and has the feature of opening up once it has gone through the contact area.

INNOVATIVE ELEMENTS

The first innovative element found in the Trident system is that the V-shaped retaining ring is set over the wedge rather than next to it. The importance of this is that they do not compete for the interproximal space. This also enables the wedge to be manipulated. The wedge can be removed and replaced without taking the retaining ring off. In addition, the matrix is anatomically correct and allows the contact point to be at the correct height and the marginal ridge evenly achieved. There is actually more curvature on this matrix than other matrices. Also, the anatomically correct shape of the Wave-Wedge mimics the shape

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of the interproximal space. It has a blunt tip so that it does not skewer the gingival papillae on the exit side when it is being pushed through.

The Pin-Tweezers ease the manipulation of these small parts. Pin-Tweezers are auto-closing. There is a tab on the matrix that allows the dentist to bend it like a contra-angled handpiece so the matrix can easily be pushed in an apical direction. The Pin-Tweezers also permit the wedges to be held securely so that when they are passed from assistant to dentist they are not dropped on the floor. The dentist can also use the Pin-Tweezers to place the matrix on the back of the left hand and rotate it into the right orientation.

The V3 ring has a nickel-titanium spring has excellent physical properties to enable the correct separating force to be applied across a range of different tooth sizes. It is also autoclavable. Research shows that most rings survive at least 800 openings.

TREATMENT PLANNING

There is no difference in the treatment planning for the Trident system as opposed to other systems.

TREATMENT CONSIDERATIONS

Preparation Phase

The following is the author's preferred technique for class II composite restorations. Begin by placing a purple Wave-Wedge interproximally *before* preparing the cavity (Figure 10-12).

If a purple Wave-Wedge cannot be firmly pushed through, the next size down is used (pink or white). This has several benefits: (1) it totally protects the gingival col during prepping, (2) it controls moisture and bleeding, and (3) it forces the wedge to take up a good position below the contact point. If the contact point is removed first and then the wedge is placed, there is nothing to push the wedge down into its correct position, which may result in a contact point that is too high. Having a wedge in place during the cavity preparation also prevents burs from lacerating the interproximal rubber dam.

This technique also allows all the margins to be beveled without causing bleeding. The preferred instrument for handling the Wave-Wedge and matrix is Pin-Tweezers because they hold the item passively.

Once the cavity preparation is complete, the V3 Matrix can usually be slipped into position *without* removing the Wave-Wedge (Figure 10-13). If the matrix will not go in properly, the tab of the V3 Matrix is trapped against the neighboring tooth, and the Wave-Wedge is partially removed, and pushed back in again. This allows the matrix to slip into the correct vertical position to take full advantage of the marginal ridge shape.

Procedure

It is also important to select the correct-sized matrix. The V3 Matrix comes in three different heights—4.5 mm, 5.5 mm, and 6.5 mm. If the matrix will not set at the correct height, it is best to select a more appropriately sized matrix.

For placing the V3 Ring, there are a few tips worth noting. The author prefers to hold the Triodent forceps with thumb and middle finger and keep the index finger free to operate the locking bar. Triodent forceps should open the V3 ring

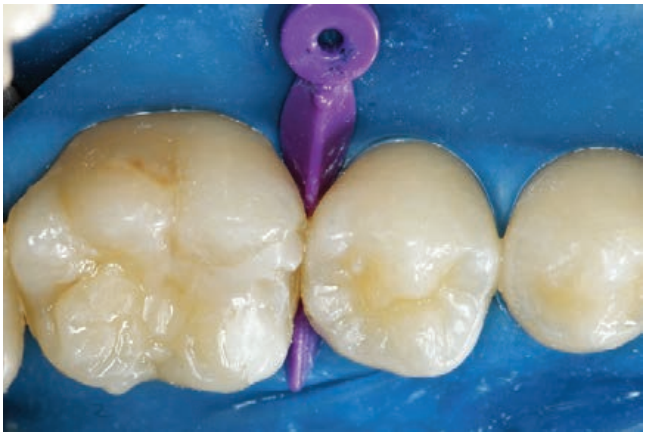


FIGURE 10-12 Purple Wave-Wedge placed before cavity preparation. Mesio-occlusal cavity in the first molar.



FIGURE 10-13 A, The V3 Matrix is slipped into position without removing the Wave-Wedge. B, Purple Wave-Wedge placed before cavity preparation. Mesio-occlusal cavity in the first molar.

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sufficiently to fit over the teeth, but not so far that the nickel-titanium spring could be damaged. One effective method is to position the tines over the Wave-Wedge on one side and then roll the forceps so that the other set of tines comes into position. It is essential to use a finger rest to steady the forceps. Before releasing the forceps, The author always places a finger above the restoration and press down to prevent any movement of the V3 ring as the forceps are released and removed (see Figure 10-13, *B*).

It is essential to carefully examine the matrix setup and ensure that it is correct. The goal is to achieve a seal around the cavity margin. Sometimes there is a gap between the matrix and the gingival margin of the cavity. This can be closed be either placing a second Wave-Wedge from the other side or by tugging the wing of the V3 Matrix with a probe.

One method of doing that is to take an explorer probe and place it into one of the lingual holes in the wings of the matrix, then push the matrix into the correct position (Figure 10-14). Sometimes it is necessary to release the strain on the spring.

This can be done by holding the forceps in the left hand and opening the spring just enough so that the matrix can be moved into its ideal position.

Finishing

On the finishing side, ideally the dentist should cure the composite, taking into account the C-factor, but that is beyond the scope of this chapter. Once the curing is complete, the V3 ring is removed and the bucco-lingual wings of the matrix are lifted. More curing from the buccal and lingual side may be needed if insufficient light reaches the proximal box. If this is not done, sometimes uncured composite adheres to the matrix, causing frustration.

Sometimes operators have difficulty removing the matrix and rip it. The best thing to do is to use a probe or flat plastic instrument and slide it between the matrix and the restoration. This peels the matrix away from the composite. The author suggests testing to make sure the matrix is free by trying to rotate it around the contact point. If it does not rotate, it must be still bonded to the restoration. Great care must be taken when removing the matrix so that it does not injure the papillae.

Re-creating an anatomically accurate marginal ridge is beneficial not only because it mimics nature, but also to reduce the

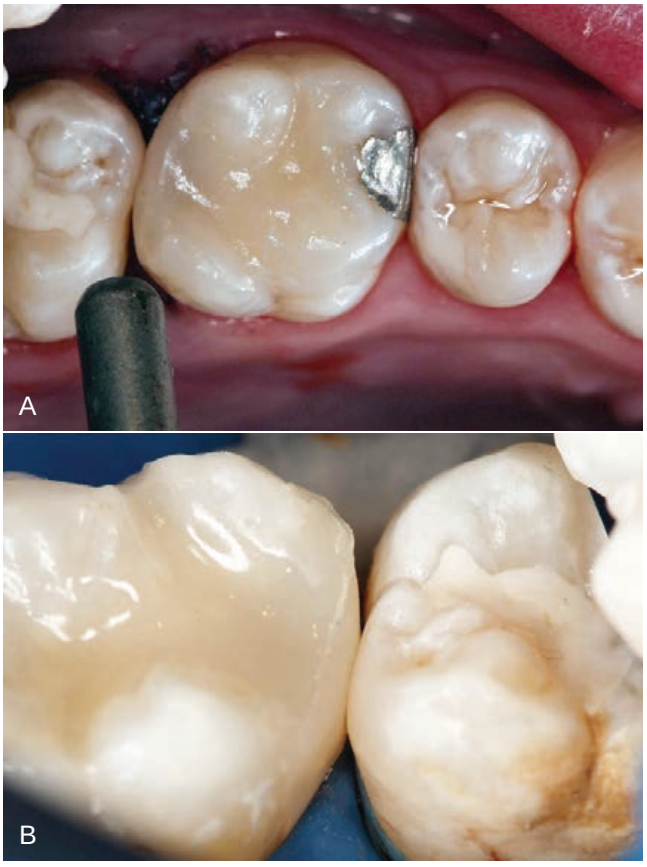


FIGURE 10-15 Minimal finishing to complete the marginal ridge.

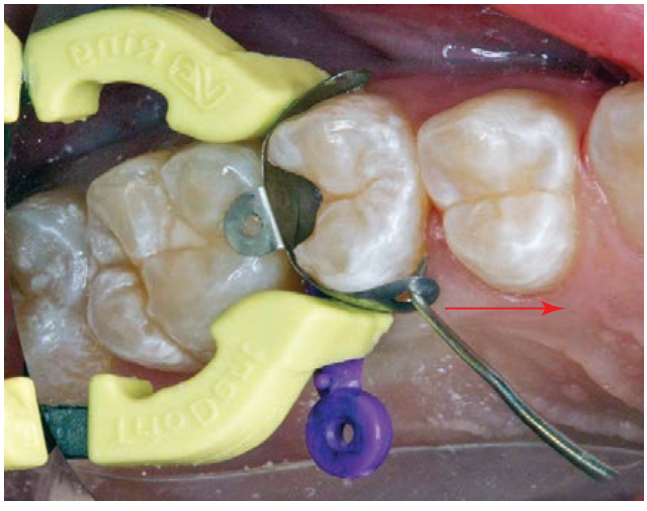


FIGURE 10-14 In this case, the matrix is adjusted by pulling the wing mesially.

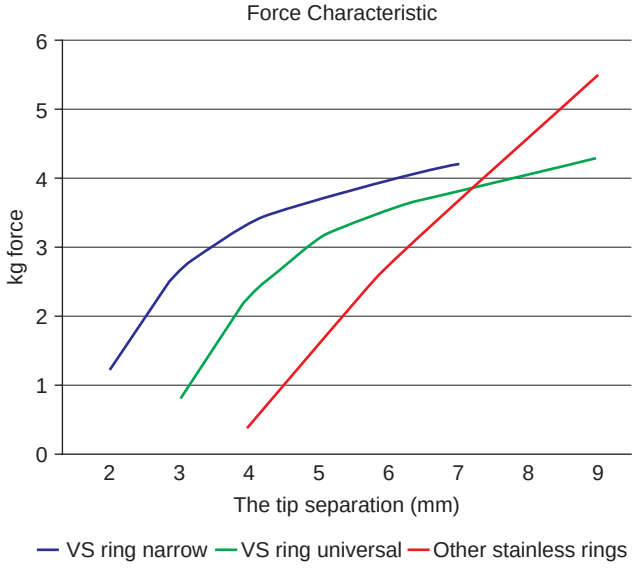


FIGURE 10-16 Force characteristic.

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chance of the marginal ridge chipping and to assist the patient when using floss. However, a good marginal ridge is difficult to create with conventional matrix bands. The V3 Matrix has addressed this issue and has a marginal ridge shape built into it (Figures 10-15 and 10-16).

EVIDENCE-BASED PRINCIPLES

One main principle behind the success of matrix systems is the separating effect caused by the ring. The teeth must be separated more than the thickness of the matrix material itself. Another is the realization that the circumferential band can push the tooth in the wrong direction, leading to a nonexistent contact once that has been removed. Nickel-titanium has the characteristic of maintaining an almost ideal force over a wide range of uses.

As mentioned earlier, the author believes that the ideal separating force is around 3 to 4 kg. The graph shows that the "other stainless ring" is in this ideal region for only a narrow band between 6.3 mm and 7.5 mm of extension, whereas the two V3 Rings generate 3 to 4 kg of force through an opening range (together) of 3 mm to 8 mm. So the clinical significance of the flattened curve is that the V3 rings generate the ideal amount of force over a wide range of use (see Figure 10-16).

In conclusion, this chapter has attempted to cover the essential techniques that turn one of the most frustrating common dental procedures to something easily managed.

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CHAPTER 11

Polishing

SECTION A

Current Technology and Clinical Approaches to Polishing of Dental Restorations

Steven R. Jefferies

RELEVANCE TO ESTHETIC DENTISTRY

Effective finishing and polishing of dental restorations not only result in optimal esthetics but also provide for the improved oral health of soft tissues and marginal integrity of the restorative interface. Some difficulties result from improperly finished and polished restorations, including increased plaque accumulation, irritation of the gingival tissues, increased surface staining, and unacceptable esthetics of the restored teeth.

Practitioners are encouraged to take the time and effort to adequately finish and polish restorations. The clinical and scientific rationale for this approach is as follows:

1. Removes restorative marginal excess and refines the margins of the restoration
2. Reduces the risk of fracture, because a rough surface is more likely to fracture
3. Reduces surface imperfections, hence diminishing surface area and the risk of surface breakdown and corrosion
4. Produces a smooth surface that is less likely to retain plaque
5. Improves oral function and mastication, because food slides more easily over polished tooth surfaces
6. Produces smooth surfaces that facilitate oral hygiene procedures, allowing access to all surfaces, marginal areas, and interproximal areas with normal toothbrushing and use of dental floss
7. Produces smooth restoration contacts, leading to less wear on opposing and adjacent teeth
8. Yields a more esthetic, naturally light-reflecting restoration

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Finishing and polishing procedures have existed since the beginning of modern restorative procedures. Diamond burs were used before tungsten carbide burs; their applications in margination, finishing, and polishing were integral. As demands for surface smoothness and esthetics have increased, loose-abrasive slurries and pastes have also evolved. Concurrent with loose-abrasive pastes, bonded abrasives consisting of rubberized abrasives were developed for both the finishing and the polishing steps. Coated abrasive disks, with very low abrasive particle sizes, are also effective for final polishing steps. Various grits of sandpaper on paper disks were initially used, but over the last three or four decades, coated abrasive disks bonded to Mylar or other thin-film plastic or polymer substrates have become available.

Most dental finishing and polishing devices operate in the two-body mode, a harder material abrading a softer material. Nevertheless, dentist, hygienists, and laboratory technicians often use loose abrasives, that is, the "three-body abrasive mode," in the form of prophy or polishing pastes. A three-body abrasive wear situation exists when loose particles move in the interface between the specimen surface and the polishing application device. Such a situation occurs when abrasives are intentionally deposited to roll on the surface of the polishing substrate. A three-body mode may also occur when small pieces of material are detached from the specimen to be polished and become trapped, or circulate, within the contact between the two first bodies. Figure 11-1 further illustrates how the various dental finishing and polishing procedures fall within these two basic tribologic mechanisms.

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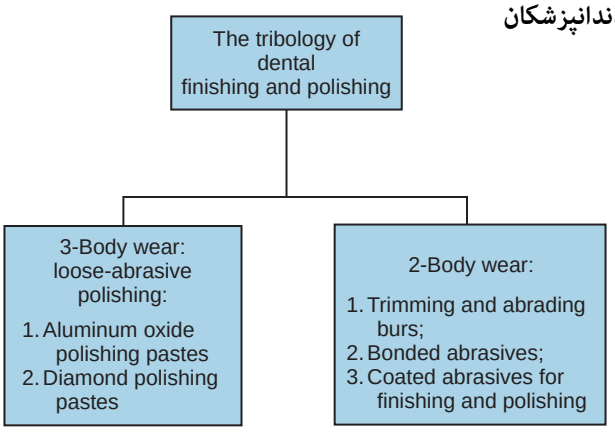


FIGURE 11-1 **Finishing and polishing procedures in restorative dentistry follow tribologic principles of abrasive wear in both two-body and three-body configurations—that is, two-body wear devices in which the abrasive particle is surface bound or impregnated within a contacting substrate, or three-body wear-abrasive situations in which loose-abrasive particles act at and in the interface between the surface of the restorative material and a polishing applicator or pad.** *(From Jefferies SR: Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review,* Dent Clin North Am *51:379, 2007.)*

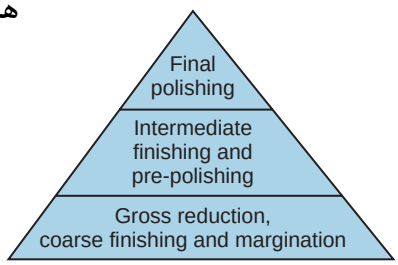


FIGURE 11-2 **Finishing and polishing of dental restorative materials encompass a progression of steps from gross reduction and contouring to final polishing. The triangle representation reflects empirical observations regarding the relative amount of time and effort spent on each segment of the process; the recent increasing emphasis on esthetics and surface polish may result in greater time and attention to final polishing procedures.** *(From Jefferies SR: Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review,* Dent Clin North Am *51:379, 2007.)*

RELATING FUNCTION AND ESTHETICS

Effective finishing and polishing of dental restorations not only produces optimal esthetics but also improves the oral health of the soft tissues and the marginal integrity of the restorative interface. Proper finishing and polishing of posterior esthetic restorations, especially certain classes of tooth-colored composite resins, may also affect the rate of occlusal wear and loss of surface material. Alternatively, proper finishing of ceramic and ceramic porcelain restorations can reduce accelerated wear of the opposing enamel.

CLINICAL CONSIDERATIONS

Indications

The polishing process is carried out after the finishing and margination steps of the finishing procedure to remove minute scratches from the surface of a restoration and to obtain a smooth, light-reflective luster. The polishing process is also intended to produce a homogeneous surface with minimal microscopic scratches and defects.

Finishing and polishing in restorative dentistry, as illustrated in Figure 11-2, involve the steps of (1) performing gross contouring of the restoration to obtain the desired anatomy, (2) reducing and smoothing the surface roughness and scratches created by finishing instruments in the process of gross reduction and initial polishing, and (3) producing a highly smooth, light-reflective, enamel-like surface.

Contraindications

Although there are no specific contraindications to finishing and polishing, use of conventional rubber prophy cups is contraindicated when fine polishing pastes are used with composite resin and ceramic restorative materials. Another consideration is the nature of the filler component of the composite resin and its effect on polishing efficacy. Classic microfills, which contain organic-based fillers, do not benefit from loose-abrasive polishing paste. Use of coated abrasive fine and extra-fine disks appears to be optimal. Likewise, hybrids containing zirconia-based filler systems appear to not benefit as much, in terms of final surface luster, from the application of aluminum oxide–containing, loose-abrasive polishing pastes, compared with barium glass-filler–based hybrid composite resin. The coated abrasive disks appear optimal for final polishing of these zirconia-based hybrid composite resin restoratives.

MATERIAL OPTIONS

Coated Abrasive Finishing and Polishing Disks and Strips

Coated abrasive disks and strips are made by bonding abrasive particles into a thin polymer or plastic backing. Finishing and polishing disks are used for gross reduction, contouring, finishing, and polishing restorations. The thin layer of abrasive present on these disks remains effective for a limited period of clinical use, making these disks single use and disposable. Most are coated with an aluminum oxide abrasive, but silicon carbide, garnet, emery, and quartz (cuttle) abrasives are also used. A sequence of grits is applied, starting with a coarser grit and

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finishing with a superfine grit. Coated abrasive disks and strips are especially useful on flat or convex surfaces. They work well especially on anterior restorations, such as the incisal edges and embrasures, and to a limited extent on posterior composites, especially on interproximal and some buccal and lingual areas. Coated finishing and polishing disks have limited utility on posterior occlusal and concave anterior lingual areas. These areas are better addressed with bonded-abrasive points and cups, including the newer abrasive-impregnated brushes.

A number of studies have documented the effectiveness of coated abrasive disk systems. The particle size distributions for coated abrasive disks vary from 100 to 55 µm for coarse-grade finishing disks to 7 to 8 µm for the ultra- or super-fine grade of finishing disk. Coated abrasive disks can finish and provide pre-polishing and polishing action for a wide range of restorative materials. Some studies indicate that coated abrasive disks are particularly effective for finishing traditional microfill composite resin materials.

Coated abrasive disks are available from a number of manufacturers. Some of these products include the EP Esthetic Polishing System (Brasseler USA, Savannah, Georgia), FlexiDisc (Cosmedent, Inc., Chicago, Illinois), Moore-Flex polishing system and Moore silicon carbide disks (E.C. Moore, Dearborn, Michigan), OptiDisc, (Kerr Corporation, Orange, California), Sof-Lex Finishing and Polishing System (3M ESPE, St Paul, Minnesota), and Super-Snap system (Shofu Dental Corporation, San Marcos, California).

Rubber Wheels, Cups, and Points

Rubber polishing instruments are used to finish, smooth, and/or polish composites. These finishing and polishing instruments are abrasive instruments based on fine or ultra-fine hard, abrasive particles dispersed and held in a softer, elastic matrix. The various configurations of these flexible or rubber finishers and polishers complement the access limitations of the coated abrasive disks for areas such as anterior lingual and posterior occlusal surfaces. Shapes, with varying sizes and dimensions, include disks, wheels, cups, and points. Figure 11-3 depicts the wide range of different types of bonded and elastomeric finishers and polishers available. They are often sold as kits with a variety of shapes and grits to accommodate the differing tooth dimensions and contours seen in clinical practice. Flexible, bonded-abrasive devices are made by molding abrasive particles, of varying particle size and size distribution, in an elastomeric matrix. The elastomeric matrix can be a natural or synthetic rubber, silicone, or other synthetic elastic polymer. One system uses a "urethane" elastic polymer in which a wide range of abrasive particles can be dispersed, including aluminum oxide and diamond.

Molded or bonded elastomeric abrasives come in a variety of grits, sizes, shapes, and firmnesses. These elastomeric, bonded abrasives are usually molded to a latch-type mandrel for slow-speed handpieces. The mandrels are constructed from both stainless steel and high-strength plastic. Some of these products are fabricated to be reusable after sterilization. The abrasives used within these instruments usually comprise silicon carbide, aluminum oxide, diamond, silicon dioxide, and zirconium oxide. The particle size distributions typically range from about 40 µm for an elastomeric aluminum oxide finishing device to 6 µm for elastomeric "rubber" diamond polishing instruments.



FIGURE 11-3 The wide diversity of elastomeric or rubberized abrasive rotary finishing and polishing devices. Coarser finishing and pre-polishing devices are on the top row; polishing devices are aligned on the lower row of the illustration. *(From Jefferies SR: Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review,* Dent Clin North Am *51:379, 2007.)*

Some of these instruments may be useful in intermediate finishing and in anatomic contouring, as well as pre-polishing. Recent studies have evaluated the efficacy of various bonded, elastomeric abrasive finishers and polishers. Some of the commercial finishing and pre-polishing devices (including complete finishing-polishing systems) evaluated include Astropol (Ivoclar Vivadent, Amherst, New York); Comprepol and Composhine (Diatech, Dental Inc., Charleston, South Carolina); Enhance system (DENTSPLY Caulk, Milford, Delaware); FlexiCups (Cosmedent Inc.); Identoflex Points (Identoflex AG, Buchs, Switzerland); Identoflex (Kerr Corporation); Silicone Points C type (Shofu Dental Coporation).

Other diamond-containing elastomeric or rubber-like rotary devices have been introduced more recently for use in finer pre-polishing or final polishing. There appears to be a range of effectiveness in the ability to produce smooth surfaces on direct restorative materials. Diamond-impregnated polishers are particularly effective, with many one- and two-step polishing device systems reaching surface smoothness comparable to that of multi-step, coated-abrasive disk systems. Such diamond one-step polishers include CompoMaster (Shofu Dental Coporation) and PoGo (DENTSPLY Caulk).

Diamond-containing polishing devices produce more frictional heat than other bonded-abrasive devices; heavy pressure must be avoided to minimize the surface temperature rise. A significant increase in temperature can potentially be deleterious to the restoration as well as the tooth itself.

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Loose-Abrasive Polishing Pastes and Rotary Applicator Devices for Loose Abrasives

Loose-abrasive polishing pastes are used extensively in industrial and scientific applications. In the three-body, loose-abrasive polishing process, the loose-abrasive wear induces cutting and plowing on a micrometer and nanometer scale. Following the example from other industrial and scientific disciplines, dentists have used loose-abrasive finishing and polishing compositions for several decades. Loose-abrasive polishing pastes, used in dental applications, are predominantly based on dispersed and suspended ultra-fine aluminum oxide or diamond particles. Aluminum oxide polishing pastes are usually glycerin based, with a mean particle size distribution of 1 µm or less. Diamond polishing pastes also use a glycerin-based material but with a larger mean particle distribution—10 µm to less than 1 µm. Two diamond polishing pastes contain mean sizes of diamond particles on the order of 4 to 6 µm and less than 1 µm. In a study examining the surface morphology and smoothness of the transition from a glass-ceramic insert to a bonded composite resin interface, samples finished with a sequence of progressively smoother diamond abrasive finishing burs (45 µm, 25 µm, and 10 µm), followed by polishing with first a 4- to 6-µm–grit diamond polishing paste and then a sub-micron diamond polishing paste, exhibited the smoothest transition from composite resin to insert. Of perhaps equal importance, studies and research findings have indicated that the mode of application and the structure and the composition of the applicator device can be as important as the composition of the paste used in the polishing procedure. Although the commonly used method for applying polishing paste is the flexible rubber prophy cup, surface roughness data strongly suggest that such a mode of application results in *increased* surface roughness, or at best no improvement in surface smoothness. On the other hand, use of soft foam or felt applicators can significantly improve the efficacy of loose-abrasive polishing paste, especially those pastes containing aluminum oxide as the abrasive agent. Surface roughness decreased by 50% when a 1-µm aluminum oxide polishing paste was applied with a porous synthetic foam cup ($R_a \cong 0.10$),* as compared with application of the same paste with a conventional rubber prophy cup ($R_a \cong 0.20$).

Figure 11-4 depicts visually the wide range of types and sizes of both felt and foam polishing paste applicators that are best for loose-abrasive polishing of dental restorations. These applicators can be used with both aluminum oxide–based and diamond-based polishing pastes.

The technique or mode of application of the polishing paste is also critical. Based on polishing applications in the scientific and industrial fields, it is recommended to frequently renew the pad (with fresh polishing paste) and to keep it always wet in order to avoid crystallization of the colloidal contaminants (such as silica), which can produce scratches. In fact, polishing pastes can probably act both in a more aggressive, pre-polishing or finishing mode when applied in a dry, anhydrous condition and in a polishing mode with the addition of water, facilitating finer abrasive action at nanometer levels on the treated surface. In this mode, polishing pastes tend to produce greater specular reflectance, which in turn produces a higher visual surface gloss.

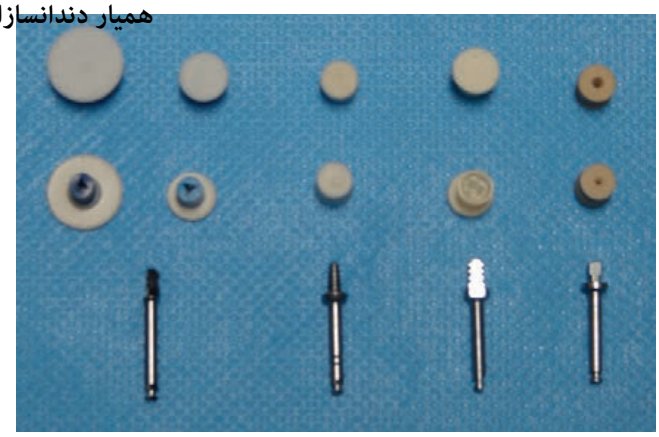


FIGURE 11-4 Synthetic and natural foam or felted polishing paste rotary applicators provide for a more efficacious and efficient final polishing step using loose-abrasive polishing pastes. Synthetic and natural felt applicators appear on the left and center of the photograph; synthetic foam cup applicator appears on the far right. *(From Jefferies SR: Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review,* Dent Clin North Am *51:379, 2007.)*

With respect to the comparative efficacy of polishing pastes as a method for final polishing of composite resins, several investigations report favorable results in producing highly smooth, light-reflective surfaces. These studies involved the use of both conventional diamond-stylus contact profilometry and non-contact, three-dimensional surface profile analysis. A differential benefit of polishing paste on various restorative materials has also been noted, with optimal benefits on a sub-micron, highly filled hybrid material and surface smoothness equivalent to several commercially available bonded-abrasive diamond polishing instruments (without the use of polishing paste). The benefit of using a loose-abrasive, aluminum oxide polishing paste after using sequential, aluminum oxide–coated abrasive disks for finishing and pre-polishing has also been noted. One investigation has demonstrated that sequentially applied aluminum oxide polishing pastes produce a visually smooth and light-reflective surface on microfill and small-particle hybrid composites, directly after the sequential use of 12- and 30- to 40-fluted carbide finishing burs. With very careful technique, a finishing-polishing sequence from multi-fluted carbide burs to sequential polishing pastes is feasible. It is advisable to introduce intermediate finishing and pre-polishing devices (coated disks; rubber-like, bonded abrasives) between high-speed contouring-finishing burs and diamonds before applying polishing pastes for both composite and porcelain restorative materials.

*R_a stands for "average surface roughness," which is defined as the arithmetic mean of the absolute values of the profile departures within the sample or evaluation length being measured.

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Advantages

Multi-step polishing using both bonded-abrasive devices and loose-abrasive polishing provides the best final polish, with optimal longevity. Alternatively, polishing with diamond or other abrasive elastomeric, bonded abrasives is quick and eliminates the use of loose-abrasive polishing pastes.

Disadvantages

Loose-abrasive polishing is time-consuming and technique sensitive. The exclusive use of bonded-abrasive polishing points, cups, and disks usually provides a less-than-optimal surface polish, compared with the proper use of loose-abrasive polishing pastes. Nevertheless, these bonded-abrasive polishing devices eliminate the splatter that can be associated with the use of loose-abrasive polishing paste.

Current Best Approach

Although the pursuit of a one-step polishing device has been a major focus in product development in this area, optimal polishing and surface preparation involves multiple devices, moving from more aggressive or abrasive instruments to finer, less abrasive instruments or materials. Before the polishing steps, gross and intermediate deduction and finishing instruments ranging from fine and extra-fine micron diamonds, multi-fluted carbide finishing burs, and bonded-abrasive, rubberized finishing devices—applied in the that sequential order—are used. Optimal polishing is then obtained by sequential application of 1- and 0.3-micron aluminum oxide polishing pastes, applied with a felt or synthetic foam cup or rotary application device. An alternative approach involves the use of an elastomeric diamond polishing disk, cup, or point, which may be used exclusively or in a sequence before application of polishing pastes.

OTHER CONSIDERATIONS

Technique considerations are important in effective finishing and polishing. Although the emphasis has been placed on fewer steps and devices to reduce time and motions in the finishing and polishing procedure, experience and basic principles of tribiology indicate that a certain number of sequential steps are needed to prepare the surface for polishing and the polishing procedure. With both loose-abrasive and bonded-abrasive polishing, the technique of application and the steps before polishing are critical.

INNOVATIVE ELEMENTS

Scientific and Technological Elements

The recent innovations in polishing have included the introduction of alternatives to rubber cups for the application of polishing pastes. These include felt and synthetic foam devices. In addition, numerous diamond-based, flexible, bonded-abrasive polishing devices are now available as alternatives to loose-abrasive polishing pastes.

Artistic Elements

Optimal finishing and polishing procedures can produce the highly light-reflective, enamel-like surface that is required for optimal esthetics. One major objective of the pre-polishing and final polishing steps is to achieve a surface reflectance and appearance similar to that of natural enamel. The average surface roughness (R_a) of human enamel polished with 1200-grit aluminum oxide rotary polishing disks ranges from 0.05 to 0.03 µm—a very high level of surface smoothness. For a light reflectivity similar to that of native tooth enamel on the surface of a composite resin restorative, the final average surface roughness (R_a value) of a composite resin needs to be below an R_a value of 0.15 µm (traditional microfills), and preferably at or below 0.12 µm for sub-micron hybrid composite resins.

TREATMENT CONSIDERATIONS

Preparation

It is important to use and evaluate a number of finishing and polishing devices to determine the optimal number, proper sequence of instruments and devices, and mode of application.

Procedure

Always consult literature references and review articles. Finishing and polishing procedures involve an orderly sequence of steps that progressively refine and smooth scratches and defects introduced during the initial gross reduction step. With respect to gross reduction of composite resin materials, it is now generally accepted that fine and extra-fine finishing diamonds are used first, followed by carbide multi-fluted finishing burs. The next step of intermediate finishing is a critical bridge between gross reduction and final polishing. Commonly used intermediate finishing and pre-polishing devices include rubber-like, elastomeric bonded abrasive, in cup, disk, and point configurations. Medium, fine, and extra-fine coated abrasive disks from various manufacturers also provide intermediate finishing options, especially for facial and interproximal embrasure locations. After use of one to three of these various intermediate finishing devices, the next step is final polishing of the restoration. The specific steps and procedure for final polishing will be considered in the case presentation later. Nevertheless, the practitioner needs to experiment at the bench with various finishing and polishing devices and the composite resin and ceramic restorative materials used in routine clinical practice. It is advisable to practice with various devices on cured samples of various restorative materials to work out the efficient used and sequence of these devices and products.

EVIDENCE-BASED PRINCIPLES

Plaque accumulation on various restorative materials appears to increase when average surface roughness (R_a) values exceed approximately 0.2 µm. Surface gloss and reflectance on the

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surface of a restorative material require R_a values below 0.2 µm.

CLINICAL CONSERVATION CONCEPTS

When finishing and polishing tooth-colored restorative materials in a conservative, adhesive restorative procedure, finishing and polishing adequately at the enamel interface is critical to optimal esthetics. It must eliminate, as much as possible, the visual distinction between the restoration and the retained tooth structure.

MAINTENANCE

Repolishing of esthetic restorations during routine hygiene procedures can be highly beneficial but is underused. Dental hygienists should be provided with additional armamentarium, as described in this chapter, to provide optimal esthetic and functional maintenance of tooth-colored restorations.

CONTROVERSIES

Although finishing and polishing are not commonly thought as an area of significant controversies, there are several issues in this area that provide for debate and discussion. Some of these questions under debate on this topic are as follows:

1. Why do I need to polish the restoration, as after contouring and some intermediate finishing, the "wet" restoration looks esthetic?
   As has been cited in this discussion, adequate polishing brings the surface of the restoration to a surface smoothness that limits plaque accumulation and enhances the surface reflectivity to match that of native enamel.
2. Is a one-step polishing device approach truly effective and beneficial in all situations?
   Limiting the number of devices one routinely uses can produce a less-than-optimal surface and also works against efficiency and delivery effectiveness.
3. Why are polishing devices (rubber discs/cups/points and or polishing pastes) necessary? I often use them without much effect on the surface gloss of the restoration?
   By expanding their knowledge of the action of various finishing and polishing devices, clinicians can decisively and quickly choose the proper instrument in a given situation.
4. Are the fastest and easiest procedures the most beneficial?
   Finally, there doesn't yet exist a finishing or polishing device that provides the full range of both finishing and final polishing action. Hence, we examine various combinations of devices that provide adequate finishing and provide sufficient smoothness on the restoration surface to achieve an effective transition to various polishing instruments, thus achieving an optimally polished surface.

NEAR-FUTURE DEVELOPMENTS

Recent New Technology in the Realm of Dental Finishing and Polishing

Although most new products in the dental finishing and polishing area are incremental improvements in existing products, new designs or abrasive compositions periodically appear.

Abrasive-Impregnated Brushes and Felt Devices

Abrasive-impregnated, latch-type polishing brushes were introduced to the profession in the late 1990s. These polishing brushes are provided in several shapes (pointed; cup shaped), with various types of polymer "bristles" impregnated with different abrasive polishing particles. The brushes are intended to reach into the grooves, fissures, and interproximal areas of ceramic and resin composite restorations, areas that cannot be reached with other finishing or polishing devices without unintentionally removing anatomic grooves, fissures, and contours. Several of these brushes are depicted in Figure 11-5. Aschmann and colleagues (U.S. Patent 6,312,257) describe a "brush for surface treatments in restorative dentistry [that] comprises one or several lamellar abrasive elements." Dubbe and colleagues (U.S. Patent 6,554,614) describe "a brush for a dental handpiece … wherein at least some of the bristles comprise an elastomeric material and a number of abrasive particles distributed



FIGURE 11-5 A recent technologic development in restorative polishing involves abrasive-impregnated brushes, which are depicted in this photograph. The three abrasive brushes from left to right contain diamond particles as the abrasive. The brush on the far right contains silicon carbide. *(From Jefferies SR: Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review,* Dent Clin North Am *51:379, 2007.)*

همیار دندانسازان و دندانپزشکان

throughout the elastomeric material." The particulate abrasive used in the Sof-Lex Brush (3M ESPE, St Paul, Minnesota) is aluminum oxide.

A precursor to this specific abrasive-impregnated brush technology was the diamond-impregnated felt wheel for polishing hybrid composite resin. These wheels effectively smooth the surface of a hybrid composite resin after initial finishing with various sequences of high-speed diamond burs, tungsten carbide finishing burs, or combinations of diamond and carbide finishing burs. An early report on these new polishing devices described a new polishing brush composed of rigid polycarbonate fibers impregnated with silicon carbide abrasive particles (Occlubrush, Hawe-Neos; now Kerr Corporation, Orange, California). The investigators found that the silicon carbide–impregnated bristle polishing brush maintained surface texture during the polishing procedure, produced a composite surface smoothness somewhere between that created by a 25-µm finishing diamond and an extra-fine coated abrasive disk, achieved a surface luster subjectively greater than an extra-fine coated abrasive disk (on both composite resin and enamel), could be reused with autoclaving up to 15 to 19 times, and was no more deleterious to enamel surface quality or restoration marginal quality than a 25-µm finishing diamond.

More recently, a few in vitro evaluations have assessed the polishing efficacy of these abrasive-impregnated polishing brushes. Yap and co-workers evaluated the residual surface roughness after using the Sof-Lex Brush and found that it produced a smooth, polished surface comparable to that achieved with a rubber or bonded-abrasive diamond polishing device. Venturini and colleagues evaluated a silicon carbide–impregnated polishing brush (Jiffy Polishing Brush, Ultradent Products, South Jordan, Utah) after finishing and pre-polishing with sequential rubber polishing cups (FlexiCups, Cosmedent, Inc.). They found a high level of surface smoothness in both microfilm and hybrid composite resins after polishing with this impregnated brush using both the immediate and the delayed polishing technique. This polishing device design is interesting in its approach to providing improved "micro-access" for bonded-abrasive polishing. Further laboratory and clinical evaluations are needed.

Rotary Resin-Matrix Stain, Cement, and Composite Removing Devices

Several rotary devices based on a polymer or composite resin binder or matrix, with apparent "controlled" abrasivity, have recently been introduced to selectively remove surface-adherent restorative materials, including composite resin and residual cement (Figure 11-6). Among this new class of abrasive devices is Flashbuster (Danville Materials, San Ramon, California), a latch-type, rotary composite fiber bur that is claimed to remove residual composite with no damage to either enamel or porcelain. It can also remove residual orthodontic adhesive and stains from areas with limited access and can be used in periodontal root planing. The structure of the rod bur consists of fibers and particles embedded in a resin matrix. This yields a working surface that has continuous abrasive power.

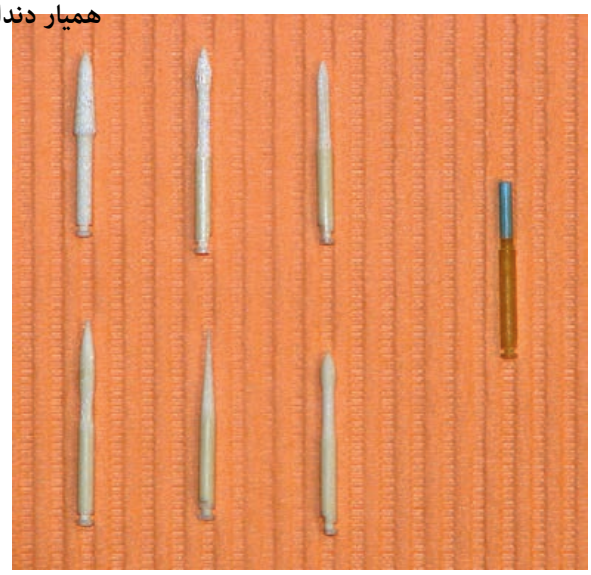


FIGURE 11-6 **Newer rotary devices have broadened the range of indications for finishing and polishing devices. The white, fiber-impregnated polymer rotary burs have been suggested and indicated for "minimally" abrasive action—that is, stain removal and selective composite removal. The blue rotary bur *(right)* is suggested for removal and cleaning of temporary cement on tooth preparations before final cementation.** *(From Jefferies SR: Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review,* Dent Clin North Am *51:379, 2007.)*

It can be used for cleaning and polishing the surface of teeth and/or composite materials of dental fillings. The embedded fibers are made from a glass enriched with zirconium oxide, making the instrument highly resistant to alkaline and acidic agents and detectable by electromagnetic radiation.

OptiClean (Kerr Corporation) is a latch-type rotary bur composed of aromatic polyamide containing 40-µm aluminum oxide. OptiClean is intended for the removal of temporary cement and debris on tooth preparations before final cementation. Therefore it replaces other methods of preparation surface cleaning, such as a rubber cup and pumice or the use of hand instruments.

Both of these products await further independent studies and evaluations before their performance can be fully understood.

CLINICAL TECHNIQUES

Patient History

The patient is treatment planned to receive a class I posterior occlusal composite resin restoration on the lower right second molar.

Relevant Conditions

Technique photos demonstrate both the use of diamond, bonded-abrasive devices and the application of loose-abrasive polishing pastes, after initial gross reduction and finishing procedures.

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FIGURE 11-7 **A,** An appropriate device for the optimal application of aluminum oxide polishing pastes—namely a porous, synthetic foam cup in a low-speed handpiece. **B,** The initial application of the 1-micron, aluminum oxide polishing paste (Prisma Gloss). Note that the porous surface of the synthetic foam polishing cup eliminates the need to carry excess paste; the paste is carried in the surface porosities of the foam cup. **C,** The flexibility of the synthetic foam polishing cup to adapt to the contour of the occlusal surface during the application of the loose-abrasive polishing paste. **D,** The important next step in the proper use of loose-abrasive polishing pastes. After dry polishing with the undiluted polishing paste, small, incremental amounts of water are applied to the surface of the restoration. **E,** Rotary re-application of the polishing paste to the wet surface. The diluted paste is applied in a continuous motion over the entire restoration. The application of water somewhat dilutes the paste and decreases the coefficient of friction at the restoration surface, producing a high level of polishing action on the surface. **F,** The smooth, uniform surface of the class I occlusal composite restoration on the lower right second molar.

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Treatment Planning Process

Small to moderately sized class I occlusal cavity preparations are appropriate for restoration with composite resin materials. This patient was treatment planned for caries excavation and cavity preparation for an occlusal, Class I composite involving this lower second molar. Size of the restoration is a critical consideration in the use of direct placement composite resin in molar teeth, especially lower second molar teeth. The size of this cavity preparation is appropriate for the use of direct composite resin.

Clinical Step by Step

Step 1 (not shown): Using fine and micro-fine finishing diamonds and multi-fluted carbide, gross excess of the composite resin is removed, avoiding excessive contact with or damage to the enamel portion of the restoration margin. The marginal areas (and selected occlusal areas) of the class I composite restoration are carefully trimmed and finished using an aluminum oxide–containing bonded-abrasive finishing point or cup. The occlusion is checked and adjusted with fine and extra-fine diamonds, multi-fluted finishing burs, and the elastic bonded-abrasive finishing cups, points, and/or disks.

Step 2: Figure 11-7, *A*, illustrates an appropriate device for the optimal application of aluminum oxide polishing pastes—namely, a porous synthetic foam cup in a low-speed handpiece.

Step 3: Figure 11-7, *B*, illustrates the initial application of the 1-micron aluminum oxide polishing paste (Prisma Gloss, DENTSPLY Caulk). Note that the porous surface of the synthetic foam polishing cup eliminates the need to carry excess paste; the paste is carried in the surface porosities of the foam cup.

Step 4: Figure 11-7, *C*, illustrates the flexibility of the synthetic foam polishing cup to adapt to the contour of the occlusal surface during the application of the loose-abrasive polishing paste. A critical element in the polishing paste procedure is the rotary application of the polishing paste *dry* (without water) in a continuous motion over the surface of the restoration. Application times of 30 to 60 seconds are sufficient for this step.

Step 5: Figure 11-7, *D*, illustrates the important next step in the proper use of loose-abrasive polishing pastes. After dry polishing with the undiluted polishing paste, small, incremental amounts of water are applied to the surface of the restoration and tooth, followed by rotary re-application of the polishing paste to the wet surface (Figure 11-7, *E*). The diluted paste is applied in a continuous motion over the entire restoration. The application of water somewhat dilutes the paste and decreases the coefficient of friction at the restoration surface, producing a high level of polishing action on the surface and producing the highly light-reflective surface. Time of application for this "wet-polishing" step is anywhere from 30 to 60 seconds, or, in anterior restorations, until a highly light-reflective surface is produced.



FIGURE 11-8 **Final polishing can alternatively be accomplished using a diamond-impregnated, elastomeric (rubber-like) polishing cup. The cup is applied with light pressure, using continuous sweeping movements over the occlusal surface of the restoration. Avoid excessive pressure when using diamond-impregnated polishing devices, as excessive heat buildup is a likely result.**

Step 6: Figure 11-7, *F*, illustrates the smooth, uniform surface of the class I occlusal composite restoration on the lower right second molar.

Alternative Procedure

As depicted in Figure 11-8, final polishing can, alternatively, be accomplished using a diamond-impregnated, elastomeric (rubber-like) polishing cup (PoGo, DENTSPLY Caulk). The cup is applied with light pressure, using continuous sweeping movements over the occlusal surface of the restoration. Avoid excessive pressure when using diamond-impregnated polishing devices, as excessive heat buildup is a likely result. Application of these devices requires 60 to 120 seconds of continuous motion, with light pressure, to produce a highly smooth, light-reflective surface. If additional polishing is desired, application of a loose-abrasive polishing paste (as described earlier in steps 2 through 6), after use of the polishing cup, can be done.

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SECTION B

Finishing and Polishing

Sibel Antonson

The term *finishing* refers to obtaining a smooth surface on a restoration. The smoothness ensures that the surface will not retain plaque and pathogenic bacteria and implies elimination of protrusions or sharp edges and corners that can harm the opposing tooth and adjacent soft tissues as well as affect the longevity of the restoration. The goal is to make the transition from the tooth surface to the restoration surface seamless, and the finishing procedure provides that result.

Polishing refers to bringing the surface luster out. At times the term *polishing* also includes maintaining certain artistic surface characteristics, such as intentional micro-scratches on the restoration surface to simulate the irregular texture of the adjacent teeth's enamel surface. Functionally, perfect finishing may be unnecessary, because esthetically the dentist is trying to achieve a result that simulates the natural environment (Figure 11-9).

RELEVANCE OF FINISHING AND POLISHING TO ESTHETIC DENTISTRY

It is important to start with the end result in mind—what goal is the dentist trying to achieve? Generally, the dentist seeks either to augment tissue that has been lost because of pathology, such as caries, erosion, or abrasion, or to achieve esthetic or functional re-contouring. This may involve closing a space or realigning teeth by using direct or indirect restorations. The ultimate objective is to be able to mimic nature as closely as possible and also achieve the best esthetic and functional outcome, whether it be better shape, better occlusion, or enhanced facial features. Simulation of the natural appearance can be achieved by mimicking the final surface texture of the enamel, which is lustrous and smooth with striations, unless it is defective because of the effects of pathology, erosions, abrasions, or fractures.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF FINISHING AND POLISHING

One of the earliest materials used in finishing and polishing was sand. Techniques then evolved and became more sophisticated with respect to the use of various natural and synthetic abrasives. However, the major principle is that one must use an abrasive material that is harder than the substrate in order to eliminate surface roughness. For example, diamond is one of the hardest materials in existence and is certainly harder than enamel and much harder than resin composite systems, or even some ceramics. By applying a harder substance on a softer substrate, it is possible to eliminate imperfections and rough regions created either by gross contouring or by the natural erosion process. Engineered abrasives, from silicon carbides to aluminum oxides, are softer than diamonds but can be as effective as diamonds, depending on the hardness value of the substrate material. Other substances used abrasively include chalk, cuttle, quartz, sand, emery, garnet, and other naturally occurring or engineered materials such as synthetic diamonds.

RELATING FUNCTION AND ESTHETICS

Form follows function. First, to create a functional restoration, dentists place a material that is not originally intended to be there, and try to make this material behave, function, and look like human tissue. To achieve this, the dentist must have a seamless transition from the tooth tissue to the restoration. It is possible to achieve this with appropriate finishing and polishing procedures. Second, the dentist must maintain the integrity of the material. By finishing and then polishing, it is possible to eliminate naturally occurring porosities and overhangs and marginal excess while maintaining the structural integrity of the dental tissues. Even more important, it is possible to maintain the longevity of restorations. Dentists as healthcare professionals must provide a surface that is easy to clean and maintain in order to prevent bacterial or plaque attachment to the surface. This is achieved by reducing the surface area and surface tension characteristics. Finishing and polishing can ensure these aspects so that the patient can eliminate plaque and food particles by flossing and brushing effectively. If there are no retention points that are challenging to manage, the dentist has satisfied his or her responsibility to the patient.

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FIGURE 11-9 Application of various surface textures to create a desired appearance. A, Smooth surface. B, Medium texture applied on the cervical third. C, Heavy texture applied on the entire labial surface. *(Courtesy MicroDental, a DTI Laboratory, Dublin, California.)*

CLINICAL CONSIDERATIONS

All restorations should undergo finishing and polishing; there should be no contraindications. However, in some situations dentists can create harm through improper use of instruments and techniques and by creating heat through friction. The technique of using cutting, grinding, finishing, and polishing instruments involves a sweeping motion and adequate cooling that is incorporated into the technique. If the practitioner leans on the surface and keeps the instrument on the surface of the restoration or tooth without performing a sweeping motion, debris will accumulate between the instrument and the surface. This debris will act as an additional abrasive and create deeper scratches. More importantly, this will create more heat, which leads to pulpal insult. The dentist may cause reversible or irreversible pulpitis for the patient.

Logic or simple physics requires that operators start with coarser grit sizes and follow gradual steps to smaller sizes. If the operator skips any of those steps, it will be impossible to eliminate scratches created by the previous step. In addition, spending more time with the coarser grit sizes also creates more heat. The coarser grit sizes should be used for brief periods only. The objective is to create appropriate contouring and eliminate the initial scratches created by the coarse gross-reduction instruments. When the operator moves to smaller grit sizes, it may be necessary to spend more time, but the sweeping motion and cooling, either by water or air, prevent heat and eliminate debris that has accumulated. These are the most important steps of the procedure. Intentional striations can be created to mimic the adjacent enamel texture.

Not only do teeth that are restored need polishing or finishing, but teeth that are chipped, fractured, or worn. It is necessary to eliminate any sharp corners and edges. These imperfections create stress concentration points that may cause further chipping and fracturing within the same restoration, or chipping, wear, and fracture of the opposing or adjacent teeth or restorations.

MATERIAL OPTIONS

Instruments

Equipment can be categorized as bonded, impregnated, or coated instruments. The classic example of a *coated* instrument is the diamond bur (Figure 11-10). Diamond particles are attached to a metal shank and impregnated using specialized adhesives or sintering procedures. White stones are a form of ceramic that are sintered over a metal shank. There are also strips and disks and coated abrasive papers (Figure 11-11). The coating can be achieved using either electroplating or sintering techniques or adhesives. There are also impregnated abrasives that have a rubberized base covered by adhesive and abrasive particles (Figure 11-12).

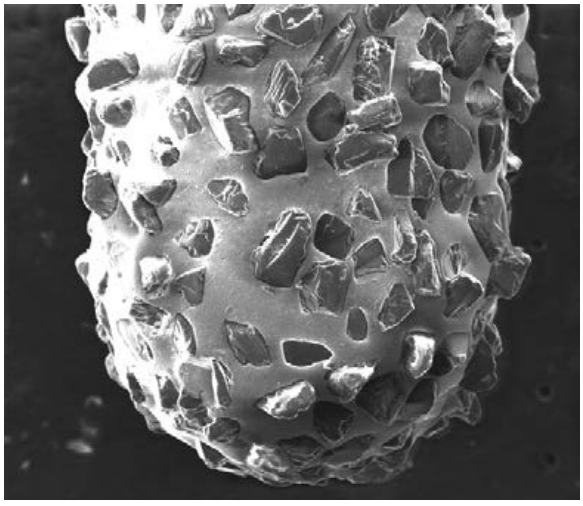


FIGURE 11-10 Scanning electron microscope image of a medium grit size diamond bur (100× magnification).

Abrasive Particles

Aluminum oxide and silicon carbide are among the most popular materials used, but the hardest abrasive particle is diamond. In considering cost, diamond is also the most expensive of the abrasives. Aluminum oxide, silicon carbide, and zirconium oxide are preferred because of their lower cost and acceptable abrasive performance.

In considering the relative hardness of an abrasive, diamond is the hardest material and aluminum oxide is next in line. The Knoop hardness number of diamond is about 7000, whereas aluminum oxide's value is in the 2000 range, then silicone

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FIGURE 11-11 Different types of abrasives, including an abrasive coated strip. *(From Hatrick CD, Eakle WS, Bird WF:* Dental material: clinical applications for dental assistants and dental hygienists, *ed 2, St Louis, 2011, Saunders Elsevier.)*

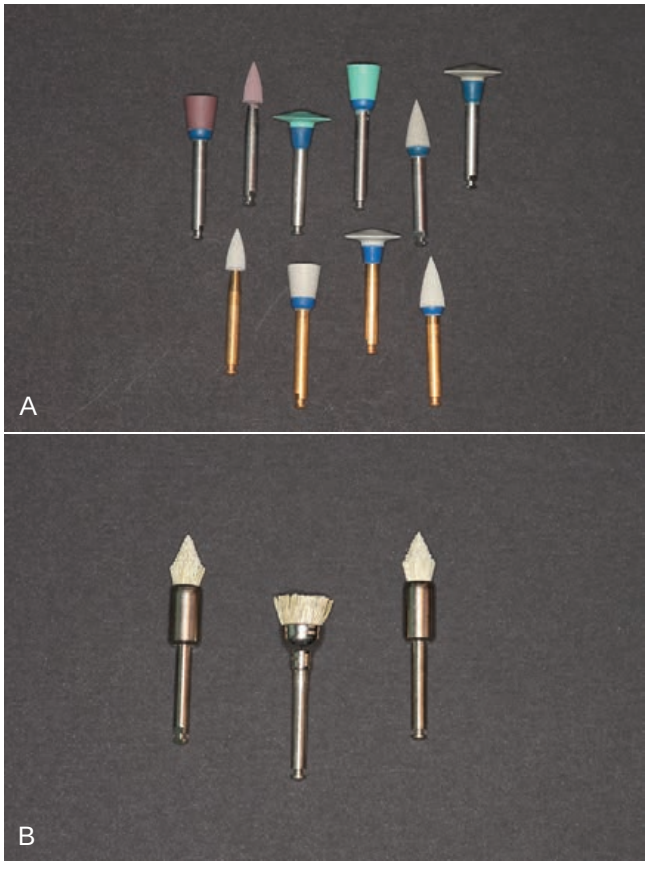


FIGURE 11-12 Abrasive impregnated rubberized finishing and polishing systems in pre-molded shapes (A) and brush form (B).

carbide and other types of carbides are about 2400—still much harder than composites, which have a value of 60 to 80. Enamel's Knoop hardness number is about 350, and porcelain's is 500 to 600, depending on the type of ceramic. These abrasive particles are significantly higher on the scale of hardness and therefore effectively reduce the irregularities on restorative surfaces or natural enamel.

Current Best Approach

Resin Composites

To polish composite, the best approach can be largely the practitioner's preference. The two methods used by most dentists are an abrasive coated disk or an abrasive impregnated instrument such as a disk, point, or cup. Also, it is important to effectively finish and polish the interproximal surfaces. For this procedure, an abrasive coated strip with a metal or plastic backing is used. These strips are coated with different grit sizes of abrasives, usually with diamond or aluminum oxide particles (Figure 11-13). With these instruments, it is possible to maintain the function and anatomy of the interproximal surface.

For an anterior surface, a finishing carbide and/or diamond burs can be used to contour the restoration. Then, either an impregnated system or coated disks are used to proceed from coarse to fine grit size, then diamond paste is used to provide the highest level of luster. Pastes must be applied with a nonabrasive carrier, for example a rubber prophy cup. It is a mistake to apply pastes with an abrasive impregnated cup (Figure 11-14). Scanning electron microscope images of the respective surfaces are shown in Figure 11-15. It should be noted that different categories of resin composites in terms of their microstructures respond differently to the specific finishing and polishing systems. Therefore the final outcome can be different for each resin composite when polished by different systems. Surfaces shown in Figure 11-16 are polished with the same abrasive impregnated rubberized finishing and polishing system.

Ceramic-Based Materials

Ceramic-based materials are significantly harder than resin composites. Therefore, it is necessary to rely on harder finishing and polishing materials. For example, in order to provide some characterization on the surface, it may be necessary to use diamond burs. Carbides are not helpful to finish or eliminate the scratches created by diamond burs on ceramic surfaces. To bring the luster out, an impregnated, and preferentially diamond-impregnated, rubbery instrument is used. Abrasive coated disks lack hardness in relationship to the ceramic. Diamond paste applied with a nonabrasive carrier provides the best level of luster to the ceramic. Research shows that with regard to the final surface of the ceramic, in comparing glazed to polished surfaces, they are almost equally functional. The polished surface is stronger than the glazed because the polishing eliminates the stress concentration points and microcracks from the ceramic surface. Direct finishing and polishing can be a more practical approach, especially with the advances in chairside computer-aided design and

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FIGURE 11-13 **Use of interproximal strips to contour (A), finish, and polish (B) the interproximal surfaces of resin composite restorations. C, Completed restoration.** *(From Antonson DE: Composite resin materials: nano-what?* Dent Today *28:124, 2009.)*

computer-assisted manufacturing (CAD-CAM) technology and the use of porcelain systems such as fluorapatite- or leucite-based ceramics (Figure 11-17).

Zirconia

Zirconia should not be used as the final surface on a restoration that is in occlusion. Zirconia is designed to be a substructure that supports layered porcelain. It is a tooth-colored material that provides an esthetic appearance, mimics dentin, and masks the dull appearance associated with gray metals. However, zirconia should not be ground, and the use of diamonds is detrimental to the zirconia surface. Specifically, the chemistry and crystalline structure of zirconia are transformed by the trauma. This may not be a problem in smaller areas, but if a gross reduction is being made, zirconia becomes much weaker and more delicate because of its crystalline transformation. Also, there are few systems on the market that can finish and polish zirconia effectively, and this procedure takes approximately 20 minutes using the laboratory motors and instruments. Because it is practically impossible to finish and polish zirconia with the chairside systems intraorally, rough surfaces created because of occlusal adjustments cannot be eliminated. This situation can lead to a significant wear of the opposing enamel. However, as the majority of zirconia restorations include an overlying porcelain, it is usually the porcelain that must be adjusted, contoured, finished, and polished.

Heating

Unfortunately, overheating is an often an overlooked issue because many dentists attribute post-operative sensitivity to the bonding procedures. Even though that may be a valid cause, additional clinical factors can cause postoperative sensitivity. Research has focused on the effects of various polishing instruments and techniques on heat generation affecting the tooth and restoration. Heat generation depends on the system used. The heat is increased significantly by coarser systems, not using a sweeping motion, not using water cooling, and sustained pressure. The term *significant heat* is in relation to the threshold values determined according to Zach and Cohen's original article from the 1960s. Based on this publication, an increase in the temperature on the pulpal surface of 5 °C may cause irreversible pulpitis, even though the methodology of this study was debatable. Incorrect technique may result in an increase of 15 °C on the internal surface of the tooth. As long as cooling is used while polishing, finishing, or grinding, and less time is spent with the coarser grinding and finishing instruments, the patient should

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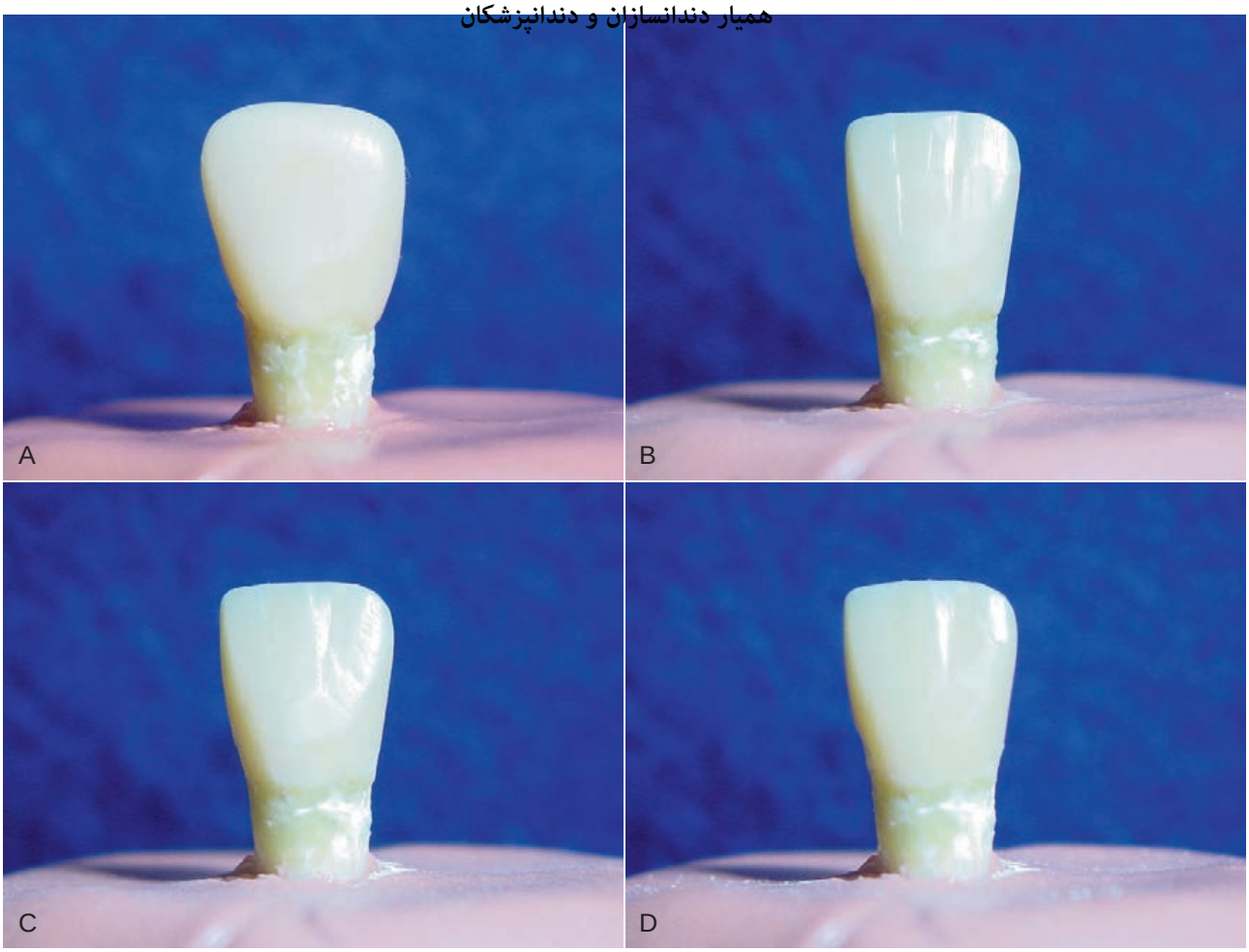


FIGURE 11-14 **Final surface textures achieved on resin composite restoration after each step of the application. A, Resin composite as placed and molded using the placement instruments. B, Restoration is contoured using carbide burs. C, Coarse- and medium-grit-size abrasive-impregnated rubberized finishing instruments were used consecutively to obtain a smooth surface. D, Final surface luster was achieved by using a super-fine diamond-impregnated rubberized polishing instrument.**

be safe from heat damage. Deviating from these principles, especially not using cooling systems, generates significant heat.

ARTISTIC ELEMENTS

Using the central incisor as an example, the highly polished surface naturally looks broader, brighter, and whiter than the less polished surface, which looks smaller and darker. Older patients' central incisors differ from those of younger patients. Because of toothbrush abrasion over the years, or simply because of the effects of an abrasive diet, surface characterization may be lost with age. As a result, the older patient will demonstrate a flatter, more highly polished scratch-free surface compared with the younger patient. The teeth of younger patients may also show mamelons, and have horizontally textured surfaces. It may be possible to duplicate that surface and intentionally create horizontal scratches by using a coarser- or medium-grit diamond bur in the intermediate stage of finishing.

TREATMENT PLANNING

With respect to resin composite restorations, if a posterior restoration is being placed, the first step is to make sure that all margins are in the right place, away from the occlusal contact points, and occlusion has been adjusted. After the final surface characteristics, occlusion, and margins are established, the finishing and polishing process can begin. The aim is to provide a seamless transition from the tooth to the restoration, then to provide a smooth, lustrous surface for an anatomically sculpted restoration surface. In an anterior restoration, finishing the margins and maintaining the occlusion or establishing the correct occlusion and anterior guidance are critical. Then, the sequencing of the contouring, finishing, and polishing steps can be undertaken. With certain indirect restorations such as porcelain-fused-to-metal or porcelain-fused-to-zirconia restorations, finishing and polishing can be accomplished extraorally; however, final finishing and polishing can be accomplished after cementation. The margins of the restorations must be perfectly

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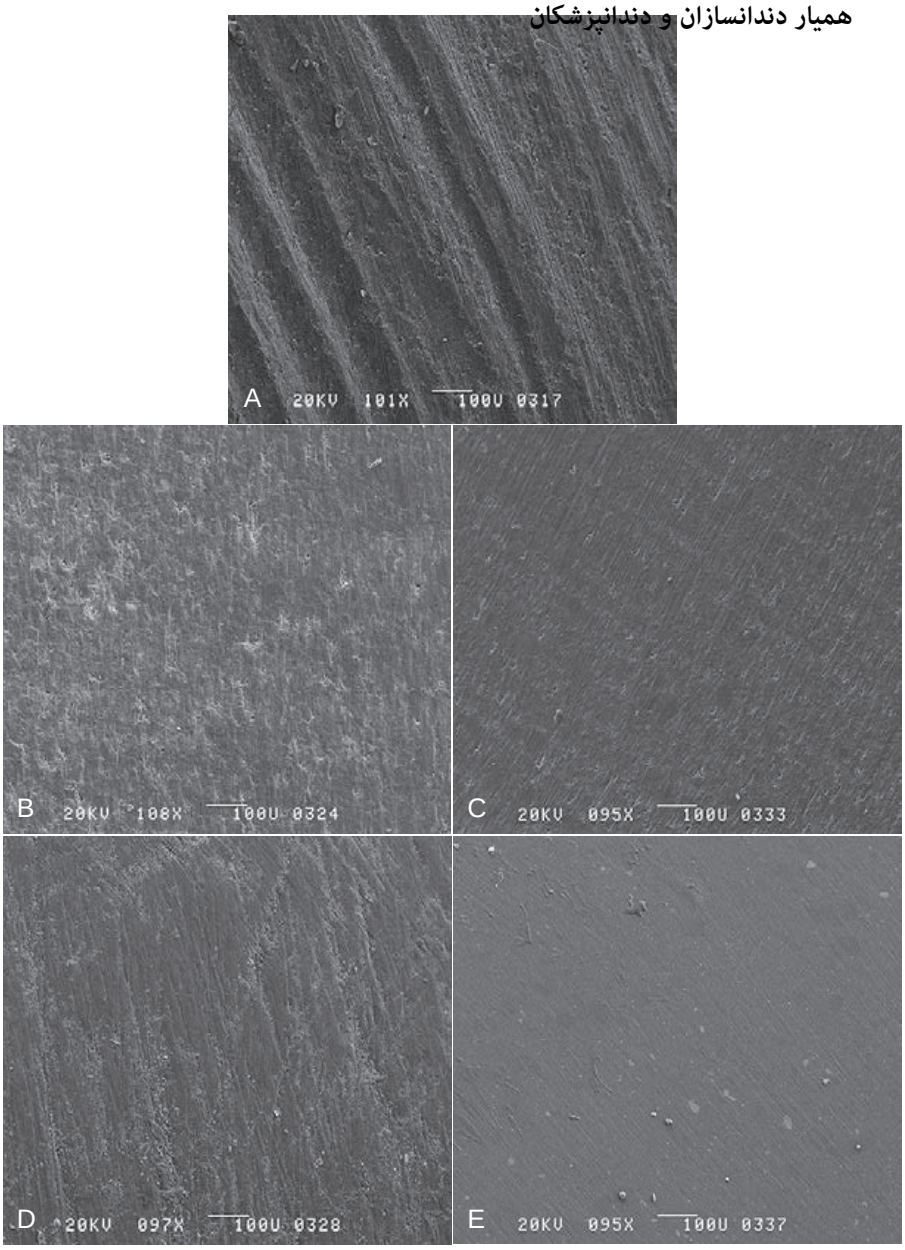


FIGURE 11-15 Scanning electron microscope image of a microhybrid resin composite surface captured after each application step of finishing and polishing procedures (100× magnification). **A,** Gross contouring using a coarse diamond bur. **B,** Contouring using a 12-blade carbide bur. **C,** Fine contouring using a 16-blade carbide bur. **D,** Finishing using abrasive impregnated rubberized finishing instruments. **E,** Polishing using a super-fine diamond-impregnated rubberized polishing instrument.

sealed; then the contouring, finishing, and polishing procedures are undertaken to achieve a seamless transition from the tooth to the restoration surface. Some indirect all-ceramic restorations, such as veneers, inlays and onlays, and especially some of the restorations generated by using the CAD-CAM technology, are more delicate. They must be cemented first to provide proper support, then the finishing and polishing are performed to finish the margin, maintain occlusion, and ensure the seamless transition from the tooth to the restorative surface.

EVIDENCE-BASED PRINCIPLES

The maintenance of a patient's oral health, including dental tissues, remaining dental hard tissues, adjacent teeth, and adjacent soft tissues, is successfully achieved by producing an appropriately finished and polished surface on the restorations. This will improve the patient's ability to perform home preventive oral healthcare, which increases the longevity of the dentition and maintains a healthy periodontium. Also, finishing the surface correctly strengthens ceramic restorations. It is well documented that by (1) eliminating the stress concentration points and microcracks created through occlusal adjustments and coarse grinding instrument use and (2) eliminating imperfections, surface microcracks, and sharp corners and edges, it is possible to increase the strength of ceramic restorations.

Improperly finished and polished ceramics can severely abrade opposing enamel. This is well documented as an iatrogenic situation in which patients can lose physiologic occlusal vertical dimension and eventually develop occlusal and possibly temporomandibular joint problems. By not properly finishing

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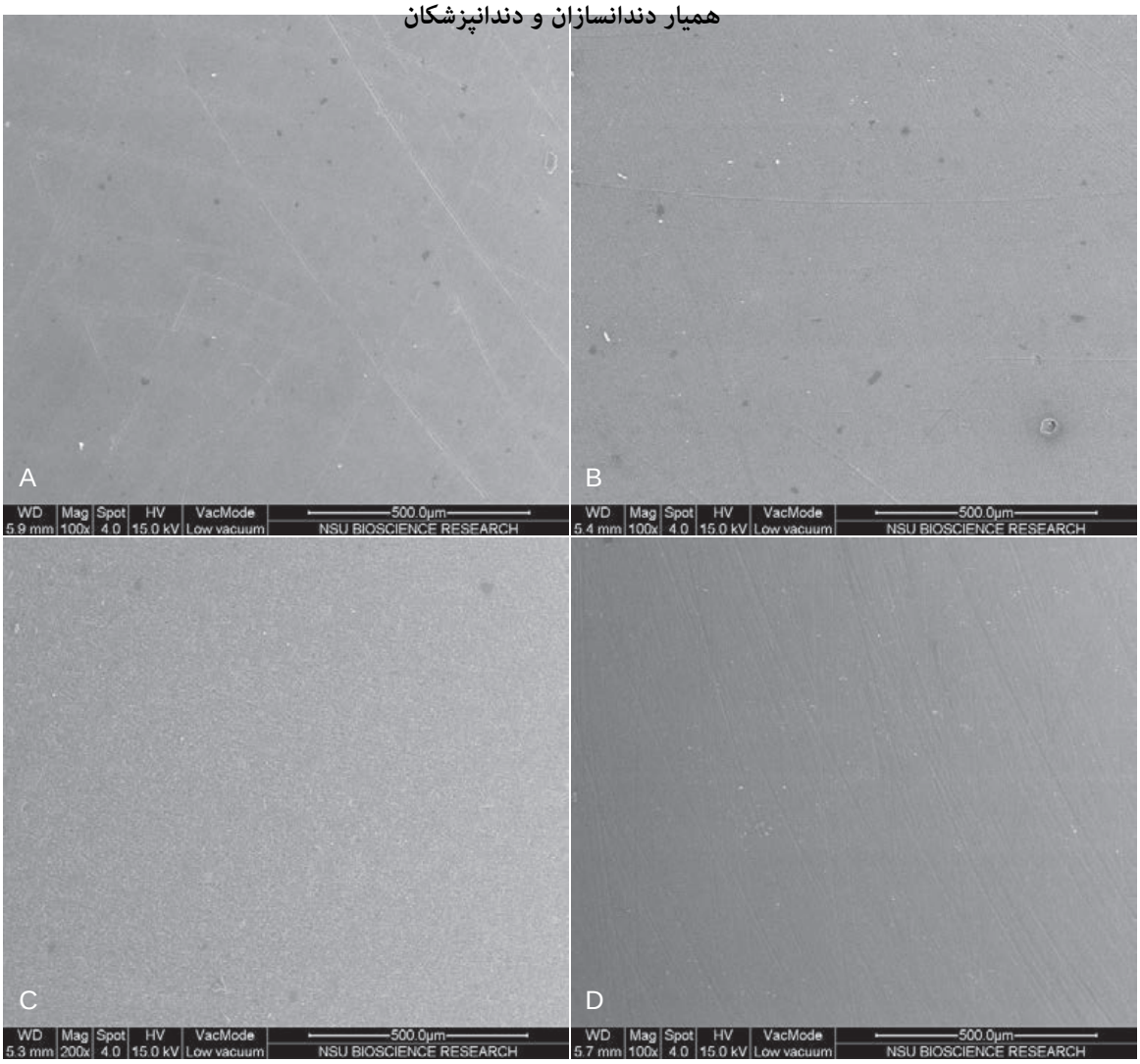


FIGURE 11-16 **Scanning electron microscope image of different microstructure resin composite surfaces captured after polishing (100× magnification). A, Flowable nanohybid resin composite (Tetric EvoFlow, Ivoclar Vivadent, Amherst, New York). B, Hybrid resin composite (Venus, Heraeus Kulzer, Hanau, Germany). C, Nanohybrid resin composite (Grandio, VOCO, Cuxhaven, Germany). D, Compomer (Dyract, DENTSPLY International, York, Pennsylvania).**

ceramics, the dentist creates an abrasive surface that will severely abrade the opposing softer enamel.

CLINICAL CONSERVATION CONCEPTS

Finishing and polishing of natural teeth with chipped corners or worn enamel, eliminates sharp corners and edges as well as the stress concentration points and enhance the life of the natural tooth. The same concept applies to existing restorations. There may be initially some imperfections, but finishing and polishing can eliminate the imperfections and enhance the life-span of the restoration.

MAINTENANCE

Scratches maybe created on composite restorations because of the patient's choice of diet, toothbrush, or dentifrice, which can lead to loss of its luster. At maintenance visits, the dentist and hygienist must observe restorations for general surface as well as margin appearance. During these periodic hygiene appointments, the type of prophy pastes used on the surface can be extremely abrasive and may cause breakdown of the restoration's surface. Prophy pastes are not highly regulated as far as their abrasive particles. Substances classified as fine prophy paste can cause deep scratches on the tooth or restoration surface, cause loss of luster on composite and ceramic restorations, or cause loss of glaze on the surface. Therefore it is extremely important to make an educated and conscious choice

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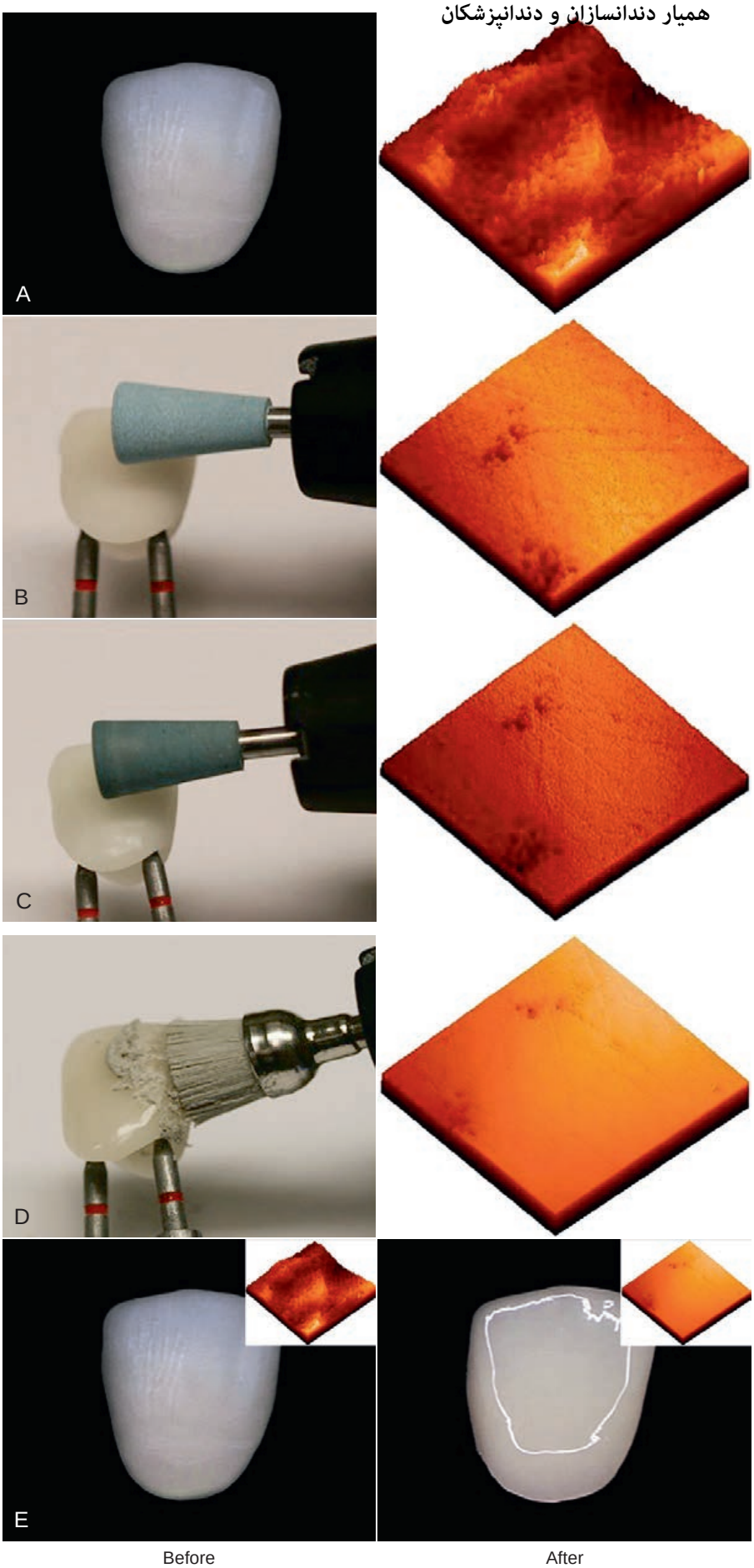


FIGURE 11-17 **Chairside finishing and polishing steps for leucite-based ceramics and corresponding magnified surface images. A, Surface roughness before finishing and polishing procedure. B, Surface texture after the use of OptraFine F finishers. C, Surface texture after the use of OptraFine P polishers. D, Surface texture after the use of OptraFine HP nylon brush and the diamond polishing paste. E, Surface comparison before and after the chairside finishing and polishing procedures.** *(Courtesy Ivoclar Vivadent, Amherst, New York.)*

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of a prophy paste that contains pumice-free abrasive particles, and carefully apply them to tooth and restoration surfaces in order to ensure successful maintenance of the surfaces originally obtained.

CONTROVERSIES

Controversies involve matters of perception and consideration of manufacturers' claims and instructions. At times, one-step polishing is used more liberally than what is intended. Consumers should be aware of the manufacturers' claims. It is the dentist's responsibility to be able to effectively finish the margin, provide smooth surfaces so the patient can maintain personal oral health, and achieve the luster needed for optimum esthetics. Dentists and hygienists must make sure that this procedure is completed using the techniques recommended by manufacturers. Also, it is the operator's responsibility to choose compatible instruments to perform contouring, finishing, and polishing procedures on specific material surfaces.

Another controversy involves whether or not to use water during polishing techniques. This should be specified by the manufacturer. However, the most important considerations are that heat generation can be prevented and debris eliminated by using air or water along with the sweeping technique.

NEAR-FUTURE DEVELOPMENTS

Although none currently exist, it is expected that materials will be developed that can self-polish through their polymer technology or certain triggers placed into the material. This is the future direction in polishing as well as new materials. Dental research has also targeted a reduction in the steps of chairside procedures. Finishing and polishing may be replaced by other techniques that can provide longevity and preserve the integrity of the restoration. Currently some surface-protecting sealants and glazes can be applied chairside over certain resin-based composites or ceramics. The challenges include how to maintain them on the surface, their wear resistance, and their compatibility with underlying surfaces as well as color stability. In the near future they will be optimized so that it will be possible to effectively provide esthetic and functional restorations for long-term service throughout the life of the restoration.

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C SECTION

Finishing and Polishing

Sandesh M. Mayekar

RELEVANCE TO ESTHETIC DENTISTRY

Finishing is associated with contouring, eliminating excess at the margins, and gross polishing; whereas polishing relates to surface smoothness, luster and gloss. Whenever a restoration is prepared, the end product should look like a natural tooth. A natural tooth always has its own characteristics, such as texture, line angles, gloss, and matt finish. Only finishing and polishing can give the necessary lifelike appearance to the restoration. Finishing and polishing contribute to the long-term success of the restoration and esthetics, which are important for oral health and function.

One of the major problems of not finishing and polishing is the early discoloration of the restoration. If the margins are not finished well, there can be marginal leakage that can lead to sensitivity and plaque accumulation (Figure 11-18). There can be white lines at the margins. And the restoration might not merge with the tooth; it would stand out and look not like a natural tooth but like a block of restorative material atop the tooth surface. Lastly, the restorations on the occlusal surface of the posterior teeth and/or palatal surface of the anteriors, especially the canines, can have problems with function. Thus if restorations are not finished and polished well, esthetics will be affected, and so will the function and maintenance of the restorations.

A BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Even during the time of amalgam fillings, polishing and finishing were considered important and necessary for the life of the restoration and function. Finishing and polishing techniques evolved with the introduction of newer materials over the years.

When tooth-colored materials were introduced, the finishing and polishing were done with polishing brushes, polishing rubber cups, and abrasive polishing paste. Diamond points of 50 to 8 grits were used to finish tooth-colored glass ionomers, and they were polished with aluminum oxide–impregnated cups, cones, and wheels. Aluminum-coated disks from coarse to super-fine were used to give better texture and polish to the restoration.

Carbide fluted burs ranging from 8- to 40-fluted were developed to finish and polish, as polishing is not possible with diamond points, which only scratch.

For tooth-colored materials such as nanofills and nanohybrids, stronger polishing agents such as diamond-impregnated or silicon-impregnated cups, cones, and wheels are used. Aluminum oxide paste is used for microfills, whereas for nanofills, diamond-impregnated paste is used. Today we have diamond-impregnated cup, cones, wheels, and diamond-impregnated polishing paste for stronger materials that give better results. Carbide carvers, Bard-Parker No. 12 blades, and the handpiece-driven oscillatory polisher (Profin handpiece, W&H Dental werk Bürmoos GmbH, Bürmoos, Austria) are also used to finish a restoration. A polishing buff, such as Flexibuff (Cosmedent Inc., Chicago, Illinois) is used to polish restorations and surface sealants to seal the borders.

Clinical Considerations

The purpose of finishing and polishing is to achieve a plaque-free, stain-free, longer-lasting esthetic restoration.

Indications

Finishing and polishing are indicated for both direct restorations (i.e., glass ionomers, composites) and indirect restoration (i.e., composite ceramic restorations).

Contraindications

Finishing and polishing are not indicated for indirect restorations that are previously finished and polished (dental laboratory), because these cannot be finished and polished intra-orally. Finishing intraorally can cause the restoration to develop microcracks and microleakage.

Also, not using the right finishing and polishing material and instruments for the right restorative materials can abuse the restoration. For example, glass ionomers cannot be polished with 8-fluted carbide burs; similarly nanofills cannot be polished with aluminum oxide–impregnated disks.

MATERIAL OPTIONS

The materials used to finish and polish depend on the restorative material used for the restoration (Table 11-1).

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FIGURE 11-18 The result of not finishing and polishing properly. A, Dull and opaque restoration. B, Restoration with stained margins.

TABLE 11-1 Materials for Finishing and Polishing

MATERIAL	ADVANTAGES	DISADVANTAGES
Diamond points (Brasseler, Premier, SS White)	Come in different shapes and grits and are used in different areas and surfaces of the tooth such as labial, proximal, cervical, lingual, palatal surfaces for gross contouring.	The surface will not be smooth. If used at high speed and pressure, they generate heat, abuse the restoration, and may cause microleakage.
Carbide burs (Brasseler, SS White, DENTSPLY)	Come in various fluted sizes and in different shapes. The head of the burs comes in 3, 4, 6, and 9 mm. The 9-mm burs are used labially on centrals and laterals; 4-mm burs for cervical-third areas of canines and premolars; and 3-mm burs for cervical-third areas of lateral incisors. The 40-fluted burs polish not only the labial surface but also the supragingival area without damaging the gingiva. The American football–shaped burs, available from 8- to 40-fluted, are used for palatal finishing.	When used at high speed and pressure will generate heat, and the resin in the composite will melt, making the particles loose and resulting in failure of the restoration.
Finishing disks (Cosmedent, Shofu, 3M ESPE)	Basically used to finish and polish hybrid, microhybrid, and microfill composites. Microfill composite resins when dry finished melts the resin filler and creates a smear layer that enhances the gloss. Finishing disks are used to create textures, to polish interdental areas and proximal areas, and to achieve a nice smooth surface.	When used at high speed and pressure, finishing disks generate heat and abuse the restoration. These cannot be used on high-strength materials such as nanofills. The posterior surface is difficult to polish, especially on the pit and fissure areas.
Rubber wheels, cups, points and cones—aluminum oxide, silicon carbide, diamond (Ultradent, Cosmedent, SS White, Ivoclar, DENTSPLY)	Basically used in posteriors, both direct and indirect, but can be used in anteriors to create textures.	Except for Enhance (DENTSPLY) cups and cones, these tools, when used at high speed and pressure, generate heat and abuse the restoration.
Proximal finishing strips—aluminum oxide, silicon carbide, diamond, metal and plastic (GC, Cosmedent, 3M ESPE, Premier, Brasseler)	Depending on the chemistry of the restorative material, these are used to make the proximal surface smooth to avoid formation of stains interdentally.	The cost is high and they cannot be reused.

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TABLE 11-1 Materials for Finishing and Polishing—cont'd

MATERIAL	ADVANTAGES	DISADVANTAGES
Bard-Parker blades, No. 12	Used in interdental areas to remove excess material and also in the junction of composite and tooth. Used to remove luting cement in laminates and veneers. Used to remove the composite that goes beyond the etch-bond area, the unwanted composite in the non-etched area before finishing and polishing a restoration.	The tip of the blade breaks and cannot be reused.
Carbide composite carvers	Used to remove excessive composites in subgingival areas and also to create textures.	Should be handled properly, as they can lacerate the gingiva. This is not a significant disadvantage.
Polishing pastes (Ultradent, DENTSPLY, Premier)	The particle size of the paste should be smaller than the particle size of the material. Diamond polishing paste can be used for nanofills. Aluminum oxide paste is used wet, but diamond polishing paste should be used dry.	No disadvantage.
Surface sealants (GC, Ultradent, Bisco)	Microcracks created at the junction of the composite and tooth structure are sealed with surface sealants so that the margins last for a long time.	Should not be used on rough surfaces and should be used only after finishing and polishing.

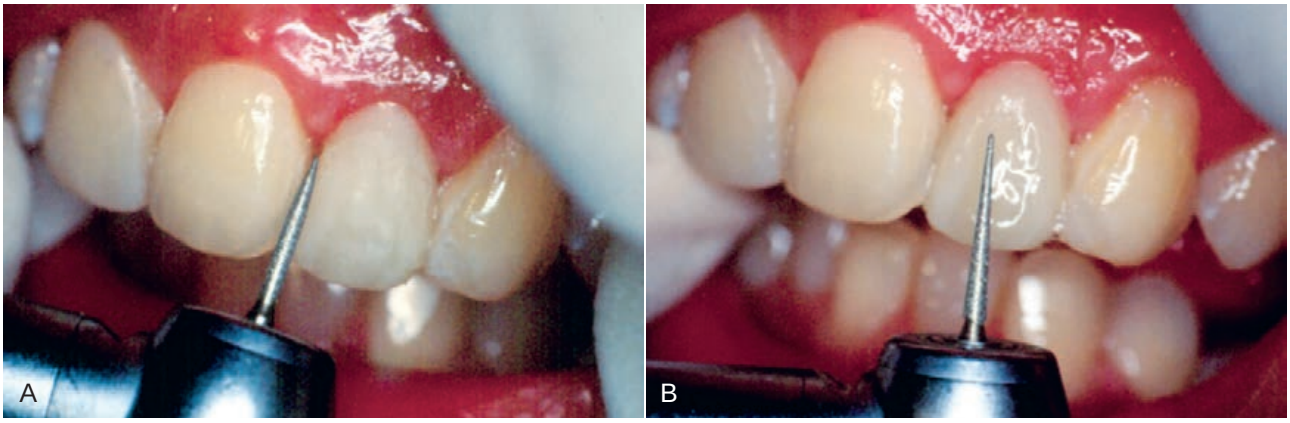


FIGURE 11-19 Removing excess and giving anatomic shape to the restoration with diamond points.

CURRENT BEST APPROACH

Using the right material in the correct sequence depending on the choice of the restorative material is the best approach to finishing and polishing to get the desired result.

It is important to finish first and then polish. However, finish can be started only after a minimum of 10 minutes after the final curing. To avoid a white line at the junction of the tooth and the restorative material from shrinkage tension, finishing should not be done in this area. Final polishing and finishing can be done only after 24 hours of curing. To finish is to remove the excess material with diamond points to give dimension and anatomy to the restoration (Figure 11-19). Carbide burs from less to more fluted are used. The more fluted burs give a smoother polish, whereas the less fluted burs remove the material faster. Depending on the amount of material to be polished, 8-, 12-, 16-, 30-, or 40-fluted carbide burs are used (Figure 11-20). Care should be taken to use the right shape on the right area. Depending on the height of the head—that is, 9 mm, 6 mm, 4 mm, or 3 mm—these burs can be used on anteriors, central incisors,

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FIGURE 11-20 Finishing with carbide burs.

laterals, canines, premolars and cervical-third area, body, or incisal area (Figure 11-21). For the palatal surface of anteriors, the right sized American football–shaped burs should be used (Figure 11-22). R.A.P.T.O.R* burs (Bisco, Inc., Schaumburg, Illinois) are used, starting from conical diamond to carbide, to finish the posteriors (Figure 11-23). Proper shapes and sizes are used depending on the tooth and area on the occlusal surface—small diamond for premolars, large for molars, and Christmas tree carbide bur for pit and fissure and inclined planes.

Subsequently, polishing disks (coarse to super-fine) and a polishing buff (Figure 11-24) are used on the anteriors to polish the labial (Figure 11-25) and the proximal surfaces (Figure 11-26) and to create the textures (Figure 11-27). For harder materials, silicon carbide– and diamond-impregnated cups, cones, and wheels are used instead.

For the posteriors, cups, cones, and wheels are used in a coarse- to medium-fine sequence (Figure 11-28). A polishing disk is used to polish the marginal ridge area but should be used in one direction only. The final polishing is achieved with a polishing paste. For softer materials, aluminum oxide paste is used wet; and for harder materials, diamond polishing paste is used dry (Figure 11-29).

Other Considerations

The polishers and finishers should be used in a sequence starting with diamond or carbide burs, disk, cup, cone, and wheels. The advantage of finishing and polishing is that the line angles, texture, convexities, and concavities can be seen; however, finishing and polishing might generate heat and damage the restoration. Finishing and polishing wet do not generate heat and the restoration is not damaged; however, the reflection of the water that gets into the micro-porosity of the restoration makes seeing the line angles and textures difficult. Hence, finishing and polishing should necessarily be in a combination of wet and dry with low pressure and slow speed in which the line angles can be seen and no heat would be generated (Figure 11-30). Paper disks are used dry with microfills, but the sequence of coarse to super-fine needs to be maintained.

*Rapid adapting precision transformer for occlusal resins.

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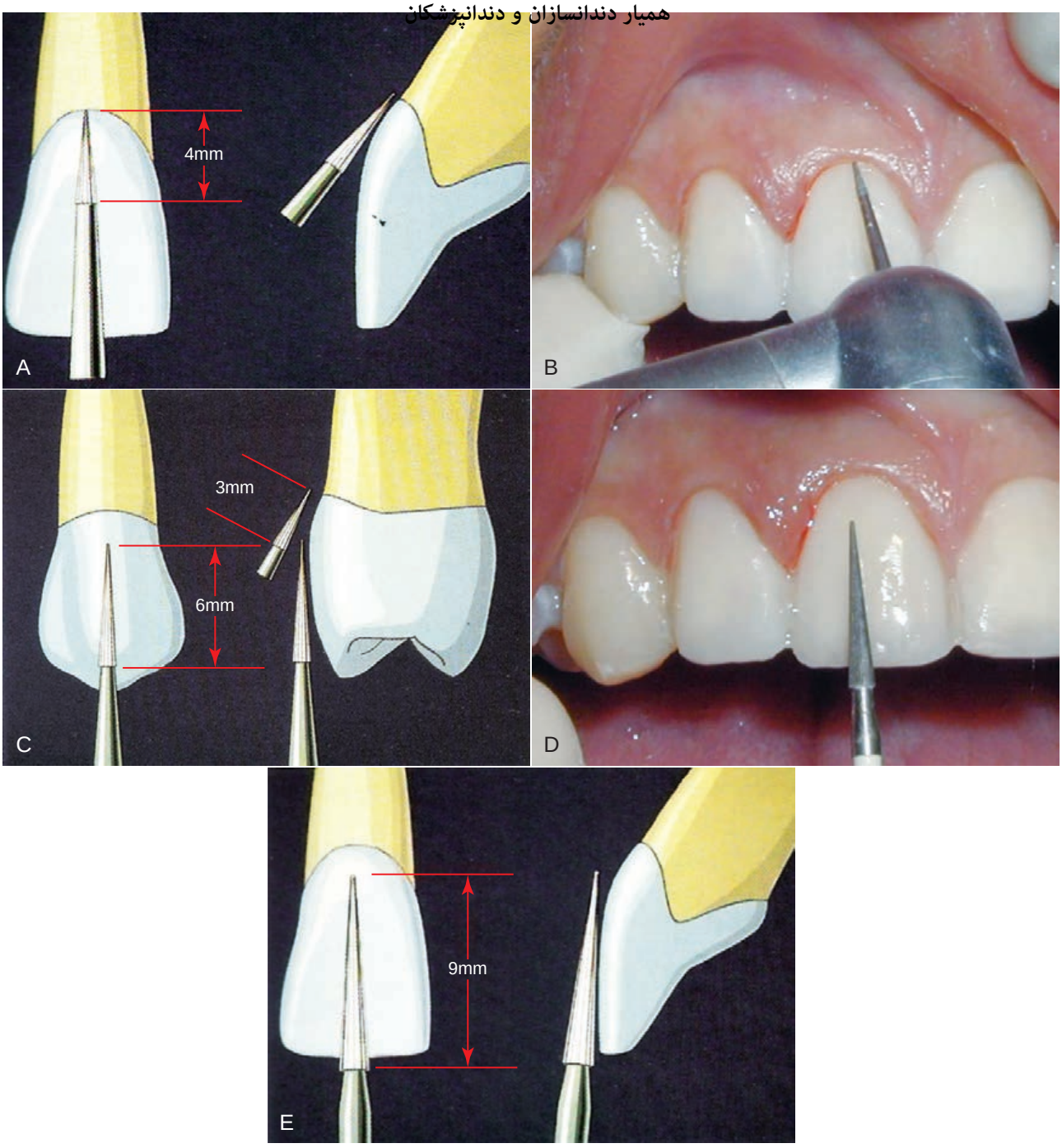


FIGURE 11-21 Different carbide burs used in different locations.

INNOVATIVE ELEMENTS

Scientific and Technologic Elements

One of the scientific innovative elements is STAINBUSTER (Abrasive Technology, Inc., Lewis Center, Ohio), a new type of composite bur with fibers in it (Figure 11-31) that removes stains from natural teeth, composite, and ceramic. Its biggest advantage is that it does not damage the restorative material; neither does it damage the tooth enamel or dentin. These burs have fiber sections with abrasive power. These fiber sections cover the entire working area and split into small fragments as and when they act on a hard surface. These burs can be reused, as their abrasive power is retained until they disintegrate. Technologically, the bur is quite useful and economical; it can be used to remove stains and polish the restoration. These burs can basically be used for maintenance of the restoration.

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FIGURE 11-22 American football–shaped bur polishing palatal surface.



FIGURE 11-23 R.A.P.T.O.R. burs.



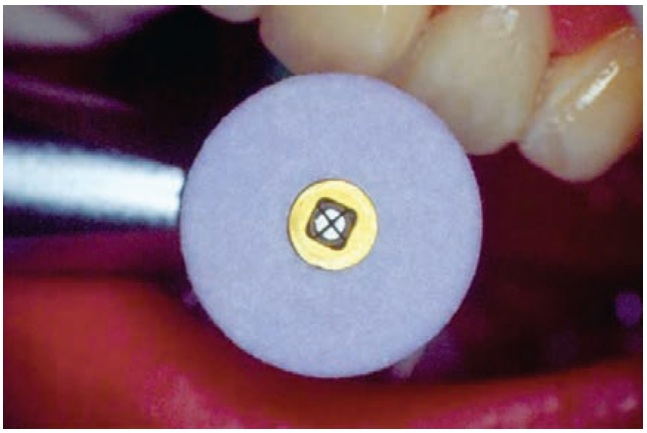


FIGURE 11-24 Sof-Lex disks (3M ESPE), coarse to superfine, and polishing buff (Cosmedent).

Artistic Elements

To create the artistic elements in a restoration, the first thing to understand is the dental composition and anatomy of the tooth (Figure 11-32)—that is, incisal and emergence profile, incisal and facial embrasures, and concavities and convexities in the surface texture.

The law of the face: shadows are created as light strikes the labial surface of the tooth shadows, beginning at the transitional line angles. These shadows delineate the boundaries of the face should also be understood to create an illusion (i.e., the art of changing perception to cause an object to appear different than it actually is). The illusion can be created during finishing and polishing by surface texturing, angling the reflection of light, and angling the proximal corners (Figure 11-33). Until lighting perspective and rendering of textures have been mastered, illusion cannot be created.

Another artistic approach is to use the right pressure and the right disks. Firm disks are used to create vertical texture, whereas flexible disks are used to polish the corners of the line angles in the incisal and proximal areas (see Figures 11-26 and 11-27). To polish interdentally, firm disks are used at a right angle, moving toward the labial surface. Cups, cones, and wheels are used to create concavities, convexities, and textures. Then finish and polish.

The law of the face and the principles of creating illusion are very important to create the artistic elements in a restoration.

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FIGURE 11-25 Polishing labial surface with Shofu polishing disk without mandrel in the center.



FIGURE 11-26 Polishing proximal surface.

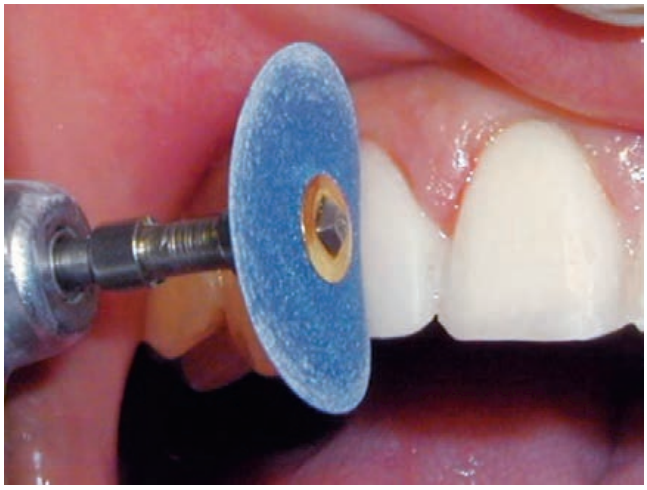


FIGURE 11-27 Creating textures on labial surface.

RELATING FINISHING AND POLISHING TO FUNCTIONAL ESTHETICS

Finishing is performed to remove the excess at the margins as well the excess material at the occlusal surfaces during maxillary-mandibular relationship (during occlusion). An unfinished restoration in the anteriors, especially on the palatal side, on the canines or the incisors can cause problems with the protrusive movements of the mandible or canine in lateral excursion,which in turn can cause problems with the masticatory muscles or the temporomandibular joint (TMJ). When posteriors are being finished, high points must be checked, not only on the occlusal but also on the lateral excursion too. High points in occlusal or in lateral excursion can cause a TMJ problem, headache, or neck pain. Finishing should always precede polishing. In finishing the excess is removed and the anatomy of the restoration is carved to match the natural dentition. The restoration is then polished

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FIGURE 11-28 Use of rubber cups (A), cones (B), and wheels (C) in posteriors.



FIGURE 11-29 White aluminum oxide and gray diamond polishing paste.

to make the surface texture smooth so that no excess plaque can accumulate, which can cause discoloration, accumulates.

When anteriors are being polished, it is important to take care of the line angles and maintain concavities and convexities that make the restoration look esthetically good. Creating a smooth texture further enhances the esthetics of the restoration.

In class III, IV, and V restorations, special attention should be given to the junction of the composite and the tooth structure. Finishing and polishing should blend the composite with the tooth without overhangs. Therefore polishing and finishing are equally important for both esthetics and function of the restoration.

FINISHING AND POLISHING CLASS V RESTORATIONS

Class V restorations necessitated by abrasion and erosion or abfraction are very important from the esthetic and functional point of view. Creating such restorations could be accomplished

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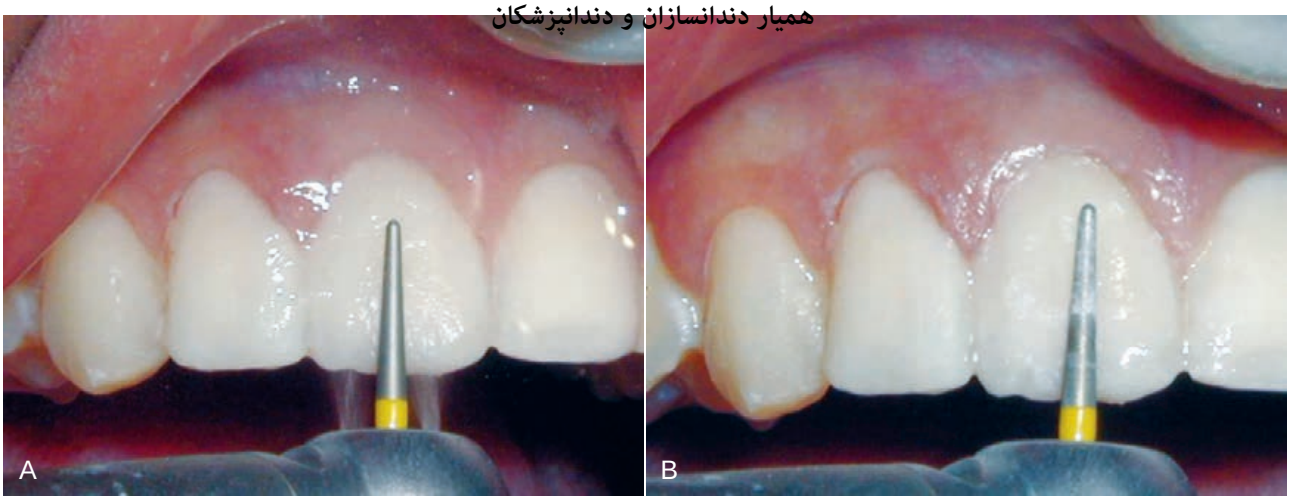


FIGURE 11-30 Wet (A) and dry (B) finishing.

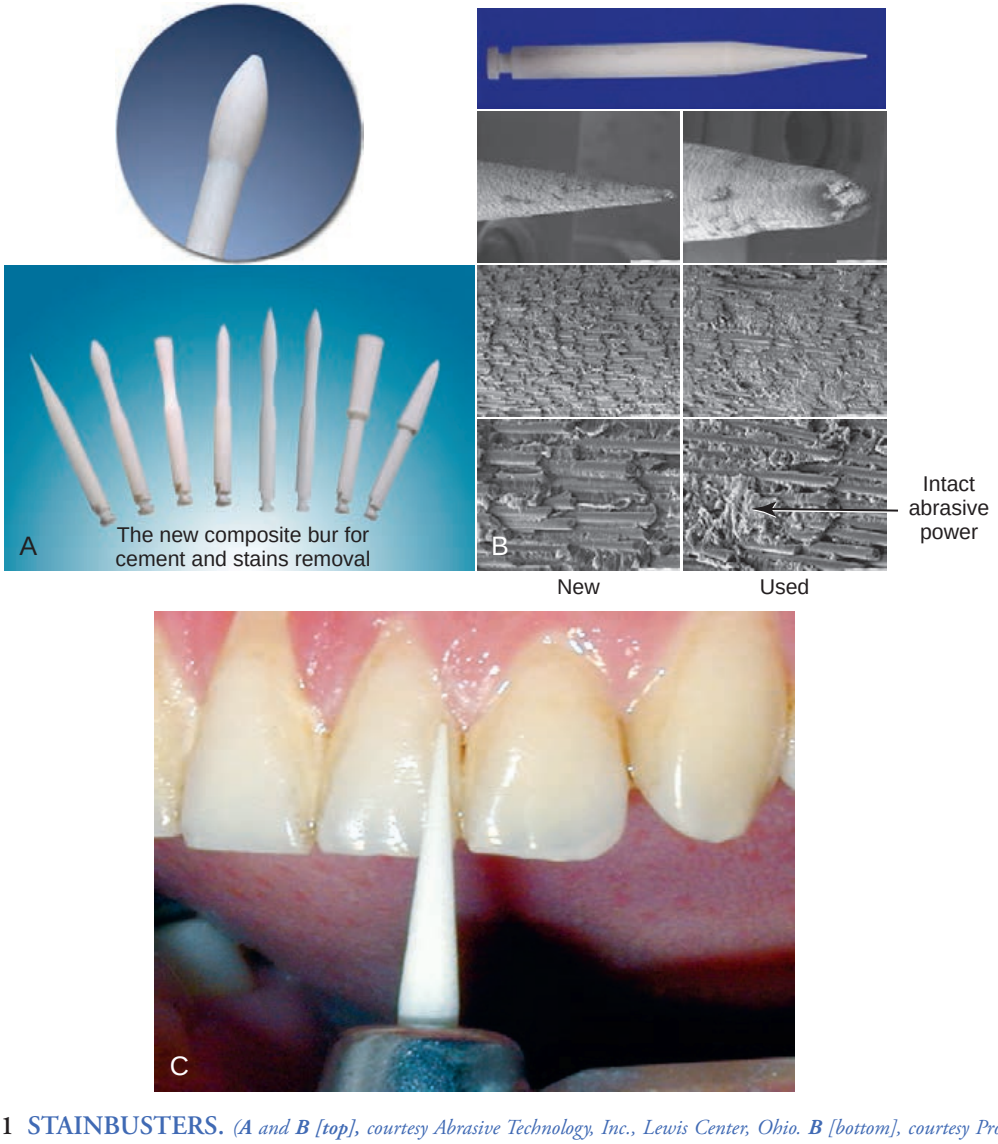


FIGURE 11-31 STAINBUSTERS. *(**A** and **B** [top], courtesy Abrasive Technology, Inc., Lewis Center, Ohio. **B** [bottom], courtesy Professor W.I. Finger.)*

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to desensitize or to prevent further damage to the tooth. The esthetics is important for class V restorations, and hence finishing and polishing are equally important to shade selection. Sometimes patients not having pain related to class V (cervical cavities/lesions) complain of post-restoration pain that arises from sensitivity and accumulation of plaque caused by lack of finishing and polishing at the cervical margin area (Figure 11-34).



FIGURE 11-32 Anatomy of the tooth.

Finishing and polishing of class V restorations are necessary to get bilateral symmetry, especially in the central ridge region, and to achieve better esthetics.

General Sequence for Finishing and Polishing

The sequence depends on the restorative material used, such as glass ionomer, composite, microfills, and ceramic, both intra-orally or extra-orally. With glass ionomers, fluted carbide burs cannot be used; only diamond points, available in different grits, with light pressure are used. For composites, fluted burs are used after diamond points, and then disks of different grits are used to finish a restoration. For ceramic, it is important to use diamond-impregnated cups, cone, and heels, in the sequence of coarse to medium to fine to super-fine, and then to polish with diamond polishing paste. Polishing paste containing aluminum oxide is used for microfills, whereas diamond polishing paste is used for nanofills and ceramics.

Use of Polishers in Sequence from Coarse to Fine

Finishing and polishing disks in different grits with aluminum oxide as the abrasive are used for microfill composites. These disks remove the unevenness on the surface of the restoration.

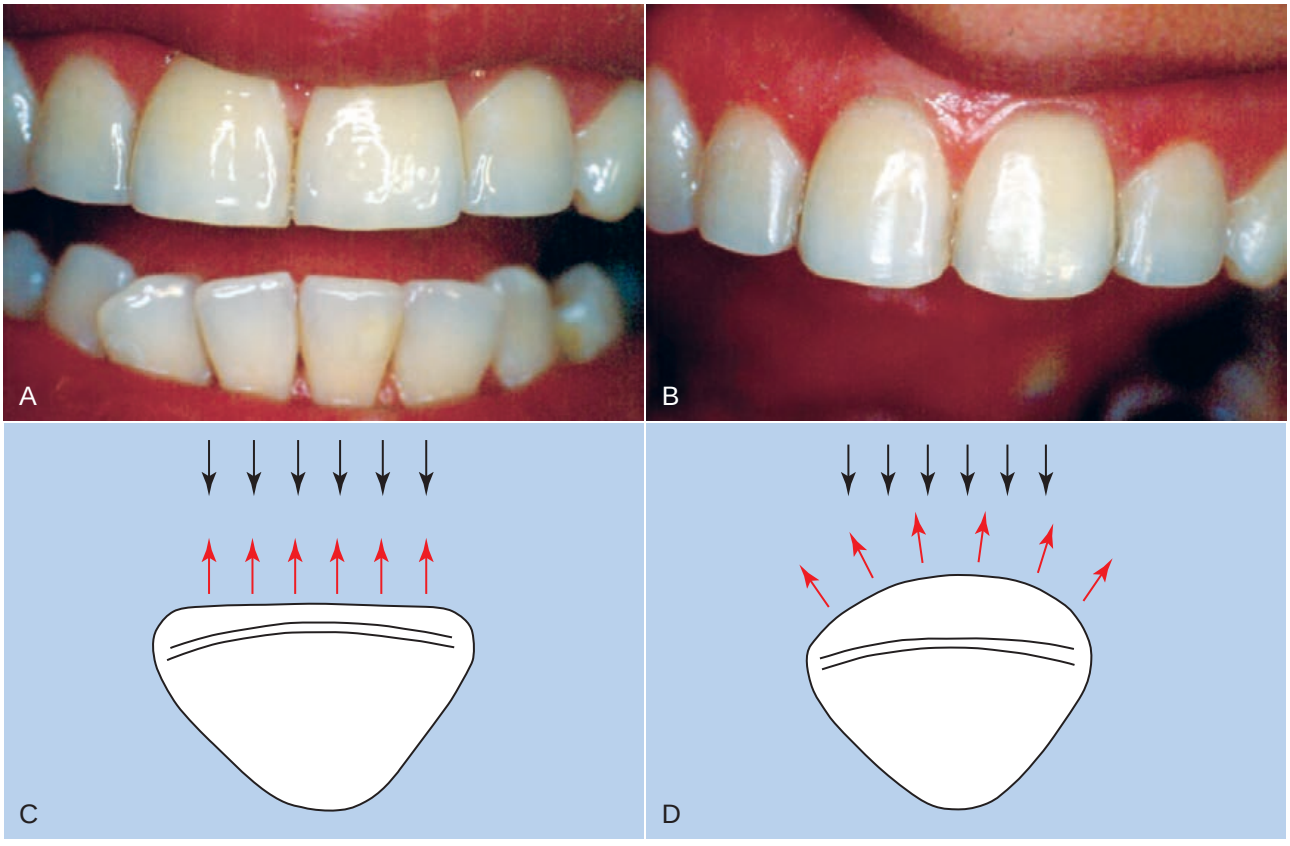


FIGURE 11-33 Creating illusion via finishing and polishing: before (A and C) and after (B and D).

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FIGURE 11-34 **Finishing and polishing at the cervical area with a small-head carbide bur retracting the gingiva.**

The coarse and medium disks are used to finish, and the fine and super-fine to polish, the restoration. Hence it is necessary to use the disks from coarse to medium to fine to super-fine in sequence to achieve the best results. Not following the sequence will not polish; instead it will damage the restoration.

TREATMENT CONSIDERATIONS FOR PREPARATION AND PROCEDURE

The treatment considerations depend on the restorative material used.

When a glass ionomer is used as a restorative material, the most important thing in preparation is its powder-liquid ratio. The best way to use a glass ionomer is to use it in a capsule or a paste-paste form. Before finishing and polishing, the restoration has to be well set and has to be protected from water absorption and dehydration. When matrices are used in class V restorations, only the margins are polished and the central portion that is already polished is left untouched (Figure 11-35).

In restorations in which matrices are not used, the initial finishing and polishing is done with 20-micron diamonds followed by aluminum oxide cones, cups, and wheels (Figure 11-36). Carbide fluted burs should not be used for glass ionomers. Lastly, the restoration is coated with surface sealants so that the restoration is protected.



FIGURE 11-35 **Use of matrices for class V glass ionomer restoration.**

For finishing and polishing composites, the restoration has to be fully polymerized and cured with the right intensity of curing light. Care should be taken regarding the power density

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FIGURE 11-36 **A, Class V cavity. B, Glass ionomer restoration. C, Finishing with diamond point. D, Polishing with aluminum oxide cone. E, Finished restoration.**

of the light. For gross finishing, diamonds of 50, 30, 15, and 8 microns are used (Figure 11-37). Carbide 8- and 12-fluted burs are used for gross contouring (see Figure 11-22), after which 16-, 30-, and 40-fluted burs are used for finishing and polishing. Depending on the smoothness of the surface to be finished, diamond points and carbide burs of different shapes and sizes are used. Subsequently, finishing disks—coarse, medium, fine, and super-fine, necessarily in the same sequence—are used for the final finish. The finishing disks are used wet except for microfills. Diamond-impregnated cups and cones are used for final finishing of nanofills. A polishing buff from Cosmedent or aluminum oxide–impregnated polishing paste is used to polish microfills, whereas diamond-impregnated polishing paste is used to polish nanofills. The particle size of the polishing paste should be smaller than the filler size of the restorative material. Finally, to avoid microleakage and staining, surface sealants such as G-Coat Plus (GC America, Alsip, Illinois) or Seal-n-Shine (Pulpdent, Corp., Watertown, Massachusetts) or PermaSeal (Ultradent Products, Inc., South Tordan, Utah) are used to seal the margins.

For the finishing and polishing of ceramic crowns, the high points are first checked and adjusted intra-orally using the green stone with a generous amount of water before polishing. The ceramic crowns can be polished extra-orally but inlays, onlays, and laminates should be polished intra-orally. If microcracks develop during finishing, ceramic crowns are usually sent to the technician for glaze. Glazing heals the microcracks. The routine procedure for extra-oral ceramic crown and bridge finishing is to remove the high points with the green stone (Figure 11-38) and then finish with coarse (green wheel) (Figure 11-39),

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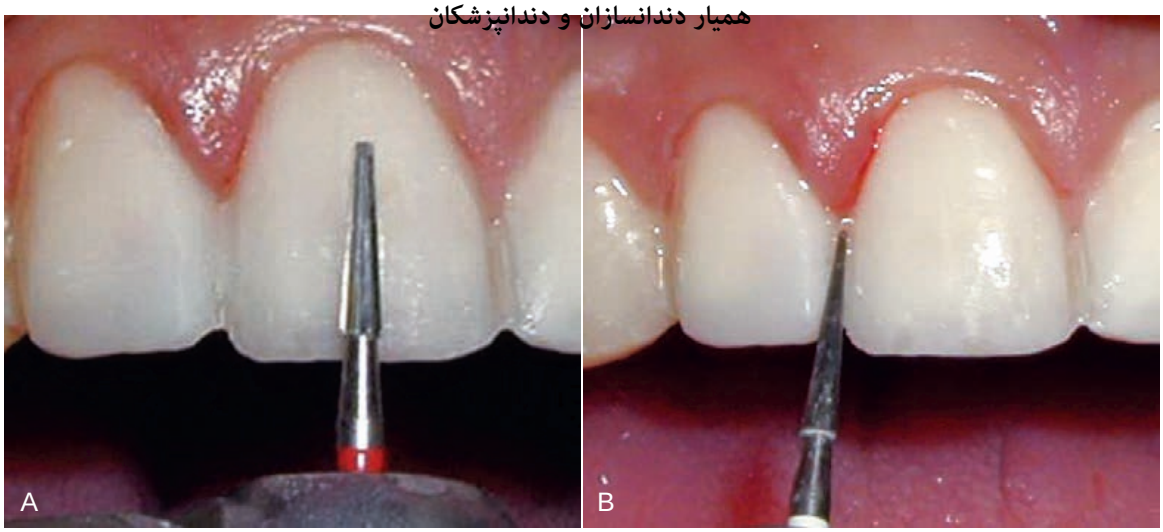


FIGURE 11-37 Gross contouring with carbide bur.

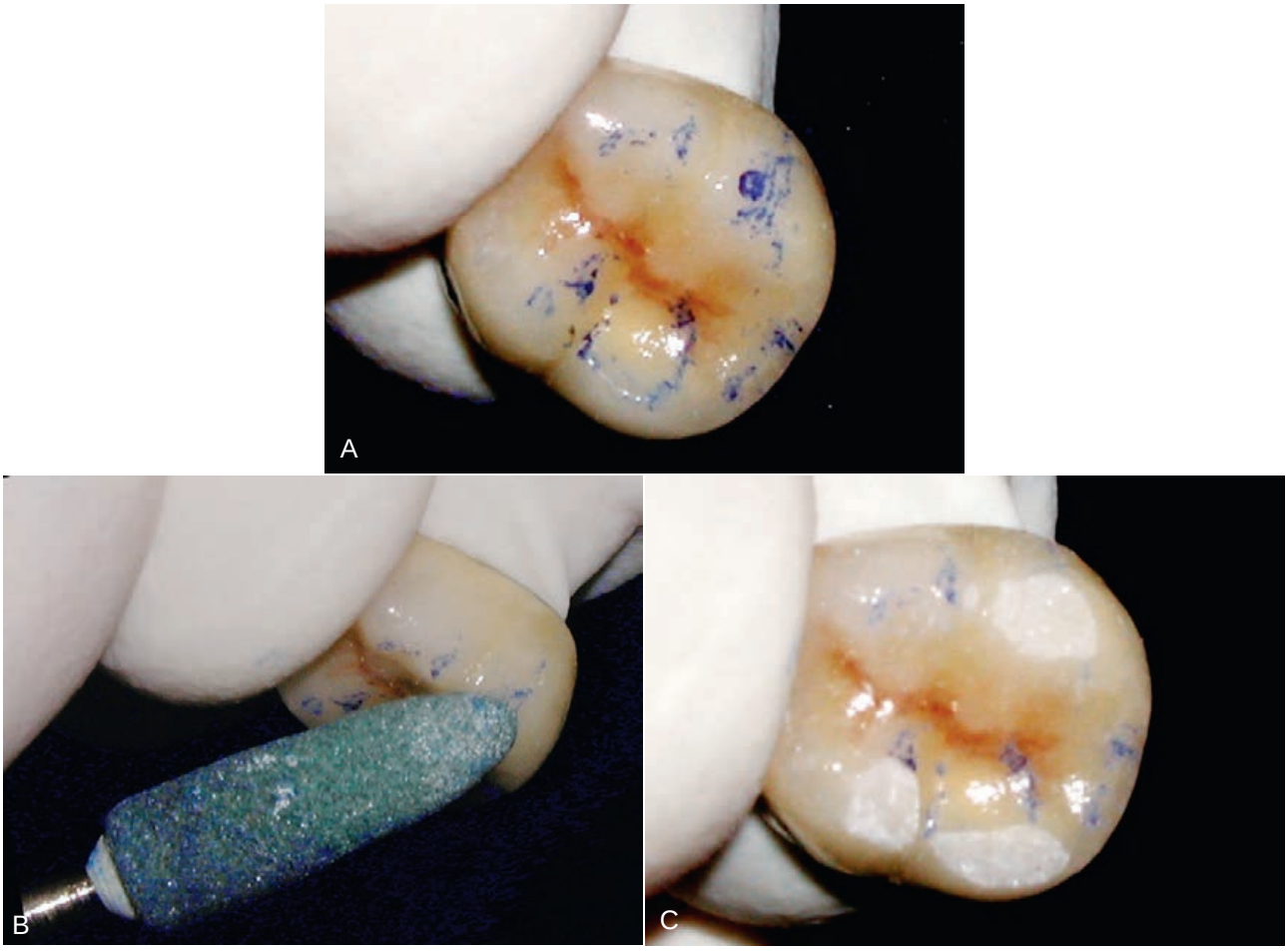


FIGURE 11-38 Polishing high points with green stones.

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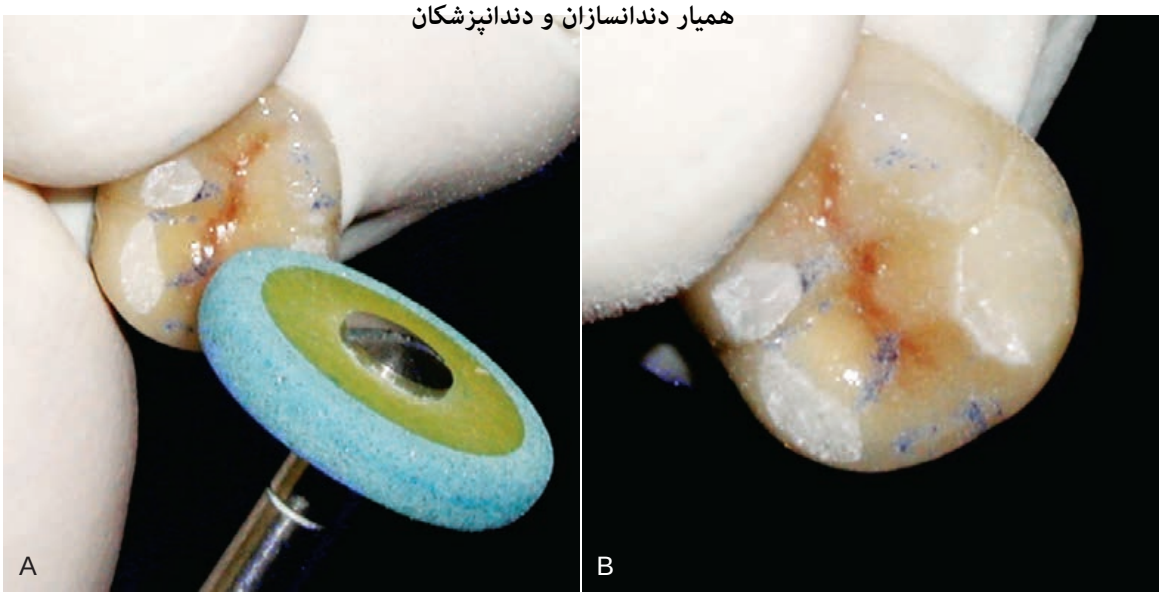


FIGURE 11-39 **A, Finishing ceramic with green (coarse diamond) wheel. B, Difference between finished surface and unfinished surface.**

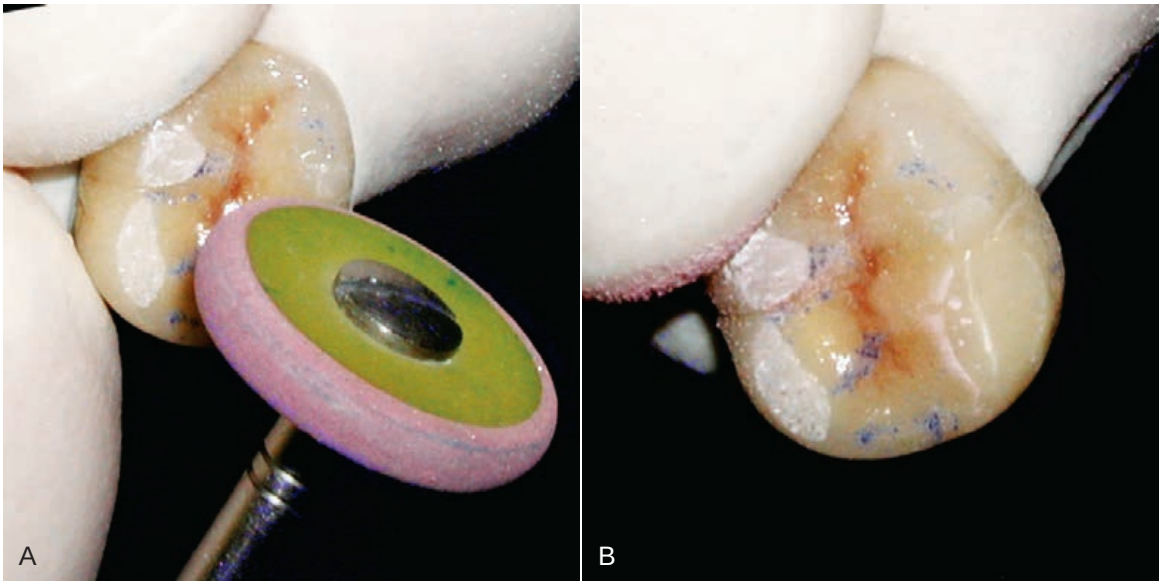


FIGURE 11-40 **A, Finishing ceramic with pink (medium diamond) wheel. B, Difference between finished surface and unfinished surface.**

medium (pink wheel) (Figure 11-40), and fine (gray wheel) (Figure 11-41) diamonds followed by polishing with diamond polishing paste (Figure 11-42).

DIFFERENCE BETWEEN POLISHING AND GLAZING

Glazing creates a uniform, shining, smooth surface, whereas a polished surface is smooth and textured. Glaze yields a homogenous reflection—that is, a smooth surface on the restoration. When surface sealants are applied on the tooth surface, it gives a momentary glaze, but a polished textured surface lasts longer.

EVIDENCE-BASED PRINCIPLES

There is much evidence in dental books and journals that finishing and polishing give good esthetics and function to both direct and indirect restorations. There is also evidence that using the right sequence and the right material to polish and finish achieve a longer-lasting and good esthetic restoration.

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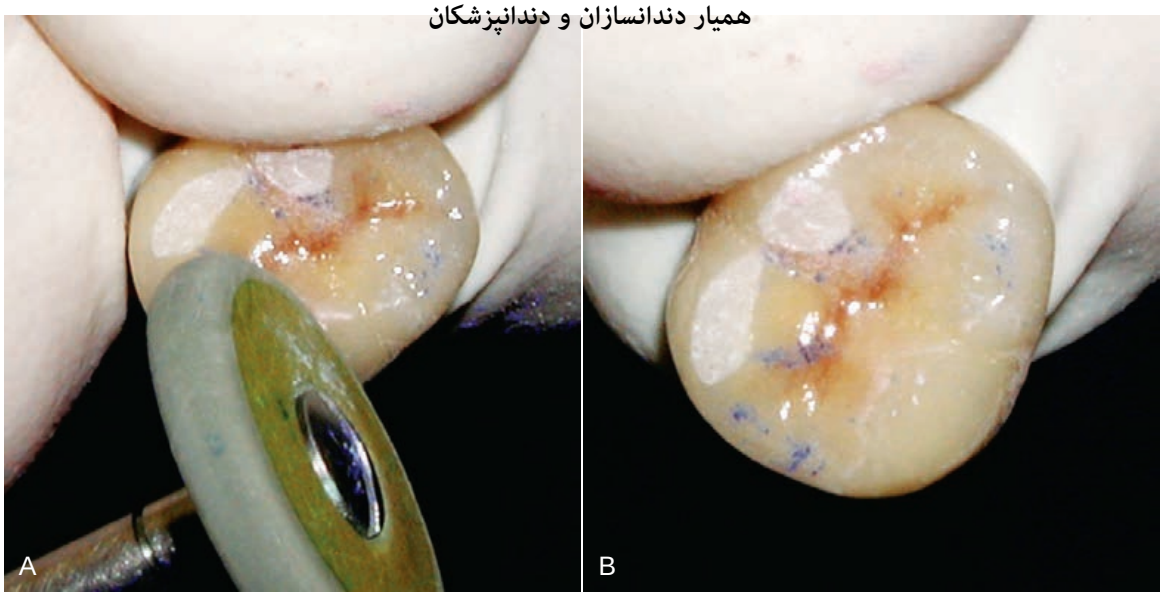


FIGURE 11-41 A, Finishing ceramic with gray (fine diamond) wheel. B, Difference between finished surface and unfinished surface.



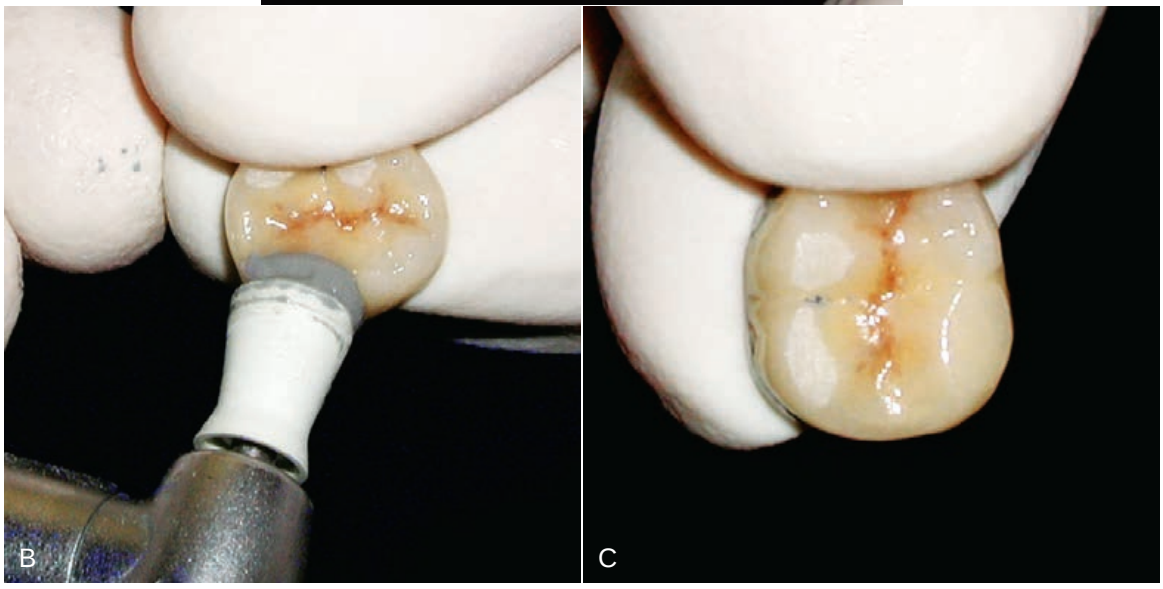


FIGURE 11-42 A, B, Polishing with diamond polishing paste. C, Difference between finished surface and unfinished surface.

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MAINTENANCE

The restoration that is well finished needs very little maintenance. There can be no damage to the material, and the restoration lasts longer and retains good esthetics and proper function. With a new restoration, the initial perception of the patient is that if he or she brushes regularly and in the normal manner, the restoration will come out. Patients need to be advised to brush and floss the restoration as they do their natural teeth and visit the dentist every 4 to 6 months for a routine checkup.

CONTROVERSIES

Per se, there are no controversies, but there is always a question about whether to use dry or wet finishing. In dry finishing and polishing, the material is abraded, but when the material is used wet, the line angles, convexities, and concavities that hamper creation of the surface textures and other characteristics in the restoration cannot be appreciated. In indirect restorations such as crowns, finishing with pressure can cause microcracks. In the case of inlays and onlays, the technician should always create a finished and polished restoration that needs no occlusal adjustments because finishing and polishing are difficult in the mouth and are not advisable.

NEAR-FUTURE DEVELOPMENTS

In the near future, there should be a material that can be used uniformly and evenly on the surface of the restoration that can protect the material beneath better than the sealants used today. The material should be as thin as possible so as not to block the textures created on the surface of the restoration.

A Single Polisher instead of Progressive Material Polishers

The chemistry of the polishing material will depend on the chemistry of the material to be polished. For example, a microfill or a hybrid can be polished with aluminum oxide, and nanofill can be polished with diamond-impregnated polishers. The best polisher would be a single polisher that can be used for all composites and ceramics.

CLINICAL TECHNIQUE

Patient History

A 27-year-old woman, a non-resident Indian living in the United States, visited the dentist for diastema closure. She was getting married in 3 days and wanted the diastema fixed before the ceremony.



FIGURE 11-43 Patient exhibiting diastema and supragingival pockets.

Relevant Conditions

On clinical examination, the patient had a diastema between her central incisors, which was found to be a developmental deformity. The clinical size of the teeth was smaller than the anatomic height owing to the supragingival pockets (Figure 11-43). The gingiva was found to be in a healthy condition. The patient's protrusive movements were functional to achieve posterior disclusion.

Treatment Planning

The ideal treatment would have been to orthodontically move the central incisors to close the diastema so that the gingiva would also move with it, creating diastemas between the central and lateral incisors on either side. After closure of these diastemas, the golden proportion would be maintained. Generally two factors are looked at together: the size and proportion of the central incisors and the golden proportion. To achieve this, a crown lengthening procedure (CLP) is considered. Thereafter, to close the diastemas between the central and lateral incisors, laminate or veneer is recommended.

Because time was a constraint, a compromise treatment was planned, in which the diastema would be closed with direct composite laminate after the CLP was performed in the anterior teeth.

Clinical Step-by-Step

Post-prophylaxis, the CLP was performed, after which the gingival retraction cord with Ultradent Clear astringent was placed (Figure 11-44) to avoid damage to the periodontium and to take care of gingival fluid. After etching, priming, and bonding, composite laminates were created using the shade selection guide, and the diastema was closed (Figure 11-45).

The gingival retraction chord was removed. After the line angles were marked, diamond points (SS White Burs, Inc.,

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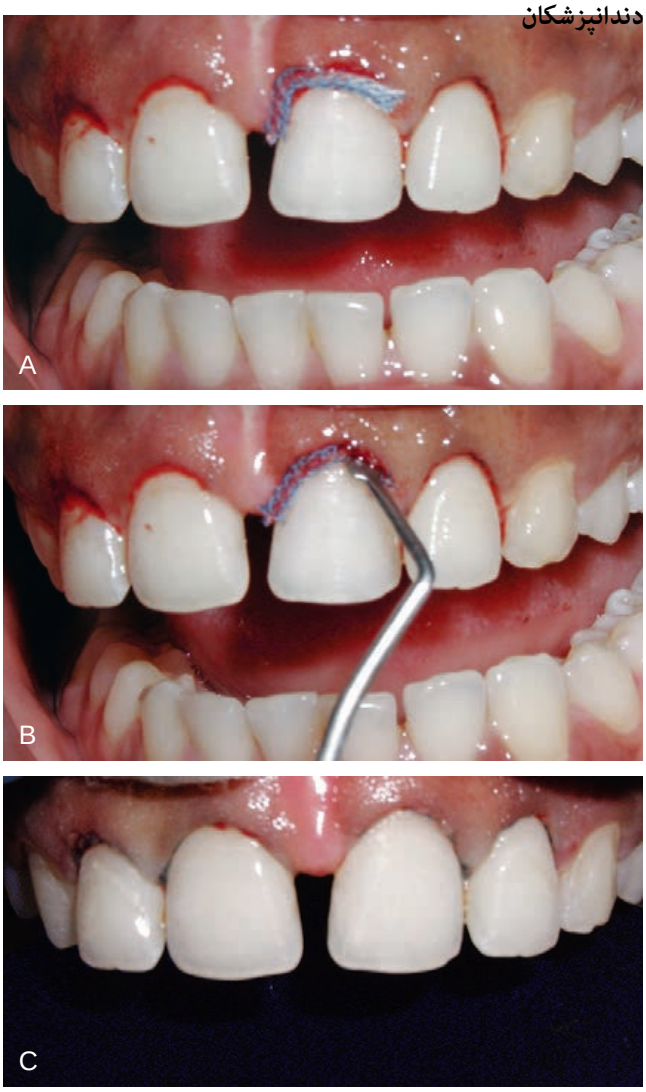


FIGURE 11-44 Insertion of retraction cord with clear astringent.



FIGURE 11-45 Closure of diastema.



FIGURE 11-46 Removing the excess with No. 12 Bard-Parker blade.

Lakewood, New Jersey) of 50 microns were used, followed by points of 20 microns and 8 microns for gross finishing. High points on the palatal side of the central incisors were checked in occlusive and protrusive movements, and gross finishing was done with American football–shaped, 100-micron diamond points (SS White) and subsequently with carbide fluted American football–shaped burs (SS White). Carbide burs (Comet, SS White) 8- to 30-fluted with different heads were used on the labial and proximal areas to give proper line angles and contours. To create an illusion by manipulating the height and width of the restoration, the carbide burs were moved from labial to the line angles and then from the line angles to proximal to give prominences to the line angles and maintain the golden proportion among the centrals, laterals, and canines. For this purpose, the line angles were marked with pencil (see Figures 11-20 and 11-22).

To create the texture and polish the restoration, Sof-Lex disks were used in a sequence from coarse to medium to fine to superfine. The disks were moved in such a way that the line angles and incisal contours were maintained, so that the central incisors were close to the golden proportion. A polishing buff (Cosmedent) was also used to give a smooth finish to the restoration. The palatal surface was polished with diamond-impregnated Jazz rubber cups, cones, and wheels (SS White) of different grades. A No. 20 Safe End finishing bur (SS White) was used to polish the cervical portion of the restoration. After a properly textured, polished surface had been achieved, a No. 12 Bard-Parker blade was used interdentally to remove the excess material and open up the joint (Figure 11-46). Subsequently floss was passed interdentally between the central and lateral incisors. Sof-Lex polishing strips were then used to polish the interdental and proximal surface, followed by polishing with diamond polishing paste to achieve a final textured, smooth, polished restoration (Figure 11-47).

The finished restoration had the same enamel-like gloss in wet or dry, which was the desired result.

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FIGURE 11-47 Before and after diastema closure.

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12 CHAPTER

Fiber Reinforcement

A SECTION

Direct Fiber-Reinforced Restorations

William E. Turner

Composites by definition are materials made up of distinct components that retain their individual identities. They have structural or functional properties not present in any individual component. The composites with which dentists are most familiar are particulate composites, consisting of a resin matrix with particles of various materials and sizes as fillers. Laminate composites are composite materials formed from materials placed in layers. The fiber-reinforced composites (FRCs) used in industrial applications are generally laminate composites. When fibers are used to reinforce dental composite, the resulting material is both a particulate and a laminate composite and is termed a *fiber-reinforced composite.*

BRIEF HISTORY AND EVOLUTION OF FIBER-REINFORCED COMPOSITES

The use of fiber-reinforced technology in dentistry dates back to the 1960s. Early attempts to adapt the technology to dental applications involved the incorporation of reinforcing fibers into polymethyl methacrylate (PMMA) denture base resin to reduce the incidence of fracture. Once composite became established as a restorative material in dentistry, attempts were made to use fiber reinforcement technology to give it enough strength for use as a fixed bridge. Some early attempts used carbon fibers and were not entirely without success. Unfortunately, carbon fibers are black or color, which is difficult to mask in esthetic dental procedures.

The earliest attempts at using FRC technology in dentistry involved adapting readily available industrial materials for use in dental restorations. In 1980, Dr. Paul C. Belvedere investigated the strength of dental composite reinforced with aramid fibers (Kevlar, DuPont, Wilmington, Delaware). Bars of dental composite 2 mm × 2 mm × 1 cm were reinforced with as much fiber as could be incorporated into the available volume. Fibers were unidirectional and extended the full length of the sample. Scanning electron microscopy determined that the samples were about 50% fiber by volume. The samples were then tested to failure using an Instron machine. The reinforced samples exhibited about a fivefold increase in flexural strength over an unreinforced control. Examination of the failed structure revealed that on failure the fibers had stretched, reducing their cross-sectional area, leaving a space around the periphery of the fibers. This suggests that the weakest links in the structure were the strength of the fibers and the bond strength between the fibers and the resin matrix.

Numerous in vitro studies have demonstrated the increased strength of dental composite when reinforced with fibers. In 1992 Goldberg and Burstone investigated the strength of composite reinforced with silane-treated S-glass fibers and compared their results with previous reports covering carbon or Kevlar fibers. They demonstrated substantially increased strength results over those of previous investigators and attributed their improved results to a higher percentage of fiber in the structure. They achieved about 40% to 45% fiber by volume. They also predicted that the challenge in developing an FRC suitable for use in dentistry is to maintain a high percentage of fiber in the mix while meeting the requirements of acceptable esthetics and ease of clinical manipulation.

In 1994 Vallittu colleagues investigated the effect of reinforcing acrylic resin with carbon, glass, and aramid (Kevlar) fibers. They observed increased fracture resistance in all samples that was proportional to the concentration of incorporated fibers. They also noted voids in the specimens that compromised the strength of the structure. These voids were more prevalent with glass and carbon fibers. A subsequent study by Vallittu showed the voids to be largely caused by polymerization shrinkage of the PMMA resin. The 21% shrinkage of the PMMA resin is

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substantially higher than the 3% to 6% observed for dental composite, and thus polymerization shrinkage would appear to be a concern.

In 1994 Viguie and co-workers looked at dental composite reinforced with carbon fibers in three configurations: short fibers, woven fibers, and long unidirectional fibers. They concluded that long unidirectional fibers provided the greatest increase in strength, followed by woven and short fibers. Their tests were conducted to failure with a bar of material 100 mm × 10 mm × 2 mm high. This, of course, is substantially larger than that used by most other investigators and much larger than anything constructed for use in the oral environment. The testing method also failed to consider the complex forces at work on a dental appliance. Still, their conclusion that long unidirectional fibers impart greater strength than short or woven fibers probably has merit, if the fibers can be oriented within the structure to resist the forces applied to it.

In 1998 Goldberg and colleagues examined four of the commercially available fiber-reinforcing systems. The glass products were consistently stronger than the polyethylene materials. Unidirectional materials were also found to be superior to those that were braided or woven.

In 1999 Dyer and Sorensen examined the effect of several design features on the strength of structures fabricated with FRC. They looked at three different configurations: (1) unidirectional glass fibers in bar form and wrapped around the abutments; (2) woven polyethylene ribbon to create an I-beam; and (3) unidirectional glass fibers for the support bar and woven fibers in a spiral wrap around the entire support bar. They found that the unidirectional glass fibers with the woven fibers wrapped around them had the highest overall strength, although this was largely a result of the fact that this configuration also resulted in the highest concentration of fibers in the structure. The I-beam configuration had greater strength than the other two designs when the percentage of fibers was factored out.

In most studies of FRC in dentistry, a simple experiment is used. A standard-size bar of the composite material is placed in a device that applies a three-point load, and the sample is tested to failure. Such studies typically find that the material's strength is increased substantially by the addition of the reinforcement fibers, but often conclude that the strength of the resulting structure is still inadequate for use as a dental restoration. Such a conclusion does not correlate well with the excellent clinical success achieved by numerous practitioners. Fiber-reinforced dental composite may not work on paper but works extremely well in the mouth.

CLINICAL CONSIDERATIONS

Beam Theory

Any understanding of FRC bridges must begin with beam theory. A *beam* is defined as a structural member that is subjected to loads applied transverse to the long axis. The simplest type of beam is known as a *cantilever* (Figure 12-1). This concept, familiar to most dentists, refers to a beam supported and retained at one end, called *encastré* by engineers. Near the middle of any

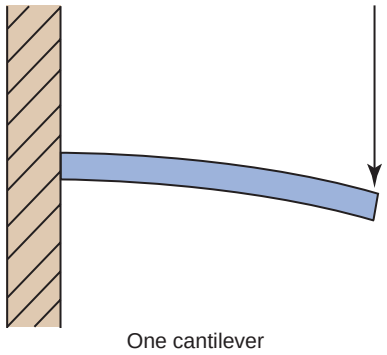


FIGURE 12-1 **A cantilever beam is supported and retained at one end.**

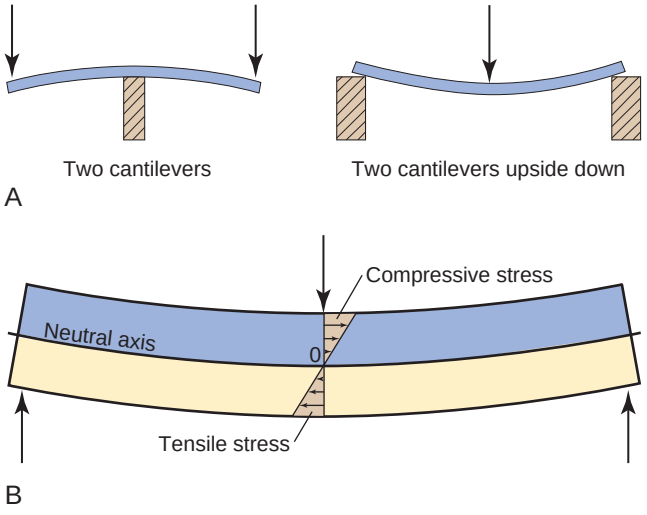


FIGURE 12-2 **A, A simply supported beam can be considered two cantilever beams back to back and upside down. B, Stresses in a simply supported beam are compressive above the neutral axis and tensile below.**

beam is a line (or a plane in three dimensions) known as the *neutral axis.* This axis coincides with the centroid or geometric center of the beam. The longitudinal stresses along this line are zero. The stresses in a cantilever beam are essentially tensile above this line and compressive below it. The farther from the neutral axis, the greater the stress. This explains the success of I-bar beams, as the greatest strength of the beam structure is concentrated farthest from the neutral axis, where there is the greatest stress.

The second type of beam is a simply supported beam. This type corresponds to a board laid across a puddle. A simply supported beam is essentially two cantilevers turned back to back and upside down (Figure 12-2, *A*). The stresses on it are compressive above the neutral axis and tensile below it (Figure 12-2, *B*).

The third type of beam is a combination of the cantilever and the simply supported beam. This beam is supported at both ends, but both ends are retained or encastré. This is the type of beam being constructed when a dental bridge is being fabricated. It has structural elements of both types of beam. Tensile stresses

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are below the neutral axis, but above the neutral axis there are compressive stresses in the beam's middle and tensile stresses toward the ends. Cutting this type of beam in the center produces two cantilevers end to end. If we release the hold on the ends, we have a simply supported beam. This may partly explain the discrepancy between the failure of FRC in the literature and its success in practice. Although it is clear that any in vitro testing requires that the material be supported at both ends to simulate what occurs when we fabricate a fixed partial denture, most studies do not specify how the material is retained for testing.

The Science of Fiber-Reinforced Composites

To understand FRC bridges, it is also important to examine the mechanism of failure of composite materials. Although a detailed discussion of fracture mechanics is beyond the scope of this book, there are factors that help to explain the discrepancy between clinical successes and laboratory failures.

Materials can be described as *brittle* or *ductile.* When the elastic limit of a material is exceeded, brittle materials fracture and ductile materials bend. Dental composites bend very little and are classified as brittle, even when the composite is reinforced with fibers.

Dental composites, like all brittle materials, fail as a result of crack propagation. Geometric defects within the structure act as points of stress concentration. These irregularities can be holes, bubbles, cracks, sharp corners, and so on. These faults cause the stresses within the material to become focused at these points, causing the initiation of fracture, even though the overall stress within the material is well within its theoretical strength. This is the same principle used in cutting glass. A small scratch is etched on the glass surface, and a stress is applied to the material. The scratch acts as a source of stress concentration, and the glass fractures cleanly along the line scratched in its surface. If the scratch does not continue completely across the sample, the fracture still begins where the scratch concentrates the stress and propagates irregularly across the glass, because the end of the fracture becomes the new point of stress concentration, until failure occurs. Clinical success or failure of FRC may be as much a function of our success in minimizing the microcracks and irregularities in the structure as of the inherent strength of the materials.

The fracture resistance of any material is less a function of its strength than of its toughness. Fracture toughness is the resistance of a material to form cracks and is a measure of the damage tolerance of the structure. Glass and steel have similar tensile strengths, but no one would suggest the two are interchangeable; steel is tougher than glass. One small crack in a pane of glass results in rapid propagation of the crack, resulting in fracture of the glass. Small cracks in steel do not necessarily produce fracture. When the structure is placed under stress, thousands of microcracks are created within the material. These microcracks tend to travel through the structure and, if they are permitted to connect with one another, eventually coalesce into macroscopic cracks, then fracture lines.

The fibers within FRC enhance the load-bearing capacity of the structure by two separate and distinct mechanisms. First, the fibers act as a stress-bearing component, as would be intuitively expected. They support the forces of occlusion much like cables in a suspension bridge. They also strengthen the composite by acting as a crack-stopping and crack-deflecting component. As microcracks propagate through the resin matrix, if they encounter a fiber, they are stopped and deflected along the interface between the fiber and resin. The fiber becomes circumferentially detached from the resin matrix. When the crack intercepts another fiber, it forks and divides, multiplying the number of cracks in the structure. The creation of each new crack consumes energy and increases the work of fracture for the material. This mechanism dissipates the energy applied to the structure. The process of branching of cracks continues until energy demands become too high or the material fractures. Over time, the accumulation of cracks within the structure begins to act as a stress relief mechanism. Stresses are relieved by the friction between the material surfaces in contact at the crack. Flexure of the prosthesis also transfers stresses to the fibers, which then support the structure as a stress-bearing component.

Which of these two mechanisms is more important is open to some debate. Rudo and Karbhari argue in their article "Physical Behaviors of Fiber Reinforcement as Applied to Tooth Stabilization" that woven material is superior to unidirectional material in vivo. Whereas unidirectional material exhibits superior strength in the direction of the fibers, there is little correlation between the stresses placed on a dental restoration and the unidirectional stresses placed on the materials in laboratory testing. Rudo and Karbhari argue that the load-bearing action of the fibers is secondary to their crack-stopping function. Therefore the fibers need not be unidirectional. Woven fibers may offer greater strength, because the intersecting fibers are more effective at stopping and deflecting cracks.

Regardless of the mechanism, the incorporation of reinforcing fibers into dental composite increases the material's strength. The tensile (and therefore the flexural) strength of the resulting structure is enhanced by the fibers. The more fibers that can be incorporated, the greater the strength achieved. The principle is well stated in the *rule of mixtures,* which states that the mechanical properties of a composite material are proportional to the volume and properties of the individual components in the mix. In reality, the strength of FRC dental restorations tends to be less than theory would suggest, mainly because the limitations imposed by the space and design considerations of a dental restoration reduce the amount of fiber that can be incorporated into the structure. The literature tells us that the amount of fiber incorporated into most dental structures is low, usually on the order of 15% by volume.

MATERIAL OPTIONS

FRCs have been used with great success in industrial applications for many years. The most common and best known of these materials is fiberglass, the generic term for various forms of plastic reinforced with glass fibers. (Fiberglas [with one *s*] is a

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registered trademark belonging to Owens-Corning [Toledo, Ohio] for their glass fibers, which are used both in composite materials and as insulation.) These materials are used in the manufacture of myriad products, including boat hulls, automobile bodies, aircraft propellers, and windmill blades. The enormous popularity of high-performance homebuilt aircraft was made possible in large part by the availability and reliability of FRCs. Available materials include epoxy and polyester resins reinforced with fibers such as glass, aramid, graphite, and ceramic. In addition, these fibers are available in various configurations, including unidirectional, bidirectional, woven, and braided.

Commercially Available Fiber Systems

All fiber reinforcement products are variations on two major systems: plastic or glass. Plastic fibers generally have handling characteristics superior to those of glass, whereas glass is generally the stronger material.

Most plastic fiber systems are polyethylene. The fibers are usually braided or woven into a ribbon, with each manufacturer claiming to have the superior configuration. In reality, how fibers are woven makes little difference in the strength of the resulting restoration. It can, however, result in differences in how the material handles. Concerns also arise about the ability to fully impregnate certain tightly woven configurations of fibers with resin.

The surface of plastic fibers is usually treated with cold gas plasma to enhance the bond between fibers and resin. In this technique the fibers are exposed to a partially ionized oxygen gas that acts through a process of ablation and activation. The ablation results in an etching of the fiber and an increase in the presence of chemically active groups on the fiber surface. These groups chemically bond to the resin, while the etched surface facilitates a micromechanical bond. The plasma treatment also enhances the wettability of the fiber surface, which increases the resin in contact with the fiber and helps to reduce the presence of voids and bubbles at the resin-fiber interface, which act as points of stress concentration. Cold gas plasma treatment is highly susceptible to contamination, however. The fibers therefore must be handled carefully to prevent contamination before they are impregnated with resin. One manufacturer includes a pair of cotton gloves in the kit to protect the fibers during handling, but these are not practical. Carefully avoiding touching the fibers before impregnating them is adequate.

Glass fibers are of two types, E-glass or S-glass. The two materials are different chemically, but handling is essentially identical. S-glass is the stronger of the two and has a higher modulus of elasticity. Glass fibers are stronger in theory than plastic, but their stiffness makes them much more difficult to work with clinically. S-glass fibers are stiffer, so elastic memory is more problematic in handling and placement for dental applications.

Glass fibers are etched and silanated to enhance the resin-to-fiber bond. The etching process is similar to etching porcelain before bonding, although the actual process is proprietary. Etching glass fibers is, by all reports, duration and chemistry critical. Glass fibers cannot be etched and silanated chairside. If they are over-etched, their strength diminishes dramatically; if they are under-etched, the bond to resin is inadequate.

TREATMENT CONSIDERATIONS

The introduction of FRC represented the first opportunity for composite bridge fabrication that could be considered successful. Numerous authors have described techniques meeting with varying degrees of success. The techniques may be indirect or direct.

Indirect Methods

Several manufacturers have developed FRC materials for laboratory-fabricated prostheses, with mixed success. One advantage of the indirect technique is that it uses techniques and procedures reasonably familiar to most dentists. The concepts of preparing the teeth, making an impression, and fabricating a provisional restoration differ little from making a porcelain-fused-to-metal bridge. The procedure for bonding the prosthesis is the only departure from more traditional techniques.

Another advantage to the indirect technique is that it is possible to cure the composite using heat and pressure to enhance the strength and wear resistance of the cured composite. Unfortunately, this also results in the greatest shortcoming of indirect composite techniques. When a composite restoration is fabricated in a laboratory, especially when it is cured with heat and pressure, it must be bonded using almost entirely micromechanical means, because the polymerization of the composite will have progressed to the point that there will be few free radicals left for chemical bonding to the composite resin. The composite's surface may also become corrupted by myriad contaminants during the fabrication process, including the surface of the stone cast. These contaminants must then be removed. Whatever technique is employed to clean and etch the surface before bonding will remove any air-inhibited layer, eliminating any chance for chemical bonding. Thus there is an obvious advantage to fabricating the entire prosthesis in place in the mouth.

Direct Methods

In 1981, Belvedere placed some of the first directly bonded FRC resin bridges using Kevlar fibers. The first bridge was a four-unit prosthesis replacing two maxillary central incisors using the laterals as abutments in a 22-year-old woman. At last report (1989) the bridge was still in service and had not been repaired or replaced. Nearly 400 bridges have been reported to be in service, with a 98% survival rate over an 8-year period.

In 1994 Abel described a technique for the direct fabrication of an FRC bridge to replace incisor teeth. The technique was a bold attempt but failed to deal with several important issues. Significant in any bridge design is the tissue contact surface of the pontic, and Abel's technique fails to address this. The article is unclear, but it appears that he simply fabricated the pontic in place, in direct contact with the tissue, and allowed the gingiva

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of the edentulous space to develop the tissue surface form of the pontic.

Culy and Tyas described a technique for direct fabrication of FRC anterior bridges. They replaced 26 single upper anterior teeth and one premolar using hybrid composite reinforced with plasma etched polyalkane fibers (Fibrespan, Nulite Systems, Sydney, Australia). They followed their cases for only 10 months, and two bridges failed as a result of trauma. Of the 27 bridges, 25 were of cantilever design, which the authors argue is more predictable because there is no differential movement between the abutments. This runs counter to conventional wisdom regarding bridge design. The authors also found the process to be "technically demanding," particularly with respect to the pontic saddle design, but offered the technique as a viable option for conservative tooth replacement.

In 1998 Belvedere described how to fabricate a direct FRC bridge to replace missing central or lateral incisors. His technique addresses the problem of controlling the tissue surface of the pontic with the fabrication of a "pontic button." The portion of the pontic in contact with the tissue is fabricated in place in the mouth and trimmed, and the tissue surface is contoured and polished before being incorporated into the restoration. The abutment teeth are prepared and bonded, the fibers are placed, and the pontic button is positioned under the fibers. The coronal portion of the pontic is then custom fabricated in place in the mouth. The technique is a marked improvement over previous attempts but requires significant clinical skill to manipulate all the parts and materials successfully into position.

Although many of the problems associated with the direct fabrication of FRC resin bridges have been solved, the clinical techniques for bridge fabrication still need refinement. Belvedere's technique addresses the problem of controlling the tissue surface of the pontic. Unfortunately the technique is so technically demanding that few clinicians are willing to attempt it on a regular basis.

Technical Considerations for Direct Bridge Fabrication

Several issues must be considered when fabricating FRC bridges directly in the mouth. Voids and bubbles act as points of stress concentration within the structure, so it is worthwhile to minimize the bubbles trapped within the mix. The greatest problem in accomplishing this is adequately wetting the fibers. Fibers require wetting with an unfilled resin; filled or flowable materials have higher viscosity and do not wet the fibers as effectively, permitting bubbles and voids to become entrapped on the fiber surface. Once the fibers have been wetted with unfilled resin, they can be further wetted with a flowable composite before they are introduced to the more highly filled composite. Although intuitively this seems to represent the greatest potential for getting filled composite in intimate contact with the reinforcing fibers, at the time of this writing this has not been supported or disproved by research.

In deciding on the placement of the fibers within the restoration, beam theory can supply guidance. In a three-unit bridge supported at both ends, the tensile stresses are concentrated below the neutral axis of the beam. In a bridge that is encastré (retained) at both ends, as in a fixed partial denture, tensile stresses are also located above the neutral axis toward the ends of the bridge. In a cantilever beam (or a cantilever bridge), tensile stresses are located above the neutral axis of the beam. Beam theory teaches that the stress on a beam increases as the square of the distance from the neutral axis to the tensile side. Fibers should be located where they will absorb the tensile stresses within the structure, so when a cantilever bridge is being constructed, the fibers must be concentrated toward the occlusal or incisal part of the restoration. In fabricating a three-unit fixed prosthesis, fibers should be concentrated below the neutral axis—that is, toward the gingival portion of the bridge. In practical terms, it is desirable to incorporate as much fiber into the structure as possible. The limitations of fabricating a dental prosthesis, especially directly in the mouth, are such that we can seldom incorporate as much fiber as desired. The risk of using too much does not exist from a structural standpoint but can be a problem in that it must be completely covered with composite resin.

Unfortunately, the forces applied to a dental prosthesis are not as simple as they are when building a floor. Among the complex forces seen in clinical applications of fiber-reinforced technology is the phenomenon of torquing of posterior bridge pontics. When occlusal loads are applied to a posterior bridge pontic, they are not necessarily applied to the center of the pontic or beam. Off-center loading results in a torsional force, or twisting of the pontic or beam. These torsional forces are best resisted by fabricating a pontic or beam with long unidirectional fibers that are spiral wrapped with unidirectional fibers. This can be accomplished in the fabrication of indirect prostheses and is included in several of the commercially available systems used for laboratory fabrication. Unfortunately, spiral wrapping of the reinforcing fibers is an engineering principle that is difficult to achieve when fabricating the restoration directly in the mouth. For direct posterior bridge fabrication in the mouth, one must keep the bucco-lingual width of the pontic to a minimum and design the anatomy to eliminate working and balancing contacts. This reduces the potential for off-center loading of the pontic and the resulting torsional stresses on the bridge.

CLINICAL CONSERVATION CONCEPTS WITH FIBER-REINFORCED COMPOSITE BRIDGES

The concept of preserving tooth structure is hardly new to dentistry. Partial veneer crown retainers, pinledge retainers, and the MacBoyle retainer were all attempts to preserve as much valuable tooth structure as possible, although the motivation behind this may have been more the inability to imitate enamel with then available materials. Today's restorative materials are so predictable and esthetic that preserving tooth enamel may not seem as essential as in the past, but it is still an important consideration in dentistry.

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With the development of acid etch bonding by Dr. Michael Buonocore in the mid-1950s, the potential for conservative, esthetic tooth replacement increased dramatically. In the late 1970s the Maryland and Rochette bridge designs were developed as conservative methods of anterior tooth replacement. These were the first to find their way into routine use in dentistry. Ironically, both proved to be more effective as posterior bridge techniques, largely because the bond between tooth and metal was not adequate to retain the bridge without supplementation by mechanical retention. Both techniques continue in use as conservative alternatives to fixed prosthetics with full coverage retainers. With proper case selection and careful implementation they provide predictable and conservative restoration. Their disadvantages include a tendency of the retainer color to be transmitted through the abutment teeth causing a gray discoloration, and frequent debonding from the abutment teeth.

Other attempts to develop conservative techniques for tooth replacement include the technique described by McIntyre for replacing maxillary first bicuspids and lateral incisors using a bridge design with a conventional full-coverage retainer on one end and a small metal extension on the other end that is embedded in composite in a conservative class III preparation. A similar technique for replacing posterior teeth was described by El-Mowafy. In this technique a bridge is fabricated with cast projections on both ends. These projections are embedded in composite in conservative preparations in the abutment teeth.

In the late 1970s, Belvedere used fine wire mesh to reinforce bonded composite bridges, but these were not particularly successful. With no bond between the metal mesh and the composite, the metal did little to reinforce the structure and may have weakened it by acting as a focus of stress concentration.

Before fiber-reinforced technology was developed, attempts were made to bond acrylic denture teeth directly to natural teeth. Ibsen first described a technique for using unreinforced composite to bond acrylic denture teeth to natural teeth in 1973. In 1978 Jenkins reported on 31 bridges placed in 22 patients using acrylic teeth bonded in place with composite resin. The technique was spectacularly unsuccessful, with a slightly better than 50% survival rate at 3 years. The mode of failure of the restorations was consistently fracture of the composite. He found the success rate for lower prostheses to be encouraging, however. A likely explanation for the discrepancy between the upper and lower restorations is the fact that the uppers are subjected to a greater proportion of tensile loading, whereas the lowers are subjected to more compressive loads, which particulate composite is better suited to resist.

In 1980 Jordan and colleagues reported on 88 bridges in 78 patients fabricated using acrylic denture teeth bonded in place with composite resin, with pins used in the abutment teeth for additional retention in some cases. The results were disappointing, the majority being lost within a year. The researchers observed that when failure occurred, it was invariably fracture of the composite, and concluded that the limiting factor in the technique was the strength of the composites available. They also concluded that the most predictable application of the technique is the replacement of a single mandibular incisor.

Simonsen hypothesized that the weak link in the acrylic denture tooth bridge was the bond between the acrylic tooth and composite resin. He further reasoned that if the pontic were made from composite, the bridge would be stronger. In his technique the pontic was fabricated from composite resin using a clear plastic crown form. The pontic was then bonded into place with the same technique as for acrylic denture teeth. The survival rate for prostheses fabricated with a composite pontic was an improvement over the acrylic denture tooth technique.

CLINICAL TECHNIQUES

Bridge Fabrication

Fabrication of the pontic button is the key to this technique. Until the procedure for fabricating the pontic button and polishing it out of the mouth was developed by Belvedere, direct FRC bridges were doomed to have an irregular and potentially uncleansable tissue contact surface. Unfortunately, fabrication of the pontic button and its subsequent incorporation into the structure along with the fibers also complicate the procedure. It can be quite challenging to manipulate all of the parts into place and hold them there long enough to polymerize them without contamination with saliva. The following techniques are modifications of Belvedere's approach and designed to simplify the process by keeping the number of components that must be positioned at the same time to a minimum.

Anterior Bridge Technique

The technique for direct intra-oral fabrication of an anterior FRC bridge begins with a set of study models. The model is modified with wax or composite to create the lingual contours desired of the completed bridge (Figure 12-3, *A*). The author typically uses composite to mock up the lingual portion of the pontic and then flows inlay wax onto the lingual surface of the abutment teeth on the models to simulate the thickness of the retainer and the fibers on these teeth. The labial surface of the pontic is of no concern at this stage; it will be developed in the mouth when the bridge is fabricated.

A matrix is then fabricated using clear polyvinyl impression or bite registration material. This material is mixed according to the manufacturer's instructions and applied to the lingual surface of the model to register the contours developed in the mock-up (Figure 12-3, *B*). Opaque matrix material can be used as shown in Figure 12-3, *B*, but transparent materials allow for the structure to be polymerized through the matrix after the initial transenamel polymerization, which ensures all the composite will fully gel before the matrix is removed.

It has been argued that the need to do a mock-up on the study model negates its advantage of being completed in one visit. This is rarely a problem, as study models are such a routine part of the diagnostic procedure before fabrication of any bridge. Because the entire bridge fabrication procedure takes the average dentist about 2 hours, it is unlikely that the procedure will be performed on a patient who has never been seen before.

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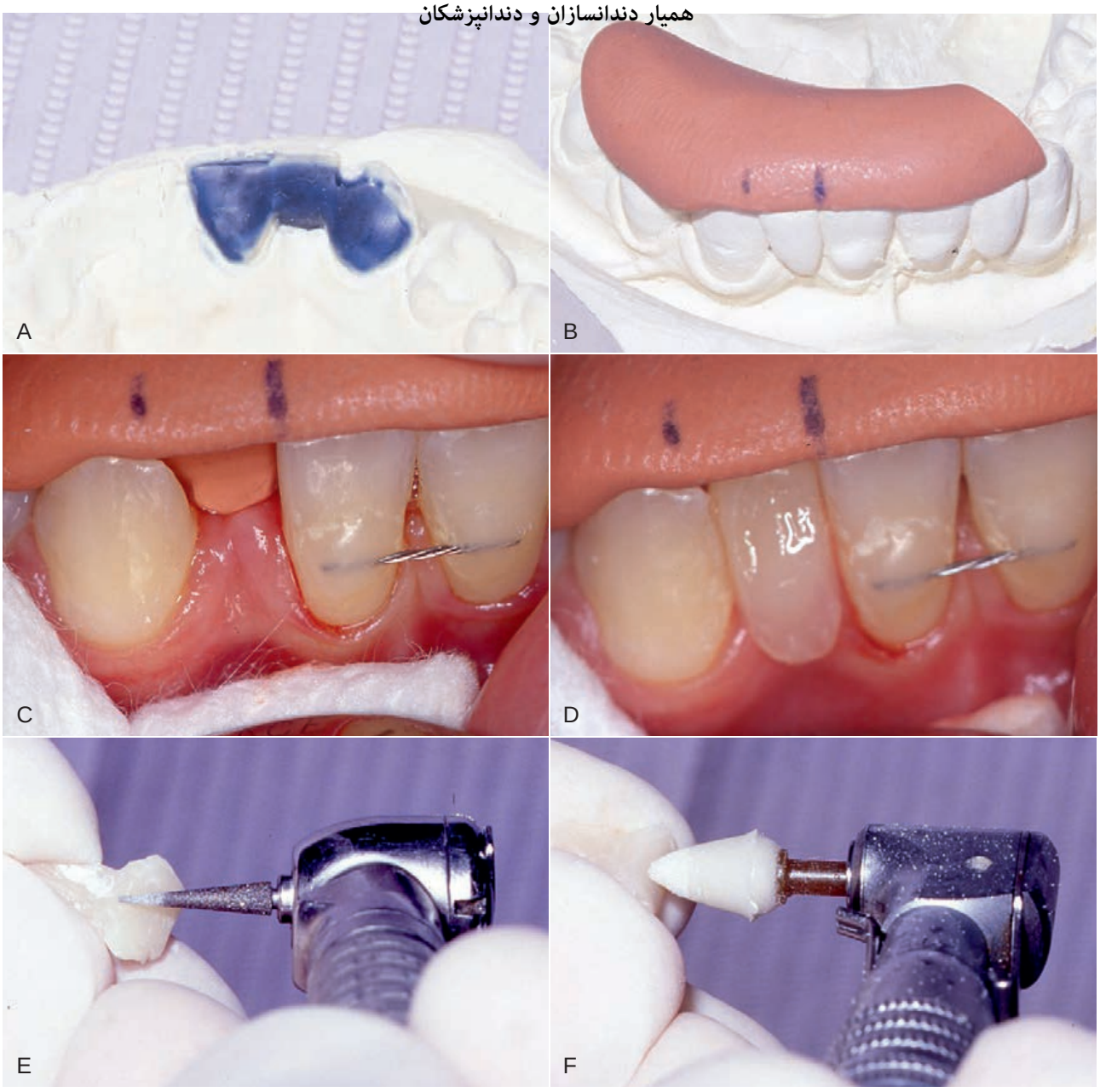


FIGURE 12-3 **A, The lingual contours of the bridge are mocked up in composite or wax on a study model. B, The matrix is fabricated from vinyl polysiloxane putty. If teeth are dark or opaque, transparent material can be used to permit polymerization through the matrix. C, The matrix is inserted in the mouth to ensure good fit. It will be used as a mold to form the lingual and gingival surfaces of the pontic button. Marks on the matrix are made to simplify placement of the matrix in the mouth. D, Composite is injected into the space created by the matrix, tissues, and abutment teeth to create the basic form of the pontic button. E, The pontic button is trimmed to establish an outline form and tissue surface contours. F, Once the appropriate contours are established, the tissue surface and lingual surface of the pontic button are polished to a high shine.**

At the fabrication appointment the abutment teeth are anesthetized and carefully scaled and polished to remove plaque or calculus. The appropriate shade or shades of composite are selected. The previously fabricated matrix is positioned in the mouth, and composite is injected or pressed into the matrix and edentulous space so that the edentulous ridge acts as a mold for the tissue surface and the matrix molds to the lingual surface (Figure 12-3, *C* and *D*). The material chosen should be an appropriate shade and highly polishable. A microhybrid is a good choice. This composite forms the pontic button and is polymerized enough to make it sufficiently solid to manipulate. Thorough polymerization is neither necessary nor desirable at this stage. If the pontic button remains only initially polymerized, it will bond better to the rest of the structure when incorporated into the bridge.

The pontic button is removed from the mouth, and the tissue surface is contoured to the desired pontic form (Figure 12-3, *E*). The tissue surface of the pontic button is polished to a high shine

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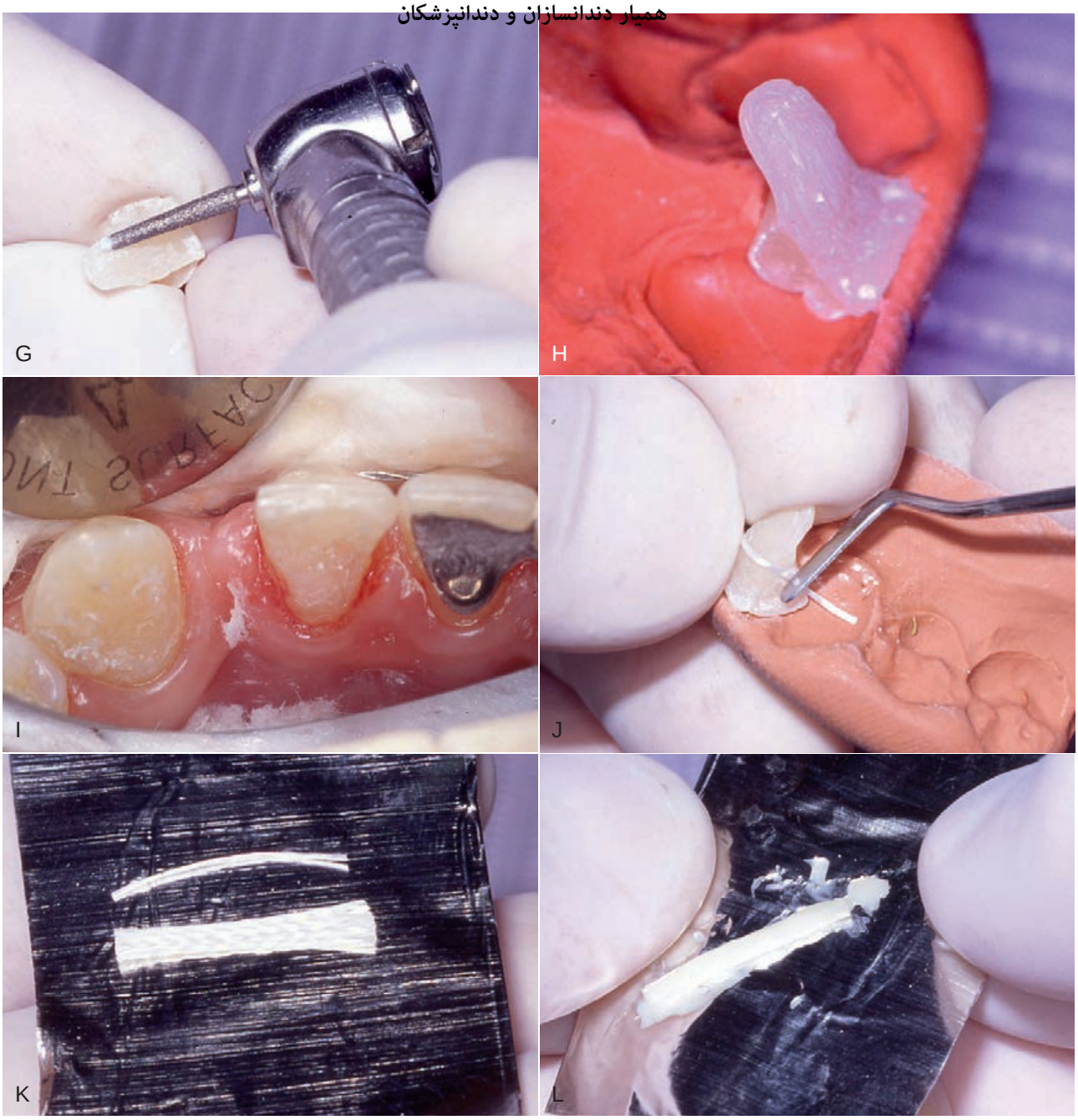


FIGURE 12-3, cont'd **G,** A chamfer finishing line is created around the outline of the labial surface to establish a well-defined line to finish the composite to when developing the rest of the pontic. At this time the pontic is also contoured to ensure adequate room for the fibers to pass between the pontic button and the abutment teeth. **H,** The completed pontic button should be reasonably stable when placed back on the matrix. **I,** When the fibers and the pontic button are ready, the teeth are prepared by roughening the enamel and preparing conservative class III preparations on the abutments. The teeth are then etched and a dentin adhesive applied. **J,** Dental tape or floss is positioned and cut to length to serve as a pattern for the fibers. **K,** The dental tape pattern is used to measure the length of the fibers required. The fibers are cut to length and placed on a piece of tin foil, which will be used to protect the wetted fibers from ambient light while the teeth are prepared for bonding. A light-resistant container can also be used. **L,** The fibers are wetted with unfilled resin and then impregnated with light body composite resin.

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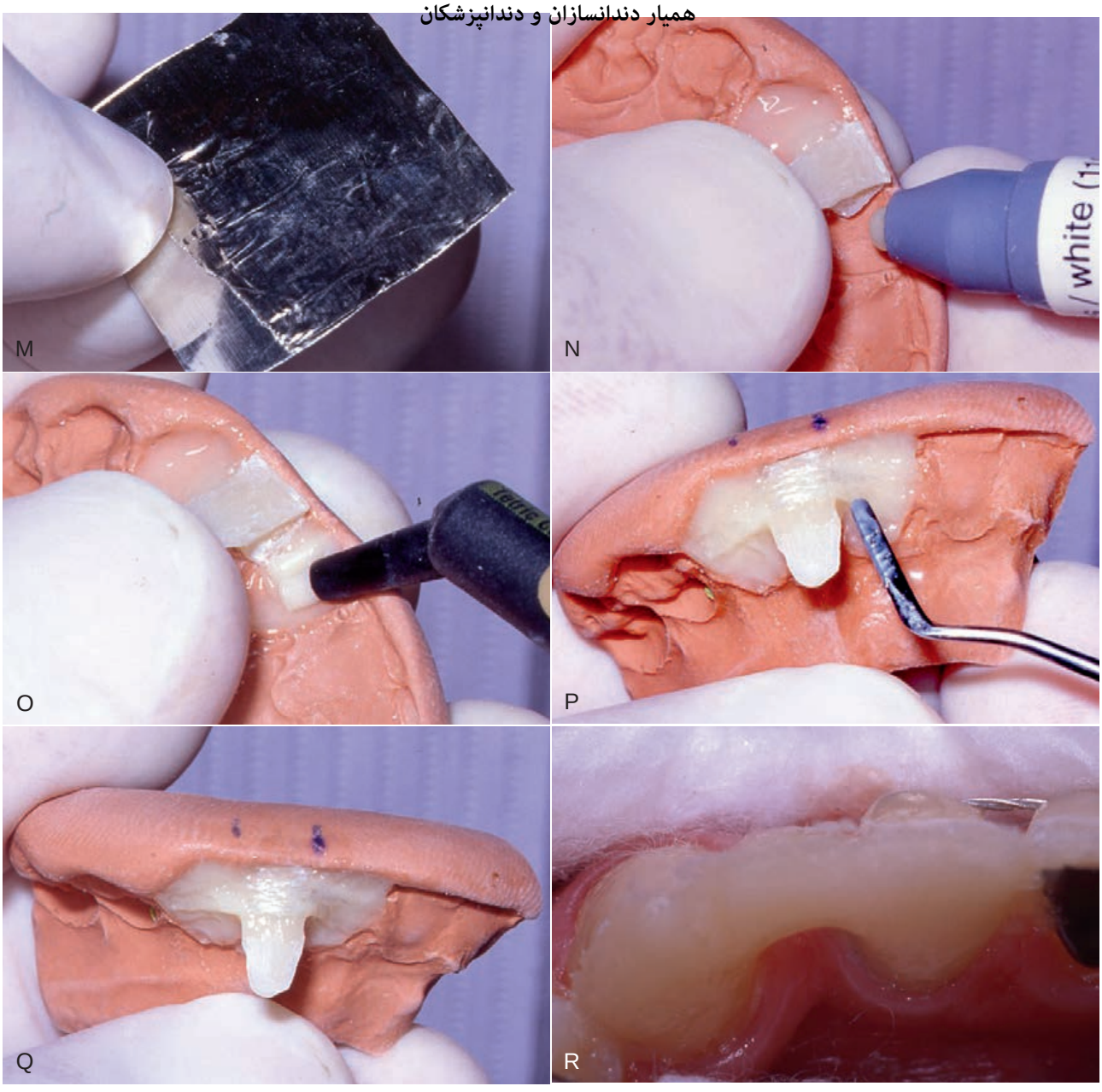


FIGURE 12-3, cont'd **M, The tin foil is folded over to protect the impregnated fibers from ambient light and set aside. N, As the assistant ensures the teeth remain dry and uncontaminated, the dentist places the pontic button on the matrix and a small amount of low-viscosity composite on the abutment area of the matrix. O and P, Composite is then applied to the abutment areas of the matrix. The impregnated fibers are recovered from the tin foil and placed in position on the matrix. Q, All parts of the anterior direct fiber-reinforced composite bridge are shown in place on the matrix and ready for insertion in the mouth. R, After curing with the matrix in place, the lingual surface of the bridge is essentially complete. Only minor trimming and polishing are required.**

to discourage plaque accumulation (Figure 12-3, *F*). The labial surface of the pontic button is contoured to allow for adequate bulk of fibers and composite to complete the bridge. The margins of the pontic button are finished with a round end crown and bridge diamond to create a definite finishing line, similar to what is done in a veneer preparation (Figure 12-3, *G*). This allows the composite that will form the balance of the pontic to be finished to this line, avoiding the creation of any flash that could compromise the highly polished tissue surface of the pontic. It should be reasonably stable when fitted into the matrix. Both the matrix and the pontic button should fit in position in the mouth, with the pontic button seated on the matrix (Figure 12-3, *H*). The completed pontic button and matrix are set aside.

The abutment teeth can now be prepared (Figure 12-3, *I*). The outer layer of enamel is often fluoride rich and will be contaminated with salivary proteins and other debris. For adequate bonding, this layer must be removed. The entire lingual

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FIGURE 12-3, cont'd **S and T, The lingual surface of the completed bridge demonstrates a modified ridge lap pontic design to facilitate hygiene. U and V, This 8-year follow-up of the case demonstrates that direct fiber-reinforced bridges no longer need to be considered purely provisional or temporary restorations.**

surface should be cleaned and roughened with a diamond bur. The amount of tooth structure actually removed amounts to a few microns. If greater clearance is required for occlusal considerations, 1-mm deep dovetail slots are cut in the lingual surface of the abutment teeth to make room for the composite and fibers. The grit of the diamonds used for preparation is a matter of personal preference. The author prefers to use a medium diamond, which leaves a slightly rough surface for better retention. Small class III preparations are made in the abutment teeth as well. These preparations should be internally rounded, but with an overall rectangular form to resist displacement of the composite that will eventually fill them. Any existing composite restorations should also be removed at this time. They will be replaced with composite, which will become part of the bridge structure.

Fibers are now selected. Which material to use is again dictated by personal preference. The author prefers to use polyethylene products because they are easier to position. The glass fibers are quite springy and tend to resist all attempts to position them, but they can be used as well. The pontic button is positioned on the matrix, and a length of dental tape or floss is laid across the matrix and the pontic button and trimmed to length so that the floss extends from about 1 mm short of the distal aspect of one abutment tooth, over the pontic button, to the same point on the other abutment tooth (Figure 12-3, *J*). The overall length for a three-unit bridge is about the mesio-distal width of the three teeth involved. The dental floss pattern is used to measure the fibers, which are cut to the appropriate length using a sharp scalpel or serrated scissors (Figure 12-3, *K*). The more fibers that can be incorporated into the finished structure, the better.

The fibers are impregnated with resin by applying a few drops of unfilled resin. They are then laid on a mixing pad and the excess resin "milked" out of the fibers with a mixing spatula or other instrument. This should leave the fibers fully and uniformly wetted with unfilled resin. A low-viscosity filled resin is then applied to the fibers. This can be a flowable composite or the light-cured component of a dual-cure resin luting cement. The resin is worked well into the fibers until they are thoroughly wetted. The fibers are placed on a piece of tin foil, which is then folded over to protect the impregnated fibers from ambient light and set aside (Figure 12-3, *L* and *M*).

With all the components ready for assembly, the teeth can be prepared for bonding. After cleaning and disinfection with 5% sodium hypochlorite or other agent, the teeth are etched with 35% phosphoric acid in the usual manner. An appropriate

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dentin bonding agent is applied to the teeth and either light cured or not, according to the manufacturer's instructions and/or the preference of the operator. After the teeth have been prepared for bonding, the assistant takes control of the prepared teeth, ensuring that they do not become contaminated while the dentist readies the remaining parts of the bridge for assembly.

The dentist retrieves the matrix and positions the pontic button on it. A small amount of the low-viscosity composite is applied to the matrix in the area of the abutment teeth (Figure 12-3, *N*). Over this is applied a small portion of hybrid composite followed by the fibers, which are laid across the matrix in the way they will be positioned in the final bridge structure, starting at one abutment, across the pontic button, and over the other abutment (Figure 12-3, *O* and *P*).

The matrix with the pontic button, fibers, and composite is placed in position in the mouth (Figure 12-3, *Q*). Sufficient pressure is applied to seat the matrix against the teeth, ensuring that the pontic button is properly positioned in the edentulous space. In an ovate pontic design a small amount of pressure can be applied to the pontic button with an instrument to press the pontic into the edentulous ridge as the composite is polymerized. Once the matrix, pontic button, fibers, and composite are appropriately positioned, any excess composite that can be accessed with the matrix in place is removed using an appropriately shaped artist's brush. When all excess composite has been shaped or removed, the entire assembly is light cured by applying the light guide to the labial surface, illuminating the entire tooth. Light is transmitted through the tooth, polymerizing the composite through trans-enamel polymerization. Sixty seconds of light application to the labial surface of each abutment tooth is usually sufficient to cause the composite on the lingual to gel sufficiently for the matrix to be removed. The use of a transparent matrix permits the light to be applied through the matrix as well. The matrix can be removed when the operator is confident the lingual composite has gelled. The composite is then thoroughly polymerized from all directions.

At this point the lingual surface of the bridge is essentially completed, the final shape having been created by the matrix (Figure 12-3, *R*). The labial surface of the pontic is then fabricated by applying composite exactly as if making a direct composite veneer. Opaquer may be required before composite application with some composite systems to block light transmission through the structure, which will give the pontic a grayish cast. Hybrid composite is preferable for its superior strength in any stress-bearing areas. Microfill can be used in esthetic zones for its polishability. Once the buildup of the pontic is complete, any excess is trimmed, the occlusion adjusted, and the completed structure polished to a high shine (Figure 12-3, *S* and *T*). As with any other bridge, the patient is instructed in the use of a floss threader to maintain hygiene gingival to the pontic. Figure 12-3, *U* and *V*, show the 8-year follow-up of this case.

Posterior Bridge Technique

Posterior bridges do not require the use of a matrix to position the pontic button. As with the anterior bridge procedure, the patient is anesthetized and the teeth are scaled and polished thoroughly. The rubber dam is a useful adjunct to control the cheeks and tongue. Usually a slit dam technique is more than adequate and allows for exposure of the edentulous ridge.

Unlike the anterior technique, preparation of the teeth precedes the fabrication of a pontic button (Figure 12-4, *A*). Preparation of the teeth begins with removal of any existing restorations. Proximal box preparations should be made on the abutment teeth adjacent to the edentulous space to allow the fibers to pass from the occlusal portion of the preparations to the gingival portion of the pontic. Remember that the fibers should be located toward the gingival part of the pontic in a three-unit bridge. Proximal cavosurface margins are created with a long bevel using a fine finishing diamond.

Once the preparations are complete, the pontic button is fabricated. The choice of composite for the pontic button is the same as for the anterior technique. Microfill or microhybrid composite of the appropriate color is used to ensure a highly polished surface in contact with the soft tissue. A quantity of composite is rolled into a ball and pressed into place in the edentulous space (Figure 12-4, *B*). The pontic button is shaped with the composite-forming instrument of choice. The pontic button should extend to the gingival outline of the pontic and slightly into the proximal boxes of the abutment teeth. These small steps in the proximal boxes will serve as positive stops, which will assist in positioning the pontic button as the bridge is assembled.

The pontic button is then trimmed and polished in a manner similar to that used for the button in the anterior technique. The tissue contact surface is trimmed and polished to a high shine. The peripheral areas are treated to a heavy chamfered finishing line to which the composite forming the rest of the pontic can be finished (Figure 12-4, *C*). The completed pontic button should be as thin as practical, highly polished on the underside, and should seat positively into position using the rests in the proximal boxes of the abutment teeth (Figure 12-4, *D*). The completed pontic button is set aside (Figure 12-4, *E*).

The length for the fibers is selected by measuring the prepared teeth. The fibers should extend the full length of the bridge, from the mesial part of the mesial-most prepared tooth to the distal extent of the distal-most prepared tooth. A Boley gauge or divider is useful for establishing this measurement. A dental tape or floss pattern can also be used. The fibers of choice are cut to length using a sharp scalpel or serrated scissors and impregnated first with unfilled resin, then with filled low-viscosity composite, as before. Once again, the impregnated fibers are wrapped in tin foil to protect them from ambient light and set aside.

The teeth are now prepared for bonding. They are cleaned and disinfected with 5% sodium hypochlorite or other appropriate agent, rinsed, etched with 35% phosphoric acid, and rinsed, and the dentin adhesive is applied. If the abutment teeth have missing walls other than where the fibers will go, these should be restored at this time. For example, if the mesial abutment tooth has a mesial-occlusal-distal (MOD) preparation, a clear Mylar matrix band is placed and the mesial box is restored,

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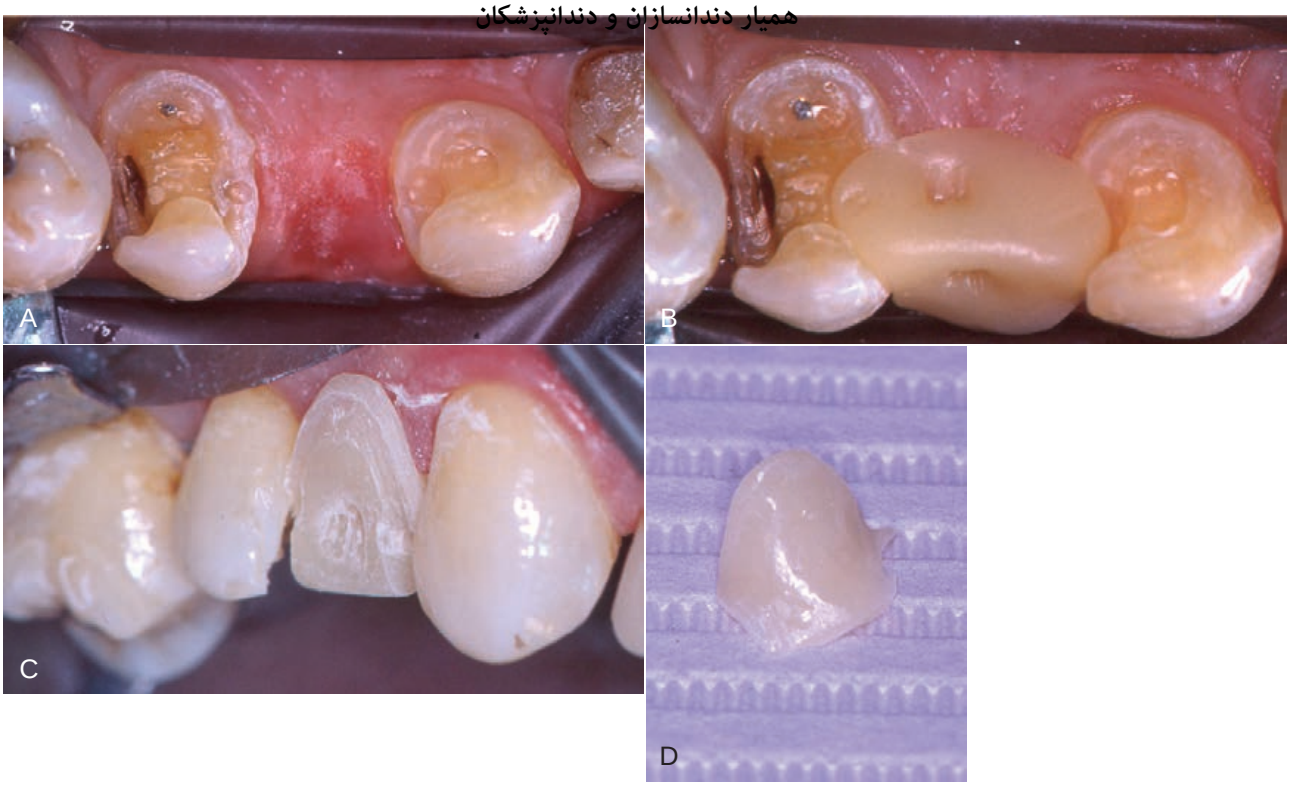


FIGURE 12-4 **A, The existing bridge is removed along with all restorative materials. The pin under the lingual cusp of the bicuspid could not be removed and was cut off level with the dentin. B, A ball of composite is pressed into the edentulous space to form the pontic button. The composite overlaps the gingival floor of the proximal boxes of the abutment teeth. This will provide a positive stop to assist in positioning the pontic button. C, A chamfer margin is created around the outline of the labial surface to create a finishing line for the composite that will form the rest of the pontic. D, The tissue surface of the pontic is polished to a high shine.**

Continued

leaving the occlusal and distal portions of the preparation empty at this time.

When the teeth are ready, the pontic button is carried to place, and a small drop of flowable composite is positioned where the pontic button contacts the abutment teeth. Excess flowable composite is removed using a small artist's brush. The flowable composite is then light cured. This is sufficient to maintain the pontic button in position while the rest of the bridge is completed (Figure 12-4, *F*).

The fibers can now be placed in the prepared teeth and over the pontic button. They should be thoroughly wetted with low-viscosity composite. More composite can be added at this stage if there are any voids or bubbles. As much fiber as possible should be incorporated into the bridge (Figure 12-4, *G*). Hybrid composite is applied over the fiber and shaped until it is as close to the final contour as possible. There should be just enough hybrid composite over the fibers to prevent exposure of the fibers when adjusting the occlusion. The final shape of the pontic and the abutment teeth is created in composite, and the entire structure is cured thoroughly. The completed bridge is trimmed and polished to a high shine (Figure 12-4, *H*). Occlusion is adjusted, and the patient is instructed in maintaining oral hygiene.

Fiber-Reinforced Provisional Bridges

It is not uncommon in complex restorative cases to provisionalize the case for several months. In these cases contemporary provisional materials can be problematic. Because these materials are designed to stand up for only a week or two, such patients frequently visit the dentist with fractured provisionals, a frustrating situation for dentist and patient alike. In addition, some patients simply break temporaries in short order. Fiber reinforcement is a quick and convenient method of reinforcing provisional bridges for longer-term survival.

Incorporating fiber-reinforced composite into a provisional restoration is simply a matter of fabricating a reinforcing beam that is wholly enclosed in the body of the restoration. A vacuum-formed stent is fabricated in advance of the patient visit, using a diagnostic wax-up or any form of mock-up of the bridge on the study model. This may be as simple as attaching a denture tooth to the edentulous space.

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FIGURE 12-4, cont'd **E, The pontic button is now reduced to make room for reinforcing fibers. The completed pontic button is set aside to await preparation of the fibers and the teeth. F, The teeth are etched and the dentin bonding agent is applied. A partial matrix is placed and the distal surface of the bicuspid is restored, leaving room for the fibers. The pontic button is positioned between the abutment teeth, and a drop of low viscosity composite is placed at the point where it contacts the abutment teeth, and polymerized to tack the pontic button in place. G, The fibers are impregnated thoroughly, first with unfilled resin and then with low viscosity composite. The wetted fibers are laid in position over the pontic button and into the prepared teeth and polymerized. H, Completed prosthesis displays natural color and harmonious contours. Although the tissue is inflamed in this immediate postoperative view, the ultimate response of the tissue to the bridge is excellent.**

After the teeth are prepared and the impression is made, a section of reinforcing fiber is cut to sufficient length to span the abutment teeth and overlap the occlusal surfaces of the preparations. The same design considerations apply as when fabricating a composite bridge. The fibers should be positioned to resist the tensile forces found in the lower (gingival) part of the pontic. Although it is generally advantageous to incorporate as much fiber as possible into a prosthesis, a provisional bridge usually requires only a single reinforcing band.

The fibers are impregnated with unfilled resin and then flowable composite and set aside in a light resistant container (Figures 12-5, *A* and *B*). If the teeth have been restored with composite cores on the same day as the bridge is being fabricated, a separating medium should be applied to the abutment teeth to prevent the fibers from bonding to the abutment teeth. Glycerin is a suitable separating medium as it is easily removed with water and will not interfere with bonding of the final restoration.

The impregnated fibers are recovered from their light-resistant container, laid across the abutment teeth, and cured (Figure 12-5, *C*). The desired configuration is easily achieved if the fibers are positioned in stages. Using a small (4 mm) tip on the curing light, spot cure the ends of the fibers to the abutment teeth. The rest of the fiber bundle can be positioned with an instrument and cured in the desired shape.

The vacuum-formed stent is then filled with the provisional acrylic material and positioned in the mouth over the abutment teeth and the reinforcing fibers (Figure 12-5, *D*). Once the bridge has reached the appropriate state of cure, it can be removed, trimmed, polished, and cemented as usual (Figures 12-5, *E* to *G*).

The incorporation of reinforcing fibers into a provisional bridge substantially increases its resistance to fracture and can be a tremendous advantage when the patient has a history of fractured provisionals or in complex cases in which long-term provisionalization is required.

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FIGURE 12-5 **A,** Fibers are cut to length and wetted with unfilled resin and flowable composite before being placed in a light-resistant container. Here a piece of tin foil is used to protect the wetted fibers from ambient light. **B,** The tin foil is simply folded over to protect the wetted fibers from ambient light. **C,** The wetted fibers are positioned on the prepared teeth and cured in place. **D,** The vacuum-formed stent is filled with provisional acrylic and placed over the prepared teeth and the reinforcing fibers.

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FIGURE 12-5, cont'd **E, The provisional restoration is removed and trimmed. F, The provisional restoration is checked for occlusion. G, The completed provisional bridge is polished and cemented with a suitable provisional cement.**

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B SECTION

Ceramic Fiber Reinforcement: A Unique Treatment Modality

Jonathan Scharf

RELEVANCE OF FIBERS TO ESTHETIC DENTISTRY

One of the more popular current trends in dental treatment is the use of non-metallic restorative materials. Removing metal from restorations makes them more esthetically pleasing because there is no added bulk from the metal and the non-metallic materials are in general more lifelike in appearance. Non-metallic dentistry also allows for alternative techniques. It permits the dentist to decide what materials to use as opposed to relying exclusively on the laboratory. Composite resins with internal reinforcement fibers can be directly placed, giving the dentist control of function and esthetics in the dental office. Dentists must be careful not to overextend the use of composite resin in stress-bearing areas of the mouth. When using alternative materials such as composite resins for bridgework to span across spaces in the mouth, dentists must be aware that the materials have more than adequate compressive strength but lack tensile and flexural strength. Through incorporation of fibers for internal reinforcement, additional tensile and flexural strength can be achieved, providing successful performance across long spans.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF FIBER REINFORCEMENT IN DENTISTRY

The concept of internal reinforcement is not new. In ancient times straw was placed into clay bricks for the creation of the pyramids. In the twentieth century, long-span bridges made of concrete also employed similar reinforcement techniques. Concrete is very much like composite resin and has tremendous compressive strength. However, when spanned across rivers, the material does not exhibit adequate flexural and tensile strength required to support the structure. Steel girders and steel rods are placed within the concrete to reinforce the material. Currently, internal reinforcement is used with composite structures in the aerospace and aeronautic industries as well as for automotive composite structural components, which are used to lighten and strengthen automobiles. It is common to see composite structures with internal reinforcing materials in almost every field. Fiberglass vehicles and boats are lightweight but strong because of reinforcement fibers. Most non-metallic items in the sports industry, such as golf clubs and poles for vaulting, are made of high-performance fiber-reinforced materials.

Historically, the dental bonding revolution began in 1955 when Dr. Michael Buonocore published his paper "A Simple Method of Increasing the Adhesion of Acrylic Materials to Enamel Surfaces." A second significant advancement occurred in 1962 with Dr Ray Bowen's development of "Bowen's Formula," which used the bisphenol A-glycidyl methacrylate (BIS-GMA) molecule to form the basis for most of the modern composite resins used in dentistry. In 1982 porcelain laminate veneers used in conjunction with silane coupling agents were introduced commercially to the dental profession. Clinicians were now able to take a ceramic material, etch that material, silanate it, and apply composite cement to adhere it to tooth surfaces. In 1983, Dr. Jeff Golub-Evans used fabric to support freestanding composite restorations (Box 12-1). This led to the introduction of the Silk-Wrap concept and the Manhattan bridge. The author of this section was teaching ceramic dentistry and working on a flexible ceramic bonding material at that time. He used an etched, silanated fiberglass to achieve the same type of results that Golub-Evans did with silk-wrapped material and believed, however, that the ceramic material was stronger, would hold up better, and exhibited specific properties shown through porcelain veneer technology to be advantageous. In 1992 he introduced the first article on flexible ceramic bonding in the *Journal of the American Academy of Cosmetic Dentistry* ("Direct Flexible Ceramic Bonding—A New Treatment Modality"), which discussed the use of etched, silanated E-glass fiber to internally support all types of unique restorations. In 1993, GlasSpan (GlasSpan, Inc., Exton, Pennsylvania), a ceramic fiber reinforcement material, was released to the dental profession. Since that time, a number of ceramic and plastic fiber reinforcement systems have been made available for use in dentistry, allowing fiber reinforcement to be a significant tool in the restorative armamentarium.

RELATING FUNCTION AND ESTHETICS

Composite resins are mostly used for direct techniques. These materials exhibit more than satisfactory compressive strength but lack the tensile and flexural strength required to span long

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BOX 12.1 Fiber Folklore—Jeff Golub-Evans and Fiber Reinforcement

One of the more interesting applications of fiber reinforcement technology occurred in the early 1980s in the office of Dr. Jeffrey Golub-Evans, a Manhattan "dentist to the stars." The lead singer of an extremely popular rock band had a concert scheduled on a Saturday night but was involved in a barroom fight before the show, resulting in two badly fractured central incisors; he felt unable to perform with his teeth in that condition. He sought Dr. Golub-Evans for help. In the early 1980s, however, there was no known conventional way to extend the available types of composite resin to that length and expect them to remain in place unsupported. Dr. Golub-Evans cleverly cut a piece of fabric from a white t-shirt, soaked it in clear resin, and bonded it to the teeth. This formed the matrix upon which he reconstructed the teeth with tooth-colored composite. The procedure, which worked extremely well, was one of the earliest known applications of fiber reinforcement in dentistry and led to the introduction by Dr. Golub-Evans of the Silk-Wrap system and the Manhattan Bridge.

distances. Spaces that result when teeth are lost have necessitated the use of alternative splinting approaches. Conventional composite resin cannot be stretched across a missing tooth space without fracturing owing to the lack of flexural and tensile strength If an internal fiber is incorporated, it adds enough strength that the material can function successfully. The synergistic effect of the compressive strength from the composite resin and the tensile and flexural strength from the internal fiber gives the dentist a stronger, more functional result.

CLINICAL CONSIDERATIONS

GlasSpan fiber-reinforced material has been used successfully for at least 15 years. Some of the primary uses for fiber-reinforced materials are periodontal splinting, post-orthodontic retention, trauma splints, re-implantation of avulsed teeth, immediate tooth replacements, denture and retainer reinforcement, fiber-reinforced posts and cores, and the reinforcement of transitional bridgework, as well as a unique method of space maintenance.

Advantages

The advantage of any fiber-reinforced material is its profound effectiveness in the absence of any metallic support. The fibers offer the same support that is achieved when metallic restorations are used. In addition, the laboratory does not need to be involved in these restorations, so the dentist is in complete control. In addition, most of these procedures are designed for immediate application, and the procedures can be accomplished in one visit.

The technique employs a synergistic effect, taking advantage of the compressive strength of the composite and flexural and tensile strength of the fibers to provided more than adequate clinical strength to the restorations.

Once the dentist understands how these materials work, they are very easy to use. They present an extremely cost-effective alternative for patients who are not good candidates for conventional bridgework. In the event of a partial failure, most are easy to repair. If minimally invasive dentistry and conservatism are a treatment objective, fiber-reinforced restorations can be a good treatment choice. It should be noted that the technique should be limited to cases where conventional bridgework is not a good alternative, and, as stated earlier, the dentist must make sure the patient does not have unrealistic expectations of the restoration's longevity.

Contraindications

There are some contraindications to the use of the internal fiber reinforcement techniques. Overextension is one such contraindication. If the distance to be spanned is too great, there is an increased chance of restoration failure. Cases need to be chosen carefully. As with any other dental procedure, if there is sensitivity to any of the components in the restoration—that is, the fibrous material, the bonding agents, or the composite resin—the use of these materials in the patient's mouth is contraindicated. Significant consideration should be given to patient expectations. The dentist must ensure that patients understand the life expectancy of the materials and of the restoration itself and not have an unrealistic expectation about how long these alternative restorations will last. This is not to imply that they do not last; three- and four-unit bridges and periodontal splints placed almost 15 years ago are still functioning properly and are esthetically acceptable.

MATERIAL OPTIONS

Fiber reinforcement materials can be broken down into three basic groups; there are certain commonalities and differences among these groups. Ceramic fibers, plastic fibers, and unconventional types of fibers have been used successfully to internally reinforce dental restorations.

Ceramic Fibers

Ceramic fibers include the following:

- GlasSpan—an etched, silanated, E-glass fiber that is good for most if not all of the applications considered matches for fiber reinforcement. The author has used the GlasSpan system to produce all of the restorations mentioned earlier. It employs a clear fiber that attaches both mechanically and chemically to the composite resin with which it is paired. It is compatible with most composite and acrylic resins on the market.

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- Splint-It (Pentron Clinical, Wallingford, Connecticut)—a resin-coated glass fiber. It is not etched or silanated, but it is pre-impregnated with clear resin. It is appropriate for general use.
- Fiber-Splint (Polydentia SA, Switzerland)—a relatively unknown ceramic fiber appropriate for general use. It is not used by many dentists but is cited for historical purposes.
- Stick Tech (Stick Tech Ltd, Turku, Finland)—a resin-coated, glass fiber that has a propensity to be cost prohibitive. Its cost can make it more appropriate to use conventional dental procedures when finances enter into the diagnostic decision-making process.
- Targis and Ventris (Ivoclar Vivadent, Amherst, New York) and Sculpture and FibreKor (Pentron Clinical)—laboratory fibers often used as internal reinforcement for laboratory restorations.

Plastic Fibers

Plastic fibers include the following:

- Ribbond (Ribbond Corporation, Seattle, Washington)—a plasma-coated polyethylene fiber for general use.
- Connect (Kerr Corporation, Orange, California)—open-weave polyethylene ribbon.

Other Types of Fibers and Applications

The third category of fibers is less well-known:

- Fibreflex (BioComp, Ventura, California)—a Kevlar fiber. Kevlar is a yellow, opaque material that is especially useful in non-esthetic areas. It works extremely well as an orthodontic appliance reinforcement or as a repair material because it is extremely strong.
- C-POST (Bisco, Inc., Schaumburg, Illinois)—the original material (carbon) was black. When all-ceramic crowns are used on top of a C-POST, the challenge is trying to mask the black color. As a result, the use of the C-POST was rather limited, especially in the smile zone.
- Fiber-Post (Pentron Clinical)—a material that was considered an improvement over the carbon fiber post. It is a glass fiber post that is neutral in color. It improves the esthetic results when compared with metallic posts. Another advantage of the Fiber-Post is that it has more toothlike flexural characteristics than metal posts, reducing the chance of tooth fracture during placement.

Advantages and Disadvantages

One of the advantages of ceramics is that they are esthetic materials, strong enough to support most of the restorations described. They are biocompatible materials and, most important, dimensionally stable. Ceramic materials do not exhibit a characteristic called *creep*, a phenomenon that occurs when a fiber is stretched from point A to point B and a load is placed on it. Elongation of the material under that pressure is creep. Once creep occurs, the material no longer imparts the required tensile strength to the restoration. Ceramic materials are much more dimensionally stable than plastic materials and do not creep and elongate under the stresses and pressures of chewing. For that reason, they provide the required amount of tensile strength over time for long-term success. GlasSpan is the only ceramic fiber reinforcement material that has a patented etched and silanated surface treatment—very much like a porcelain veneer. It ensures a continuous, strong bonded attachment to the composite resin in which it is embedded.

Generally, ceramic materials exhibit lower absorption and do not *wick.* Wicking is the phenomenon that draws moisture into the fiber and permits it to enter the restoration, increasing the potential for failure. Should any of the fibers become exposed because of chewing or partial fracture, ceramic fibers will not wick water moisture into the restoration. Plastic fibers exhibit a certain amount of wicking. If the fibers become exposed to the surface, there is the potential for moisture to enter the restoration internally, causing it to fail.

Ceramic materials have a much higher melting point, so it is possible for dentists to post-cure them in a heating oven. This is particularly useful if the dentist would like to increase the strength, longevity and polishability of direct bridge pontics by heat processing. Most plastic fibers cannot withstand the heat required, so ceramic fibers are considerably more desirable if post-curing and heating are part of the restorative process.

In the future, it is expected that some very high-performance ceramic fibers will be developed that can be embedded into porcelain restorations and fired at extremely high temperatures without melting. One such ceramic material, Astroquartz (JPS Composite Materials Corporation, Anderson, South Carolina), is an example of a fiber that can withstand extremely high heat and shows promise in this area. Plastic materials, on the other hand, cannot be heated to the same extent because their melting points are considerably lower. One consideration when cutting some of the ceramic fibers is their slight "memory," or inclination to "unwind." The dentist must place a small amount of clear bonding resin and light-cure at the cutting point to prevent this effect. Once the dentist understands the technique, it presents no real obstacle.

As a group, plastic materials have the advantages of being esthetic, strong, and biocompatible. Some also include a surface treatment to improve the adhesion to the composite resin. Ribbond has a plasma-coated surface treatment that ensures a strong bond to the composite resin. However, plastic materials can be dimensionally unstable and exhibit creep, as previously noted. In addition, these materials have potentially a high water absorption rate. If the fibers become exposed to the surface or if there is a partial fracture, they can wick and allow internal contamination with saliva. If wicking occurs, it can cause failure of the restoration. Furthermore, plastic's lower melting point somewhat restricts the ability to heat process these materials. The plasma coating on the Ribbond cannot be touched with fingers or with saliva because once it is contaminated it must be discarded. Ribbond is more difficult to cut than some of the other materials, requiring a special pair of scissors included with the kit, or a stainless steel razor blade.

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Kevlar has the distinct advantage of being extremely strong—one of the strongest fibers available. Its disadvantage is that it is a yellow material that is un-esthetic and cannot be used in esthetic areas. It is useful to reinforce orthodontic retainers.

Carbon is also very strong and exhibits tremendous dimensional stability. Because of its black color, it is un-esthetic and can be used only in areas not requiring acceptable esthetics.

EVIDENCE-BASED PRINCIPLES

During the past 15 years the author, Dr. Scharf, has taken an empirical approach toward reviewing and observing the clinical success of the fiber reinforcement technique. Multiple restorations placed by Dr. Scharf as well as thousands by other notable clinicians in every category have resulted in overwhelming clinical success and patient satisfaction with a minimal failure rate.

CLINICAL CONSERVATION CONCEPTS

The concept of fiber reinforcement is consistent with a minimally invasive dental approach. Many of these restorations can be placed extracoronally if they do not interfere with the patient's occlusion. This makes tooth reduction completely unnecessary. Even when intracoronal placement is required, minimal preparation will usually be sufficient owing to the availability of ultra-thin tape configurations offered by a number of fiber reinforcement manufacturers.

MAINTENANCE

Proper home care instruction, including the use of floss threaders where teeth have been connected together, and routine office checkups are part of an appropriate dental regimen, especially when these types of restorations have been placed. The patient needs to understand the importance of a routine professional maintenance schedule in order to monitor the integrity of these restorations as well as their overall oral health. If the patient does not need to significantly alter his or her lifestyle or eating habits, the treatment approach was appropriate and maintenance should not be difficult—the restoration can be considered a success.

CONTROVERSIES

A sufficient number of these restorations have been placed utilizing these techniques, leaving no question that there is an advantage to using internal fiber reinforcement where indicated. Most of the controversy relates to the choice of material. Ultimately, the successes of these techniques far outweigh the controversy of which material to use. It is important to realize that fiber reinforcement is a great addition to the dental armamentarium that allows the dentist to perform procedures that are otherwise difficult or impossible. The choice of material is basically an individual decision based on the clinician's personal preference.

NEAR-FUTURE DEVELOPMENTS

The use of specific high-performance fibers such as Astroquartz is being tested. Astroquartz is a flexible quartz fiber that has a melting point high enough to allow porcelain to be fired around it. Potentially, the laboratory may be able to use porcelain pontics fired in an oven with internal fiber reinforcement and fiber wings. Thus a fiber-reinforced, laboratory-fabricated, indirect bridge with porcelain as opposed to composite pontics becomes a possibility.

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CASE 1 Fabrication of the GlasSpan Natural Tooth Bridge

"Recycling" of tooth structure is uniquely consistent with the philosophy of preserving the natural dentition. When extraction becomes necessary because of diseased roots, the use of a GlasSpan natural tooth bridge offers many advantages. The natural tooth bridge fits easily into the available space and is shaped and shaded to blend properly with existing dentition. Also, the emotional loss felt by some patients is minimized because the visible portion of the natural tooth is retained.

The natural tooth bridge technique has been simplified and the long-term prognosis greatly improved through the development of the GlasSpan fiber reinforcement system, which uses flexible ceramic ropes and tapes. GlasSpan includes a special surface treatment, allowing it to easily bond to and strengthen dental restorative resins.

Components of the system are supplied in a kit (Figure 12-6, *A*) that includes 12 flexible-strength members in four braided rope and tape configurations (Figure 12-6, *B*), sufficient for 12 applications. Custom kits are also available. A 20-page illustrated manual provides detailed instructions for various chairside and laboratory procedures such as post-orthodontic retention, periodontal splinting, immediate replacement of lost or missing teeth, transitional implant bridges, and construction of a natural tooth bridge. The natural tooth bridge is especially useful for transitional tooth replacement when financial considerations prohibit placement of permanent fixed bridgework.

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CASE 1 Fabrication of the GlasSpan Natural Tooth Bridge (cont'd)

This 37-year-old female patient had several complaints, including pain, inflammation, and suppuration surrounding her maxillary left lateral incisor (Figure 12-6, *C*). Radiographic examination (Figure 12-6, *D*) revealed advanced external resorption, leaving the tooth with a hopeless prognosis. The patient exhibited extreme anxiety over losing the tooth and wanted to save as much of it as possible, so placement of a GlasSpan natural tooth bridge became the treatment of choice.

After careful tooth extraction, the surgical flap was tightly sutured to prevent fluid contamination of the operative field (Figure 12-6, *E*). It is important to preserve the buccal plate of bone for maximum esthetics. Examination of the tooth revealed severe destruction caused by external resorption (Figure 12-6, *F*).

A measurement was made to determine the length of the natural tooth to be saved (Figure 12-6, *G* and *H*). The granulation tissue was débrided from the area of resorption, and the root was removed at the determined length (Figure 12-6, *I*). The tooth structure lost to the resorptive process was reconstructed using a restorative composite resin. These procedures produced an ovate-shaped pontic that presents a more natural emergence profile from the ridge. A channel was cut into the lingual surface of the natural tooth pontic (Figure 12-6, *J*).

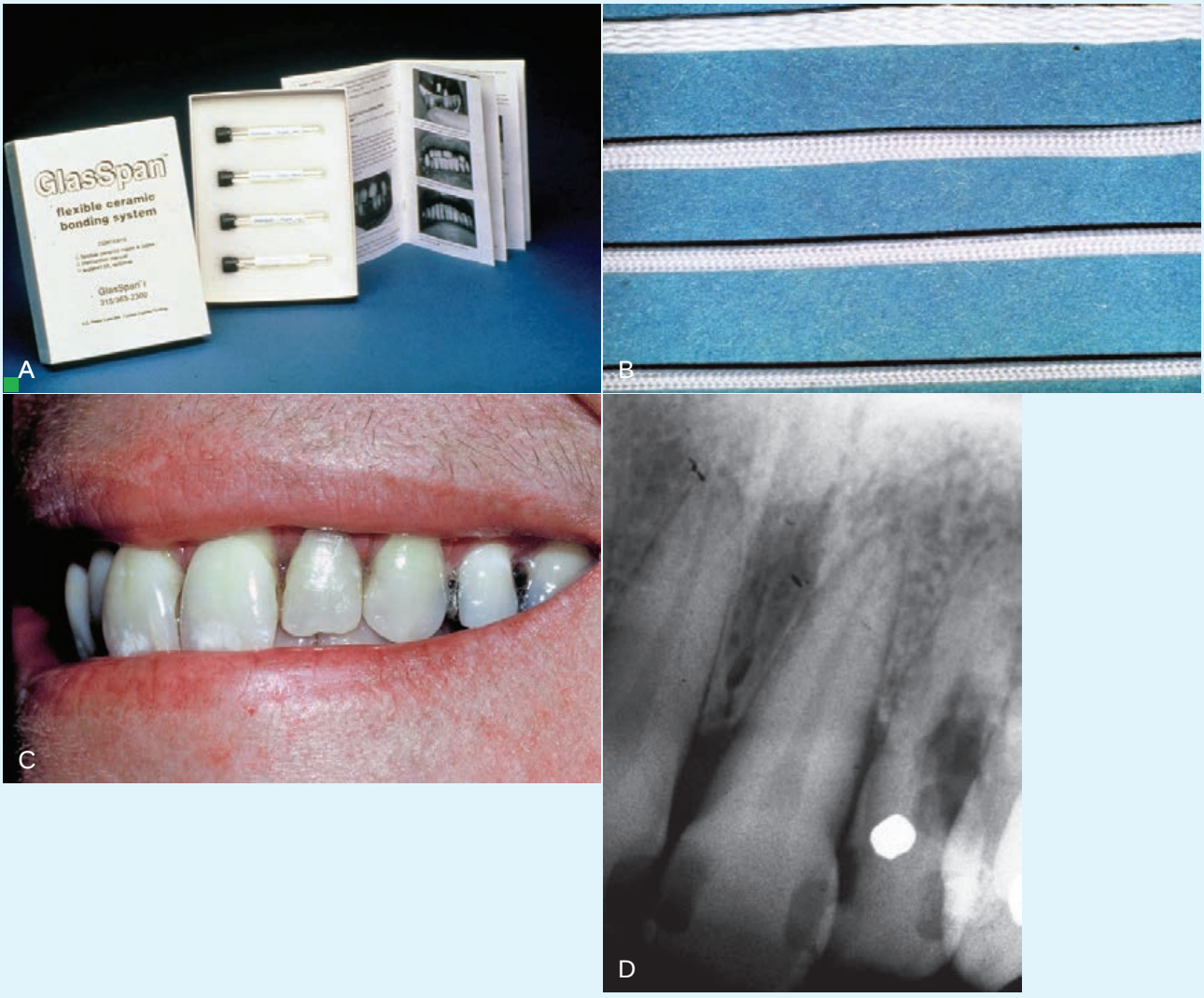


FIGURE 12-6 **A, The GlasSpan fiber reinforcement system. B, Flexible strength members in braided rope and tape configurations. C, Inflammation and suppuration surrounding patient's maxillary left lateral incisor. D, Radiograph showing advanced external resorption.**

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CASE 1 Fabrication of the GlasSpan Natural Tooth Bridge (cont'd)

A GlasSpan rope was selected to reinforce the bridge (Figure 12-6, *K*). The portion of ceramic rope to receive the pontic was treated with a flowable composite resin and left uncured. A layer of hybrid composite resin was placed into the pontic's channel. The rope was seated and then completely covered over with a second layer of composite resin (Figure 12-6, *L*). This was polymerized using a visible light-curing unit. The ceramic ropes extending from each side of the natural pontic served as attachments to adjacent natural dentition and remained untreated at this time (Figure 12-6, *M*).

Class III preparations were made on the adjacent teeth to ready them for placement of the rope attachments (Figure 12-6, *N*). A try-in of the natural tooth bridge confirmed proper fit and adequate tooth preparation. The two rope attachments were treated with a flowable composite resin and left uncured. The abutment tooth

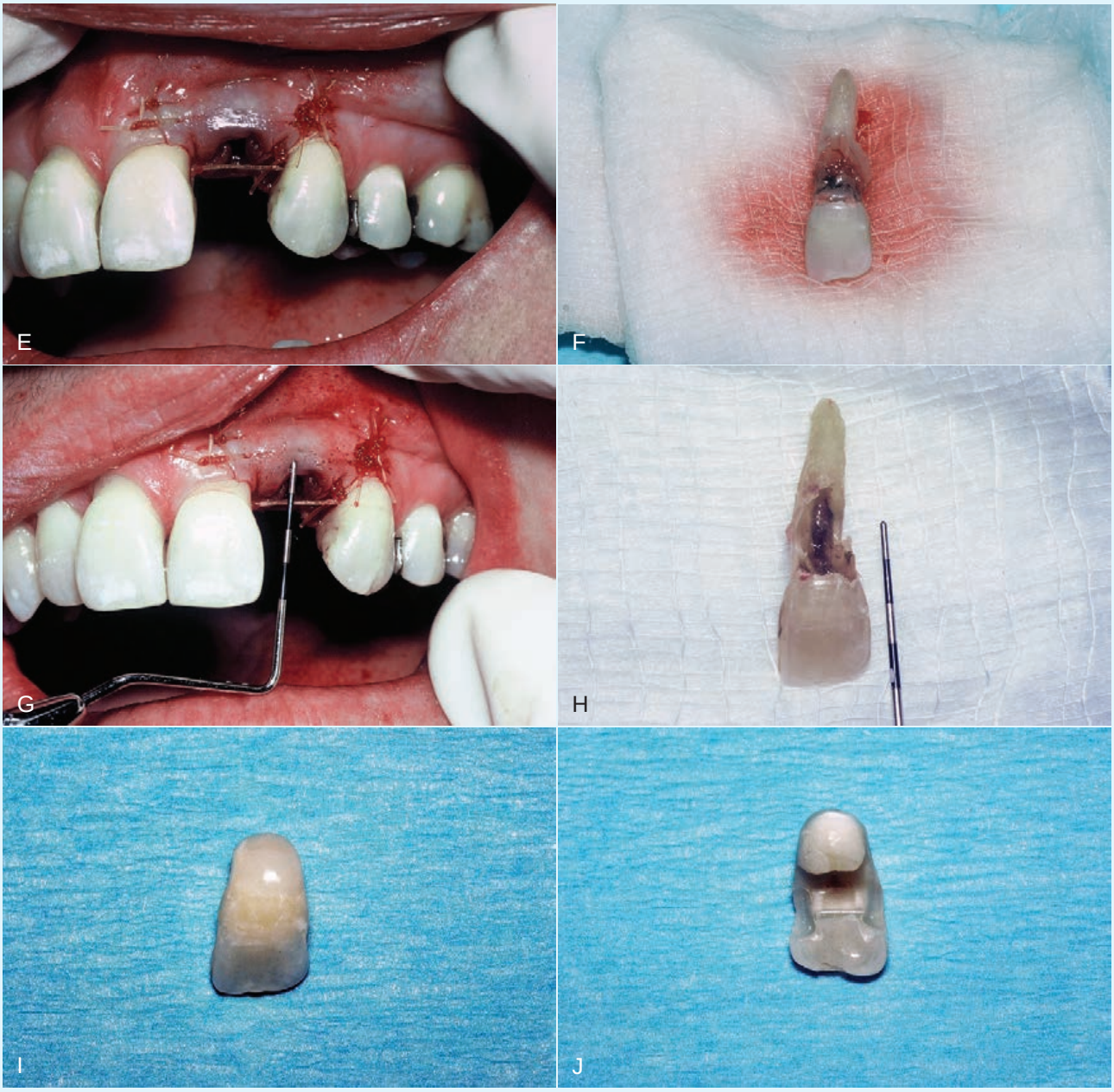


FIGURE 12-6, cont'd **E, After tooth extraction, tightly sutured surgical flap that prevents fluid contamination in the operative field. F, Extracted tooth showing severe destruction caused by external resorption. G and H, Measurement determines the length of the natural tooth to be saved. I, The tooth structure lost to the resorptive process reconstructed using a restorative composite resin. An ovate-shaped pontic was produced that gives a more natural emergence profile from the ridge. J, Channel cut into the lingual surface of the natural tooth pontic.**

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CASE 1 Fabrication of the GlasSpan Natural Tooth Bridge (cont'd)

surfaces to receive the attachments were treated with an adhesive bonding system. A layer of hybrid composite resin was placed into the class III preparations, and the bridge was seated (Figure 12-6, *O*). The rope attachments were completely covered over with an additional layer of composite resin. This was again polymerized using a visible light-curing unit. After the occlusion was checked and adjusted, conventional fluted carbides, interproximal carvers, and polishing agents were used to open embrasures, provide acceptable contours, and impart a final surface luster to the restoration (Figure 12-6, *P*). Although wound healing still needed to take place (Figure 12-6, *Q*), the patient was instructed in the proper use of floss threaders and other oral hygiene procedures for cleaning the natural tooth bridge.

Final finishing and polishing of the restoration were performed 2 weeks postoperatively (Figure 12-6, *R* and *S*). The final treatment result (Figure 12-6, *T* and *U*) is both natural in appearance and satisfying to the patient.

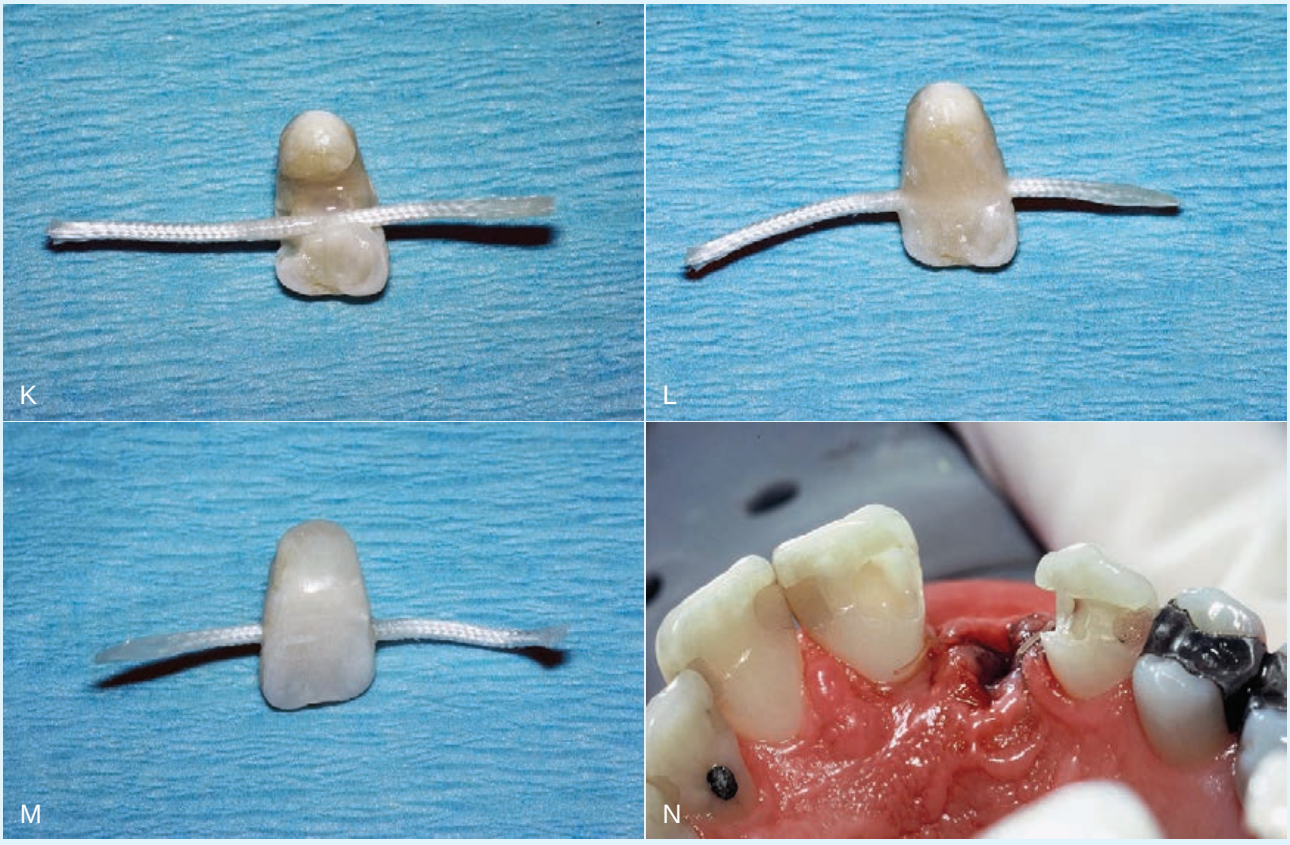


FIGURE 12-6, cont'd **K and L, GlasSpan rope reinforces the bridge. M, Ceramic ropes extending from each side of the natural pontic serve as attachments to adjacent natural dentition. N, Class III preparations made on the adjacent teeth to ready them for placement of the rope attachments.**

همیار دندانسازان و دندانپزشکان



FIGURE 12-6, cont'd **O,** A layer of hybrid composite resin placed into the class III preparations and the bridge seated. Results immediately after treatment. **P,** Occlusion adjusted and contouring of the restoration. **Q,** Final finishing and polishing of the restoration performed 2 weeks postoperatively. **R** and **S,** Final treatment results shown.

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CASE 2 Simplified Trauma Splints Using the GlasSpan Single Use Trauma Kit

Rapid stabilization and fixation of traumatized or avulsed teeth are often critical to their long-term prognosis. Immediate placement of a trauma splint on injured teeth is often needed to facilitate healing as well as improve the patient's comfort level when eating. Traditional methods using metal ligating wire in conjunction with composite resin are time-consuming and uncomfortable for the patient and potentially create more trauma in already compromised teeth. A simplified trauma splint may be fabricated using the GlasSpan Single Use Trauma Kit.

This 46-year-old female patient had fallen and struck her face on a hard floor. Her chief complaint was that her upper front teeth were painful and loose. Clinical examination revealed mobility in the maxillary centrals and laterals, with no apparent fractures of the clinical crowns of these teeth. Radiographic examination confirmed the absence of any fractured roots. The treatment of choice was stabilization of these teeth using the GlasSpan Single Use Trauma Kit.

The GlasSpan Trauma Kit (Figure 12-7, *A*) uses bondable ceramic ropes to give exceptional flexural and tensile strength to a flowable composite resin, which allows the clinician to quickly and easily stabilize injured teeth. Components of the system are supplied in a kit that includes two flexible strength members (15 cm) in a hollow braided rope configuration, sufficient for stabilizing two arches, as well as a self-etch adhesive, a light-cured nanohybrid flowable composite resin, an applicator brush, a syringe tip, and illustrated instructions (Figure 12-7, *B*). The GlasSpan etch-bond is a one-step adhesive particularly useful for this technique because it can be placed in a moist environment, which is often the case when there is a trauma situation. The GlasSpan flowable, light-cured, nanohybrid composite is uniquely suited to the splinting technique, especially in conjunction with the specially designed GlasSpan injectable, hollow braided rope material.

A piece of GlasSpan rope was cut and measured to the desired length using sharp scissors (Figure 12-7, *C*). The dentist must be sure to remove the end binders on both ends of the GlasSpan so the cut ends unravel (Figure 12-7, *D*), facilitating injection of the flowable resin into the GlasSpan rope. A needle tip was placed on the tube of GlasSpan flowable composite resin and inserted 2 to 3 mm into one end of the hollow GlasSpan rope (Figure 12-7, *E*). The composite was injected until it extruded from the other end of the rope, ensuring complete wetting of the ceramic fibers internally (Figure 12-7, *F*). The external surface of the GlasSpan rope was then completely covered with the flowable composite (Figure 12-7, *G*) and set aside, protected from light. *Clinical note: Do not light polymerize at this time.*

The foil cover of the GlasSpan etch-bond is penetrated using the applicator brush (Figure 12-7, *H*). The etch-bond was applied with the applicator brush onto the wet enamel and dentinal surfaces (Figure 12-7, *I*) to receive the splint and agitated for 30 seconds. A gentle air stream was used for 10 seconds to thin the adhesive and then polymerized for 10 seconds (Figure 12-7, *J*). A bead of GlasSpan flowable composite resin was placed on the tooth surfaces to receive the splint (Figure 12-7, *K*). *Clinical note: Do not polymerize at this time.* The treated GlasSpan rope was then placed onto the teeth against the beads of composite and polymerized for 20 seconds on each tooth (Figure 12-7, *L*). Additional flowable composite resin was applied over the GlasSpan rope to cover all exposed fibers and light polymerized for an additional 20 seconds for each tooth (Figure 12-7, *M*). The completed splint required about 15 minutes of chair time (Figure 12-7, *N*). The patient experienced immediate relief and was able to eat normally during the healing period until the teeth were restabilized. Removal of the splint was easily accomplished 3 weeks later using multifluted carbides in a high-speed handpiece with water spray.

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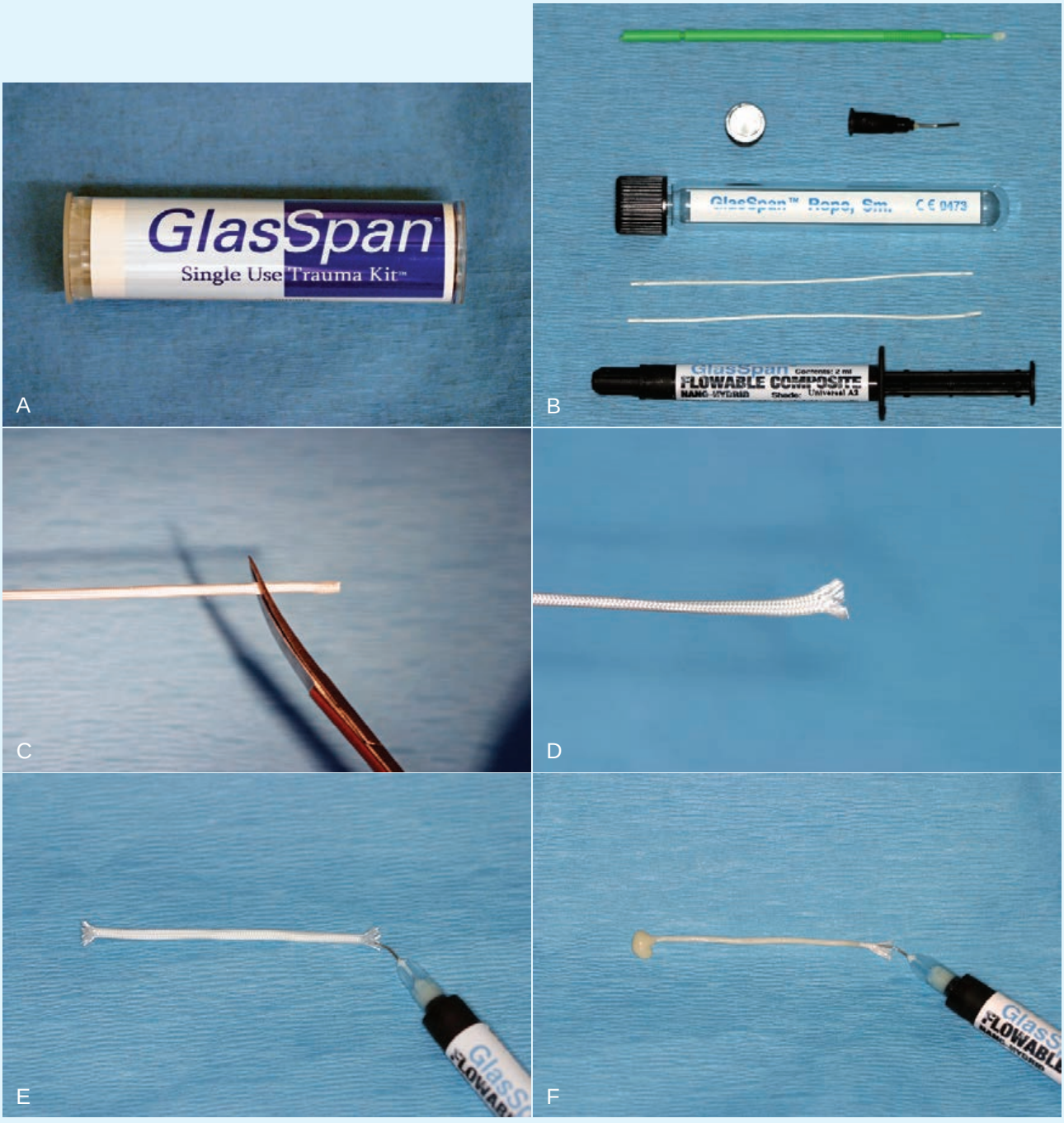


FIGURE 12-7 **A,** The GlasSpan Trauma Kit. **B,** Components of trauma kit. *Top to bottom,* Applicator brush, self-etch adhesive *(left),* syringe tip *(right),* GlasSpan rope container, two flexible strength members (15 cm) in a hollow braided rope configuration, and light-cured nanohybrid flowable composite resin. **C,** A piece of GlasSpan rope cut to the desired length using sharp scissors. **D,** End binder removed from the GlasSpan rope. Open end facilitates the injection of flowable resin. **E,** Needle tip placed on the tube of GlasSpan flowable composite resin and inserted 2 to 3 mm into one end of the hollow GlasSpan rope. **F,** Composite injected until it extruded from the other end of the rope. **G,** The external surface of the GlasSpan rope completely covered with the flowable composite. **H,** Foil cover of the GlasSpan etch-bond penetrated using the applicator brush. **I,** Etch-bond applied with the applicator brush onto the wet enamel and dentinal surfaces to receive the splint. **J,** A gentle air stream used for 10 seconds to thin the adhesive; the adhesive is polymerized for 10 seconds. **K,** A bead of GlasSpan flowable composite resin placed on the teeth surfaces to receive the splint. **L,** Treated GlasSpan rope placed onto the teeth against the beads of composite and polymerized for 20 seconds on each tooth. **M,** Additional flowable composite resin applied over the GlasSpan rope to cover all exposed fibers. It is light polymerized for an additional 20 seconds for each tooth. **N,** The completed splint.

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CASE 2 Simplified Trauma Splints Using the GlasSpan Single Use Trauma Kit (cont'd)



FIGURE 12-7, cont'd

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CASE 3 Combination Splinting with Tooth and Soft Tissue Replacement, Direct and Indirect Method

The primary presurgical prosthetic management objectives in the periodontal patient include the stabilization of mobile teeth, the replacement of lost or missing teeth, and the esthetic correction of defects resulting from previous surgery, trauma, or the disease process itself. This case demonstrates the use of a number of dental restoratives used in a unique way to achieve these objectives.

The GlasSpan fiber reinforcement system, composed of silane-treated etched-glass fiber ropes and tapes, served to strengthen the periodontal splint made from composite resin, while eliminating the need for unsightly cast-metal or bent-wire support in the final restoration. It also served as a matrix on which a pontic was constructed. The pontic was fabricated indirectly in the laboratory using a conventional posterior composite resin. The high melting point of the GlasSpan ceramic fiber allowed the pontic to be heat-cured under pressure to increase its surface hardness. A gingiva-colored composite resin was bonded directly to the tooth surfaces where recession had occurred and incorporated into the tissue base of the pontic to replace lost alveolar ridge tissue. The case description that follows is intended to provide the clinician with an insight as to the usefulness of these contemporary materials and techniques and how they may simplify the challenges commonly encountered during the presurgical prosthetic management phase of comprehensive periodontal therapy or alternative therapy if required.

A 61-year-old female patient reported discomfort in the upper right quadrant caused by mobility of her second bicuspid tooth with chewing (Figure 12-8, *A*). Clinical and radiographic examination revealed that the tooth, although exhibiting a mobility degree of 2, had sufficient support to warrant inclusion in a future permanent prosthesis but would benefit from immediate stabilization (Figure 12-8, *B*). The first and second bicuspids, which demonstrated areas of gingival recession, cervical erosion, and previously placed restorations with current decay on their facial surfaces, were un-esthetically "long" in appearance. The upper right first molar tooth was missing, and the second molar was heavily restored with amalgam.

During the first clinical visit the following were obtained: an alginate impression of the arch to be restored, a counter-impression for indirect laboratory fabrication of the transitional bridge, and a bite registration (Figure 12-8, *C*).

The shades for the pontic and soft tissue base were selected at this time (Figure 12-8, *D*). Lumin A-3.5 was chosen for the pontic, and, using the Gingiblend shade guide, it was determined that the medium gingiva-toned composite was the closest shade to the adjacent attached gingiva. By adding a white modifier, a more exact shade match to the natural soft tissue was achieved. A test sample was mixed and polymerized on a toothpick to confirm the suitability of the color blend. The impressions were poured. *Clinical note: All subsequent steps in the prosthesis fabrication can be completed by the dentist or by a laboratory technician.*

In the laboratory the models were mounted and articulated. The location of the attachments was marked with a pencil (Figure 12-8, *E*). The abutment teeth were prepared on the model to accept a continuous strand of GlasSpan rope (Figure 12-8, *F* and *G*). This may be a straight channel, horseshoe-shaped channel, or class II preparation. The GlasSpan rope was placed into the preparation on the model and tacked into the pontic area with a flowable composite resin (Figure 12-8, *H*). The free ends of the GlasSpan were trimmed away (Figure 12-8, *I*). The entire portion of the GlasSpan to receive the pontic was also treated with a clear resin and a coating of porcelain veneer luting paste (Figure 12-8, *J*). The pontic was constructed directly on the rope using a posterior composite resin (Figure 12-8, *K*). For this purpose, an auto-cure, light-cure, or heat-processed resin restorative system may be used. As the GlasSpan will accept all composite and acrylic resins, the technician is free to choose the system with which he or she is most familiar or that is already available in the laboratory.

The tissue base for the pontic was created from the previously determined shade mix of gingival-colored composite resin. Owing to tooth shifting, the available space permitted a pontic with the mesio-distal dimension approximating that of a bicuspid (Figure 12-8, *L* and *M*).

During the second clinical visit, local anesthesia was administered to ensure patient comfort. Although occlusal channels or class II preparations are generally suitable for receiving the GlasSpan rope, the second molar, with an extensive amalgam restoration and recurrent decay, required more extensive preparation (Figure 12-8, *N*). Try-in of the GlasSpan splint and bridge combination confirmed proper fit and ridge adaptation as well as adequate tooth preparation, good shade match, and sufficient extension of the GlasSpan support material (Figure 12-8, *O*). The second molar was etched with 37% phosphoric acid for 10 to 15 seconds, and a dental adhesive was placed. The lost tooth structure was restored using a tooth-colored posterior composite resin. A channel was made in the occlusal surface of the composite to receive the GlasSpan rope. A depression was also placed in the composite extending from the existing soft tissue margin on the labial surface to the level at which

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CASE 3 Combination Splinting with Tooth and Soft Tissue Replacement, Direct and Indirect Method (cont'd)

the new gingival border was to be created. This was filled with the previously chosen shade of gingival-colored composite and then light cured.

The flexible attachments of the bridge were treated with the appropriate resins as previously described (Figure 12-8, *P*). Tooth surfaces were prepared using a dental bonding adhesive (Figure 12-8, *Q*). A layer of posterior composite was placed on the floor of the tooth preparation, and the bridge was seated into place (Figure 12-8, *R*). The patient was asked to bite down to help position the bridge while the composite was light cured. The



FIGURE 12-8 Pre-treatment clinical photo (A) and radiograph (B) show the first and second bicuspids with areas of gingival recession, cervical erosion, and previously placed restorations with decay on their facial surfaces. They are un-esthetically "long" in appearance. The upper right first molar tooth is missing and the second molar heavily restored with amalgam. C, Alginate impression stone model of the arch to be restored *(top left)*, counter-impression for indirect laboratory fabrication of the transitional bridge *(top right)*, and bite registration *(bottom)*. D, Shade guide used to select correct color for the pontic. E, Location of the attachments marked on the model with a pencil. F, Abutment teeth prepared on the model for fiber reinforcement.

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CASE 3 Combination Splinting with Tooth and Soft Tissue Replacement, Direct and Indirect Method (cont'd)

GlasSpan attachments were completely covered over with restorative composite resin to the level of the occlusal surfaces, which were then polymerized with a curing light (Figure 12-8, *S*). The occlusion was checked and adjusted (Figure 12-8, *T*). Conventional fluted carbides, interproximal carvers, and polishing agents were used to open embrasures, provide acceptable contours, and impart a final surface luster to the restoration (Figure 12-8, *U*).

The existing restorations were removed from the facial surfaces of the bicuspid teeth, and the recurrent decay was excavated (Figure 12-8, *V*). To eliminate the "long" appearance of the teeth and establish a more pleasing

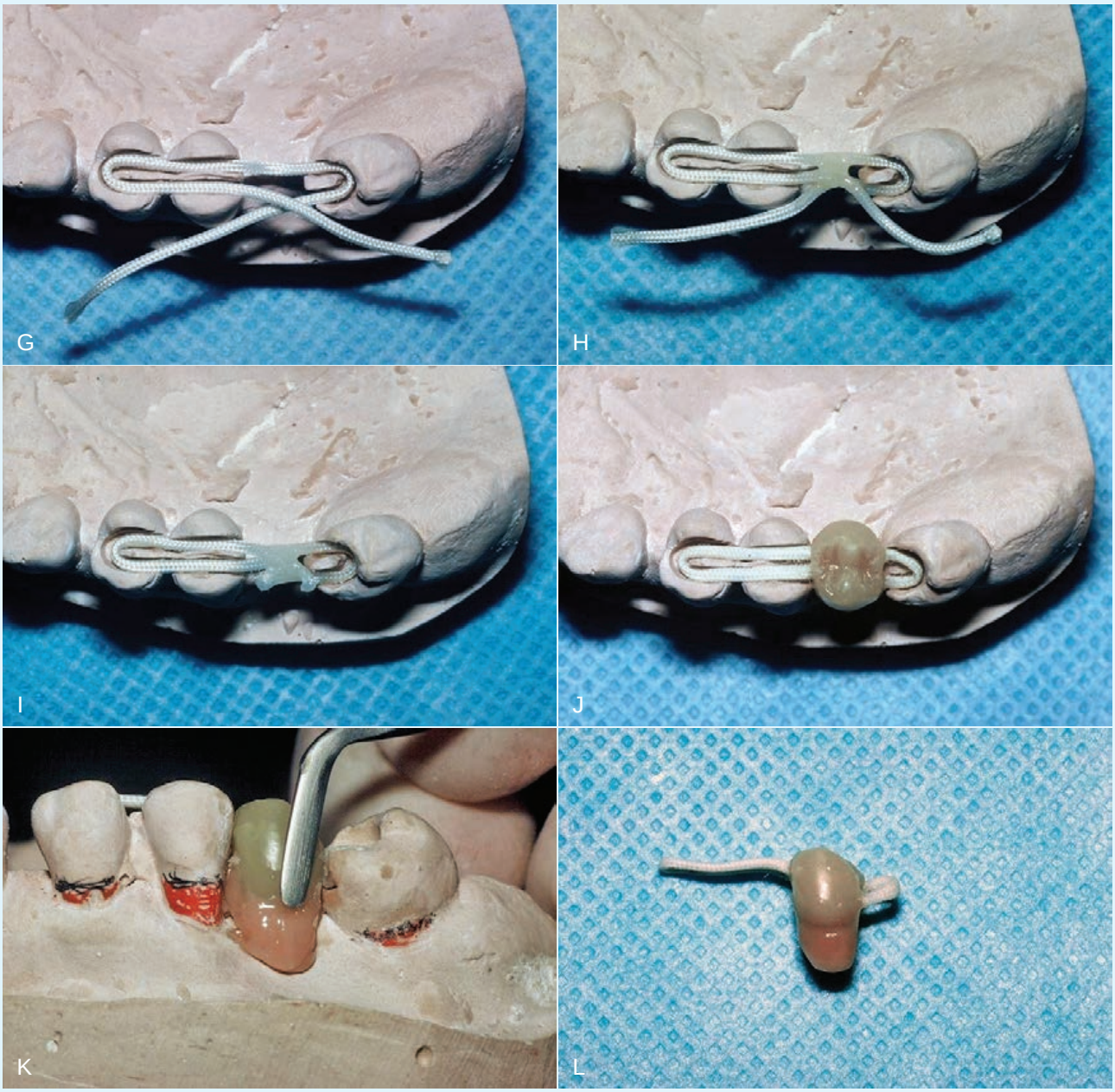


FIGURE 12-8, cont'd **G, A continuous strand of GlasSpan rope forced into the prepared teeth in the mode. H and I, The GlasSpan rope placed into the preparation on the model and tacked into the pontic area with a flowable composite resin (H). The free ends of the GlasSpan trimmed away (I) and the entire portion of the GlasSpan to receive the pontic treated with a clear resin and a coating of porcelain veneer luting paste. J, The pontic constructed directly on the rope using a posterior composite resin. K, Tissue base for the pontic created from the previously determined shade mix of gingiva-colored composite resin. L and M, The pontic has the mesio-distal dimension approximating that of a bicuspid.**

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CASE 3 Combination Splinting with Tooth and Soft Tissue Replacement, Direct and Indirect Method (cont'd)

balance between crown length and soft tissue height, a combination of tooth and gingival-colored composite was used as previously described (Figure 12-8, *W* and *X*). Fluted carbides followed by composite polishing paste (Figure 12-8, *Y*) provided a final contour and luster to the composite surfaces.

The esthetic result successfully eliminated mobility in the quadrant and offered a unique method of tooth replacement (Figure 12-8, *Z*). This restoration has remained clinically intact and esthetically pleasing for 15 years at the time of this writing.



FIGURE 12-8, cont'd **N,** Teeth prepared for receiving the GlasSpan rope. The second molar, with an extensive amalgam restoration and recurrent decay, required more extensive preparation. **O,** Try-in of the GlasSpan splint and bridge combination. This confirmed proper fit and ridge adaptation, adequate tooth preparation, good shade match, and sufficient extension of the GlasSpan support material. **P,** The flexible attachments of the bridge treated with the appropriate resins. **Q,** Tooth surfaces prepared using a dental bonding adhesive. **R,** A layer of posterior composite placed on the floor of the tooth preparation and the bridge seated into place.

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FIGURE 12-8, cont'd S, GlasSpan attachments completely covered over and the preparations filled with restorative composite resin. T, Fluted carbide used to provide proper contours. U, The restoration showing the final anatomy and luster of occlusal surface. V, Existing restorations removed from the facial surfaces of the bicuspid teeth and recurrent decay excavated. W and X, Combination of tooth (W) and gingiva-colored composite (X) used to eliminate the "long" appearance of the teeth and establish a more pleasing balance between crown length and soft tissue height. Y, Composite polishing paste used to provide a final contour and luster to the composite on facial surfaces. Z, The completed restoration.

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Glass Ionomer Restoratives

Carlos A. Muñoz-Viveros

RELEVANCE TO ESTHETIC DENTISTRY

Although glass ionomer restoratives are not highly esthetic, they are considered the material of choice for class V lesions in patients at high risk for caries and erosion lesions. They are also used in deciduous class I and II restorations. Glass ionomers in general are tooth colored but rather opaque in appearance. Esthetically they are inferior to conventional resin composites, but they offer the advantages of providing adhesion and fluoride release. The physical properties of glass ionomers tend to be inferior to those of resin composites, so they cannot be used for large restorations or cavities that will be subjected to occlusal forces.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Glass ionomers were developed in the 1970s by mixing silicate cement with polyacrylic acid. They set via an acid-base chemical reaction. They bond chemically to enamel and dentin. Glass ionomers are supplied as a liquid and powder system.

Because of the poor physical properties of glass ionomers, in the late 1980s resin-modified glass ionomers were introduced. They have an acid-base reaction in addition to free radical polymerization, either light or chemically activated. These refined materials (also called *hybrid ionomer cements*) offer better physical properties, are easier to finish, and set on demand.

In the early 1990s compomers were developed to mimic resins. These can be used with conventional dental adhesive systems. A liquid water-free polyacid monomer is used in place of the polyacrylic acid. Compomers bond and set like composite systems. Initially they release fluoride but that diminishes with time. Compomers are fairly popular in pediatric cases. In the late 1990s metal-reinforced glass ionomers were introduced for use as core buildups. These contain a silver alloy admix.

CLINICAL CONSIDERATIONS

Although the caries-inhibiting effect of glass ionomers has been established, their clinical effectiveness has been questioned because of their relatively short clinical durability. Glass ionomers can recharge any lost fluoride (i.e., add fluoride back into the restorations for subsequent release) by exposing the surfaces to fluoride ion sources such as fluoride-containing toothpastes, fluoride mouthrinses, or topical fluorides. This temporarily boosts the fluoride concentration, but unfortunately the boosted levels are not high enough for even a short time to be considered clinically efficacious as an anticaries therapy.

Indications

Glass ionomers are useful for posterior class II restorations, class II restorations prepared using the open sandwich technique (placed in the proximal box of a preparation at the cementum and dentin interface), and carious or noncarious class V restorations. They also serve as pit and fissure sealants and in atraumatic restorative technique (ART) restorations.

Contraindications

Glass ionomers should not be used in stress-bearing restorations or areas where esthetics is a concern. Large class II, class III, and class IV restorations are better handled with other materials.

MATERIAL OPTIONS

Advantages

Conventional glass ionomers offer many biotherapeutic advantages (Table 13-1). They provide long term release of fluoride ions, ability to bond to tooth structure and are very biocompatible. Because they posses a coefficient of thermal expansion similar to tooth structure, they are able to provide excellent marginal seal around the preparation. They have adequate strength and release fluoride. These materials are not very expensive.

Disadvantages

Despite the long term release of fluoride, glass ionomers have limited clinical applications. Compared with other restorative materials, glass ionomers are less durable, harder to finish, sensitive to changes in its water content and not very esthetic. It is also necessary to use a protective glazing coat over the surface.

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TABLE 13-1 Representative Glass Ionomers and Modified Glass Ionomers

GLASS IONOMERS	RESIN-MODIFIED GLASS IONOMER	POLYACID-MODIFIED RESIN COMPOSITES (i.e., COMPOMERS)	METAL-REINFORCED GLASS IONOMERS	LINERS
Ketac-Fil+	Fuji II LC	Dyract eXtra (DENTSPLY Caulk)	Ketac Silver	Vitrebond Plus
Ketac-Molar	Fuji Filling LC	Hytac Aplitip	(3M ESPE)	(3M ESPE)
(3M ESPE)	(GC America)	(3M ESPE)		Fuji Lining LC
Fuji II	Vitremer	Compoglass F (Ivoclar Vivadent)		(GC America)
Fuji IX	Photac-Fil Quick			
Fuji Triage	Ketac Nano			
(GC America)	(3M ESPE)			

Current Best Approach

It is best to use resin-modified glass ionomers for general restorative procedures.

OTHER CONSIDERATIONS

Highly viscous glass ionomer materials are useful for ART restorations.

INNOVATIVE ELEMENTS

Scientific Elements

The original glass ionomers developed in the 1970s are still on the market. Over the years, several improved versions have been introduced during the past 30 years. More recently a new generation of high-strength glass ionomers has been developed. These materials are very popular especially for use on children and older aldults.

Technological Elements

Encapsulated versions make this material easier to use. Automix syringe versions have recently been introduced to the marketplace.

TREATMENT PLANNING

Options

Glass ionomers are the ideal materials for older individuals with decreased salivary flow, individuals with poor oral hygiene, and persons with disabilities. These materials are also being used as a liner under resin composite restorations, a base, a core build-up, and in individuals who are a high risk for developing carious lesions.

Sequence

Case evaluation is very important. Traditionally, radiographic evidence of demineralization was the main decision process for placing a restoration. Modern research has shown that the treatment should be based on the interpretation of the activity of the lesion and risk assessment. For example, patients are living longer, and an increasingly larger number are taking medications that decrease salivary flow. This increases the potential for rampant caries: a thorough assessment of the caries activity, oral hygiene, and risk assessment should be fully evaluated before deciding on a non-invasive or invasive restorative option.

TREATMENT CONSIDERATIONS

Preparation

The dentist begins with rubber dam isolation. A traditional preparation with no bevels is performed, including small retentive undercuts if needed. Otherwise no retention is needed. Any unsupported enamel is removed.

Procedure

The cavity is cleaned with polyacrylic acid and rinsed. The matrix is applied, followed by the restorative material. The restoration can be either light cured or allowed to harden.

Finishing

is the new generation of glass ionomers allows the practitioner to contour and polish the material immediately. However, placement procedures that minimize the need to finish and polish glass ionomers should be used. Several manufacturers provide a resin-based protective coating to be applied over the restoration after finishing.

CLINICAL CONSERVATION CONCEPTS

As new materials are developed, it becomes increasingly difficult to choose the most appropriate material for a particular clinical situation. Currently there are no specific clinical guidelines, and no long-term, evidence-based clinical studies are available. The physical properties of current glass ionomers, especially their poor wear resistance, limit the use of these materials.

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FIGURE 13-1 **A, Microleakage observed on class II restorations in a high-risk caries patient. B, Removal of existing restoration and preparation. C, One-year postoperative view of glass ionomer restoration. D, Glass ionomer class V restorations after 1 year. Note the loss of gloss on the restoration surface.**

MAINTENANCE

In general, glass ionomer cements need to be replaced more often than conventional resins. However, newer generation of glass ionomers have shown to be successful after 10 years of clinical use.

CONTROVERSIES

There is insufficient clinical documentation to show that glass ionomers are a viable permanent option for long-term use. Manufacturers are developing and introducing new materials with very little clinical evidence, which creates further confusion among dentists.

NEAR-FUTURE DEVELOPMENTS

Glass ionomers with higher viscosity, higher fluoride content, and greater ability to recharge are being developed.

CLINICAL TECHNIQUES

The senior patient in Figure 13-1 had recurrent caries under restorations. Physical examination revealed poor oral hygiene and mild xerostomia. There were several recurrent lesions, some of which were located subgingivally. Esthetics was not an issue. It was determined that amalgam, resins, and flowables were not suitable for this situation.

The treatment plan was to remove the old restorations and any recurrent carious lesions. After removal of the old restoration and re-shaping the preparation, the cavity was cleaned with a mild acid. The new restoration was placed, contoured, and finished. A protective coating was applied.

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CHAPTER 14

Bleaching

SECTION A

Bleaching and Its Relevance to Esthetic Dentistry

George Freedman

As the techniques and materials available to dentists have improved over the past few decades, better and more conservative restorations have become possible. Extensive preparation and tooth destruction have given way to a genuine concern for the preservation of tooth structure. Most recently, much attention has been devoted to the esthetic aspects of dentistry and the patient's concerns regarding appearance. The past three decades have been the most dynamic period that the profession has ever seen.

As the population's dental awareness has grown, so has its demand for a natural (or preferably supernatural) smile. The one inescapable fact is that patients are very eager to have whiter and brighter smiles. The desire for whiter teeth is the strongest driving force in people's quest for dental treatment. Whereas oral health and function are paramount for the practitioner, the patient's attention tends to focus rather exclusively on appearance and esthetics. In the cultural environment encouraged by toothpaste advertisements and Hollywood and bolstered by the personal need to appear healthy and young, discolored or dark teeth are no longer socially acceptable. Patients are therefore seeking, and even self-administering, dentist-mediated as well as exotic and questionable treatments to achieve the whiter smiles they desire. It is the dentist's responsibility to supervise patients who seek to undergo a whitening treatment to ensure that the maximum cosmetic benefit is within the boundaries of oral and systemic health.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

The desire for whiter teeth is not completely a recent phenomenon. Even in Biblical times white dentition was considered, attractive, youthful, and desirable. In third-century BC Greece, Theophrastus wrote that it was "considered a virtue to shave frequently and to have white teeth."

If any attention was paid to dental hygiene and appearance during the Middle Ages, there is little surviving documentation. Life spans were short, education was minimal, and the primary concerns were survival, food, and shelter.

Guy de Chauliac, a fourteenth-century surgeon, commented extensively on his dental observations and produced a set of rules for oral hygiene that included the following tooth-whitening procedure: "Clean the teeth gently with a mixture of honey and burnt salt to which some vinegar has been added." His texts were considered authoritative for the subsequent 300 years.

The following era of dentistry brought the study of dental anatomy and oral disease and a great interest in the prosthetic replacement of teeth whose loss could not yet be avoided. As the craft of dental technology expanded, dentists were better able to replicate both form and function. Then, in the nineteenth century, dentistry began its recognizably modern form of restoring carious and even infected teeth. These advancing skills resulted in patients retaining their teeth for a greater portion of their lives, and an expectation that these aged teeth could be made visually acceptable.

Patient demands, combined with rapidly advancing medical chemistry, resulted in the first vital tooth bleaching agents and procedures. Chapple proposed oxalic acid as the material of choice in 1877. Shortly after, Taft suggested calcium hypochlorite as an effective whitening solution. The first mention of peroxide as a whitening agent was over a century ago; in 1884 Harlan published a report concerning a material that he called *hydrogen dioxide.*

Some of the more arcane bleaching proposals at the turn of the century included electric currents and ultraviolet waves (Rosenthal). Obviously, neither of these really caught on with the mainstream dentist. Acid dissolution of brown fluoride stains was yet another approach to discoloration. This technique was first documented by Kane in 1916. The technique involved

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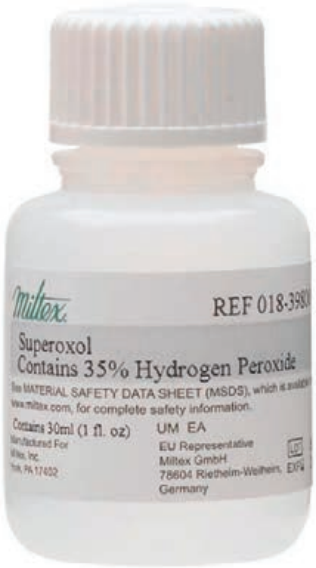


FIGURE 14-1 Superoxol, a whitening agent whose effects were pioneered by Abbot in 1918. *(Permission granted by Integra Miltex, a business of Integra LifeSciences Corporation, Plainsboro, New Jersey.)*



FIGURE 14-2 The custom-molded tray bleaching process was introduced in 1989. (Pictured: White & Brite Professional Tooth Whitening System [3M ESPE, St. Paul, Minnesota].)

the use of 18% HCI to dissolve the superficial layers of enamel. Further investigations were conducted by McCloskey in 1984. In 1918, Abbot pioneered the whitening effects of Superoxol (Figure 14-1). He found that although the chemical was suitable for bleaching teeth, its activity could be enhanced by the addition of heat and light. Some current bleaching techniques are based on Kane and Abbot's developments.

The earliest attempts at non-vital bleaching were made at the end of the nineteenth century, but little progress was made until the 1950s. As endodontic therapy became a routine part of dental practice, the increase in functional but un-esthetic teeth prompted dentists to search for newer tooth-whitening techniques. In 1958 Pearson reported on the use of Superoxol sealed within the pulp chamber. He stated that within 3 days the oxygen-releasing capacity of the solution had whitened the experimental teeth to some degree.

By 1967 Nutting and Poe had refined this method, a technique now known as "walking bleaching." A 30% mixture of Superoxol and sodium perborate was left in the pulp chamber for up to 1 week. This technique provided a dependable treatment modality for tooth bleaching, but its use was obviously limited to endodontically treated teeth. This technique was for several years the most dependable system available but was often associated with internal absorption of the tooth structure some years later. It is no longer used extensively. Far-fetched as it may now seem, before the new vital tooth–whitening procedures, some dentists actually recommended the removal of healthy pulp tissue for the sole purpose of introducing bleaching solutions inside the chamber of severely discolored teeth.

It is only in the last two decades that dentistry has finally begun to provide patients with reasonable methods for vital tooth color de-staining. In 1989 a new procedure was developed (Figure 14-2) whereby a stabilized solution of carbamide peroxide or perhydrol-urea was placed into a custom molded tray, which the patient was required to place over the teeth for hours at a time. This gentle solution worked to gradually whiten the teeth in a much more predictable, safer manner than the earlier bleaching methods.

As the dental awareness of the population has increased, the most common esthetic complaint has been a generalized tooth discoloration or darkness visible when the patient smiles. Today the anterior teeth are nearly always vital. The desired whitening change is often a moderate modification such as lessening the yellow or gray component of the overall color scheme of the teeth. Given that the teeth are vital and therefore more likely to be sensitized by aggressive treatment, and that the desired color change is not a radical one, there is no need to use the caustic materials and extensive procedures that were associated with earlier bleaching techniques.

Safe vital whitening requires an activating material that is acceptable to both the hard and soft tissues, one that is both non-caustic and non-toxic. Feinman, in discussing peroxide-heat-light bleaching procedures, stated that bleaching vital teeth was more difficult than treating non-vital ones. With the more recent, less caustic tooth whitening techniques, precisely the opposite is now true. It is not only much easier to whiten vital teeth than non-vital ones, it is even easier to whiten the entire arch than to work with a single discolored tooth. This paradigm shift alone may account for the immediate acceptance of at-home tooth whitening by the dental community (Box 14-1).

The historical background of in-office tooth whitening is rather extensive. Whereas historically tooth whitening was first tried about 150 years ago, the materials were very toxic, caustic, and not always effective. In the early 1990s the innovative techniques of at-home bleaching created a demand for a more accelerated in-office procedure. Not all patients were content to wait the weeks required with at-home or tray-mediated bleaching.

The innovations attempted by dentists and manufacturers were usually designed to increase the percentage of the active ingredient, either carbamide peroxide or hydrogen peroxide, in the bleaching gel. The typical 10% carbamide peroxide used in

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BOX 14.1 Tooth Whitening Timeline

Initial Attempts at Bleaching

1877 Chapple—oxalic acid
1888 Taft—calcium hypochlorite
1884 Harlan—hydrogen dioxide
1895 Electrical currents

Non-Vital Bleaching Initiated

1895 Garretson
1911 Rosenthal—ultraviolet waves
1916 Kane—18% hydrochloric acid

Modern Bleaching Techniques Begin

1918 Abbot—Superoxol and heat

Successful Non-Vital Bleaching

1958 Pearson—intrapulpal bleach
1967 Nutting and Poe—walking bleach
1978 Superoxol heat and light

Modern Techniques

1989 Munro—outpatient tooth whitening
1990s General use—in-office vital bleaching
1995 Yarborough—laser-assisted beaching

early products was increased to about 35% carbamide peroxide (Lumibrite, Den-Mat, Santa Maria California). The carbamide peroxide was applied for short periods of time in a tray. This material was somewhat caustic to the gingiva but performed effective bleaching of tooth structures. However, materials with an anhydrous formula tended to suck moisture out of the tooth structures, causing both treatment and post-treatment sensitivity, which could be significantly uncomfortableat times.

The percentage of hydrogen peroxide in gel or liquid form was also increased. The problem with this innovation was that hydrogen peroxide, even in low concentrations such as 10%, can be quite caustic to the soft tissues. Although it does not appreciably affect the hard tissues, it can create peroxide burns on the gingiva or papillae and nearby oral soft tissues. Thus, application of higher percentage peroxides, up to 35% or 50%, required an effective paint-on rubber dam barrier to protect the gingiva and the oral tissues. Regular rubber dams allowed liquid peroxides to seep between the teeth and the dam and burn the peridental soft tissues. Protective gels were often applied to the soft tissues as well, but some of the higher-concentration peroxides still managed to cause damage. The paint-on rubber dams (Figure 14-3) (Pulpdent Kool-Dam paint-on dam) offered protection for the lips, cheeks, and face.

RELATING FUNCTION TO ESTHETICS

Because tooth bleaching does not affect the structural integrity of the dentition, there is no relationship of tooth function and de-coloration. Both staining and de-staining affect only the



FIGURE 14-3 Paint-on rubber dam isolation techniques offer gingival protection to the soft tissues during the in-office bleaching process (Pictured: Kool-Dam, Pulpdent Corporation, Watertown, Massachusetts.)

appearance of the surface enamel and dentin layers through the deposition or elimination of chromogenic molecules. These stains do not affect the interocclusal or interproximal relationships of the dentition. Thus there need be no concern about altering these relationships during the bleaching procedure.

In general, tooth de-coloration should be undertaken *before* restorative treatment, but not for functional reasons. It makes sense to establish the baseline coloration of the overall dentition so that all restorative efforts can be directed toward a definitive goal. Thus, in the esthetic algorithm, the bleaching process is often the first to be undertaken and completed. Coincidentally, this conforms to the patients' goals as well.

CLINICAL CONSIDERATIONS

In-office bleaching is useful in the removal of stains throughout the arch (e.g., age, diet or tetracycline staining), for lightening a single tooth in an arch (e.g., post-endodontically), or perhaps even for treating specific areas of a single tooth (e.g., as in some types of fluorosis). The dentist is in complete control of the process throughout treatment. This provides the advantage of being able to continue treatment or to terminate the de-staining process at any time. In-office bleaching is usually so rapid that visible results are observed after even a single visit. As patients become visually motivated at the first appointment, they tend to be more compliant for the second and third appointments that are often required to complete the in-office treatment process. Many patients prefer bleaching by the dental professional (rather than utilizing at-home techniques) because it requires less active participation on their part. In order to best serve their patients, dentists should ideally be familiar with both at-home and in-office treatment modalities. It is not uncommon to combine both techniques for a customized whitening treatment of a single patient. In this way the patient sees immediate results and is encouraged to continue the treatment both at

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home and in the office. By the combination of these two techniques, the whitening process is continued between the office bleaching sessions, and thus the final result is achieved more rapidly than if either technique were to be used alone.

Indications

The only necessary indication for tooth whitening is the patient's desire for whiter teeth. The choice of whitening technique depends on the specific cause of the discoloration; for instance, non-vital bleaching techniques should be used only for non-vital teeth. Bleaching techniques are use to treat some or all of the following:

- Developmental or acquired stains
- Stains in enamel and dentin
- Yellow-brown stains
- Age-yellowed smiles
- White or brown fluorosis
- Mild to moderate tetracycline stains

Contraindications

There are few contraindications for tooth whitening or bleaching. Of course, any patient who is allergic or sensitive to any of the bleaching components or materials should not attempt the treatment. Allergies of this type are virtually nonexistent.

Women who are pregnant or nursing should also not undergo tooth bleaching. Although there are no reports of problems with this population group, it is simply safer not to begin or continue cosmetic procedures whose effects may, under certain specific conditions, be deleterious to the fetus or newborn. Again, there is no evidence that such effects have ever occurred, but safe is better than sorry.

Vital tooth bleaching techniques, whether performed at home or in office, should be avoided for teeth with large pulp chambers or those that have exhibited sensitivity. In fact, all patients who complain of tooth sensitivity should have this problem solved before commencing tooth de-staining.

Patients with erosions, whether chemical, abrasive, or caused by recession, may experience more bleaching sensitivity through and after treatment, and thus these erosions should be treated before treatment. The same treatment approach should be followed for those with abfractions.

Factors that can limit the success of bleaching are the degree and quality of the discoloration. If the teeth are extremely dark, no matter what the cause, the whitening procedures may require supplementation with other restorative procedures, such as porcelain veneers. This is particularly true with stains in the gray-blue range, which do not respond as well to whitening as stains in the yellow-brown range.

Differentiating Stains

Differentiating the quality and cause of stains is of more than merely academic interest. Knowing what caused the dental staining allows the dentist to better plan the whitening technique and to provide a more accurate prediction of the outcome. Staining and discoloration of the teeth can be caused by many factors.

BOX 14.2 Tooth Stains

Extrinsic Stains
Tobacco
Foods and beverages
Medications

Intrinsic Stains
Pre-Eruptively Caused Discolorations
Alkaptonuria
Amelogenesis imperfecta
Dentinogenesis imperfecta
Endemic fluorosis
Erythroblastosis fetalis
Porphyria
Sickle cell anemia
Thalassemia
Tetracycline staining
Post-Eruptively Caused Discolorations
Age
Dental metals
Foods, beverages, and habits such as smoking
Idiopathic pulpal recession
Non-alloy dental material
Traumatic injury

Traditionally, tooth discolorations are divided into *extrinsic* and *intrinsic* categories (Box 14-2).

Extrinsic Stains

Long-chain polysaccharides and proteinaceous materials create a tenacious coating on the exposed surface of teeth called the *pellicle.* The pellicle is easily stained, with the most severe stains occurring at the gingival margin and in the interproximal areas, which are less accessible to toothbrushing. The pellicle can display many colors, ranging from white to red to brown to green, and can become extremely opaque, depending on the pigmentation source.

Extrinsic stains are routinely removed during standard prophylaxis. Patients can remove this layer daily during brushing. Effective oral hygiene instruction can help them to achieve maximum results. Occasionally patients must use toothpastes with a relatively high index of abrasion or even a medium- to hard-bristled toothbrush. Usually, simple persistence with a soft brush and low-abrasive toothpaste is sufficient.

Intrinsic Stains

Intrinsic stains are the result of color changes in the internal structures of the teeth caused by factors that are may be systemic or local in origin. Not only are intrinsic stains more difficult to treat than extrinsic stains, but because of their distribution throughout the tooth, they are more readily apparent. With modern tooth-whitening procedures, most intrinsic stains can be removed. Those difficult situations that do not respond to

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tooth-whitening procedures can be esthetically improved using composite or porcelain veneers, porcelain crowns.

Intrinsic stains can be divided into those arising during odontogenesis and those occurring after tooth eruption. The difficulties in removing stains and the expected degree of success depend on the type of discoloration being addressed. During odontogenesis, teeth may incorporate discolorations into the enamel or dentin through quantitative or qualitative changes or by the inclusion of pigments to their structure. Post-eruptively, teeth can become intrinsically discolored when discoloring agents are integrated into the hard tissues internally from the pulp chamber or extrinsically from the tooth surface.

Intrinsic Discolorations Created during Odontogenesis

Alkaptonuria is a recessive genetic deficiency resulting in the incomplete oxidation of tyrosine and phenylalanine, causing increased levels of homogentisic (or melanic) acid. It is also known as *phenylketonuria* and *ochronosis.* The condition can cause a dark brown pigmentation of the permanent teeth. Tooth whitening can lessen or even eliminate the discoloration. In severe cases the teeth may require restorative esthetic procedures to achieve acceptable results.

Amelogenesis imperfecta (Figure 14-4) is considered a genetic defect that can affect both the primary and the permanent dentitions. The most common modes of inheritance are either autosomal recessive or autosomal dominant. Three categories have been identified: hypomaturation, hypocalcific, and hypoplastic. These display considerable differences in appearance both within and among groups. Hypomaturation has an autosomal dominant mode of inheritance, and presents as enamel that has chipped away from the underlying dentin. Hypocalcific cases exhibit enamel that has normal thickness but is soft. The enamel is often completely abraded away soon after eruption. The tooth crown ranges in appearance from a dull opaque white to a dark brown. These teeth are also have a rough and pitted surface. Hypoplastic teeth have enamel that is quite thin, often to the point where interproximal contacts are eliminateed. Hypoplastic teeth have a smooth, hard, yellow appearance, with pitting found on occasion.

The treatment of amelogenesis imperfecta depends on the condition of the enamel. If the enamel is sufficiently thick, the teeth are aggressively treated with topical fluoride, after which direct bonding procedures may be appropriate; the more predictable treatment, however, is providing full prosthetic coverage for the affected teeth; insufficient tooth thickness or abraded enamel are indications for full prosthetic coverage.

Dentinogenesis imperfecta (Figure 14-5) is an inherited trait that is the most prevalent hereditary dystrophy affecting tooth structure. Typically seen more severely in the primary dentition, the clinical crowns appear reddish-brown to gray opalescent. The enamel is often friable and breaks off soon after eruption. The exposed softened dentin rapidly abrades away. The thin or nonexistent enamel makes full prosthetic coverage the only viable treatment option. Vital bleaching is contraindicated.

Endemic fluorosis (Figure 14-6) is an enamel discoloration caused by excessive intake of fluoride during odontogenesis.



FIGURE 14-4 Amelogenesis imperfecta, hypocalcified type. *(From Pinkham J, Casamassimo P, Fields H, et al:* Pediatric dentistry: infancy through adolescence, *ed 4, St Louis, 2006, Mosby.)*

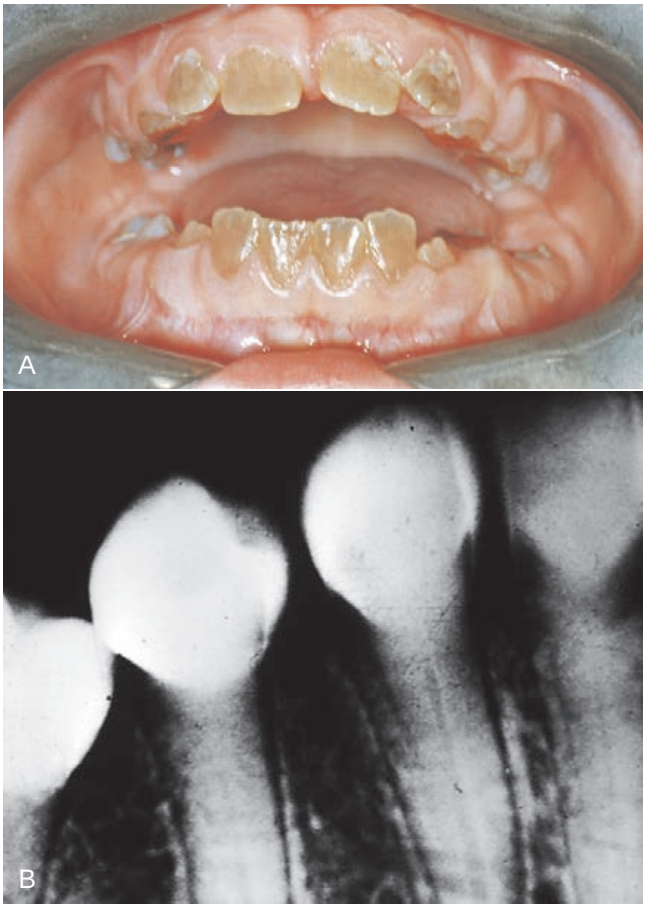


FIGURE 14-5 (A) Clinical and (B) radiographic appearance of dentinogenesis imperfecta. *(From Ibsen O, Phelan J:* Oral pathology for the dental hygienist, *ed 5, St Louis, 2009, Saunders.)*

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FIGURE 14-6 Fluorosis. A, Mild form of fluoride mottling, exhibiting white opaque flecks near the incisal edges with the surface remaining smooth and intact. B, Moderate form of fluoride mottling with ridges of hypoplasia and white and brownish enamel. C, Severe form of fluoride-induced hypoplasia and discoloration with associated cracking and chipping of the enamel. *(From Sapp JP, Eversole L, Wysocki G:* Contemporary oral and maxillofacial pathology, *ed 2, St Louis, 2004, Mosby.)*

Fluorosed teeth range from slight wisps or flecks of opaque white to mottled or pitted darkened surfaces. The condition was described as early as 1916, although the causative agent was not identified until 1931. Black thought the stain was caused by replacement of the normal cementing substance between enamel rods by a material that he named "brownin." It is now known that dental fluorosis is a form of enamel hypoplasia, resulting from metabolic alteration of the ameloblast during enamel formation. Dental fluorosis is often found in communities where the fluoride content of the drinking water exceeds 1 part per million. The severity of the staining is directly proportional to the amount of fluoride absorbed. The teeth can be affected from the second trimester in utero through age 9 years.

Areas of the tooth that are darkened by endemic fluorosis respond to vital tooth-whitening procedures. If the stains are set deep into the tooth and are very opaque, however, only limited success can be achieved. In these cases, tooth-whitening procedures should be followed by bonded porcelain or composite. Teeth that exhibit white areas cannot be darkened by the tooth-whitening process. For superficial areas, enamel abrasion (although it is invasive of tooth structure) can be used. If the tooth has both dark and opaque white areas, the treatment of choice is abrasion of the areas where the stain is superficial, followed by tooth-whitening procedures. If the improvement is not sufficient, conservative bonding procedures are indicated.

Erythroblastosis fetalis is a blood disorder of the neonate caused by Rh incompatibility between the fetal and maternal blood supplies. It is characterized by agglutination and hemolysis of the erythrocytes, producing free blood pigments. These can discolor all the teeth that are in the process of being concurrently formed. Affected teeth can range in color from brown to green-blue. This condition is usually self-treating, and the staining resolves as the child matures. Treatment is usually not needed.

Porphyria (Figure 14-7) is a porphyrin metabolism disorder that results in increased formation and excretion of porphyrins. It is usually genetically transmitted and rare, but may develop later in life. Neurological, psychological, and gastrointestinal symptoms may present as well. The hematoporphyrin pigment causes a characteristic reddish-brown discoloration of the teeth (erythrodontia). The dental effects are more common in the primary than the permanent dentition. Coloration is dispersed throughout the enamel, dentin, and cementum, and fluoresces under ultraviolet light. Tooth whitening, and possibly bonding, can be effective.

Sickle cell anemia and *thalassemia* are both inherited blood dyscrasias that result in tooth discoloration similar to that caused

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FIGURE 14-7 Congenital erythropoietic porphyria. Brownish teeth fluoresce under Wood lamp examination. *(From Kliegman R, Behrman R, Jenson H, Stanton B:* Nelson textbook of pediatrics, *ed 18, St Louis, 2008, Saunders.)*



FIGURE 14-8 Teeth stained as a result of tetracycline administration. This is an extreme example of tetracycline staining: the entire enamel (and dentin) has become pigmented. As the staining is built into the structure of the tooth, bleaching procedures do not usually greatly improve the appearance of these teeth. Crowns or, more conservatively, veneers will do so. *(From Berkovitz BKB, Holland GR, Maxham BJ:* Oral anatomy, histology, and embryology, *ed 4, St Louis, 2010, Mosby.) (Courtesy Dr. M. Ignelz.)*

by erythroblastosis fetalis. Unfortunately, unlike erythroblastosis fetalis, these discolorations are more severe and do not improve with time. Tooth whitening plus bonding procedures can be effective for the more difficult cases.

The potential for *tetracycline* to cause discoloration (Figure 14-8) of the dentition is well documented and studied since it was first reported by Schwachman and Schuster in 1956. Because tetracycline can cross the placental barrier, tetracycline affects both the deciduous and permanent dentitions, making the teeth vulnerable throughout odontogenesis. Even an exposure as short as 3 days can cause discoloration of the teeth at any time between 4 months in utero and age 9 years. The mechanism of the staining caused by tetracyclines is related to the calcium binding in the tooth. Tetracycline binds to the tooth calcium, forming a tetracycline–calcium phosphate complex. It occurs throughout the tooth but is most highly concentrated in the dentin near the dentino-enamel junction. Both the quality and the severity of the discoloration are directly related to the specific tetracycline ingested as well as the dose. Some early investigations revealed that teeth affected by tetracycline first exhibit a yellow coloration and a bright yellow fluorescence that differs significantly from the blue fluorescence of normal, healthy teeth. The color of the affected teeth gradually changes over the succeeding months or years. The shade change is most noticeable in those teeth that are most exposed to extraoral light—specifically, the facial surfaces of the anterior teeth. Wallman and Hilton clearly demonstrated the role of light in this process in 1962 by splitting a tetracycline-stained tooth lengthwise and exposing only one half to light. The light-exposed half underwent a color change to brown, whereas the unexposed half remained yellow. For this reason many researchers believe that the use of heat and light bleaching systems to treat tetracycline stains may be contraindicated.

Clinically, tetracycline-stained teeth can exhibit light-yellow to dark-gray bands. These bands may correspond to the active area of tooth formation at the specific time that the tetracycline exposure occurred. Usually the darker shades are confined to the gingival third of the teeth, but the lighter, hay-colored shades are most often located in the incisal third. Standard tooth whitening can be expected to improve the appearance, although the results are less than ideal. The differentiation between the light and dark tooth areas is usually diminished by the whitening process. On some teeth, selectively etching the darker enamel areas prior to whitening can further improve the result. Bonding is usually required in more darkly stained teeth to achieve an acceptable result, although the degree of improvement from vital tooth whitening alone can be profound. Because the differentiation between the lighter and darker areas becomes less distinct, many patients are satisfied and content to defer bonding. Teeth with a yellow or brown discoloration generally whiten more completely than those with a gray or blue stains.

Post-Eruptive Discoloration

Age can be a cause of discoloration. Several non-pathologic conditions related to the aging process gradually discolor the teeth. The natural process of gradual pulp withdrawal with the simultaneous formation of secondary dentin causes the tooth to appear more yellowish-brown. This is perhaps the most common indication for tooth whitening. The results are the most rapid and predictable. Standard vital tooth whitening treatment options are applicable.

Dental metals are the most ubiquitous source of staining—specifically, leeching of amalgam corrosion products (Figure 14-9). Threaded stainless steel pins or gold-plated retentive pins can cause similar extremely dark stains that pose significant challenges for any whitening effort.

Teeth that are stained by dental alloys or pins must first have the offending dental metals replaced by composite or porcelain restorations. If the stain is very dark, the whitening prognosis is

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FIGURE 14-9 Extrinsic metallic stain. *(From Daniel S, Harfst S, Wilder R:* Mosby's dental hygiene, *ed 2, St Louis, 2008, Mosby.)*



FIGURE 14-10 Custom-fabricated bleaching tray for at-home whitening procedure.

not good. Adhesive restorative procedures are required for clinically acceptable results.

Some of the most common staining agents are *foods and beverages,* such as tea, coffee, and soft drinks and *lifestyle choice* substances such as smoking and chewing tobacco. The degree and quality of staining directly reflect the type, frequency, length, and intensity of exposure to the staining agents. Fortunately, tooth whitening prognosis excels with these stain categories. The standard techniques can be expected to produce rapid, dramatic results in most cases.

Idiopathic pulpal recession sometimes occurs in teeth. The teeth remain vital but gradually display a yellow to brown darkening. The appearance is often similar to that of a non-vital tooth; vitality testing differentiates the two. Such teeth usually typically exhibit a diminished pulp chamber diameter on radiographic examination. Standard tooth-whitening procedures are indicated if the desired result is an overall whitening of all the teeth. This procedure effectively removes the discoloration of the tooth with idiopathic pulpal recession and usually whitens all the neighboring teeth as well. The discolored teeth typically destain more rapidly than the other teeth, resulting in a better blending and better matching of the shades of adjacent teeth. The patient thereby eliminates the problem of a single darker non-matching tooth, and whitens all the others in the arch through the course of treatment. Where there are porcelain crowns that match the existing general shade, this approach is not desirable, as ceramic restorations are *not* made whiter by bleaching. An alternative in this situation is to mask the discoloration with composite.

Many of the materials used routinely in dentistry have the potential to cause tooth discoloration. *Non-alloy dental materials* such as eugenol, formocresol, and root canal sealers are implicated in a wide range of tooth discolorations. The prescribed treatment is the same as for dental alloy stains. If the tooth is vital, standard vital tooth whitening is usually effective. The most common complication is that the stain may be very specifically localized. The selected destaining procedure is determined in the same fashion as for idiopathic pulpal recession stains. If the tooth is non-vital, standard non-vital bleaching can be used. Occasionally the stains are so dark and resistant to whitening that additional adhesive restorative dentistry is indicated.

Traumatic injury to the tooth may result in an internal hemorrhage. The ensuing diffusion of bilirubin into the dentin tubules causes an initial pink discoloration that is usually develops over time to a darker, diffuse red-brown stain.

If the pulp is sufficiently resilient to avoid necrotic degeneration, the crown's natural color returns within a few weeks after injury. If the pulp degenerates, the natural color does not return and the discoloration becomes darker. In some cases, a growing pink spot on the enamel surface indicates progressive internal resorption.

Tooth whitening treatment should not be instituted until the dentist is certain that the tooth has fully recovered from the trauma. Sometimes the natural color returns without intervention. In cases with residual staining, the tooth is tested for vitality and radiographed. If the tooth is vital with no evidence of internal or external resorption, tooth-whitening procedures can be initiated. If the tooth is non-vital, endodontic therapy is followed by non-vital bleaching. If there is internal resorption in a vital tooth, endodontic therapy is indicated, then non-vital bleaching.

MATERIAL OPTIONS

The material options for at-home bleaching include bleaching trays. In most cases a custom-made tray is fabricated by the dental office or laboratory and given to the patient (Figure 14-10). The patient injects the bleaching agent into the tray during the day, overnight, or both, and inserts the tray over the teeth; treatment for an entire arch (or both arches) typically requires about 2 to

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FIGURE 14-11 Tray-less at home whitening systems have an inner soft tray containing the bleaching material and a harder outer tray used to position the soft tray over the teeth. (Pictured: Opalescence Trèswhite Supreme *([courtesy Ultradent Products, Inc., South Jordan, Utah].)*



FIGURE 14-13 Bleaching strips are worn for about 30 minutes per application.



FIGURE 14-12 Bleaching strips are placed over the teeth and adapted to the teeth with the patient's fingers.

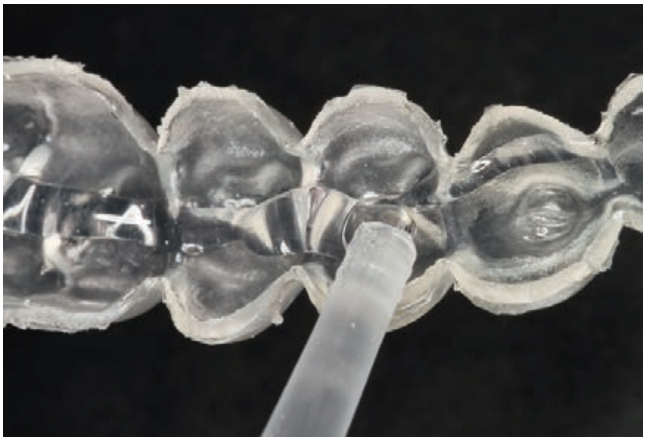


FIGURE 14-14 Custom trays provide predictable volume of bleach application to the teeth.

4 weeks. At-home tray-less techniques are similar; no prefabricated or custom-fabricated trays are needed. Double-tray systems, such as Opalescence Trèswhite Supreme (Ultradent Products, Inc., South Jordan, Utah), have an inner, softer tray pre-loaded with the bleaching gel and an outer harder tray that is used to position the entire system over the teeth (Figure 14-11). This technique does not require the in-office fabrication of a tray and thus offers time advantages for most practices. Bleaching strips without trays, such as Crest 3D White Whitestrips (Procter & Gamble, Cincinnati, Ohio), are placed over the teeth and manually adapted to the tooth anatomy (Figure 14-12). The patient pats the strips onto the tooth surfaces and leaves them in place for about 30 minutes per application (Figure 14-13).

Tray Bleaching Systems

Advantages of the tray system include the predictable volume (Figure 14-14) of the bleach applied to the teeth and the ability to effectively spread the bleach to every tooth, covering their occlusal, buccal, lingual and interproximal aspects as well. The tray can be comfortably worn for several hours to overnight, even though the efficacy of the bleaching gel decreases progressively and the material becomes inactive for bleaching after 3 to 4 hours. Most of the bleaching effect occurs in the first 30 to 60 minutes. Reservoirs can be built into the internal surface of the tray (Figure 14-15) on the buccals of some or all of the teeth to increase the speed of the bleaching by leaving more carbamide peroxide in contact with the dental surfaces. The tray is generally quite thin and is made of transparent material so it can be worn during the day, even during work (Figure 14-16).

Disadvantages of the tray system include the need to acquire an impression (Figure 14-17) of the dentition prior to tray fabrication. This impression is then poured in stone, and a tray is fabricated with a heat and suck-down tray-former such as the UltraVac Vacuum Former (Figure 14-18) (Ultradent Products, Inc.). This device is relatively easy to operate but does require some chairside and in-office laboratory time. Typically tray fabrication in the dental office can be delegated to an auxiliary who will complete the task in 30 to 60 minutes. Since the bleaching treatment is often an impulse decision for the

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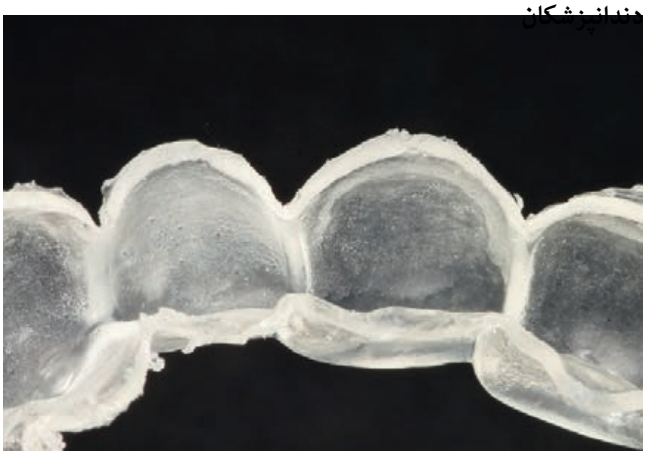


FIGURE 14-15 Reservoirs built into the custom tray increases the speed of bleaching by allowing more carbamide peroxide to be in contact with the tooth surface.



FIGURE 14-16 Custom trays are thin and transparent, allowing the patient the convenience of bleaching the teeth anywhere and anytime.

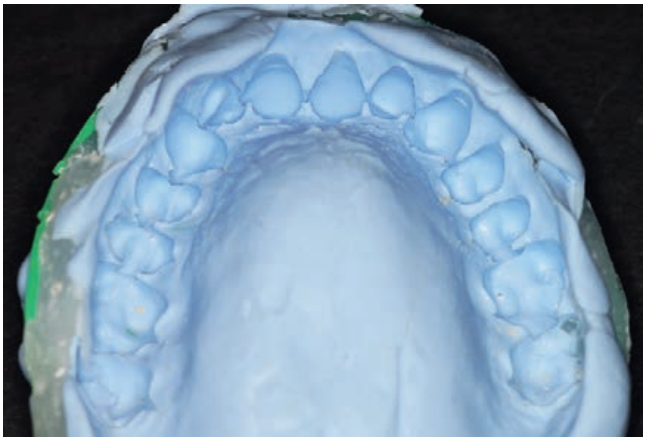


FIGURE 14-17 A disadvantage of the custom bleaching tray is the requirement for an impression.



FIGURE 14-18 Custom bleaching trays are formed using a vacuum former.



FIGURE 14-19 Scissor trimming of the custom bleaching tray.

patient, it is typically unplanned. As a direct result, tray fabrication can contribute to scheduling problems. However, it is important once the patient decides to have their teeth bleached to begin treatment as soon as possible, thus taking advantage of the patient's active, but possibly fleeting, interest in the color of their dentition. Furthermore, most auxiliaries are not particularly fond of trimming the bleaching trays (Figures 14-19 and 14-20), which should terminate just shy of the gingival margin of the soft tissues. Generally it is a good idea to not have the bleaching tray impinge on the soft tissues (Figure 14-21), as this may cause gingival irritation and patient discomfort. The tissues must be approached as closely as possible (Figure 14-22) to maximize the whitening effect and to minimize treatment time.

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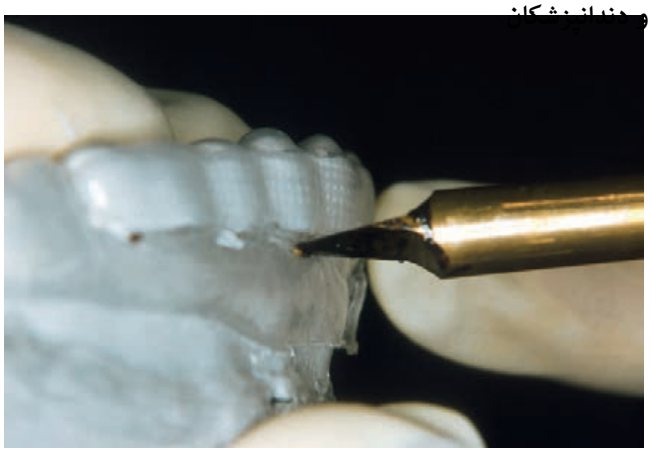


FIGURE 14-20 Custom bleaching trays should be trimmed just shy of the gingival margin of the soft tissues.



FIGURE 14-23 The soft tray material in the tray-less bleaching systems may slip off sooner than desired.



FIGURE 14-21 Custom trays should not impinge on the soft tissues, as this will cause gingival irritation and patient discomfort.



FIGURE 14-24 The tray-less bleaching system in place.



FIGURE 14-22 The custom tray should approach the soft tissues as closely as possible without actually making contact to minimize the treatment time.

Customizing the margins to adapt them to the dentition takes several minutes and can be exacting, even with the proper scissors.

Prefabricated Tray and Tray-less Bleaching Systems

The major advantage of the at-home prefabricated tray system is that no bleaching tray need be fabricated in the office. The only real caveat is that the patient must be thoroughly instructed in the use of the prefabricated tray bleaching process. He or she must fully understand how to properly insert the pre-loaded trays on their dentition.

Disadvantages include: the inner, soft tray material (Figures 14-23 and 14-24) that is adapted to the teeth can slip off sooner than desired, leaving the teeth less bleached than anticipated.

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FIGURE 14-25 Strip systems cover cuspid to cuspid but not much beyond these teeth.

Most patients lose comfort (and patience) with the bleaching material on their teeth after about 20 or 30 minutes, and sometimes even less. The soft tray is very easy to remove. Thus compliance with the prefabricated tray system is not as predictable as with the custom-fabricated tray systems.

Advantages of the Crest 3D White Whitestrips tray-less system are ease of application, reduced expense, and less labor compared with the tray systems. The only clinical time requirement is that set aside for the patient instruction to properly use the material and place the strips over the teeth. Disadvantages include that the strips tend to slip off (or are removed by patients) somewhat sooner than desirable. It is relatively easy to slip the strips off the teeth with the tongue or fingers. Neither the at-home prefabricated tray, nor the strip systems have as much patient compliance as the custom-fabricated tray system. However, the strip systems are very easy to use and rather inexpensive.

Strip systems can be limited by their overall length; they cover the teeth cuspid to cuspid but not much beyond these teeth (Figure 14-25). Once strip bleaching is completed, the cuspids or first bicuspids will be whitened but the molars will remain more or less at their original color. If these teeth are visible on the smile, supplemental tooth whitening treatment is necessary.

AT-HOME BLEACHING CONSIDERATIONS

The Safety of Tooth Whitening

The dentist's primary concern for any dental procedure must be its safety. The entire dental team must have absolute confidence in, and comfort with, the dental treatments that are recommended to patients. Safety is typically established by one of two well established mechanisms:

1. A new product can be tested on animals in order to predict its toxicity in humans
2. The performance record of the product or a material that has previously been used for human treatment can be examined for deleterious side effects.

As was to be expected, concerns were raised regarding the safety implications of vital tooth whitening when the technique was first introduced. These issues were largely related to the use of carbamide peroxide (a buffered hydrogen peroxide solution or gel) in the oral environment. (The terms *carbamide peroxide, urea peroxide,* and *perhydrol urea* are often used interchangeably.) The typical worries centered on whether carbamide peroxide might be toxic, dangerous, or oncogenic in the short and long terms. These apprehensions were simply the evidence-based inquiries of a responsible profession, as no scientific evidence had been advanced to support these positions. Some of the initial commentaries also asserted that dentistry had little experience with this particular chemistry.

This was not entirely true; although the profession had little direct experience with carbamide peroxide for tooth-whitening purposes, there was a scientific record of the intra-oral use of carbamide peroxide for other purposes that spanned 50 years. The recorded scientific data include both animal and human studies, short and long term, that have evaluated the issue of this material's safety in the oral cavity.

The testing revealed that carbamide peroxide not only promotes gingival healing but is actively anti-plaque in nature and may be anti-cariogenic, as well. The focus of the carbamide peroxide testing in past years was to evaluate it as an antiseptic (not as a tooth-whitening agent), but the intra-oral conditions under which the tests were conducted were identical to those associated with whitening procedures.

Carbamide peroxide is not a substance that is new to dentistry, nor was its development for dental purposes accidental. Aqueous hydrogen peroxide has long been used by the dental (and medical) profession; its lack of toxicity and minimal side effects, combined with both cleansing and bactericidal properties, make it particularly attractive for intra-oral use. A major practical problem with hydrogen peroxide is its extremely rapid breakdown on contact with body tissues, a reaction that is greatly accelerated by peroxidase and catalase enzymes, which are commonly found in the mouth and the body. Foaming (Figure 14-26) is often observed at the initial application (or re-application) of hydrogen peroxide whitening agents. This is an oxygenated foam that demonstrates the catalysis of the peroxide. A 10% preparation of carbamide peroxide in anhydrous glycerin is equivalent in chemical activity to 3% aqueous hydrogen peroxide, yet far more stable and predictable.

The search for effective clinical materials led to the investigation of more stable and longer acting peroxides. It was found that carbamide peroxide has a much slower rate of reaction and oxygen release at tissue surfaces, particularly at oral and room temperatures (hydrogen peroxide in warm concentrated solutions lacks stability). In fact, carbamide peroxide was found to still be active after 20 minutes of body tissue contact. When the peroxide is held adjacent to intra-oral surfaces by a glycerin or Carbopol solution, the effective reaction time is significantly prolonged.

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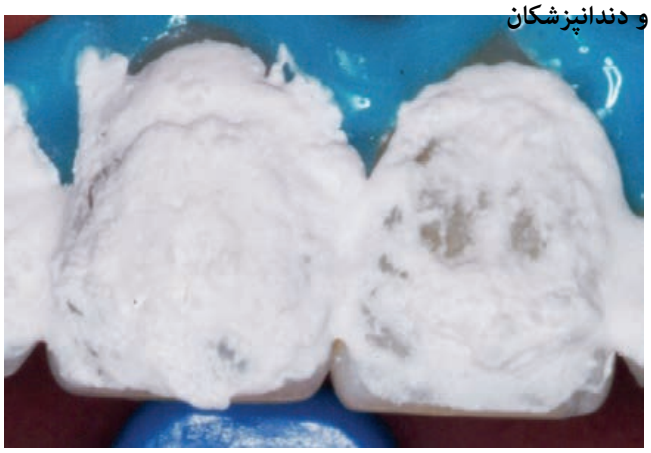


FIGURE 14-26 **Foaming is often observed with the application of hydrogen peroxide whitening agents. This oxygenated foam demonstrates the catalysis of the peroxide.**

Ambrose reported favorably on the use of carbamide peroxide in the cleansing of tooth surfaces prepared for restorations. Arnim recorded the improvement in plaque control provided by carbamide peroxide in anhydrous glycerol in the absence of any other means of hygiene. Just four minutes of rinsing per day provided significant plaque reduction with no negative side effects reported.

Manhold compared four oxygenating agents, all available commercially, for their effects on wounded rat tissues. All the oxygenating agents helped to promote faster healing than would have been expected, and carbamide peroxide provided the fastest and most complete therapy. Another rat study in 1982 determined that the anti-cariogenic effectiveness of the oxygenating topical agents was related to their ability to release active oxygen rather than their ability to neutralize plaque acid. Carbamide peroxide was found to be highly effective in reducing plaque accumulation and caries incidence. Carbamide peroxide has even been tested with neonates to treat oral candidiasis. It was found to be very effective and without any adverse effects.

The following studies demonstrate the safety of extended experimental oral contact with carbamide peroxide. This allows the dentist to calibrate the recommended time parameters for the comprehensive home whitening procedure. Currently available at-home bleaching techniques require 20 to 200 hours of oral exposure over a period of several weeks.

Williams advocated the use of carbamide peroxide to combat pharyngeal and throat infections. The total contact time over 1 week was about 10 hours, and to ensure that the test material was adequately distributed throughout the infected areas, patients were instructed to swallow it after gargling. It was observed that any minimal side effects were transitory, that the treatment was analgesic, and that tissue irritation was reduced. The clinical effectiveness of carbamide peroxide in reducing dental plaque and gingival inflammation with institutionalized patients was observed by Zinner. The total treatment time was 15 hours over 4 weeks. No side effects were reported. To evaluate an effective oral hygiene supplement for the severely handicapped, carbamide peroxide was used as a rinse five times per day for 3 weeks. Even when the formula was used at twice the recommended dosage and frequency, no irritation or inflammation were produced in the subjects.

Fogel and Magill conducted research with orthodontic patients. Carbamide peroxide in anhydrous glycerol was applied orally to prevent caries development. Seventy full-banding patients participated in this study for 2 to 3 years. Four daily applications and no rinsing afterward provided an effective tissue-contact time of up to 2 hours per day or 1500 to 2300 hours total exposure over the entire orthodontic treatment study. The results were positively anti-cariogenic, and there were no reported side effects.

Shipman investigated the effects of an 11% carbamide peroxide gel on the gingiva over a period of 1 month (11 hours of tissue contact time) and pronounced the material safe. In 1976, it was suggested that carbamide peroxide should be considered as a routine oral hygiene adjunct. In another study, sixty orthodontic patients rinsed with carbamide peroxide over a period of 3 months (90 hours of tissue exposure). Significant plaque reductions were observed, and no adverse reactions noted.

The studies just listed, and many others that have reached similar conclusions, indicate the safety, local and systemic, of 10% to 15% carbamide peroxide in a carrier gel. Although at-home tooth whitening is a relatively novel dental service, the safety and efficacy of the various materials used in the procedure are well documented and well established. It is unlikely that any new treatment modality can be introduced with an established safety history, but at-home bleaching comes as close to that ideal as possible.

Long-Term Stability of Tooth Whitening

Tooth whitening begins to relapse at the very moment the active bleaching process is ended. It is quite obvious that certain deleterious habits such as smoking, excessive coffee, cola or tea, and chewing tobacco or betel nut paan may cause the teeth to discolor more rapidly and should be avoided. Normal dietary items can be equally guilty in the re-staining of the teeth, however. Blueberries, red wine, and beets, just as examples, can color teeth quite rapidly. In fact, most natural foods are somewhat pigmented, and many processed foods incorporate harmless dyes that can stain teeth. Fortunately, after an initial rapid color fallback, the progress of re-staining is rather slow. The positive color changes of tooth whitening are often still clearly visible (and measurable) 3 to 5 years after the original treatment.

An educated avoidance (or decreased consumption) of chromogenic foods, particularly during and immediately after tooth whitening, can delay the inevitable color relapse. A meticulous regimen of oral hygiene on the patient's part (Figure 14-27) also assists in maintaining the whiteness of the teeth for a longer period. Improved home care is often a noticeable and beneficial consequence of whitening procedures, as the patient becomes more personally aware of the benefits of a healthy smile.

Tooth whitening should be considered a cosmetic treatment that can provide a major appearance-related benefit to the patient, but one that is transient, much like a hair-dyeing

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FIGURE 14-27 **Meticulous home care assists in maintaining the whiteness of teeth (Pictured: Crest Pro Health Whitening Toothpaste).**



FIGURE 14-28 **Including a color check at routine checkups for patients with bleached teeth increases patient awareness.** *(Courtesy Vident, Brea, California.)*

treatment or a manicure. Because dental bleaching does not compromise the teeth or soft tissues, it can be repeated as necessary (in the patient's evaluation). Most manufacturers provide touch-up kits—scaled-down versions of the original whitening kits. The application of carbamide peroxide to teeth that have been previously treated is quite dramatic; the final bleached coloration can be re-achieved in a few hours or over a night or two.

Inserting a color "check" for patients with bleached teeth (Figure 14-28) as a part of the routine checkup makes these appointments more significant to the patient and increases recall cooperation. Most patients are far more interested in maintaining their appearance and smile than they are in undergoing caries diagnosis, gingival health evaluation, and the scaling of subgingival calculus. Thus the color check is often more successful in motivating patients to attend recare appointments on a regular basis. This serves the primary care dentist well in providing opportunities for regular cleaning, dental checkups and professional monitoring. Patients must also be informed that although their teeth are more esthetic, they are no more resistant to decay or periodontal problems than they were before whitening.

At-Home Innovative Elements

Scientific Elements

The underlying scientific innovation for at-home dental bleaching was the application re-orientation of a series of commonly used, proven-safe materials that had the ability to de-stain both vital and non-vital teeth. Fortuitously, there had been extensive research (and published documentation) of the use of these materials intra-orally for purposes other than tooth whitening. For example, carbamide peroxide rinses had been used for more than 50 years to decrease gingival inflammation. It had been noted that an unintended side effect of these rinses was that the teeth appeared to become whiter with continued use. Until Munro applied the same chemistry and an innovative application format to bleaching use, the potential value of these materials as tooth whiteners was not recognized. The availability of a safe, easy-to-use, and relatively predictable material that was capable of whitening the teeth made carbamide peroxide bleaching much more attractive and popular. In fact, there should be a warning on the label of each at-home bleaching kit that as an unintended side effect, gingival health will improve.

Rinsing with carbamide peroxide liquid *will* whiten teeth, but unfortunately the destaining process would be very slow and rather tedious. Most patients would lose interest in the process long before their teeth became visibly whiter.

Technologic Elements

Several technologic advances have had a great impact on the interest in at-home tooth whitening over the years. These were often minor procedural or product changes that, although not very dramatic on their own, made the patient use and the office delivery of at-home whitening more comfortable, more pleasant, and more practical.

One of the early problems with carbamide peroxide home bleaching was the flavor of the active ingredient. Carbamide peroxide is also known as *urea peroxide;* for obvious reasons, it does not have a particularly pleasant taste. The early at-home tooth-whitening products reflected the urea flavor, and many patients chose to not complete the recommended regimen. In the mid 1990s the introduction of a mint flavor into the bleaching gel (Figure 14-29) created an overnight boom in the popularity of at-home bleaching. Although the flavor tended to dissipate within a few minutes, the initial urea taste shock was absent, and patients were less likely to react negatively when the flavor turned less than minty.

The reservoir technique (Figure 14-30) was designed to deliver increased oxygen ion presence at the tooth surface. The patient's impression was poured with a fast-setting stone. Once the stone model was set and dry, a drop of colored resin was cured on the buccal surfaces of the teeth to be whitened. When

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FIGURE 14-29 The mid 1990s brought the introduction of mint-flavored bleaching gel. *(Pictured: NiteWhite, [Discus Dental, Culver City, California].)*

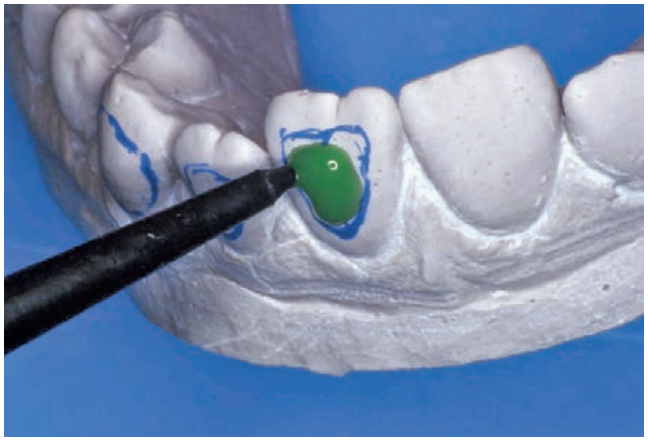


FIGURE 14-30 The reservoir technique was designed to increase the oxygen ion presence at the tooth surface.

the model was vacuum formed, the resin bubble left a small space, or reservoir for additional whitening material, immediately adjacent to the buccal surface of each tooth. The additional bleaching agent that was trapped in the reservoirs released more oxygen ions, whitening the teeth more quickly and more effectively.

The Bleaching Tray Lab Technique

It is first and foremost important to have the best impression possible. It is essential to have the ideal mix of water and stone in pouring the impression to create the model. The prescribed amount of water (as described in the manufacturer's instructions) is measured (Figure 14-31, *A*) and added into the mixing bowl first (Figure 14-31, *B*). This prevents caking of unwetted stone at the bottom of the mixing bowl. The stone powder is pre-measured as well, and added to the water in the bowl (Figure 14-31, *C*). The slurry is thoroughly mixed with a spatula to a smooth consistency (Figure 14-31, *D*) either manually or preferably on a mixing turntable. The height of the stone pour is marked on the impression (Figure 14-31, *E*). This height should be at least 3 or 4 mm beyond the gingival margins of every tooth that is to be included in the bleaching tray. The stone is vibrated into the impression beginning at the posterior of one side of the arch (Figure 14-31, *F*) and flowed consistently from there until it covers the entire arch up to the previously marked height line (Figure 14-31, *G*). The excess stone in the posterior is trimmed with a spatula (Figure 14-31, *H*), and the top of the stone is flattened (Figure 14-31, *I*). This surface will form the base of the model. For maxillary trays, the palate area is cleared (Figure 14-31, *J*). The use of a fast-set stone permits the modeling stone to be set for tray fabrication in a much shorter period of time (Figure 14-31, *K*). When the stone has hardened, the impression and the stone are wetted underwater (Figure 14-31, *L*) to make the separation of the stone from the impression easier (Figure 14-31, *M*). A cleoid-discoid or similar pointed instrument is used to accentuate the margins of the teeth both on the buccal and on the lingual (Figure 14-31, *N*). This creates a better seal at the margins to keep the bleach and released oxygen ions in close proximity to the tooth. The base of the stone model is trimmed and the flanges are removed to minimize the footprint of the stone arch model (Figure 14-31, *O*). This allows the vacuum former to work at its maximum efficiency. For the reservoir technique, a light-cured colored resin is placed on the buccal surface of the teeth to be bleached (Figure 14-31, *P*). The general parameters for the reservoir dictate that its margins should be located at least 1 mm from the incisal edge and the mesial, distal, and gingival margins so as not to interfere with retention and to maximize the tray's seal over the dentition. Generally all the teeth to be bleached should have reservoirs fabricated on the model (Figure 14-31, *Q*). The model is then placed on the suction surface of the vacuum former; the plastic tray material is secured in the upper armature close to the heating element (Figure 14-31, *R*). As the heating progresses, the plastic sags below the retention arm (Figure 14-31, *S*). The vacuum is turned on at the same time as the entire upper armature including the heated tray material is quickly brought down over the model (Figure 14-31, *T*). With the vacuum continuing to draw the plastic onto the model, the plastic is contoured and adapted onto the model with a wet gauze (Figure 14-31, *U*). It is possible to trim the tray material into the final intra-oral form with scissors, but it is much easier to accomplish this with a heated instrument (Trim-Rite electric knife). The heated knife is first used to separate the bulk of the tray plastic from the stone model well away from the marginal areas (Figure 14-31, *V*). This leaves an over-extended tray whose margins impinging on the mucosa could irritate the soft tissues if worn as is (Figure 14-31, *W*). Another cut is made right at the gingival margin to develop the anatomic margins of the bleaching tray (Figure 14-31, *X*). This leaves a tray that is well adapted and just shy of the gingival margins both at the buccal and the lingual over the entire arch (Figure 14-31, *Y*). The tray can then be removed from the stone model and tried in the patient's mouth (Figure 14-31, *Z*).

Most of the early carbamide peroxide products were supplied in an anhydrous gel. These gels, by their chemistry, tended to suck out water and moisture from the tooth surface, creating sensitivity during and after bleaching. The use of non-anhydrous gels in later bleaching products made the process much more

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FIGURE 14-31 **A,** The prescribed amount of water is measured. **B,** The pre-measured amount of water is added to the mixing bowl. **C,** The pre-measured amount of stone powder is added to the liquid. **D,** The slurry is mixed with a spatula to a smooth consistency. **E,** The desired height of the stone is marked on the impression. **F,** The stone slurry is vibrated into the impression beginning at the posterior. **G,** The stone is flowed in consistently until it reaches the previously marked line. **H,** Excess stone is trimmed with a spatula. **I,** The top of the stone is flattened. **J,** The palate is cleared for the fabrication of maxillary trays. **K,** The use of fast-set stone accelerates the tray fabrication procedure. **L,** Once the stone has hardened, the impression and stone are placed under the tap. **M,** The wetting of the impression and model makes their separation easier. **N,** A cleoid-discoid instrument is used to accentuate the margins lingually and buccally. **O,** The base is trimmed and flanges are removed to minimize the footprint of the stone model. **P,** A light-cured colored resin is used to create a reservoir. **Q,** A reservoir is created for each tooth in the arch to be whitened. **R,** The model is placed on the vacuum former, and the plastic tray material is secured on the heating platform. **S,** As the tray material heats, it sags below the retention arm.

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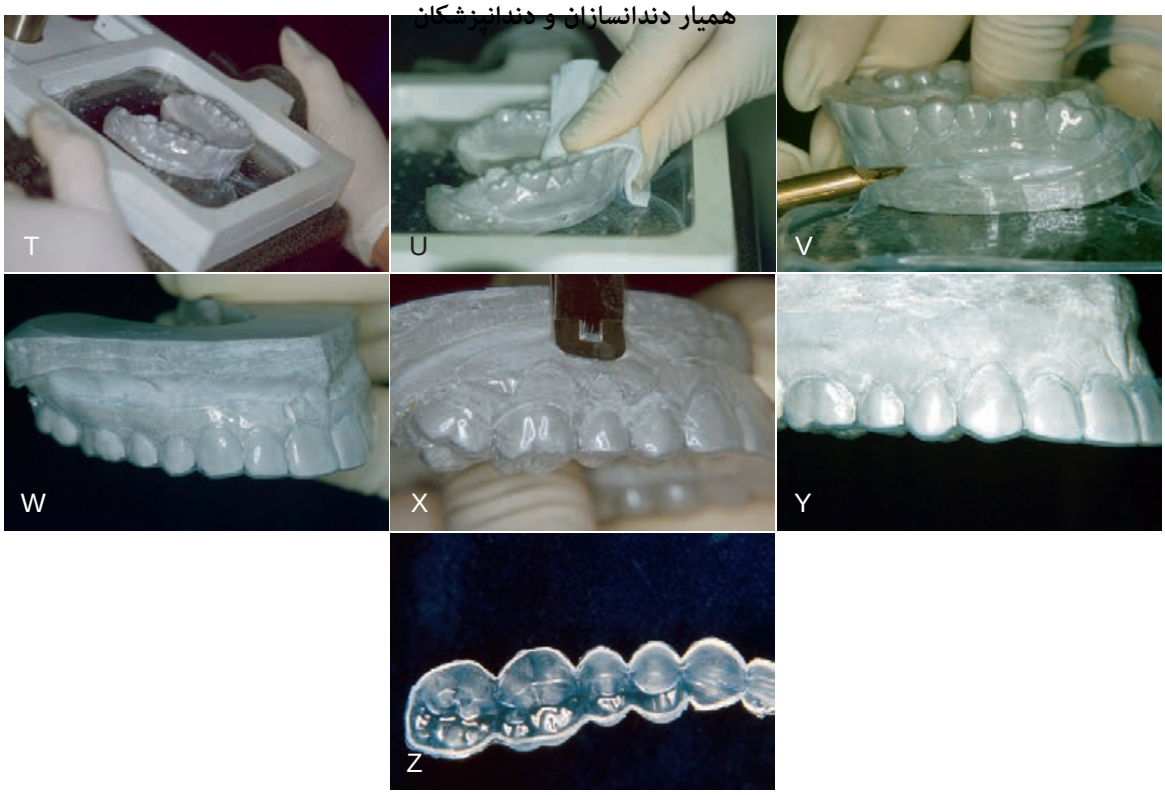


FIGURE 14-31, cont'd **T, The vacuum is turned on and the heated tray material is brought down over the model. U, Wet gauze is used to contour the soft plastic onto the stone model. V, A heated knife is used to separate the bulk of the plastic material from the stone model. W, An over-extended tray will irritate soft tissues. X, A heated knife is used to trim the tray to the required height at the gingival margin. Y, The trimmed tray is well adapted, just shy of the gingival margins buccally and lingually. Z, The tray is removed from the model for delivery to the patient.**

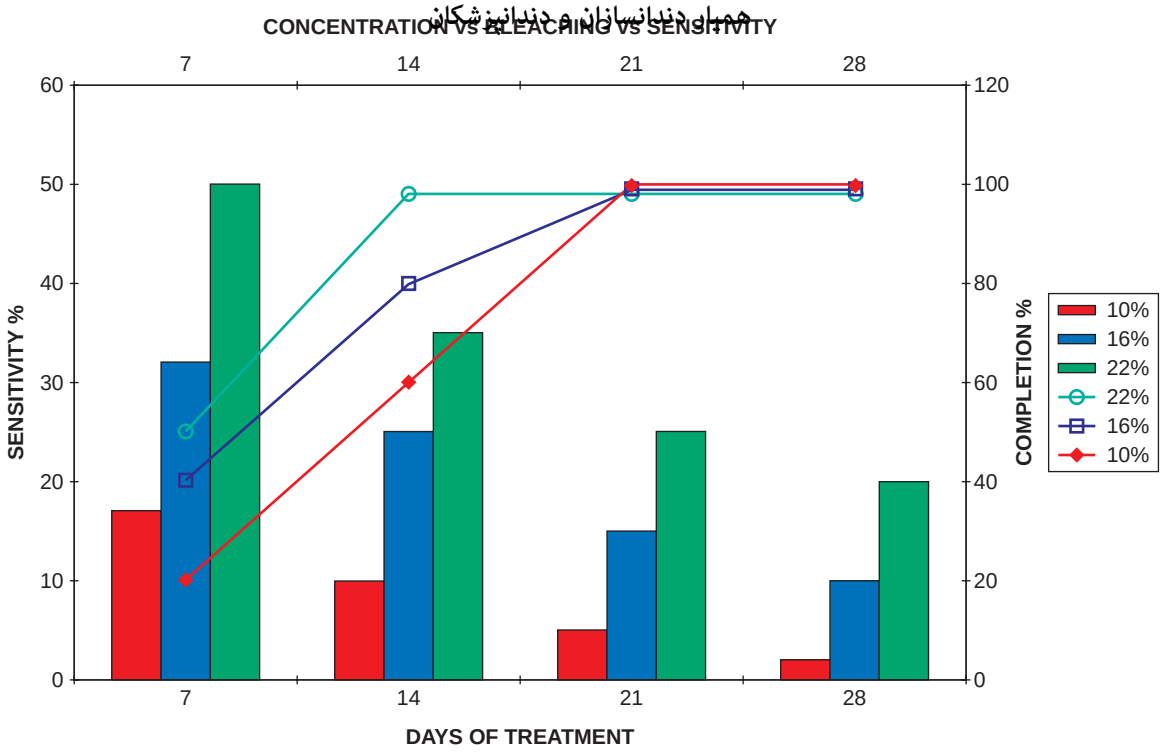
comfortable for patients and less problematic for dentists and their staff.

The process of tray fabrication for the at-home procedure is, by necessity, an in-office task; however, when at-home bleaching was first introduced most dental offices and auxiliaries were not particularly familiar with the associated techniques. On the other hand, it was financially impractical to ask the dental laboratory to fabricate these bleaching trays and to pay for the bi-directional transportation. The development of auto-heating and single-switch suck-down tray formers made the tray fabrication process much easier, significantly faster and more predictably accurate. However, the task of trimming the bleaching tray around the gingival margins on both the buccal and the lingual of every single tooth in each arch was still a time-consuming and tedious task. Unfortunately, the anatomic adaptation step in tray preparation step has not been made easier over time.

Over the years there has been a trend to speed up the bleaching process by increasing the concentration of the active ingredient. The concept was reasonable; if the concentration was doubled from 10% to 20%, then the at-home bleaching time could be reciprocally cut in half. Although it is demonstrable that increasing the carbamide peroxide concentration does speed up the bleaching process somewhat, one unforeseen side effect is that in-treatment and post-treatment sensitivity increase as well. In Graph 1 it can be seen that as the concentration of the carbamide peroxide in the bleaching gel is increased, the length of time needed to achieve maximum tooth whitening is decreased somewhat. It is important to note that there is a ceiling of whiteness beyond which additional carbamide peroxide at-home treatment (or in-office, for that matter) does not seem to whiten the teeth. The downside to this approach is that as carbamide peroxide concentration is increased from 10% to 16%, the cases of reported sensitivity are doubled. If the concentration of the carbamide peroxide is increased from 16% to 22%, there is another doubling of reported sensitivity in the first 7 days of at-home treatment. Thus, while the process of bleaching can be accelerated to eliminate several days from a total treatment span of 14 to 28 days, the concomitant rise in reported sensitivity does not make this approach acceptable.

Although the sensitivity that is associated with at-home bleaching is transient, lasting several hours or days but rarely longer, the patient can be very uncomfortable, particularly if the reaction is severe. The fact that this sensitivity has always disappeared within 30 days after treatment does not make the suffering any easier for the patient or the dental team. The prudent practitioner chooses an approach that is most likely to achieve successful bleaching within a reasonable treatment period and is

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GRAPH 1

least likely to cause sensitivity that requires additional patient care and chairtime.

The development of bleaching strips that adhere to the teeth had a major impact on the delivery of tooth whitening. Crest 3D White Whitestrips were simple-to-use and less expensive alternatives to earlier bleaching procedures. Professional Whitestrips (with a higher concentration of bleach) are available for the dental practice, whereas regular Whitestrips can be purchased over the counter at numerous outlets. The ubiquitous promotion that was put into motion at the time of the commercial introduction of Whitestrips created an immediate worldwide awareness of the bleaching process and its advantages. The impact of this promotional campaign was such that the global standards for esthetic smiles were redefined virtually overnight. Whitestrips focus on the anterior dentition, typically covering the front six to eight teeth. They often create an additional demand for further bleaching at the professional level to de-stain the remaining teeth. In virtually all cases, patients who have used Whitestrips are more aware of their dentition and more focused on their appearance and health—an impetus to seek regular and comprehensive dental care.

The most recent technical innovation in at-home tooth whitening has been the development of the pre-formed double-tray system (Figure 14-32, *A*) (Opalescence Trèswhite). The dental team delivers a treatment regimen of 10 each upper and lower pre-loaded whitening trays (Figure 14-32, *B*). The patient is instructed to insert the carrier tray over the appropriate arch (Figure 14-32, *C*) (the mandibular tray is smaller than the maxillary tray), and then finger form the pre-loaded whitening tray onto the teeth. Once the bleaching gel has adhered to the dental surfaces, the carrier tray is removed (Figure 14-32, *D*). This leaves the inside, pre-loaded tray formed over the dentition (over the entire arch) (Figure 14-32, *E*). The inside tray containing the bleaching material should be left in place for up to 30 minutes. This approach eliminates the need to fabricate vacuum-formed custom bleaching trays in the office and eliminates approximately 30 to 60 minutes of auxiliary chairtime.

At-Home Treatment Planning

Tooth whitening actually begins with the patient evaluation, because a thorough medical and dental history should be performed before any therapy is initiated. In addition to the usual health history, however, information should be gathered regarding the probable causes of the patient's present condition, as well as the patient's hopes and expectations for the treatment. Photographs are also taken before any whitening or other treatment, including prophylaxis. These should include at least one photograph with a standard shade guide tab in the field for color reference. If another method of color assay is available, such as a full-spectrum colorimeter, it can be used in place of the shade tabs (VITA Easyshade Compact, Vident, Brea, California, and MHT, Arbizzano di Negrar, Italy).

Notations should be made in the patient's chart describing the shade and condition of the teeth before treatment. It is advisable to make the patient aware of the starting shade.

In addition to performing the normal clinical evaluation, the dentist should carefully inspect all teeth that will come into contact with the whitening liquid. Of particular interest is the

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FIGURE 14-32 **A,** A pre-formed double-tray at-home whitening system (Opalescence Trèswhite). The treatment contains a regimen of 10 upper and 10 lower pre-loaded whitening trays. **B,** The carrier tray is squeezed, which in turn forms the inner tray to the teeth. **C,** The carrier tray is placed over the appropriate arch. **D,** The outer carrier tray is then removed. **E,** The inner tray containing the bleaching material is left in place for approximately 30 minutes.

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discovery of major cracks in the teeth or decay or leakage under existing restorations. Transillumination can be of great help in detecting these problems. Leaky fillings or frank caries may be restored temporarily before the whitening process is initiated. The patient should be informed that these and all other existing tooth-colored fillings will remain largely unchanged, even though the teeth themselves can be expected to whiten. In fact, the degree of whitening can often be gauged by the increasing contrast between the existing composite restorations and the surrounding tooth structure. The patient should also be informed before whitening that any visible anterior composites or crowns will probably need to be replaced at the end of the bleaching procedure. The dentist should also note any cervical abrasion, exposed root structure, or severely diminished enamel thickness.

After the establishment of these baseline conditions, it is usually necessary to perform a thorough prophylaxis of the teeth, which is then followed by a re-examination. At this point it is important, although not critical, to ascertain the type of discoloration that has affected the teeth. This analysis will help in predicting the degree of lightening that can be expected, along with the amount of treatment time needed. Careful discussions using good listening skills should be employed to gauge the patient's level of expectation for the procedure. Once the type and severity of the discoloration have been diagnosed, the dentist must align the patient's expectations with reality. Often, discussions concerning the treatment plan can be more meaningful if the patient is shown photographs of similar situations with other patients and the type and the extent of favorable results that have been achieved. If this is done, however, the patient must be made aware that every dentition is different and the examples cannot constitute a guarantee of similar results with his or her particular teeth.

Patients should also be told exactly what to expect in terms of the treatment itself. They are naturally interested in knowing such things as whether there will be any discomfort, whether they will be able to talk while wearing the tray, and whether they can eat while wearing the tray. Before initiating any sort of treatment, all of these aspects should be discussed and clear financial arrangements made.

Once the patient has elected to have the whitening procedure performed, the dentist can fill in any large areas of cervical abrasion or abfraction on the teeth to be whitened. If this is not done, there may be a slight risk of sensitivity during the whitening procedure. In addition, if the tray is closely adapted to the facial anatomy of teeth, into the cervical abrasions, the tray becomes difficult to insert and remove. Therefore these provisional cervical restorations should be placed at this time, knowing full well that they will need replacement after tooth whitening is completed.

Even when all cervical abrasions are bonded over with resin, patients with exposed root structure or severely diminished enamel thickness should be informed that they may have to limit the time of continuous exposure to the whitening liquid if they experience any sensitivity. During treatment, they should generally avoid exposure to citrus fruits, apples, and other acid-containing substances to avoid exacerbating dental sensitivity.

MATERIAL OPTIONS: IN-OFFICE BLEACHING

In-office bleaching materials generally consist of higher-concentration oxygen-releasing compounds that are considered safe for intra-oral use. They are expected to work rapidly and effectively, but always under the direct supervision of the dentist or the designated auxiliary.

The "power" bleach or gel materials include varying concentrations of hydrogen peroxide liquid, liquid and powder, or gel (fluid thickened with stabilizers and/or coloring agents). The hydrogen peroxides are designed to be used at 15% to 35%. Those power bleaching products that are premixed tend to lose effectiveness over time with storage and by heating during transport; the materials where the components are packaged separately and mixed immediately before use are more likely to be closer to their advertised oxygenating strength.

Higher-strength carbamide peroxides can also be used for in-office tooth whitening. Even the 35% concentrations of the *carbamide* products can be used safely, but carefully, without soft tissue protection (35% carbamide peroxide has the bleaching effectiveness of a 10% to 12% hydrogen peroxide solution).

Light- and laser-mediated in-office bleaching has been popular within the profession, but ***wildly*** popular among patients, since its appearance in the mid 1990s. The most important question that the professional must ask is whether there is an actual photoinitiator or photoactivator within the bleaching liquid or gel. This specific ingredient can make the process a "light" or "laser" treatment; the absence of a photo-reactive material in the bleach makes this claim inaccurate.

Many terms are used to describe in-office bleaching. They can be confusing for the professional and even more so for patients.

- *In-office bleaching* contrasts the professionally monitored process with patient-administered at-home procedures.
- *Chairside bleaching* is just another term that reflects the in-office nature of the procedure.
- *Power bleaching* is a reference to the higher concentrations of bleaching materials that are used.
- *Laser bleaching* refers specifically to a laser-light–mediated treatment but in practice is the terminology used to describe any light source that is utilized as part of a whitening process. The light may be an argon laser, a diode laser, a curing light, or a proprietary "activating" light.

ADVANTAGES

The underlying advantage of in-office bleaches is that they can claim to work more quickly than the at-home products. For the most part, this claim is true. There are other possible benefits, as well. Some manufacturers claim the use of an in-office gel bleach decreases the incidence of tooth sensitivity by reducing the tooth desiccation commonly observed with the liquid and the liquid-powder products. The gels typically contain 10% to 20% water, which serves to rehydrate the teeth throughout the

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bleaching procedure. The viscous consistency of the gel allows it to remain in more intimate contact with the tooth, more predictably and for longer periods. The presence of water in the gel reduces the shelf-life, and some of these products must be refrigerated both during transport and in the practice until they are used.

The thicker gels decrease the incidence of inadvertent soft tissue contact as they tend to remain where they are placed on the tooth surfaces. The viscous nature of the gels may promote increased oxidizing ion penetration into the enamel and dentin by allowing the gel to act as a blanket to prevent the escape of the liberated oxygen ions. Gels can be freshly mixed immediately before treatment, and a fresh solution should be mixed for each patient. (Hydrogen peroxide shelf-life is rather limited—as little as 6 months. Always verify the expiration date of the hydrogen peroxide liquid *before* mixing it with the powder to form a gel.)

Disadvantages

There are several disadvantages to power bleaching that must be considered. It takes more chairside time in the operatory and thus has a greater practice cost associated with it. The results of in-office bleaching can be rather unpredictable, as it is not known exactly how well the teeth will respond to the whitening procedure in the very short term.

Typically the procedure involves longer and more frequent in-office appointments than at-home bleaching, as one session is often insufficient to achieve an acceptable color change. The chair time and material costs for each subsequent in-office bleaching appointment (or re-treatment) are the same as those for the initial treatment, whereas at-home bleaching is less expensive with respect to consumables and much less expensive with respect to chair-time.

In 1991, Rosensteil, followed the re-staining that occurs after use of 30% hydrogen peroxide to bleach teeth in vivo. It was reported that there was a 50% drop-off from the immediate post-treatment color change effect at 1 week, and only 14% of the whitening remained at 6 to 9 months. These results indicate that although hydrogen peroxide alone is an efficient short-term bleaching agent, significant re-staining occurs with time after a single bleaching treatment. Regression of the color may occur much more quickly with in-office treatments than with at-home bleaching. Therefore multiple appointments are required, and in-office whitening should be accompanied by an at-home treatment component in-between or after in-office sessions.

It is well known that the teeth are dehydrated during bleaching treatment. This can complicate the accurate measurement and evaluation of actual bleaching shade change. The rehydration of desiccated bleached teeth manifests as a somewhat darker coloration and is often misinterpreted by patients as rebound discoloration.

There are serious safety considerations with in-office bleaching, as well. The chairside bleach often employs a stronger, more caustic peroxide concentration and can be problematic if it spreads beyond the hard tissues. Soft tissue burns can occur on the patient's lips, cheeks, and gingiva simply from transient contact with the bleach. Protection of the patient's face, soft tissues, eyes, skin, and lips is mandatory!

Dental assistants can also experience tissue burns as they mix the materials or clean up after the appointment. Meticulous and defined protocols are therefore required for preparing and disposing of bleaching materials.

Thirty-five percent hydrogen peroxide bleaching agent are unstable and have a very short shelf-life. They should be refrigerated or stored at a cool temperature.

Finally, but very significantly, Bowles, Thompson, and Ungwuneri found that the teeth may be made more sensitive with the in-office technique alone.

Complications with Stronger Bleach Concentrations

Stronger concentrations of hydrogen peroxide, such as 35%, can cause soft tissue damage, gingival ulcerations, and skin burns. These soft tissue irritations appear as a white lesion surrounded by a red rim.

The patient may be the first to notice a tingling or burning in the gums during the bleaching treatment. They should be continually questioned during the procedure to ascertain whether this is happening. If a tissue burn does occur, it should be rinsed with copious amounts of water to neutralize the peroxide effects on the soft tissue. "Blanching," or gingival burns, are quite common. These typically disappear after a few minutes, heal quickly, and are very unlikely to cause any permanent damage. When tissue burns do occur, the patient must be told, shown, and reassured.

It is advisable to use soft tissue protection for most in-office bleaching techniques: rubber dam or light-activated liquid resin soft tissue coverage.

CURRENT BEST APPROACH

The current best approach for in-office bleaching requires a number of components and a number of steps. Typically in-office bleaching, particularly if it encompasses several sequential in-chair sessions for the patient, should involve at-home bleaching in between the sessions. For single-appointment in-office bleaching procedures, there should be a post-bleaching regimen accomplished at home to de-stain the teeth as well. Today's best approach may also consist of a combination of procedures for difficult stains such as tetracycline (or to increase the rapidity of the treatment, or to decrease postoperative sensitivity). Some improved bleaching materials include a much lower level of hydrogen peroxide, 3% to 3.5%, compared with many in-office bleaching materials, which contain up to 35% hydrogen peroxide.

Advantages of the lower level peroxide bleaching materials include their direct application to the patient's dentition without risk of damage to the surrounding gingiva, tongue, mucosa, and other parts of the oral cavity. Although it is still a good idea to place barriers on these non-bleachable soft tissue

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areas, the accidental exposure to 3.5% hydrogen peroxide bleach is unlikely to have any major effects in terms of sensitivity, discomfort, or surface irritation. These low-peroxide bleaches work with the addition of an activating material that accelerates the bleaching process. Initiators include the sodium pyrophosphate family and potentiate the effect of the peroxide de-staining even at very low concentrations. They are applied in the same fashion as conventional procedures and can be delivered either directly or with gauze to keep the bleach in place. The bleach is applied three times over the course of a single treatment session. After each application, the spent material that has exhausted its bleaching properties is wiped off the dentition and replaced with freshly reactive material. Thus the threefold application of the bleaching material to the teeth, directly or indirectly, with or without light, preferably at lower peroxide concentrations and with as little postoperative sensitivity as possible, is the preferred application or best approach at this time.

OTHER CONSIDERATIONS

One of the most important practice considerations is that tooth whitening or bleaching often opens up the doors to additional treatment requests by the patient. Most patients are really not all that aware of, or focused on, their teeth; once they have seen the possibilities offered by the bleaching of their teeth, however, and the vast improvement that this generates in their appearance and their self-confidence, they develop increased interest in having veneers, crowns, and other esthetic procedures done. As a corollary effect, patients also tend to significantly improve their oral hygiene as a direct consequence of their increased focus on their teeth.

Tooth bleaching is offered not only by the dentist; kits are available over the counter from numerous dental or dentally related companies. In many countries, the patient can pick up a treatment kit in a pharmacy or supermarket. During the first 11 years of tooth bleaching (1990 to 2001), when dental de-staining was available exclusively from dental practitioners, about 15 million individuals, mostly in North America, had their teeth whitened. Since these products became available over the counter, combined with the massive advertising power of large companies such as Procter & Gamble (Whitestrips line), it is estimated that more than 500 million people worldwide have whitened their teeth to some extent. This not only opens up tremendous opportunities for patients, it also focuses their minds on oral health, creating more regular attendance at the dental practice for treatment and, in particular, maintenance.

Given that in many jurisdictions tooth bleaching can be accomplished by auxiliary personnel, the procedure helps to extend a dentist's time and treatment capabilities to more patients within a limited amount of clinical time. Fortunately, very few ill effects have been reported with tooth whitening, consisting mostly of tooth and/or gingival postoperative sensitivity. These problems can generally be avoided by selecting appropriate bleaching materials and applying them with the recommended techniques. When sensitivity does occur, it can be readily treated in the practice or at home. Gingival sensitivity, even when left untreated, typically resolves within 1 to 2 days. Tooth sensitivity can be readily eliminated with various desensitizing agents but will often disappear within 1 to 2 weeks.

INNOVATIVE ELEMENTS

Recent innovations have tended to make the chemistry of bleaching materials less caustic and thus less irritating to the soft tissues, as well as more effective in the bleaching of the tooth structures. Some materials, such as tetrasodium pyrophosphate, have been shown to potentiate the effects of the bleaching. As a result, much lower concentrations of the active bleach ingredient can be used. A 3.5% hydrogen peroxide bleach with tetrasodium pyrophosphate is comparable to hydrogen peroxide alone in concentrations up to 35%. Despite a significantly lower concentration of hydrogen peroxide, the catalytic effect of the tetrasodium pyrophosphate can provide excellent bleaching power. This lower-concentration peroxide can be used safely and effectively without gingival protection (gel, paint-on resin, or rubber dam). It should be noted that 3.5% hydrogen peroxide is equivalent in terms of tissue causticity to 10% carbamide peroxide, a material that is routinely used without protection on the soft tissues of the mouth.

The chemical approach to improving the parameters of dental bleaching materials will continue to advance bleaching effectiveness, bleaching speed, and patient comfort and safety. As these technologies are added to the dental armamentarium, more difficult cases such as tetracycline staining can be more readily addressed.

BLEACHING LIGHTS

Bleaching lights have been portrayed by some, particularly the manufacturers of the lights, as tremendously enhancing the tooth-whitening procedure. These lights are offered in various forms: freestanding, chair mounted, or handheld; small, medium, or large; and of general or limited-range wavelengths. They may be sleek and exciting or simply functional.

Whatever the parameters, the general feeling among the patient population is that bleaching lights actually assist in the tooth-whitening process. In actual fact, most research indicates that bleaching lights do not make any difference whatsoever in the speed, effectiveness, or duration of the whitening process, nor do lights alter the results of the treatment on the teeth. Furthermore, there are some specific problems associated with the use of bleaching lights. The early lights were very hot and they were typically positioned quite close to the face in order to raise the temperature of the bleach at the tooth surface. This rather significant temperature change (often greater than 10° C) occasionally led to severe operative and/or postoperative dental sensitivity owing to the effect of the heat on the dental pulp. In some cases, the prolonged heating of the teeth caused irreversible pulpitis and eventually necessitated endodontic treatment. Some bleaching lights had emissions in the ultraviolet range, which

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can be dangerous for unprotected eyes (patients, staff, and dentist) as well as any exposed skin. Patients required very comprehensive skin protection for their faces and appropriately filtered safety glasses for their eyes. The operator and the auxiliary staff also required similar protection. Heat-based bleaching lamps, if they were held too close to the mouth, were capable of overheating (and occasionally burning) the lips and the facial skin.

Theoretically, the bleaching light has two possible modes of action. One is the stimulation of a photo-activating substance within the bleach; the other is a temperature increase that catalyzes a faster bleaching reaction. The photo-activator option is most easily dealt with. A photo-reactive substance in the bleaching material could conceivably catalyze the treatment to proceed more rapidly and more effectively during light stimulation. If there is no photo-reactive substance contained within the bleach, no catalytic effect can possibly occur. Most "power" bleaching procedures that recommend bleaching lights do not list any catalytic substances among their ingredients. Thus, no photo-stimulation is possible.

The heat-bleaching concept is based on the fact that most reactions progress more quickly at higher temperatures. Chemical reaction speeds are calculated using Kelvin ratios, or the environmental temperatures as they relate to absolute zero (0° Kelvin or −273° Celsius). Generally, a reaction taking place at a higher ambient temperature proceeds at a faster rate, and the speed of the reaction can be calculated as a direct ratio of the temperature differential between the two environments.

This phenomenon likely occurs with heated bleaching products on the teeth as well but can be shown to be insignificant clinically. The temperature of the teeth (the same as the body's temperature, or slightly lower) is typically 37° C, which translates to 310° Kelvin. When a bleaching material is heated to a temperature of 320° K from a normal mouth temperature of 310° K, the bleaching reaction *does* proceed faster, at a heat-mediated rate that is approximately 3% greater (320/310 = 1.03 or +3%) than at regular body temperature. Clinically, this means that a 60-minute in-office bleaching procedure can be shortened by 3%, or 2 minutes.

The risks of heating teeth are significant (Figure 14-33), however. Heating a tooth 10° C is the temperature differential that has been recommended to activate bleaching but even this thermal change is likely to cause severe sensitivity and possible pulpal damage. Furthermore, even this risky process of overheating the teeth to the point of endangering the integrity of the pulp can only realize a maximum 3% increase in bleaching speed.

For these reasons, both from the technological and chemical perspectives, neither the application of a bleaching light or curing light nor the raising of the surface temperature of the teeth has any significant clinical benefit for the patient undergoing bleaching. In fact, there are numerous dangers inherent to both of these approaches that can lead to significant ancillary problems for both hard and soft tissues.

As a result of the advertising, promotion, and media exposure over the past 15 years or so, many patients expect and even demand that a "light" or "laser" be incorporated into their bleaching treatment. In some cases, the patient cannot rationally accept that the bleaching light adds no benefit to treatment, and may in fact be problematic from a health perspective. Rather than arguing the point with the patient, it is acceptable to use a bleaching light that is far enough away from the mouth (Figure 14-34) to cause no heating of the teeth. This offers the patient the required psychological support without endangering the health of his or her teeth and soft tissues. The distant light source causes no damage; however, it provides an adjunct that is important to the patient. Thus it constitutes a patient management approach that, while not contributing any treatment advantage, does make the patient more comfortable and more confident, contributing to the success of the overall treatment process.

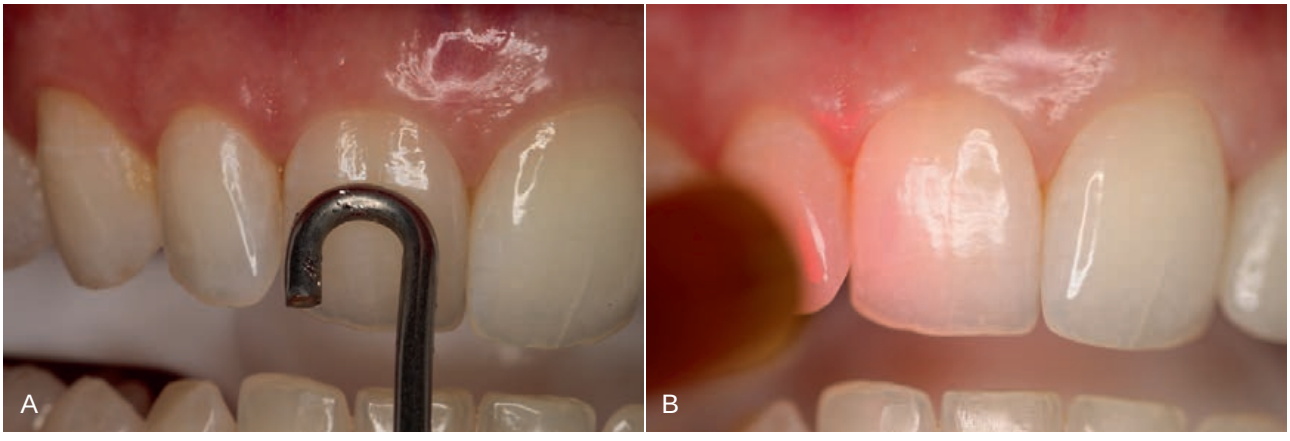


FIGURE 14-33 **A, Heating the tooth with an instrument. B, Heating the tooth with a light. The risks associated with the heating of the teeth during a whitening procedure are significant. An increase of 10° C is likely to cause sensitivity and possible pulpal damage.**

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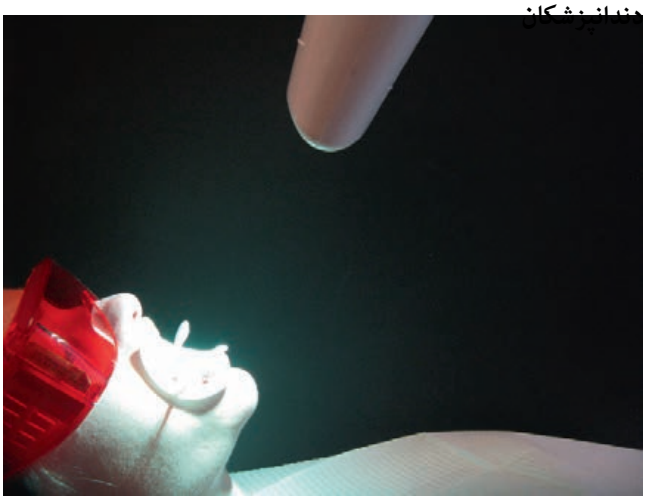


FIGURE 14-34 It is best to have the bleaching light at a further distance from the patient's mouth to avoid heating of the teeth.

IN-OFFICE BLEACHING: TREATMENT PLANNING SEQUENCE

Power Bleaching Techniques Using Heat

The bleaching effects of heat and oxygen ions released from hydrogen peroxide on the pulp were analyzed numerous times from the 1960s to the 1980s. Heat has been shown to cause decreases in pulpal circulation, increases in pulpal inflammation, and irregular dentin formation. These factors can explain much of the sensitivity that some patients report during and/or after power bleaching. Excess heat activation increases the intrapulpal temperature, damaging odontoblasts, and causing inflammatory changes to the organic portions of the tooth that often lead to irreversible pulpal damage. A small number of oxygen ions from hydrogen peroxide inevitably penetrate the pulp during bleaching but have been shown to have no discernible effect. Although heat mediated bleaching is rarely used today, the various heating procedures are described briefly in the following sections.

Bleaching with a Heating Instrument

1. The rubber dam and mucosal protection are placed on the teeth and soft tissues (Figure 14-35, *A*).
2. Gauze soaked in 35% hydrogen peroxide liquid is placed on the teeth (Figure 14-35, *B*).
3. A heating instrument is positioned on the gauze to enhance and/or speed the bleaching effect (Figure 14-35, *C*).
4. The heat can be applied for up to 3 minutes, assuming that the patient can tolerate the discomfort.
5. The dentist must avoid touching hard or soft tissues with the heater (Figures 14-35, *D* and *E*).

Bleaching with a Bleaching Light

1. The rubber dam and mucosal protection are placed on the teeth and soft tissues (Figure 14-36, *A*).
2. Facial and ocular protection are placed on the patient's head (Figure 14-36, *B*).
3. Gauze soaked in 35% hydrogen peroxide liquid is placed on the teeth and allowed to stay for periods as long as 30 minutes (Figure 14-36, *C*).
4. A heating light is set approximately 30 cm away from the teeth to warm the peroxide (Figure 14-36, *D*).
5. The procedure may be repeated at 1- or 2-week intervals.

Patients can expect their teeth to be sensitive for a few days after treatments owing to the heating effect of the light on the dentition. The desiccation of the teeth through any heat-mediated bleaching procedure adds to the patient's discomfort.

Bleaching with Lasers

Laser-assisted bleaching was introduced in the mid 1990s as an attempt to improve and accelerate the bleaching process. The U.S. Food and Drug Administration (FDA) approved Ion Laser Technology's (Salt Lake City, Utah) argon and carbon dioxide lasers in 1996. The patient population, always enthralled by lasers, was very keen to try laser bleaching, which was promoted as a procedure superior to earlier bleaching methods. There was, and is, little clinical research to support the laser bleaching technique, its safety, or its benefits. There is little documentary evidence to indicate that lasers are any more effective than traditional bleaching methods. Most of the published reports in this area are anecdotal and empirical. Jones's in vitro study in 1999 indicated that one session of laser bleaching did not demonstrate any perceivable color change and recommended that additional or longer applications may be required. This study found that exposure to 20% carbamide peroxide produced the greatest perceivable color change. However, this was an in vitro study and did not account for the intra-oral presence of saliva and in vivo hydrodynamic pulpal pressures.

Types of Lasers

Many lasers have dental applications, including diode, carbon dioxide, argon, neodymium-doped:yttrium-aluminum-garnet (Nd:YAG), and erbium, chromium:yttrium-scandium-gallium-garnet (ErCr:YSGG) lasers. Some are used for bleaching procedures.

The Role of Lasers in the Bleaching Process

Lasers are intended to enhance the efficiency of bleaching materials. Lasers catalyze the oxidation reaction by providing additional energy for the more rapid breakdown of hydrogen peroxide into its components—water and an oxygen ion. This serves to increase and speed the release of the oxygen ions into the stained tooth surface. The liberated oxygen free radicals break apart the double bonds of the longer stain molecules into shorter, more soluble, and possibly less pigmented chains.

Laser manufacturers claim that there is no pulpal effect during laser bleaching; the laser energy heats the bleaching solution far more quickly and efficiently than conventional heat sources (heating instrument or light source), with most of the

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FIGURE 14-35 **A, The rubber dam and mucosal protection are placed on the teeth and soft tissues. B, Gauze soaked in 35% hydrogen peroxide liquid is placed on the teeth. C, A heating instrument is positioned on the gauze for up to 3 minutes to enhance and/or speed the bleaching effect. D and E, The dentist must avoid touching soft or hard tissues with the heater.**

energy absorbed directly into the chemical reaction and dissipated quickly thereafter. Some manufacturers claim that their laser is focused on catalyzing the water-based bleaching reaction. Others assert that the laser energy is totally absorbed by the bleaching gel on the tooth surface.

Advantages of Laser Bleaching

Laser bleaching may work more quickly owing to a higher concentration of the active bleaching ingredient or a more defined and localized release of the active oxygen ions in close proximity to the tooth surface. It is often used to jump-start more difficult cases such as tetracycline staining and fluorosis.

Disadvantages of Laser Bleaching

1. Equipment cost: lasers are expensive.
2. Chairside cost: the procedure, like all in-office bleaching treatment, is time-consuming.
3. Postoperative sensitivity can be significant. (Anecdotal reports indicate moderate to severe post-treatment pain after laser-assisted bleaching.)

Laser Bleaching Procedure (Dr. David K. Yarborough)

1. The patient is first assessed both clinically and radiographically (Figure 14-37, *A* and *B*).

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FIGURE 14-36 **A, The rubber dam and mucosal protection are placed on the teeth and soft tissues. B, Facial and ocular protection are placed on the patient's head. C, Gauze soaked in 35% hydrogen peroxide liquid is placed on the teeth and allowed to stay for periods as long as 30 minutes. D, A heating light is set approximately 30 cm away from the teeth to warm the peroxide.**

2. The proposed treatment plans are discussed and evaluated, and the course of treatment is selected.
3. The appropriate consent forms are completed and signed.
4. Pre-operative photographs of the teeth must be recorded, preferably under repeatable conditions (Figure 14-37, *C*).
5. The teeth are isolated with a protective mucous membrane seal to protect the gingiva (Figure 14-37, *D*).
6. The laser bleaching gel is mixed according to the manufacturer's instructions (Figure 14-37, *E*).
7. The gel is placed in a 1- to 2-mm thickness on the buccal surface of the teeth to be bleached (Figure 14-37, *F*).
8. The 488-nm argon laser light is applied for 30 seconds about 1 to 2 cm from the buccal surface of each tooth and moved from right to left over the tooth's surface (Figure 14-37, *G*).
9. After laser illumination, the gel is left on the tooth for 3 minutes.
10. The spent bleaching gel is then removed from the teeth, wiped with a damp gauze to avoid splatter of the highly caustic 35% hydrogen peroxide gel (Figure 14-37, *H*).
11. The teeth are then washed and rinsed, and the bleach is re-applied up to five more times in a single appointment. The entire procedure takes approximately 60 to 90 minutes of chairtime (Figure 14-37, *I*).
12. Use of aluminum oxide disks and/or diamond polishing paste restores the enamel's luster (Figure 14-37, *J* and *K*).
13. The dam and then the protective soft tissue seal are removed, and the mouth is rinsed (Figure 14-37, *L*).
14. The shade of the teeth is now re-assessed.
15. Postoperative photographs must be recorded under the same conditions as the pre-operative images (Figure 14-37, *M*).
16. The patient can see the bleaching result in a mirror (Figure 14-37, *N*).

An alternative technique involves using both argon and carbon dioxide lasers. The argon laser is used as described; then the carbon dioxide laser is employed with another peroxide-based solution to enhance the penetration of the bleaching agent into the tooth to whiten below the surface. Argon–carbon dioxide laser bleaching can take 1 to 3 hours.

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FIGURE 14-37 **A and B, The patient is first assessed both clinically and radiographically. C, Pre-operative photographs of the teeth must be recorded, preferably under repeatable conditions. D, The teeth are isolated with a protective mucous membrane seal to protect the gingiva. E, The laser bleaching gel is mixed according to the manufacturer's instructions. F, The gel is placed in a 1- to 2-mm thickness on the buccal surface of the teeth to be bleached. G, The 488-nm argon laser light is applied for 30 seconds about 1 to 2 cm from the buccal surface of each tooth and moved from right to left over the tooth's surface. After laser illumination, the gel is left on the tooth for 3 minutes. H, The bleach gel is then removed from the teeth, wiping with a damp gauze to avoid splatter of the highly caustic 35% hydrogen peroxide gel. I, The teeth are then washed and rinsed and the bleach is re-applied up to five more times in a single appointment. The entire procedure takes approximately 60 to 90 minutes in the chair. J, The dam and then the mucosal membrane seal are removed, and the mouth is rinsed. K and L, Aluminum oxide disks and/or diamond polishing paste is used to restore the enamel's luster. M, Postoperative photographs must be recorded under the same conditions as the pre-operative images. N, The patient is shown the bleaching result in a mirror.**

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Clinical Techniques

In-Office Tooth Whitening with Light Application—"Dry" Technique

The smile image (Figure 14-38, *A*) reveals the anterior 12 teeth and a corresponding close-up of the maxillary anterior teeth (Figure 14-38, *B*) before bleaching. The accumulated stains in the teeth are seen darkening and yellowing the tooth surfaces on both the maxillary and the mandibular arches. Once the decision has been reached by the patient and the dentist to proceed with bleaching, the next step is to prepare the patient's mouth and teeth for the bleaching process and materials. The teeth have been polished with a non-fluoride prophylaxis paste. Tooth cleansing systems that deliver a remineralizing bioactive glass such as NovaMin (calcium sodium phosphosilicate) (Figure 14-38, *C*) can be used not only to clean the surface but also to harden both the enamel and the dentin through a process called *peening* (Figure 14-38, *D*).

Several steps are required before bleaching is commenced. The first step of the process is to retract the cheeks in order to provide clear visibility of the all the teeth to be treated, to allow clinical access, to separate the upper and lower teeth, and to block the tongue from interfering for the next 60 minutes or so. The facial shield, which protects the surfaces of the lips and face, is applied and secured along with the cheek retractor. The blue gingival barrier is also applied to protect the marginal soft tissues from the peroxide bleach. The barrier is placed on the gingival areas that approximate the margin of the gingiva at the tooth interface. This material is delivered in a thin 2- to 3-mm viscous gel layer positioned on the soft tissues just beyond the margins of the tooth-gingiva interface. The gel is immediately light cured to ensure that it stays in place throughout the procedure. This barrier protects the free gingiva adjacent to the teeth that are to be bleached in case the caustic bleaching materials overflow the hard tisuue surfaces (Figure 14-38, *E*).

Although the bleaching materials, when used as instructed, do not affect the tooth surface in any deleterious way, they can occasionally cause white chemical burns (Figure 14-38, *F*) on exposed gingival tissues. These tissue burn areas are not generally detrimental to the patient but can certainly cause patient alarm as well as generating localized and transient sensitivity in the affected tissues. If required, cotton rolls can be applied in the occlusal folds distal to the bleaching to further isolate these areas, to prevent salivary contamination, and to improve access and visibility.

Many bleaching systems recommend a pre-whitening step. This is typically an agent that conditions the enamel and dentin surfaces to bleach more quickly and/or effectively. In this case the conditioning liquid and powder are mixed together to yield a 35% hydrogen peroxide paste, which is subsequently applied to the tooth surfaces, the gingival barrier keeping it away from the gingival areas (Figure 14-38, *G*).

The air-water spray is contraindicated to wash away this layer, as the water can reactivate the peroxide and inadvertently spray it into unprotected areas of the mouth where the caustic slurry can irritate the soft tissues. The spent conditioning material is now ready for wet gauze removal (Figure 14-38, *H*).

The patient is reclined horizontally, gingival tissues are isolated, and the peroxide paste on the tooth surfaces is illuminated by the bleaching light (Figure 14-38, *I*). The light may be useful in activating the bleaching materials. The slow-speed suction extends out of the patient's mouth, continually removing excess saliva to keep the bleaching area free from contamination. The light activates the material for about 10 minutes, drying it until it becomes very opaque white. Re-wetting of the peroxide paste is not recommended at this stage.

The spent bleaching material is mostly removed from the teeth with a wet gauze (Figure 14-38, *J*). Some bleaching material remains interproximally and toward the gingival. This remnant can be left pending the next step of the bleaching procedure.

The bleaching gel is re-applied to the surfaces of the teeth (Figure 14-38, *K*). The gel is automixed through a dual-barrel syringe, ensuring that the mixing of the components occurs immediately before use and that the peroxide paste is therefore always fresh and at its maximum bleaching potential. Segregated component storage extends shelf-life considerably. The material is spread evenly over the facial surfaces of the teeth and over the incisal edges, ensuring that all the visible surfaces of the teeth are whitened and that the material does not seep beyond the gingival barrier to the soft tissues, facial surfaces, lips, or tongue.

The patient is reclining with the next gel application in place on the maxillary and mandibular tooth surfaces with the activating light on (Figure 14-38, *L*). The application lasts 10 minutes. Once completed, the material is simply suctioned off without rinsing. Fresh gel is re-applied and the patient again undergoes the 10-minute light-activation procedure. This application of light-activated gel is repeated a total of three times as part of the overall treatment sequence.

Figure 14-38, *M* shows the patient during the gel light-activation step with the slow-speed suction removing excess saliva. The maxillary and mandibular teeth are separated and the cheeks retracted. The surfaces of the face and lips are covered by the face protector, and the gingival barrier protects the teeth. The patient is not in a position where he or she can easily read or watch a television screen during this phase of treatment. The bleaching light can be seen at the top of the image.

Once the three bleaching applications have been completed, the spent bleaching gel is suctioned away with high-speed suction. A wet gauze is used to remove as much of the remaining bleaching gel as possible. Then the gingival barrier, the cheek retractor, and the facial barrier are removed and the patient is asked to rinse with water. After rinsing, the full-smile (Figure 14-38, *N*) and close-up (Figure 14-38, *O*) images demonstrate the extent to which the anterior teeth have been bleached. The teeth are now significantly whiter.

In some cases white spots may appear on the teeth. These white spots, as can be seen on the distal-incisal of tooth No. 21 (Figure 14-38, *P*), will disappear with time (2 to 5 days) as the teeth re-hydrate and remineralize. There is often a dramatic post-treatment decline of the whitening effect as the teeth re-hydrate, because at least part of the bleaching effect is the result of tooth desiccation during the bleaching appointment. A bleaching session represents 60 to 90 minutes during which



FIGURE 14-38 **A,** Pre-treatment photograph showing the upper and lower arch. **B,** Close up pre-treatment photograph. **C,** An illustration showing the benefits of cleansing the tooth surfaces. **D,** Diagrams showing the effects of remineralizing bioactive glass materials that clean the tooth surface and harden the enamel and dentin. This process is called *peening*. **E,** Light-cured resin gingival barrier protects the soft tissues during the bleaching process. **F,** Chemical burn caused by the bleaching material coming into direct contact with the gingival tissues. **G,** A powder-liquid formula is mixed to create a 35% hydrogen peroxide paste, which is applied to the teeth. **H,** A bleaching light is used to activate the bleaching material. The light is applied for 10 minutes. The low-volume suction continually removes excess saliva from the patient's mouth, keeping the bleaching area free from contamination. **I,** The spent peroxide paste is dry after the light application. **J,** The spent bleaching material is mostly removed using wet gauze. **K,** The bleaching material is re-applied to the tooth surfaces. **L,** A bleaching light is again applied for 10 minutes to activate the bleaching material. **M,** Because the patient is reclined, he or she may read or watch a ceiling-mounted television during this phase of the treatment. **N,** Postoperative image of the anterior teeth. **O,** Postoperative close-up image of the anterior teeth showing a significant change. **P,** White spots, as can be seen on the distal-incisal of tooth No. 21, will disappear with time (2 to 5 days) as the teeth re-hydrate and remineralize.

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the teeth have no contact with saliva or other non-bleaching liquids. Some dentists apply fluorides in a polish or gel onto the teeth after bleaching to speed remineralization. This step does not affect the whiteness of the teeth but may improve the surface hardness and is likely to decrease any postoperative sensitivity.

In-Office Tooth Whitening with Light Application—"Wet" Technique

The bleach and gauze technique is different from the "dry" gel application in that gauze is kept in a bleach-moistened state on the teeth throughout the treatment process. This ensures that the bleaching material is continually active in releasing oxygen ions, that active bleaching material remains in contact with the tooth surfaces at all times, and that the released oxygen ions have a decreased ability to escape the immediate proximity of the tooth surface. The bleach and gauze "wet" technique can be used with most in-office bleaching materials. Treatment modalities are selected according to clinician preference and patient comfort.

The first step in this procedure, as with most in-office bleaching systems, is to polish the surfaces of the teeth to remove all the debris and eliminate any remaining extrinsic surface stains that have not been locked into the enamel lattices and dentinal tubules. In Figure 14-39, *A,* the right central incisor is slightly darker than the other anterior teeth, possibly because of earlier trauma or injury. It is likely to bleach less effectively than the adjacent teeth.

Any commercially available prophylaxis paste that does not contain fluoride can be used, but increasingly, remineralizing materials containing NovaMin are selected. The facial protective barrier is applied and then the cheek retractor is used to separate the maxillary and mandibular arches, displace the cheeks, and expose the upper and lower anterior teeth for bleaching. Next the gingival barrier is placed in a gel form and light cured to hardness such that it is retained on the tissue without adhesives; its physical shape and the undercuts of the gingival areas are adequate to retain the barrier in place throughout the entire bleaching process (Figure 14-39, *B*).

Cotton rolls may be applied in the mucosal folds to staunch salivary flow and to keep the operating area dry. A slow-speed suction should be at the ready in case excess saliva forms in the patient's mouth. The bleaching gel is first applied on the buccal surfaces of the teeth, and then the bleach-moistened gauze is placed over the first layer of gel (Figure 14-39, *C*). The bleaching material seeps through the gauze slowly. If it is necessary to add more bleaching material to thoroughly wet the gauze, gel is added on the outside surface of the gauze. The clinical image shows one gauze on the maxillary teeth and one on the



FIGURE 14-39 **A,** Pre-operative photographs show that the right central incisor is slightly darker than the other anterior teeth. It is likely to bleach less effectively than the other teeth in the arch. **B,** The patient's soft tissues are protected with a light-cured resin barrier. **C,** The bleaching gel is applied to the buccal surface of the maxillary and mandibular teeth, followed by placement of a bleach-moistened gauze over the teeth. Additional bleaching gel can be applied if necessary. **D,** A bleaching light is applied to the buccal surface of the teeth. **E,** The application of the bleach and the light is repeated at least three times. After the barrier and retractors have been removed and the teeth have been thoroughly rinsed, the teeth are significantly whiter. **F,** A close-up of the right central incisors shows the yellow stain before treatment. **G,** A close-up of the right central incisor after treatment. Although the stain remains, it is less prominent after the bleaching procedure.

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mandibular, whitening both arches simultaneously. If the gauzes begin to desiccate, additional gel is applied on the gauze surface. The bleaching gel penetrates the gauze and may ooze out in some areas. In other areas, the gauze has insufficient bleach beneath it to be completely wetted. In these areas, whitening material is added from the outside, either buccal or lingual, to ensure that the gauze is completely moist with bleaching gel.

Although the bleaching gel with the gauze should whiten the teeth effectively, some dentists, and in particular some patients, prefer to have the light-activated protocol used in addition to the chemical reaction of the bleach. The bleaching light is applied to the surface of the gel and the underlying gauze (Figure 14-39, *D*). The objective is to always have excess gel in close proximity to the tooth. The light activation liberates oxygen ions from the bleach product, breaking down the peroxide (H_2O_2) to water (H_2O) and oxygen ions (O^-). This allows the free oxygen ions or radicals that are close to the tooth surface to penetrate the semi-permeable surface of the enamel and dentin. Once inside the tooth structures, they break down the double bonds of the long-chain stain molecules. The smaller, shorter-chain stain molecules can then pass through the semi-permeable layer from the enamel and dentin into the oral cavity, where they are rinsed or washed away.

Many bleach activating lights are available. Some bleach manufacturers recommend proprietary lights, whereas others recommend generic light sources including composite curing lights. For the practitioner the most important clinical consideration is to ensure that the selected light source does not overheat vital teeth to the point at which painful in-treatment discomfort, post-treatment sensitivity, or permanent pulpal damage can occur. In the case shown in Figure 14-39, a curing light was used to activate the bleach. Approximately 1 minute of total light-activation time, delivered from the buccal, was judged necessary per tooth. To prevent excessive heat buildup in the teeth, the "wave" technique is recommended. A 20-second application of the activating light is delivered to one tooth. The operator then moves on to an adjacent tooth for a 20-second light activation, and so on, until the entire arch has been activated. Then the operator returns the light to the first tooth for the second 20-second session of light reactivation of the gel. By this time, the tooth has cooled down from the first activation, and over-heating is far less likely. With the "wave" technique the tooth is never allowed to heat up more than 1° to 2° C over its normal intra-oral temperature. Furthermore, the tip of the activating light is kept several millimeters away from the tooth, gel, and gingival surfaces (there should not be any actual physical contact). This prevents the hot tip of the activating light from thermally damaging either the soft or the hard tissues.

The entire process of applying the gauze and the bleaching gel (and optionally the activating light) should be repeated at least three times to constitute a single bleaching procedure or session.

After the bleaching is complete, the gauze is removed with college pliers and the remaining gel is wiped away with a wet gauze. Once is the remaining gel has been thoroughly eliminated, the gingival barrier can be removed. Then the cheek retractors are taken away, and the facial protection is lifted away. The patient rinses to eliminate any bleaching gel remaining between the teeth or around the soft tissues. The teeth are now significantly whiter than they were before treatment (Figure 14-39, *E*). Some fall-back in tooth coloration can be expected to occur over the next 1 to 2 weeks (mostly caused by surface rehydration, not re-staining). The in-office procedure is typically a multi-appointment procedure encompassing two or three sessions, with home bleaching as a highly recommended course of therapy between in-office sessions. This combined in-office and at-home regimen offers the best and longest-lasting tooth-whitening results.

The right central incisor has remained somewhat yellower than the other teeth (Figure 14-39, *F* and *G*). Although it is less dark than before, it is still less bleached than the adjacent teeth. Previous trauma or injury likely caused a narrowing of the pulp chamber to make this tooth somewhat darker than the others. It is generally accepted that trauma can cause internal bleeding and circulatory damage within the pulp chamber. Bilirubin deposits from the damaged blood vessels are secreted in various layers of the tooth structure. As the bilirubin ages, it becomes yellower and/or browner, giving the entire tooth a somewhat darker tinge. These bilirubin stains can be removed, but the process may be difficult or impossible in many cases. In these situations, bleaching is not an adequate approach and veneers or crowns are indicated.

Before bleaching, the incisal composite restoration on the left central incisor was relatively well color matched to the remainder of the tooth (despite the visible margin). After bleaching, the restoration is far less color matched and has become an esthetic liability. Thus it is important to note that patients who have visible, but color-matched, anterior restorations must be warned that these restorations are likely to require replacement after bleaching to match the whitened coloration of the teeth. Typically the replacement of old restorations should not commence until at least 1 to 2 weeks after the bleaching procedure has been completed; the variable fall-back (to darker coloration with in-office procedures) or continuation (to whiter coloration with at-home procedures) that occurs after the end of the bleaching treatment is rather unpredictable. These post-treatment color changes often alter tooth shade significantly in the days immediately after bleaching. After about 2 weeks, the rehydration or de-staining of the teeth is complete, and tooth coloration becomes quite stable, changing only as a direct result of normal intra-oral staining.

In-Office Tooth Whitening to Remove White or Dark Mottling

One of the common complaints reported to dental professionals is white or brown mottling: splotches that mar the esthetic harmony of the anterior teeth. These spots may result from malformation, developmental discoloration, excessive consumption of fluoride during enamel formation, secondary to orthodontics, or poor oral hygiene. In all cases the treatment approach is the same. For post-orthodontic patients, it is essential that the dentist be certain that *all* residual composite adhesive materials and bonding agents have been removed from the tooth surface. The residual bracket adhesive resin (Figure 14-40, *A*) is often

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FIGURE 14-40 **A,** A post-orthodontic patient with residual adhesive material that has stained. This staining can be mistaken for brown mottling. **B to D,** Patient has generalized brown and white mottling of the maxillary and mandibular teeth. **E to G,** All maxillary and mandibular anterior teeth are treated with Opalustre. **H,** The teeth are polished with the custom-designed OpalCup. This is a prophy cup with bristle brushes in the polishing concavity. **I,** The Opalustre is polished to an even layer on all the teeth to be treated. **J and K,** The teeth are rinsed. **L,** After a through rinsing, the initial de-staining of the buccal surfaces can be seen. De-staining and color blending may require five or more separate Opalustre treatment steps. Operator patience is an asset during this procedure. **M to P,** Initial post-treatment photographs show that the teeth have whitened and the mottling has been diminished. **Q,** After two more in-office treatment appointments, significant de-staining and de-mottling can be seen. White mottling on the laterals, cuspids, and lower incisors is still present. **R,** After four in-office treatments, final post-treatment photographs show a whiter and less mottled smile. The patient is pleased with the esthetic result.

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stained, appearing darker than the surrounding enamel, and can be mistaken for brown mottling.

The patient in Figure 14-40 exhibited a generalized brown and white mottling of the teeth. The occurrence of *both* white and brown mottling presents the greatest de-staining challenge to the dentist. The patient had initially considered having porcelain veneer coverage of the anterior 10 maxillary teeth to improve her smile. However, since the teeth had excellent shape and proportion and the patient was under 20 years of age, it was decided to approach the situation as conservatively as possible. While keeping the porcelain veneer modality in reserve, the treatment plan commenced with a more conservative bleaching approach to determine if de-staining alone could achieve the esthetic results that the patient desired.

The mottling of the teeth, both brown and white, is quite evident both in photographs and in the smile (Figure 14-40, *B* to *D*). The dark margins of the brown discolorations indicate earlier unsuccessful attempts to bond over the stained areas. Although the patient did not remember having bonding procedures on the buccal surfaces of the central incisors, it is clinically obvious that this approach was tried. The resin material was removed very conservatively with a slow-speed round carbide bur, at less than 1000 rpm, and the bleaching procedure begun.

Opalustre bleaching (Ultradent Products, Inc.) material is applied to the teeth (Figure 14-40, *E*). A small dab of the bleach is dispensed on the central part of the buccal surface. This material is designed for chemical and mechanical enamel abrasion. It consists of a slurry that contains 6.6% hydrochloric acid (HCl) and silicon carbide micro-particles in a water-soluble paste. It is readily syringable for accurately positioned application to the specific target locations on the teeth. The manufacturer recommends that a rubber dam be in place prior to the application of Opalustre. Although this is certainly a prudent course of action, it has not been found necessary in clinical practice. The cheek retractor is used to pull the lips and cheeks well away from the bleaching operative area. The lips are protected by cotton rolls inserted into the mucogingival folds to position the soft tissues away from the teeth. The Opalustre is applied over the entire buccal surfaces of the teeth that are to be de-stained, and specifically to those areas that are mottled brown or white.

The Opalustre slurry is applied to both the maxillary and the mandibular teeth as indicated. The bulk of the material is applied directly the areas of mottling and is designed to be polished from these areas onto the remaining tooth surface. Note that the tongue extension of the cheek retractor keeps the tongue away from the potentially irritating materials that are used to bleach the teeth. The retractor also keeps the patient from licking their teeth. It is a good idea to have slow-speed suction in place at this stage to remove any excess saliva that may form in the patient's mouth.

All the maxillary and mandibular anterior teeth that are visible in the smile are to be treated with Opalustre (Figure 14-40, *F* and *G*). The permeation of the Opalustre slurry into the tooth surface is accomplished with the custom-designed OpalCup (Figure 14-40, *H*). OpalCups are prophy cups with bristle brushes in their polishing concavity. They were developed to work the bleaching material into the tooth surface more effectively in order to achieve a more rapid and more effective de-staining. The Opalustre is prophied into the buccal tooth surface with the OpalCup at a *very low speed.* The slower rotation of the OpalCup is best achieved with a gear reduction slow speed handpiece. The Opalustre is prophied into the buccal surface of every anterior tooth (and the lingual and proximal surfaces if they are accessible). The bleaching material is worked into the entire buccal surface but with a particular focus on the mottled areas. Care must be taken not to heat the tooth. Although the polishing of a tooth may last up to a total of 60 seconds, it is advisable to separate this time into 15-second segments with a "wave" technique. After one tooth has been polished for 15 seconds, the operator then moves to the adjacent tooth. When the entire arch is completed, the operator returns to the first tooth for another 15 seconds; this sequence continues repeatedly until 1 minute of polishing has been completed for each tooth. This allows the tooth to remain cool throughout the treatment (shorter polishing sessions) and to cool between consecutive 15-second sessions. The Opalustre paste is polished to a more evenly distributed layer on the teeth (Figure 14-40, *I*). The slurry may inadvertently be sprayed onto the gingiva; this has never caused any gingival irritations or burns, and has never been a concern in past treatments.

The operator has the option of leaving the Opalustre slurry on the teeth for a number of minutes to intensify the decoloration, or rinsing as soon as the prophylaxis is complete.

The teeth are rinsed as shown in Figure 14-40, *J.* It is not a problem if some of the Opalustre or the rinsed Opalustre happens to be sprayed onto the gingiva. However, it is good practice to completely eliminate the bleaching material from the mouth with a thorough rinsing. It might be necessary at this stage to replace the cotton rolls if they have become wet with saliva or water, but it is important to keep the cheek retractor in place.

In Figure 14-40, *K,* additional rinsing has washed most of the Opalustre from the surfaces of the teeth. Although this is only an intermediate stage, the de-staining of the buccal tooth surfaces can be readily seen.

The Opalustre de-staining process is a gradual one. Whereas some teeth may be more affected than others, it is often found that there is little evidence of de-mottling after the first, second, or even third Opalustre application. It is important not to be discouraged at this stage. The nature of the Opalustre is such that a certain critical level of tooth surface oxygenation must be attained before the dental appearance actually begin to improve. De-staining and color blending may occur after a single application of Opalustre (Figure 14-40, *L*) or it may take five or more separate treatment steps, but invariably it does occur at some point. Operator patience is definitely an asset.

In the course of treatment the teeth have become de-stained and de-mottled but there is now a small thin layer of stained composite that is still present (Figure 14-40, *M* to *P*). Because the Opalustre cannot be expected to de-stain the adhesive resin, this composite must be very gently removed. The best method

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for eliminating this residual resin material is to abrade it with a fine round diamond or carbide bur, removing the stained composite, layer by layer, very gently and without any anesthetic. The most predictable method for differentiating between healthy enamel and composite resin is to dry the tooth surface and to observe the differing levels of glossiness in the two materials. Composite typically appears more matte, whereas enamel is more glossy. If there is any doubt as to whether the surface material is enamel or composite, it should be left until after the next application of Opalustre. The surface differences between composite and enamel are magnified by bleaching, allowing the practitioner to remove the restorative material with greater confidence.

The Opalustre was rinsed and re-applied to the teeth five separate times, with the process repeated exactly as shown. Each application step, or pass, takes about 10 minutes, and the appointment should be scheduled accordingly.

It is very difficult to estimate in advance how many bleaching passes will be required for any particular case. Patients are generally informed that the bleaching passes will be repeated until they are satisfied with the color of their teeth (with a limit of five to eight passes per appointment). The teeth can nearly always be made whiter. The underlying question is the patient's personal tooth coloration goal. There is always a convergence point at which the patient's desire for whiter teeth is balanced by his or her willingness to pay for additional bleaching. The Opalustre procedure does not damage the teeth or the tooth surfaces; thus from a dental perspective it can be considered a strictly cosmetic treatment and continued until the patient is satisfied.

After every Opalustre treatment session, whether it involves one, five, or up to eight applications in a single appointment, a fluoride application is advantageous. Ultradent recommends Flor-Opal Varnish, a 5% sodium fluoride compound. Fluorides can be used, but some are more suitable than others. Stannous fluorides can often cause tooth coloration to regress somewhat into the darker shades; acidulated phosphate fluorides cause tooth sensitivity and may etch the enamel and dentin surfaces, leaving them susceptible to rapid re-staining.

The patient is seen after two in-office appointments (Figure 14-40, *Q*). Significant de-staining of the centrals has been achieved, but the white mottling of the laterals, cuspids, and lower incisors is still present. The patient elected to continue with the treatment to better blend the colors and to achieve a more esthetic result.

For this particular patient the process was long but not arduous. While the treatment involved several chair-hours for the patient, there was no discomfort at any stage and no anesthesia was required at any time. The mottling was stubborn, with the white mottling even more difficult to eliminate than the brown. It took four appointments to achieve an esthetically acceptable result that left the patient in her esthetic comfort zone (Figure 14-40, *R*). This end point will vary for every patient. It is difficult, if not impossible, to accurately predict, in advance, the number of treatment sessions that will be required for the de-staining process.

It can be expected that in-office bleached teeth will experience some fall-back in coloration (owing to rehydration) over the next 1 to 2 weeks unless at-home bleaching is provided concurrently with the in-office procedure. Therefore the patient was asked to use a home bleaching regimen between scheduled appointments to prevent the in-office whitening results from falling back in the interim.

Most important, the procedure is ultraconservative. There was no removal of tooth structure and no damage to the dentin, enamel, or soft tissues. When selecting the ideal esthetic technique, the most conservative one is always the best choice.

EVIDENCE-BASED PRINCIPLES

A large body of evidence-based scientific data is available to support both the safety and the efficacy of bleaching. Bleaching actually works on the basis of dissolving long-chain stain molecules within the enamel and the dentin. Short-chain stain molecules enter the enamel lattices and dentinal surfaces, where they join with double bonds to form longer-chain molecules, which are not easily dislodged. Over time the buildup of long-chain stain molecule formation within the enamel and dentin makes the tooth appear darker.

Figure 14-41 shows a stylized cross-section of the whiter enamel, yellower dentin, and reddish pulp. Each stylized dental component is representative of the tooth structures in the human mouth. There is a micro-porous semi-permeable barrier at the enamel and dentin surface that can be permeated by small liquid molecules from both sides—the oral cavity and the enamel and dentin of the tooth. *Semi-permeable* implies that stain molecules can readily be exchanged between the oral cavity and the enamel and dentin. The passage of these liquid stain molecules is limited only by their size; molecules that are smaller than the porosities can pass through, whereas molecules that are larger cannot.

Staining liquids originate from sources outside of the mouth: food, drinks, or other materials that the patient consumes or places into the mouth (Figure 14-42). The staining liquids typically consist of smaller molecules that are readily able to pass through the semi-permeable membrane and enter the enamel and the dentin (Figure 14-43). Stains may flow back and forth through the membrane. Larger-molecule stains are kept out by the semi-permeable membrane because they are too large to fit through the porosities. Inside the enamel lattices and the dentin (dentinal tubules and intertubular dentin), the smaller stain molecules tend to polymerize by forming double bonds with other small stain molecules, becoming longer-chain stain molecules (Figure 14-44). In both the enamel and the dentin, these larger, longer-chain stain molecules are too big to exit through the semi-permeable membrane porosities and remain trapped within the tooth (Figure 14-45).With time, the stain builds up in both the enamel and the dentin, making the tooth structures appear progressively darker.

The stains in the enamel and dentin can be treated with a variety of bleaching materials. The most common treatment modalities include hydrogen peroxide and carbamide peroxide.

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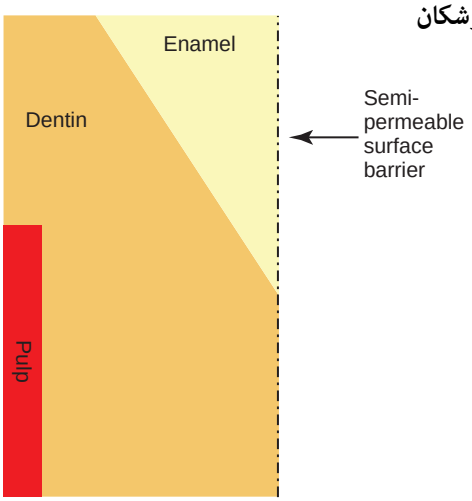


FIGURE 14-41 Stylized cross-section of tooth structure showing white-yellow enamel, yellower dentin, and reddish pulp. The semi-permeable layer that exists at the enamel and dentin surfaces can allow the absorption of very small liquid stain molecules.

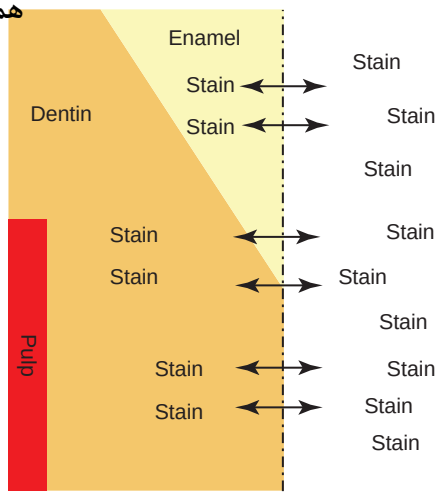


FIGURE 14-43 Staining liquids typically consist of smaller molecules that can pass through the semi-permeable membrane. Stains may flow back and forth through the membrane.

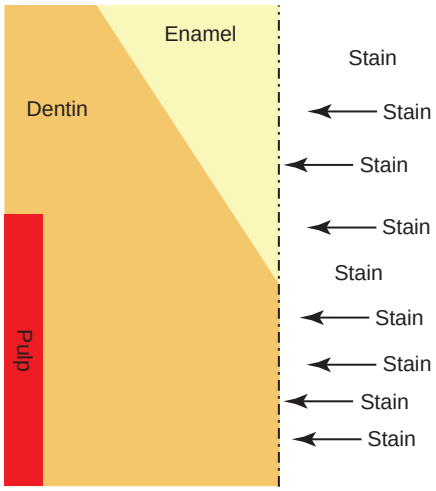


FIGURE 14-42 Staining liquids originate from food, drink, or other materials that are placed in the mouth.

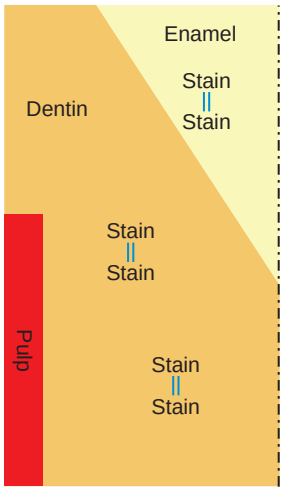


FIGURE 14-44 Once inside the enamel and dentin, the smaller stain molecules tend to form double bonds, becoming longer-chain molecules.

Carbamide peroxide is a buffered form of hydrogen peroxide that is less caustic to soft tissues but also liberates significantly less whitening ionic oxygen at the tooth surface. Carbamide peroxide is applied to the tooth surface in a tray delivery format (Figure 14-46). This buffered bleaching material breaks down quickly into its components, carbamide and peroxide (Figure 14-47). Carbamide is a common dietary product that is routinely encountered by the digestive system in the consumption of meats, nuts, beans, and other protein foodstuffs. It passes through the human alimentary system without any ill effects, with the exception of occasionally increasing flatulence. In turn, the peroxide breaks down into molecular water and oxygen ions (Figure 14-48). Water, of course, is the most abundant single chemical in the human body and is readily processed by the digestive system. Thus, carbamide peroxide, the active bleaching agent, is quickly reduced in the oral cavity to its constituents: carbamide, water, and oxygen. The first two byproducts (carbamide and water) pass through the alimentary system quite naturally and without harm or irritation, leaving the oxygen ions in close proximity to the tooth surfaces (Figure 14-49). There are, ideally, vast numbers of oxygen ions remaining from the breakdown of the peroxide in the vicinity of the tooth. These oxygen ions can attach to one another to form oxygen molecules, escape into the oral cavity, or percolate into the tooth structures (enamel and dentin) through the semi-permeable membrane. In order to increase the likelihood of the latter option, a tray or

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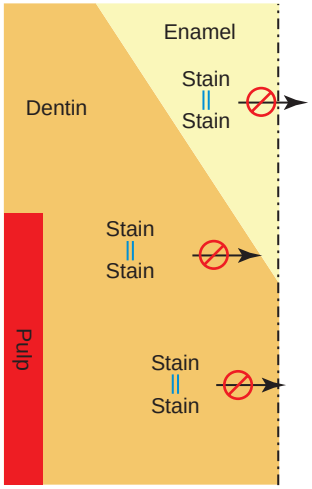


FIGURE 14-45 The longer-chain stain molecules are now too big to exit through the semi-permeable membrane and remain trapped in the tooth, causing the teeth to look yellower and darker.

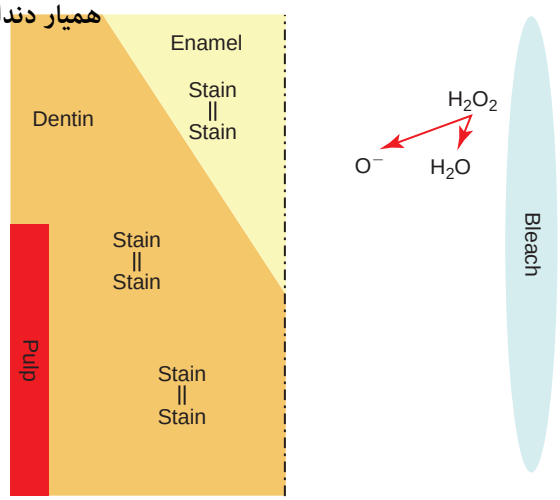


FIGURE 14-48 The peroxide breaks down into water molecules and oxygen ions.

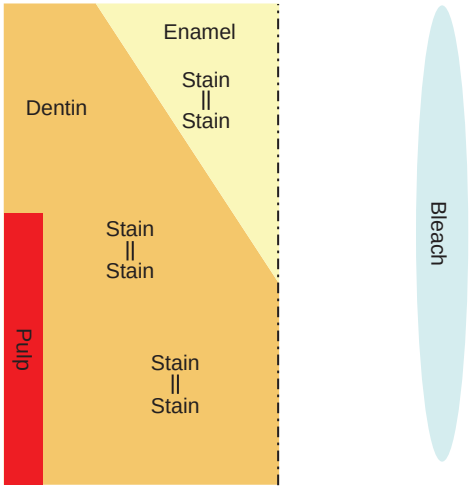


FIGURE 14-46 Bleaching material is applied to the tooth surface.

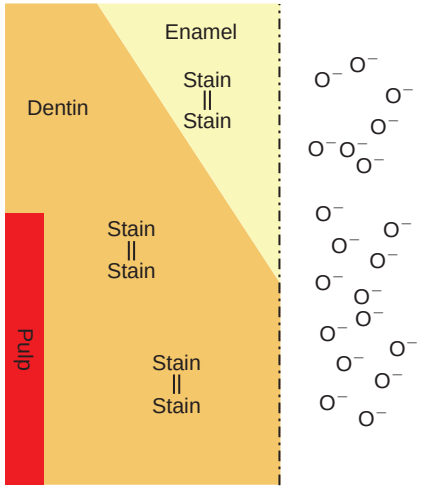


FIGURE 14-49 The carbamide and water pass through the human alimentary system without any ill effects, leaving oxygen ions in close proximity to the tooth surface.

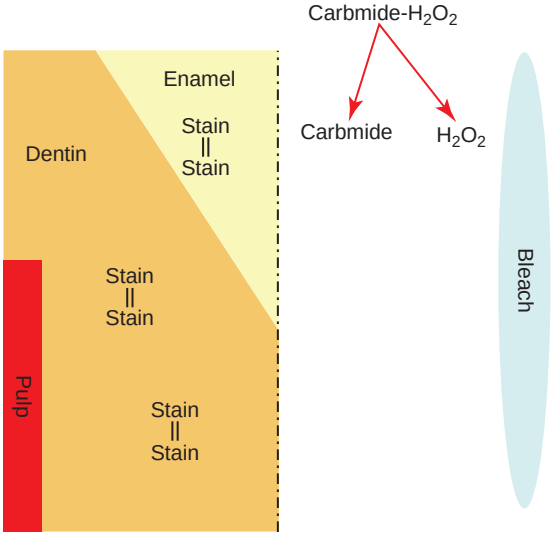


FIGURE 14-47 The buffered bleaching material breaks down into its components, carbamide and peroxide.

similar containment device is used to keep the bleach and the liberated oxygen ions close to the tooth surface (Figure 14-50). The bleaching tray prevents the ions from escaping and positions them in close proximity to the tooth surface to maximize the de-staining result.

When the liberated oxygen ions are contained effectively and forced into the tooth surface rather than being allowed to escape into the oral cavity, they tend to penetrate the enamel, dentin, and pulp within 5 to 15 minutes (Figure 14-51). The oxygen ions do not have any deleterious effects on any of these structures, including the pulp. They can, however, destroy the double bonds that have grown the stain molecules so large that they cannot escape through the semi-permeable membrane.

The oxygen ions attack the double bonds of the long-chain stain molecules (Figure 14-52) and break the bonds, reducing the stains into their original shorter constituents (Figure 14-53).

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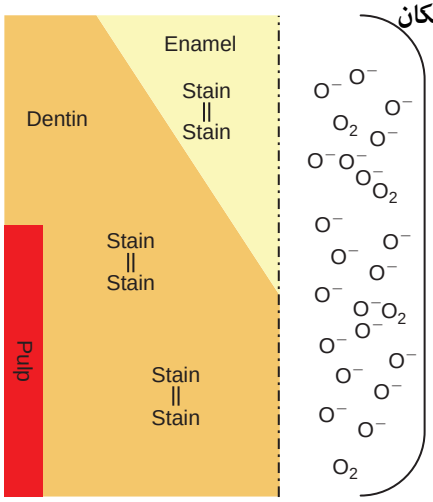


FIGURE 14-50 The oxygen ions can join together to form oxygen molecules or remain as free oxygen ion radicals. The use of a bleaching tray or similar containment device keeps the bleach and the released oxygen ions in close proximity to the tooth surface.

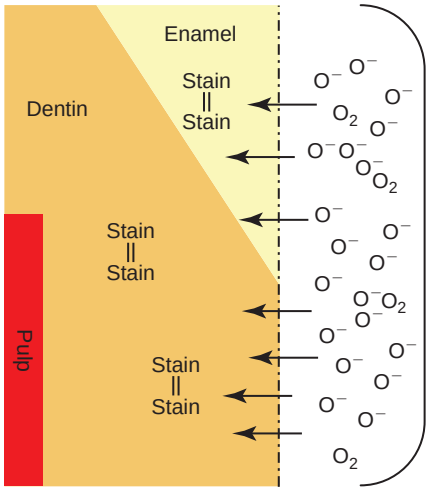


FIGURE 14-51 Effectively contained oxygen ions are forced into the tooth surface to penetrate the enamel and the dentin as well as the pulp.

The elimination of the double bonds shortens the stain molecules to their original sizes, such that they can again pass through the semi-permeable membrane at the tooth surface. This allows the stains molecules to exit the enamel and dentin into the oral cavity (Figure 14-54). Within a short period, typically days, most of the stain has left the tooth structures (Figure 14-55).

The tray is removed after each treatment session and the teeth are rinsed with water (Figure 14-56). The patient should be encouraged to brush and floss to remove the remaining stain molecules and to maintain the whiter smile (Figure 14-57).

The tooth appears less dark because the double-bonded long-chain stain molecules are no longer present in the enamel or the dentin. After bleaching, both the enamel and the dentin are less

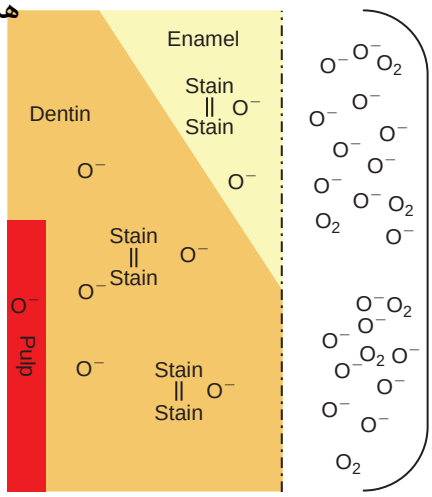


FIGURE 14-52 The oxygen ions attack the double bonds of the long-chain stain molecules.

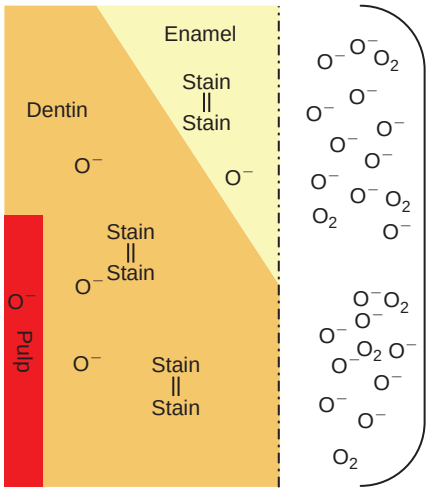


FIGURE 14-53 The double bonds are broken by the oxygen ion radicals, and the stains are returned to their original shorter components.

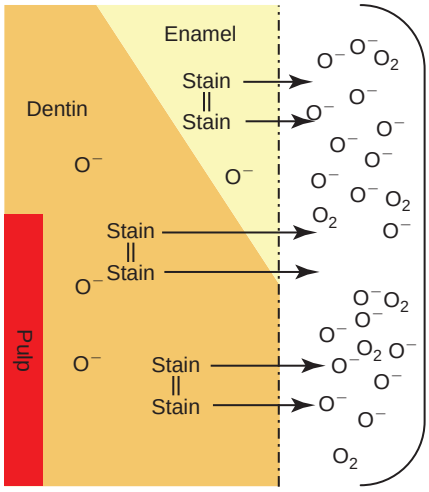


FIGURE 14-54 The shorter stain molecules can now again pass through the semi-permeable membrane and exit from the enamel and dentin into the oral cavity.

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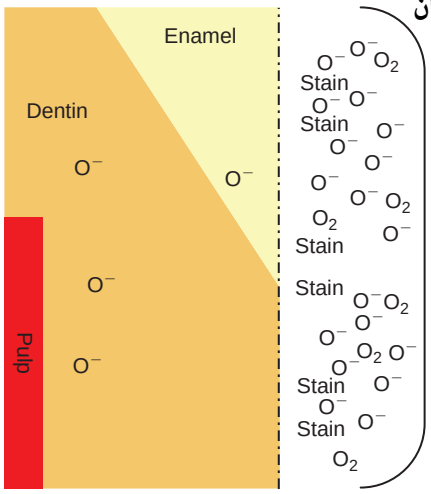


FIGURE 14-55 Within a short period of time, most of the stain has left the tooth structures.

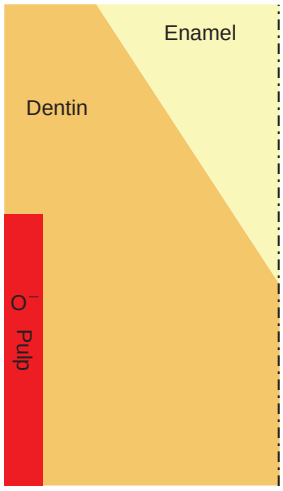


FIGURE 14-57 Brushing and flossing are encouraged to maintain the teeth at their whitest.

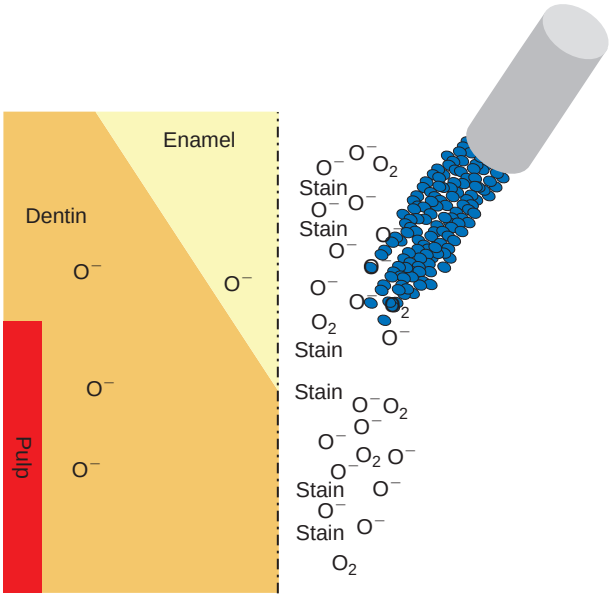


FIGURE 14-56 The tray is removed, and the teeth are rinsed with water, eliminating the stain molecules from the oral cavity.

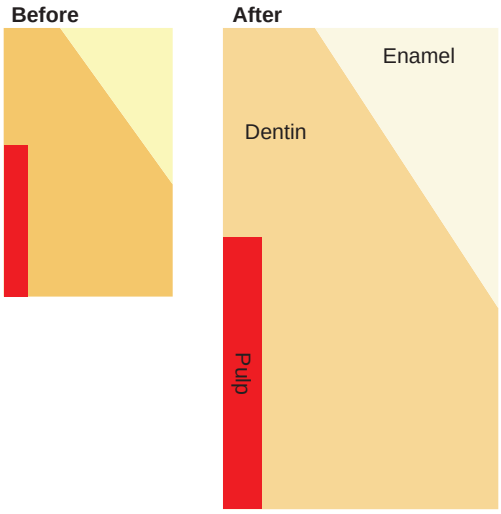


FIGURE 14-58 Both the enamel and dentin have been whitened. The pulp is unaffected.

discolored than they were before (Figure 14-58), as confirmed by many clinical studies.

CONSERVATION CONCEPTS

Tooth whitening or bleaching is simply the most conservative procedure that is available to the dental profession. De-staining of the teeth is even less abrasive than routine prophylaxis and scaling. There is no loss of tooth structure, dentin, or enamel and no weakening of the surfaces if appropriate materials are used according to instructions. Numerous studies have confirmed that there is no demineralization of the enamel or the dentin during tooth whitening or thereafter.

The process of bleaching is conservative because it does not act on tooth structures; the process is specifically targeted to the double bonds of long-chain stain molecules that have taken up residence inside tooth structures. The oxygen ions released by bleaching techniques attack these double bonds, breaking down the long-chain stain molecules. The shorter stain components dissolve into the oral fluids and are carried away from the tooth during normal masticatory function and cleansing.

The conservative and successful nature of tooth bleaching, combined with the widespread public awareness of the procedure, creates a demand for further restorative and reparative conservative procedures in the minds of patients and professionals alike. Tooth whitening has set a high standard: it provides a great change in the patient's smile with no impact or ill effects on the hard and soft tissue structures of the mouth. This has now become the stated goal of all restorative dentistry. Of course, it is not always possible to be quite this conservative, but

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certainly the focus of dentistry has shifted from surgical intervention to prevention, minimal intervention, and healing.

More specifically, in the dental practice a patient's dental bleaching experience leads to increased dental awareness, increased dental health motivation, and increased consumption of minimally invasive services such as adhesive restorations, veneers, and conservative crowns and onlays.

The currently popular bleaching techniques were introduced to the dental profession concurrently with glass ionomer restorative materials and predictable resin-adhesive restorations. Together, these innovations have transformed the dental practice and the public perception of dentistry. They have also revolutionized patients' perceptions of their own smiles and the profession that is responsible for transforming appearances.

It is not a coincidence that the last two decades have been the most productive and exciting in the history of the dental profession.

MAINTENANCE

The basic question of maintaining the bleached appearance of the smile presents an interesting dilemma. Patients often ask how they can keep their teeth white. The answer is relatively simple: avoid eating and/or drinking foods that have the potential to stain. Unfortunately, virtually all foods contain chromogenic molecules that can migrate into the enamel and dentin, thereby staining them. In fact, both patients and dentists recognize that staining is a normal side effect of living and aging. There are certain food consumption patterns that can be modified, but few can be eliminated. Asking patients to avoid stain-inducing foods and beverages is impractical and unlikely to be successful.

In recognition of this fact, patients should be encouraged and motivated to brush regularly, floss their teeth daily, and return to the practice for routine prophylaxis and scaling two to four times a year. Even those patients who are quite fastidious in their oral health maintenance are likely to exhibit staining over time. It is important to identify and to warn against foods that have the greatest staining potential. These dietary components vary by region and by diet. For example, blueberries are known to impart a very dark stain to the teeth, as are red wine, curries, colas, and soy-based sauces, among a multitude of other foods. The stain tends to vary in direct proportion to the staining potential of chromogenic food and its quantity. Even tinted mouth rinses have been implicated in tooth staining. The dental team should suggest that patients rinse their mouths thoroughly after consumption of these products, if at all possible. The immediate dissolution of the stains combined with habitual home care and regularly scheduled professional cleaning should be enough to keep the teeth relatively free of stain.

It has been observed that bleaching effects regress over time. It is not the bleaching effect that changes, but simply the dietary and habit-induced staining that is undoing the whiteness of the teeth. For many individuals, re-staining can take years, but for some, particularly heavy drinkers of red wine and smokers, the esthetic benefits of bleaching can diminish rather quickly. Fortunately, bleaching touch-ups are easily accomplished. There is no contraindication to re-bleaching teeth, and there is no minimal waiting time before additional whitening procedures can be initiated. Thus when the patient or the dental team notes that the color of the teeth is beginning to regress, it is a simple matter to touch up the results.

Fortuitously, the touch-up process is less time-consuming than the initial whitening procedure. For an at-home bleaching treatment that initially took 2 to 4 weeks, the touch-up may involve a mere 1 or 2 nights of wearing a bleaching tray. For in-office bleaching, a touch-up can involve a single 15-minute chairside application of the bleach, or the wearing of a bleaching strip to revitalize the whiteness of the teeth.

Alternatively, there are specifically designed, easy-to-use, over-the-counter materials such as SuperSmile Quikee (Figure 14-59, *A*) (Robell Research, Supersmile, New York) that can be applied directly to the anterior teeth by the patient to de-stain the anterior teeth. Quikee specifically targets the stain accumulated over the course of a meal. It is not always practical or possible to brush one's teeth, or even to carry around a toothbrush outside of the home. The Quikee tube is small and easy to open unobtrusively (Figure 14-59, *B*). A small dab of the Quikee paste is applied to the teeth (Figure 14-59, *C*) and innocuously spread over the anterior teeth by the tongue (Figure 14-59, *D*). The peroxide in the Quikee eliminates the meal stain and brightens the teeth in moments (Figure 14-59, *E*). The Quikee tube can be quietly slipped into a pocket (Figure 14-59, *F*). Teeth have never looked so good after a staining meal.

Many people like to chew gum. It is important that these products not contain sugars that attract and feed bacteria, leading to acidulation at the tooth surface. Numerous chewing gum products are safe; in fact, some have beneficial effects on the dentition. There are even tooth-whitening chewing gums available. Supersmile Professional Whitening Gum (Figure 14-60, *A*) packets contain two pieces of gum. The gum tablet can be unobtrusively inserted into the mouth (Figure 14-60, *B*), where the beneficial sugar-free effects of the gum are combined with the peroxide-releasing chemistry to maintain or even enhance tooth coloration (Figure 14-60, *C*).

The overriding guiding principle of maintaining tooth whiteness is that re-staining cannot be avoided, but the re-bleaching or touch-up process is simple, quick, and effective.

CONTROVERSIES

The earliest recent bleaching controversies (1990s) centered on the introduction of the at-home bleaching systems. Naturally, the manufacturers and proponents of the in-office heat-mediated bleaching then in vogue reacted negatively to the newer, more patient-friendly techniques. The claims that at-home bleaching materials were dangerous, ineffective, and possibly carcinogenic were known to be spurious given the extensive existing research and documentation but were disseminated anyway.

The last claim specifically targeted one of the most likely consumer groups for at-home tooth whitening: smokers. It is also important to note that the segment of the population that

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FIGURE 14-59 **A, Over-the-counter de-staining material Quikee SuperSmile. B, Quikee is packaged in a small, easy-to-open tube. C, Quikee is applied directly to the teeth after a staining meal. D, Quikee material is spread over the teeth with the tongue. E, Food stains are quickly and easily eliminated. F, The Quikee tube is easily returned to a pocket or purse.** *(A, Courtesy Robell Research Inc. [SuperSmile], New York, New York.)*



FIGURE 14-60 **A, Supersmile Professional Whitening Gum packets each contain two pieces of gum (Robell Research Inc., New York, New York). B, Many people are regular gum chewers. C, The sugar-free effects of the gum combined with the peroxide-releasing chemistry maintain and even enhance tooth coloration.**

smoked at that time was much greater than it is today. In retrospect, none of these claims were evidence or observation based, and none turned out to be relevant.

At-home bleaching materials are actually quite unique in that they were used intra-orally to treat conditions other than stained teeth for more than 50 years, and their safety was established, well researched, and documented.

Since the introduction of at-home tooth bleaching, several hundreds of millions of cases have been documented worldwide. No ill effects have been reported with professionally delivered bleaching and with the proper use of direct-to-patient products. Eventually the weight of clinical evidence eliminated most bleaching controversies.

One problem that often arises in the practice is how to treat very young or very old patients who are interested in bleaching. The active ingredients are safe at any age. In fact, neonates have been treated with carbamide peroxide for candidiasis. Thus, in theory, bleaching the teeth immediately after eruption is not contraindicated. However, unless there are exceptional circumstances, there is little reason to consider bleaching the deciduous dentition or the permanent dentition until at least the mid-teen years. Bleaching products do not contain any components that interfere with the medications or health conditions of older patients, although this should always be individually confirmed. The other issues with bleaching at a very early or very advanced age are the patient's tolerance for the intra-oral trays and the length of the bleaching procedure. The dentist must also consider the age of the young patient and evaluate whether the desire for whiter teeth is realistic in the context of the patient's age. Children under 6 years of age are not likely to be affected by the color of their teeth because they do not readily identify a self-image. Teens, on the other hand, are extremely self-conscious. It is up to the dental team and the parents to balance the normal and reasonable color of the dentition with the teen patient's desire to improve his or her perceived appearance. In this age group, there are physiological and psychological forces at play, and the judgment of the practitioner is paramount.

Surprisingly, some dental professionals still question the role of tooth whitening in dentistry. Many dentists are focused on function as the most important dental parameter. Bleaching, of course, has no effect or role in function, but bleaching is the basis for the smile. It can restore or develop the patient's confidence and self-esteem. An improved smile can have a major impact on the psychological mindset of an individual, and an engaging smile has been shown to have a dramatically positive effect on an individual's personal life, relationships, career development, and success. If the dentist can improve the patient's life in so many areas with a non-invasive, non-harmful procedure,

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does this not become the dental profession's responsibility? It must be added that no other profession is licensed or able to treat the dentition, and the dental team is by far the best equipped to provide this treatment from diagnostics to treatment planning to treatment delivery and to post-treatment maintenance.

Tooth whitening is a treatment that falls squarely within the scope of the dental practice, and every dentist should be familiar with various procedures that can be used, the available materials, and the benefits that can be afforded to patients.

NEAR-FUTURE DEVELOPMENTS

Bleaching has always been more popular with patients than with the profession. The past two decades have seen a regular progression of the bleaching process; it has become easier and faster. Recent significant developments have included the elimination of the need for the dental auxiliary to fabricate a custom tray in the practice. Procter & Gamble's Crest 3D White Whitestrips (Figure 14-61) and Ultradent Opalescence Trèswhite (see Figure 14-13) have led the field. The Whitestrips are simply adhered to the teeth by the patient, and the Opalescence Trèswhite system uses a pre-loaded, pre-fabricated tray system.

There has been a tendency to increase the percentage of carbamide peroxide and hydrogen peroxide in bleaching agents



FIGURE 14-61 Crest 3D White Whitestrips have led the market in over-the-counter bleaching products.



FIGURE 14-62 A, Peroxide activating rods have begun to appear on both professional and over-the-counter markets (Pictured: Supersmile Professional Activating Rods). B, Opening of the activating rod package. C, The capsule is broken. D, The swab is inserted, allowing the activating agent to wet the cotton tip. E, The swab is fully inserted when the cotton tip is thoroughly wetted. F, The peroxide is applied directly to the tooth surface. G, These activating rods are often used in conjunction with a whitening toothpaste system. (Pictured: Supersmile Professional Whitening Toothpaste system. *A and G, Courtesy Robell Research Inc. [SuperSmile], New York, New York.)*

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FIGURE 14-63 **A, Severe tetracycline staining. B, Treatment plan for this case included continuous home bleaching and regularly scheduled in-office procedures every 6 weeks. C, Three months into the treatment, there is obvious tooth color change. D, At 9 months of treatment, the patient is satisfied with the esthetic result of the bleaching treatment.**

to speed the whitening process. The additional oxygen ions function as desired, but the side effect is increased sensitivity. Various buffering agents have been introduced to decrease or eliminate this post-treatment discomfort. These buffers have improved with time, and within the next 10 years should be perfected to a point where rapid tooth bleaching can be initiated without any concern for sensitivity, whether during or after treatment.

A number of paint-on bleaching products have appeared. These "bleaching pens" are best used for a single discolored tooth. The user has to be careful, of course, not to touch the bleached area with the tongue, lips, or teeth in order to avoid peroxide soft tissue burns.

Peroxide activating rods have begun to appear at both the professional and the over-the-counter levels (Figure 14-62, *A*). Simply open the product (Figure 14-62, *B*), break the capsule (Figure 14-62, *C*), and insert the swab (Figure 14-62, *D*) until the bleaching liquid thoroughly wets the cotton tip (Figure 14-62, *E*). These rods dispense various levels of peroxide directly onto selected teeth (Figure 14-62, *F*). They are often used concurrently with a whitening toothpaste system (Figure 14-62, *G*). The immediate results can be significant, particularly considering that there is no tooth desiccation possible in such a brief period of time.

Tetracycline, medication, and metal stains can be treated more predictably than in the past. The treatment process for these cases is often long, sometimes lasting a full year, and involves many sessions. On the positive side, treatment for these disfiguring conditions is at last possible. In the case shown in Figure 14-63, *A,* the teeth were severely stained by tetracycline at an early age. The treatment plan for the maxillary teeth included continuous at-home bleaching and regularly scheduled in-office procedures every 6 weeks. The improvement is obvious at 3 months (Figure 14-63, *B*) and is more pronounced at 6 months (Figure 14-63, *C*) and finally at 9 months (Figure 14-63, *D*). The patient was satisfied with the maxillary coloration and ready to begin the mandibular teeth. In most cases, the maxillary and mandibular teeth are treated simultaneously.

The profession is likely to see expansion of these concepts as well as combinations of various delivery formats that improve the bleaching process over the next few years. The inexorable process of research and development in dentistry assures the profession that future bleaching procedures will be better, faster, and easier.

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B SECTION

Innovative Elements from a Scientific or Technological Perspective that Have Appeared in Bleaching over the Past Decade

Robert W. Gerlach

RELEVANCE OF BLEACHING TO ESTHETIC DENTISTRY

Bleaching, now commonly referred to as *tooth whitening,* is the most popular of the esthetic dental procedures. *Whitening is broadly applicable with few contraindications* and represents perhaps the least invasive procedure in dentistry. Because it is typically one of the first cosmetic procedures accessed by dental patients, it is directly relevant as a useful introduction to the broader field of esthetic dentistry.

Tooth whitening can influence patient demand for additional dental services, whether esthetic or restorative. In fact, tooth whitening is a major driver of interest in both general and esthetic dentistry. There is considerable evidence that where tooth whitening is advertised or promoted in the general media and there is broad access to tooth-whitening agents, access to and use of all types of esthetic dentistry have increased.

The recent introduction of the innovative easy-to-use products that have been heavily promoted in the mainstream media provides one such example. After the introduction of easy-to-use whitening strips in North America, tooth whitening emerged as the single most-asked common topic of patients to dentists, and one of the most requested dental procedures. This level of patient awareness and the linkage of beauty and health have contributed to demand for more definitive care after tooth whitening.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENTS AND EVOLUTION OF THE TOOTH-WHITENING PROCEDURE IN DENTISTRY

There is a long history of peroxide use in dentistry. Initial applications in tooth whitening were for non-vital bleaching, with different peroxide applications used over the past century to lighten the color of non-vital teeth. The introduction of whitening of vital teeth is a phenomenon that derives a heritage, in part, from clinical observation after use of peroxides in periodontal therapy to control plaque bacteria and reduce gingivitis. Although many techniques were proposed, some dentists used peroxide in mouth guards overnight for patients with persistent disease. Coincidentally, unanticipated tooth color changes were noticed as a side effect of treatment, and these observations ultimately contributed to the night guard vital bleaching technique.

This adaption of periodontal treatment explicitly to whiten teeth was the first breakthrough in vital tooth bleaching. First described in the literature in 1989, this technique involved use of a 10% carbamide peroxide gel in a custom tray overnight over several weeks for tooth whitening.[1] This custom-tray and peroxide gel approach was adapted to yield other dentist-dispensed whitening methods that could be readily accomplished by patients at-home. The second breakthrough was the introduction in 2001 of easy-to-use whitening strips. These strips, which carry a peroxide gel on one side only, are typically removed from a backing liner and then applied directly to the desired arch (Figure 14-64). This allowed broad application of a controlled peroxide dose over a short period of time under different settings than were available with the custom-tray night guard vital bleaching approach.[2]

A number of other products have been introduced and technologies developed. One area of particular focus has been techniques to improve the speed of whitening. Research and development are ongoing, but to date, few products have shown consistent promise, and none has risen to the level of popularity of the original custom trays or the more recent easy-to-use strips.

RELATING FUNCTION AND ESTHETICS

Whereas tooth whitening can be quite successful and may represent a useful early step in esthetic dentistry, it is not a proven solution for nonbehavioral function-related issues. Tooth whitening per se directly improves appearance and indirectly improves patient motivation, interest, and acceptance of esthetic and other dental procedures. If the patient has functional issues that are not strictly behaviorally related, tooth whitening may not be appropriate because it will likely neither promote nor degrade functional situations.

Tooth whitening could play a potential role in behavioral function–related issues. For example, numerous case studies illustrate how white teeth can favorably affect both first-person

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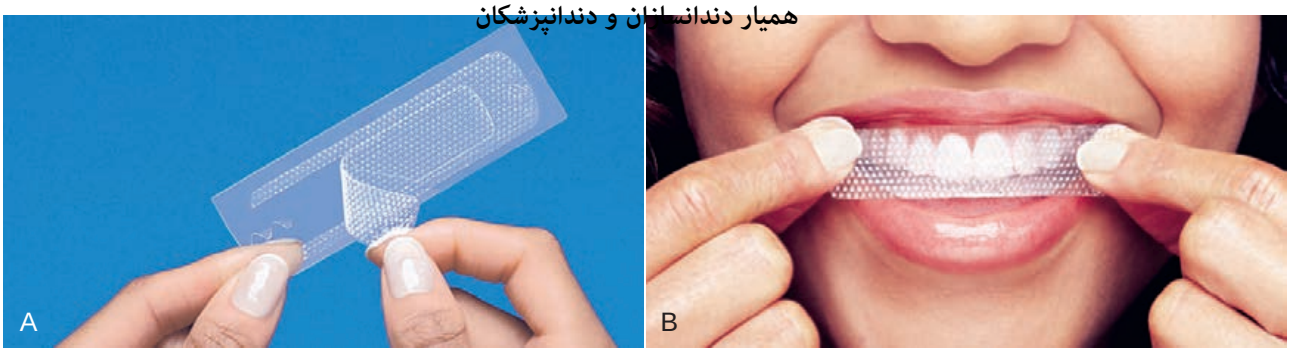


FIGURE 14-64 A, One type of maxillary whitening strip on a backing liner. B, Strip application on the maxillary arch.

and second-person perception. Whether improved perception translates to increased focus on health and functional needs is a matter of some speculation. Research to date is generally unrevealing, but in the absence of contrary research, tooth whitening likely has a neutral or supportive impact on function.

CLINICAL CONSIDERATIONS

Indications

Few techniques in dentistry are as broadly applicable as tooth whitening. The indications for tooth whitening are direct—patient desire for tooth whitening and/or restorative treatment needs involving the overtly visible smile. First, the patient has to desire whiter teeth and a more uniform tooth color. Because the most prominent whitening techniques are consistently successful, tooth color will improve relatively quickly, and these changes will be readily evident to the patient (first person) and others (second person).

The second indication involves patients with a treatment plan that includes restorative or esthetic dentistry involving the visible dentition. Individuals requiring anterior cervical restorations, single or multiple crowns or veneers, posterior esthetic restorations, and the like typically are optimal patients for tooth whitening. In these cases pre-restoration whitening allows for optimal restorative care later.

Contraindications

While there are few contraindications, *special consideration should be applied in cases of sensitivity, pediatrics, or pregnancy.* First, existing tooth sensitivity is a potential contraindication. If the patient has sensitive teeth (thermal or tactile dentinal hypersensitivity), peroxide application will generally not diminish that sensitivity; rather, tooth sensitivity may be exacerbated over the short term. If there is pre-existing sensitivity that goes unnoticed and is not addressed as part of treatment planning, it can interfere with patient compliance and thereby become problematic. For these reasons, existing tooth sensitivity is perhaps the most important contraindication to whitening.

The second potential contraindication involves pediatric use to whiten the primary dentition. There is little information to date, so these cases must be undertaken with caution. A few case studies suggest that these agents can be readily used on primary teeth, but there are few to no randomized controlled studies, so the quality of the evidence is uncertain.

A third area often considered a contraindication is pregnancy. Women of childbearing potential represent the most common group undergoing whitening, and there is no evidence of medical complications associated with treatment of these women. The perceived contraindication is likely related to explicit warnings found on some common whitening products that caution against use in pregnancy. Few practices recommend pregnancy testing before whitening, so dentists may want to consider use of one of the appropriately labeled products, and/or limit use to one of the lowest peroxide dosage options when treating women of childbearing age.

TECHNIQUE OPTIONS FOR TOOTH WHITENING

Tooth whitening covers a broad range of techniques. For example, various oral hygiene products such as dentifrices or rinses may contribute to appearance via extrinsic stain removal or inhibition of surface staining. Whereas some of these may contain peroxides for stain control, these products are generally indicated for use in controlling surface staining associated with diet (such as coffee and tea consumption) or behavior (such as tobacco use). In contrast, durable tooth whitening targets intrinsic tooth color. This method uses application of peroxide to tooth surfaces, generally for a period of 5 minutes or longer; treatment is commonly repeated several times over a short period until intrinsic color change (whitening) is achieved. This approach, often called *intensive whitening,* represents the principal approach used to achieve durable tooth whitening.

With the most recent innovations, *tooth whitening may be professionally administered, professionally dispensed, or self-directed.*[3] Table 14-1 summarizes the different tooth-whitening treatment options and their implications for treatment planning and use.

With professionally administered tooth whitening, treatment is administered in the office by the dental professional after diagnosis and patient consent. The whitening process is totally under professional control. Typically, very high concentrations of peroxide-containing products are used, along with light or other vehicles to presumptively boost the whitening process.

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TABLE 14-1 Summary of Whitening Treatment Options

	Whitening Treatment Options		
	PROFESSIONALLY ADMINISTERED	PROFESSIONALLY DISPENSED	SELF-DIRECTED
Diagnosis/need	Dentist	Dentist	Patient
Treatment	Dentist	Patient	Patient
Peroxide levels	High or very high	Low to medium	Very low to medium
Popular products	Zoom! in-office bleaching*	Opalescence Trèswhite supreme pre-load tray†	Crest 3D White Whitening strips‡

*Discus Dental, Culver City, California.
†Ultradent Products Inc., South Jordan, Utah.
‡Procter & Gamble, Cincinnati, Ohio.

The second treatment category involves the use of professionally dispensed products. The most prominent systems use custom trays to deliver a peroxide gel to the teeth for extended periods overnight, or optionally during the day. Peroxide concentrations vary widely across products, from relatively low to relatively high levels. Other products have been introduced, for example, the semi-custom trays that can be adapted to fit many dental arch forms, thereby eliminating the need for a separate visit for custom tray fabrication; and more recently some practitioners have chosen to use high-concentration whitening strips for home use. Irrespective of the delivery system (custom trays, semi-custom trays, or strips), the diagnosis is rendered by the professional and peroxide application is accomplished at home over a period of days or weeks.

The third treatment category is the self-directed use of peroxides for tooth whitening. With this method the patient or another individual decides the patient should undergo tooth whitening. The individual monitors his or her own status and provides treatment at home. Products may be obtained through the pharmacy, over the counter, via the Internet, or through various other sources. Peroxide application may be via a stock tray, strip, paint-on system, or various other delivery options. The most prominent of these are the easy-to-use hydrogen peroxide whitening strips. Different versions of strips may be available, ranging from short-term use over a few days to regular use. In addition, there are a few non–peroxide-containing products on the market, but evidence of their ability to actually change internal tooth color is not clear.

Current Best Approach

There are clear advantages to each technique. Some research reports that in-office products can result in immediate whitening, making it possible for the patient to leave the dental office with whiter teeth. Treatment time can be quite short. Peroxide is applied by a clinician (which could be useful where "spot" treatment were necessary), and care is directly monitored in the office should adverse events occur.

Tray products, particularly those that use carbamide peroxide or hydrogen peroxide, deliver generally consistent results with overnight use and somewhat consistent results with daytime use. These products often represent a standard of professional care, offering predictable whitening results when used overnight. Often, these professionally dispensed trays are used in combination with in-office treatment in order to yield immediate whitening and a durable benefit that can last over a period of months or years.

Self-directed products can be easy to use, accessible, and affordable. It is important to note that these techniques can offer real advantages with respect to control, because whitening onset may be more gradual compared with other methods. For whitening strips in particular, there is a fixed, usually low amount of peroxide, so the total peroxide dose tends to be minimal. Like the professionally dispensed trays, these whitening strips have been shown to yield consistent results, and unlike with the professional trays, the evidence extends beyond patients to include the general population and several sub-groups.

There are clear disadvantages with each technique. The in-office technique can necessitate multiple visits, and clearly follow-up is needed, often meaning a combination of treatments in the office and at home. The trays can deliver more peroxide than necessary to whiten teeth, and tissue impingement can be a problem. The patient can experience some irritation, soreness, or sensitivity from the tray alone, even without peroxide. The strips also typically whiten only the anterior facial tooth surfaces. Although that may be an advantage with respect to convenience or safety, it might be a disadvantage for certain types of smiles.

The current best approach for in-office treatment is use of a high-concentration peroxide gel followed by a lower-concentration take-home tray. That has the potential to whiten immediately and also deliver sustained, meaningful, durable whitening over time. The best trays are custom bleaching trays, much akin to a night guard, that are used overnight with low to intermediate concentrations of peroxide. The current best approach for the self-directed products is use of the hydrogen peroxide whitening strips for short periods of time during the day over the course of 7 to 21 days or so, depending on which products are selected.

OTHER CONSIDERATIONS

Other considerations concerning whitening involve the presence of white spots on the teeth. Mild fluorosis or snow capping can respond quite favorably to tooth whitening with peroxide. This

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produces a much more uniform appearance of the teeth and blends the white snow capping from dental fluorosis out very nicely. Iatrogenic white spots, injury-related white spots, or stains that appear in the middle of the central incisors respond quite differently depending on the nature of the white spots. Response for these sites can be highly variable, so the informed consent process should identify a priori the possibility of more complex esthetic treatment after whitening.

One other case type warrants special consideration: patients with existing esthetic restorations, especially in the anterior dentition, who want to forgo further dental care. Although whitening is not contraindicated, existing restorations will likely not change during whitening. Whitening the natural dentition for esthetic purposes, then, could yield a different kind of cosmetic problem after treatment: unmatched restorations. Patients should be adequately informed of these outcomes and the potential need for further restorative or esthetic care after successful whitening.

A final consideration is behavior and compliance. If patients are not likely to comply with long-term treatment, it may be more appropriate to prescribe short-term or higher-concentration products that fit patient behavior. For patients who are unlikely to sleep with mouth guards, a short-term daytime program with a tray or whitening strip may be a better choice. Knowing patient compliance and expectations is always an important component of treatment planning and case management.

INNOVATIVE ELEMENTS

Innovative elements in tooth whitening leverage the known concentration and contact time effects of peroxide and tooth whitening. Each is a clear and important driver of clinical response. There is extensive evidence demonstrating (other things being equal) that *increased peroxide concentration or increased peroxide contact time will yield better whitening* per unit of time. This peroxide concentration and contact time paradigm provides the fundamental rationale for the use of a physical barrier (such as a tray) during tooth whitening for optimal results. For intrinsic whitening to be achieved, peroxide must remain in contact with tooth surfaces for a period of time for diffusion into and through enamel, with whitening resulting from the oxidation of intrinsic stains within the tooth surface.

The innovation found with the easy-to-use whitening strips leverages this paradigm. With the whitening strips, a low fixed amount of peroxide at a higher concentration is applied directly to tooth surfaces and adjacent gingiva, without need to protect the gingiva with a rubber dam or other isolation technique. The whitening strips further demonstrate that it is possible to limit treatment to the visible dentition and not treat lingual surfaces of posterior teeth that are not readily visible.

Because the strips use hydrogen peroxide, a 6% strip is approximately the equivalent concentration of an 18% carbamide peroxide gel used for tray whitening. The strip technology allows a decrease in the overall amount of peroxide administered, to improve tolerability and reduce total peroxide exposure relative to other methods. Clinical response with hydrogen peroxide strips can be visible within a few days. Treating the maxillary arch first can further promote patient compliance, as the contrast between the treated maxillary arch and the untreated mandibular arch becomes readily evident (Figure 14-65).



FIGURE 14-65 Maxillary arch after strip whitening. *(Courtesy Dr Ingvar Magnusson.)*



FIGURE 14-66 Maxillary arch strip whitening in an adolescent. *(Courtesy Dr Kevin Donly.)*

Introduction of the easy-to-use whitening strips has (1) resulted in an entirely new technology to be able to whiten teeth easily at home, and (2) contributed an extensive body of clinical trial evidence on patient safety with and efficacy of tooth whitening.[4] One important finding is that *there is a clear relationship between patient age, tooth color, and whitening response.* This fundamental understanding helps dentistry define patient populations and likely response—younger patients and those with yellower teeth will achieve better whitening—and can help clinicians direct treatment to nontraditional patient types. For example, dentists can readily recommend tooth whitening for adolescents, after orthodontia or at other time points, with predictable clinical response that is clearly visible and appreciated (Figure 14-66).[5] In addition,

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FIGURE 14-67 Maxillary arch strip whitening in an older adult with lower salivary flow. *(Courtesy Dr Athena Papas.)*



FIGURE 14-68 Maxillary arch strip whitening of tetracycline stain. *(Courtesy Dr Gerard Kugel.)*

recent research shows that older adults and elderly individuals can be successfully treated, even under conditions of hyposalivation (Figure 14-67).[6]

ARTISTIC ELEMENTS

Artistic elements of importance to tooth whitening include pre-existing esthetic or restorative dentistry, starting tooth color, tooth shape and alignment, and other factors. Whereas peroxide-based whitening generally results in a more uniform tooth color overall, adjacent (unchanged) esthetic restorations may become more visible after whitening. Treatment planning may need to identify this possibility and plan for subsequent replacement after whitening is completed.

The actual nature of the tooth color is also a factor. Although yellowish tooth colors will probably have great responses (VITA shades in the As or Bs on the VITA Shade Guide [Vident, Brea, California]), tooth colors that are greenish (VITA C shades) can yield compromised outcomes. Some of these patients, such as individuals with evidence of tetracycline discoloration, may require treatment for several months.[7] From an artistic perspective, tetracycline-stained teeth that are banded can whiten first at the incisal tips, with response slowly progressing apically. This may cause a temporary increase in banding, which in turn could adversely affect perception and compliance. Although tooth color will improve with extended treatment, the end result of these tetracycline cases may appear "dead white," lacking color characterizations (Figure 14-68). Further esthetic dentistry may be indicated to achieve optimal outcomes.

A third artistic element is obvious. Whitening products do not improve tooth shape or alignment in any fashion. Therefore any pre-existing conditions affecting tooth form or architecture are not treated through the process of whitening. After completion of whitening, some patients now focus on achieving an even better smile, so treatment planning may need to anticipate further care to meet expanded patient expectations.

TREATMENT PLANNING

Options for Patients

The treatment options involve trade-offs between concentration and contact time, plus cost and convenience. It is possible to increase the amount and rate of whitening and decrease the total treatment time if the concentration of peroxide is increased. Dentists can select a higher-concentration tray-based option, for example, a 15% to 16% carbamide peroxide gel instead of a 10% carbamide peroxide product, to diminish the total treatment time. The trade-off involves an expected increase in adverse events (usually transient tooth sensitivity and oral irritation) during treatment.

The trade-offs are best addressed through the selection of one of the three options for care (professionally administered, professionally dispensed, or self-directed) that best meets the needs of each individual patient. Convenience, cost, and patient expectations often drive this choice, rather than safety or effectiveness, because each of the options can be successful.

Options for Dentists

Professionally one must consider the presence or absence of existing restorations. If there are existing esthetic restorations in the anterior dentition that are not being replaced in the esthetic plan, whitening adjacent teeth may be best accomplished with a low-intensity whitening system that will whiten teeth gradually. Use of one of these systems at home, such as a daytime tray or whitening strips for a short period (perhaps an hour), allows self-assessment and limits the potential for overtreatment. If there are no existing esthetic restorations, a larger portfolio is available for use, with age and tooth color as driving factors in terms of treatment planning.

For patients who have existing tooth sensitivity, options are to lower the peroxide concentration, shorten the contact time, or even skip treatments for periods when they are especially

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sensitive. Temporary restorations, desensitizing agents, or other treatments may be indicated to help prevent sensitivity.

Sequence

Generally, tooth whitening occurs early in the treatment sequence, usually after any preceding emergency or other care indicated to stabilize oral health. There are both direct and indirect reasons for such early treatment. Perhaps the most direct reason involves planning subsequent dental care to match the color esthetics of the newly whitened smile. Depending on the system used, it may take a few days or weeks for tooth color to stabilize after treatment, after which further esthetic restorations can be placed. Indirect benefits relate to the effects of whitening on patient motivation and compliance. Because results from whitening can be readily seen within a few days (on both first- and second-person bases), favorable patient recognition can contribute to good compliance and support for other esthetic or restorative dental care.

There is one other reason to defer treatment for a few days or weeks after completion of whitening. Some literature indicates that tooth whitening can interfere with certain bonding agents. The evidence is limited to a few combinations of bonding materials, and peroxide whitening systems, so these findings may not be generalized to all cases. Nonetheless, research suggests that immediate post-bleaching bonding may affect bond integrity and thereby contribute to restoration failure. Delaying bonding for a few weeks after the completion of whitening may be preferred.

TREATMENT CONSIDERATIONS DURING PREPARATION, PROCEDURE, AND FINISHING

Recent innovations in tooth whitening have contributed to newfound treatment considerations for esthetic dentistry. In addition to the increased patient demand for white teeth, there is an emerging new recognition by patients (and clinicians) as to what constitutes "white." Some patients expect (and some clinicians treat) to achieve greater degrees of whitening. For broader esthetic care, this has been manifested in dental materials science by innovations in shade guides and the different colors of restorative materials to meet the increased expectations as to what constitutes white. This requires dentists to have good informed consent discussions with patients and to guide them in setting their expectations as to what they will see at the end of treatment.

In use, patients will reach a plateau on the amount of tooth whitening that can be achieved with topical application of peroxide. This may occur earlier in treatment with higher-concentration products and later with lower-concentration products, but overall, at-home treatment will not likely take patients to some unnatural, unrealistic level of whiteness. Although it is possible to treat unnecessarily, *at-home use of peroxide will not generally result in overtreatment* or "whiter than white" outcomes. Informed consent is always an important factor, particularly for patients with "paper white" expectations.



FIGURE 14-69 **Oral irritation seen with tooth whitening and aggressive brushing.**

One other consideration in at-home treatment involves possible oral irritation. Although dental plaque does not need to be removed in order for peroxide to diffuse through enamel at a level sufficient to cause tooth whitening, patients may believe that rigorous oral hygiene will actually help the bleaching process. In addition, detergents in toothpastes can temporarily deactivate local protective enzymes in oral soft tissue and saliva, such that immediate post-brushing bleaching can result in local minor burning or irritation. Adverse outcomes are usually symptomatic only, but occasionally clinical signs may develop that are consistent with toothbrush trauma (Figure 14-69).

One practical tip to limit oral irritation is to separate toothbrushing and tooth whitening. Separating the brushing and bleaching processes by a few minutes will reduce the potential for oral irritation. In addition, some clinicians elect to fabricate custom trays far short of the gingival margin to limit peroxide contact in those areas. With many in-office systems, a gingival barrier is applied to prevent the very high-concentration peroxide from contacting the adjacent gingival and oral soft tissue. The barrier integrity must be checked, whether liquid or simple rubber dams, to prevent the very high-peroxide gels from contacting the adjacent tissue, resulting in local gingival irritation.

Peroxide will diffuse in various directions, so it does not have to be placed immediately adjacent to the soft tissue to whiten teeth next to soft tissue. Trays should be tried in because they can impinge on the dentition and generate orthodontic forces, and the empty custom tray has been reported to contribute to oral pain.[8] First use should be demonstrated. Although this is not a problem with uniform fixed-dose products such as whitening strips, patients commonly dispense more peroxide gel than needed into their tray prior to insertion. The excess can run up over the tray onto the gingiva, and sometimes down the back of the throat. Among other things, research leading to the development of the low-peroxide whitening strips demonstrates that very little gel is needed to effectively whiten teeth.

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Care must be taken with the concurrent use of local anesthetics and peroxide-based tooth whitening. For patients with existing sensitivity, some clinicians advocate use of local anesthesia to improve tolerability and allow timely accomplishment of in-office whitening. Unfortunately, there is virtually no adequate and well-controlled research on this practice. To date, tooth whitening has been extraordinarily safe, with essentially no reports of serious adverse events, irrespective of the method used. Strips, in-office systems, trays—these methods are almost universally exceedingly safe because the intact pain response likely plays a key role in limiting excess exposure. Although it is possible to conduct clinical and radiographic examinations for the presence of cracks or cavitations, peroxide readily diffuses through intact enamel and into the dental pulp irrespective of the application method. The mild-to-moderate sensitivity occasionally experienced during whitening is likely a local inflammatory response to peroxide application. That pain is not persistent, and research demonstrates that short-term discontinuation of treatment is the best palliative treatment. Therefore for patients who are sensitive, dentists should use lower-concentration products for shorter periods of time or look at treatments besides tooth whitening to improve tooth color rather than using local anesthetics to block the pain sensation.

EVIDENCE-BASED PRINCIPLES

There is considerable and substantial evidence concerning the safety and effectiveness of tooth whitening. The most rigorous form of evidence is traditionally considered to be the randomized double-blind controlled clinical trial. Two of the approaches—the tray-based method and the whitening strips—have considerable randomized double-blind clinical trial evidence and systematic review support. Prominent published reviews describe the safety and effectiveness of certain tray-based and strip-based systems.[8,9]

The two approaches with the greatest amount of randomized clinical trial research and systematic evidence involve very specific types: custom tray–based systems using 10% carbamide peroxide, and whitening strips at various peroxide concentrations. One of these—whitening strips—actually represents the most studied dental technology during the past decade. Other tooth-whitening systems have little to no evidence and few if any randomized controlled trials to support them.

CLINICAL CONSERVATIVE CONCEPTS

Tooth whitening is the most conservative esthetic procedure, and one of the most conservative treatments in dentistry. It is non-invasive, with few to no contraindications, and treatment can be administered with or without supervision by healthcare professionals. Adverse events are generally few in number and self-limiting, with mild and transient tooth sensitivity and oral irritation representing the most common undesired outcomes. Such cases typically fully resolve during treatment (without modifying use) or soon after discontinuation.

MAINTENANCE

Maintenance is one of the more interesting aspects of tooth whitening. It has risen to prominence, with millions of people having undergone tooth whitening since the advent of the easy-to-use whitening strips. Thus there is a large body of evidence, including various clinical studies that have evaluated patients over time. Findings indicate that tooth color will relapse after the completion of intrinsic whitening, and separately, that teeth will become discolored due to staining over time. Whitening color relapse and superficial staining are separate processes, and vary considerably based on the type of whitening material used for treatment, the initial color response, personal behavior, and other factors. Immediate treatment, such as the in-office systems, carry the greatest risk for relapse, and research shows this relapse may occur over a period of several days or weeks.[10] Response with the tray- or strip-based systems is generally more durable, and although there is little systematic evaluation, most evidence suggests that re-treatment may be indicated every 3 years or so. The re-treatment process is identical to but typically shorter than the original care.

There is some evidence to support the use of whitening toothpastes and rinses after tooth whitening, but the area has not been extensively studied. Whitening toothpaste and rinses may help with stain formation superficially, especially for individuals who follow certain diets or behaviors that contribute to staining. Staining can be perceived as an overall color change, which can contribute to the perception of decreased intrinsic tooth color. Whitening toothpastes or rinses and regular routine dental maintenance care may play a role in keeping teeth white over time.

CONTROVERSIES

There are two areas of controversy, one within the profession and one outside the profession. The controversy inside the profession revolves around the usefulness or appropriateness of light- or heat-aided in-office treatment to accelerate peroxide reactivity and provide tooth color changes in the office using short contact times with high-concentration products. A considerable body of conflicting research exists, with some studies showing improved response and others showing no meaningful benefits. Cost and safety trade-offs further complicate assessment of accelerated whitening systems, leading to controversy in the profession.

The controversy outside the profession concerns local regulations that can limit access to tooth-whitening products. In some parts of the world, popular tooth-whitening products are readily available and accessible to both clinicians and patients. This access has been shown to benefit dentistry, especially esthetic dentistry, by improving awareness and removing certain barriers to treatment. Other parts of the globe have very limited access

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to products with very limited usage, with local regulations and other factors affecting availability of tooth whitening. Awareness of benefits of esthetic dentistry can lag in those areas.

NEAR-FUTURE DEVELOPMENTS

There is active research ongoing, and new products are being introduced to improve the magnitude and durability of whitening that occurs with in-office systems. In the past those products as stand-alone treatments did not deliver the kind of whitening possible with take-home products because of the limitations on peroxide concentration contact time. Newer products have been developed that offer potential benefits over some of the original products, and further research and development may yield greater tooth color changes from in-office whitening alone that are more durable than possible with the early approaches.

Efforts are also being made to improve the easy-to-use products. Easy-to-use products have as their major characteristics affordability, accessibility, and ease of use, but they give up some things esthetically. Whitening strips and trays used on the mandibular arch can slip or move, adversely affecting the results. Newer and better options are being developed to improve adherence of the peroxide to the tooth surfaces and hold it in place under a barrier. In addition, considerable effort has been expended on developing barrier-free peroxide-containing products, and peroxide-free products, but little promise has been shown with either approach.

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Tooth Bleaching

Linda Helene Greenwall

RELEVANCE OF TOOTH BLEACHING TO ESTHETIC DENTISTRY

There general public is self-driven to have healthy-looking white teeth. In addition to having the teeth cleaned regularly, patients see bleaching as a way to improve their smiles and enhance their dental appearance. Bleaching is normally the first step in esthetic treatment after emergency treatment has been undertaken and the mouth is stable. It will continue to be a part of ongoing esthetic maintenance after the comprehensive treatment plan is completed.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND THE EVOLUTION OF BLEACHING

Improving the shade of discolored teeth has been a quest among patients for many years. Although many techniques and materials have been used over the last 400 years in attempts to lighten discolored teeth, it was the very early "dental" practitioners who used uric acid to whiten teeth. There was a major upsurge in the late 1880s when power bleaching first became fashionable; 30% hydrogen peroxide liquid was applied directly onto the teeth via strips of gauze. Sometimes a light emitting heat was used in an attempt to enhance the whitening effect. Procedures continued to develop throughout the rest of the nineteenth century, and well into the twentieth century.

Hydrogen peroxide has been identified as the most predictable material for bleaching teeth. Developments in the 1950s and 1960s included non-vital bleaching and a "walking bleach" technique (utilizing a mixture of sodium perborate and water). In 1961, H.F. Spasser first described sealing a mixture of sodium perborate and water into the endodontically treated pulp chamber for a period of 1 week. The combination walking bleach technique was described in 1963 by E.B. Nutting and G.S. Poe. They used a combination of 30% hydrogen peroxide and sodium peroxide sealed into the pulp chamber for 1 week.

These developments were initially widely accepted, but problems soon surfaced. A combination of 35% hydrogen peroxide and sodium perborate had a synergistic effect, producing a definitive concentration of 50% hydrogen peroxide, which can be too strong to be sealed inside the pulp chamber of a non-vital tooth. The literature reported internal resorption of the root and cervical resorption of the tooth, although these may have been secondary effects of the devitalizing trauma to the tooth. The typically extreme heat and light that were associated with the bleaching may have contributed to these failures. Research focused on seeking safer and more predictable methods, including sodium perborate and water. Van B. Haywood recommended that peroxide mouthwash used in a tray could whiten teeth. William Klusmeier, an orthodontist in Fort Smith, Arkansas had been using the technique since the 1960s. He noticed that the gingivae became inflamed during and after orthodontic treatment, and recommended that his patients use a peroxide mouthwash in their orthodontic positioner at night after completion of orthodontic treatment. He recorded that with this approach the gingivae were healthier and the teeth were whitened. Haywood and Heymann (1989) showed that night guard vital bleaching was a very predictable, safe method for whitening teeth. These researchers used 10% carbamide peroxide overnight in the night guard. Freedman (1990) reviewed the proven safety of carbamide and hydrogen peroxide in widespread medical and dental use over the previous half century. Extensive research over the past 20 years has confirmed the efficacy, safety, and predictability of night guard vital (home) bleaching. Further research on power bleaching has focused on newer chemistry, as well as light to accelerate the bleaching effect and to shorten treatment duration.

In 2000, over-the-counter (OTC) whitening materials were introduced. The modalities for the general public include those that lighten the six anterior teeth using strips coated with varying concentrations of hydrogen peroxide. Controversy has developed as whitening procedures have been expanded to non-professional settings such as bleaching bar kiosks under the direction of non-dental professionals. Beauty therapists in a variety of "spas" are undertaking to deliver tooth whitening, but their lack of knowledge, resources, and education often makes the treatments ineffective and the materials that are used may be damaging.

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RELATING TOOTH BLEACHING TO FUNCTION

The goal of bleaching is to whiten all the teeth to the same lighter shade. When a bleaching tray is worn, an individual cannot drink or eat, and thus some bleaching treatments are undertaken overnight, so normal function can be maintained. However, patients who brux will quickly wear through a normal bleaching tray; they require a stronger one that is manufactured from thicker plastic. The bleaching tray should extend across the peripheral surface of the teeth from the most posterior teeth across the arch.

CLINICAL CONSIDERATIONS

Indications

Bleaching is undertaken for the treatment of tooth discoloration. Tooth discoloration is classified as extrinsic or intrinsic. Extrinsic stain occurs on the outside of the teeth and can be removed with a professional cleaning, not necessarily requiring bleaching. Intrinsic stain occurs inside the tooth, always requiring bleaching. The most common causes of tooth discoloration are age yellowing, diet, smoking, tetracycline, tooth trauma, excess exposure to fluoride, and chemicals. However, many persons who have normally shaded teeth also tend to want whiter teeth. There are two patient categories: those with significant general discoloration and those with normal tooth coloration who desire to whiten and lighten their dentition. Treatment of both classes of patients can be successful, but require dentist-patient discussions prior to treatment and clear explanations of the benefits, risks, and length of treatment.

Tetracycline Staining

Patients who have intrinsic stains such as tetracycline can benefit from whitening. There are four categories of tetracycline staining, depending on the degree of tetracycline exposure:

- 1°—**mild tetracycline staining**—yellow to gray staining with no banding, and uniformly spread throughout the tooth.
- 2°—**moderate tetracycline staining**—yellow-brown to dark gray staining.
- 3°—**severe tetracycline staining**—blue-gray or black staining, accompanied by significant banding across the tooth.
- 4°—**intractable staining—**very dark gray-brown and black staining that often cannot be successfully removed with whitening, but treatment should be attempted in any case.

Research shows that tetracycline stains can be removed from the teeth with an extended period of bleaching, sometimes taking as long as 12 months. Six weeks may elapse before the bleaching becomes noticeably effective.

Another form of tetracycline stain is caused by minocycline, an acne therapy often given to teenagers. The minocycline is incorporated into the tooth structure, causing gray-blue staining well after tooth formation is complete. Minocycline stain can be very difficult to remove with whitening.

Fluorosis Staining

In fluorosis staining, the patient's excessive uptake of fluoride over many years as the tooth is developing causes brown, yellow, and orange staining (see Figure 14-71). These teeth are susceptible to whitening treatments. The typical whitening treatment removes the brown stain first, then the orange, and finally the yellow-brown. Some patients may also have white mottling. The contrast of the white spots is of concern to patients. Bleaching lightens the background color of the tooth and the spots become less obvious. However, patients should be warned that the white spots become even whiter during treatment to alleviate transitory concerns.

Intrinsic discolorations can also result from genetic and systemic conditions and medications taken during gestation and infancy. Tooth discoloration are seen in patients with hematological problems such as bilirubin and hemoglobin insufficiencies.

Pulpal Changes

Pulp necrosis can result from bacterial, mechanical, or chemical irritation of the pulp. These teeth require endodontic treatment prior to bleaching.

Tooth trauma may result in tooth darkening due to internal bleeding from the pulp. The teeth may become gray or black-brown and then turn dark yellow-brown. The discoloration results from intradental hemorrhage followed by lysis of the red blood cells into products such as iron sulfide that enter the dentin tubules staining the surrounding dentin.

Dentin hypercalcification or calcific metamorphosis (CM) (see Case 1) is the result of the traumatized tooth forming tertiary or excessive irregular dentin that can invade and obliterate the pulp chamber and canal,. A trauma-related temporary disruption in the blood supply is followed by atypical odontoblast activity. Many of these teeth remain vital although they have a dark yellow appearance.

Caries

Dental caries can cause staining as well. Amalgam restorations can become less gray as whitening eliminates the oxide layer from the surrounding tooth structures.

Aging

Aging changes contribute to tooth discoloration. As the patient ages, the enamel thins through wear, erosion, abrasion, and abfraction, the yellower dentin underneath shows through and darkens the tooth's appearance. With age, the dentin also thickens and darkens, resulting in the yellow and brown shades seen in older patients.

Activities That Cause Staining

Smoking causes both intrinsic and extrinsic stains that can be difficult to remove, particularly if there are vertical or horizontal craze lines through the tooth.

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BOX 14.3 Contraindications to Bleaching

- Patients with unrealistic expectations
- Deep discolorations
- Tetracycline discolorations
- Patients with insufficient enamel to bleach
- Patients with existing extreme sensitivity

Patients who swim often in chemically treated pools exhibit chlorine staining. Staining is also may be observed in patients with a penchant for fried foods; the frying reaction that browns foods can also affect the teeth. Long-term ingestion of iron tablets may cause reddish staining of the teeth.

Contraindications

Bleaching is contraindicated for patients who have reduced tooth enamel thickness caused by severe erosion and those with heavily restored teeth that have little remaining enamel to whiten. These patients may be better treated with restorative dentistry to cover eroded areas**.** Patients who have unrealistic outcome expectations may not be suitable. Another contraindication is severe mucosal disease such as lichen planus, which can be exacerbated by whitening chemistry; while there is no scientific evidence for this, it has been observed clinically. Patients taking medications that interact with ultraviolet light may also be poor candidates for certain power bleaching treatments (Box 14-3).

There are no age restrictions on tooth bleaching. A child or adolescent who is psychologically affected by severe tooth discoloration can be encouraged to undertake treatment.

Patients undergoing or scheduled for chemotherapy or other cancer treatments should only have whitening treatments if they have had clearance from their oncologist or medical doctor. Individuals affected by gastric problems must check with their gastroenterologist about their susceptibility to whitening products. In general, patients with complex medical histories and significant medicament lists, must be cleared by their general medical practitioners before they commence tooth whitening.

MATERIAL OPTIONS

The basic bleaching materials consist of hydrogen peroxide and carbamide peroxide. The hydrogen peroxide materials have been used for bleaching teeth for more than 100 years, and there is ample evidence to demonstrate that they are effective for dental bleaching and whitening treatments. Carbamide peroxide breaks down into to hydrogen peroxide and urea. The urea breaks down into ammonia and carbon dioxide. The hydrogen peroxide breaks down further into water and oxygen ions, and it is the oxygen ions that penetrate through the enamel into the dentin, usually within 15 minutes. Oxygen is the effective ingredient in cleansing the pigment molecule and allowing the teeth to become whiter. The carbamide peroxide agent contains urea, which elevates the pH of the product. The urea also stabilizes the hydrogen peroxide and improves the wound healing properties of the whitening gel.

A disadvantage of using hydrogen and carbamide peroxide treatments is that patients can develop transient tooth sensitivity; the most common side effect. Hydrogen peroxide products release oxygen more quickly than the carbamide peroxides.

Patients may express concern if they do not observe their teeth becoming rapidly whiter. It is important to discuss the stages and phases of the bleaching treatment before treatment is undertaken with them. Impatience may allow for insufficient bleaching. This is most common with lower anteriors and upper cuspids, and yields a "snow-capped" appearance of a half bleached tooth. Since the bleaching process works from the incisal tip, the cervical part of the tooth remains yellow well into the bleaching treatment. Patients must be encouraged to continue treatment for a longer period of time until the entire tooth is uniformly whiter. Some of the newer bleaching materials have sensitivity reduction agents incorporated that significantly reduce the sensitivity of the teeth during the bleaching process. These agents include potassium nitrate, various fluorides, and amorphous calcium phosphate (ACP). They may be incorporated into the bleaching gel, applied directly onto the teeth by patients, or worn in the bleaching trays between whitening treatments.

Current Best Approach

It is essential to explain all the steps of the bleaching process and the risks and benefits of treatment to patients that they fully understand what is involved. This encourages the patient to cooperate and comply with the instructions. The best and most predictable approach is home bleaching; it is the most predictable and longest-lasting. Many patients are influenced by media and television programs to believe that power bleaching is the only way to go, not realizing that the advertisements use misleading time-lapse photography. Normally, more than one power bleaching session is required to achieve the desired white shade. Home bleaching is the safest, most effective, and most cost-effective method. Published research has documented positive results lasting up to 17 years.

OTHER CONSIDERATIONS

Concentrations of Carbamide Peroxide

The most commonly used material is 10% carbamide peroxide. Other concentrations are also used, but most of the research confirms the safety and effectiveness of the 10% solution. While a higher concentration assures faster bleaching, it is also associated with a greater likelihood of sensitivity. Some patients prefer 15% carbamide peroxide, as bleaching takes place more quickly. The carbamide peroxide materials can be used overnight or for 1 to 2 hours depending on the patient's schedule. Higher concentrations of carbamide peroxide, 20% to 30%, are introduced

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into pulp chambers for the non-vital bleaching. Single dark vital teeth and dark cuspids are treated with 20% carbamide peroxide. Thirty-five percent carbamide peroxide is used for power bleaching procedures. All these materials can be placed directly onto the teeth or into the bleaching trays, though the higher concentrations may require gingival protection with a light-cured resin material.

Power bleaching materials range from 6% to 35% hydrogen peroxide. Power bleaching treatments are scheduled for 1 to 2 hours because the unbuffered oxygen dissipates rapidly. Hydrogen peroxide materials can be used in trays as well; they require less application time. Hydrogen peroxide tray products are indicated for daytime (waking) use.

Bleaching Treatment Classifications

Not all bleaching treatments are the same. They are classified for purposes of treatment planning and fee assessment.

Basic bleaching involves healthy teeth requiring no restorative dentistry. The bleaching takes 2 to 6 weeks to achieve shade B1.

Intermediate bleaching is used to manage a combination of bleaching treatments, such as general non-vital bleaching and power bleaching and/or microabrasion. It may take longer to achieve the B1 shade, but it can be achieved. Some restorative dentistry may be needed before and/or after bleaching treatment.

Advanced bleaching manages severe discoloration and requires prolonged or extended bleaching treatments. Advanced restorative dentistry may also required, possibly including complex implant treatment, veneers, or microabrasion to remove residual dark or white spots. It may not always be possible to achieve complete whitening, but the discolorations can be considerably improved.

Discussions prior to treatment are designed to ensure that the patient understands the realistic limits of treatment. Box 14-4 provides a brief summary of the different classifications of bleaching treatments.

BOX 14.4 Summary of the Different Bleaching Treatments

- *Basic bleaching treatment* patients have healthy teeth requiring no restorative dentistry. Bleaching treatments are straightforward: either a home bleaching treatment, such as night guard vital bleaching, or a single power whitening session. It can take up to 6 weeks to reach shade B1.
- *Intermediate bleaching* is a combination of treatments such as non-vital bleaching and home bleaching, home bleaching and microabrasion, or home bleaching or power bleaching followed by home bleaching. It may take 4 to 8 weeks to reach shade B1. These patients may require some basic restorative dentistry after whitening.
- *Advanced bleaching* could require a combination of bleaching treatments and/or advanced restorative dentistry or advanced esthetic dentistry. These treatments can include extensive tetracycline bleaching, which can take 6 to 52 weeks to improve the shade to B1.

INNOVATIVE ELEMENTS

Scientific Elements

While bleaching is not recommended for extended periods of time, recent research shows that bleaching materials improve gingival health, reduce root decay for the elderly, and improve caries reduction rates. New bleaching additives offer a reduced incidence of sensitivity and continuing safety.

Technological Elements

Innovative home bleaching and OTC methods have been developed for administering the bleaching gel. A novel tooth whitening use is that teeth can be bleached while the patient is undergoing clear retainer orthodontic treatment. It has become popular to bleach during Invisalign treatment, commencing about a month after the orthodontic treatment is under way. The bleaching process may be more rapid, as the trays are more rigid, have a tighter fit, and the patient wears the aligners 24 hours a day.

ARTISTIC ELEMENTS

Patients may want to have white teeth because they do not accept that their teeth are becoming yellower with age, or it may reflect the growing trend for people to equate whiter teeth with health and success. After whitening or bleaching treatment, the patient is often inspired and motivated to improve their oral hygiene and to seek additional esthetic dentistry. Research shows that of patients who undertake whitening, 80% return for further procedures. After whitening treatment, many patients choose to have their amalgam fillings replaced with composite restorations. The use of composite bonding has become a routine part of the treatment plan with the development of "bleach" shade composites and porcelains. There is even a new shade guide for the whiter bleach shades. The artistic element is the continued improvement in the natural smile and in the composite materials. Sometimes it is necessary to refurbish earlier dentistry to match the new shade of the whitened teeth.

TREATMENT PLANNING

It is essential that protocols be established before bleaching is undertaken. A thorough clinical evaluation, patient history, and a detailed clinical examination are documented to arrive at

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a differential diagnosis to determine the nature of the discoloration and explore options for bleaching treatment. Clinical discussions with patients should cover the risks and benefits of the treatment. The dentist must explain what can be realistically achieved and what the patiuent can expect. Patients must be fully informed regarding the expected outcome and what could go wrong during treatment. They must be told that further dentistry might be needed after bleaching. For example, dark teeth with existing shade-matched composites may require replacement restorations matched to the new shade once the teeth have been whitened. This should be noted on the treatment plan before starting the bleaching. Bleaching is normally the first step of treatment, after any emergency treatment. The treatment plan should outline, in full, the comprehensive treatment that the patient requires. This starts with the bleaching, continues to the bonding, and then includes more complex interventions, such as composite or porcelain inlays, onlays, or crowns. Patients should be informed of the different types of bleaching treatments available: home, power and combination.

Definitive restorative treatment should not start immediately on completion of bleaching. After the penetration of oxygen into the tooth, there is a period of time, normally 2 weeks, before the shade settles to its stable long-term color. At that stage, all the oxygen will have effectively dissipated through the tooth. The author recommends a wait of 3 weeks prior to undertaking composite restorations and up to 6 weeks before porcelain laminates or crowns.

Assessing the Teeth

Radiographs of the teeth assess that the teeth are healthy coronally and periapically. Any discolored teeth must be assessed for vitality as well. Endodontic treatment should be undertaken for non-vital teeth or those with an existing periapical lesion, before bleaching. It is customary to wait 1 month post-endodontically before bleaching. A comprehensive intra-oral evaluation includes assessment of the teeth, occlusion, restorations, and surrounding tissues, including periodontal charting, recession and periodontal tissue thickness documentation, and mobility testing. The nature of the discoloration is diagnosed and the bleaching modality selected. Discussion treatment options and further esthetic dentistry with the patient is important.

A pre-examination questionnaire that determines the patient's aspirations and expectations for the whitening treatment and with esthetic dentistry in general. It is also used to discover the shade that the patient desires. These issues are important in assessing whether the patient has realistic or unrealistic expectations.

Patients must have a full explanation of the nature of the procedure, what steps are involved in bleaching, what the treatment will do for them, what modality they will require, how long the treatment will take, how long it will last, how long the whiter dental shade can be maintained, whether further treatments will be needed to maintain the white shade, and what to expect during and after treatment.

The procedure and sequencing of the home bleaching treatment are also important. The patient must be shown how to place the gel in the bleaching tray, how much gel to use, and how to seat the tray in the mouth. The dentist should ensure that the patient has confidence in using the bleaching materials in the tray and can follow the instructions at home. The gel is given to the patient, and arrangements are made for the next appointment.

In sequencing home bleaching, the upper teeth are treated first. Whitening is achieved more quickly on the upper teeth, and there is often greater comfort and less sensitivity with the upper trays. Two weeks later the patient is assessed and bleaching of the lower teeth begins. Lower tooth bleaching is normally undertaken for 3 weeks with overnight treatment. Then the shades of the upper and lower teeth are reassessed to ensure that the patient is happy with the treatment progress. The patient is assessed every 2 weeks until the patient and the dentist are satisfied with the level of whiteness.

It is essential to explain the full power bleaching procedure to the patient, as well. This includes pointing out the existing tooth shade, that the bleaching involves sitting under a light for 1 to 2 hours, and the sequence of clinical steps. The information includes the strength of the light, the heat, and whether there is a possibility of transient post-operative dental sensitivity. The patient should be told analgesics may be required after the power lightening treatment, how to manage these medications at home, and what to do post-operatively to maintain the new shade of whiteness and to reduce the sensitivity. Medico-legal complaints after power whitening revolve around not having received sufficient pre-treatment explanations and the soft tissue irritations that can occur if the gel inadvertently touches the gingiva, mucosa, or tongue. In addition, the patient may be disappointed with the outcome. It is important for the patient to be forewarned about all possible complications.

Once the patient is satisfied that sufficient whitening has been achieved, it is important to discuss maintenance. After the recommended 3 to 6 weeks home bleaching protocol, he or she no rewhitening should be required for several years. The teeth may remain whiter than the original shade for up to 17 years. Power bleaching patients who complete the treatment may need further whitening applications to maintain the white shade. If the patient does not wish to wear bleaching trays, bleaching strips can be used.

Documentation

Signed treatment consent forms are eseential. Documentation in the take-home pack includes a discussion about what to expect during and after bleaching, answers to commonly asked questions, information about how to manage sensitivity, instructions for applying the bleaching gel into the trays, and a bleaching log to monitor treatment times and the presence of sensitivity. Patients often do not remember all the verbal instructions received at the dental practice and may need to refer to the written instructions.

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Photography

Standardized photographs before, during, and after the bleaching treatment are mandatory. Photographs taken before bleaching show the range of existing shades. This allows the patient to see the shade of the teeth before, during, and after treatment and to evaluate the results of bleaching. Normally it is the porcelain shade guide that is used to assess the shades during bleaching. It is important to standardize the location of the shade guide at a particular position in the smile. The author's preference is to place it opposite the upper left teeth. The shade tab must be parallel with the teeth, and it is palced in the exact same position at the second and other bleaching appointments.

These photographs can be used for practice marketing as well. Before-and-after images are a dramatic demonstration of the results of tooth whitening. Most patients prefer a full-smile view to cheeks retracted view. The patient information and marketing smile library consists of only portrait and smile views.

The first photograph taken before treatment is a small portrait of the smiling patient. At the end of treatment, a similar portrait is taken (see Cases 1 and 2). These pictures are taken before retractors are used because retractors can leave marks on the lips and cheeks. Standardization of these photographs allows fair before and after comparisons. The dentist photograph is the full-smile retracted view documenting the smile more clearly. Patients may forget these original shades. Viewing photographs before and after treatment shows the full effect of the bleaching treatment throughout the teeth.

TYPES OF TREATMENTS

Home Bleaching

Home bleaching falls into two broad categories: OTC kits sold directly to the patient and professional kits available only through a dentist. OTC kits comprise a variety of products that are manufactured by both larger and smaller oral health companies. The three most common types of OTC systems available are whitening strips, brush-on whitening products, and non–custom-fitted trays with bleaching gels. Results are typically not as dramatic as those achieved with dentist-supervised products and occasionally gingival and tooth surface damage can occur. Overextended trays irritate the gingiva and other soft tissue structures, and acidic bleaching gels damage the enamel and dentin, pitting, dissolving, and staining the surfaces. Most professional kits involve a custom-fitted tray made in the dental office (or at the dental laboratory), which is loaded with a carbamide or hydrogen peroxide gel. Usage regimens vary, but the results are relatively predictable, with the teeth often significantly lighter and brighter after the process.

Side Effects

- Gingival irritation can be caused by: an overextended tray, too much bleach applied into the tray, and an exaggerated concentration of peroxide in the bleaching gel.
- Soft-tissue irritation can be caused by: an ill-fitting tray or excess bleaching gel.
- Altered taste sensation can be caused by: concentrated flavors such as cinnamon (no longer used)
- Thermal tooth sensitivity: typically transient. Disappears once treatment is terminated.
- Gastric irritation may be caused by: prolonged bleaching (rare).

Power Bleaching

Power bleaching (also known as *chairside whitening*) takes place in the dental office and involves the use of various strengths of hydrogen peroxide liquids and gels. This approach is popular with both patients and dentists, as it can be completed in as little as 1 hour. The teeth to be whitened are isolated with dental rubber dam or light-cured resin. The whitening agent is applied to the teeth, and a light or laser source may be employed to augment the process.

Side Effects (Box 14-5)

- Thermal sensitivity is normally transient.
- Soft tissue irritation and blanching can occur if the highly concentrated bleach gel contacts the soft tissues. Patients should be warned to notify the supervising staff member should they experience any tingling or burning during the whitening procedure.
- Soft tissue chemical burns can result from patients moving their mouths unexpectedly. Quick action should be taken to limit its severity (see Box 14-5).
- Whitened teeth may suddenly turn yellow or brown immediately after the ingestion of curry or red wine after power bleaching. This is rare side effect.
- Patients may exhibit claustrophobia when undergoing treatment. The intraoral bleaching apparatus plus the proximity of the light source may be intimidating for some individuals. A treatment supervisor should always be present to immediately manage any possible problems or side effects.
- Dehydration is caused by anhydrous bleaching materials or extended bleaching time.
- Gingival ulceration is the result of irritating materials that contact the peridental tissues for extended periods of time.
- Swollen lips are observed after extended bleaching sessions, and are caused by excessive heat or desiccation. Temperature management and tissue lubrication solve this problem.
- Post bleaching sensitivity typically occurs due to an excessive increase in dental temperature or dehydration of tooth surfaces during bleaching.

MANAGEMENT OF SENSITIVITY

Because sensitivity is a common side effect of bleaching treatments, it is essential to have protocols in place to manage the discomfort that patients experience during and after the

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BOX 14.5 Treating Problems That Occur during Power Bleaching

Chemical Burn

A chemical burn can often occur on the papilla between the central incisors.



This can happen unexpectedly if the patient moves the mouth. A proprietary soothing material can be applied directly onto the surfaces of the teeth to reduce sensitivity.



Sensitivity

A disposable tray with preloaded fluoride is used. The tray, which is sealed in a blister pack,



is applied onto the teeth and squeezed tightly. The outer green tray is removed, leaving the softer inner tray behind.



This is worn for a period of about 1 hour. This can be used for the reduction of sensitivity for power and home bleaching. The patient is given trays to take home to use if further sensitivity should occur.

Dehydration

Fluoride gel, a soothing material, is placed directly onto the tooth. This will help to reduce the likelihood of sensitivity occurring as a result of dehydration of the teeth during power bleaching.

treatment. There are several possible mechanisms that cause sensitivity to occur: bleaching materials and/or oxygen rapidly entering the dentin tubules and the pulp may be responsible, complicated by treatment time, the pH of the whitening gel, and the frequency of application. Patients should be warned of the possibility of sensitivity, and be given desensitizing materials to use at home.

Materials Used to Reduce Sensitivity during Bleaching

- Fluoride, in gel form or in pre-loaded disposable trays, reduces the sensitivity by blocking the dentinal tubules.
- Potassium nitrate in toothpaste, gel, or disposable tray format.
- Amorphous Calcium Phosphate (ACP) seals open dentinal tubules and remineralizes tooth surfaces.

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- Dentin bonding agents.
- Dentin desensitizing agents.
- Desensitizing whitening toothpastes.
- Proprietary soothing agents, which may contain a combination of fluoride, potassium nitrate, or ACP.

EVIDENCE-BASED PRINCIPLES

More than 20 years of clinical research has been conducted in the specific area of nightguard vital bleaching, demonstrating the efficacy, safety, and health benefits of bleaching teeth with various peroxide concentrations. The effective management of sensitivity, treatment timing, and the use of desensitizing materials has also been extensively explored. Research on the enamel, the dentin, and the pulp has demonstrated that it is safe to treat enamel with dentist-prescribed products without long-lasting negative effects or damage to the teeth.

CLINICAL CONSERVATION CONCEPTS

Bleaching is the most conservative treatment possible for enamel and dentin surfaces. All the original enamel is preserved without preparation or restorative intervention. There is no change or damage to the surface or the micromorphology of the enamel. The enamel, dentin, and pulp are preserved in their entirety. Because bleaching is the most conservative treatment possible, it is the first option, and always the first step, when esthetically improving the teeth.

MAINTENANCE

At the end of whitening treatment, the patient must understand the maintenance required. The home bleaching protocols that have been described require less maintenance. Most do not see a whiteness drop-off for several years. Some patients request a touch-up treatment after 1 to 2 years. A single tube of touch-up bleaching material is administered to the patient, who uses the home treatment for 3 to 4 days to re-establish the white shade. However, patients who whiten quickly with high-concentration whitening may not be able to maintain the bleached shade for a long period of time. Those patients may need to constantly re-whiten to maintain their coloration. Restricting the intake of heavily staining drinks (coffee, tea) and foods helps to maintain the whiteness. "Over" maintenance may lead to patients becoming obsessed with the white shade of the teeth. This condition is called "bleachorexia," the patient continually whitens their teeth, even though they are already very white, and are not getting any whiter. They become obsessed with extremely white tooth shades and want to continue to extreme whiteness. These patients tend to constantly ask the dentist to supply additional whitening gel. It is the dentist's responsibility to explain these problems to the patient and to ensure that the patient understands this condition, and then not supply additional bleaching gel. A pre-agreed bleaching end point should be establsihed between the dentist and the patient.

CONTROVERSIES

The danger for patients who over-bleach or bleach for too long is that their teeth may appear. very translucent teeth; further bleaching lightens them to extreme levels where they develop a blue-gray shade. There is an endpoint for bleaching after which no further whitening will be achieved although tetracycline research shows that it is safe to bleach for up to 1 year for severe discoloration.

Whitening withouth the supervision of a dental professional is also controversial. The individuals delivering the bleaching are not qualified, unprepared to assess patient suitability, or to expertly examine and evaluate the mouth, periodontal status, abscesses, and mucosal conditions. While some may say that dentists are simply protecting their control over the whitening practice, there is no data to indicate bleaching safety, longevity, or effectiveness under non-dental supervision. Some "beauty therapist" whitening involves chlorine dioxide. Chlorine dioxide is an acidic substance, and may cause permanent damage to the tooth. Chlorine dioxide abuse in spas cause the patient's teeth to become permanently etched and rough, picking up darker and more resistant stains that do not respond to whitening. The teeth actually become darker than their original shade.

NEAR-FUTURE DEVELOPMENTS

The near-future will see an introduction of faster whitening with power accelerators. These chemicals will be part of the bleaching material to speed up the whitening process. There may be a more effective use of lasers, ozone therapy, and lights to accelerate and enhance whitening procedures.

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CLINICAL CASES

CASE 1 Single Dark Tooth and Home Bleaching (Figure 14-70)

This case involved a patient who had sustained trauma to the upper left central incisor tooth 15 years previously. As a result of the trauma, the upper left central incisor had became discolored. The patient was also concerned about the yellow discoloration of the other teeth. It was the goal of the treatment to improve the whiteness of all the teeth generally, and to specifically whiten the single dark tooth to match the new shade of the dentition.

The upper teeth were treated first using 10% carbamide peroxide in the bleaching tray overnight for 2 weeks. The upper left central incisor was treated using 20% carbamide peroxide for 4 weeks. (This tooth had experienced trauma, and subsequently, obliteration of the pulp chamber by secondary and tertiary dentin. The nerve was vital. This post-traumatic repair process slows bleaching in that more, and darker, dentin must be whitened.) The treatment protocol should include the extra time necessary to achieve the whiteness of the central incisor. Higher concentrations of bleaching gel can be used on this darkened tooth as the obliteration of the pulp canal makes it unlikely to be sensitive. While the upper left central incisor was treated with 20% carbamide peroxide, the rest of the upper teeth were treated with 10% carbamide peroxide.

Once the desired shade had been reached for the upper arch, treatment continued with the left central incisor until it matched the right central incisor exactly. The lower teeth were treated with 10% carbamide peroxide in the tray overnight for 3 weeks to achieve the desired shade and until they matched the shade of the upper teeth. The upper and lower trays are often applied separately to improve patient compliance; upper teeth are treated first, as bleaching is more rapid on the maxilalry arch. Then, the lower tray whitens the teeth to match the upper teeth.



FIGURE 14-70 **A, Appearance of the teeth before whitening. The upper left central incisor tooth had become discolored owing to mild trauma 15 years previously. B, Retracted view of the teeth showing the dark shade of the upper left central incisor and the contrast with the surrounding teeth. C, The appearance of the teeth after whitening using 10% carbamide peroxide for a total of 6 weeks. D, Before *(left)* and after *(right)* portrait shots of the patient. E, The improvement in the white color of the teeth. At the end of treatment, the upper central incisor matches the adjacent teeth.**

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This case involved fluorosis staining of the enamel on the two upper central incisor teeth, and the overall color of the teeth is yellow-orange. Treatment plan options included bleaching with extended bleaching treatments, with possible microabrasion if this was not completely successful. The patient was also a candidate for composite bonding or porcelain veneers. These plans were discussed in detail with the patient prior to treatment.

The treatment plan implemented involved extended overnight home bleaching for 6 to 8 weeks using 10% carbamide peroxide gel in trays. During treatment, the white band on the central incisors became whiter. After the desired general whitening shade had been achieved, the teeth were treated with two sessions of microabrasion. The material used for the microabrasion treatment was 5% hydrochloric acid in a silica carbide paste. The aim of the microabrasion treatment was to reduce, or preferably, eliminate the white stains that remained after whitening. Although some of the small white stains persisted, the overall treatment has resulted in a vastly improved appearance of the teeth.



FIGURE 14-71 **A and B, Appearance of the teeth before treatment. The teeth are stained and mottled owing to fluorosis. C, The retracted view showing mottled appearance of the teeth. D, Retracted view showing appearance of the teeth after whitening of the upper teeth only. E and F, Retracted views of the teeth from the left lateral position (E) and right lateral position (F) showing the results after whitening. G, Retracted view of the teeth after completion of whitening treatment. H and I, The portrait of the patient (H) and her smile (I) after completion of treatment. The shade has whitened and there is improvement in the color and less mottling visible. The patient was delighted with the result.**

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Direct Veneers

Direct Composite Bonding

Emanuel Layliev, Jeff Golub-Evans

RELEVANCE TO ESTHETIC DENTISTRY OF DIRECT COMPOSITE BONDING

Direct composite bonding has been around since the 1970s. It has had an enormously beneficial impact, making it possible to improve a patient's appearance via a very simple, straightforward technique without impression and a laboratory to make porcelain veneers. With composite, a better smile can be created for the patient very quickly and efficiently using a noninvasive technique. Dentists are able to dramatically change a patient's appearance and thus improve self-image and boost confidence.

Essentially, the procedure is done in a single sitting by the dentist. Patients come in and within a matter of hours leave with their new look. It is a fairly predictable procedure because the esthetic dentist is in full control of the procedure. It also allows for modifications in the future, as it is possible to add to the composite for further improvement. Patients have the opportunity to influence the outcome as well. Their involvement in the treatment process makes them more likely to be satisfied with the final result.

BRIEF HISTORY OF THE DEVELOPMENT AND EVOLUTION OF THE DIRECT COMPOSITE BONDING PROCEDURE

The procedure for direct composite bonding has undergone an incredible evolution, along with an upgrade in materials that help create proper esthetic anatomy, characterization, hue, value, chroma, position, form, function, direction, and texture. It is now possible to improve a patient's look predictably.

In the late 1970s macrofill composites were not very polishable, so dentists could not achieve as much of a shine as is possible today. These resins gave way to two classes of materials in the middle 1980s: the microfills, hybrid microfills and nanofills. The microfills are extremely polishable but stain over time. The nanofills did not evolve into successful products until after the 1990s.

In the 1990s, hybrids came into a fairly common use. These combine larger and smaller particles to fill the spaces between the resin filler material. With less resin material, there is less stainability. The hybrids are harder resulting from longer lasting surfaces.

Around the turn of the century, the nanohybrids were introduced. Extremely tiny particles fill in even smaller spaces and eliminate much of the resinous material. This makes the material stronger, more polishable, and less likely to stain. Today bonding is done with nanohybrids, sometimes including a very thin surface layer of microfills for even greater polishability.

Patient Expectations

In the 1980s patients were happy with rectangular white teeth. Today's patients are much more educated, discerning, and demanding. They want their teeth to look very natural and want replacement teeth that cannot be differentiated from natural healthy teeth.

In the 1980s, only porcelain veneers could produce an acceptable result. Today, dentists can replicate the look of porcelain with composite, although its durability and polishability are not as good. Composite is not as natural in appearance as porcelain, but it has evolved to create a better immediate result. Composite normally requires some maintenance at least every 1 to 3 years to polish the surface or correct any chips that may have occurred.

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BOX 15.1 Relating Function and Esthetics

1. Check for functional problems:
   - Previous
   - Current
2. Include functional treatment as part of the esthetic plan

RELATING ANTERIOR FUNCTION AND ESTHETICS

The typical reason a patient requires the placement of direct composites in the anterior include normal wear and tear, occlusal disturbances, aggressive tooth brushing, or eating too much crunchy food. To create the proper look cosmetically, it must first be determined what has made such treatment necessary. It is important to evaluate the patient's habits and normal function. This will reveal occlusal problems, perhaps abrasion, nutritional problems, erosion, or bruxism. The wear is evaluated to identify its cause, and then treatment possibilities and precautions are planned (Box 15-1). The goal is to avoid such wear in the future or at least minimize the threat of repetition. This involves evaluating what has happened to the individual's teeth, and to the opposing dentition (e.g., the lower arch) to ensure that a better profile, shape, and position can be created for those teeth. Various modalities such as Invisalign (Align Technology, Inc., San Jose, California), bonding, or enameloplasty may be employed.

If the esthetic evaluation indicates that it is desirable to extend the patient's central incisors by 2 mm in length incisally, it must be assessed whether this is possible. The outcome depends on functional, protrusive excursive, and lateral excursive movements. It may also be necessary to extend the coverage of the composite onto the tooth more to the lingual surface to create a stronger restoration, a night guard, and to evaluate the **condition** of the posterior teeth to rearrange the vertical dimension so it is possible to build up the anterior segment by 2 mm. This generally involves opening the bite in the posterior region by less than 2 mm.

To summarize, first evaluate the functional situation for both previous and current problems and then keep those situations in mind when planning treatment. Functional treatment planning is an essential part of the esthetic program. If esthetics and function are not addressed together, the case will fail.

CLINICAL CONSIDERATIONS

Indications

If a patient has chipped, discolored, stained, underdeveloped, fractured, or worn teeth, it is possible to bond and repair specific areas to improve the condition. When addressing a chipped tooth, the chip restoration and veneering can be done at the same time. Discolored or stained teeth generally require a masking layer, an opaquer, placed first and then a buildup of the desired colors in layers.

Underdeveloped teeth, such as a peg lateral, are usually not color compromised. Generally, existing tooth structure and composite are used to build out a functional, larger, more true-to-life tooth in the space available. With orthodontically compromised teeth, orthodontic therapy can be done first or a buildup to create a thicker tooth to compensate for the malposition. Fractured and chipped teeth are treated similarly. Worn teeth are the result of parafunction, faulty occlusion, or loss of vertical dimension. It is essential to pay careful attention to how function and the desired esthetics relate, evaluate the condition on a mounted model using a face-bow.

Contraindications

Contraindications include limitations. One must be very aware of the limitations that prevent the opening of the bite for one reason or another. The best way to evaluate whether it is possible is to add some composite incrementally to the posterior dentition. A night guard also open a patient's bite. Then the patient can determine if he or she is comfortable in that raised vertical position.

Contraindications to using direct composite bonding include gross loss of tooth structure where composite would not be strong enough. In these cases a porcelain, crown, or veneer may be more suitable. A grossly decayed, or brittle teeth or poor oral hygiene are also negative indicators. With poor hygiene it is difficult to maintain the margins, and decay will reoccur.

MATERIAL OPTIONS

It is the author's recommendation to use a 37% phosphoric acid–etch with a light-cured adhesive (fifth generation), specifically, OptiBond Solo (Kerr Corporation, Orange, California). Composite materials used for veneering include hybrid Point 4 (Kerr Corporation) available in various shades, including opaques. As a final layer, Herculite (Kerr Corporation) Enamel Light or Extra Light is placed. Obviously the material of choice depends on whether the adjacent and other teeth are light enough to match. The color is built up in a microhybrid used below a microfill. The actual color of the dentin is placed over that. At times translucency is required. Vitalescence (Ultradent Products, South Jordan, Utah) and Trans Smoke or Iridescent Blue shade are excellent.

Advantages

The advantages of composite versus porcelain direct veneers include that they are the more conservative option, are noninvasive, give immediate results, involve no lab expense, and are more predictable because they are done chairside. They are less expensive for the patient than porcelain veneers. They are indicated over ceramic while the candidate is still developing, up to age 22 or 23 years. Composite veneers are reversible because the tooth structure does not need to be prepared.

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Disadvantages

All required maintenance is a disadvantage. Composites can stain, chip, and lose luster. They are also very technique sensitive; the dentist must be adept and very detail oriented to achieve a successful result. It is necessary to polish composites to establish a superficial layer that replicates the glaze of natural tooth structure. Polishing is also important to avoid future staining. Stain can accumulate in days or weeks from normal food intake. Patients are advised to not drink or eat anything that may stain the composite for about 2 days after treatment because the composite is slightly porous. However, microfill is not as porous as a hybrid. In addition, if one polishes well enough, it will diminish the chance of staining and dulling.

Patients who smoke, drink dark beverages (red wine and dark coffee), or eat highly staining foods are at greater risk for staining their direct composite veneers. Such habits must be evaluated, and patients advised to avoid and limit them as much possible. Patients should be made aware that the composites may need regular polishing or resurfacing.

Current Best Approach

Young adults are better candidates for direct composite bonding than they are for porcelain veneers because their teeth are still developing. The gingival margins can show once the teeth fully develop. Later, composites can be upgraded to porcelain veneers. Patients should be given the choice of a porcelain veneer or a composite direct veneer bonding and the rationale behind each choice, the advantages of each, and the cost.

When patients have had bonding in place for over 5 or 10 years, they may be ready for the porcelain upgrade, or they may choose resurfacing, the removal and reapplication of the composite in its entirety or partially.

For the patient without any anterior decay, composite veneers are very popular. They are noninvasive and conservative, offering a more holistic approach without any reduction of tooth structure.

OTHER CONSIDERATIONS

Some of the other considerations are the natural look of porcelain, the invasiveness of the procedure, and finances. Porcelain best emulates enamel because it can recreate natural-appearing translucency more predictably than composite.

Porcelain veneers are a more invasive option because a certain space is necessary. Veneers usually require reduction, although ultimately it depends on the position of the teeth. In most cases, preparation is necessary to create retention or to break the contact between the interproximal teeth.

When looking at the financial considerations, there is a lab expense involved with porcelain and the price reflects that fee. The price of composite veneers is about 50% to 75% of the cost of porcelain veneers. In addition, porcelain veneers often last 15 to 20 years compared with only 8 to 10 years for composite bonding. Generally the gingival line recedes away from the gingival margins of the restoration, and as the gum recedes, the margins may stain, or black triangles can be created at the gingival embrasures.

The time spent on a composite veneer is about 60% to 70% that of a porcelain veneer. No second visit is required for the composite, aside from a follow-up evaluation.

INNOVATIVE ELEMENTS

Scientific Elements

Increased bond strengths are the major element that has made composites successful and predictable. These materials are also more polishable and are available in a wide range of shades. This is important considering patient desires to make teeth look as white as possible. Ten to 15 years ago, people were not as aware cosmetically and did not expect the esthetic results that can be achieved now. Today media hype and celebrities drive patients' desire to get teeth super white. Shade, increased bond strength, and increased polishability are scientific elements that have advanced.

Technologic Elements

Research leads to a continuing upgrade in materials. With this dynamic evolution, there is always something new at conventions with regard to the sixth- and seventh-generation adhesives and better composites. Every decade has brought a quantum leap in technology, so composites are now easier to place, more convenient, stronger, and more esthetic.

Relationship among Adhesives, Bonding, and Etching

Typically 34% to 37% phosphoric acid is used as an etchant. It is available from many manufacturers. Once the enamel and dentin have been prepared with phosphoric acid, dental bonding agents and restorative composite materials complete the process.

There are two major categories of composites and adhesive materials in dentistry. One is BIS-GMA, and the other is polyurethane. Fortunately for the dental profession, these materials interact seamlessly. Without knowing the chemistry of individual bonding agents and veneer composites, the dentist can feel secure in using any bonding agent with any composite. Manufacturers prefer that the dentist use the bonding agent and composite within the same system, but from a dentist's perspective, if an adhesive from one manufacturer and a composite from another manufacturer seem to be more suitable, this is not a problem in terms of chemistry, longevity, or adhesion.

ARTISTIC ELEMENTS

It is necessary to evaluate the impact of bonding on the face, not just on the actual appearance of the teeth. The entire face must be considered. This includes analyzing the shape of the lips and cheeks.

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In analyzing the look of the face, it can be measured or visualized. For example, a patient may have a round or oval face. The treatment choice depends on what the patient wants. If the teeth look too flat and make the face look too round, the dentist can solve the problem by making the teeth appear a bit longer. If the patient's face is too oval, the dentist can shorten the length of the teeth. If it appears that there is too much negative space at the buccal corridor in the posterior, the dentist can refurbish the smile by adding more tooth structure, thus plumping out the arch and creating a fuller, more youthful appearance.

Golden Proportion

The golden proportion relates to the anterior teeth as they progress toward the posterior. It is a specific ratio, 1.618:1. The two central incisors are larger than the corresponding laterals. The visual proportion of the centrals to the laterals is 1.618:1. The visual proportion of the laterals to the cuspids (viewed from the front) is 1.618:1. The visual proportion of the premolars and molars follows a similar ratio.

This proportion appears repeatedly in nature, and seems to have a very pleasing effect on the human eye, although it is not clearly understood why this is so. The effect occurs consistently, in dentistry and in other areas of esthetic harmony.

Hue, Chroma, and Value

The **hue** is the actual color portrayed. The **chroma** is the saturation and richness of that specific color. The **value** is the degree of gray versus white. Usually the dentin imparts the hue and chroma, and the enamel layer imparts the value. If one has a high value, the teeth are white; if the value is low, the teeth are grayish or dark. Of the three, value is the one that is the most important, the one feature that the eye picks up most readily.

Translucency, Opacity, and Fluorescence

Tooth structure is also **translucent**, a quality that must be matched in the restoration. Normally enamel is not completely transparent but translucent to a degree. To recreate that look requires various staining composites. Translucency is usually more pronounced in the incisal thirds of teeth.

To create translucency, the violet, blue, and red are added as appropriate. For female patients a blue hue is used; for male patients a more violet color is chosen. The enamel layer (or microfill) is placed over the translucent characterization.

Opacity originates in the dentin. It is seen throughout the entire tooth structure, mostly at the gingival third and mid-third, but is less apparent interproximally. As one approaches the incisal segment, the teeth are translucent rather than opaque. In building up a chipped tooth, the internal dimension requires a more opaque layer.

Fluorescence is defined as the look of the teeth under a "black" or ultraviolet light. Natural teeth sparkle white, unnaturally so, under a black light. The dentist must use composites that have fluorescence built in to recreate this. Otherwise, anterior veneers built up with a nonfluorescent composite disappear under black light conditions. It seems that the individual's teeth are missing, which is not esthetically pleasing. Natural fluorescence also has components that benefit the appearance under natural and sunlit conditions, creating a certain "glint" that is defined as natural looking. Natural fluorescence is an important addition to composites used in direct composite bonding.

TREATMENT PLANNING OPTIONS

The options for treatment are presented to the patient so that, along with the dentist, a mutual decision can be made regarding what will be done. The orthodontic condition of the teeth must first be assessed. It may be wise to first reposition the teeth with either traditional orthodontic care or with Invisalign. Once completed, one can alter the position, shape, and color of the teeth with either porcelain or composite veneers. Another method is to temporarily alter the appearance with a "Snap-on Smile" technique in which an impression is taken and sent to the laboratory; the shade is chosen to create the desired look and color of the teeth.

Sequence

It is best to pre-evaluate what can be done on the teeth with orthodontic wax applied on the tooth structures. This is the traditional initial wax mock-up. Alternatively, composite can be used, a digital imaging software system may be used as well. These smile design programs can be used to create an esthetic look. The images are printed out and given to the patient to consider. Photographs and impressions are also taken. A wax mock-up can be constructed on a model in a laboratory, or in the office. A three-dimensional model is made to show the patient the desired look.

Assuming the patient has accepted the treatment, an appointment is scheduled. Anesthetic can be used or not. There is no need to numb the patient unless the procedure is more invasive. The dentist and patient commit to the procedure and determine whether it is necessary to reduce a tooth. Then the actual bonding process is undertaken, followed by polishing. A follow-up visit checks on the integrity of the bonding, to make sure the contacts are proper, to ensure that the margins of the composite do not impinge on healthy gingiva, and to protect the veneers with a night guard to prevent chippings from parafunctional activity.

The impression for the night guard is taken after the composite have been applied. If the patient is happy with the look, an impression can be taken then, and a night guard fabricated in the office. The type of night guard depends on the parafunctional activity. There are different types of designs, laboratory, and in-house. The NTI Tension Suppression System, made by Trident Dental Laboratories (Hawthorne, California), an anterior

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incline, covering either the entire arch or half of the arch from canine to canine. These soft splints have a soft interior and a hard exterior.

TREATMENT CONSIDERATIONS

Treatment depends on the position and shape of the teeth and whether they are chipped, discolored, and so on. Generally the dentist tries to prepare as little as possible. The goal is to be on the enamel and not in the dentin because enamel achieves a better bond. If the tooth exhibits sharp ridges or sharp edges, it is not necessary to reduce it. It may be possible to add the composite to it without reduction. The author's practice is to bevel the enamel to create a flare so the finish appears flush with the superficial tooth structure. Beveling increases the surface area for maximum durability and esthetics.

If there is a very dark but limited discoloration, it is removed with a bur before application of composite.

Preferred Locations for Margin on the Buccal

The extent of the esthetic problem dictates how much of the tooth structure is involved. It may be advisable to extend it all the way down to the gum line, or to stop midway through the tooth with a bevel.

Preference for Finishing Margin on the Lingual

On the lingual, the margin is positioned where there is enough space to retain the beveled surface without sharp edges. When the patient occludes, the occlusion should not be at the margin, where composite meets the enamel. Occlusion should occur either on the composite or on natural tooth structure, not at the actual margin.

Preferences Interproximally

In the interproximal, it is preferable to break contact only when absolutely necessary. Results are more predictable when tooth structure remains at the contact area.

Treatment Considerations for Bonding

For the bonding procedure the goal is to have as much enamel present as possible. The enamel is completely etched and rinsed but not completely desiccated. Adhesive is then applied. The site is isolated from the adjacent tooth with a clear Mylar strip.

After application, air drying, and light curing of the bonding agent, the initial layer of composite is adapted to the tooth, starting at the interior of the preparation and building out. A base layer is applied to control color over the whole tooth. This is cured, and then subsequent layers are placed, curing between each layer of composite.

To recreate the ideal three-dimensional incisal anatomy of the anterior teeth, the composite is applied to the inner dentin first. The lingual portion of the incisal is placed against a matrix of silicone or rubber template to recreate the lingual. There are usually three layers applied up to the incisal area, depending on the degree of transition needed. The goal is to impart a natural look of translucency and to include any necessary stain.

Most of the buildup is done with microhybrid material, then a layer of microfill is added to the correct buccal anatomy without overbuilding. If needed, trimming can be done.

Finishing

Finishing diamonds are used from coarse to medium to fine. Then polishing carbides create a smoother finish followed by a white stone. Finally disks Super Snap Shofu, from coarse to fine. Dental Corp. (San Marcos, California) followed by diamond polish paste called Diaglaze by Antraco Inc. (Livingston, New Jersey) to produce a polished texture.

Clinical Conservation Concepts

Basically, direct composite bonding is the most conservative approach after the orthodontic option because it is noninvasive and "reversible"—the dentist does not trim healthy tooth structure.

MAINTENANCE

Composite bonding should be checked yearly, at least, and touch-ups may be required. It is possible to resurface the composite using the above technique. It is also possible to revitalize composite. At times they may absorb some pigment and stain from consumed substances. Polishing the dull surfaces improve their appearance immediately. Patients are also advised to avoid or minimize eating things that are too hard or crunchy. Examples include ribs and pistachio nuts. Patients must be meticulous in their homecare. This includes oral hygiene.

CONTROVERSIES

It is important to ensure no gingival irritant from the margin of the composite is introduced that might affects the health of the gingiva.

NEAR-FUTURE DEVELOPMENTS

All of the composite materials available are excellent, but there is always room for improvement. One goal is to emulate tooth structure as well porcelain.

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CASE 1

A female patient had short and narrow upper anterior teeth with space present interproximally. She was unhappy with her appearance (Figure 15-1, *A* and *B*). A treatment plan was established to include bonding the maxillary anteriors, canine to canine, while the rest of her upper dentition involved crown and bridgework. The end result portrays teeth that met her esthetic and functional expectations, and made her look attractive, and complemented her appealing facial features (Figure 15-1, *C* and *D*). The procedure took about 4 hours to complete and was done in a single sitting. She returned for a follow-up about 2 weeks later to make sure her gingiva were healthy, the bonding intact, and the esthetics up to her expectations.



FIGURE 15-1 Pre-treatment intraoral (A) and full face (B) photos showing short and narrow upper anterior teeth with space present interproximally. Post-treatment intraoral (C) and full face (D) photos showing an esthetically pleasing result.

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SECTION B

Transitional Bonding

Corky Willhite

RELEVANCE OF TRANSITIONAL BONDING TO ESTHETIC DENTISTRY

Transitional bonding allows practitioners to make major or minor changes in occlusion and esthetics with little or no reduction of tooth structure (Figure 15-2). With this approach it is possible to address cases with various esthetic problems, and, perhaps more important, health issues can often be treated. Examples include wear from bruxing; loss of occlusal tooth structure from erosion, decay, or fractures; and numerous teeth missing. Such situations may cause a decrease in vertical dimension leading to esthetic and functional problems. Restoring teeth that have worn down or are developmentally small so that the teeth are long enough or large enough to look more attractive without opening the bite could create a very deep overbite or other negative change. By increasing the vertical dimension one can often compensate for that.

Increasing the vertical dimension of occlusion (VDO) allows more space or clearance for restoring wear and lengthening the teeth. Most people will experience some loss of VDO with age. Many adults by the age of 50 could benefit from treatment that lengthens teeth for esthetic and/or functional improvements.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF MATERIALS AND TECHNIQUES

The ability to adhere restorative materials to enamel and dentin is a critical development. Clinical dentists are now able to bond composite to tooth structure with a strength comparable to the bond of enamel to dentin. This adhesive bond is very long lasting and, under normal occlusal forces, will provide retention of a restoration for years.

Current composites are not routinely more fracture resistant than early versions, but by having particle sizes that allow them to be more polishable, the current materials are more esthetic. These materials' wear resistance is similar to that of enamel as well. The microhybrid and nanofill composites that have been developed in the last 20 to 25 years are critical for the success of transitional bonding. Handling properties that allow for placement, sculpting, curing on demand, contouring, and polishing allow these restorations to mimic natural tooth structure.

In the last few years the advantages of increasing VDO for patients who have lost some vertical dimension or who never had a fully developed VDO have become more accepted. This procedure can be predictably successful when the occlusion is handled properly.

RELATING FUNCTION AND ESTHETICS

Often the dentist is faced with conflicting demands between function and esthetics. The first step in preparing for any major change is an esthetic evaluation of the patient, using photography, study models, and a clinical examination. For a patient with obvious esthetic shortcomings, an "improved smile" should *not* be the goal—that is too easy. The goal should be to determine what changes would provide the "best smile possible" for a patient. A systematic approach to smile analysis, using smile design principles, promotes this goal. This would include principles such as the height-to-width ratio of the esthetic zone, width-to-length ratio of the upper central incisors, arch and tooth widths and proportions, and smile line, as well as numerous others.

Once the esthetic treatment plan has been determined, then the tooth size, shape, and position are evaluated in terms of whether they permit the ideal functional outcome. At this point the dentist determines whether the centrals have been lengthened sufficiently and whether that would create a deep bite that might compromise occlusal function. Determination of whether, and how, to adjust the occlusion to obtain ideal function would be the next important step. That might include increasing vertical dimension or, rarely, decreasing it. After occlusal principles have been used to confirm whether this esthetic change will work functionally, then the proposed treatment plan for the patient can be presented.

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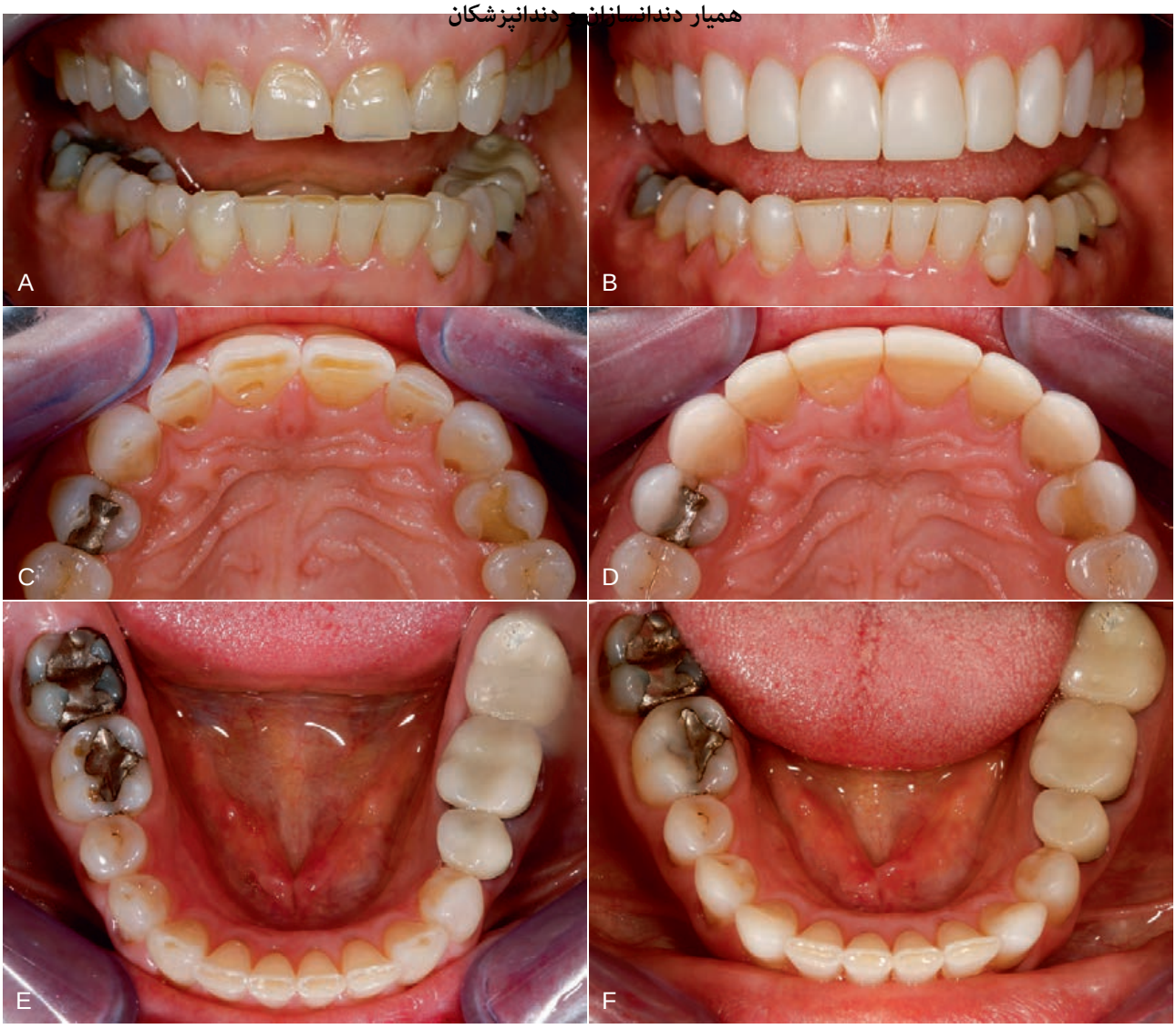


FIGURE 15-2 **Transitional bonding completed on the eight upper teeth, the cusps of the lower premolars, and the first molars to restore wear for esthetics and function. Vertical dimension of occlusion (VDO) was increased slightly. Pre-treatment (A, C, and E) and post-treatment (B, D, and F) photos.**

There will be some cases in which the esthetic and functional treatment plans cannot be rectified. For instance, increasing upper anterior tooth length results in greater overbite unless the VDO is increased. If the patient is an occlusal Class II, increasing VDO to compensate for this will result in an increased overjet if the mandible is in centric relation. So a compromise may be required to either the esthetic or the functional plan.

Each case is evaluated considering the dental and periodontal condition, but occlusion is a major factor. Generally, the goal is to end up with teeth of normal size and length, having a normal amount of overbite and overjet, with anterior guidance in protrusive and canine guidance in right and left lateral excursions. Ideally the guidance provides posterior disclusion. In successful cases these esthetic and functional goals will have been achieved.

CLINICAL CONSIDERATIONS

Indications

A common situation is severe wear caused by bruxism, in which the patient has a reduced vertical dimension. Such teeth can be restored to their original condition or better. In less common cases there may be a skeletal growth problem that produces a mismatch in the size of the maxilla and mandible, and a Class II or III occlusion. In a Class III patient whose maxilla is underdeveloped and tooth display is less than desired, upper teeth can be lengthened and bulked out facially for better esthetics including increased tooth display and lip support. By opening the vertical dimension in such cases, it may be possible to alter these cases enough that a Class I occlusion results, because when the mandible is in centric relation and VDO is increased, overjet also increases.

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Extensive decay is a less common indication. Decay may be severe enough that loss of tooth structure has allowed some collapse of VDO as with tooth loss. Restoration of the teeth including increasing VDO creates better esthetics and function.

Another indication is a bulimic patient who has sufficient erosion of the upper lingual surfaces that anterior teeth have supererupted. Such patients may not have experienced an actual loss of vertical dimension if the posterior teeth are intact, but opening the bite can create enough occlusal clearance to restore these eroded surfaces without having to prepare them as for a traditional restoration—probably a crown—resulting in more loss of tooth structure.

The prior examples all include increasing VDO. However, the majority of restorative cases will not require that. A more common indication would be a patient who has worn the anterior teeth enough that anterior guidance is deficient, with resulting posterior interferences. Restoring anterior guidance can be accomplished without opening the bite. Building more guidance than the patient originally had may also be possible—in patients with developmentally small teeth, for example.

Overbite is increased if incisal length is added without increasing VDO. As long as this result is not excessive, there is no reason to consider this a deterrent.

Ideally, incisal and canine guidance should be built so that the posterior teeth disclude in all excursions. This posterior disclusion protects the posterior teeth. If the anterior teeth continue to wear, then rebuilding them as posterior interferences recur is a valid option, as opposed to equilibrating away enamel on posterior cusps.

Another indication would be a patient who has a slide from centric relation (CR) to maximum intercuspal position (MIP). Rather than equilibrate (removing enamel) to correct this, consider positioning the mandible at the first point of contact (typically second molars touching on one side) and augmenting other cusp tips to create new occlusal stops to stabilize this mandibular position, which now becomes the MIP. The slide can be eliminated without any enamel loss. Anterior centric stops can be built by adding to the lower incisal edges, but more commonly the author achieves this by adding to the lingual of the upper anterior teeth; often in combination with lengthening the upper anteriors.

This type of approach provides the patient with a more ideal occlusion (CR now coincides with MIP, and anterior guidance provides posterior disclusion) and results in a more esthetically pleasing smile (restoring worn upper anterior teeth for more tooth display); and conserves tooth structure (little or no prepping, nor an equilibration, is required). Numerous other advantages are achieved as well, but these alone make this option very desirable.

Contraindications

Periodontal disease and tooth mobility with anterior flaring could also be a reason for decreased VDO and a collapsed bite. One contraindication to lengthening teeth is periodontally involved, unstable, mobile teeth.

Another significant contraindication is the dentist who does not feel confident of his or her clinical skills related to technique. Transitional bonding is a somewhat technique-sensitive procedure, and without the training and experience to achieve predictable results, many dentists should hesitate to attempt it.

MATERIAL OPTIONS

Glass ionomers and resin ionomers are not appropriate material choices because of handling and mechanical properties. The material should be sculptable and fairly viscous, providing enough working time to adapt the material and then cure on demand. These materials do not hold up well in the occlusal situations with incisal edges and built up cusp tips. The compressive and shear forces during normal mastication—and certainly during bruxing—would likely cause fracture and wear on surfaces subjected to mastication. Esthetically these materials are lacking, as well.

Amalgam is not appropriate because of its un-esthetic properties and the difficulty in building up an incisal edge. Certain posterior situations might allow amalgam to be one choice—for instance, if old fillings or carious lesions also need restoration.

Ceramics may be appropriate but only for a definitive restoration—not a transitional restoration. Cost is a significant disadvantage as well. There are situations in which it is appropriate to restore some teeth in porcelain, whereas other areas of the mouth are treated with transitional bonding.

Composite is the ideal material for this procedure. It is the most versatile of all restorative materials and offers many advantages including the ability to adhere to tooth structure even in the most non-retentive situations. Handling and mechanical properties allow these restorations to be built intra-orally and to survive for an extended time.

Advantages of Composite

A significant advantage of using composite and the transitional bonding procedure is that it is possible to be extremely conservative in maintaining tooth structure. The great majority of cases require little or no preparation. If preparation is needed, it is more conservative than with any other option.

Another advantage is that these restorations are very easy to adjust as the dentist is refining occlusion or completing esthetic contouring. The composite can be reduced quite quickly or can be added to without much difficulty, if necessary.

The technique is a direct technique, so it does not require laboratory involvement other than for a diagnostic wax-up. A wax-up on mounted models is recommended so as to create a template (e.g., putty index) to aid in the intra-oral procedure. An excellent alternative to obtaining a lab wax-up is for the dentist to use composite on the mounted models and mock up the case. This provides valuable practice in handling composite, sculpting, and contouring—all skills that enhance the intra-oral result.

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Composite can be very esthetic. Although the transitional bonding technique does not maximize the esthetic results—because there is no layering of materials for effects such as incisal translucency or shade blending—a major esthetic improvement can still be expected. The author estimates that 70% to 90% of the esthetic improvement can be accomplished with transitional bonding as compared to "ultimate esthetics" composite restorations or porcelain restorations.

Another advantage is the option to upgrade the treated teeth to definitive ceramic restorations at some point (either all at once or phased in a few teeth at a time), using any remaining composite—after preparation—as a core buildup. Another option is to improve the esthetics with composite by prepping away a portion of the transitional bonding and then layering composites of varying shades and/or translucencies for a more ideal, esthetic result.

In addition, the compatibility of composite with natural tooth structure in terms of wear is ideal. Having a material that wears slightly faster than enamel is desirable because it is preferable to have restorations wear rather than opposing natural teeth, as may occur with porcelain restorations.

Fracture resistance is another advantage. The fracture toughness values are so similar between composite and feldspathic porcelain that there is no significant statistical difference. In normal situations when the restorations are built properly, there should be no greater incidence of fracture than with porcelain restorations, similar to the incidence with natural teeth, as well.

Marginal integrity is an advantage, as well. With composite it is possible to develop margins that are extremely smooth and sealed—especially supragingival margins ending in a feathered finish over a bevel on enamel. On the other hand, consider the margin of a class II posterior composite with a deep proximal box: there is little or no enamel to bond to, more distance from the curing light, potential moisture control problems—all routine challenges for achieving sealed, smooth margins in class II composites. Most of the margins built in transitional bonding are supragingival, so the situation at the margin is very different; there is enamel, and a beveled margin means minimal bulk of composite, making polymerization shrinkage less critical—all factors that lead to margins that are very resistant to microleakage.

Finally, fees should be lower than for definitive restorations. If only anterior teeth are being treated, the savings may not be as dramatic as when many posterior teeth are included. The time to complete anterior teeth should be less than performing definitive restorations, but there is a much greater differential when building up buccal cusps of posterior teeth. So when more teeth are included in the treatment plan, generally the savings grow exponentially. This is a critical advantage for many patients.

Disadvantages of Composite

Longevity is still not as good as one might like. The restorations will not last as long, in most instances, as porcelain restorations. The dentist should appreciate that longevity is not every patient's highest priority. The advantages described earlier may be more valuable to many patients than longevity.

Technique sensitivity of any adhesive restoration is still a challenge. Moisture control in the wet environment of the mouth is often less successful than desirable—but this equally affects all materials to be bonded, not just composite.

Current Best Approach

Composite resin is the only material available that allows dentists to accomplish the transitional bonding procedure. The best approach is with composite.

OTHER CONSIDERATIONS

Since transitional bonding takes less time than definitive treatment, and no lab fees are incurred, the cost should be less than for almost any other option. It is easier for more patients to accept treatment when it can be offered at a more affordable cost. Financial considerations are the most important factor for many patients. Having an option between "traditional definitive treatment" and "no treatment" allows more patients to take advantage of what dentistry can do to improve their lives.

INNOVATIVE ELEMENTS

The ability to make a major change—whether it be a smile makeover for cosmetic purposes or a full-mouth rehabilitation for patients with severe breakdown—without prepping or with only very minor prepping is an important step forward. There is essentially no loss of tooth structure even though the esthetics and occlusion are dramatically improved.

Therefore, transitional bonding in most cases could be considered reversible treatment. When dealing with complex cases or very demanding patients, the option to "give the patient their old teeth back" may be very appealing.

The ability to bond composite to tooth structure is critical. Using adhesive techniques that provide predictably excellent bond strengths is easy today, with many adhesive systems and options available.

Current composite materials provide many benefits including good handling properties, fracture resistance comparable to most porcelains, wear compatibility with tooth structure, excellent esthetics, and polishability.

TREATMENT PLANNING

Options

Depending on the patient's needs and goals, the major portion of the treatment plan could be transitional bonding. If traditional, definitive treatment is planned—such as ceramic veneers or crowns—the provisional stage should accomplish many of the same benefits as transitional bonding. For more complex cases or demanding patients, transitional bonding allows more time

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to work out esthetic or functional issues as needed, before definitive treatment.

Many treatment plans could include some definitive treatment combined with transitional bonding. An example would be 10 maxillary porcelain veneers and on the mandibular, transitional bonding to align worn incisal edges and open the VDO slightly to enhance the overall result, for a patient who cannot afford all the teeth to be restored in porcelain.

Another option is that additional treatment may be accomplished when specialists are involved, so interdisciplinary treatment can be completed before definitive restorations. This option can help ensure that costs are minimized. For example, a patient needs periodontal surgery to correct a dehiscence but also needs restorations because of significant wear that affects the occlusion and may be contributing to the periodontal problem. The transitional bonding can be done first to achieve most of the esthetic and occlusal goals, then the surgery can be completed and time allowed for healing. If the surgery is successful, definitive treatment can proceed, and if not, an extraction is followed by an implant or bridge.

Sequence

After an initial consultation, a comprehensive clinical examination of the patient is done. Once those records are gathered, diagnosis and treatment planning are accomplished. For cases with major changes, a diagnostic wax-up on mounted models is invaluable (Figure 15-3). Providing detailed instructions to the laboratory regarding tooth size, shape, and occlusal considerations helps ensure a successful outcome.

With the diagnostic wax-up in hand, a template is made to aid in the actual fabrication of the restorations in the mouth using a rigid polyvinyl siloxane material dispensed from an automix cartridge system or a hand-mixed putty. The template will be used to build the lingual and incisal surfaces of these restorations.

If upper and lower anterior teeth are to be restored, the lower anterior teeth should be treated first, followed by the upper anteriors. Generally the template is used to form the lingual and incisal surfaces of the anterior teeth being treated. Rarely should more than six teeth be augmented at once; attempting more will make control more difficult, increasing the chance of bonding teeth together. Then each individual tooth is directly built up on the facial and proximal surfaces freehand.

Once the anterior teeth have been completed, setting changes in vertical dimension and anterior guidance, then the posterior teeth are started. Normally the buccal cusp tips on *lower* teeth are functional cusps (accepting crossbite cases) and it is not necessary to build the lingual, non-functional cusps; lower buccal cusps create the new centric stops on the existing upper occlusal surfaces. On the other hand, the *upper* buccal cusps are non-functional, so they are built only for esthetic reasons, typically to blend the smile line of the longer anterior teeth toward the posterior; upper lingual cusps are functional, but as long as there is at least one centric stop on each tooth, long-term stability can be expected.

The lower posteriors should be completed before the upper teeth. When building lower buccal cusp tips—these functional cusps can be built up 1 mm or so to increase VDO—it should save time to avoid the template so that as each cusp tip is sculpted the patient can occlude into the new bite position before curing. This single uncured composite cusp conforms to the opposing tooth and is cured while the patient is holding that bite. After initial curing, the patient opens and the excess can be quickly contoured. If the amount of composite sculpted onto the cusp tip is fairly close to the correct amount, each cusp can be built in about 10 minutes so that all the posterior centric stops may be developed in an hour or two. If more than 1.5 to 2.0 mm is to be added to any cusp, it may be necessary to add composite to upper occlusal surfaces as well to create centric stops, so the lower buccal cusps do not become too long and pointed.

The upper posterior buccal cusps are completed last. These may be simple enough to sculpt freehand, or it may be helpful to cut the upper template in half (at the centrals) and use the right and left halves to form these longer cusps. Once the upper and lower posterior teeth are completed, checking excursions for posterior interferences is the next step. Adjusting the occlusion so that the centric stops are maintained and interferences are eliminated is accomplished by contouring only on the cusp slopes, not at the cusp tip with the centric stop.

TREATMENT CONSIDERATIONS

Preparation

There is virtually no preparation needed for most of these restorations. It is recommended that the teeth be pumiced with plain water mixed with fine pumice to ensure that the surface has no plaque, stain, or even pellicle layer to potentially inhibit adhesion. Next, any worn or chipped enamel surface should be lightly prepped, along with any exposed dentin. This accomplishes two goals: first, any sharp edges that have worn in should be rounded slightly; second, any sclerotic dentin should be lightly "freshened" for maximum adhesion.

On any anterior teeth that are visible in a smile, a very shallow bevel on the *facial* surface will provide a better blend from the composite to any visible tooth structure, which minimizes a "two-tone" effect. This bevel should be so minimal that dentin should never be exposed. In fact, the author recommends that less than half of the facial enamel thickness be reduced even where the preparation would be deepest—at the incisal edge—becoming shallower as the bevel extends to the margin. There should be no chamfer, with the bevel ending on the facial surface 2 to 3 mm from the incisal edge; a general guideline would be to make the bevel about as long as the amount of length to be added by the restoration (Figure 15-4).

Procedure

Because transitional bonding is so conservative, there is rarely a need for anesthetic. Unless a tooth is hypersensitive or there are subgingival extensions of the restorations, anesthesia should be unnecessary for the great majority of patients.

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FIGURE 15-3 **A to C, Pre-operative condition: severely worn teeth resulting from bruxism. D to F, Diagnostic wax-up at the new, increased vertical dimension of occlusion (VDO). G to I, Teeth restored with transitional bonding. Occlusal views demonstrate the pre-operative condition of the worn teeth (J and K).**

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FIGURE 15-3, cont'd **L and M, the diagnostic wax-up with the new occlusal stops at an increased VDO. Note that the upper anterior teeth have had wax added to the lingual and incisal surfaces, the lower anterior teeth have had wax added to the facial and incisal surfaces, and the posterior stops are developed by adding to the lower buccal cusps only. The post-operative photos (N and O) have the occlusal indicator paper marks present to highlight the new centric stops around the arch. These marks also show the protrusive, right and left lateral excursive contacts—this anterior guidance provides posterior disclusion.**

Pre-operative Procedure

A template is fabricated on a duplicate model of the wax-up using a rigid and accurate material. The template is trimmed to form the lingual and incisal surfaces while fully exposing the facial. Time is allowed for a polyvinyl siloxane material to de-gas before any composite is loaded. The template should extend beyond the teeth to be treated and onto surfaces without planned augmentation (including some of the lingual gingival tissue) to provide a place to apply pressure to fully seat the template. It is important not to press hard where composite is being added, as this could distort the template as it is seated.

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FIGURE 15-4 **A and B, The transitional bonding completed on the central and lateral incisors, demonstrating the shade blend from composite to enamel as viewed from the facial. Facial (C) and occlusal (D) views of an upper central incisor (before the minimal preparation) showing severe wear and dentin exposure. E and F, Minimal preparation with sharp corners slightly rounded, sclerotic dentin freshened, and a shallow facial bevel. Note the thickness of the facial enamel in the pre-operative view compared with the prepped view, which shows that less than half of the facial enamel thickness is reduced.**

Shade Selection

The shade and opacity of composite closest to the body shade of the tooth to be restored are chosen. The same shade is not used for all the teeth if the shades vary. For example, the incisors may be A1, whereas more chromatic canines may be A2. If the final result will disguise the entire visible tooth, a different shade may be chosen, although typically the author does not whiten the overall smile very much during transitional bonding; that is reserved for the upgrade to definitive treatment.

Preparation Minimal preparation may be necessary, although many teeth should require no tooth reduction at all. If there are worn surfaces the preparation would involve *slightly* rounding any sharp corners and freshening exposed sclerotic dentin with a fine diamond bur. In addition, any facial surfaces that will not be completely covered with composite require a bevel to blend the shade *if* the margin will be visible with a full smile. Margins that are not visible need not have a bevel, because the bevel is used strictly for esthetic reasons, not for retention.

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FIGURE 15-5 **Before (A) and after (B) views. Using a template—fabricated from a wax-up or mock-up—can save time when building composite restorations. These "before and after" views show the old composite that was replaced on the upper six anterior teeth. Part B was taken immediately post-operatively.**

Clean any unprepped surfaces with plain fine pumice and water in a prophy cup. It is important to remove any plaque, stain, or pellicle to achieve maximum adhesion.

Template Technique (Figure 15-5)

Loading the Template Generally the template is used to form the lingual and incisal surfaces of the anterior teeth being treated (Figure 15-6, *A* and *B*). Again, note that if the template is used for more than six teeth at a time, controlling the composite may be difficult.

Try in the template and evaluate how much composite should be loaded so as to develop the lingual and incisal surfaces (Figure 15-6, *C*). Having too much or too little material loaded will likely create time-consuming side effects such as gaps at the lingual margin or teeth bonded together. Using compules may save time loading the template with composite. Then the material should be smoothed and shaped so the proximals are separated (Figure 15-6, *D*). Place the loaded template in a dark place (a cabinet drawer may be a good option) until ready for seating.

Etch and Adhesive No shortcuts should be taken! The unprepped enamel is etched for approximately 60 seconds and the dentin for no longer than 15 seconds; prepped enamel can be etched for any length of time from 15 to 60 seconds. The directions for the adhesive of choice should be followed to ensure a good bond strength. Caution: Self-etching primers (sixth-generation agents) do not reliably bond to unprepped enamel.

Seat the Template The template is fully seated, and any excess is sculpted away, with special care taken to maintain a slight gap between teeth so as not to bond teeth together (Figure 15-6, *E*).

Light Cure and Remove the Template Curing from the facial is performed for a long enough time to set the composite on the lingual (Figure 15-6, *F*). The template is removed (Figure 15-6, *G*), and the lingual is checked for any areas of uncured composite; any pulled areas are sculpted and smoothed, then the material is cured.

Ensure Separation If any composite has bridged the proximals, it is recommended to separate the teeth using a diamond strip or saw before continuing.

Fully Form Each Tooth Add composite to the proximal and facial surfaces. Incremental buildup may be done for convenience but is not a requirement because the same composite is used to build the entire restoration. The restoration is light cured.

Contour Contouring is extremely important for achievement of the best esthetic result. Because transitional bonding restorations are a single shade, correct contour will offset somewhat the lack of polychromy. Without good contours however, these restorations can appear very unnatural and "Chiclet-like." Taking the time to learn accurate contours—especially of the upper anterior teeth—goes a long way toward having satisfied patients, regardless of the material and technique being used.

Using fluted carbide burs as well as contouring disks and strips is the most effective way to accurately develop contours, including adjusting occlusion. It is recommended that the finishing process be considered as two separate steps: contouring and polishing. Contouring should be completed before any polishing.

Final Cure Light curing in the presence of air creates an oxygen-inhibited layer on the surface of composite. If this layer is not removed, the surface of the restoration will be less resistant to wear and stain, and it will not polish as well. To ensure this is avoided, the restoration is covered with glycerin gel to block the air, then cured. Although curing for 5 to 10 seconds is generally sufficient to set an increment of composite so that it is rigid, 60 seconds is required for it to be maximally cured. So at some point after a restoration is fully formed but before it is polished, a final cure of 60 seconds with glycerin gel in place is advised. Commonly this is done after several teeth are built up, and the final cure is done on all these teeth at once by the dental assistant.

Polish Once the contours are correct, it is appropriate to polish. If any polishing occurs and more contouring is needed after that, the polishing will have been a wasted step. It may be helpful to accomplish the basic contours during the first treatment appointment but have the patient return another day to fine-tune the contours and polish. When one's eyes and attention are fresh, it can be easier to see what needs to be changed. This is even more

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FIGURE 15-6 Template technique. **A,** A composite mock-up on a stone model is used to make the template from a rigid polyvinyl siloxane material. **B,** The template is trimmed so the entire facial surface is free and clear while the lingual surface and the full incisal edge of each tooth are formed by the template. **C,** The old composite is carefully removed so the underlying tooth structure is maintained. (There is a history of peg laterals in the patient's family.) After any minimal preparation is completed, the template is tried in to evaluate for how much composite should be placed into it. Once the template is loaded and the composite smoothed (**D**), it is stored in the dark to prevent premature curing (a drawer may be a good spot). After etch and adhesive, fully seat the template. **E,** Remove excess composite and blend so all junctions with the tooth structure are smooth. Ensure that the composite does not bond teeth together. **F,** Light cure sufficiently to set the composite. Curing to set the lingual may take a little longer. **G,** Remove the template and check that all areas of composite are cured. Smooth and light cure more if necessary. The lingual and incisal surfaces should be formed. Then each tooth is built up freehand to complete the case.

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effective if photographs and study models are taken for review before the patient's return.

Polishing with finer disks and strips, or polishing cups embedded with polishing agents, should be a rapid process once the contours are correct. Within 1 to 2 minutes, a correctly contoured restoration should have the best polish the material can offer.

End Result Because much of transitional bonding is done freehand, it can be a fairly tedious process. To perform the procedure on eight to 12 teeth, assuming that at least six are anterior teeth, may require a full-day appointment in the office. Doing a full mouth could take 2 full days. Posterior teeth can generally be built much faster than anterior teeth, but overall it is still a relatively slow procedure. But considering that several restorations can be accomplished in a single appointment (because no "delivery" appointment is needed) it can still be time-efficient and certainly well worth the effort.

EVIDENCE-BASED PRINCIPLES

This procedure is a new application of composite and a dramatic change from the traditional uses commonly accepted for this material. Numerous articles validate the material properties of composites including a wear rate similar to that of enamel and fracture resistance similar to that of porcelain and tooth structure. Although the application of the material is innovative, the history of the material is long-standing.

CLINICAL CONSERVATION CONCEPTS

Conservation of tooth structure is a primary benefit of this technique. This is such a significant advantage that it makes this technique worth considering for many patients.

Another aspect that makes this beneficial is how composite fails. It is likely to be a "kinder, gentler" method of failure similar to enamel—development of wear facets or small chips—compared to a more dramatic failure with porcelain. Patients who traditionally would be treated with porcelain—usually considered the "strongest" esthetic restorative material—may be better served by having composite used. Consider a patient who is a bruxer but is unwilling to wear a nighttime appliance. (Of course, even patients who intend to be compliant often do not consistently wear their appliances.) Noncompliant patients will likely damage any restorations or opposing natural teeth much sooner than expected, therefore composite may be a more ideal choice for these patients since opposing teeth are unharmed and failure of the restorations are more similar to enamel failure. That includes noncompliant bruxers as well as patients who have habits such as biting their fingernails or crunching on ice.

The author believes transitional bonding could be a better option in the long run for noncompliant patients than more definitive treatment because of lower initial cost, ease of repair, and smaller risk to opposing natural teeth. Furthermore, the underlying tooth is essentially still intact (little or no preparation having been needed).

MAINTENANCE

Patients are instructed to treat these restorations in the same way as natural teeth. That means using them normally but not abusing them. Patients who are bruxing should wear a proper appliance every night. Harmful habits should be limited; it is important that patients be cautioned not to "use the teeth as tools" such as fingernail clippers, nut crackers, or scissors.

Normal use—chewing and incising—is acceptable with composite restorations, porcelain restorations, or natural teeth. Abuse, however, is not likely to be consistent with maximum longevity with any of these.

In the practice, the hygienist should use aluminum oxide polishing paste rather than typical prophy paste during prophylaxis, to maintain the finish on the restorations longer.

CONTROVERSIES

There are questions about whether major changes—esthetically and occlusally—should be accomplished with composite. Traditionally considered a "second rate material" compared with porcelain or gold, the idea that the same cases can be treated with composite is controversial to some. None of these cases will hold up as well over many years compared with traditional restorative options, yet it is important to consider that transitional bonding can conserve virtually all of the tooth structure and that it can save the patient potentially thousands of dollars in the initial treatment. For many patients, these benefits offset or outweigh the issue of longevity.

NEAR-FUTURE DEVELOPMENTS

Ideally the computer-aided design and manufacturing (CAD-CAM) technology available for porcelain will be available for uncured composite, so it would be possible to have the incisal edges or occlusal surfaces of the teeth custom made and presented to the dentist for placement. Uncured composite, if highly filled, should be rigid enough to hold its shape. Such restorations could be fabricated from impressions of teeth with the minimal preparation already completed, if needed (such minimal preparation would rarely necessitate temporaries).

Potentially this could be accomplished entirely with a digital system at some point in the future. With fairly rigid yet uncured restorations in hand, the teeth could be etched, adhesive placed, and each restoration positioned, with margins smoothed with a sculpting instrument, and then cured. In some cases the patient could bite onto the restoration before curing, for an easier adjusting of the occlusion. That would be an impressive time-saver and would make this technique much more likely to be used more frequently. In addition, esthetics and functional

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properties might be improved to the point that this could be considered another definitive treatment option—greatly benefiting both patients and dentists.

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SECTION C

A Histological Approach to Layering Direct Anterior Composite Restorations

Jeff T. Blank

RELEVANCE TO ESTHETIC DENTISTRY

The continued evolution of composite layering techniques has significantly enhanced clinical delivery of predictable and natural-looking resin restorations. Dentists today are embracing the concept of composite stratification, and most contemporary composite systems include an assortment of opacities designed for use in advanced layering techniques. Simply stated, replacing or repairing natural tooth structure conservatively and beautifully is the future of dentistry. Whereas trends in dentistry evolve with the constant development of new restorative materials and techniques, one tenet endures, and that is to treat with the most conservative modality available. In this age of communication, the term "cosmetic dentistry" has entered the global vernacular of the general population. As more information about health and beauty becomes widely available, patients seeking esthetic dental services have become educated consumers. Dental practitioners today must be equipped both technically and verbally to address the complex concerns and desires of patients who come for esthetic reconstruction. The hallmark of a truly conscientious esthetic dentist is taking the time to listen to the patient, develop an understanding of the treatment goals, and communicate all of the acceptable alternatives available. Quite often this includes minimally invasive procedures such as orthodontics, vital tooth bleaching, or conservative bonding procedures. Highly invasive procedures such as full-coverage crowns and indirect laminates or inlays have their place in modern esthetic care, but should be reserved for cases in which conservative techniques are structurally inappropriate or definitively unacceptable to the patient.

Although direct restorations may have a more limited life span than some indirect restorations, they possess certain advantages:

- They are kinder to opposing dentition than porcelain alternatives.
- Composites are more easily (and dependably) repaired.
- Less tooth reduction (sometimes none at all) is involved.
- With proper skill, expenses can be significantly less than with indirect restorations.
- Depending on the situation, fewer appointments may be required.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF DIRECT ANTERIOR COMPOSITE RESTORATIONS

Early composite systems were based on the overall hue, value, and chroma of natural teeth and did not consider the optical characteristics of each histological layer of natural teeth. They offered a range of colors, often based on the VITA Shade Guide (Vident, Brea, California), and rendered effective but inferior vitality compared with the more advanced systems today. If dentists wanted to create transition zones of saturation, darker shades such as A4 were placed at the gingival third, then A3, followed by A2, then A1 sequentially to the incisal edge. This yielded an apparently polychromatic restoration in terms of overall hue, but the result lacked the translucent properties of natural teeth.

CLINICAL CONSIDERATIONS

Indications

Patient Factors

Direct composite veneers are best suited for improving basic tooth color, morphological enhancement, and closure of small (less than 2 mm) diastemata. Though direct composite veneers are appropriate for patients of all ages, they are particularly suited for teens and young adults. These patients often present with healthy, but esthetically displeasing smiles where conservative "low prep" or "no prep" direct composite veneers may be an ideal alternative to more expensive and possibly more invasive indirect laminates. Young patients who are still actively growing may experience some degree of continued eruption of the anterior dentition which may lead to unesthetic exposure of un-restored tooth structure gingival to restoration. When direct composite veneers are utilized, these areas can easily be augmented with composite, whereas porcelain laminates may have to be replaced to yield an equally esthetic result.

Direct composite veneers are typically less expensive than porcelain laminates because fewer appointments are required and lab fees are either minimal or non-existent. Many patients desire the benefits of cosmetic dentistry, but simply cannot

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afford the higher cost of indirect porcelain laminates. When practitioners expand their skill and knowledge of advanced composite techniques and materials, this significantly increases patient access to esthetic care. Increased access leads to higher case acceptance which enhances practice revenues and satisfies consumer demand.

Clinical Factors

One of the primary clinical considerations when considering DCVs as a restorative option is the patient's occlusal scheme. DCVs are best indicated for patients with Class I or II occlusions when there is adequate cuspid and group function with no anterior interferences in excursions. Unmanaged, active bruxism and parafunctional activity such as nail biting can mitigate objectionable shear forces that may lead to premature fracture. DCVs can also be an appropriate option for patients with mild to moderate crowding and mild to moderate spacing issues (diastemata).

Contraindications

Patient Factors

Patients must be made aware that direct restorations of any formulation do not possess the same physical properties as indirect porcelain in terms of fracture toughness, wear strength, or flexural strength. Patients who are unwilling to accept a compromise in longevity compared with indirect alternatives are not good candidates for some large direct composite restorations (where indirect restorations would also be indicated) or DCVs. In addition, patients who consume large amounts of chromogenic foods and beverages (coffee, tea, red wine, dark sauces for certain food preparations) or who smoke may not be pleased with the potential for direct anterior restorations to stain over time. Direct composite restorations are light-cured materials that achieve about an 80% degree of conversion (degree of polymerization). Some laboratory-processed composites (e.g., belleGlass, Kerr Dental Laboratory Products, Orange, California) can achieve 100% polymerization in a laboratory curing oven. The unpolymerized resin component residual in composite systems is the weak link in water sorption and absorption of chromagenic food and beverage stains. Poorly finished and polished composite restorations are less resistant to staining over time, so proper finishing and polishing technique is essential.

Patients must also be willing to accept the potential for a color shift or "fade" over time. Such shifts are caused by the formation of colored degradation products, changes in surface morphology (roughening or losing surface gloss as a result of wear or poor finishing), or extrinsic staining. Also, in light-cured composites, certain formulations of tertiary amine accelerators (photoinitiators such as camphorquinone) tend to display a color shift to orange when exposed to ultraviolet light over time. Improved color stability for this commonly used initiator is in progress and many current materials offer formulations that may eliminate degrading color stabilty. Innovations include proprietary additions to the amine ring and other photoinitiators such as phenyl-propanedione (PPD) and Lucirin TPO to reduce this color shifting tendency.

Clinical Factors

Regardless of case selection, all candidates for direct composite veneers should be made aware of the increased potential for chipping and fractures over time compared with indirect porcelain. Direct composite materials have less fracture toughness, compressive strength, and greater flexural modulus than most porcelain systems, therefore patients must be willing to accept the potential for increased maintenance of these restorations over time in exchange for lower placement costs. Case selection for direct composite veneers is critical. DCVs are generally not recommended for Class III occlusions (end-to-end bites). Some patients may be candidates, depending on posterior guidance status (malocclusions). Patients presenting with large diastemata (greater than 2 mm) are often poor candidates for DCVs because the compressive strength of composite may not be sufficient to be cantilevered to this extent when opposing occlusal forces are significant. Patients who exhibit signs of uncontrolled bruxism, oral habits such as nail biting, or severe crowding may not benefit from the use of DCVs. Cases such as these may be more predictably restored with indirect alternatives.

MATERIAL OPTIONS

When selecting composite materials for direct composite veneers, the primary considerations include overall physical properties, optical characteristics, handling, color stability, polishability, and retention of surface luster over time. Over the past 20 years, major advances have been made in composite formulations and clinicians now have a wide variety of composite materials that are ideally suited for direct composite veneer placement.

Historically, microfill composites have been the desired material for direct anterior esthetic composite restorations because of their vital translucency and high, sustainable polish. The filler content of microfills consists primarily of 0.004-µm fumed silica, a fine particle embedded in resin that is extremely polishable. However, the major limitations to microfills are the inherent low strength physical properties and lack of opacity than come with high resin content and minimal filler loading. Some microfill composites exhibit 50% to 70% lower fracture toughness, 60% to 75% lower flexural modulus, and 50% lower flexural strength compared to modern hybrids, nano-hybrids and true nanofilled materials. However, this material is extremely desirable where the pre-existing arch form is ideal and occlusal forces are minimal. In less than ideal cases, some dentists chose to make arch form corrections (such as adding incisal edge length, closing diastemata, or Class IV repairs) with a more durable micro-hybrid or nanofilled material and then utilize a microfill as the surface "enamel" layer.

One particular issue with older hybrids was the large-particle fillers, which led to poor optics and esthetics as well as unacceptable wear. Additionally, over time the larger glass fillers were loosened by degradation of the surrounding resin, resulting in particle loss and a subsequent void in the resin matrix. Termed "particle plucking," this negative attribute of early hybrids led to poor gloss retention and extensive staining. Modern microhybrids now have high filler volume (75% to 85% filler by

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weight) and use various fillers with optical qualities similar to those of the resin matrix. This permits what should be a very opaque material to be translucent and vital in appearance. Modern micro-hybrids have an average particle size of 1 μm or less. The proprietary formulations affix the glass to the resin chains to reduce the potential of particle plucking. Thus optical qualities are highly improved and the polish rivals that of microfills. This polish is sustainable because particles stay attached to the resin chain and do not fall out, leaving craters in the resin to scatter light. Examples of microhybrid systems are Esthet-X HD (DENTSPLY Caulk, Milford, Delaware), Gradia (GC America, ALSip, Illinois), and Venus (Heraeus Kulzer, South Bend, Indiana).

Nanofillers have been around for years in the form of fumed silica. However, in recent years the ability to mill or fabricate filler particles in the "nano" size range (0.001 μm) has been achieved. Some composites use nanofillers exclusively (e.g., Filtek Supreme Ultra [3M EPSE, St Paul, Minnesota]), whereas others mix traditional microfills with nanofiller particles (e.g., Artiste [Pentron Clinical Technologies, Wallingford, Connecticut]). These systems claim high filler loading comparable to that of micro-hybrids, high polishability, and excellent physical properties.

Current Best Approach

Because physical properties and polishability are similar among micro-hybrids and nanofilled composites, the selection of material is usually based on handling characteristics and the availability and accuracy of various shades and opacities. Some clinicians prefer creamier handling characteristics, whereas others prefer a system that sculpts and stays put as each layer is built. What is essential in polychromatic layering is the use of a composite system that follows a "histological" layering approach. These systems have a minimum of three opacities, each corresponding to the degree of opacity found in the three distinct histological layers of natural teeth. Therefore for best results clinicians should use a composite system that has an opaque material that mimics the optical characteristics of deeper, more opaque dentin; a dentin body opacity that mimics the optical properties of shallow or intermediate-depth dentin; and a more translucent, mildly tinted enamel opacity that mimics natural enamel. It is important to choose a system that is designed to mimic the fluorescence and opalescence of natural teeth. In addition, radiopaque materials are often preferred, particularly in the posterior region.

OTHER CONSIDERATIONS

With a histological approach, only the opacities that mimic the layers being restored are used. For instance, if the lesion is a class IV anterior restoration, all three histological layers are missing (deep opaque dentin, intermediate-depth or shallow dentin, and enamel). Therefore a three-opacity system is preferred. For low- or no-prep veneers, only intermediate dentin and enamel are required. It is important to recognize that the majority of natural tooth color (hue and chroma) is imparted by the intermediate dentin layer Enamel predominantly serves as a modulator of dentin color, and depending on its thickness, serves to primarily influence the value, or brightness of the underlying dentin substrate

Dentin has a unique shape and contour. The dentin layer is thickest at the cervical third of the tooth where it is close to the labial surface. Because dentin is the most chromatic histological layer, the proximity of dentin to the labial enamel surface creates greater saturation in the cervical third. Concomitantly, the enamel layer is thinnest in the cervical area, which also contributes to greater color saturation in the cervical third. Dentin tapers to the lingual as it approaches the incisal two thirds of the tooth. As the chromatic dentin layer thins, the enamel layer becomes thicker, leading to desaturation of overall hue. This desaturation progresses from the cervical third to the incisal edge. Dentin typically ends about 1 to 2 mm from the incisal or occlusal edge or surface. The thickness of enamel on the incisal or occlusal edge or /surface varies based on heredity, wear and age, and fractures.

Dentin itself has a unique morphology as it approaches the incisal third. Typically it displays a highly variable lobular or scalloped form (not consistent from tooth to tooth in the same mouth). Often called "dentin mammelons," the lobed or "notched" form, especially in anterior teeth, creates highly variable incisal translucent edge effects that impart vitality and youth to teeth. Because the overlying enamel is basically transparent with some degree of tint, the darker oral cavity behind the anterior teeth shows through these dentin mammelons and, depending on the tint of the overlying enamel, creates erratic clear, gray, or blue internal translucent zones. In natural teeth, light passes into the tooth and is communicated both cervically and incisally to illuminate the tooth like a fiber optic bundle. As light exits the incisal edge of anterior teeth, the finite edge often appears to glow. This glowing incisal edge is often called an incisal "halo." The exuberance of this halo depends on the conductivity of deeper chromogenic portions of the tooth and the bevel or slope of the incisal edge.

Enamel is basically a translucent histological layer that offers little hue or chroma to the overall tooth appearance. Though highly variable, enamel commonly displays gray, white, or yellow tints. Some enamel is so translucent it appears as a clear layer. Enamel thickens as it approaches the incisal or occlusal two thirds and serves to desaturate the more chromatic underlying dentin. Enamel is thickest in the incisal or occlusal third and, depending on heredity and wear, about 1 to 2 mm in depth.

Internal maverick tints also are often present in natural teeth. During the formation of the dentin and enamel layer, many genetically and environmentally induced colored inclusions are deposited just under the enamel layer. Examples of environmental inclusions are heavy metal deposits and other colored inclusions induced by febrile events, illnesses, medications, or high fluoride levels in drinking water. These maverick tints are highly variable but often appear as gray (tetracycline induced), brown, or amber zones or inclusions.

Hypermineralized and hypomineralized areas must also be considered. A number of environmental and genetic variables

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can influence the degree of mineralization of a natural tooth and alter its appearance. Often termed "dysplasia," patched or under-mineralized or over-mineralized portions of a tooth can lead to a white, spotty appearance. These areas can be diffuse throughout the entire dentition, or localized and appear as "white spots" or zones in a select number of teeth or even a single tooth. Hyper-mineralized zones of tooth structure (hyperplasia) can be genetic or environmentally induced by excessive calcium, phosphate, or fluoride levels present during tooth formation. External environmental factors such as acids released by long-standing plaque colonies (poor oral hygiene), acidic foods and drinks (citrus fruits, soft drinks, sports drinks, energy drinks), and excessive digestive acids can de-mineralize the external portions of enamel. Conditions leading to an excess of digestive acids include gastro-esophageal reflux disease (GERD), bulimia, morning sickness in pregnant women, and the frequent vomiting of alcoholism that occurs while conscious or unconscious. These areas of demineralization often appear as frosty, white patches in variable areas of teeth, depending on the acid exposure. Both hyper-mineralized and hypo-mineralized areas affect the overall appearance of a natural tooth and often must be replicated in direct composite restorative clinical scenarios.

INNOVATIVE ELEMENTS

Nearly all modern composite systems currently available contain not only the full range of the VITA shades but also a variety of bleach shades. Most systems offer a range of opacities that mimic the histological layers of natural teeth and permit the replication of each tooth layer being restored in a material with appropriate optical characteristics. The popular composite systems (e.g., Filtek Supreme Ultra [3M EPSE], Esthet-X HD [DENTSPLY Caulk], or Artiste [Pentron Clinical]) usually include at least three opacities: opaque dentin, body shades, and translucent enamel or incisal shades.

The opaque dentin formulations have optical properties that mimic those of deep dentin. Most are a more opaque version of the body shade. These are the most chromatic or color-intense materials. This layer is helpful in masking undesirable dentin stains and eliminating show-through of the darker oral cavity behind class IV restorations and diastema closures.

Body shades are the most commonly used composite materials and possess the optical properties of shallow or immediate dentin. When used in a layered DCV, the body shade is the optically dominant material that imparts the primary hue of the final restoration. Body shade composite materials are sometimes called "dentin body" shades and typically correspond to the VITA Guide plus bleach shades. Although color rich, these materials possess a degree of translucency that is greater than their opaque dentin counterparts and varies based on formulation and filler composition.

Translucent enamel or incisal shades are often tinted to mimic the vitality and natural translucency of enamel. Some systems offer more sophisticated levels of opacities (e.g., Vitalescence [Ultradent Products, Inc., South Jordan, Utah] or 4 Seasons [Ivoclar Vivadent, Amherst, New York]) that when used skillfully can prove useful to clinicians seeking to match or replicate the subtle intricacies of the human dentition. These may include shaded translucent and value-influencing enamel formulations to mimic the translucent effects found in the incisal edge of natural teeth. The nomenclature of the "incisal" or enamel materials can be confusing (e.g., "T1" Venus [Heraeus Kulzer], "Pearl Frost" Vitalescence [Ultradent], or "V1" 4 Seasons [Ivoclar Vivadent]). Systems that use simplified nomenclature for the enamel materials such as "grey enamel" (Esthet-X HD, DENTSPLY Caulk) or "A Enamel" (Artiste, Pentron Clinical) are also available.

Nano Technology

The traditional composite formulations use filler particles such as glass, quartz, and/or fused silica ranging from fractions of a micron to 20 μm in size. The term "nano" in material science implies a particle size of 1 billionth of a meter, which is much smaller than the typical bacterium. Nanofillers used in dentistry range from 2 to 20 nm but in general average 15 nm in size.

Nanofillers are synthetically engineered on the molecular level from colloidal solutions of silica and zirconyl salts. Nanofillers can be isolated as independent particles or aggregated into engineered nanoclusters (e.g., Filtek Supreme Ultra [3M EPSE]). They are chemically bonded to the resin matrix via proprietary coupling with ester functional groups. High filler loading can be achieved with larger numbers of nanoparticles and nanoclusters similar to or better than traditional microhybrids. This produces composites with physical properties equal to or superior to those of microhybrids.

Nanoclusters (pre-engineered aggregates) typically are similar in size to microhybrid fillers but, when subjected to wear, release independent nanofills attached to the cluster. Microhybrids typically eject the entire larger filler particle, leaving a larger void in the resin matrix (particle plucking). By avoiding particle plucking, nanofilled composites have the potential to retain polish over time. An example of nanoformulation is Filtek Supreme Ultra (3M EPSE).

Low-Shrinkage Composite Formulations

One primary objective for manufacturers of new composite formulations is the reduction of polymerization contraction stress. Traditionally, composite polymerization of carbon-based formulations (e.g., BIS-GMA) is accomplished through a chain-shortening chemistry. Carbon double bonds are converted to carbon single bonds, initiated by free radical attack and combined with co-monomer cross-linking, typically producing 1% to 4% volumetric reduction. Excessive polymerization stress is relative to the formulation of the composite monomer, the degree of filler loading, the rate of polymerization, the degree of polymerization and cross-linking, and the volume or thickness of the composite placed at one time. Excessive polymerization stress can result in debonding of composite from the cavity wall, open margins, white lines, and postoperative sensitivity.

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Traditional BIS-GMA Resins

Until recently, nearly all dental composite materials used the BIS-GMA monomer developed in 1956 and modified in the early 1960s by Rafael Bowen. BIS-GMA is an acronym for the monomer 2,2-bis[4-(2-hydroxy-3-methacryloyl-oxyporoxy) phenyl] propane. Monomers of similar functionality, such as triethylene glycol dimethacrylate (TEGDMA) and ethylene glycol dimethacrylate (EGDMA), are frequently used with or in substitution for BIS-GMA to improve degree of polymerization, color stability, and other physical properties. The polymerization of BIS-GMA resin-based materials involves a reduction in volumetric mass of the dimethacrylate monomer by polymer chain shortening through covalent bond formation. This involves exchanging van der Waals' inter-carbon distances for covalent bonds. In addition, the intermolecular distance decreases from 0.3 nm to covalent bond lengths of 0.15 nm, and there is cross-linking of the polymetric chains.

In general the volumetric shrinkage of BIS-GMA monomers ranges from 2% to 6%. Factors determining the shrinkage that occurs include the types and quantity of monomers used, the level of filler loading (the less monomer, the less shrinkage), the degree of polymerization and cross-linking (degree of conversion), and the rate of polymerization (the slower the rate, the more time for cross-linking).

The current approach to reducing polymerization shrinkage and polymerization stress with traditional BIS-GMA monomers is to first increase filler loading. This is accomplished through the control of size and distribution of glass, and/or fumed silica and the use of nanofills and nanoclusters. Second, the rate of polymerization is controlled through the use of free-radical inhibitors. Third, proprietary mixtures of various monomers are used. Fourth, it is achieved through the use of low–elastic modulus formulations in the form of "flowables" under more wear-resistant higher–elastic modulus final restorative materials. Examples include SureFil SDR (DENTSPLY Caulk), Fusio (Pentron Clinical) and Vertise Flow (Kerr). These are "bulk fill" flowable formulations that are specifically designed to be used as rapid dentin replacement materials, either are self-adhesive themselves or are used with self-etching adhesives, and can significantly expedite posterior composite placement. These current materials lack the physical properties of traditional restoratives and must be overlayed with traditional restorative material.

New Low-Shrinkage Monomers

The latest innovation in reducing polymerization contraction stress is the use of spiro orthocarbonates (SOCs) and oxiranes. Epoxy-based monomers that are very different from traditional BIS-GMA can be used, as can bicyclic compounds that use "ring opening" during polymerization. With these compounds, for every van der Waals distance converted to covalent distances, at least two rings are opened during polymerization. The net in overall "shrinkage" of the monomer is close to zero. In lay terms, the material polymerizes without creating stress on the bond. A current example is Filtek Supreme LS (low shrink) (3M ESPE).

Limitations of this technology include the need for a dedicated, non–BIS-GMA–compatible bonding resin. These materials also exhibit inferior optical properties compared with current BIS-GMA formulations and delayed final polymerization.

ARTISTIC ELEMENTS

Although one may argue that porcelain veneers and crowns are the established gold standard for creating and restoring beautiful smiles currently, not every patient desires indirect restorations, nor is it always appropriate to place them. Within the past few years, manufacturers of direct composite resin systems have begun to offer practitioners tools that rival the most advanced indirect systems in terms of beauty, ease of placement, and range of color and opacity. It is now possible to create beauty in the dental office, but some practitioners hesitate to recommend DCVs for various reasons.

The three primary obstacles preventing many practitioners from offering DCVs as an alternative to indirect materials are as follows.

1. Foremost is the fear of complete reliance on the dentist to be the "artist" in creating natural, vital-appearing restorations. Because most dentists are trained primarily as "clinicians," many have not received advanced training in the basic layering techniques commonly used by talented ceramists. Through an acquired dependence on laboratories, many practitioners have not developed the artistic skill required to perform this valuable service.
2. The time involved in the placement of DCVs is directly proportional to the clinician's technique of placement. Although many courses are available that teach polychromatic layering, replete with the use of tints, opaquers, stains, and varying opacities and formulations of composite, some courses fail to address the clinical reality that doctors must be able to perform this service quickly in order to be productive. Taking hours to veneer one tooth usually translates to lost productivity, which serves as a key deterrent for many otherwise talented esthetic dentists.
3. Clinicians long for a simplified technique that will generate consistent, predictable results and address the first two objections.

By developing and exercising the skills and techniques associated with direct bonding, the clinician may develop a unique and deeper understanding of the complex dynamics associated with smile reconstruction. With modern direct bonding techniques and materials, practitioners can mask aberrant stains and inappropriately dark tooth structure, create illusions of length and width, develop esthetic gingival and incisal embrasures, and control tissue contours to alleviate negative interdental space. In addition, learning to create vitality through polychromatic stratification of color, eliminating negative "show-through" with proper opaque and body materials, and developing proper edge position, gingival zenith, and surface morphology give the practitioner immeasurable depth that

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parlays to other disciplines such as indirect restorative procedures. Just as the conductor of an orchestra must understand each instrument in order to lead a symphony, clinicians who physically understand the complex dynamics of esthetic restoration construction can better communicate, and therefore delegate, the fabrication of an indirect restoration to a technician when the conditions dictate.

TREATMENT PLANNING

Options

Case planning for anterior direct composite restorations must consider whether the need is restorative or cosmetic. There are many restorative clinical conditions that dictate when direct anterior composites are ideal. Primarily these are the most conservative in terms of tooth preparation, with low- to no-prep situations often possible; are cost-effective, involving no laboratory cost and done at one appointment; are time effective; and are esthetic restorations. It is far easier to match the shade of the existing dentition directly than to communicate the subtleties of hue, value, chroma, and internal tints and translucency to a laboratory technician. Specific indications include minor to moderate class IV fractures, minor to moderate class III and V restorations dictated by decay or failing restorations, incisal edge fractures, and white-spot lesions (areas of hypo-mineralized enamel and dentin). Some white spots extend well into the dentin. Clinicians who have tried to simply use a body shade to repair these types of lesions recognize the value of histological layering. In lesions such as these, it is imperative to replace the dentin portion of the preparation with a material that matches the optical properties of dentin, and the enamel with a translucent enamel material.

When patients are considering a cosmetic smile enhancement, histologically layered DCVs are an excellent option. It is important to consider the indications already listed. In addition, DCVs are indicated when the patient is seeking an affordable alternative to indirect ceramic restorations; desires a conservative low-prep, or even no-prep, reversible procedure (e.g., diastema closure); or is an adolescent or young adult patient for whom tooth conservation is considered extremely important.

Sequence

Whether restorative or cosmetic, a comprehensive clinical examination along with appropriate radiographs and preoperative photographs is mandatory. In addition, a thorough evaluation of the patient's occlusal scheme, potential malocclusion, and presence of abfractions, aberrant wear facets, history of nocturnal bruxism, signs of temporomandibular joint disorder, or lack of adequate vertical dimension must be conducted. It is the author's opinion and clinical observation that occlusal dysfunction and parafunctional habits such as nail biting are the primary factors that cause DCVs to fail prematurely. These issues must be diagnosed and managed before initiation of cosmetic bonding procedures.

When there are numerous changes to the axial inclination or arch alignment, preliminary diagnostic impressions should be made, and planned changes corrected on the casts to assess the scope of the esthetic reconstruction. This permits the use of a silicone index transferring occlusion and lingual and facial embrasures. Major corrections to the smile line can be accomplished on the articulator via a simple "stick bite" or by using the Kois Dento-Facial Analyzer System (Panadent, Cotton, California). The stick bite consists of aligning a cotton-tipped applicator with the interpupillary line so that the casts can be mounted such that they are oriented level to the horizone Preplanning the case reduces improvisation at the chair and defines the smile line, axial inclination, and general width and length of the teeth.

A direct composite mock-up is advisable for large class IV restorations, for large diastema closures, and when moderate to severe changes in incisal length are indicated. This approach allows the dentist to establish the lingual plane in proper occlusion and thereby eliminate the potential for destroying layers on occlusal adjustment. In addition, a silicone index transferring occlusion and lingual and facial embrasures can be created. Facial contours are inconsequential in mock-up.

Freehand Technique

The freehand technique is used when dealing with minor tooth alignment and minor diastemata. Obviously it is something that is more appropriate for single-tooth restorations and some class IV situations. Generally, this occurs when the axial alignment and the general smile line harmonized with the patient's esthetic preferences and occlusion. In these cases the dentist is not making major changes to the overall edge position or labial or lingual position, but only to the patient's axial inclination.

The freehand option typically employs minimal preparations and often does not involve any increased edge length. It is the most basic of all the options for doing DCVs. The dentist uses a body type material. If some sort of adhesive edge material is to be added, that can be done with various techniques.

TREATMENT CONSIDERATIONS

Preparation

Possibly the most attractive feature of DCVs is that, with proper skill and technique, they can generate outstanding esthetic results with little to no tooth preparation. When patients have mild to moderate crowding and/or rotations, only the ectopically displaced portions of teeth need to be prepared to permit the creation of ideal alignment. It is optimal to have all preparations for DCVs in enamel, extending into dentin only when absolutely necessary to correct minor alignment problems. Long-term, enamel preparations are superior to those in dentin. It is preferable to have the finish line in interproximal diastema situations along the mesial or distal

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marginal ridge so that the entire interproximal contact areas are developed in composite.

Procedure—Three-Layered Trendy Technique

Dr Didier Dietschi of Geneva, Switzerland first termed this procedure the *three-layered trendy technique.*[1] Typically it involves the use of a silicone index, made from either a preoperative wax-up or a chairside mock-up, to create a transparent lingual "shelf" onto which subsequent layers are stratified. This lingual shelf is used as scaffolding on which a dentin body and enamel materials are applied. The three opacities used are the opaque, body, and translucent materials. This technique has been advocated by many asthetic clinicians. Although it is challenging to master this method, the results generated are extremely impressive.

Finishing

Finishing and polishing are among the most important aspects affecting the overall appearance and durability of DCVs. **Finishing** is the act of defining various anatomical features previously placed in the composite layering process. **Polishing** is the act of creating a luster or shine and involves a minimal amount of morphological alteration. Composite finishing often begins with the use of progressively less abrasive diamond or carbide burs at varying speeds. Numerous composite finishing and polishing kits are on the market, and dentists often use a mixture of burs, sandpaper disks, and silicone polishers on a single restoration. For instance, carbide or diamond composite finishing burs may be used to refine interproximal and subgingival areas as well as to initiate refinement of developmental lobes and line angles. Silicone cups, points, and disks are ideal for creating and refining developmental depressions, lingual contouring, and polishing. Sandpaper disks of varying grit are highly efficient and popular tools for final finishing and polishing. Available with thicker paper backing or thinner plastic backing, many clinicians find the "feel" of sandpaper disks to be ideal, particularly when creating a final high shine. Regardless of which system is used, it is imperative to actually achieve a uniform and substantial state of finish before actually beginning the polishing process.

Surface texture and secondary and tertiary anatomy are best accomplished at lower speeds. It is important for clinicians to recognize the subtle nuances of surface texture, reflective line angles, developmental lobes, and height of contour before initiating finishing and polishing. It is often useful for clinicians to use a colored pencil to map or highlight desired anatomical features directly on the composite surface. When a single tooth or large class IV restoration is placed, a pencil may also be used to highlight various morphological features of the un-restored contralateral tooth, creating a blueprint to guide the finishing process of the restoration. Though some clinicians are adept at using diamond and carbide burs of varying grit and shape at high speed (200,000 rpm), most current electric handpiece systems permit more intricate details to be created at much lower speeds.

EVIDENCE-BASED PRINCIPLES

The techniques discussed in this chapter and the various materials and technology available today have been widely used in dentistry, some for over 50 years. Until recently, most composite formulations have used derivatives of BIS-GMA resins. Recently, higher–molecular-weight monomers such as that found in Kalore (GC America) have been introduced, and others are being studied. Historically, the primary focus of composite resin technology has been improvement of physical properties, handling, optical properties, and polish. Clinically, the current materials, such as nanofilled composites, microhybrids, and combinations thereof, are finding great success in dentistry. Failure rates have been low, and successes in terms of creation of histologically layered polychromatic restorations are well documented.

CLINICAL CONSERVATION CONCEPTS

The most conservative restorations available in dentistry are the direct composite restorations. Often preparation is minimal and existing fractures are evident, so clinically the dentist simply replaces the segments of the teeth lost rather than using an indirect alternative. If the indirect choice is a crown, that demands circumferential removal of tooth structure, which is more aggressive than the direct bonded technique. Although crowns and other indirect preparations have their place in dentistry, they should not be used indiscriminately. Direct composites should be considered as a conservative alternative to more aggressive indirect restorations.

MAINTENANCE

Maintenance of direct composite restorations by the patient, at home, centers around avoiding chromogenic foods such as red wine, sauces, or berries that may cause staining. Smokers typically struggle more to maintain a good surface color because staining is more likely in these patients. Patients are advised to avoid chromogenic foods in excess and to continue with normal brushing and flossing habits as prescribed. Composites are wear resistant to toothbrush abrasion, and the modern formulations typically tolerate not only manual tooth brushing but also sonic and rotary tooth brushing. Obviously the use of an approved toothpaste formulation is wise. Such a dentifrice will not unnecessarily scratch or mar the surface finish.

In terms of office maintenance, hygienists should be advised not to use coarse prophy paste when polishing direct restorations. It is actually more appropriate to use a very fine prophy paste or limit the polishing of the restoration to composite polishing paste, several of which are available. Such pastes are

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manufactured in medium and fine polishing textures. Obviously one of the critical issues in terms of both home care and dental office care are adequate marginal seal, good interproximal finishing, and no ragged edges. The use of various sandpaper strips or diamond strips can ensure that floss does not catch and that there are no food or plaque entrapment zones and no areas of irritation that can lead to gingivitis and gingival inflammation.

CONTROVERSIES

There are few controversies surrounding DCVs. The most common concern is typically focused on the inherent durability compared to indirect porcelain alternatives. However, patients who are receiving cosmetic care can be properly informed that composites may have a life expectancy less than that of indirect alternatives but offer benefits such as being more conservative, less expensive, and often completed in a single visit. Estimating the longevity of direct composite veneers is difficult. It is the author's opinion that when done meticulously on ideal candidates, DCV restorations can last 8 to 10 years before they begin to show signs of heavy wear or degradation of color. The primary factors that compromises the longevity of direct composites are untoward occlusal forces, parafunctional bruxism, and noxious habits such as nail biting. Though some clinicians may be concerned with the color stability of DCVs over time, modern formulations show great promise in correcting previously observed color shifts in older materials. The color degradation of modern composites is typically due to overly aggressive tooth brushing with coarse toothpastes and the use of highly chromagenic foods, beverages and tobacco products. It is the author's opinion that when careful attention is paid to case selection and the major contraindications are avoided, the longevity of direct composite veneers is largely contingent on the patient's care of the restoration. Patients should be educated on how best to maintain their restorations and they should willingly demonstrate the desire to be compliant. It is advisable to assess each patient's dentition prior to treatment for aberrant chips or fractures of incisal edges and to query the patient as to how they occurred. Often patients will admit to using their teeth to tear open packages, hold nails or hair pins in their teeth, crunching ice, or number of other bad habits. If they have been able to chip or fracture their natural teeth, it is highly likely that they will break any restoration placed on them unless they cease such habits.

Photographic documentation of the pre-existing condition of each patient's dentition is imperative. Accidents do happen, and composite restorations can often be repaired easily. However, dentists should not assume the responsibility of maintaining direct composite veneers for "life"; and patients must be willing to pay the costs associated with repairs over time. If they are not willing to assume this responsibility, then it is wise to consider more durable indirect alternatives and null the patient as a candidate for direct composite veneers.

NEAR-FUTURE DEVELOPMENTS

There are numerous conceptual ideas about how to improve composites. One proposal is the use of actual organic enamel crystals as filler content. Another is the use of truly fluoride-releasing compounds, fluoride-based filler particles, or engineered filler particles, such as fluorohydroxyapatite. There is also talk of having antibacterial composites. Most of the things on the immediate horizon are continuing improvements on low-shrinkage monomers. Such improvements include spiral carbonates, improved color, better finishing procedures, and greater compatibility with existing bonding resins rather than having to work with proprietary bonding resins. The likely changes tend to be incremental and evolutionary rather than revolutionary.

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CASE 1 Direct Bonded Layered Composite to Improve Esthetics

A 24-year-old woman came for a cosmetic consultation. She had been dissatisfied primarily with multiple gaps between her teeth. She was engaged to be married and had recently finished college, so economically she could not afford expensive options such as indirect alternatives using porcelain. The patient was seeking a lower-cost, more immediate service, and DCVs were discussed as a remedy for her esthetic concerns. She chose to move forward with a direct bonded layered composite. A comprehensive examination was done, revealing no temporomandibular dysfunction, and her occlusion was optimal for this type of procedure. With regard to her tooth alignment in general, the spacing was fairly uniform. A preoperative photograph and impressions were taken. A stick bite was taken to orient models on an articulator, and the case was waxed up. A silicone lingual index was created on the wax up and used as a guide, the lingual walls were reconstructed by placing an opaque dentin material in the index and seated on the etched and bonded teeth and light cured. The selected shade of dentin body material was placed over the more opacious lingual material, and sculpted to cover the facial aspect of the teeth and the interproximal areas (Figure 15-7).

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FIGURE 15-7 **A,** Preoperative facial view. **B,** Pre-operative intraoral view. There are multiple diastemata between the teeth but relatively good alignment. The patient's occlusion is a Class I, and she does not exhibit any excessive signs of bruxism. She was a good candidate for direct bonded veneers. **C,** Esthetic wax-up created by the dental laboratory. The golden proportion is obviously met. The general smile line, the alignment of teeth as positioned, incisal embrasures, occlusion—all were worked out in this diagnostic construct.



FIGURE 15-7, cont'd **D,** Laboratory-based silicon index, an incisal edge guide, and a lingual in the closing of the diastema. **E,** The prepared teeth. In this case, all margins were kept in the enamel. For the preparations to continue to the enamel, some interproximal reduction was done primarily on the maxillary right lateral incisor. Preoperatively there was no large diastema present there, yet there was one between the left central incisor and the left lateral. With that kind of disparity in a smile, it is best to make the right lateral incisor the same size as the left lateral incisor. Sometimes this kind of reduction is needed to permit the proper width and proportions on both sides of the midline. **F,** The freehand bonding technique with a unique body microhybrid material on the facial and interproximal surfaces of the teeth from the first premolar to the first premolar on the opposite side. The body material is used to fill the full contour. The silicon index created from the wax-up is constantly reseated and checked for the lingual and interproximal contours, incisal edge length, smile line, and incisal embrasures.



FIGURE 15-7, cont'd **G to I,** The length of the body layer has been developed on the teeth from the maxillary right first premolar to the maxillary left first premolar. The incisal edge characterization or incisal translucency can be placed by cutting back the body layer.

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FIGURE 15-7, cont'd **J,** Use of a medium or defined flame-shaped diamond is seen here inside of dentin. Mamelons are actually created similar to what is done in the three-layer trendy technique. The dentin mamelon lines allow show-through on the darker oral cavity and create a thin germ of incisal translucency mimicking natural teeth. The cut-back technique is typically employed only in a smile makeover of the central and lateral maxillary incisors. The cut-back is in the incisal third of the tooth, and characteristic notches or dentin mamelons are created. **J,** The incisal edge cut-back has been created. The teeth are then rinsed. They are etched for cleaning purposes only to remove debris and oral or salivary contaminants that may be on the tooth. They have been rinsed again, and the bonding agent applied to an individual tooth, in this case the maxillary right incisor. **K,** A translucent enamel material is placed in the incisal two thirds of the tooth. Changes in the enamel material allow the darker oral cavity to shine through the dentin bonding on dentin mamelons created through the cut-back technique and permit the display of incisal translucency. **K, L,** Placement of an incisal layer, which is an optical path plot seen naturally in teeth by the exit of light. On the incisal edge it is often displayed naturally in ceramics as well as in composites. Often the tooth has inadequate incisal halo or white frame or glowing to the incisal edge. A more opaque white composite material can be placed on the incisal edge to mimic this natural phenomenon.



FIGURE 15-7, cont'd **M,** Immediate result of placement of the direct composite veneers with incisal edge characterization. Note the polychromatic effect of the restoration. There is more saturation in the gingival half of the tooth because no enamel material was placed over the dentin bonding material in that region. The saturation diminishes as the restoration approaches the incisal edge. The translucent edge is also apparent. The restorations show a desaturation in the gingival edge of the incisal edge by increasing the thickness of the enamel layer applied on the incisal third of the restoration. Note the glowing edge of the incisal halo that was placed. A series of carbide finishing burs, sandpaper disks, and composite paste and finishing points were used to accomplish this luster. **N,** Two-week postoperative portrait of the smile makeover. Note how the smile integrates with the patient's face and lips. The buccal corridors have been sealed off. The immediate concerns regarding the patient's spatial and color issues were addressed. **O,** The retracted view. Note again the overall lifelike characterization achievable through histologic layering and stratification of the various opacities of composite material.



FIGURE 15-7, cont'd **P,** Preoperative smile of the patient. **Q,** Postoperative smile of the patient. Note the gingival health of the interproximal contours, the alignment of the incisal edge, and the lifelike characterization in the restoration.

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CASE 2 Class IV Fracture Repair Using the Three-Layer Trendy Technique

An 8-year-old boy had a significant class IV fracture on the maxillary right central incisor as the result of a bicycle accident. The tooth tested vital, and a direct composite repair was prescribed. The rationale behind direct composite versus veneer or crown was obviously age: the tooth was only partially erupted, and the patient was a child. A properly done DCV could last into his early adult years, at which time the restoration could be replaced or a porcelain veneer or crown could be placed. The technique recommended for this type of repair is called the three-layer trendy technique. With only minor beveling indicated, no anesthesia is required, and this treatment is considered additive. Anything other than a no-prep porcelain veneer requires prepping healthy tooth structure, so direct repair is the most conservative approach (Figure 15-8).

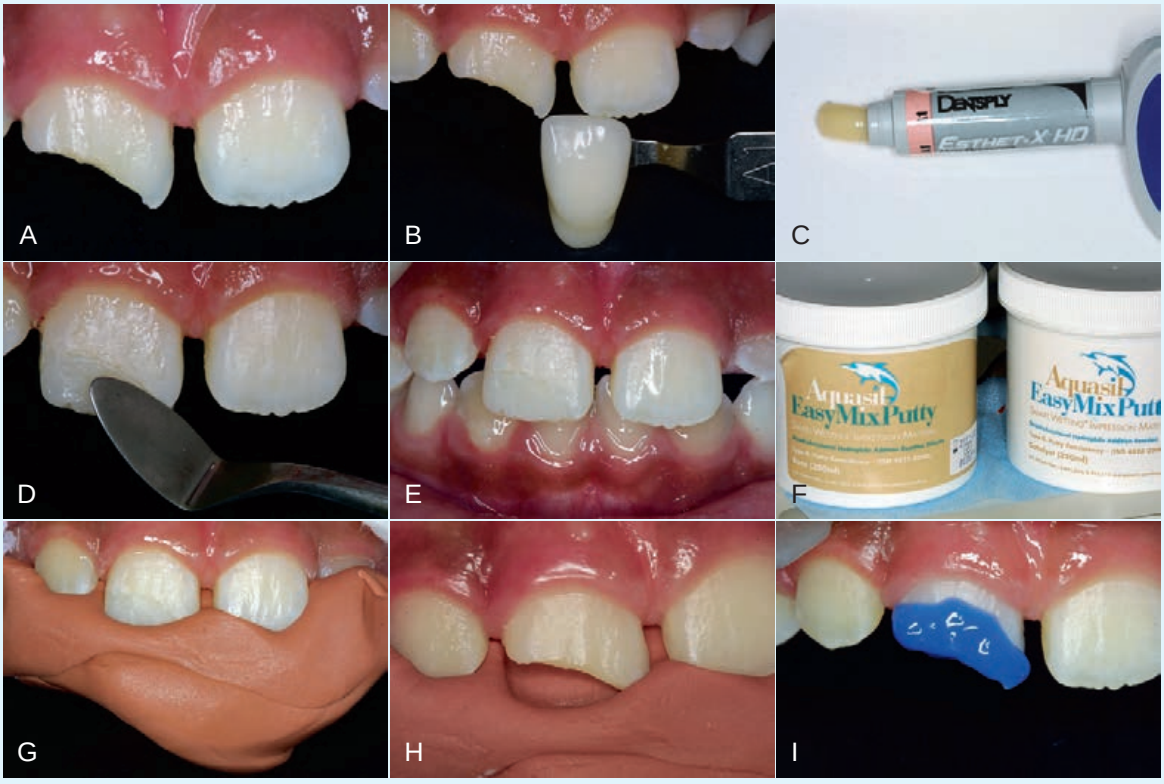


FIGURE 15-8 **A,** Preoperative appearance of the tooth. **B** and **C,** With Esthet-X HD, the "recipe" for the three layers is printed on the shade tab for the system. In this case, A-1 is selected, which denotes White Opaque (WO), A1 Body, and GE enamel. **D** and **E,** Mock-up is created with the body shade. The focus of a mock-up is primarily to establish lingual contours and occlusion. In simple terms, there is nothing more frustrating than to attempt to freehand layer a class IV restoration and find at the end that the occlusion is off, so it is necessary to grind away the back layers. The mock-up is done quickly without etching (the author applies a little bonding agent) for easy removal. The general outline of the tooth form is shaped and the occlusion is adjusted. **E** shows the final mock-up. **F,** DENTSPLY Caulk Aquasil Putty, which is ideal for making indexes. **G,** The putty is mixed, seated on the lingual aspect of the restoration, wrapped over the incisal edge, and allowed to set. **H,** The mock-up restoration is removed and the index seated to inspect adaptation. Note that all friable enamel is smoothed with a 1- to 2-mm bevel on all margins. **I,** The tooth is etched for 15 seconds, then rinsed, and the dentin is left moist.

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CASE 2 Class IV Fracture Repair Using the Three-Layer Trendy Technique (cont'd)

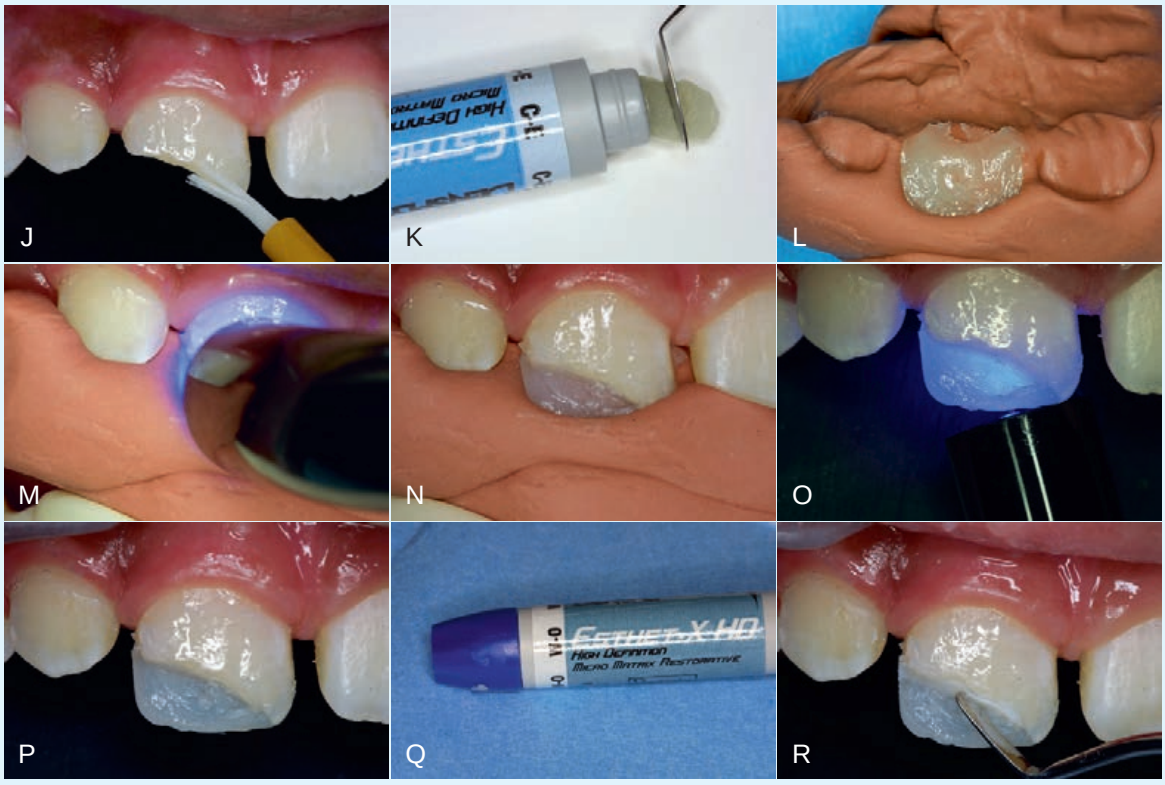


FIGURE 15-8, cont'd **J,** DENTSPLY Caulk XP Bond is applied in multiple coats over 20 seconds, air volatilized, and light cured for 10 seconds. It is unique in that it contains butanol rather than ethanol or acetone. Compared with NT it has a longer evaporating time, and is not as sensitive to dentin moisture. **K,** Esthet-X HD shade CE (Clear Enamel) is used for the lingual shelf. It is important to use a clear shade here because light must be able to communicate through it for vitality. **L,** Shade CE is applied to lubricated (with XP bond) index. The objective is to create as thin and even a layer as possible. Approximately 0.5 to 1 mm is ideal. The dentist must ensure that this layer is well adapted to the lingual margin and leaves room for two or three layers facial to this shelf. **M** to **P,** The lingual shelf creation in detail. **Q,** A major problem with class IV situations is hiding the transition seam between natural tooth structure and the restoration. The author advocates placing a thin ribbon-shaped amount of opaque material (the shade of which is determined from the Esthet-X shade guide) along the cavosurface fracture line as demonstrated here. This layer is adapted against the clear lingual shelf and kept well shy of the facial surface, leaving room for both body and enamel shades on top of it. **R** and **S,** Technique for application and curing of opaque.

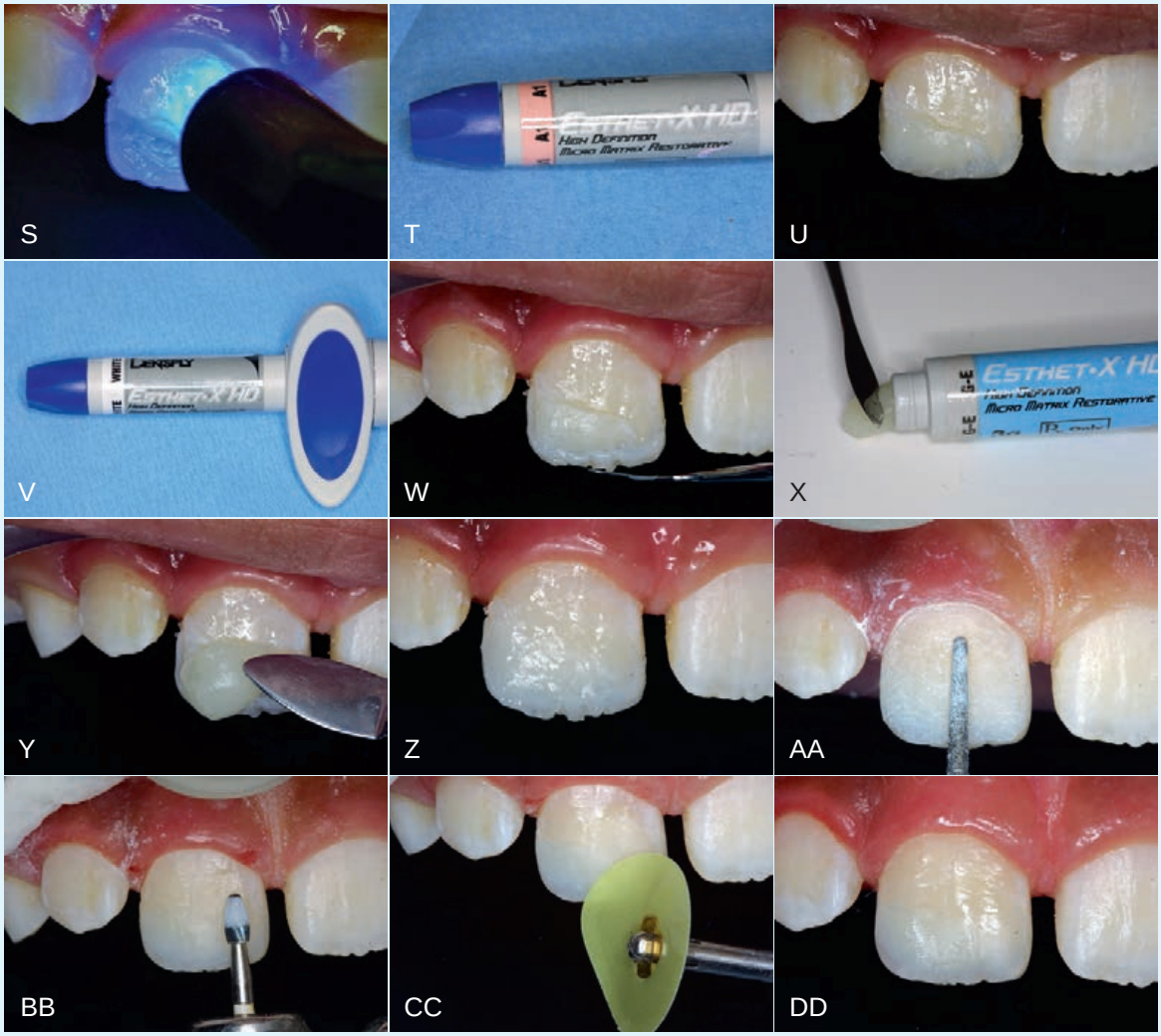


FIGURE 15-8, cont'd **T,** Body shade of Esthet-X HD shade A1 from shade tab recipe. **U,** This layer is adapted to the lingual shelf and covers the opaque layer. It is slightly thicker (to the facial) at the fracture margin and tapers back to the lingual as it approaches the incisal edge. Dentin mamelons are created in a random notch pattern just shy of the incisal extent of the lingual shelf. **V,** An incisal halo or milky white frosty appearing edge is created by using Esthet-X HD body shade "White." **W,** A small amount of "White" is dispensed and rolled into a ribbon shape, applied to the incisal edge, and wrapped slightly along the mesial and distal line angles. It is then light cured. **X,** The final layer is the GE enamel layer. **Y,** The final layer is blended at the cavosurface bevel and applied in increasing thickness as it approaches the incisal edge. By being applied in this fashion, the translucent enamel desaturates the more chromogenic body layer beneath, giving the restoration depth and vitality. **Z,** Layered restoration before finishing and polishing. **AA to CC,** Finishing and polishing are completed with a mixture of coarse diamonds for surface texture and various composite finishing carbides (the author recommends Q-Finishers [Komet USA, Rock Hill, South Carolina]) and various grits of sandpaper disks (Cosmedent, Inc., Chicago, Illinois). The final luster is achieved with Cosmedent's FlexiBuff and their paste (Enamelize). **DD,** Final restoration. Note the proper saturation of color, the seamless transition from restoration to tooth, the vitality and depth of the overall restoration, and the translucent edge effects and incisal halo.

SUGGESTED READINGS

Data source: Comparison of manufacturer data from Esthet-X (Dentsply Caulk), Vitalescence (Ultradent), Herculite XRV (Kerr), Renamel Microfill (Cosmedent), Durafill VS (Kulzer), Silux Plus (3M).

Dietchi D: Free-hand bonding in esthetic treatment of anterior teeth: creating the illusion, *J Esthetic Dent* 9:156-164, 1997.

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16 CHAPTER

Porcelain Veneers

A SECTION

Porcelain Veneers

Ross W. Nash

RELEVANCE OF PORCELAIN VENEERS TO ESTHETIC DENTISTRY AND BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

The application of porcelain veneers has been in the general dentist's list of procedures since the early 1980s when it was discovered that one could etch the inside of a porcelain restoration and get micromechanical retention similar to that achieved on etched enamel. It was also possible to treat the surface with silane and thereby increase bond strength. Surface treatments with etching and silane achieved bond strengths of over 2000 pounds per square inch (psi) whereas, without these steps only about 230 psi was possible. A further discovery was that thin layers of porcelain could be bonded to tooth structure; this was far better than having to remove significant tooth structure for a thicker restoration in order to attain the retention and resistance form, needed with G.V. Black's preparation designs for amalgam, gold, and porcelain-fused-to-metal.

As a result of these discoveries, dentists could be more conservative with respect to tooth reduction. It was possible to maintain the maximum amount of natural tooth structure and still achieve the results the patient wanted in terms of tooth appearance. Surface improvements included better color, apparent angulation and positioning (i.e., making teeth that were not entirely straight look straight), and the closing of spaces without orthodontic treatment. It became possible to do these things without removing extensive amounts of tooth structure. Sometimes none was removed at all.

The author began offering porcelain veneers in the mid-1980s, after having applied many direct composite veneers, which were used for essentially the same purpose. Porcelain veneers made it possible to utilize the services of a talented dental technician and to adopt a team approach rather than building the entire restoration freehand on the patient's tooth structure, as with direct composite. Indirect porcelain veneers also offered other advantages: the ceramic material has a more durable surface than composite restoratives. Ceramic does not have a resin matrix to absorb fluid, and thus it is more color stable. It also exhibits great physical strength once it has been laminated to an underlying structure, whether tooth or another material.

The reason the thin layers of porcelain work, even in functional areas, is because of the lamination process. Ceramics are inherently brittle, but when supported, their strength is considerable. An example is a piece of floor tile. A strong man can break a piece of floor tile in his hands, but once it is laminated to the floor, it generally never breaks as long as the adhesive stays intact. Supported ceramic materials are very strong. In porcelain-fused-to-metal restorations, the porcelain is laminated to a metal substrate. Now it is possible to laminate it directly to the tooth structure. This expands the possibilities. Thin layers of laminated porcelain are strong enough to withstand the forces of intraoral function well. The lamination process is also known as the bonding procedure.

Porcelain veneers differ from porcelain laminates. Laminates can cover any part of the tooth, whereas a porcelain veneer is usually limited to the buccal or facial of the tooth. The lamination process can be used successfully on any part of the tooth—lingual, occlusal, facial, or proximal. These restorations can be thought of as "extended veneers." Knowledge of function and bite patterns is required for correct usage of this technique. Through the use of these types of restorations, patients have options that were not available before.

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RELATING FUNCTION AND ESTHETICS

There is no real separation between function and esthetics. Restorations must function properly or they will not function in the mouth. When they function properly, they tend to look right. Apparently the ultimate design of tooth structure in an oral environment was the appropriate one. Function is something that all dentists need to focus on and understand as completely as possible before they begin placing any restorations, particularly elective ones.

CLINICAL CONSIDERATIONS

Some considerations arise when ceramic materials are laminated to tooth structure. Most have to do with function; if interocclusal relationships are developed incorrectly, the entire system is likely to fail, even if it is natural tooth structure.

Indications

Porcelain veneers are applicable in general dentistry when the patient wants a restorative process for the teeth and in elective situations where the patient wishes to have not only a functional tooth but an esthetic appearance as well. The word *elective* is quite significant today. Many people are choosing to improve their smile, something not required for health and function at all, purely for cosmetic purposes. So the indications for porcelain veneers can be to improve function, but the procedure also can be totally elective, for improved appearance.

Contraindications

Contraindications are usually related to function. If the functional situation in the mouth does not allow rebuilding of a tooth with ceramic restorative material, instead requiring the strength of gold, then that is a contraindication, as is poor dental health. To start elective treatment in the presence of dental disease is a prescription for failure. The disease must be addressed first. As healthcare professionals, dentists should keep the treatment of disease and the return of the patient to health in the forefront of their minds. One should not try to do elective work in the presence of dental disease. However, in the presence of dental health, elective cosmetic dentistry can be wonderful for a person's self-esteem.

MATERIAL OPTIONS

Several materials are available for indirect laminates and veneers today. Indirect composite resin can be heat-treated and polymerized to a much greater degree than direct composite and thus is suitable for indirect veneers. Most practitioners, however, prefer to use ceramic veneers for the purpose of laminating teeth.

Stacked porcelain is composed of ground glass particles and/or manufactured powdered glass. The ceramist adds a little liquid, mostly water, to that powder, forming a paste or slurry. This is applied incrementally, approximating tooth anatomy, to a refractory cast; the cast is inserted into the porcelain oven and then is cut away from the stone model after the ceramic is baked. The ceramic can also be swedged onto a platinum foil matrix as in the porcelain jacket technique where the matrix is teased off the die and placed in the oven, with the matrix peeled off after baking. Regardless of the technique, these ceramic materials all involve incremental layering. The ceramist then has the opportunity to add color and opaquers to the ceramic during this build phase. This allows the colors to blend into the porcelain itself, making the stacked porcelain look very natural, preventing unesthetic surface tinting or surface staining.

The use of the stacked porcelain technique—whether employing natural or synthetic material—requires less aggressive tooth reduction than other techniques. The ultimate restoration does not have as much strength in most cases as a pressed ceramic, which is manufactured in much the same way as cast gold or metallic restorations; it is waxed up to the full contour and then sprued. Next, the wax pattern is invested in stone and melted out. A molten glass pellet is then pressure-forced into the vacant mold. Due to the nature of the pressing process, the ceramic material gains a higher density and therefore higher bending and compressive strengths. Bending strength is important in ceramic materials. Unlike composite resins, ceramics have no resilience and cannot rebound after stress.

The higher bending strength of the pressed ceramics is advantageous for functional areas, where these materials are generally preferred over stacked porcelain. However, their major disadvantage is that they are monochromatic; they are pressed in one step from a single ingot and exhibit one single color throughout. To gain the vitality of stacked porcelain restorations, the practitioner must leave adequate space to cut back about 0.2 mm from the pressed material to develop the esthetic depth and staining of the layering porcelain, which yields the desired color. Thus, more working space and a deeper tooth reduction is needed for the pressed ceramic restoration unless the patient is willing to accept a monochromatic appearance or is satisfied with surface or inside staining and/or tinting. For conventional restorations with pressed ceramics, up to 1.0 mm of tooth reduction is required, whereas stacked porcelain needs only half that preparation. Over the years, practitioners have learned to use pressed ceramics for many different purposes, including laminate veneers.

Conventional pressed ceramics are made from silica-based materials. Lithium disilicate, however, is now available for pressing as well. It has a much higher strength and can be utilized in layers as thin as stacked ceramics. Of course, it is still monochromatic until layering porcelain is added to characterize the surface. The additional strength provided by this material allows thin veneers, full crowns, and bridges to be pressed. There are

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even several pressed block products on the market that can be milled to produce veneers.

Current Best Approach

The current best choices depend on clinical philosophy. The author's philosophy is to maintain the maximum amount of natural tooth structure; consequently, the layered porcelain technique is preferred for elective cases. Sometimes, no tooth structure at all is removed. If there is adequate room after the clinical preparation, pressed ceramic may be chosen because it has wonderful marginal adaptation and higher structural strength than most stacked alternatives. However, room should not be created by additional tooth reduction if stacked porcelain will function well. The author's preference is to select whichever process allows saving the maximum amount of tooth structure while still achieving the desired functional and esthetic results.

OTHER CONSIDERATIONS

The clinician or patient may prefer having a porcelain coverage on the lingual surfaces of teeth, particularly the six maxillary anteriors, despite the downside that the placement of ceramic material on these areas often requires additional tooth preparation (since there is no clearance space or room between the mandibular and the maxillary incisors in the normal Class I occlusion).

Extended veneers, or 360° laminates, are sometimes used to cover the circumferential surfaces of a tooth. These veneers can actually be considered crowns because they encircle the tooth. These laminates are inserted over the contacts, creating a "taco shell" laminate. This method bonds porcelain on both the facial and lingual surfaces of the maxillary or the mandibular anterior teeth. This approach is often very successful because it involves bonding ceramic to enamel, a particularly strong adhesive relationship.

INNOVATIVE ELEMENTS

Scientific Elements

Porcelain maintains its surface smoothness and color over time, unlike composite resin, which tends to absorb staining fluids and to lose its surface hardness, smoothness, polish, and luster. The surface structure of ceramic is durable in the long term, stain resistant, and esthetic, which are all significant advantages.

Technologic Elements

Researchers have discovered how to make porcelain stronger, color stable, esthetic, and adhesive to tooth structures. Innovative ceramic applications have transformed many aspects of dentistry in the past fifty years, and continue to do so.

ARTISTIC ELEMENTS

Every dentist can learn to bond ceramic materials to the teeth with clinical success; it is simply a matter of training. The patient's overall smile appearance is improved more through artistry than science or mechanical procedures, however. Thus, one dentist may achieve an extremely beautiful result, whereas another dentist, using the same materials and techniques, may develop an appearance that is unsatisfactory.

The artistry lies in the skills not only of the dentist, but also in the capabilities of the team that the dentist selects. A very few dentist-ceramists are able to prepare the tooth, undertake the laboratory procedures for the restoration, and place it in the patient's mouth. Most practitioners take the team approach, and seek out talented ceramists who can use these dental products artistically. Dentists employ the technician's skills to complement their personal talents in patient treatment; a successful combination yields magnificent restorations. Art is not inexpensive, however, and the personalized process often requires additional time.

For elective procedures, clinical success is unimportant if the patient does not like the appearance of the restoration. If the dentist chooses to accept an elective case, it is imperative that the patient's esthetic concerns be satisfied. Dentists must educate patients on the appearance of natural teeth, but ultimately, what the patient wants is paramount. The process becomes an interactive art. The successful dentist develops the artistic skills related to patient treatment and the management skills related to patient satisfaction. It is necessary to learn and practice the science behind dentistry, but the art is an essential part as well.

Continuing education courses that are taken after graduation from dental school offer the most significant training. Many progressive dental schools today offer courses in esthetics, but there is so much to learn at the undergraduate level that it is generally difficult to allocate adequate time to esthetics training that is necessary for the performance of such procedures, until after dental school. Most dentists subscribe to post-graduate continuing education to achieve competency in this and other areas.

Smile design principles are essential to the study of artistry in dentistry. Training in such artistic elements is offered through dental school–sponsored continuing education courses and at independent schools or institutes. Practicing dentists have the opportunity to learn skills and to develop information-sharing relationships with mentors. There is much more to esthetics than just science and technology; smile design and occlusion principles must also be mastered. Education must address function and patient feelings about appearance at a high level to contribute to the practice of esthetic dentistry.

TREATMENT PLANNING

In a general practice, dentists have an opportunity to discuss esthetics with their patients as they address other dental health concerns. Certain practices are focused on esthetics; patients

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seek these venues out specifically for esthetic or cosmetic reasons. There are three types of dentistry offered in general practice:

Conventional dentistry focuses on treatment for dental disease and diminished oral function (traditional dentistry).

Esthetic dentistry also focuses on treatment for dental disease and function, but has the added proviso that the restoration strongly resembles the original tooth in shape and color.

Cosmetic dentistry focuses on *elective* treatment. The difference between esthetics and cosmetics is semantic: esthetic dentistry is needed dentistry with a naturally esthetic result whereas cosmetic dentistry is elective dentistry that alters the appearance beyond natural parameters.

Most dentists see patients on an ongoing basis for dental health treatment only. Once patients become aware that the dentist offers esthetic treatment modalities, however, they tend to request these procedures. Ideally, the patient asks for the treatment spontaneously or after education. This is far better than the dentist trying to "sell" a treatment approach. Dentists prefer to have the patient say, "Doctor, I would like to have this procedure. I know you do it well. I have seen your other patients." This is a situation that is set up for success. Many patients in a general practice are interested in esthetic procedures. They simply are not aware that the dentist provides these treatment options. Dentist and dental team education to the patients on what is available is the key.

The first step in a cosmetic consultation or during a general practice esthetic discussion is the taking of photographs. These images include: a full-face image, a smile picture, angled smile views, side views, retracted views, and occlusal views. Those images are uploaded onto a computer screen in the operatory or in a consultation room so that patients can see themselves more accurately than even before. It is almost as though they are looking at someone else because they perceive the images to be different from what they see in a mirror. Patients are not accustomed to viewing their smiles in this clinical fashion. They also tend to be more objective when looking at a picture rather than looking in the mirror. The dentist and patient examine the images together and decide the extent of the smile zone, typically the front 10 maxillary teeth and the front eight mandibular teeth. They then determine what changes need to be made, whether a single tooth is involved, all the smile zone teeth, or all the teeth. This initial evaluation can often be conducted without radiographic or full clinical examinations. Once the patient decides to proceed, the dentist completes the full clinical and radiographic examinations to supplement the photographic record. The patient then decides their treatment objective and the dentist recommends suitable clinical procedures.

TREATMENT CONSIDERATIONS

Preparation

Once it has been decided that the patient will proceed with treatment, a full set of radiographs is obtained. Panoramic, bite wing, and a full set of periapical films are taken, and a complete diagnostic evaluation is performed. A thorough periodontal diagnostic evaluation thoroughly evaluates the periodontal status, charting each individual tooth. Full upper and lower impressions and a bite record are obtained so the laboratory can pour study models and mount them in a centric relation position on a semi-adjustable articulator. The author uses the Denar face-bow system (Whip Mix Corporation, Louisville, Kentucky).

Procedure

At the pre-operative appointment, a full set of digital photographic images is recorded, including full-face, smile, retracted, and occlusal views. Photography serves as a communication tool between doctor and patient and doctor and laboratory, provides documentation, and is a learning tool. This "records" appointment lasts 60-90 minutes. All materials are sent to the laboratory. The technician then pours the full-arch models, mounts the models on a semi-adjustable articulator, and does a complete wax-up of the case as the dentist and patient would like it to look when it is finished.

Smile design principles are followed in a critique of the angulation, proportions, and alignment of each tooth for the patient. The design is based on sound anatomy and occlusion and usually takes a week or so for the lab to complete

The patient then returns for the first operative appointment. For some patients, the author uses conscious sedation and relaxation techniques. These are particularly useful for very long appointments. Others patients require only a local anesthetic. The ultimate goal is to help the patients relax. To this end, they may be given a comfortable blanket, earphones so they can listen to soft music, a dark eye mask to shut out light, or a massaging chair's back massage. Once the patient is totally comfortable, the dentist can apply the anesthetic.

The dentist then begins the preparation of the selected teeth, a process which may take several hours. After tooth preparation, occlusal registrations and the final impressions are obtained. The dentist fabricates provisionals at the first operative appointment with a putty stent technique. (A polyvinyl siloxane putty impression over the wax-up is used to make a stent, which in turn is used to fabricate provisional restorations for the patient.)

Provisionals are made with a bis-acrylic material applied directly onto the prepared teeth. These can be made to look very esthetic and to simulate the appearance of the finished ceramic restorations. The colors of these acrylic materials are similar to the shades of the proposed ceramics. The patient can actually preview the final result through the provisional process. The patient normally wears the provisionals for 2 to 3 weeks.

The impressions and bite registrations are sent to the laboratory. Photographs have been taken at every step along the way to show the prepared teeth, the shade guide with the prepared teeth, the provisionals, and models of the provisionals. The dentist communicates with the laboratory using all of this information.

Once the technician has fabricated the ceramic veneers or laminates, the patient returns and the dentist spends up to a full day placing these restorations. The patient is relaxed and then

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anesthetized at this second appointment. The provisionals must first be removed. (While they can function well for several weeks, provisionals ultimately fail.) During removal, the dentist typically breaks them apart to protect the underlying tooth structures; they are not reusable.

With routine home care, the tissue should be relatively healthy. Gingival bleeding can make the adhesion process difficult or impossible. The dentist tries on the laboratory-fabricated restorations on the prepared teeth. Water may be used as a try-in medium between the teeth and the ceramic. If the restoration looks good with water, an untinted resin luting cement is used to bond it into place. If some color modification is necessary, tinted resin cement materials may be considered at this time.

The dentist must ensure that the patient is satisfied with the results at this stage. The patient typically inspects these restorations while lying down on the dental chair through a hand-held mirror; this is the worst way imaginable to look at the restoration, but is the only practical option. This is the step where the dentist must solicit the patient's approval for the restoration. Ideally, the esthetics are right the very first time. If the patient is less than satisfied, and does not like the appearance, the restorations are not yet cemented, and the dentist can change them as needed.

Finishing

Once the patient has approved the restorations, the dentist goes through the steps required to bond them to the tooth. A total-etch procedure, utilizing tooth etching, adhesive bonding agents, and luting composite may be used. After the luting material is polymerized, the dentist must clean away any excess resin from around the margins. The occlusion must be verified and/or adjusted *after* the laminates have been bonded into place because the ultimate strength of the restoration is gained only through the lamination process. When occlusal adjustments are required, fine diamonds, 30-fluted carbide finishing burs, and porcelain polishing points are used, in that order, to obtain a finished surface that is actually smoother than glazed porcelain.

Patients are usually asked to return 1 to 2 weeks later for a final check and a complimentary cleaning. All the margins are smoothed yet again, and any remaining excess resin is removed. A 3 month follow-up is scheduled, and then the patient is placed on a 6-month recall rotation.

EVIDENCE-BASED PRINCIPLES

Like most practicing dentists, the author can offer his clinical experience as evidence. He has provided laminated porcelain for patients for well over 20 years.

Dentists and patients should understand that these restorations require on-going long-term maintenance. There are no permanent dental restorations. Natural teeth suffer from fatigue, wear, break, and shift positions in the oral environment; so certainly do restorations. As the patient ages, both will likely need some maintenance.

The longevity of porcelain laminates has proved even better than the early expectations. Twenty five years ago, dentists hoped for a 10 year span of function and esthetics. That was enough for most patients who wanted the advantages of the porcelain veneer appearance. Generally, dentists prefer to under-promise and over-deliver. They do not want to promise results that they cannot achieve for patients. Fortunately, the early assurances proved to be inaccurate assessments; most of these patients still have their porcelain veneers, and they still look good. Some patients have experienced gingival recession, some margins have become stained, and some ceramics may have chipped due to the natural fatigue process in the oral cavity. Overall, the veneers have lasted a very long time, and this is what patients need to understand. Porcelain laminates are *not* permanent but they do tend to *last a very long time*, far longer than originally expected.

CLINICAL CONSERVATION CONCEPTS

The author's philosophy has always been to assist the patient in maintaining the maximum amount of natural tooth structure. One might ask why a dentist would want to maintain the maximum amount of natural tooth structure, when reductive preparation permits increased retention and a better resistance form (concepts that drive amalgam, gold, and porcelain-fused-to-metal techniques). The simple answer is that the author does not feel comfortable in guaranteeing the patient that porcelain laminates are a "permanent" restoration. It is likely that the process will have to be redone at some point in the future. If the dentist has previously prepared the tooth with resistance and retention form for a specific type of restoration, it is difficult to remove the restoration without removing more tooth structure. It is likely that significant additional tooth structure must be removed when the restoration is to be replaced. In situations where the tooth has been reduced to the point where there is little remaining natural structure, the patient has few options for re-treatment. It is therefore wise to maintain as much natural tooth structure as possible to maximize future choices for the patient.

Porcelain laminate products, and thus clinical treatment options, are constantly improving. Pressed ceramics appeared in the early 1990s, and zirconium in the early 2000s. These newer options are available to the patient and dentist. While the author prefers stacked porcelain laminates to pressed ceramics for elective veneers, innovative materials such as lithium disilicate allow for thin veneers that have all the strength of pressed materials. The ever-developing fields of esthetic and cosmetic dentistry continue to provide improved intraoral solutions for our patients.

The author's approach has always been to conserve as much natural tooth as possible. The best dentistry is no dentistry; minimizing the amount of tooth structure reduced is a service to the patient. Adhering to the principle of maintaining natural tooth structure is the most conservative approach.

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MAINTENANCE

A common concern is whether every porcelain veneer patient needs a night guard as part of the treatment. The author believes that functional occlusion is the key to the long-term restoration and long-term maintenance of natural tooth structures. If the patient has comfortable, good occlusion with anterior guidance and posterior disclusion, a night guard is rarely needed. Those patients who exhibit bruxism and occlusal wear of the natural teeth are furnished with appliances (these represent 10% of the author's patients who wear nightguards).

Beyond the above, patients may treat these laminates just as they do natural tooth structure. Brushing, flossing, and bi-annual dental visits are mandatory. Patients with these bonded restorations can comfortably eat corn on the cob and apples, chew meats, and function quite normally. They must be aware, however, that these laminates can fracture just like natural teeth. It is important that patients not abuse these restorations by chewing ice or hard candy or any other activity that would normally cause harm or stress to the natural anterior or posterior teeth. However, these restorations can also be replaced. A fracture or a delamination is not the end of the world; it is simply a temporary irritation.

Patients should continue regular in-office maintenance with *non-abrasive polishing paste* as the porcelain surface glaze can be scratched and the esthetic gloss lost. There are methods available to repolish porcelain if necessary. The hygienist should *not* use an ultrasonic scaler at the margins.

It is recommended that acidulated fluorides not be used because they tend to etch porcelain. A Prophy-Jet remove stains from natural tooth structures, but it can roughen the surface of porcelain and make it *more* susceptible to staining. Hand cleaning and polishing with prophy cup and nonabrasive prophy paste is sufficient.

Clinical Case Study

The elective case presented here was performed to enhance the patient's smile by providing 10 porcelain veneers with minimal preparation. Layered porcelain was used to achieve the maximum esthetics in a veneer. Figure 16-1, *A*, shows the patient's smile before treatment. Her teeth were slightly malaligned, but were in excellent condition. She was free from dental disease and was well aware that the cosmetic treatment she was seeking was not reversible and not permanent. She was comfortable with a 10- to 15-year life expectancy of her veneers and was prepared to replace them when needed to achieve the esthetic benefits they would provide. Figure 16-1, *B*, shows a retracted view of the maxillary 10 most anterior teeth before treatment, and Figure 16-1, *C* shows the incisal view of her teeth before treatment.

Preparation

The first step was to anesthetize the patient's teeth and place depth cuts of 0.5 mm on the facial surfaces of the teeth to be veneered (Figure 16-2, *A*). The depth cuts were joined with a chamfer-ended diamond bur (Figure 16-2, *B*). Subtle chamfer margins were created at the height of the tissue (Figure 16-2, *C*). Incisal preparation



FIGURE 16-1 **A, The patient's smile before treatment with elective veneers. B, Retracted view of maxillary teeth to be veneered. C, Incisal view of the maxillary teeth to be veneered.**

Continued on next page

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Clinical Case Study (cont'd)



FIGURE 16-2 **A,** Application of 0.5 mm depth cuts. **B,** Reduction of depth cuts with chamfer-ended diamond. **C,** Facial reduction complete. **D,** A 1.5-mm incisal reduction. **E,** "Elbow" preparation to the proximal contact. **F,** Interproximal stripping with diamond strip. **G,** Horizontal seating groove. **H,** Finished preparations, facial view. **I,** Lateral view of finished preparations. **J,** Incisal view of finished preparations.

Clinical Case Study (cont'd)

involved 1.0 to 1.5 mm of reduction, leaving a "butt" margin and rounded corners (Figure 16-2, *D*). Interproximal preparation involved continuing the chamfer to the proximal contacts, forming an "elbow" preparation (Figure 16-2, *E*). A diamond strip was used to slightly open the contacts (Figure 16-2, *F*). Where no occlusal preparation was performed on the premolar teeth, a 0.25-mm horizontal groove for seating purposes was placed (Figure 16-2, *G*). The finished preparations are shown from the facial view in Figure 16-2, *H*. Figure 16-2, *I*, shows the prepared teeth from the lateral view, and Figure 16-2, *J*, illustrates the preparations from the incisal view. Nearly all preparation was completed in the enamel layer.

Impressions

A polyvinyl siloxane impression material was used to take a full arch impression. A light body material was injected around the margins (Figure 16-3, *A*) as the impression tray was loaded with a heavy body material (Figure 16-3, *B*). The tray was seated (Figure 16-3, *C*) and the material was allowed to set completely before it was removed from the patient's mouth. The final impression is shown in Figure 16-3, *D*. An opposing full arch impression was also taken in a polyvinyl material (Figure 16-3, *E*). A hard-setting occlusal registration was taken (Figure 16-3, *F*). Figure 16-3, *G*, shows the bite registration after removal from the patient's mouth.

Provisional Restorations

Though provisional veneers are often unnecessary in such conservative cases, they are often desired by the patient. They can be made directly on the prepared teeth from a matrix made over a model of the unprepared teeth or a wax-up of the desired changes on a stone model. A polyvinyl siloxane material can be used to make a matrix over the wax-up, or a vacuum-formed plastic matrix can be made over a hard stone model as in this case.

"Spot" etching on the facial surfaces of the enamel can help with retention of the provisional veneers (Figure 16-4, *A*). The etching gel needs only 10 seconds for the etching process and is rinsed thoroughly. The prepared teeth are air dried, and a desensitizing agent (containing glutaraldehyde or benzalkonium chloride and HEMA in an aqueous solution) can be applied to the tooth surfaces (Figure 16-4, *B*) and dried (Figure 16-4, *C*). A bis-acrylic provisional material is then injected into the matrix (Figure 16-4, *D* and *E*) and placed over the prepared teeth (Figure 16-4, *F*) and allowed to set. The provisional material can be left in place and finished directly on the teeth or removed and replaced using light-cured flowable composite as cement. The bis-acrylic material can be shaped and polished in a similar fashion as a composite resin veneer.

Figure 16-4, *G*, shows the provisional restorations in place. The patient should be instructed in proper cleaning with floss threaders or other interproximal devices because the provisionals are splinted together.

Veneer Fabrication

The final impressions, occlusal registration, and other materials such as a face-bow record are then sent to the dental laboratory with instructions on material choices, color, translucency, texture, and other parameters desired. The veneers are delivered to the dentist after fabrication; they should be inspected and accepted. Figure 16-5, *A* shows the 10 veneers for this case on the working model. The internal etched surfaces are shown in Figure 16-5, *B*. If the laboratory does not deliver the veneers etched for micro-mechanical retention, hydrofluoric acid can be used in the dental office to etch the internal surfaces.

Placement

At the delivery appointment, the provisional veneers are removed and the tissue inspected. With good home care there should be little to no gingival hemorrhage, and no retraction cord will be necessary. If hemorrhage control is necessary, placing one long cord with an aluminum chloride solution may be desirable. In this case tissue health was excellent, and no cord was needed. Figure 16-6, *A*, shows the prepared teeth after removal of the provisional veneers.

The veneers are tried in to check for fit, contacts, and esthetics. No occlusal adjustment should be attempted until the veneers are bonded into place, because they achieve their ultimate strength after they are laminated to the teeth through the bonding process. Water is a good try-in medium as in this case, but try-in pastes can be used if desired. Figure 16-6, *B* shows the veneers tried in. They are approved by the patient, and they are removed and cleaned.

Continued on next page

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Clinical Case Study (cont'd)

In this case a multiple placement technique was used. Matrix strips are placed in the interproximal areas distal to the last veneers (Figure 16-6, *C*). Then 37% phosphoric acid gel is applied to all the prepared surfaces (Figure 16-6, *D*) and left for 10 seconds. The etching gel is thoroughly rinsed (Figure 16-6, *E*), and the teeth are left slightly moist for the wet bonding process. A fifth-generation bonding agent is liberally applied to all the prepared surfaces (Figure 16-6, *F*) and dried to remove the residual moisture and solvent carrier (Figure 16-6, *G*).



FIGURE 16-3 A, Light body impression material. B, Heavy body impression material. C, Impression in place. D, Final impression. E, Opposing impression. F, Occlusal registration in place. G, Occlusal registration.

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FIGURE 16-4 A, Spot etch for temporary retention. B, Desensitizer applied. C, Desensitizer dried. D, Bis-acrylic material injected into provisional matrix. E, Bis-acrylic material in provisional matrix. F, Provisional matrix in place. G, Provisional restorations in place.

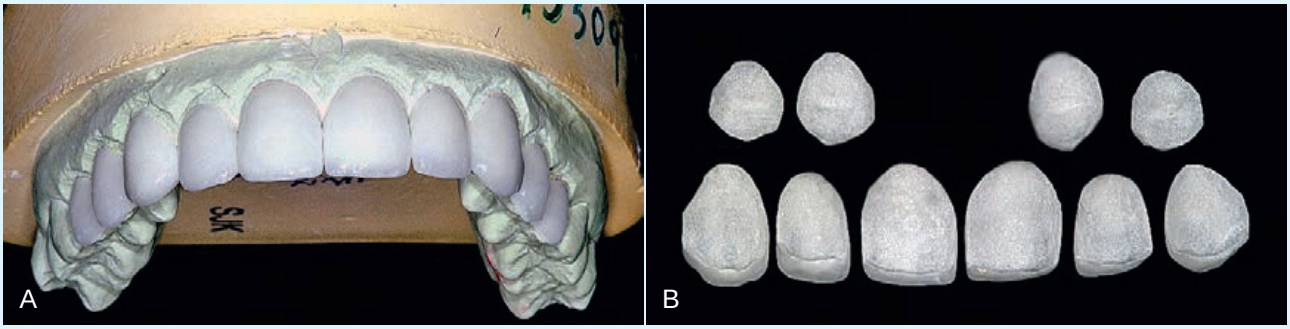


FIGURE 16-5 A, Porcelain veneers on working model. B, Internal etched surfaces of porcelain veneers.

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Clinical Case Study (cont'd)



FIGURE 16-6 A, Provisional restorations removed. B, Porcelain veneers tried in. C, Matrix bands in place. D, Acid etch. E, Etching gel rinsed. F, Bonding agent applied. G, Bonding agent dried. H, Luting composite applied. I, First veneer placed. J, Second veneer placed.



FIGURE 16-6, cont'd K, Removal of excess uncured luting composite. L, Each veneer is tack cured. M, Excess uncured luting composite is cleaned. N, Material is light cured to completion. O, Excess cured luting composite is removed with finishing carbide. P, Excess luting composite removed with abrasive cup. Q, Excess luting composite on lingual aspect removed. R, Interproximal area finished with diamond strip. S, Interproximal area polished with aluminum oxide strip.

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Clinical Case Study (cont'd)

The matrix bands are placed (Figure 16-6, *C*) and the teeth are etched (Figure 16-6, *D*) and rinsed (Figure 16-6, *E*). The bonding agent is carefully applied to the prepared tooth surfaces (Figure 16-6, *F*) and dried (Figure 16-6, *G*).

Silane is applied to the etched internal surfaces of the veneers and dried. A light-cured composite luting agent is then placed into the internal surfaces of the veneers (Figure 16-6, *H*). Each veneer is set into place (Figure 16-6, *I* and *J*). Excess luting composite is cleaned with a brush (Figure 16-6, *K*), and each veneer is held in place and "spot" cured for 2 seconds with a light-emitting diode (LED) curing light (Figure 16-6, *L*). Additional cleanup is then accomplished with floss and instruments (Figure 16-6, *M*). Final light curing is accomplished with an LED curing light (Figure 16-6, *N*).

Remaining excess cured luting composite is removed with carbide finishing burs in a high-speed handpiece and abrasive cups in a slow-speed handpiece (Figure 16-6, *O* to *Q*). Interproximal smoothing is accomplished with diamond strips (Figure 16-6, *R*) and aluminum oxide strips (Figure 16-6, *S*).

Final Result

The finished veneers are shown from the facial view in Figure 16-7, *A* and *B* and from the incisal view in Figure 16-7, *C*. The patient's new smile can be seen in Figure 16-7, *D*.



FIGURE 16-7 **A, Ten porcelain veneers in place (facial view). B, Lateral view of final result. C, Incisal view of final result. D, Patient's new smile.**

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Inserting Esthetic Restorations

Graeme Milicich

RELEVANCE TO ESTHETIC DENTISTRY

One of the major challenges in placing indirect esthetic restorations is handling and controlling the restoration during preparation for bonding, loading with bonding material, and accurate placement of the restoration. The Griptab system (Triodent Corp., Katikati, New Zealand) (Figure 16-8) has been designed as a universal system for controlling all indirect restorations during prebonding and cementation procedures. It comes with plastic tabs of three different shapes that can be bonded to porcelain and metal restorations with a light-cured adhesive. The Griptab is held with a pair of pin tweezers that provides a secure grip while at the same time allowing free rotation through 180 degrees in one plane.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Several products have come to market trying to deal with these issues. None have been completely successful in achieving the goals of reliable adhesion, ease of placement, and the ability to passively release the restoration and pick it up again during preparation for bonding and then to passively release the restoration again once it has been located on the tooth. Some products work adequately with veneers but do not work with irregularly shaped inlays, onlays, and crowns. The goal has been to develop a product that has universal application to all restoration types, reliable adhesion to the restoration, ease of pickup and release, and easy and clean removal after placement of the restoration.

RELATING FUNCTION AND ESTHETICS

Accurate placement of veneers is critical. The removal of adhesive stick systems can lead to accidental displacement of a veneer, causing accidental and unnoticed air entrapment, and failure at either a bonding or esthetic level.

The Griptab provides total and secure control of the restoration. Modifying the internal tints and colors in bonding resins for veneers requires a firm, stable grip on the veneer while various areas of the veneers are loaded with different colored resins as needed for optimal esthetic matching.

Managing small inlays and onlays during hydrofluoric etching and silanation is problematic. The Griptab system provides total control, not only during preparation for bonding, but also during the placement of the resin cements and final placement of the restoration in the cavity.

CLINICAL CONSIDERATIONS

Indications

The Griptab is designed as a universal system for the prebonding steps and placement of all ceramic and metal restorations. It is also effective in many clinical situations when control of small objects is required, including the placement of Maryland bridges, rebonding of extracted teeth using Ribbond wings, and the placement of implant abutments, to name a few. The use of this system will be limited only by dentists' imaginations once they see its simplicity and logic.

Griptab Being Used to Manage a Difficult Restorative Problem

An elderly patient with limited financial means had a periodontally involved tooth No. 31 that had to be extracted. The lower anteriors would also have benefited from periodontal splinting, and the patient did not want to wear a removable prosthesis. The newly edentulous space was restored 5 days after extraction by bonding the extracted tooth 31 (lower left central incisor) into place using Ribbond after the tip of the root had been removed (Figure 16-9, *A*). At the same time the lower anterior teeth were splinted. Control of the small tooth and attached Ribbond would have been very difficult but for the Griptab attached to the labial surface before the beginning of the procedure. A groove was cut in the lingual of the tooth and Ribbond attached into the groove, ensuring that no bonding resin extended out into the exposed Ribbond (Figure 16-9, *B* and *C*). Easy manipulation of the tooth and Ribbond simplified resin bonding and placement of a layer of composite onto the Ribbond (Figure 16-9, *D*) before placement of the splint or bridge into

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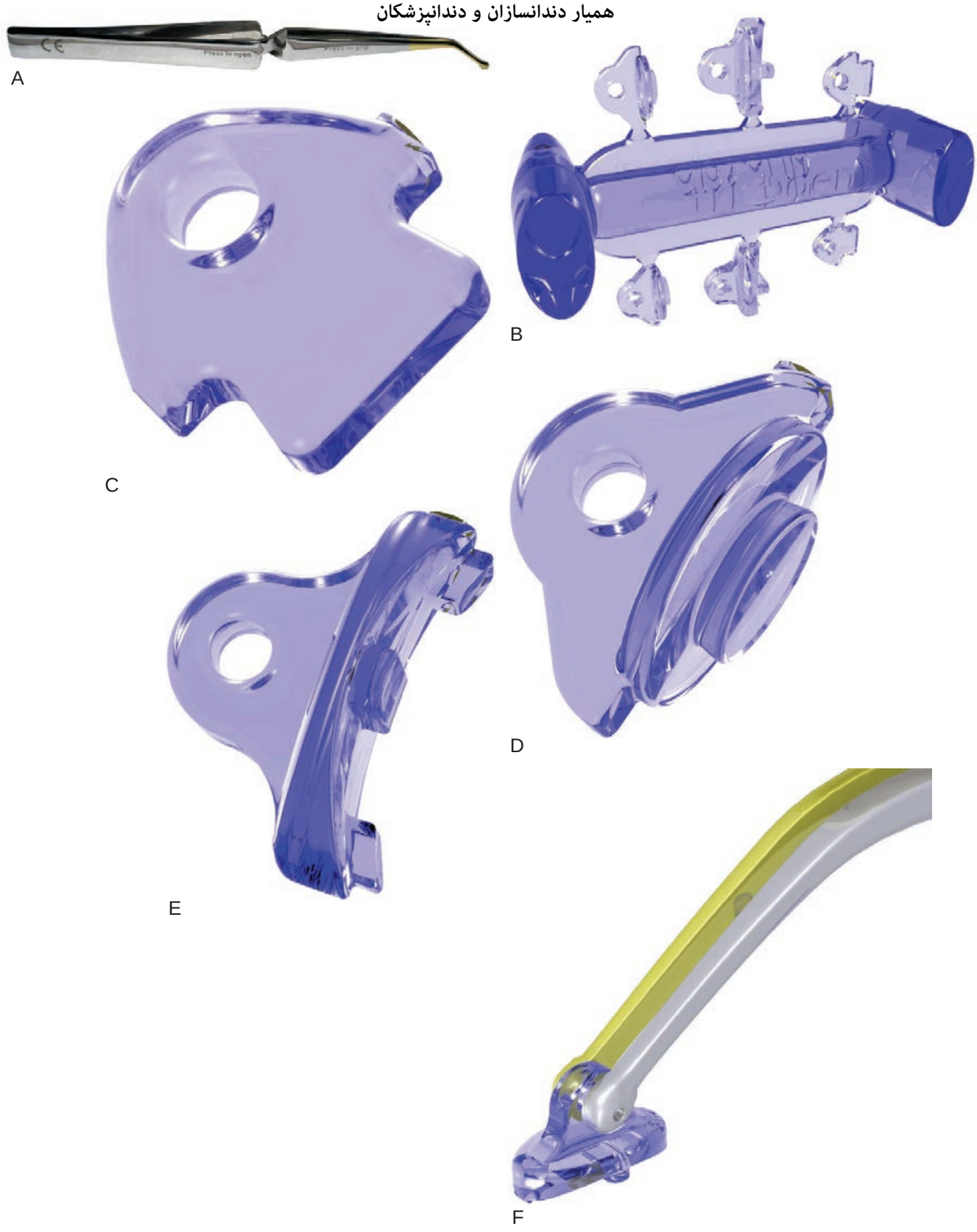


FIGURE 16-8 The Griptab system. **A,** Pin-Tweezers used for holding the Griptab, Wave-Wedges and Tab-Matrices from the V3 Ring system. **B,** Assortment of Griptabs on rack. **C to E,** The three sizes of Griptab. The small one (**C**) is designed for inlays and small onlays. The medium one (**D**) is for average-sized restorations and veneers, and the large one (**E**) is for full crowns and bridges. **F,** Griptab being held with the pin tweezers. *(Courtesy Triodent Corp., Katikati, New Zealand.)*

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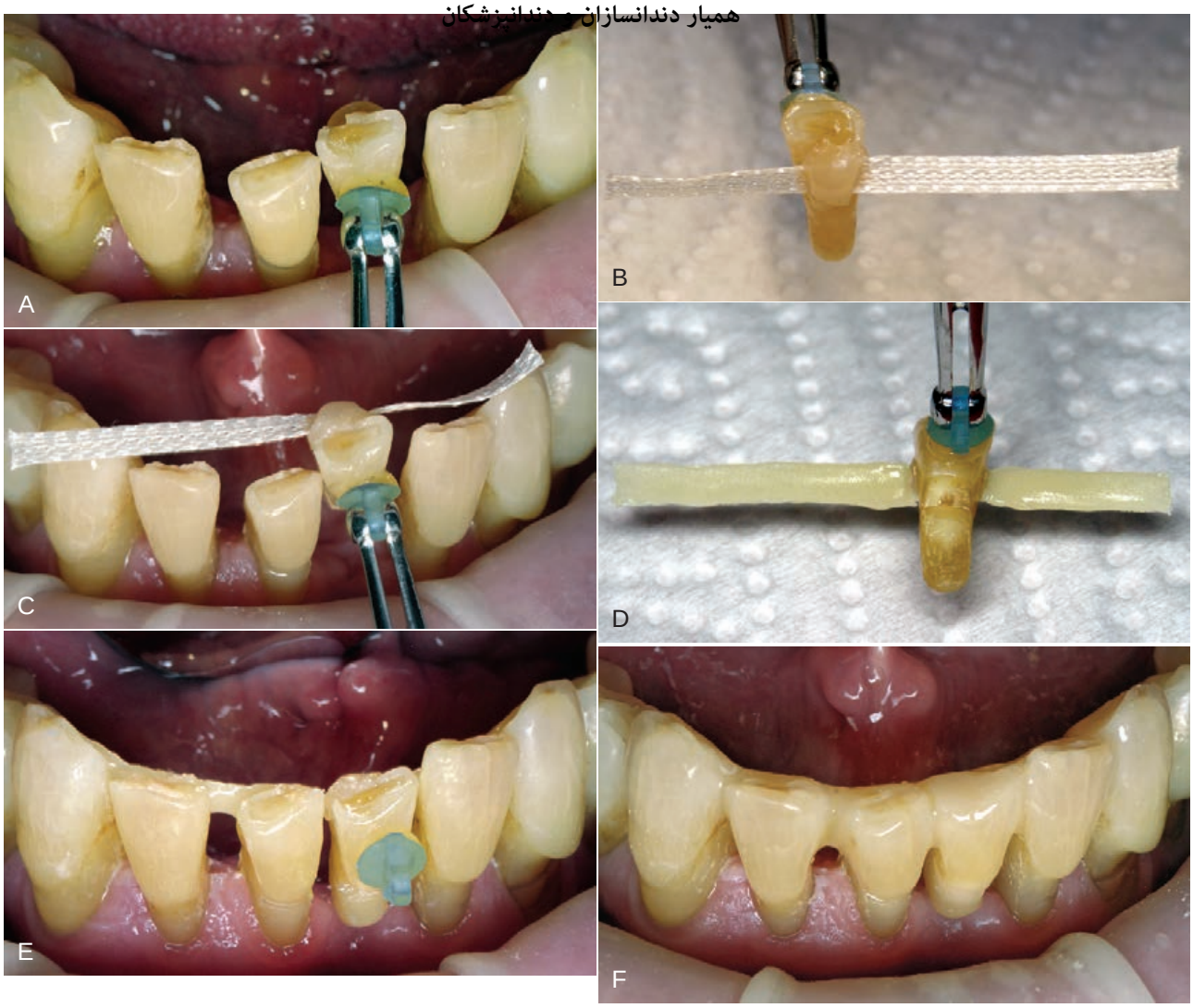


FIGURE 16-9 **A, Griptab bonded to extracted tooth after root tip removal and held with the pin tweezers. Try-in to check length of root reduction. B, Ribbond bonded to lingual groove. Ease of manipulation provided by the Griptab. C, Try-in to check accurate length of the Ribbond. D, Ribbond impregnated with resin, and composite layered onto the Ribbond with a composite unidose tip. This is very difficult to accomplish without the control provided by the Griptab. E, Initial placement and contouring of the composite-loaded Ribbond to the etched, bonded teeth. Griptab remains in place when released from the pin tweezers. F, Completed composite buildup before polishing.**

the mouth. Final placement of the splint or bridge was facilitated by the use of the Griptab to accurately locate the tooth while the splint was initially polymerized (Figure 16-9, *E* and *F*).

Contraindications

There are no contraindications.

MATERIAL OPTIONS

Advantages

The Griptab system allows total control of any restoration. The use of the pin tweezers to hold the Griptab means angulation can be changed at will and there is control of the rotational element during insertion. By simply allowing the pin tweezers to rotate on the Griptab, any torquing moment is removed, allowing the restoration to be passively seated. The occlusion can be checked on crowns and onlays while the Griptab is still attached. After placement and the setting of the restoration adhesive, the Griptab can be easily peeled off the restoration with no adherent residue.

Disadvantages

New users may accidentally hold the wrong end of the pin tweezers and accidentally release the restoration. Holding the proximal end of the tweezers keeps them closed, and squeezing on the distal half of the tweezers releases the Griptab. The bite cannot be checked when placing small inlays while the

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Griptab is attached, but this is not possible with any of the placement systems available. The Griptab adhesive is specially formulated to bond to ceramics. Dentists must not be tempted to use ordinary dental resins as a replacement for the Griptab adhesive, as they provide a very unreliable bond to glazed and polished porcelain and will fail at the most inopportune moment.

Current Best Approach

Other approaches include various adhesive sticks, waxes, and vacuum systems. All have shortcomings that leave dentists struggling to find a universal approach to confidently manage indirect adhesive restorations. The Griptab system is the most useful modality available today.

INNOVATIVE ELEMENTS

Scientific Elements

Scientific elements include a simple, semi-flexible, light-cured ceramic adhesive, combined with an innovative tab that is bonded to the restoration. The bonding adhesive is light cured with a conventional dental curing light and changes from red to gold when polymerized.

Technological Elements

The combination of a simple pin tweezer design, in conjunction with the Griptab and associated adhesive, provides secure control of the restoration. There are three Griptab sizes to accommodate all types of restorations, ranging from bridges, crowns, veneers, and onlays and down to the smallest of inlays.

Artistic Elements

As suggested, the Griptab aids in the control of veneers during the loading of the bonding resins. If subtle color matching is required, the Griptab provides a secure and stable grip of the restoration while various areas of the veneers are layered with different tints or flowable composite. This improves the accuracy of resin placement and consequently improves the esthetic outcome.

TREATMENT PLANNING

Options

What system should be used that is appropriate for the current case? There are several systems available on the market that go some way toward addressing the problems associated with control, handling, and placement of indirect restorations. The Griptab system comprehensively addresses all the issues, with the goal being to make life as simple as possible for the practitioner. Griptabs were designed by dentists, for dentists.

TREATMENT CONSIDERATIONS

Preparation

The dentist must ensure that the surface the Griptab is being bonded to is clean. No wax, oil, or silane should be present.

Procedure

The adhesive is applied to the Griptab, which is then placed on the desired surface of the restoration, and the adhesive is polymerized for 10 to 20 seconds. The Griptab is bonded before commencement of any prebonding preparation such as Hydrofluoric acid etching and silanation.

Finishing

The Griptab is peeled off with a flat-bladed metal instrument. No further finishing is required. If remnants of the adhesive remain on an inlay, they can be easily removed with a sharp curette or scaler.

CLINICAL CONSERVATION CONCEPTS

The Griptab reduces stress by eliminating the juggling act associated with controlling and placing small, slippery, cement-laden restorations.

CLINICAL STEP-BY-STEP PROCESS

Once the restorations are ready for placement, the appropriate Griptab is selected from the strip, grasped with the pin tweezers, and twisted off the rack. There is the option for laboratories to provide indirect restorations to the dentist with the Griptab already attached.

The dentist ensures that the restoration is free of any oil or contamination by wiping with alcohol. To ensure a secure bond, the Griptab is applied before hydrofluoric acid etching and silanation. The presence of silane will prevent a secure bond between the porcelain and the Griptab. A small amount of adhesive is applied to the fitting surface of the Griptab, and the Griptab is placed onto the desired area of the clean restoration, taking into account the area of the mouth into which the restoration is going to be placed. It might be easier in certain situations for the Griptab to be placed on the palatal surface of an upper posterior crown, rather than the buccal. Depending on the stability of the Griptab, it can be released from the pin tweezers before light curing of the adhesive, or the Griptab can be held on the restoration while the adhesive is cured. Depending on the intensity of the curing light, the adhesive will polymerize in 10 to 20 seconds and change from red to gold. It is

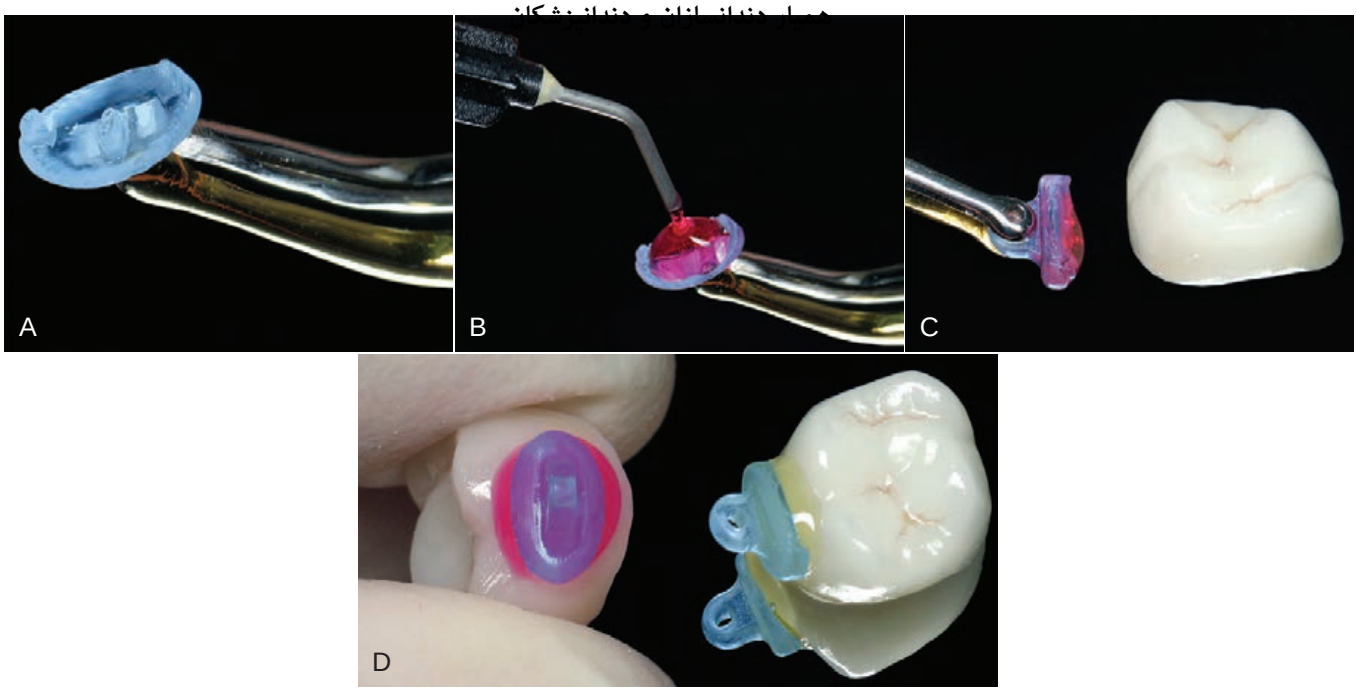


FIGURE 16-10 **Adhesive is applied to the Griptab (A and B), which is applied onto the crown (C and D). It is then light cured.**

important that the adhesive be well cured to ensure a sound bond (Figure 16-10).

The placement of inlays requires a slightly different technique. A small amount of adhesive is dispensed onto a pad, the end of the inlay Griptab is dipped into the resin, and this is applied to the occlusal surface just behind the marginal ridge. This technique avoids accidental overloading of the Griptab and having the adhesive flow over the margins of the restoration, compromising the seating of the inlay (Figure 16-11).

Once the Griptab has been attached (Figure 16-12), the restoration can be picked up and put down again as often as is required during the prebonding preparation phase (Figure 16-13). The Griptab will stay securely attached if the restoration requires ultrasonic cleaning at any stage in the preparation procedure.

Once the restoration is ready to be loaded with cement and placed, the restoration is picked up such that the orientation of the pin tweezers will provide the best angulation for ease of placement of the restoration (Figure 16-14). Once the restoration is placed, the pin tweezers are released, and cleanup and polymerization of the cement continue. The Griptab is then removed by peeling it off the restoration with a flat-bladed metal instrument such as a Ward wax carver (Figure 16-15). One should not try to remove a Griptab from an inlay or a veneer before it has been bonded in place, as there is a risk of fracturing the restoration.

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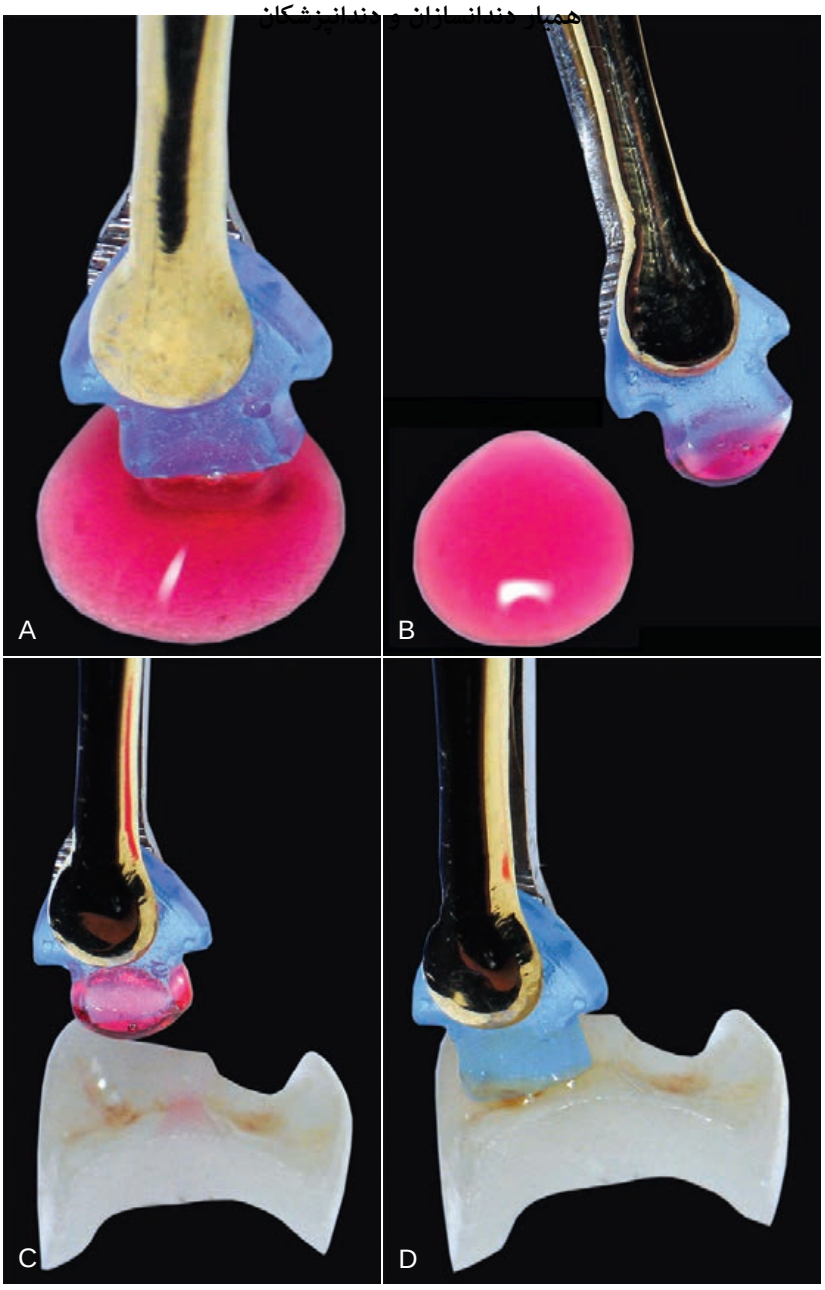


FIGURE 16-11 Inlay Griptab dipped into adhesive (A and B) and located on one of the marginal ridges and polymerized (C and D). Locating the Griptab at one end of the restoration will aid in placing the restoration in the correct orientation.



FIGURE 16-12 Griptabs applied to an onlay, crown, veneers, and inlays, ready for bonding.

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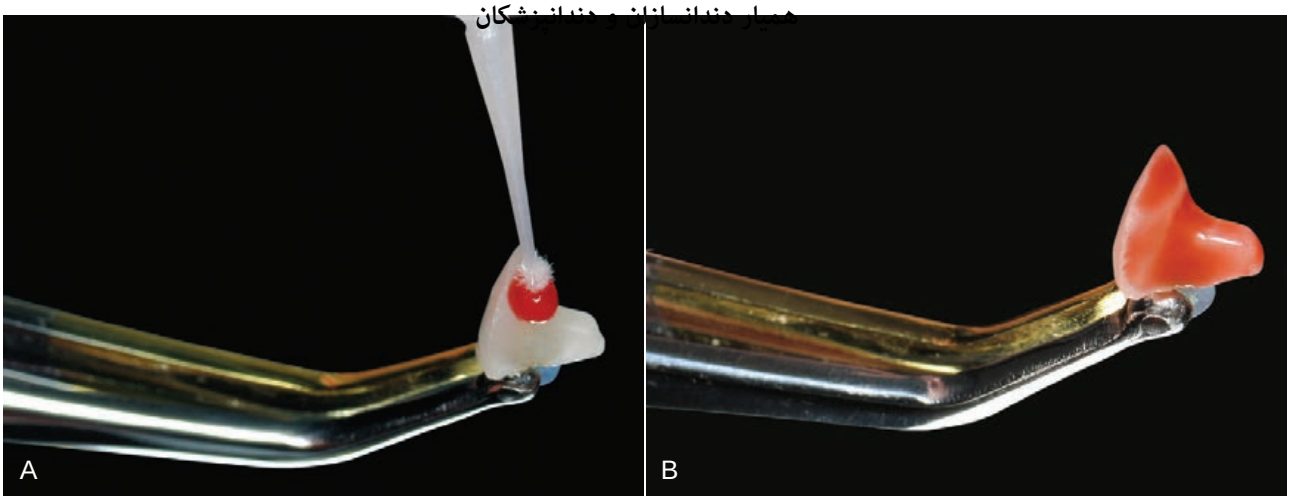


FIGURE 16-13 The Griptabs provide easy manipulation and control during hydrofluoric etching and silanation of the restorations.

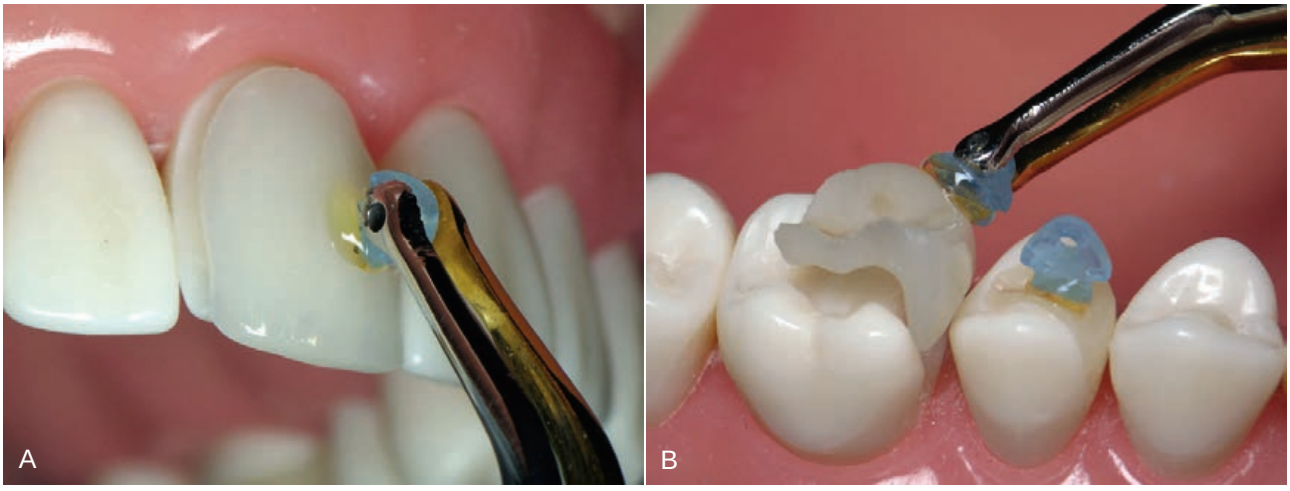


FIGURE 16-14 Griptabs being used for the location of a veneer (A), inlay, and onlay (B). Note the location of the Griptab on the onlay. The ability to rotate the Griptab within the pin tweezers makes this a simple procedure.

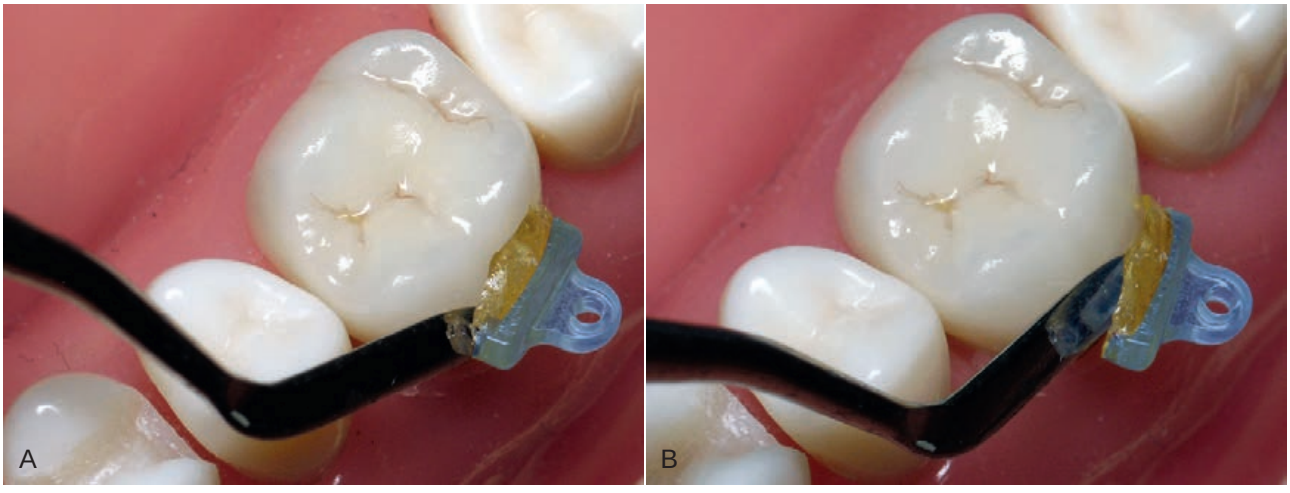


FIGURE 16-15 The Griptab adhesive is semi-flexible and can be peeled off the restoration with a flat bladed metal instrument.

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Case Study

After completion of endodontics on the first molar, the first and second molars (Figure 16-16, *A*) were restored with E4D computer-aided design and manufacturing (CAD-CAM) restorations using e.max CAD porcelain.

The prepared teeth were scanned and the restorations then designed and milled in e.max porcelain, then glazed and fired (Figure 16-16, *B*). An inlay Griptab was bonded to the occlusal surface of the second molar restoration, and a mid-sized Griptab was bonded to the buccal surface of the first molar endodontic onlay (Figure 16-16, *C*).

Once the Griptabs were bonded, they were used to control the restorations during hydrofluoric acid etching (Figure 16-16, *D*), then placed into an ultrasonic cleaner to remove the etching byproducts from the porcelain (Figure 16-16, *E*) before being picked up again with the pin tweezers for silanation (Figure 16-16, *F*). The Griptabs are not affected by ultrasonic cleaning, and the adhesive is not challenged by the presence of silane once it has been polymerized.

After placement of an Isolite (Isolite Systems, Santa Barbara, California), Triodent Wave-Wedges were placed below the gingival interproximal margin to aid in control of the cleanup of the bonding cements. The restoration was placed first, and then the appropriate-sized Wave-Wedge was gently placed. Observation was made to see whether or not the wedge had displaced the restoration. The restoration was removed by reattaching the pin tweezers to the Griptab, but the Wave-Wedges were left in place. Alternatively, as was the case in this situation, the Wave-Wedges can be placed first (Figure 16-16, *G* and *H*) and then the restorations can be tried-in, checking

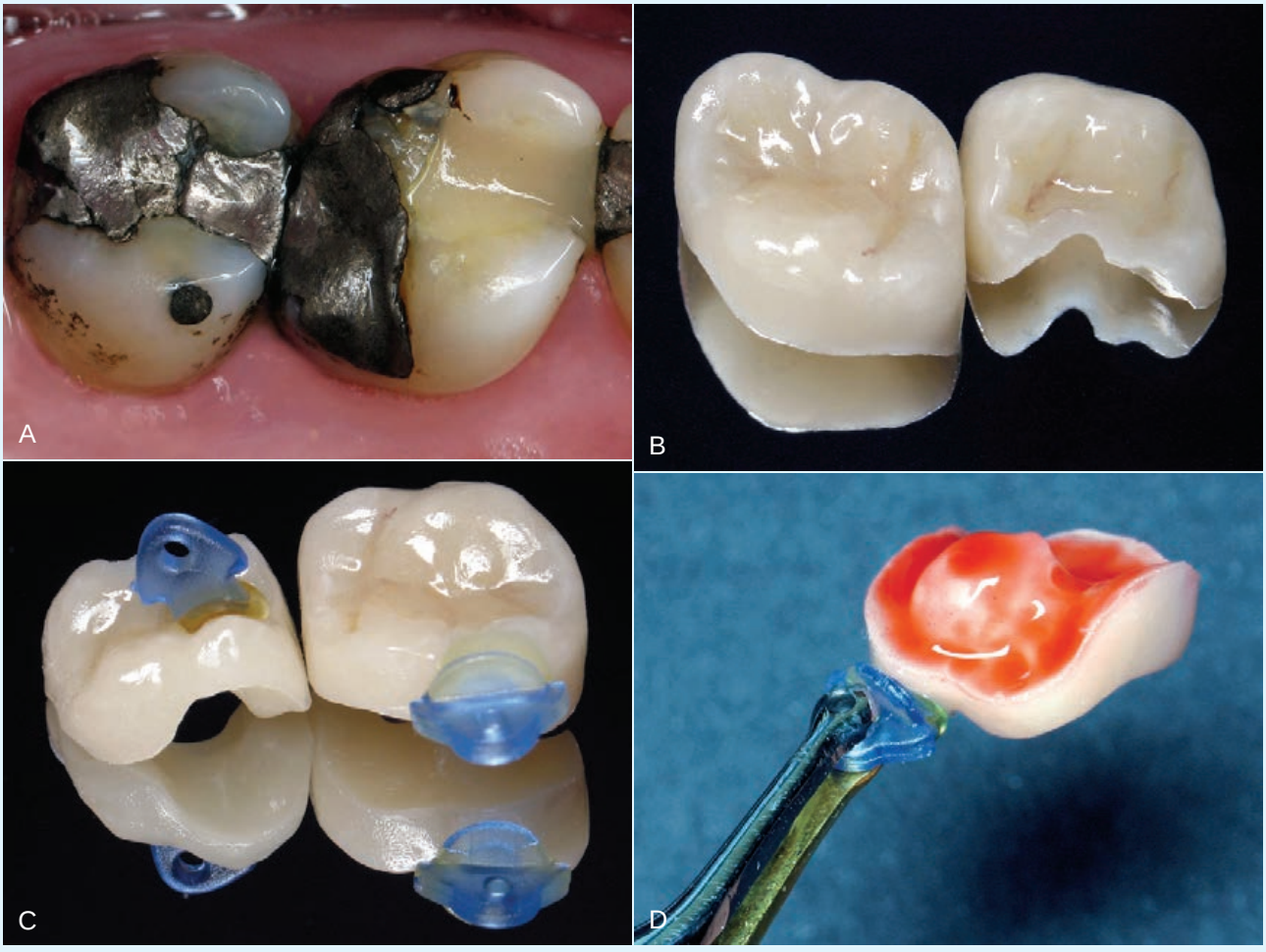


FIGURE 16-16 **A, Pre-treatment state of the teeth. B, Completed E4D computer-aided design and manufacturing e.max low-translucency restorations. C, Griptabs bonded to the restorations. D, Pin tweezers holding the Griptab during hydrofluoric acid etching.**

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Case Study (cont'd)



FIGURE 16-16, cont'd E, Ultrasonic cleaning. F, Pin tweezers holding the Griptab during silanation of the restoration. G, Placement of the Wave-Wedge with the pin tweezers. H, Interdental papillae protected with Wave-Wedges of different sizes. They also control the flow of expressed cement, aiding in cleanup. I, Minimal interproximal cement was present once the Wave-Wedges were removed. J, Completed restorations immediately post-cementation.

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Case Study (cont'd)

that the margins are closed to confirm that the wedges are not interfering with the seating of the restorations. The Wave-Wedges also protect the interdental papilla when the preparation surfaces are air abraded before the bonding procedures.

The bonding procedures were completed for the tooth and restoration, and the bonding cement was placed on the restoration, which was placed again into the cavity. The Wave-Wedge will prevent excess cement from contaminating the interproximal restoration margins and reduce the volume of interproximal excess. Once the cement has begun to gel, removal of the minimal excess cement is facilitated by the removal of the Wave-Wedge (Figures 16-16, *I* and *J*).

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SECTION C

Porcelain Laminate Veneers

Galip Gurel

RELEVANCE OF PORCELAIN VENEERS TO ESTHETIC DENTISTRY

Veneers are one of the most revolutionary techniques developed over the past 25 years. Implants and bonding changed the profession of dentistry. When dental professionals realized that porcelain can bond onto composite and therefore onto the tooth surface, it changed everyone's lives—including patients'. With veneers it is possible to create amazing esthetic results and yet retain considerable solid tooth structure. The key to being successful in these restorations is keeping tooth preparation as minimal as possible. In that way dental professionals respect the tooth structure by leaving enamel in place. The bonding figures change dramatically when all the enamel is removed from the tooth surface. By maintaining enamel, the dentist prepares a good surface for bonding. The focus is on the patient in the chair and trying to save all the sound tooth structure and yet produce an esthetically pleasing result.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Pioneers in the field, Drs John R. Calamia and Harold Horn were the first to publish on this procedure, and dental technician Adrian Jurim was the first to make it a feasible discipline. In the early 1980s, because of the adhesives available, it was not possible to bond to dentin. At that time the dentist's goal was simply to keep the preparation in the enamel, and this made it sometimes impossible to obtain the best esthetic results owing to tooth positioning. When newer and better bonding agents were developed and it became possible to bond onto dentin, it was then possible to both expose some dentin and obtain a better esthetic result. Dentists pushed the limits too far when they tried to treat all cases with veneers, no matter how crowded the teeth were or what their positioning, and exposed a lot of dentin structure. When the concept of interdisciplinary dentistry came to the forefront, dentists' thinking changed toward how best to align teeth on the dental arch. After the teeth had been brought into correct position, the preparation focused on how to get the best esthetic results without removing too much sound tooth structure.

Currently, the name of the game when it comes to minimal tooth preparation is being **additive** on the tooth surface. Except in the case of color changes, veneers are mainly being applied on middle-aged or older teeth. Regardless, besides the incisal attrition on the incisors, some volume is lost on the facial sides of the tooth, and they needed to be brought back to their original volumes. Even if there is no abrasion on the facial surface, dentists need to try to create the smile design by adding onto the teeth. The more that is added, the more space is created for the post (tooth) structure. Working in an additive fashion, with mock-ups and smile design, is the best way to be minimally invasive but to achieve maximum esthetics. People with thick lips can easily support such buildups. If it is impossible to achieve the esthetics, meaning whatever is added to the patient's smile does not look good, then adjunctive therapy, such as orthodontics or aligning those teeth 0.5 mm more lingually to create space for porcelain, should achieve the desired result.

RELATING FUNCTION AND ESTHETICS

The goal should consist of equal parts function and esthetics. If one or the other is compromised, the case is prone to failure.

The first step is to complete the mock-up in mouth, trying to roughly gauge the esthetic outcome on the face. If the occlusion is working relatively well, the mock-up is transferred to the

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laboratory and the laboratory technicians are asked to wax up the case on a mounted model. With that it is possible to see (1) the esthetic outcome and (2) how the restoration fits with the patient's functional movements (occlusion). Usually either the shape or the length of the teeth is altered. This allows the dentist to modify the anterior guidance in the patient's mouth.

The wax-up is sent back from the laboratory and tried in the patient's mouth. (The author refers to the wax-up as the *aesthetic pre-evaluation temporary* [APT], as the test for esthetics and function.) The patient has not been anesthetized and the teeth have not been prepared, but the model is in the patient's mouth. It can be left in place for a couple of minutes or a couple of days. After the occlusion and the esthetic outcome have been double-checked, if everything is working fine, the case can proceed.

CLINICAL CONSIDERATIONS

Indications

There are many indications for veneers: changing the shape of the teeth, changing the color of the teeth, aligning the teeth, and, when there are existing composite veneers that are chipping, changing color or replacing them for better esthetics.

Contraindications

Veneers are contraindicated when the tooth preparation will result in excessive exposure of the dentin and when conditions affect tooth alignment. If there is extreme protrusion, a better treatment option is the interdisciplinary approach to bring the teeth in or to carefully prepare the surfaces where the veneer will be bonded. Another contraindication is damaged dentin that needs to be bonded (e.g., sclerotic dentin). These critical issues should be considered before beginning a treatment using veneers.

CLINICAL OPTIONS

Patients can be treated with ceramic veneers, composite veneers, crowns, or not at all. The whole process begins with the patient's expectations and needs. If the patient comes to the office for a posterior filling and does not require anything additional, it is not necessary to introduce veneers. But if the patient asks for better esthetic results, the option should be offered. The simplest treatment can be a composite or a porcelain veneer. If the case involves a single tooth or two teeth that must be better positioned, composites can do a great job. For creating a new smile design, composite veneers are not the first choice. The author prefers to do the mock-up with composite and then to bring the case (with the wax-up) to a talented ceramist to get the best results. If the tooth has not been previously prepared for a crown, there is no need for a crown restoration. Today the bonding materials are so strong, whether bonding to dentin or enamel, that whatever is sound in the tooth structure should be left on the tooth, and dentists should push the limits to make veneers or composite veneers instead of crowns, which should be the last option.

Current Best Approach

When a patient has esthetic concerns for the front teeth, the dentist should always have an in-depth conversation with the patient in order best understand what the patient really wants. Sometimes the patient can have unrealistic expectations. It is essential that the dentist understand what the patient needs *and* expects.

Next the dentist should communicate with the patient on a three-dimensional basis using a solid mock-up. This mock-up should approximate the new length of the teeth. The increased volume on the facial surfaces of the teeth can effect lip support and may also have a partial impact on phonetics. The mock up will give an idea of what can be achieved toward the desired end.

The author first builds up the case as desired, including all the esthetic parameters, utilizing his artistic ability in the new smile design. If the patient likes it, the case can be continued right away. If the patient finds that the mock-up is short or long, that it is too bulky, and so on, then adjustments can be made until the patient's and dentist's esthetic values line up. Once the patient and dentist agree on the incisal edge position (vertically and horizontally) and the facial contours of the teeth with this mock-up, this information is transferred to the laboratory. The laboratory then makes an index and builds the wax-up according to the index. This wax-up is basically the same as the mock-up, but it incorporates small details such as the incisal silhouette of the incisors, incisal embrasures, interproximal contact, and surface features. The dentist then creates a clinical index and a template from this wax-up. This is brought chairside for the second appointment.

Before the author starts treatment (anesthetizing the patient, tooth preparation), the template is placed in the patient's mouth using a provisional material. As mentioned earlier, this can be referred to as the *aesthetic pre-evaluative temporary* (APT) because it fits precisely in the patient's mouth, making it easy to check the lip supports, the final esthetic values, the phonetics, and the occlusion. It is possible to see if a constricted envelope has been created, whether the patient feels trapped by the length of the upper and lower veneers, and so on. There are two possible results at this stage: everything looks fine, or the patient or dentist may have complaints about the wax-up that can easily be corrected. If changes are needed, an impression is taken and sent back to the laboratory to guide the buildup.

INNOVATIVE ELEMENTS

Several scientific elements have changed over the last 30 years to make porcelain veneers possible. In the early 1980s, veneers had limited indications because dentistry considered them only

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something to be built on the enamel surface. With the introduction of third-generation bonding materials that could be used on dentin and with wet bonding, dentists realized that it was possible to bond porcelain to the dentin surface. The newly expanded indications started the development of veneer material. The introduction of pressable ceramics, refractory die systems, and platinum foil systems have all added to the profession. Today's veneers (and some partial veneers) can be bonded on non-prepared teeth, which makes it possible to keep the entire sound tooth structure intact and still achieve great esthetic results with porcelain.

ARTISTIC ELEMENTS

One of today's significant artistic elements involves building up from the outside in, which means developing the smile design first and then adding appropriate elements to the buildup. These elements can be veneers, implants, or crowns, but the main starting point is determining the proper design for the esthetic outcome. In addition to this design, relating the form, the surface texture, and the layered colored element within the porcelain buildup structure are all extremely important. It is also important to relate the form, the shape, and the texture of the teeth so that they will match the character and age of the patient.

All of these elements have a major influence on the esthetic outcome. For example, matching the veneers with a patient's age requires careful consideration. Young teeth have great texture and a surface refractive index that is totally different from that of an aged person's teeth. A young tooth has a brighter color and a more reflective index. As a patient ages, the shape of the tooth also ages. There may be some attrition in the incisal edges, which will make the tooth look shorter. The shorter the teeth the smaller the incisal embrasures, so the incisal curvature turns out to be an incisal line with no embrasures. The facial structure also begins to round, and sharp surface textures start to soften. The color hue gets higher, and the value gets lower. These changes develop from the teenage years through the mid-30s and the 40s and into old age.

When treating a 60-year-old patient, the dentist may find that all the surface texture is gone, the teeth are shorter, and the need is to restore an esthetic smile. In planning for smile restoration, the first goal is to make the patient look younger. The elements found in a younger appearance include longer central teeth, teeth following the lips, and better incisal embrasures. The key is to decide what age to bring that patient to. For a 60-year-old patient, the maximum aim should be making the smile look 10 to 15 years younger, not 40 years younger. Instead of using the elements seen in a teenager, it is best to analyze what the tooth or the smile could look like for this patient at age 45 years. It is not appropriate to attempt to produce a drastic surface texture, dramatic incisal embrasures, or extremely wide teeth.

When beautifying a smile, many things must be approached carefully, including the color of the tooth and how imperfections are included in a smile to make it look more natural. Making a wide, bright, straightforward smile may be the easiest thing to do, but creating a natural smile should be the focus in today's dentistry.

TREATMENT CONSIDERATIONS

Preparation

Each case is unique and will have its own special considerations. For minimally invasive dentistry, it is necessary to try to work as additively as possible. Adding materials, especially with the thickness of a veneer, is the best approach. This will result in the removal of a minimal amount of tooth structure or possibly even no tooth structure removal.

The first stage in any case is the mock-up. This mock-up will give a rough indication of the smile design. Once the mock-up has been created and the patient and dentist have agreed on the incisal edge positions and the facial contours of the restorations, then the mock-up is sent to the laboratory so a real-size wax-up can be created. Using silicone indexes and matrices, the laboratory attempts to make the exact smile design out of wax. When the wax-up is returned to the dentist (stage two), it is placed into the mouth as an APT, which allows both the dentist and the patient to see the results before beginning the case. It is possible that the patient may not like it, and rarely it may be necessary to stop the case at this point. If the patient's expectations are very high or impossible to reach, usually this will be revealed at this stage. The patient is not numb, which means there is lip control and it is possible to check phonetics, the incisal edge, lip posture, and so on. If the patient is happy, the teeth can be prepared.

The APT, which defines the final facial contours of the expanded restoration, is left on the tooth. The dentist starts preparing the tooth through the APT. The author recommends using a depth cutter, chosen on the basis of the thickness of the porcelain to be applied. That depends on the color of the tooth, the porcelain material being used, and so on. The depth cutter chosen will be used through the APT and will yield an exact thickness of the porcelain to be built on that tooth. Most of the time the dentist will not even touch the tooth surface, as it is built up additively at the mock-up stage. The author suggests that this is the best type of smile design, because, when it comes to the tooth preparation, this leads to the most minimally invasive tooth preparation techniques. Once the facial (average 0.5 mm) and incisal (average 1.5 mm) reductions have been done, the remnants of the APT are removed and the preparation of the margins is continued under high magnification (with loupes or microscope). During that time, 99% of the preparations will be limited to the enamel, so the bonding will be perfect—no microleakage, no delamination risks. If the dentist appropriately manages the occlusion, there will be almost no breakages.

Next the dentist makes an impression and, by using the same wax-up template, finishes the provisionals of the patient. These steps produce a predictable, precise, and repeatable result each time, whether an easy or a complicated case.

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Procedure

The author uses the depth cutter on the APT and concentrates on preserving tissue around the tooth. It is important to be very precise with the margins. Subgingival margins are avoided unless one is closing a gap or masking a discoloration. Otherwise, placing the margin in either a gingival or supragingival location is appropriate. Margins are finished under the microscope. There should be no sharp right angles or sharp corners. The best way to accomplish this is to finish all the preparations with extra-fine round and fine finishing burs. The author recommends a sandpaper disk for rounding all the sharp edges. The author also uses a white Arkansas stone finish of the preparations to polish. For impression taking, the author rarely uses retraction cords but instead tries to keep the tooth and soft tissues as dry as possible in order to achieve the best result, no matter which impression material is used.

After the impression is obtained, a provisional is made. (For this provisional the author recommends using the rapid simplified veneer provisionals [RSVP] technique developed by Robert Margeas and Robert Nixon.) First, a one-third incisal is placed into the patient's mouth, light cured, and fully polymerized. The shrinkage of the composite (or any kind of provisional material) will cause it to lock itself to the incisal embrasures so that the provisional veneers will not come off. The other two-thirds gingival part is filled with freehand carved composites. These are some simple tricks that can be used every time.

Finishing

The author uses a sectional rubber dam when finishing veneers in almost every case. It makes the work very easy, but if there is sulcular fluid exuding, only a retraction cord or a rubber dam specifically prepared for that single tooth can be used.

The second stage starts with bonding the veneer. First, the inside of the veneer is filled with the luting resin; it is applied from the incisal tip to the incisal edge of the tooth and gently rolled. This helps to avoid having air bubbles that could be blocked under the veneer. When the veneer is gently pressed over the tooth, the dentist should feel the excess luting agent expressing at all the margins. If not, that means there isn't enough luting resin in the area, and there is a chance of leaving a small gap between the tooth and the veneer.

One should not fully polymerize at this stage. The dentist may want to clear out the excess resin with some cotton-tipped swabs. However, the whole area may become extremely messy. The author's preference is to spot tack the middle third with a 2-mm turbotip in order to hold the veneer in place. The dentist then switches to a larger light-curing tip and gently light cures it for 1 or 2 seconds. This brings all the excess materials into a jelly-like consistency that can be easily peeled off. The dentist then cures the veneer completely, with nothing left to do at the margins. It is vital to not touch the margins with any kind of bur after the veneer has been cemented until *all* the veneers are in place. The whole thing should be cleaned before polymerization. If there is any material left, it can be removed using No. 12 blades.

EVIDENCE-BASED PRINCIPLES

When it comes to porcelain veneers, every step is evidence based. The major concern is the tooth preparation. The tooth has a certain amount of flexure in it. The more a tooth is prepared, the greater this flexure will be. Much research has been done showing that if all the enamel is removed from the surface of the tooth, this flexure becomes dramatically higher. It is always better to keep the preparation minimal in order to avoid tooth flexure. With all the enamel on the tooth surface, there is less flexure because enamel is a very brittle but rigid substance that protects tooth integrity. The more enamel that is removed, the more flexure there will be, and the more danger that the veneer may break afterward.

Another advantage of making teeth preparations minimally invasive is that it allows margins to stay on enamel. Hundreds of evidence-based research papers cover how composites or luting resins bond to enamel. There is also an extensive amount of research that documents how best to prepare the internal force of the veneer to obtain optimal bonding surfaces. The time frame for application of the acid, the concentration of the acid, the type of the porcelain, and whether it is glass based, pressed, or reinforced—all these factors will affect the quality of the porcelain surface treatment. The applications of saline solution, adhesive, and luting resins are all evidence based and must also be considered.

The veneer can hold onto dentin surfaces. It is possible to bond veneer composites on dentin surfaces, but on a natural tooth there is an amazing fusion of enamel to dentin that cannot be replaced by artificial materials. Therefore it is always better to keep natural enamel and dentin fusion and to add something on top of it. If, for some reason, this junction is lost, then it is possible to bond veneers on the dentin surface as well. It is impossible, however, to recreate the same strength as bonding on enamel.

CLINICAL CONSERVATION CONCEPTS

With today's bonding possibilities, there is almost no reason to prepare a tooth for full-crown coverage when there is a lot of sound tooth structure tissue. An exception might be teeth that have already been prepared for a crown or teeth that need to be the anchors of bridgework. The author rarely prepares teeth for a full-coverage crown.

Porcelain veneers are the optimal choice. In some cases these offer the opportunity to treat teeth without preparation. If the indication is there, prep-less porcelain veneers should definitely be the first choice. In many cases dentists should also consider the interdisciplinary approach.

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There are two ways of making (or attempting to make) prepless veneers:

1. If possible, an additive technique must be used to keep the tooth in its original position. The goal is to add the optimal volume to the tooth in order to bring the tooth back to its previous volume. Patients with thicker lips will accept this more readily. If material can be added onto that surface and the esthetics are acceptable, it is a good choice because then the thickness of the mock-up will be replaced by the thickness of the veneer. This means dentists will prepare almost nothing from the tooth structure.
2. If the appearance is not esthetically pleasing, dentists have the choice of using orthodontics to bring those teeth 0.5 to 1 mm palatally, creating space for the porcelain to be applied.

MAINTENANCE

Once veneers are in place on the patient's teeth, issues in maintenance must be considered. Whenever a piece of glass is bonded onto the patient's teeth, the material is brittle and needs to be protected. This can be accomplished in two ways. For example, if the patient's occlusion is not adjusted well, it is likely that the veneers will break. Habits also play an important role. These include habits such as biting a pencil and grinding or clenching during sleep. It is strongly urged that patients wear a night guard after the veneers are in place.

Commonly, all veneers are finished supragingivally, so the dental hygienist scales the area well away from the veneers. However, if the margin is located subgingivally, the hygienist may need to use plastic tips around these areas.

CONTROVERSIES

The major controversy concerns exposing too much dentin. The question of whether one should immediately seal the dentin in these cases arises. Strong data indicate that this is appropriate, but some data indicate that it is not important. There is nothing wrong with sealing the dentin in advance, but it complicates the provisional process, as the dentin must be sealed completely so that the veneer will not bond onto that surface. If the patient is hypersensitive, sealing immediately when the teeth are prepared will prevent hypersensitivity reactions. Bonding on fresh dentin is always best.

In immediate dentin sealing, the surface is sandblasted, the surface energy reactivated, and then the bond is generated. The author recommends the immediate dentin bonding technique but notes that it should be done using a thick filled adhesive. Later, when bonding the veneer, the author gently sandblasts it and then re-etches and bond to that surface.

NEAR-FUTURE DEVELOPMENTS

The materials available now have extremely nice optical effects. The bonding strength to porcelain is already beyond the strength needed. There may be stronger porcelain developed, but the strength of even the weakest porcelain is 60 to 70 megapascals—more than enough if the veneers are bonded properly.

It is possible that manufacturing systems may be able to mill the glass ceramics down into 0.05 to 0.1 mm. That would create extremely thin cosmetic porcelain.

Clear or transparent veneer cements are already available. Colored cements tend to change color with time, becoming darker or yellower, and an opaquing color resin does not help when dealing with a major color problem. To make this work perfectly, good communication between the laboratory and the dentist should be established. The communication should not be simply written or verbal, but should include several photos in different settings showing the problem areas. In the laboratory the veneers should be built on a specifically colored duplicate die material and the final veneer color adjusted so that when the veneers come back the color should be correct.

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Clinical Case

A 50-year-old man desired treatment for an un-esthetic smile. There was loss of enamel on the facial surfaces owing to excessive lemon consumption. The patient received veneers, and the esthetic outcome was successful (Figure 16-17).



FIGURE 16-17 **A to C, Un-esthetic smile with incisally chipped and abraded teeth. D to F, Loss of enamel on the facial surfaces of the teeth from the excessive consumption of lemons.**

Clinical Case (cont'd)



FIGURE 16-17, cont'd **G and H, Views of the palatal surfaces, which have not been affected by acid erosion. I, The aesthetic pre-evaluation temporary (APT) built up in the mouth. APTs are completed chairside (before tooth preparation) with the help of the template done from the wax-up. J to L, Both functional (occlusal) contacts and esthetic outcomes are evaluated and communicated with the patient.**

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Clinical Case (cont'd)

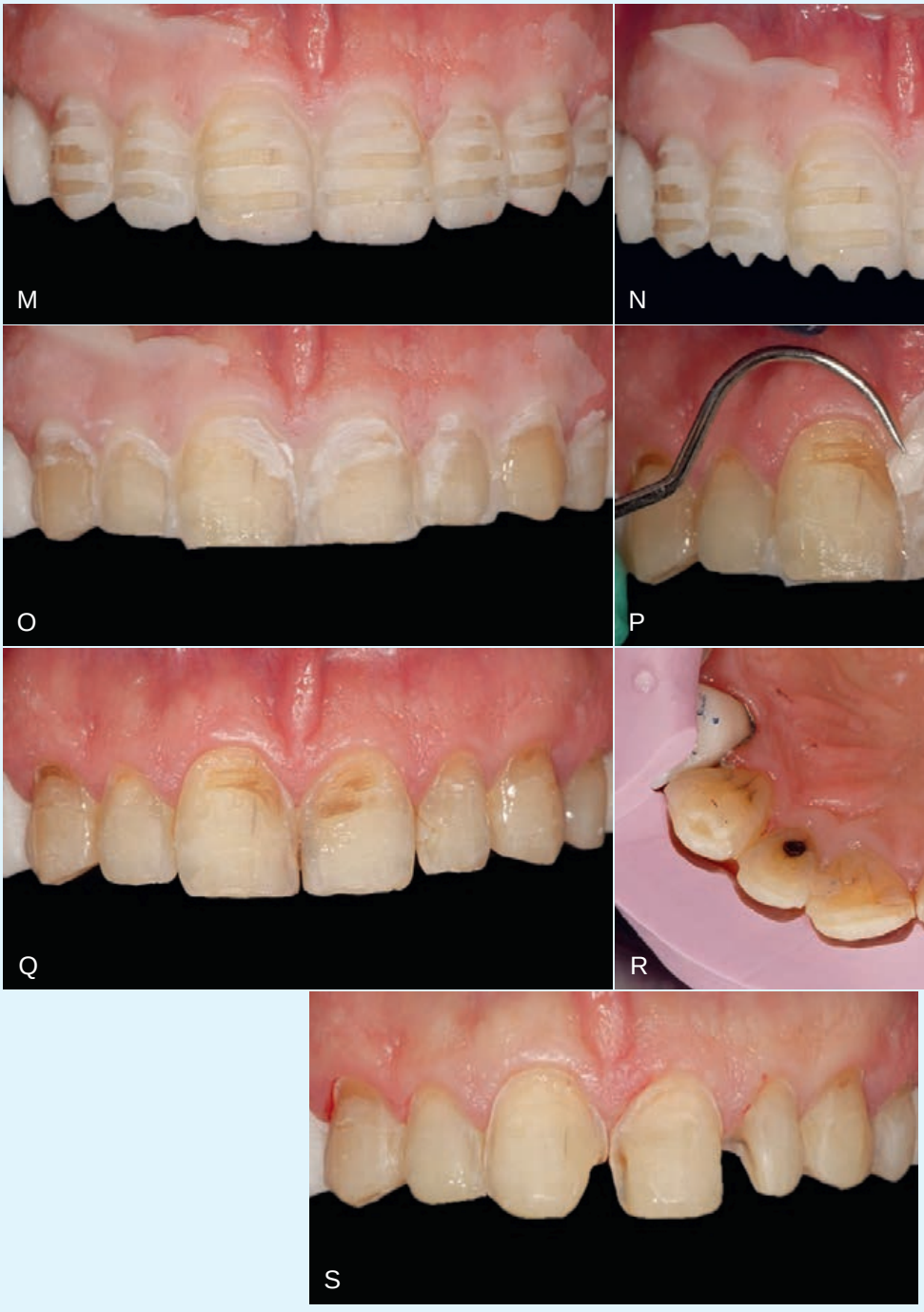


FIGURE 16-17, cont'd **M,** Tooth preparation through the APT using depth cutter burs. **N,** The necessary depths created facially and incisally. **O,** The main gross reductions made according to the initial preps using the depth cutter. **P,** The remaining APT material removed (mostly from the interproximal areas). **Q,** Note the minimal preparation that was necessary as a result of the use of the technique. **R,** The depth is double-checked with the help of a silicone matrix created from the wax-up. **S,** The old composite fillings are removed and the preparations are complete.

Clinical Case (cont'd)



FIGURE 16-17, cont'd T to V, The same strategy described for the upper teeth is used on the lower teeth: necessary depths (T), minimal preparation (U), and depth double-checked (V). W and X, Facial (W) and lateral (X) views of the smile after the veneers have been placed. Y to AA, Intraoral views of the veneers. Note the corrected occlusal plane.

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Clinical Case (cont'd)



FIGURE 16-17, cont'd **BB and CC, Occlusal views of the veneers. DD to FF, Before-treatment view (DD) and after-treatment views (EE and FF) of the patient's smile.**

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Esthetic Inlays and Onlays

Ron Jackson

RELEVANCE TO ESTHETIC DENTISTRY

Esthetic inlays and onlays have become viable restorative alternatives for moderately broken down posterior teeth and an integral means of restoring teeth. Advances in adhesive technology and esthetic dental materials—for example, composite resins and ceramics—have enabled clinicians to use conservative preparations to place restorations that also reinforce the remaining tooth structures. In addition, these restorations satisfy the increasing patient expectations for a natural or enhanced appearance. The directly placed resin restoration is clearly the most conservative posterior restoration in contemporary dentistry. Although this technique requires only that diseased tooth structures be removed and replaced, direct resin is subject to shrinkage when it is light cured. This can result in stretch forces on the bond or the tooth with the potential for postoperative sensitivity and/or microleakage if these forces are not relieved by elastomeric flow in the resin. Although this development is less problematic in smaller class II cavities and can be controlled or limited somewhat by technique, it is of greater concern in larger carious lesions. Esthetic inlay and onlay restorations attempt to minimize this inherent property of light-cured resins, because only the thin layer of luting resin is subject to polymerization shrinkage at restoration placement.

The effect of patient expectations on the growth of tooth colored posterior restorations has been significant. In 1990, 94% of American dentists chose amalgam as their primary posterior filling material, but this dropped to 76% by 1995. In 2010 Limoli & Associates, a company that tracks dental procedures and fees, reported that posterior composite restorations outnumbered amalgam by 2 to 1. In a survey conducted by the American Dental Association in 2002, the question was asked, "In your dental practices, is amalgam still your material of choice?" At that time only 54% of dentists chose amalgam as their primary filling material. By 2005, about a third of U.S. dentists no longer used amalgam at all, and the remaining two thirds reported that amalgam use was continually declining. A significant impetus for this change in practice has come from patients. Also, a significant number of dentists, perhaps the majority, believe that a conservative, bonded, tooth-reinforcing, sealed restoration is restoratively better than an amalgam filling. Patients, however, focus almost exclusively on appearance, a reflection of society's desire for "nice smiles" and better-looking teeth.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF ESTHETIC INLAY AND ONLAY PROCEDURES

Development and Use of Direct Amalgam Fillings and Gold Inlays and Onlays

Amalgam fillings have been used for well over a century and offer the most user-friendly material for restoring posterior teeth. Their low technology advantages include technique forgiveness and tolerance for conditions encountered when not using a rubber dam, such as susceptibility to contamination from blood, sulcular fluid, or saliva. Amalgams are also condensable, so contact can be more readily achieved. From the dentist's standpoint, amalgam has been a good restorative material, being applied through a technique that is easy to learn and execute. Amalgam also has good longevity and the lowest cost of any of the restorative materials. Among amalgam's significant deficiencies are its susceptibility to constant corrosion, inability to strengthen the teeth, inability to seal teeth initially, and lack of esthetics. Many patients and dentists are also concerned about the mercury issue, because amalgam is 50% mercury. Recently, environmental concerns about contamination of the water supply have led to increased regulations and even calls for a ban on further use, which has been instituted in some countries. *Cast gold* has been used for over a century. Gold is an inert material, can be alloyed to almost an ideal hardness value, so as to be kind to opposing tooth structure, and when properly applied has been shown to have a longevity of decades. Often gold is considered the "gold standard" of restorative dentistry. Its main deficiency is its color. However, when the restoration is placed in second molars or when the patient is not concerned about the color, selecting cast gold for moderate to large cavities is one of the wisest choices the dentist can make.

The esthetic inlay and onlay procedure successfully using *ceramic and/or processed composites* began to be used around the mid-to-late 1980s, shortly after the introduction of ceramic veneers for anterior teeth. Both treatments paralleled advances in adhesive dentistry in general. Stacked, feldspathic porcelain or indirect composite inlays and onlays were also introduced to address some of the deficiencies of direct composites, which at the time, were considerable when applied to posterior teeth.

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They included high wear, low strength, high shrinkage, and difficult placement, especially in light of dentists' training in placing metals in posterior teeth, a technique quite different from what is used for direct composites. In addition, laboratory-fabricated ceramic and processed indirect composite yielded improved physical properties, improved contours, predictable ideal proximal contacts, and the potential for better, more appropriately placed functional occlusal contacts.

RELATING FUNCTION AND ESTHETICS

Achieving a predictable-quality proximal contact can be challenging in class II direct resin restorations, particularly in a moderately broken down tooth. It can also be difficult to routinely achieve adequate contacts in teeth with a compromised arch position or a mal-alignment. Certainly, the amount of tooth structure being replaced can be a factor in treatment planning specific to the ease of placement and quality of the definitive result. The functional loading on the restorative material, especially when one or more cusps are missing, is certainly greater than in smaller cavities. Also, it is known that occluding forces increase from anterior to posterior. Therefore, posterior esthetic restorations not only have to satisfy patient desires for natural appearance, but they need the necessary strength factors to be durable over time.

Finally, the reduction of microleakage, particularly when gingival margins are in dentin, may also be a factor when choosing an inlay or onlay over a direct composite restoration, especially in larger cavities. Although there are studies showing these type of indirect restorations show reduced microleakage in such instances, not all investigations are in agreement, and complete elimination of microleakage at dentin margins has not been achieved by any of the current adhesive systems.

CLINICAL CONSIDERATIONS

Indications

The two primary esthetic inlay or onlay restoration indications are as follows: (1) the patient's desire for a nonmetal restoration, making this indication essentially patient driven, and (2) restorative considerations determined by the clinician.

Generally it is believed that a direct resin restoration should be restricted to smaller cavities, defined as those whose cavity width is one third or less of the buccal lingual width of the tooth. Once the cavity exceeds a third of the buccal lingual width, a significant amount of the functional demand is being placed on the restoration, with much less on the tooth. In these cases, indirect composite or ceramic restorations should be considered rather than direct resin restorations. Even using the maximum polymerization energy and time, direct composites that are light polymerized achieve a maximum conversion of about 60%. When the composite is secondarily processed in the laboratory, polymerization can be driven to 95% or higher and the material's physical properties are increased accordingly. Ceramic has much higher compressive strength, flexural strength, and modulus of elasticity than direct composite.

In essence, these restorations are ideal for the moderately broken-down posterior tooth, the type of situation in which the cavity is too large or the tooth is subjected to too much functional demand, contraindicating the placement of an amalgam or direct resin restoration, yet in which the dentist may be uncomfortable preparing the whole tooth for a full-coverage crown. This consideration is becoming increasingly important as patients are educated about the benefits of modern adhesive dentistry, for example, esthetics, conservation of tooth structure, better seal, and tooth reinforcement. When patients understand the reduction of the natural tooth needed for crown restorations, they often prefer esthetic inlay or onlay restorations to preserve remaining healthy tooth structure.

Contraindications

Similar to all adhesive restorations, inlay or onlay restorations are contraindicated when adequate isolation and control of saliva, sulcular fluid, or blood contamination cannot be achieved for the adhesive process. Second molars, when they are the last tooth in the dental arch, can be particularly challenging esthetic inlay or onlay restorations. They frequently have short clinical crowns, can be difficult to isolate, and are subject to higher occlusal forces, particularly in patients who clench or brux. Over-engineering the restoration in these teeth may be a wise approach, meaning onlaying cusps that might not be onlayed on other teeth or proceeding to a full-coverage crown rather than placing a large multicusp onlay. It is the author's opinion that a cast gold inlay or onlay is restoratively preferable to an esthetic one in the second molar location. Fortunately, many patients are okay with the lack of esthetics because of the reduced visibility.

MATERIAL OPTIONS

Commercial and indirect resin ceramic systems are listed in Table 17-1.

Advantages

Some of the laboratory-fabricated resin systems have been in existence for 10 to over 22 years and have proven clinical efficacy. In recent years the physical properties and clinical performance of these materials have improved significantly (see Table 17-1). Although controversy exists as to which material, indirect composite or ceramic, provides the optimum long-term, durable, esthetic restoration, this author believes both indirect resin and ceramics can be used successfully. The final determination should rest with the clinician and be guided by personal preference. Numerous factors contribute to a high-quality restoration, and each must be examined with respect to the material, the fabrication process, and the clinical technique. Clearly, indirect composite materials are being fabricated with enhanced durability, wear resistance, and fit. The ultimate long-term success is a function of the materials used, the technique used by the clinician and the laboratory technician, and the patient's care.

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TABLE 17-1 Commercial and Indirect Resin Ceramic Systems

PRODUCT NAME (PREVIOUS GENERATION)	PRODUCT NAME (CURRENT GENERATION)	MANUFACTURER
Commercial Indirect Resin Systems		
Visio Gem	Sinfony	3M ESPE (St Paul, Minnesota)
Conquest	Sculpture Plus	Pentron Clinical (Wallingford, Connecticut)
Herculite Lab	Premise Indirect†	Kerr Corp. (Orange, California)
Concept*	Adoro‡	Ivoclar (Schaan, Liechtenstein; Amherst, New York)
—	Cristobal+	DENTSPLY International (York, Pennsylvania)
—	Gradia Indirect	GC America (Aslip, Illinois)
—	Tescera ATL	Bisco Inc. (Schaumberg, Illinois)
Commercial Ceramic Systems		
—	Duceram LFC	DENTSPLY International (York, Pennsylvania)
—	Omega 900	Vident (Brea, California)
—	Finesse or Finesse All Ceramic	DENTSPLY International (York, Pennsylvania)
—	Authentic	Jensen Dental (North Haven, Connecticut)
—	OPC	Pentron Clinical (Wallingford, Connecticut)
—	IPS Empress or IPS e.max	Ivoclar Vivadent (Schaan, Liechtenstein; Amherst, New York)

*Concept was known as Isosit SR Inlay/Onlay outside North America.
†Premise Indirect was formerly belleGlass HP.
‡Adoro is available only outside the United States.

In comparison to ceramic materials, inlay or onlay restorations composed of composite resin can generally be fabricated with greater ease in the laboratory. Resins also demonstrate improved wear compatibility against opposing tooth structure and can be repaired more easily intra-orally. For inlays, indirect composite seems to be currently the preferred material. For onlays the marketplace is weighted more toward ceramics than indirect composite but not by much. Numerous clinical trials have shown ceramic inlays or onlays to be viable restorations over time.

TREATMENT PLANNING FOR ESTHETIC INLAYS OR ONLAYS

Options

Figure 17-1 shows a very large amalgam in the first molar replacing a cusp. In the second molar there is an occlusal amalgam. In treatment planning for the second molar, which has some recurrent caries, the amalgam restoration can easily be replaced with a direct composite because of the relatively small size. The first molar has a very large amount of amalgam in need of replacement, so the decision is between going to a full-coverage crown, which would necessitate virtually removing the three remaining cusps, or removing all the old alloy plus any associated disease, leaving the three remaining cusps, and placing a bonded esthetic onlay. The latter is far more conservative because of the tooth reinforcement achieved by bonding to a significant amount of enamel and because the three cusps are preserved. Potentially this tooth may never need to be crowned. The case in Figure 17-2 shows the advantages, both conservative and esthetic, of adhesive onlay restorations.

Figure 17-3 shows four amalgams, two in molars and two in premolars. Those in the premolars would be defined as relatively small restorations. When one also considers the amount of occlusal force premolars are subjected to, these amalgams could be replaced with direct composite resin restorations.

The distal lingual cusp of the first molar is cracked. Because the restoration will be an onlay, and given the heavy functional demand on first molars, this author believes that an onlay is the best restoration, whether it be cast gold, ceramic, or indirect composite. This patient preferred an esthetic restoration, so an indirect composite was used. The width of the cavity in the second molar qualifies it as a small cavity, which might be well served by a direct composite restoration. However, the functional aspects of this particular tooth must also be considered. There is a greater than normal inter-tooth distance between the first and second molars as evidenced by the placement of the amalgam on the distal of the first molar well into the proximal space and the placement of the amalgam in the second molar well into the proximal space so that these two fillings contact. This creates a very large gingival embrasure and a lack of support. Although this is not a particular problem with amalgam, which has great strength to withstand function without tooth support, direct resin has neither the flexural strength nor the fracture toughness to withstand the functional forces in the second molar area when the restoration is virtually cantilevered into the proximal area. Therefore an indirect restoration, such as indirect composite or ceramic inlay, would be preferred over direct composite material, which otherwise might have been considered because of the small size of the cavity.

The ideal option for the second molar is an inlay, but that inlay could have been of cast gold as well as an esthetic material. The patient desired a non-metallic restoration (Figure 17-4).

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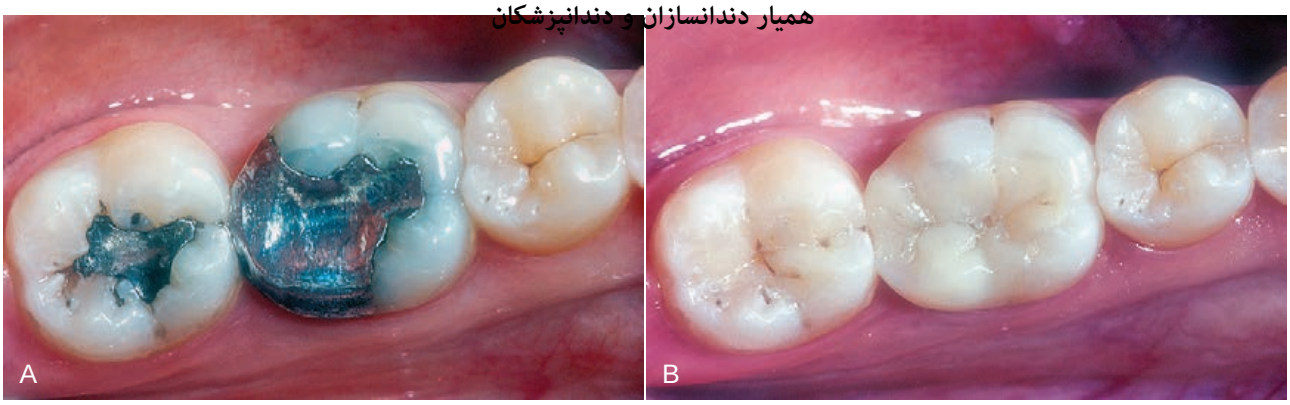


FIGURE 17-1 Case demonstrating the advantages (conservative and esthetic) of adhesive onlay restorations.

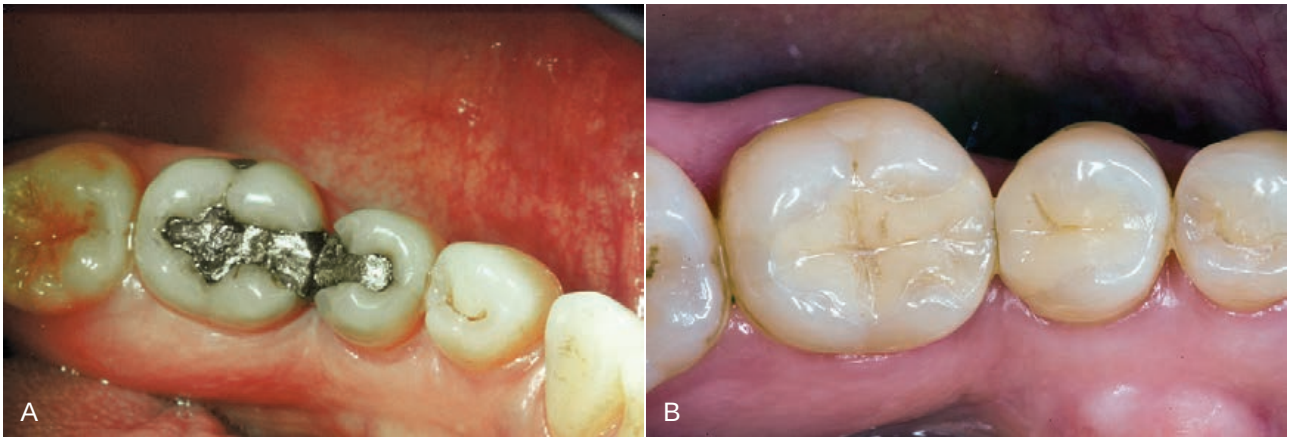


FIGURE 17-2 A, A very large amalgam in the first molar (replacing a cusp) and occlusal amalgam in second molar. B, Amalgam replaced with direct composite (second molar) and bonded esthetic onlay (first molar).



FIGURE 17-3 Four amalgams, two in molars and two in premolars.



FIGURE 17-4 Non-metallic restoration of the case in Figure 17-3.

Sequence

Unless full-mouth reconstruction is planned along with an increase in vertical dimension, esthetic inlay or onlay restorations can be sequenced according to urgency of need. As with all adhesive restorations, if the patient is undergoing bleaching, a minimum of 2 to 3 weeks should pass before one proceeds to restoring the teeth. The timing of inlays and onlays versus other restorative services is determined on a case-by-case basis. Although patients are often eager to proceed with anterior esthetic improvements, they need to understand that restored stability in the posterior is critical to the durability and longevity of any cosmetic anterior service.

CLINICAL PROCEDURES

Preparation

The principles of cavity preparation for esthetic inlays or onlays differ from those for gold restorations. For esthetic inlay or onlay restorations, bevels and retention forms are not needed. Resistance form is generally not necessary but may be required in very large onlay restorations. Cavity walls are flared 5 degrees to

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15 degrees in total (10 degrees to 12 degrees ideal), and the gingival floor can be prepared with a butt joint. The internal line angles are rounded, the minimum isthmus width is 2 mm, and the minimum depth thickness is 1.5 mm (Figure 17-5).

For onlay restorations, nonworking and working cusps are covered with at least 1.5 mm and 2 mm of material, respectively. If the cusp to be onlayed shows in the patient's smile, a more esthetic blended margin is achieved by a further 1- to 2-mm reduction with a 1-mm chamfer (Figure 17-6). The proper cavity form can be prepared using bur kits (e.g., Esthetic Inlay/Onlay, Brasseler USA, Savannah, Georgia).

When the occlusal aspect of the cavity is prepared, undercuts should not be eliminated by removing healthy tooth structure, which compromises the conservatism of this approach. The objective is to establish divergence in the enamel, then block out all undercuts. This is possible using bonded resin or a resin-modified glass ionomer. For cemented castings it is generally best to overlay a working cusp when the cavosurface margin is more than 50% up the incline of the cusp. The cavosurface margin can extend up to 75% up the cuspal incline of a nonworking cusp before overlaying of the cusp is considered. Studies have investigated the use of bonded inlay or onlay restorations for this area, but no clinical consensus on when to remove a cusp has been reached. Because these restorations reinforce the remaining tooth structure, the traditional guidelines for overlaying a cusp as in cast gold onlays have been modified. When there is no dentin support directly underneath the cusp tip, the author routinely onlays the cusp. The palatal or working cusp is onlayed, even with dentin support if the margin is within 1 mm of the cusp tip (Figure 17-7). When the margin is beyond 1 mm from the cusp tip, the cusp gains dentin support and bond strength increases. The horizontal lines depict the direction of the enamel rods. At the cusp tip the enamel rods are almost vertical and etching would be on their sides. As the margin moves away from the cusp tip the ends become etched, which has been shown to increase bond strength (Figure 17-8).

The non-working or buccal cusp is not onlayed in this diagram even when the margin is at the cusp tip. If the posterior teeth are discluded in lateral jaw movements, there are no forces applied to this cusp.

In the author's experience it is not uncommon to find cracks on the pulpal floor under cusps when removing amalgams that have been in place for some time, particularly moderate-sized ones. Whether the teeth exhibit pain on chewing (e.g., cracked tooth syndrome) or are asymptomatic, these cusps should be overlayed.

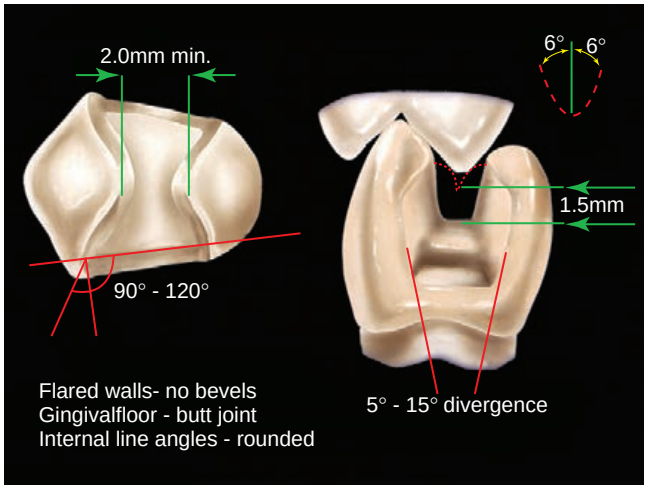


FIGURE 17-5 Preparation for aesthetic inlay. *(Courtesy Montage Media Corporation, Mahwah, New Jersey.)*

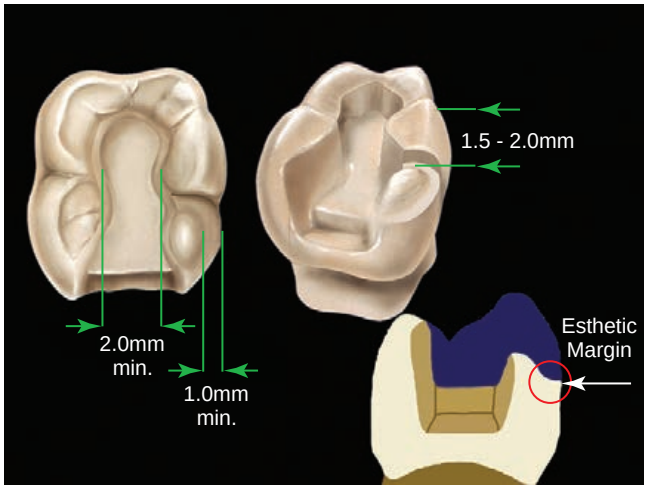


FIGURE 17-6 Preparation for aesthetic onlay. *(Courtesy Montage Media Corporation, Mahwah, New Jersey.)*

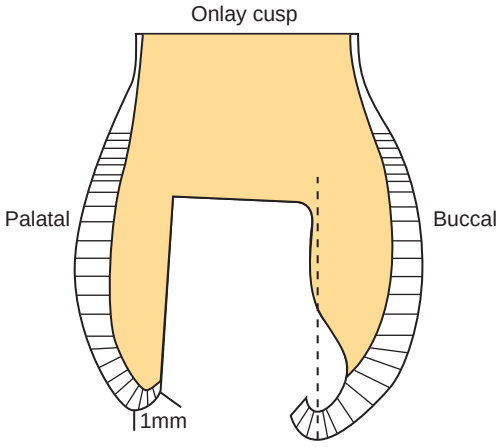


FIGURE 17-7 Onlay cusp.

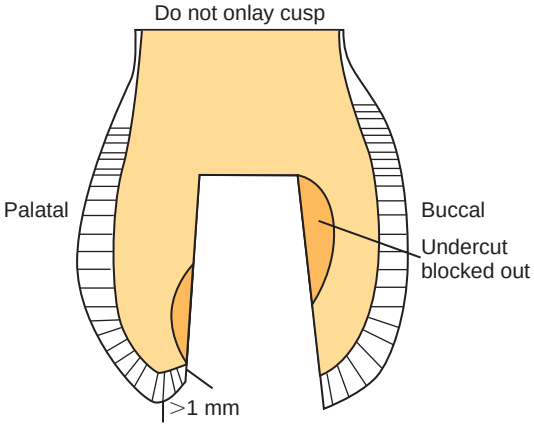


FIGURE 17-8 Do not onlay cusp.

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Logic also dictates that for patients with parafunctional habits (e.g., bruxism or clenching) the cusps should be overlayed more aggressively.

A popular technique to which this author subscribes is called *immediate dentin sealing* (IDS). First described by Paul and Scharer in 1997, this technique has been clinically popularized by Dr Pascal Magne. The technique is based on the logic that the strongest dentin bond is achieved when dentin is bonded immediately after being cut and before becoming contaminated, such as occurs during the provisional phase. Besides the pulpal protection afforded by this procedure, the patient has more comfort while the provisional is in place. Finally, early data show that the ultimate bond of the restoration and the marginal integrity over time are improved. There are different approaches using different adhesives to achieve IDS, but this author prefers placing a self-etching adhesive followed immediately after curing by a very thin layer of very-low-viscosity flowable composite resin. Any undercuts are blocked out simultaneously with the flowable resin. After curing, it is necessary to remove the air-inhibited layer. This can be done by wiping the surface with a cotton pledget soaked in alcohol. An alternative technique is to cover the surface with a glycerin product such as DeOx (Ultradent, Products, Inc., South Jordan, Utah) and light curing again. After washing and drying, the vertical enamel walls are prepared again with a finishing bur to remove any adhesive that may have flowed onto these surfaces.

After preparation, an impression is obtained using an accurate re-pourable material. This is sent to the laboratory with any additional models, records, or information needed to fabricate the restoration. The level of esthetics achieved with this restoration is directly proportional to the level of communication between the clinician and laboratory technician. Consequently, the color prescription must contain the occlusal base shade of the restoration, the gradient of shade from central fossa to cavosurface margin, the degree and color of the desired pit and fissure stains, and any maverick highlights present. For onlay restorations in the esthetic zone, the base shade at the facial margin must be communicated to the laboratory technician via a detailed color prescription or a color photograph that includes a shade tab in the picture. The shade is taken before preparation to avoid the misleading effects produced in a desiccated tooth. Once this diagnostic information has been obtained, a direct provisional restoration (e.g., E-Z Temp Inlay or Onlay [Cosmedent Inc., Chicago, Illinois], Systemp Inlay or Onlay [Ivoclar Vivadent, Amherst, New York]) is placed while the definitive restorations are fabricated in the laboratory.

EVIDENCE-BASED PRINCIPLES

Effectiveness and Potential Longevity

A good deal of science is documented in studies over the past 20 years. Significant evidence details the effectiveness of the enamel bonds in terms of both bond strength and durability. For esthetic inlays or onlays, evidence supports the effectiveness of these enamel bonds with regard to tooth reinforcement. The literature lists tooth reinforcement numbers that indicate that when there are significant enamel bond surfaces, tooth reinforcement is achieved, even up to 70% to 80% of the original strength of the tooth. Clinical evidence also supports the longevity of these restorations. A significant number of patients show longevity greater than 10 years.

Maintenance

There are two aspects to maintenance: normal patient maintenance (brushing, flossing, and routine home care) and reparability of the restoration. Compared with ceramic, indirect composite is more predictable in terms of intra-oral repair. Having a reparable restoration extends its longevity without replacement issues, which almost always involve the removal of extra tooth structure and added tooth trauma.

In repair of an indirect composite resin, first the fractured area—including the enamel and the existing resin composite restoration—is roughened using a diamond bur. Often the restoration is also micro-etched before etching of the cavity and placement of the bonding agent. The missing structure is then built up in direct composite. The restoration is then finished and polished.

NEAR-FUTURE DEVELOPMENTS

The computer-assisted design and computer-assisted manufacturing (CAD-CAM) approach is a valid procedure for fabricating esthetic inlays or onlays. Many of the ceramic inlays or onlays ordered by dentists today are fabricated in the laboratory using milling machines. The two machines available in the marketplace today are the CEREC (Sirona Dental Systems, Charlotte, North Carolina) and the E4D (D4D Technologies, Richardson, Texas). The quality of the restorations that can be fabricated with these milling machines in the dental office today is as good as that of laboratory-fabricated indirect resin or ceramic restorations with respect to fit and function. Both approaches depend on the commitment and skill of the operator. This can be the dentist or a dental auxiliary who actually does the design and operates the milling equipment.

Because this technology has been on the marketplace for a number of years, growing literature documents the efficacy, durability, and longevity of the restorations milled in the office with CEREC machines. This technology has undergone and continues to undergo constant upgrading and improvement. The issue to be considered is the level of esthetics achieved. In most cases restorations fabricated in the laboratory are more esthetic because of the ability to do custom stains and create restorations with dentin opacity and enamel translucency. It would take increased effort in the office to do this. Some dentists fabricate the restorations on their milling machines and then stain and glaze them in porcelain ovens to create a higher level of esthetics. However, many dentists who use these machines in their offices find monochromatic esthetics more than adequate for most patients. The final considerations are (1) cost—at the present time these machines require a significant expenditure, especially in initial costs—and (2) integration of the technology seamlessly and smoothly into the practice so that it enhances production rather than delays or complicates it. It is the author's opinion that the final decision as to whether or not to use technology is not a clinical decision but a business one.

Text continued on p. 480

CASE 1

A 30-year-old man had a large failing mesial occlusal lingual amalgam in his lower right first molar (Figure 17-9, *A*). He stated that it had been sensitive to cold for some time. On examination, marginal breakdown and recurrent decay were evident. All other teeth in the quadrant were virgin, and the patient requested a tooth colored restoration. A direct composite resin was considered but rejected owing to the large cavity size and the high function of a first molar. An esthetic full-coverage crown was rejected as being too aggressive, especially in light of the patient's youth. A more conservative esthetic indirect composite onlay was prescribed (Figure 17-9, *B* to *N*).

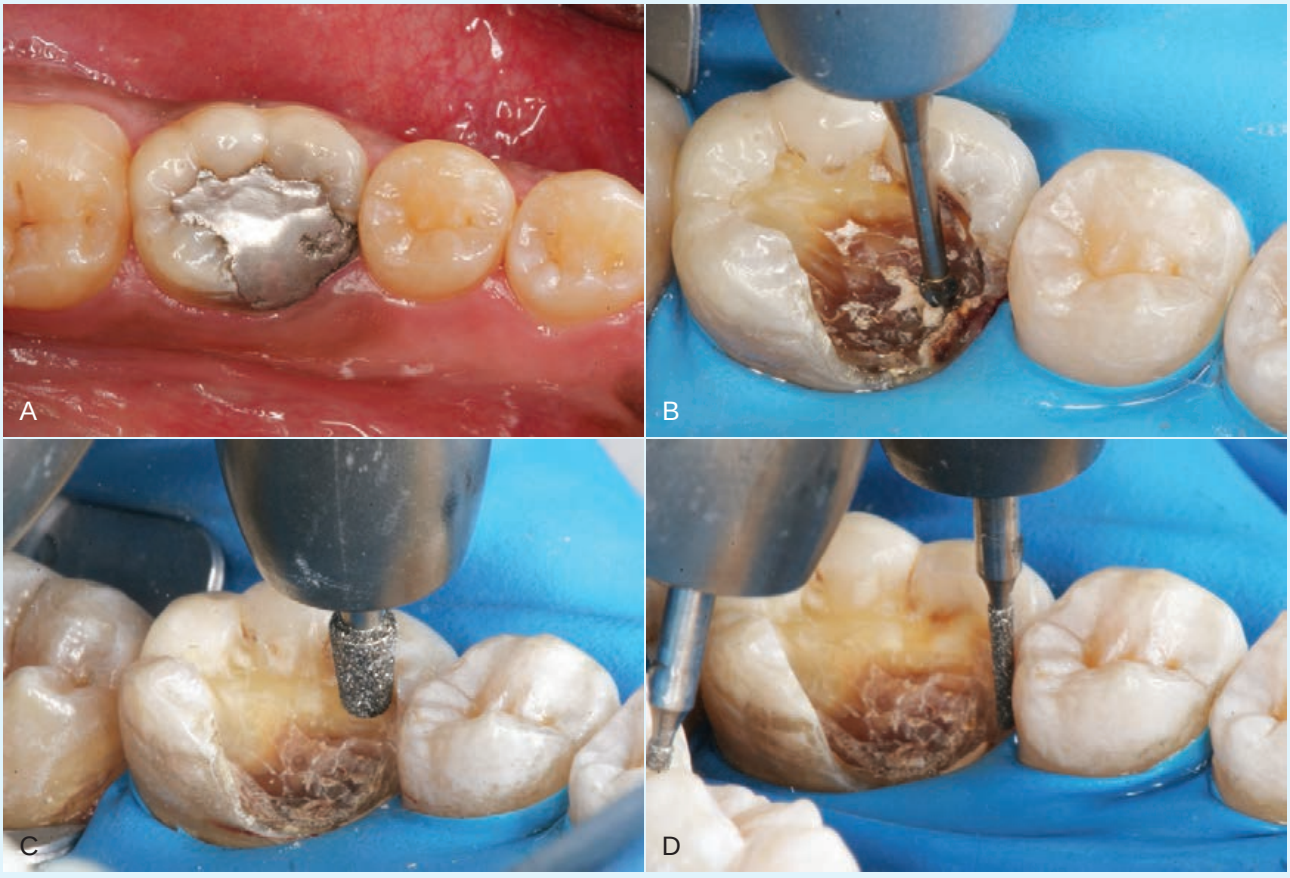


FIGURE 17-9 **A,** Lower first molar with an mesial occlusal lingual amalgam filling that exhibits broken-down margins and recurrent decay. **B,** The first step is to remove the alloy that's present without removing any tooth tissue. The second step is to remove all caries, and cement bases, or liners present, generally with a slow speed round bur. **C,** The next step in the preparation sequence is to prepare the occlusal portion of the cavity. This is done using a bucket-shaped diamond bur with a taper of about 6 degrees, giving a divergence on the occlusal surface buccal lingual aspect of about 12 degrees. The bur has a rounded shoulder so that internal angles will be rounded. Where there are undercuts, the only portion of the bur doing any work is the part that is against the enamel walls. The objective is to create a divergence of the enamel walls. Any undercuts will be blocked out, not removed by removing sound healthy tooth structures. Where there are no undercuts the bur will work along its entire length, creating from the pulpal floor up to the cavosurface margin a divergence of 6 degrees. After the preparation of the occlusal portion of the tooth, the proximal walls of the preparation are then refined. **D,** Proximal portion is prepared using a tapered diamond bur of the appropriate size—small or large—based on tightness of the preparation, closeness of the adjacent tooth, and so on. Once again, a tapered bur with a rounded shoulder end is used. The enamel walls are prepared to a divergence of about 6 degrees.

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CASE 1 (CONT'D)

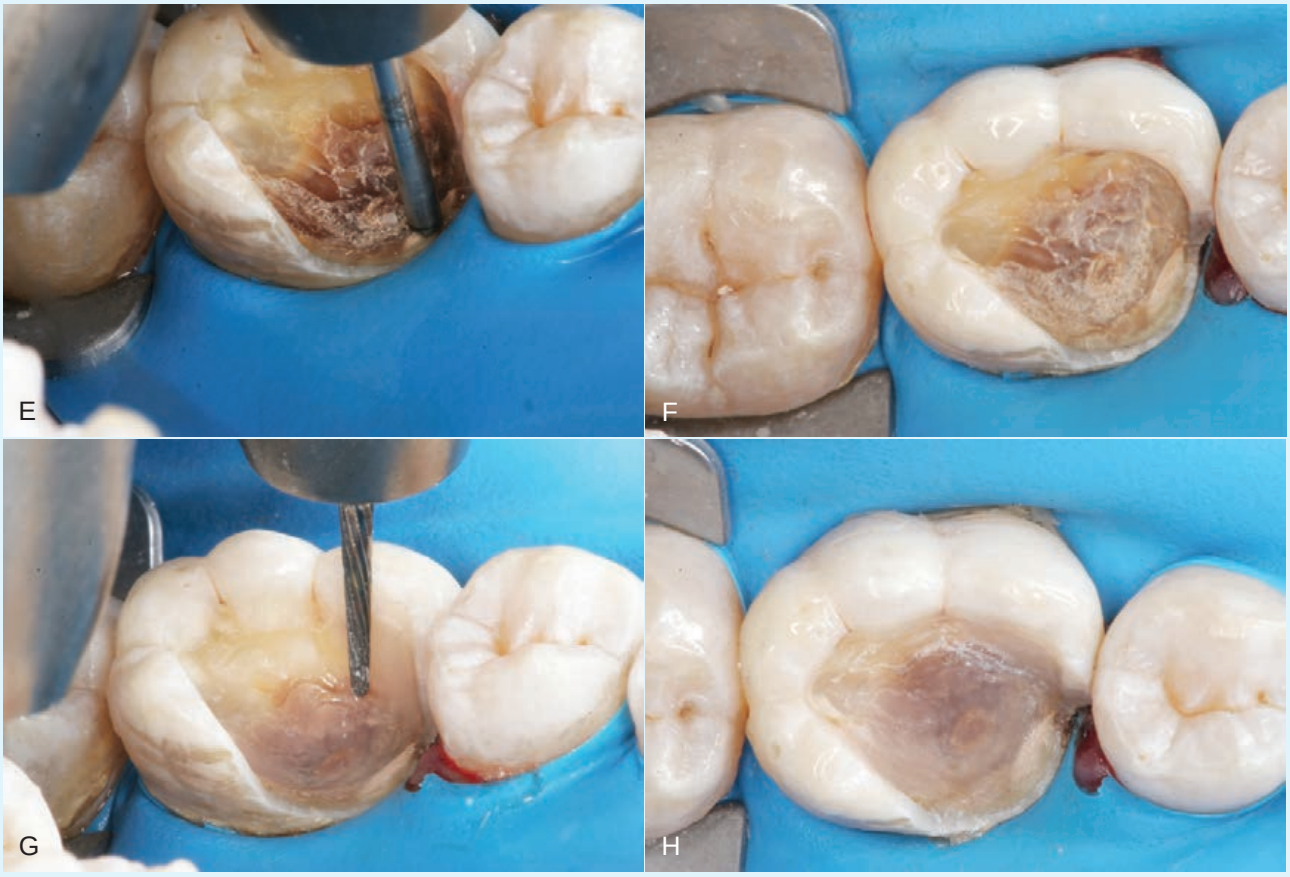


FIGURE 17-9, cont'd **E,** To prepare the gingival margin, an end-cutting diamond bur is used to create a butt joint. **F,** All caries and cement bases have been removed. Enamel walls and gingival margin are prepared. The dentin is now sealed with an adhesive. This concept is called *immediate dentin sealing* (IDS) or sometimes *resin coating*. The materials used reflect the dentist's choice. This author prefers to use a two-step self-etch adhesive, but practically any adhesive could be used. CLEARFIL SE BOND (Kuraray, America, Inc., New York), CLEARFIL PROTECT BOND (Kuraray), All-Bond SE (Bisco), and AdheSE (Ivoclar, Vivadent Amherst, New York) are examples. After the adhesive has been cured, a thin layer of flowable composite is applied in a layer 0.5 mm or less over the entire pulpal floor. The flowable composite is also used to fill in the undercuts. The air-inhibited layer is removed either by using a cotton pledget dipped in alcohol or by covering the flowable composite with glycerin and light curing again. **G,** A carbide finishing bur is used to remove any adhesive that inadvertently is placed on the enamel. Primarily, the concern is the occlusal enamel walls and occlusal portion of the proximal enamel walls. The gingival margins, whether they have enamel or not, are not refinished. The adhesive and flowable composite are carried out to the external margin in this location. **H,** With the preparation complete, the dentist removes the rubber dam and takes the impression using his or her preferred impression material and technique. Various temporary techniques can be used, including a direct light-cure temporary restoration. To prevent the material from bonding to the cured flowable liner of the preparation, a lubricant such as PRO-V COAT (Bisco) must be placed before a light-cured temporary restoration. Among direct light-cured temporary materials are E-Z Temp from Cosmedent and Systemp Inlay or Onlay from Ivoclar Vivadent. For very large onlays, when multiple cusps are missing, the dentist may want to use an indirect bis-acryl temporary material, routinely used for temporary crowns.

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CASE 1 (CONT'D)



FIGURE 17-9, cont'd **I,** The patient returns to the office to have the restoration placed. Often, because the IDS seals and protects the dentin, no anesthesia is needed. The removal of the directly placed temporary restoration is quite simple. A spoon excavator or scaler is used. Both E-Z Temp and the Systemp Inlay or Onlay direct temporaries are flexible. After removal of the temporary restoration, a rubber dam is placed and a wax floss ligature is tied around the tooth to secure the rubber dam subgingivally. The tooth is then cleaned with flour of pumice and water; the author prefers Consepsis Scrub and the ICB brush by Ultradent in a slow-speed handpiece. **J,** The restoration is tried in place. The assistant holds the restoration with an instrument while the dentist checks the contact with floss and observes for fit, correct seating, and closure of all margins. Once the contact and good fit have been achieved, the restoration is set aside while the tooth is treated. **K,** A matrix band is placed around the tooth to confine the phosphoric acid etchant to the tooth being restored. The band avoids risking etching of the adjacent tooth or having etchant flow subgingivally. At the time of this writing, phosphoric acid–etched enamel is regarded as the standard, so the author prefers an etch-and-rinse adhesive. The enamel is etched first with 30% to 40% phosphoric acid; etching extends beyond the margin on the occlusal surface, then is carried to the gingival area. The tooth is completely filled with etchant, left for 12 to 15 seconds, then washed thoroughly with water. The dentin is then blotted with a cotton pellet or Microbrushes to a slightly dull finish but not desiccated. Technically, because the dentin was sealed during the preparation, moist bonding to dentin should not be an issue. However, this careful dentin-etch procedure is used because, in the final finishing of the enamel walls at the preparation appointment, some of the dentin might have been exposed again. The three-step or two-step adhesive is applied according to the manufacturer's directions and cured. The internal surface of the restoration is sandblasted with either 50-µm aluminum oxide particles or CoJet sand (3M ESPE St. Paul, Minnesota). A handle is attached to the inlay to aid in treating and placing the restoration. These handles come in the form of a Pic-n-Stic by Pulpdent Corporation (Watertown, Massachusetts), OptraStick by Ivoclar Vivadent; or True-Grip by Clinician's Choice (New Milford, Connecticut). If the restoration is made out of indirect composite, phosphoric acid is applied to the internal surface to acidify the internal surface, then immediately washed off and the surface dried. Silane (various manufacturers) is applied and allowed to sit for 15 to 20 seconds and then air dried, preferably with warm air. If the restoration is made of pressed ceramic such as Empress, e.max Press, or e.max CAD (Ivoclar Vivadent), the internal surface of the restoration is etched with a 5% hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar). This is applied for 1 minute (Empress) or 20 seconds (e.max Press or e.max CAD), washed thoroughly, and dried. After drying, a silane of choice is applied, allowed to dry for 20 seconds, and then dried, preferably with warm air. For indirect composite and ceramic restorations thicker than 2 mm, a dual-cured luting resin is recommended, such as NX3 (Kerr, Corporation), Variolink II (Ivoclar Vivadent), Calibra (DENTSPLY), or DUO-LINK (Bisco). **L,** The cement is mixed, base and catalyst, one to one, and applied to the internal surface of the restoration. Only if all undercuts have not been blocked out would it be necessary to apply cement to the tooth.

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FIGURE 17-9, cont'd **M,** The band is removed from the tooth, and the restoration is seated. The assistant uses a ball burnisher or a plastic instrument to hold the restoration in place. Two cleaning methods can be used at this point. The dentist can either not cure the cement first or lightly cure the luting resin (flash cure). If not flash curing, the dentist cleans the excess cement from the occlusal and proximal with a rubber-tipped instrument or a plastic instrument, not a brush. Often an explorer is used for the interproximal area. The last cleaning step is to sweep floss down the proximal contact one time to clean the gingival margin. Light curing takes place with the floss left in place. The alternative technique—a flash cure—quick cures the occlusal and proximal surfaces. The dentist now peels or chips away the excess luting resin. This author prefers to do the former because it ensures bonded excess luting resin on the occlusal surface of the tooth, which helps protect the margins. After complete curing of the dual-cure cement with appropriate-intensity light, any excess luting resin can be removed with a No. 12 blade from the proximal and accessible surfaces. Interproximal surfaces sometimes require the use of either a scaler or an esthetic trimming knife—for example, CR21 Esthetic Carving Knife from Hu-Friedy (Chicago, Illinois). The rubber dam is removed and the occlusion checked and adjusted if necessary. If the restoration is indirect composite and has been adjusted, appropriate composite finishers and polishers are used to refinish and polish adjusted areas. If the restoration is ceramic, appropriate finishers and polishers are used. **N,** Two-year postoperative view of a Premise Indirect composite resin onlay.

CASE 2

A 48-year-old man had a heavily worn and fractured silver cermet filling in the second molar and a fractured distal marginal ridge with evidence of decay in the first molar (Figure 17-10, *A*). The first molar was asymptomatic, but there was pain on chewing on the second molar. The distal buccal cusp tested positive for a crack (Figure 17-10, *B* and *C*). Onlays were recommended for both teeth. The patient chose tooth colored material over gold (Figure 17-10, *D* and *E*).

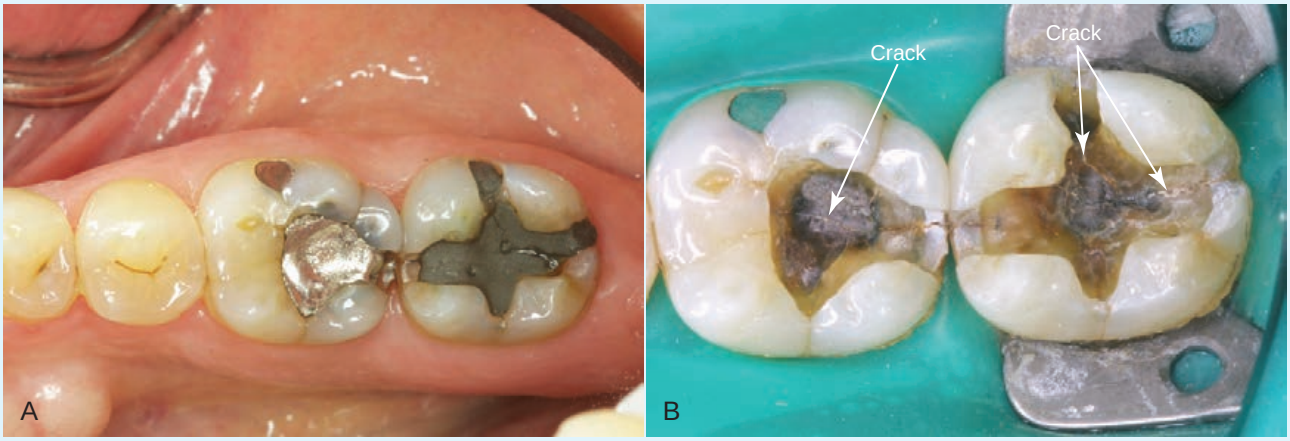


FIGURE 17-10 **A,** Two lower molars have broken-down restorations, evidence of fractured enamel, and recurrent decay. **B,** The existing fillings and caries are removed. Observing the preparation floor in the second molar, one can see a crack that starts at the distal, passes along the pulpal floor, extends under the distal buccal cusp, and exits out the buccal groove. Cracks in teeth are not uncommon in large non-supporting fillings, particularly in molar teeth. If a crack exists, symptomatic or asymptomatic, the cusp must be onlayed, so the distal buccal cusp of the second molar will be onlayed. The first molar was asymptomatic but had a crack in the pulpal floor that extends mesially, just slightly over halfway from distal to medial, and stops. With this type of horizontal crack in the floor of preparation, both cusps on the buccal and lingual are onlayed.

CASE 2 (CONT'D)



FIGURE 17-10, cont'd C, Different angle on the first molar. One can see the lack of dentin support under those buccal cusps. Even if no crack had been found, the distal buccal cusps would be onlayed because of the lack of dentin support directly under the cusp tip. D, Preparation completed. This case, done before the concept of the immediate dentin seal had been introduced, had only the undercuts blocked out with resin modified glass ionomer. The dentin was not sealed using an adhesive. E, "After" photo shows both onlays in place 1 year postoperatively. These restorations are indirect composite (Tescera ATL from Bisco). The tissue reaction is excellent, and esthetics are good. Function has been restored, and there has been no further crack progression to the point of pain or pulpitis. The erosion lesion seen on the mesial buccal (occlusal) cusp tip of the first molar was not included in the preparation outline. Instead, at onlay placement the enamel and dentin were roughened, etched, and bonded and direct composite placed.

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CASE 3

A 46-year-old man had the mesio-buccal cusp of his upper first molar fractured off (Figure 17-11, *A*). No caries was evident, and the disto-buccal cusp had been previously onlayed with amalgam. Because it makes no sense to remove two good cusps in order to replace two missing cusps, an onlay was prescribed instead of a crown (Figure 17-11, *B*).

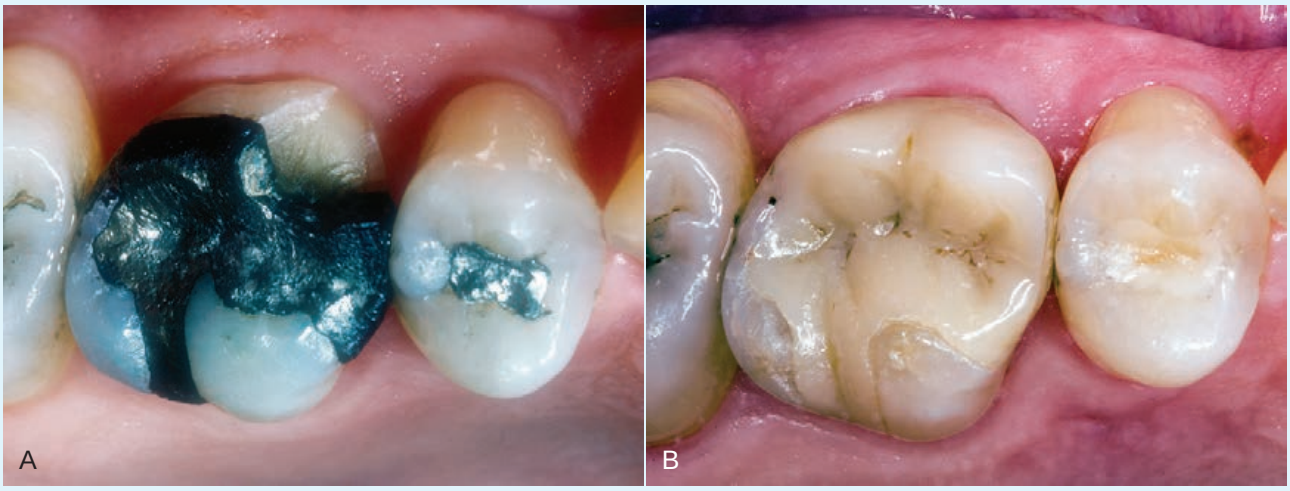


FIGURE 17-11 A, Fractured cusp in a molar with a large filling. B, Large onlay in the molar after 16½ years. Indirect composite (Concept or Isosit SR Inlay or Onlay – Ivoclar Vivadent). The patient is now 63 years old and the tooth has yet to (and may never) proceed to needing a crown.

CONCLUSION

Advances in tooth-colored materials and adhesive technology have expanded the scope of restorative dentistry. Fortunately, this progress has come at exactly the right time. Patients today want their dentistry to be more esthetic and less invasive. Also, today's patients are living longer, keeping their teeth, and placing higher value on oral health. Although dentists learn to apply inlays and onlays in dental school, it has been stated that many, if not most, do not do these restorations after entering practice. Consequently, either large non–tooth-supporting amalgams that are difficult to properly contour or crowns, which are significantly more invasive, are placed. Because they seal teeth and reinforce remaining tooth structure, esthetic inlays and onlays are considered by many teaching clinicians as ideal for the moderately broken-down tooth. These restorations may even delay or prevent the progression of medium to large cavities, previously restored with amalgam, that have already been restored with amalgam from progressing to the point at which they would require a full-coverage crown. At the very least, their conservative nature, when compared with the preparation for full-coverage crowns, "banks" the tooth structure for future use. These benefits, combined with the durability and esthetics of the indirect composite or ceramic inlay or onlay restoration, are very important to patients and should continue to direct the nature of restorative dentistry.

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Esthetic Posts

George Freedman

The increasing predictability and popularity of endodontic procedures, attributable in no small measure to the decreased discomfort associated with the process, have encouraged patients to treat and maintain their dentitions for their entire lifetimes. Largely responsible is a very successful long-term public education process by the dental profession. Increased endodontic coverage by insurance carriers also motivates more patients to choose restoration rather than extraction. In today's information-based society, patients are more aware of dental treatment options and more actively involved in co-diagnosis and co–treatment planning. Their concerns include the biocompatibility of the post-endodontic restorative materials (posts, cores, and cements), the invasiveness of the restorative procedure, and, most important, the overall functional and esthetic result.

RELEVANCE TO ESTHETIC DENTISTRY

Dental professionals' experience over the past half-century has confirmed that most, if not all, endodontically treated teeth require a comprehensive restoration such as a full crown or onlay to restore the tooth structure destroyed by decay, fracture, or endodontic access. The clinical aspects of the restoration, given the variety of post and core materials along with the remaining tooth structure, can be a challenge. Endodontically treated teeth seen in a dental practice have lost appreciable amounts of coronal tooth structure to caries and/or the access preparation. The objective of the post and core buildup is primarily to replace the missing coronal tooth structure which will provide retention and resistance for the crown that will ultimately restore the tooth's function and esthetics. Although some controversy surrounds the absolute need for post and core treatments, the issue can be reduced to mechanical terms. When much of the coronal tooth structure remains, a post may be indicated but not required. When the remaining root exhibits little or no remaining coronal tooth structure, the foundation provided by the post and core buildup is an absolute precondition for crown preparation. The post anchors the restoration to the remaining radicular dentin without necessarily strengthening the root.

The prognosis is often directly proportional to the bulk of the remaining dentin: the greater the remaining dentin thickness, the greater the fracture resistance. Posts are selected to provide maximal retention for the overlying restoration while minimally invading remaining dentinal tissue. Adhesively bonded posts increase the retention of the post and core system and improve the restored tooth's prognosis. Bonded non-metallic posts also tend to distribute functional stresses over larger internal radicular surfaces, decreasing the force per area of root and thus the possibility of root fracture. The core platform is the accessible and visible supragingival extension of the post that supports the crown. Because the core is the physical link between the remaining subgingival dentin and the overlying crown, its shape and position are critical in managing the direction and magnitude of forces transferred to the remaining tooth. The core material may be exposed through partially translucent or ceramic crowns, and thus the ideal core coloration is the dentinal shade.

The post-endodontic complex forms a monobloc which comprises the multi-layered tooth-to-restoration structure with no inherently weak interlayer interfaces. Sequential bonding of the dentin to the post resin cement, to the post, to the core, to the crown resin cement, and to the crown is critical. The adhesive strength at each interface must be greater than the bond of the natural tooth to itself. Successful treatment offers strength and resistance to the post-endodontic continuum from the residual dentin to the final restoration that approach the strength and resistance of the original non-decayed tooth.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF POSTS AND CORES

Post and core materials are divided into three separate classes: post material, core material, and cement. The criteria that dental professionals must use for determining which materials to use are based mostly on scientific data, the dentist's clinical experience, and, to a lesser extent, patient preference. The first two would seem to be self-evident. The material must work in the realm of scientific predictability and it must be successful clinically in terms of time spent, results achieved, and comfort of both patient and practitioner. Patient preference is largely a matter of esthetics. As more and more all-ceramic restorations find their way into dental treatment, the nature of the

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sub-structure that supports the crown is increasingly relevant to the ultimate esthetics of the final restoration. If metal shows through a tooth-colored ceramic and creates a shadow on the surface of the restored tooth, the esthetics of the restoration will not be acceptable. Therefore, of all the criteria for post and core treatment, esthetics is among the most important.

Dental posts first began as gold pins inserted into teeth, possibly at considerable pain to the patients. They were used about 2500 years ago in the Etruscan lands of ancient Italy. These retentive pins were inserted into the radicular canals, which were probably untreated, and anchored carved ivory chunks to restore the patient's function and appearance. Over the past 150 years or so, cast gold has played a significant role in restoring endodontically treated teeth. Gold posts were cast using a lost wax process and fit the post space more or less accurately. About 30 years ago, the prefabricated stainless steel post was introduced. It was stronger and easier to fit, in some respects, than gold. The titanium post, manufactured from an even stronger material, was next to be used in dentistry. Subsequently, the carbon fiber post was introduced, noted less for its strength than its ability to be slightly bendable. However, carbon fibers have the black coloring of carbon and were not esthetically acceptable. They were relatively quickly replaced by various glass and fiber rod posts. Core materials have also progressed from gold to amalgam to glass ionomer, and finally to composite resin materials. Cements began with zinc phosphate materials, and have been relatively unchanged until recently, when composite resin cements became available.

RELATING FUNCTION AND ESTHETICS OF POSTS

Typically, the post becomes virtually invisible when it is covered by a porcelain-fused-to-metal crown. Areas that may pose a visible liability include around the gingival margin where a shine-through of the metal—gold, stainless steel, or titanium—through thin dentinal root walls and thin gingival attached tissue covering the bone on the buccal of anteriors, can give the entire tooth a grayish appearance. This is particularly problematic when patients have high lip lines and tend to smile a lot.

An esthetic post should assume the same coloration as the underlying dentin, ideally becoming indistinguishable. Thus, whether working with a porcelain-fused-to-metal or a ceramic crown, there is no shine-through. The only shade that is actually visible is of the same hue as the dentin and blends into the tooth structure. A slight discrepancy is easy to cover up with current ceramic restoration technologies. It is also very important to use a cement that is either dentin colored or preferably translucent when developing the esthetics of the post and core. Translucent cement materials allow the underlying tooth coloration to shine through and to blend with the ceramic margin. Tinted cements often create the potential for an additional color mismatch that further complicates the marginal esthetics of the restoration.

The function of the post and core as the intermediate restoration between the remaining root and the crown depends on a strong adhesion among the various restored components. The dentin adheres to the cement, the cement adheres to the post, the post adheres to the core, and the core adheres to the crown. All adhesive strengths exceed the natural adhesive strength of the tooth to itself. With an adhesively retained post and core, and subsequently an adhesively retained crown, the tooth can actually be as strong as the natural dentition prior to any decay. Earlier cements such as zinc phosphate and polycarboxylate provided no bonding strength to any of the substrates to which they attached—enamel, dentin, metal, or ceramic. Resin cements attach adhesively to all of these materials effectively.

CLINICAL CONSIDERATIONS

Indications

Esthetic posts are clinically similar to and generally more conservative of tooth structure than other prefabricated posts. They can be used for virtually any post-endodontic situation. They are more conservative and easier to place than cast metal restorations and typically require one chairside appointment versus a minimum of two sessions for indirect procedures.

Esthetic posts are made of materials that are chemically inert, eliminating any hazard associated with sensitization or allergy in the patient.

Contraindications

There are no known contraindications to the placement of esthetic posts when a post (of any type) is clinically indicated.

MATERIAL OPTIONS

Posts

There are many posts available to the dental practitioner, as well as many core materials and cements. The best way to evaluate the most suitable material in each category is to review the scientific data, check the research support, and evaluate the materials. The dentist's clinical experience, including ease of clinical use, predictability, and ease of placement, are significant factors as well. The patient, of course, expects and should be receiving a long-lasting solution for their post-endodontic condition that is essentially better, faster, and easier than the other procedures available.

Of the available **post materials**, the most common are the cast metal, the prefabricated metal, and the resin fiber posts.

Cast metal posts (Box 18-1), whether in gold or base metal, have certain advantages. They are laboratory fabricated, eliminating chairside technique sensitivity. Cast as metal objects, they have great transverse strength and are very unlikely to break. The negatives of cast metal posts include difficulty taking impressions; it is hard to place hydrophobic impression materials into the narrow confines of the post-endodontic canal and to ensure the

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BOX 18.1 Pros and Cons of Cast Metal Post

Pros
- Lab fabricated
- Great transverse strength
- Long history

Cons
- Difficult impression
- Difficult fit
- High cost
- Does not bond

BOX 18.2 Pros and Cons of Prefab Metal Post

Pros
- Chairside
- Good transverse strength
- Lasts 20+ years

Cons
- Poor adaptation
- Does not bond
- Poor esthetics

absence of air or water bubbles. The pour of the impression at the dental laboratory is perhaps even more difficult; it is virtually impossible to orient the direction of the post precisely when pouring the stone impression, so the angulation of the post with respect to the tooth and/or core is often slightly off the mark. This minute discrepancy can very easily compromise the fit of the entire post and core complex.

Most dentists will identify with the difficulty of seating the cast metal post and core into the residual root. In fact, adjustments are often needed either on the restorative material or on the remaining tooth structure in order to actually develop an acceptable fit. However, the great advantage of the cast metal post is its supposedly tight fit into the remaining canal system. Therefore, in modifying this tight fit in order to be able to seat the restoration, the major advantage of the cast metal post is eliminated. The increased cost of the cast metal post arises from the expenses of the technician's work and transportation to and from the laboratory. If gold or similar precious metals are used, the cost to the dentist and patient can be even higher. The greatest problem of cast metal posts is that they are typically manufactured of noble or non-reactive materials and thus do not bond to the tooth structure—either enamel or dentin. Furthermore, these materials do not bond to the overlying crown through the cement. All the interfaces in the cast metal post system are luting interfaces which provide a filling of the space between materials, but no adhesion.

Prefabricated metal posts (Box 18-2) have the advantage of being inserted chairside, thus eliminating the need for a second appointment and incremental laboratory and transportation costs for the practitioner. The metal itself has good transverse strength. Unless the prefabricated metal post is abused during or after insertion, it is unlikely to break or bend during clinical use. More than 30 years of clinical experience with these materials have generally been very positive.

The negative aspect is that the post hole must be made to fit the shape of the post. Because this fit is an approximation at best, the adaptation between the remaining tooth structure and the post itself is not precise. The intervening space is ultimately filled by cement, typically less strong than the post. The prefabricated metal does not bond to either the underlying tooth structure or the overlying core or crown. Prefabricated metal posts tend to have the same poor esthetics as cast metal posts. They cast a gray shadow through esthetic restorations if there is not enough masking material in the core cement or the ceramic to overcome this esthetic liability.

BOX 18.3 Pros and Cons of Resin Fiber Post

Pros
- Chairside, bonds
- Excellent transverse strength
- Shock absorber
- Esthetics

Cons
- New technique
- Poor esthetics (some)

Data from Mannocci F, Ferrari M, Watson TF: Intermittent loading of teeth restored using quartz fiber, carbon-quartz fiber, and zirconium dioxide ceramic root canal posts, *J Adhes Dent* 1:153-158, 1999.

Resin fiber posts (Box 18-3) were introduced to the dental profession in the early 1990s. The advantages of these posts include the fact that they are placed chairside in a single appointment and they bond to the underlying tooth structure whether enamel or dentin, to the overlying core, and subsequently to the overlying crown if suitable resin cements and techniques are used. They have excellent transverse strength; they are composed of many fibers that are bundled together with BIS-GMA, the basic component of composite dentistry. The fibers tend to bend under load rather than break. As they bend, they also act as shock absorbers. This means that as forces are placed on the crowned tooth, the underlying post can actually absorb most of the shock rather than transmitting it to the remaining tooth structure. Resin fiber posts are available in a variety of colors. The earliest ones were black (carbon fiber), very well researched, and highly regarded by the profession but posed an esthetic liability in visible anterior areas. The more recent ones are tooth colored, white, or translucent, making them much more adaptable to an esthetic objective.

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Researchers have indicated that carbon fiber posts and glass fiber posts with composite resin cores are less likely to cause root fractures than stainless steel posts with composite resin cores.

Cores

Over the years, a number of **core materials** (Box 18-4) have been used to fabricate post and core restorations. They include cast metal, amalgam, glass ionomer, cermet, and composite resin.

The advantages of the **cast metal core** (Box 18-5) are that it is laboratory fabricated and involves little chairside work for the dentist. The thickness of the core provides great transverse strength to this part of the restoration. It is extremely unlikely to ever fracture. The cast metal post and core are actually cast as a single unit, together providing a very strong substructure for restorations. The major disadvantage of the cast metal core is its esthetic appearance under ceramic crowns. The bright yellow of the gold metal core or the darkness of the base metal shine through ceramic restorations and making esthetic results rather difficult. The color is quite intense and the porcelain thickness is limited. Masking cements are difficult to use when the discoloration is intense, so acceptable esthetics are unlikely if a ceramic restoration is placed over a cast metal core. Because cast metal cores are laboratory fabricated and require two appointments, their cost is higher, particularly when gold is used. The cast metal also does not bond either to the underlying tooth structure or to the overlying crown. The luting cement will provide stability but no chemical or mechanical adhesion.

The **amalgam core** (Box 18-6) is inexpensive, very easy to place (most dentists are familiar with its use), and has good adaptation to the internal anatomy of the pulp chamber. However, amalgam forms no chemical bond to the tooth structure even when "amalgam bonding" materials are used. It has a very poor transverse strength; any significant horizontal pressure or force on the amalgam core is likely to fracture it. Its dark coloration also offers very poor esthetics. The dark gray of the amalgam (which turns black when it is corroded by time and saliva) definitely shows through ceramic crowns or at the margins of overlying restorations. The other disadvantage of amalgam is that it tends to leech into the surrounding dentinal and soft tissues, creating amalgam tattoos. Even when it is not directly visible to the viewer, its effects can be seen as a gray silver pallor of the soft or hard tissues.

Glass ionomer cores (Box 18-7) were proposed in the mid-1980s because they release fluoride, and this was viewed as a distinct advantage. Although there is no doubt that glass ionomers *do* release fluoride, the amount of fluoride absorption by the remaining tooth structure is debatable. There is little evidence to indicate that the remaining non-vital tooth structure actually absorbs fluoride from an adjacent polymerized restorative material. Glass ionomer also has a weak bond to the tooth structure, about 6 to 10 MPa. This is considered a strength by some, but a weakness by most clinicians. Glass ionomer cores have poor compressive strength and tend to fail.

Cermets are glass ionomer materials that have metal filings added to their chemistry. These materials are supposed to be somewhat stronger than traditional glass ionomers. In fact, they have stronger compressive strength but tend to be even weaker overall than glass ionomers. They also have the esthetic liability of amalgam-like coloration.

Composite cores (Box 18-8) are very strong. They are made of the same restorative materials that were developed mid-century and have been used clinically since the 1970s. They form a strong bond to tooth structures, both enamel and dentin, as well as to all the dental cements in use today. The composite cores are bondable to the ceramics and metals of overlying crowns. They are placed onto the tooth in a flowable state and thus have an excellent adaptation to the anatomy of the chamber, the canal, and underneath the crown, as they create a monobloc.

BOX 18.4 Types of Core Materials

- Cast metal
- Amalgam
- Glass ionomer or cermet
- Composite resin

BOX 18.5 Pros and Cons of Cast Metal Core

Pros
- Lab fabricated
- Great transverse strength
- Long history

Cons
- Esthetics under ceramic crowns
- Cost
- Does not bond

BOX 18.6 Pros and Cons of Amalgam Core

Pros
- Inexpensive
- Easy
- Good adaptation

Cons
- No chemical bond
- Poor transverse strength
- Poor esthetics

BOX 18.7 Disadvantages of Glass Ionomer Core

- Poor compressive strength
- Weak bond
- Tends to fail

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BOX 18.8 Pros and Cons of Composite Core

Pros
- Strong bond to tooth, porcelain
- Excellent adaptation
- Creates monobloc

Con
- Change in clinical technique

BOX 18.9 Pros and Cons of Compomer Cement

Pros
- Releases fluoride
- Very high bond strength

Con
- May fracture overlying ceramic restorations

BOX 18.10 Pros and Cons of Resin Cement

Pros
- High bond strength to tooth, metal, ceramic
- Easy and predictable

Con
- New techniques

Cements

A number of materials are available for cementing posts into the radicular tooth structure. These include zinc phosphate and polycarboxylate luting materials, glass ionomer, compomer, and composite cements, some requiring a distinct etching step while others do not, as they are self-etching.

Clinically, it must be questioned whether cements are really necessary as a *separate step*? After all, there is little difference between adhesive resin cement and core buildup materials. They are typically quite similar in terms of chemistry, characteristics, and application mode. The major difference is that the core material is somewhat more filled. If, however, a suitable compromise can be found between the core material and the resin cement, it makes sense that the same material can be used for both applications. In fact, this has been common practice since the late 1990s. Using the same material for cementation and core buildup eliminates the waiting time for the polymerization of the cement inside the post space—a chairside gain of 7 to 10 minutes.

Zinc phosphate cements have a long history in dentistry. They are effective luting materials but do not adhere to enamel, dentin, metal, or ceramic and therefore provide no incremental strength to the restoration. With respect to the overall scheme of the monobloc, they provide an interface that offers absolutely no adhesion of the component materials. They are highly irritating to vital tooth structures due to their application acidity (pH ~2.0) and their long term acidity once set (pH ~4.5-5.0).

Polycarboxylate cements have been available since the 1970s. They were widely used because they exhibited lower postoperative sensitivity. Their lower acidity is less irritating to tissues. In the post-endodontic situation, this is not an important consideration because the removal of the nerve means that there is no sensitivity possible in the tooth. Polycarboxylate, like zinc phosphate, does not bond to enamel, dentin, metal, or ceramic. In fact, it is not as strong as zinc phosphate and therefore has even less application in the post cementation field at the present time.

Glass ionomer cements have the inherent advantage of releasing fluorides. However, they provide a weak bond to the tooth and are slowly soluble in oral fluids. As previously mentioned, there is no evidence that the fluoride released by the adjacent glass ionomer is actually picked up by the remaining dentinal tissues. Although the fluoride can act as a local antibacterial, it has little, if any strengthening effect on surrounding dentinal tissue. Glass ionomer cement proponents are satisfied with the weak bond to the tooth structure, typically 6 to 10 MPa, but it makes more sense for a post and core system to be cemented into place with a stronger bond to the tooth structure, specifically by using resin cements with bond strengths of 20 MPa or higher. Glass ionomer solubility in oral fluids is particularly critical at the restorative margins where salivary fluids and dietary acids corrode the cement. If a margin is exposed, the acid can ultimately dislodge the entire post and core complex.

Compomer cements (Box 18-9) are resin-reinforced glass ionomers, and have considerable bond strength to tooth structure, on the order of 50 MPa and higher. They also release fluoride. These properties would make them seem the ideal cementation materials for post and core systems. However, compomer cements tend to absorb water after they set, and this causes them to expand. Even a small coefficient of linear expansion translates into a very large volumetric expansion with water sorption. As a result, compomer cements have been reported to fracture overlying ceramic restorations. Theoretically, when used as post cements, they can also fracture the remaining radicular root structure. It is not possible to predict the actual direction in which the compomer cement will expand after setting. These materials should not be used for post cementation.

Resin cements (Box 18-10) entered common use in the early 1990s. Their advantages include a high bond strength to tooth structures, both dentin and enamel, as well as to metal and ceramic. They are easy to use and very predictable in their longevity. Resin cements may or may not release fluoride but are virtually insoluble in oral fluids. It is therefore expected that they will remain as placed for very long periods of time. The bond strength of resin cement to tooth structures and metal or ceramic is typically over 20 MPa. Thus the resin cement provides the ideal interface among the various components of the post-endodontic restorative monobloc. It can be used to cement every interface securely and predictably.

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There are two kinds of resin cements currently available. One involves the typical etching, bonding, and resin process wherein the tooth structures are etched, rinsed, and then bonded with the adhesive components either mixed or used in sequence. The other, more advanced option involves single-step, self-etching, self-adhesive cements applied directly into the moist prepared tooth. These materials are injected (after auto-mixing) either into the post space or onto the post. The post is then securely cemented into the tooth. These self-curing cements are light initiated and can be used for the core buildup as well.

The ideal post system (Figure 18-1) for the post-endodontic tooth is a fiber post that is adhered into the remaining prepared radicular structure with a resin cement that bonds to both the post and the root structure. This resin cement, which is the same material as a core buildup material, is used to build up the form and function of the core that will be prepared to receive the crown.

OTHER CONSIDERATIONS

Time and convenience are important chairside factors in post and core fabrication. The major advances in post development in the latter part of the twentieth century included changes in post delivery, post cementation, and core buildup. The advent of the single-appointment, single-step post and core procedure has made this process much easier for the dental practitioner; it is also far more practical and more easily financially attainable for the patient.

Post cementation has become considerably more predictable, as well. Adhesive cements have replaced luting cements, enabling the development of the adhered monobloc rather than the cemented restoration, which was readily dislodged by force, trauma, or vibration. Adhesive cements also have the advantage of distributing the load of forces over the entire radicular surface rather than focusing the forces to two areas, typically at the fulcrum and the point of a post. The most recent development in post delivery is the utilization of the cement as a core buildup material and vice versa. Using the same material for both functions eliminates the 7- to 10-minute waiting time for cement polymerization, allowing the practitioner to proceed immediately after having placed the cement and light curing. This permits the practitioner to accomplish the post and core procedure in far less time and far more efficiently than ever before.

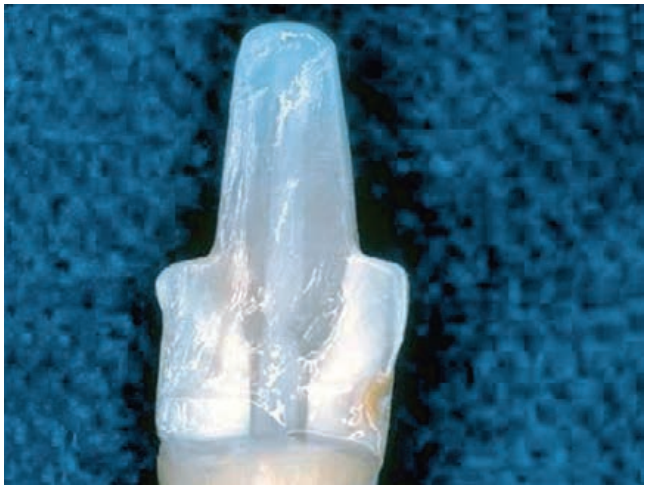


FIGURE 18-1 Ideal post system.

INNOVATIVE ELEMENTS

Scientific Elements

Among the scientific innovations in current post techniques are the self-adhesive, dual-cure resin cements. These materials eliminate the multiple steps needed to prepare the tooth structure for the resin cement. Previously, the radicular structure had to be cleansed, etched, bonded with several materials (accurately mixed or sequentially applied), and light cured, hopefully to the bottom of the post space. The cement had to be mixed and inserted. Placing the self-adhesive cements is far easier. The entire sequence of steps—etching, priming, bonding, and cementing—is accomplished in the single step of inserting the auto-mixed cement into the post space and inserting the post. In this manner, 7 to 10 minutes of preparation requiring four or six hands (the dentist plus one or two dental assistants) has been reduced to a procedure that can be readily accomplished by the solo practitioner in 30 seconds or less.

Technical Elements

The technological advances in post technology center upon the move away from cast and prefabricated metals to carbon and glass fibers. The benefit is that the metal, whether cast or prefabricated, tended to transmit most of the occlusal and lateral forces that were applied to the crown directly to the remaining tooth structure (Figure 18-2). In fact, the cast metal post transmits about 88% of all forces that are applied to it to the fulcrum areas and the apical tip of the post. This places a tremendous amount of stress on the remaining radicular tooth structure and occasionally causes root fracture. Prefabricated posts, because they do not typically fit as well as the cast posts and have the cushion of the cement between the post and the tooth to absorb some of the pressure, transmit only about 62% of the crown forces to the fulcrum and apical tip areas. These loads can also cause root fractures but are somewhat less likely to do so than the cast metal posts. The bonded fiber post actually tends to bend. All the individual fibers, which are held together by BIS-GMA or polyurethane adhesives, bend and flex slightly under pressure. Thus they tend to absorb most of the forces placed on the crown; only 28% is transmitted to the remaining tooth structure. Furthermore, the fiber post is bonded to the entire remaining radicular tooth structure; this relatively small residual force is actually spread out over the entire remaining radicular tooth structure, not concentrated on the fulcrum or post apical tip areas.

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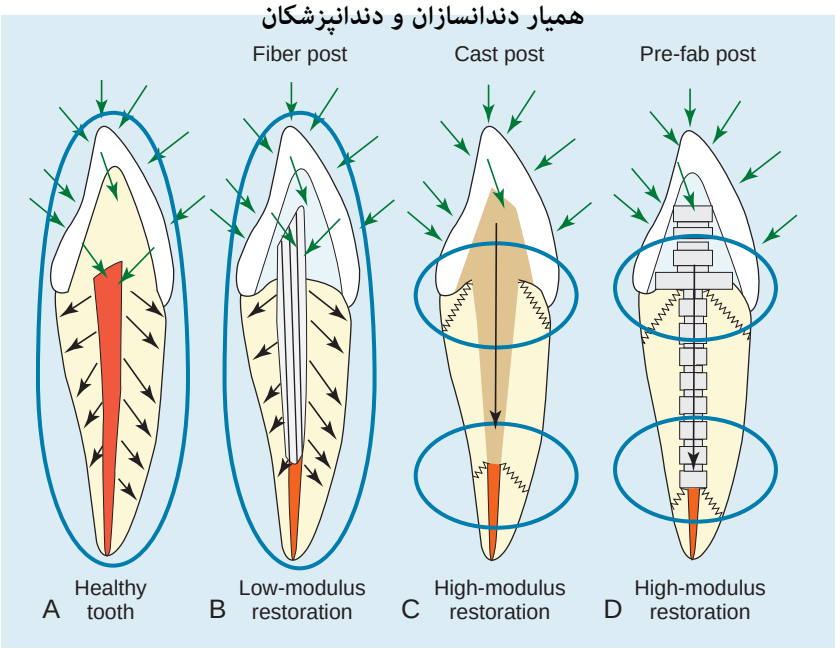


FIGURE 18-2 The healthy tooth (A) is subjected to various forces, vertical, lateral, and diagonal. The natural enamel and dentin are particularly well suited to absorbing and distributing these forces. The low-modulus fiber post restoration (B) is bonded to the remaining dentin and the core. This relationship absorbs the majority of stresses on the crown bonded to the core, and distributes them over the entire remaining radicular structure. The high–modulus cast post restoration (C) ideally fits snugly into the post space, held in place with a luting, non-adhesive cement. Forces on the cemented crown transmit and focus the majority of the forces to two specific areas, the juncture of the post and the core and the apical tip of the post. This is where most of the root fractures observed with cast posts occur. The high–modulus pre-fabricated post restoration (D) fits less snugly than the cast post; the cement acts as a shock absorber, transmitting less force from the crown than the cast post, but much more than the fiber post. The pre-fabricated post also focuses and transmits forces to the juncture of the post and the core and the apical tip of the post. Because they are less efficient in transmitting forces, pre-fabricated posts are less likely to fracture roots than cast posts.

TREATMENT PLANNING

There are a number of options for post placement in endodontically treated teeth. The fundamental issue is whether a post is actually required as part of the post-endodontic treatment plan. The literature is divided roughly half and half in this area. There is agreement, however, among all concerned that when there is little or no supragingival tooth structure left, the only method for developing the core that can accept crown placement is to anchor one or more posts in the remaining radicular tooth structure, and then to develop the occlusal end(s) into a core that protrudes above the gingival margin such that the crown can, in fact, be secured. Thus, if there is a lot of tooth structure left, it is arguable whether or not a post should be placed. If there is little or no coronal tooth structure left, there is no argument—there simply is no other method to affix a crown.

In most cases, the time the dentist invests in developing the post and core restoration in an endodontically treated tooth is far less costly and troublesome than the alternative of treating a tooth that has suffered the loss of a crown due to a post-less core that has fractured off at the gingival margin. Therefore this author recommends that a post be placed as a retentive and a protective device in *all* post-endodontically treated teeth.

Sequence

The post and core complex can be placed only after the endodontic treatment has been successfully completed. It must be securely in place before the crown preparation can start. If the endodontic procedure is not successful or not yet comfortable for the patient, it does not make sense to seal the endodontic access opening with a post and core that obstructs further endodontic intervention. Typically the practitioner should wait until all sensitivity has dissipated and the patient is comfortable enough to proceed with the post and core procedure without any need for local anesthesia. Should problems develop after the post has been placed, the bonded post is rather difficult to remove, and the tooth might require an apical endodontic procedure, or apicoectomy, directly through the buccal or lingual; this approach is certainly an option but a secondary one at best.

Treatment Considerations

In preparing the post hole, the practitioner should follow the gutta percha root filling material into the canal. To avoid perforations, the position of the reamer with respect to the gutta

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percha should be verified every 1-2 millimeters. Where direct light visibility is difficult, additional lighting can be used to identify that the gutta percha is, in fact, in the center of the post space that is being reamed with the drill. The restorative procedure should use fourth generation adhesives (followed by resin cements) or preferably the more simplified single-step self-adhesive cements.

Finishing

There is little surface finishing involved, and polishing is certainly not required. Essentially, the crown preparation constitutes the finishing procedure for the post and core.

EVIDENCE-BASED PRINCIPLES

The materials, technologies, and techniques described for the esthetic post and core procedures have been in use since the early 1990s. There is an abundent amount of scientific data on the materials and steps used in this procedure.

CLINICAL CONSERVATION CONCEPTS

The driving factor in this area is that as little remaining radicular tooth structure as possible should be removed. Therefore, sized posts that are closely adapted to the post endodontic canal diameter should be used. Most manufacturers produce a variety of post sizes and size-mated reamers. Fortunately, there is a wide variety of choices in the products available for this kind of restoration. Generally speaking, the gutta percha should be removed initially with the smallest reamer available. The reamer should be sized up to ensure that all post space preparation is located in relatively strong, healthy dentin. Once that has been achieved, the post is tried for fit and depth, and the procedure is continued.

NEAR-FUTURE DEVELOPMENTS

The current techniques for posts and cores are clinically simpler—much better, much faster, and much easier than at any time in the past. The materials are such that it is readily conceivable that the entire post and core procedure can be accomplished in no more than 15 minutes as part of the post-endodontic crown fabrication procedure. It is difficult to see how much faster and how much easier this process could be. One possibility is the self-adherent post, a post that has a self-etching, self-adhesive cement pre-applied to its surface such that it can be placed into the prepared post space without additional steps. Alternatively, posts that could be polymerized or otherwise light initiated to adhere mechanically and possibly chemically to the surrounding dentinal walls may be developed. The cement would actually be a component of the post, either surrounding it in the form of a gel cement covering, or a substance that is sound or light activated to release cement from its structure such that it adheres to the surrounding surfaces.

CLINICAL TECHNIQUES

The post-endodontic tooth is first isolated (Figure 18-3, *A*) and the reamer is used to shape and define the post space inside the tooth (Figure 18-3, *B*). Note the flecks of tooth structure and gutta percha. It is very important during the reamer preparation to keep the gutta percha centered in the canal with frequent verification. This avoids inadvertent perforation of the radicular structure. When the post space reaming is completed, the post is tried in it (Figure 18-3, *C*).

The remaining radicular structure is etched (Figure 18-3, *D*). Etching should take no more than 15 seconds. The etch is washed away completely (Figure 18-3, *E*) both on the surface and inside the post space. The bonding agent is then applied to the tooth structure (Figure 18-3, *F*). In this case a dual-curing fifth-generation bonding agent, DenTASTIC UNO-DUO (Pulpdent Corporation, Watertown, Massachusetts) is applied to the tooth structure (Figure 18-3, *G*). This material is self-curing and will be light initiated and continue to completion on its own. All the excess bonding agent must be blown away with an air syringe until there are no droplets scattering across the surface (Figure 18-3, *H*). At this point, the adhesive is cured (Figure 18-3, *I*). The curing light will not be effective for more than 2 or 3 mm into the canal or into the post space, but the dual-cure nature of the adhesive ensures that even in the deepest unlit portions of the post space there will be a self-cure within a minute. The auto-mixing resin cement or resin core material is bled onto a pad (Figure 18-3, *J*, inset) to ensure the quality of the material, then injected directly into the post space (Figure 18-3, *J*), preferably from the deepest portions out; once the post space has been filled with the resin cement, the post is inserted into the canal (Figure 18-3, *K*). It is placed into the canal passively, but the pressure of the post on the still-fluid core material eliminates any voids or air bubbles that might exist.

The post is inserted to its total depth into the still-fluid core material. The core material is Spee-Dee (Pulpdent Corporation) (Figure 18-3, *L*). After the post has been inserted, the core material is used to fill in any voids that may be visible (Figure 18-3, *M*), then the whole complex is light cured. It is then possible to continue building up the core immediately without waiting for the cement to set (Figure 18-3, *N*); each successive layer is cured separately. The process can be continued immediately after each curing step.

Once the buildup procedure has been completed, the excess post length is removed with a high-speed bur (Figure 18-3, *O*). The post and core are now ready for preparation into the crown abutment. Figures 18-3, *P* and *Q* show the prepared abutment from the occlusal and the buccal aspects.

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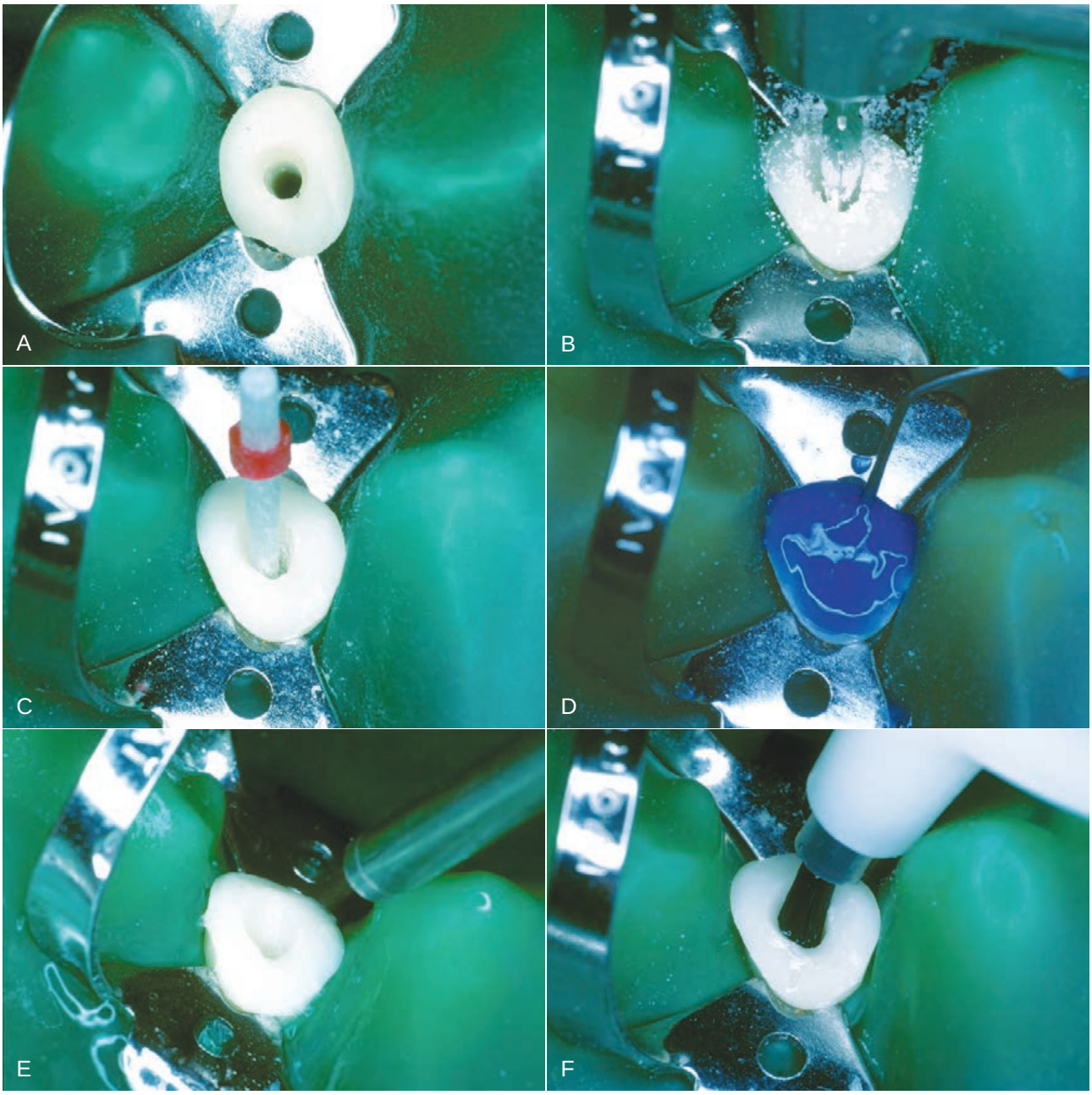


FIGURE 18-3 A, Isolated post endodontic tooth. B, Post space inside the tooth defined and shaped using a reamer. Flecks of tooth structure and gutta percha noted. C, Post tried in after the completion of post space reaming. D, Radicular structure etched. E, Etch completely washed away on the surface and inside the post space. F, Bonding agent applied to tooth structure.

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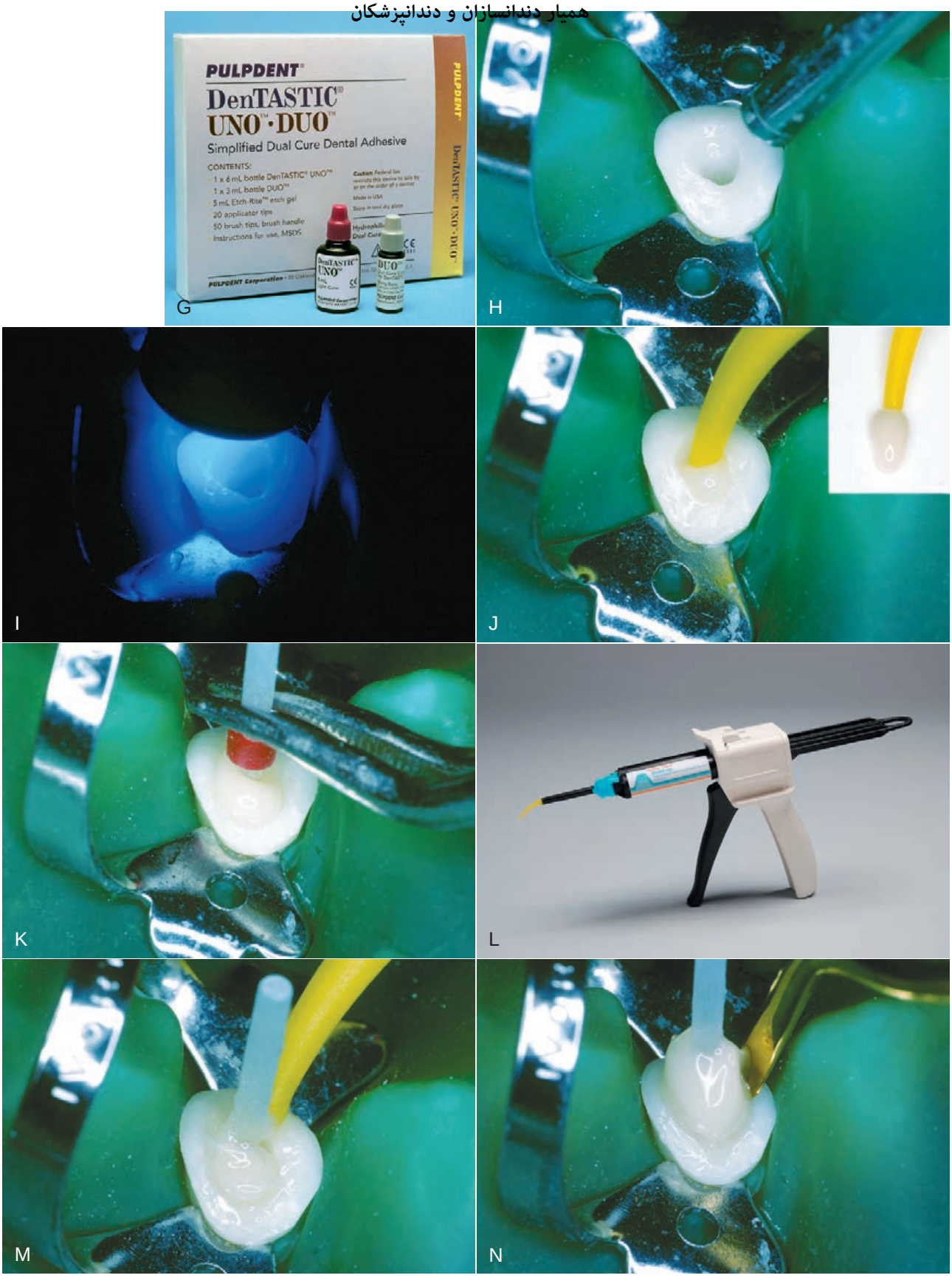


FIGURE 18-3, cont'd **G, DenTASTIC UNO-DUO bonding agent is applied to tooth structure. H, Excess bonding agent blown away with an air syringe until there are no droplets scattering across the surface. I, The adhesive being cured. J, Resin cement bleed on pad (inset photo) and resin cement injected into the post space. K, Post inserted into the canal after it is filled with the resin cement. L, Spee-Dee core material. M, Core material used to fill in any visible voids. N, Core can be built up immediately without waiting for post cement to polymerize.**

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FIGURE 18-3, cont'd O, The core is built up and excess post length is removed. P and Q, Prepared abutment, occlusal (P) and buccal (Q) views. *(**G** and **L**, Courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

CASE 1 Post and Core Restoration of an Endodontically Treated Tooth

Figure 18-4, *A*, shows a temporarily restored endodontically treated tooth. The provisional material is removed (without local anesthetic) using a Great White #557 bur (SS White Burs, Lakewood, New Jersey) (Figure 18-4, *B*), and the two canals are filled with gutta percha (Figure 18-4, *C*). Figure 18-4, *D*, shows the suitable-sized reamer used to clean out the gutta percha to the appropriate depth (Figure 18-4, *E*). It is important to note the direction of the reamer so that the posts can be inserted and cemented in the same direction. The canals are ready for adhesive procedures. The two posts are tried into the canal to ensure there is no interference as they are inserted (Figure 18-4, *F*), which may cause problems during the cementation with the access of one or the other post. The post spaces and the pulp chamber are cleaned out thoroughly (Figure 18-4, *G*); the entire post and core space is etched (Figure 18-4, *H*), and bonded. Note that the bonding procedures cannot be shown because the flash from the camera will cure the adhesive inside the canal. Silane is placed on the post to increase its adhesion to the composite (Figure 18-4, *I* inset). The core material is inserted into the two post spaces at the same time, and the posts are placed to their full depths (Figure 18-4, *I*). The core is light cured (Figure 18-4, *J*). After curing and successive layer buildup, the final step is the placement of the core all the way to the occlusal surface (Figure 18-4, *K*). The excess post length is removed with a bur (Figure 18-4, *L*). Both diamonds and carbides can be used. The occlusal surface of the tooth is polished (Figure 18-4, *M*). This tooth is now ready for function or preparation for a crown. After the rubber damn has been removed, the post-treatment view of the tooth can be seen (Figure 18-4, *N*), with the pretreatment view on the inset.

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CASE 1 Post and Core Restoration of an Endodontically Treated Tooth (cont'd)

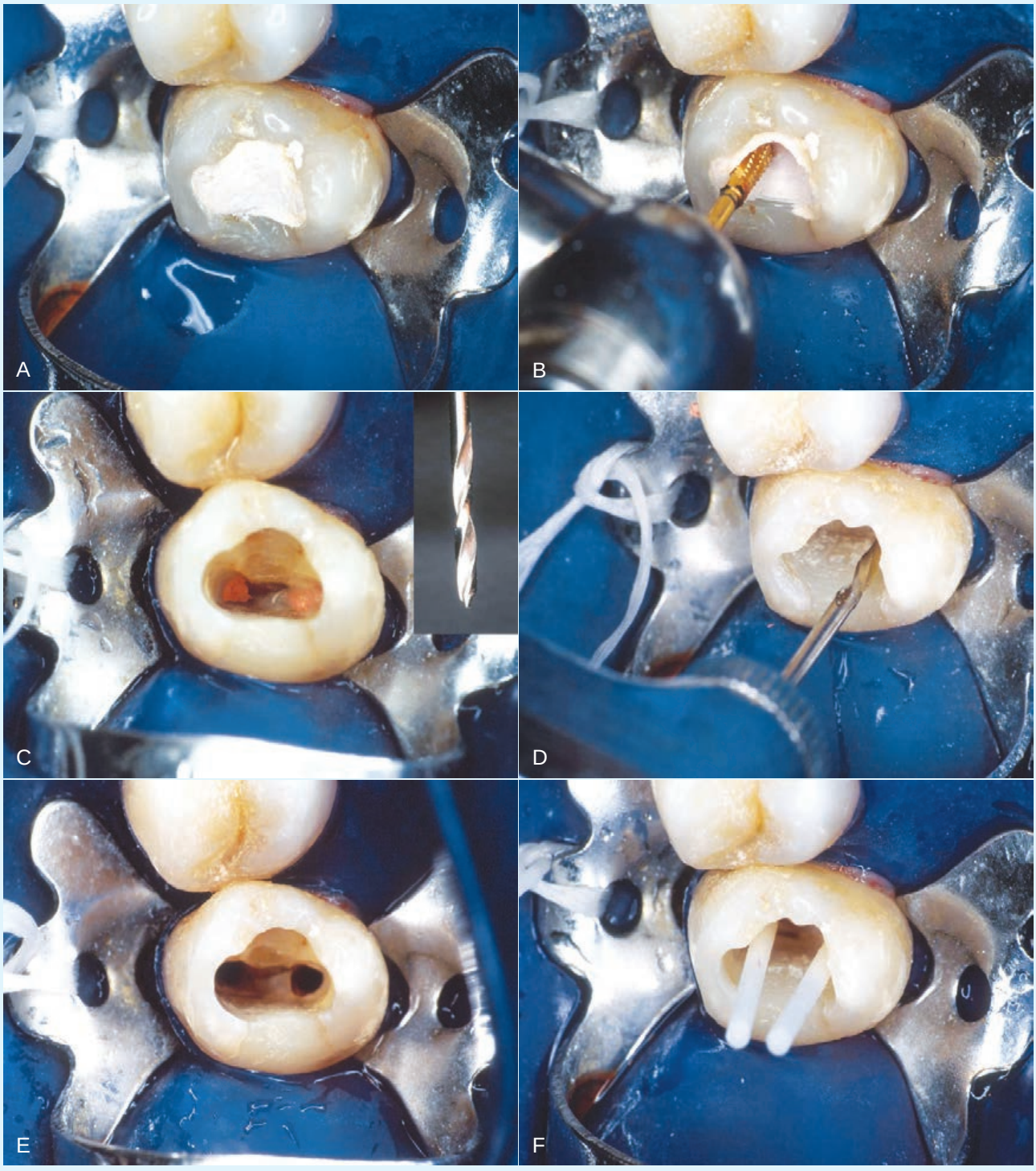


FIGURE 18-4 A, Temporarily restored endodontically treated tooth. B, Provisional material removed using a Great White bur. C, Two canals filled with gutta percha. D, The reamer used to clean out the gutta percha for the appropriate depth. E, Canals reamed to the appropriate depth and ready for adhesive procedures. F, Two posts tried into the canal.

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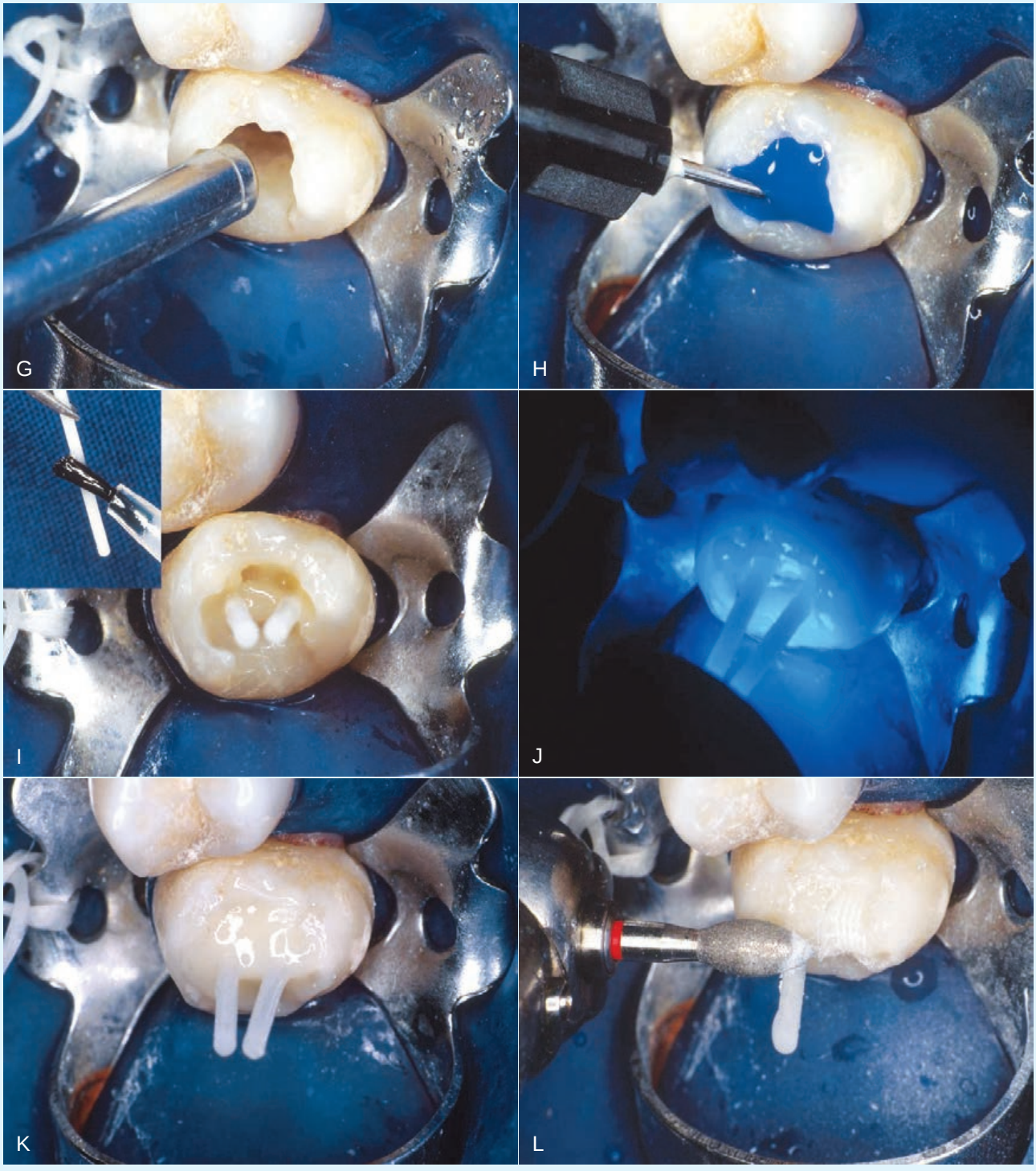


FIGURE 18-4, cont'd G, Post spaces and the pulp chamber thoroughly cleaned. H, Entire post and core space etched and bonded. I, Silane is placed on the post *(inset photo)* and core material inserted into the two post spaces. The posts are placed to their full depths. J, The core is light cured. K, Placement of the core all the way to the occlusal surface. L, Excess post length removed with a bur after final layer is cured.

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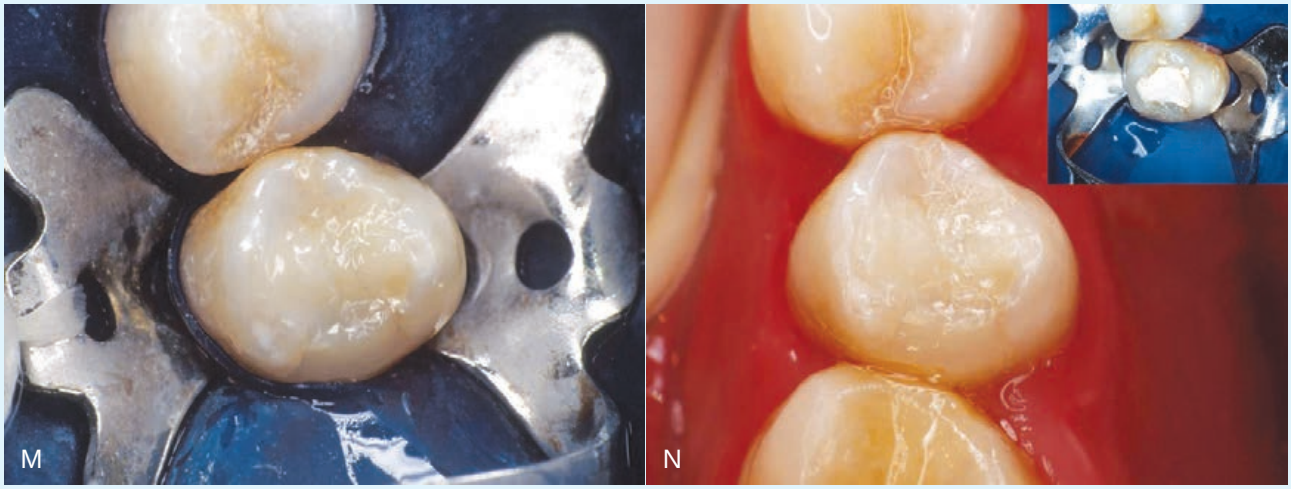


FIGURE 18-4, cont'd **M, Occlusal surface of the restoration is polished. N, Post-treatment view of the tooth, comparing it to the pretreatment view (*inset*).**

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Single-Tooth All-Ceramic Restorations

Edward Lowe

RELEVANCE OF ALL-CERAMIC SINGLE-TOOTH RESTORATIONS TO ESTHETIC DENTISTRY

All ceramic is the most esthetic choice for full-coverage restorations. If given a choice, a patient will always select the natural-looking restoration over an artificial one. Currently there is virtually no need to place a single unit with a full gold crown or a porcelain-fused-to-metal (PFM) crown in most clinical situations. Researchers have been trying for years to come up with a material similar to that of a natural tooth. Although the quest for the ideal all-ceramic material continues, some materials used today approach the esthetics and strength of the enamel-dentin complex in natural dentition.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF ALL-CERAMIC SINGLE-TOOTH RESTORATIONS

Before the development of the all-ceramic restoration, crowns made of gold or gold alloys with an acrylic or porcelain facing were considered state of the art. Esthetics were lacking, as the resulting restorations were a far cry from the look of the natural dentition.

The porcelain jacket crown (PJC) was the first tooth-colored full-coverage restoration. Introduced by Dr. Charles H. Land in 1903, the porcelain jacket was made with feldspathic porcelain clay layers successively fired over platinum foil. The finished PJC was luted to the tooth using zinc phosphate cement. Although it could fulfill some of the esthetic drawbacks of its predecessor, it was not without its shortcomings. First, the removal of the platinum foil after the crown was fired meant that there was always a substantial gap left at the margin from which the zinc phosphate cement could leach out, leaving the tooth prone to caries. Second, the porcelain tended to be too opaque to match the surrounding teeth. Finally, this old-fashioned porcelain crown inherently lacked robust physical properties and strength. PJCs were definitely contraindicated for posterior teeth, as they were prone to failure even on anterior teeth.

Early PJCs tended to fail owing to the microfractures that occurred on the internal surface. The answer to this problem first appeared in the early 1950s with renewing interest in the PFM crown. Because the internal surface of the porcelain is bonded to a metal coping in PFM restorations, the metal-porcelain bond prevents the stress cracks from developing. In the 1960s the aluminous core PJC was developed. This crown was made on a refractory die rather than on platinum foil.

PFM restorations gained popularity exponentially and are to this day the most widely used type of single-tooth full-coverage restoration. The main disadvantage of the metal ceramic restoration still appears to be the ability of the overlying porcelain to mask the underlying metal, especially in porcelain-to–metal collar and porcelain-to-margin (combination) types. This esthetic barrier resulted in a burst of research and development in ceramic technology for anterior restorations.

In the 1970s this research culminated in the development of the collarless ceramometal crown and porcelain shoulder (butt) margins. The 1980s brought developments in the posterior dentition for single-unit crowns. These included early glass ceramics such as Dicor (DENTSPLY Prosthetics, York, Pennsylvania) and Cerestore (Johnson & Johnson Professionals, Inc., East Windsor, New Jersey). Although these were fairly good restorations, they were all conventionally cemented because resin bonding and resin cements were in early development. One of the first resin cements was Resiment (JL Blosser, Inc., Liberty, Missouri), an auto-curing, filled, multipurpose cement.

An early development was VITA In-Ceram ALUMINA (glass-infiltrated alumina crowns) (VITA Zahnfabrik, Bad Säckingen, Germany). These had a very hard aluminous core, creating challenges for the dentist if one had to be removed. These crowns tended to be a bit opaque, as the layering porcelain had the dubious task of hiding the opacious coping.

This paved the way for VITA In-Ceram SPINELL (glass-infiltrated magnesium alumina crowns), which sacrificed some physical properties in flexural strength and hardness in order to produce a coping with greater translucency.

These were followed by the high-strength VITA In-Ceram ZIRCONIA (glass-infiltrated alumina with partially stabilized zirconia) crowns, which failed esthetically but were useful as high-strength posterior crowns and bridge abutments.

From the early 1990s, various leucite-reinforced glass ceramic (LRGC) materials offered anterior single-unit esthetics using either the staining or the cut-back and layering technique.

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Empress (Ivoclar Vivadent, Amherst, New York) pressed-leucite porcelain was the most esthetic material, but it was typically a weak material when used in the posterior region, especially in the case of a full-coverage restoration. If this material was used, the restorations were typically stained and not layered.

Among the indirect resins tried in the posterior area were materials such as Concept (Ivoclar Vivadent), Artglass (Heraeus Kulzer, Hanau, Germany), Targis and Vectris (Ivoclar Vivadent), belleGlass (Kerr Corporation, Orange, California), Sinfony (3M ESPE, St Paul, Minnesota), and Cristobal (DENTSPLY Prosthetics) that were never really meant to be used for full-crown restorations. Although attempts were made, the results were quite disastrous, with severe wear being the main instigator of functional failure. These crowns typically lasted 5 years or less at best.

Better esthetics with greater strength was achieved with the development of Empress 2 (Ivoclar Vivadent), although this initially met with disastrous results because of the difficulty in getting the two coefficients to match the thermal expansion coefficient of the layering porcelain made of fluorapatite. In these restorations ceramists stacked layering powder-liquid ceramic, but cracking was a problem. This led to reworking the lithium disilicate–fluorapatite formula and renaming it *Eris.*

The Procera materials (Nobel Biocare, Yorba Linda, California), which are polycrystalline ceramics, were the next thing developed. With the very hard Procera cores, the color is opacious white, almost too white. Trying to hide the white core with the layering ceramic became a challenge.

Zirconia core restorations such as Lava (3M ESPE) were developed in response to the demand for an all-ceramic framework for fixed partial dentures (FPDs) in addition to the single-unit crowns. These zirconia restorations have an infrastructure that is designed using conventional waxing techniques or computer-aided design (CAD) technology. The infrastructure is milled from yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) blanks using computer-aided manufacturing (CAM), after which the layering ceramic is stacked on to build the crown.

Lithium disilicate, Empress 2, has been re-introduced as e.max (Ivoclar Vivadent) and is available either in a pressable or a CAD-CAM form. This seems to be the ideal material because instead of cutting back the core and laying powder or liquid ceramic on top, the preparation is milled to anatomic form and stained, making this an extremely hard restoration. The whole crown is made up of lithium disilicate, which makes it monolithic rather than a bilayer ceramic, and accounts for its improved strength and esthetics. Although it can be cemented conventionally, the lithium disilicate restoration can also be bonded to the tooth with resin cement.

RELATING FUNCTION AND ESTHETICS

With the anterior single-tooth all-ceramic restoration, esthetics takes precedence. Most of the materials being used now are strong enough to be used in the anterior region, except in certain cases complicated by parafunctional activity. For the most part, these restorations are the restorations of choice. Even if it is necessary to mask out a dark post, these restorations perform very well.

Posteriorly, function is more important. Patients needing posterior restorations in general are concerned about function and longevity. The best choice for these patients often is a PFM or full gold restoration. For a single-tooth restoration focused on function plus esthetics, a zirconia or a lithium disilicate core–based restoration would be the restoration of choice. Lithium disilicate restorations work best if bonded; however they can be conventionally cemented as well. In the zirconia restoration, the core is very strong, but the layering porcelain still seems more likely to chip away from the core with a zirconia restoration than it does with a PFM restoration.

In relation to function, the best course of action is to use the most esthetic material to match an anterior tooth and use the strongest core in the posterior region. That is why lithium disilicate is an ideal material. Its core can be taken right to the surface, it is esthetic, and it has fracture resistance, thereby allowing it to be more than adequate for most situations.

CLINICAL CONSIDERATIONS

Indications

The primary indication for all-ceramic restorations is obviously improved esthetics and lower cost. The consideration for improved esthetics is apparent. The lower cost is a result of the escalating costs of precious metals. For example, in the anterior region, because the cost of precious metals is rising, the PFM crown with a porcelain butt margin ends up costing a bit more than a ceramic core restoration with porcelain on top. The other clinical considerations in the anterior are the all-ceramic restoration's ability to match the existing dentition and the ability to keep the restoration margins supragingival or equigingival, because masking the metal margins of the restoration is not a factor.

Contraindications

The physical properties and strength of all-ceramic crowns have improved. Studies show that they can provide the same length of service as a properly made metal ceramic restoration. These do well in areas without high stress. Because stress can cause fractures, even PFM crowns with porcelain occlusal surfaces are susceptible to fracture of the layering porcelain. In such cases, metal on the occlusal surface may be indicated. In areas such as the second molar region where there is inadequate room for the ceramic to achieve its peak physical properties or where tooth structure is inadequate to prepare the tooth, all-ceramic restorations are contraindicated.

MATERIAL OPTIONS

All-purpose feldspathic porcelains are mainly used with PFM restorations and ceramic core–based all-ceramic restorations as the layering ceramic in a bi-layer restoration. They may be used to create porcelain veneers, inlays, and onlays as well.

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The three main groups of materials used in the construction of an all-ceramic core are pressable glass ceramic, glass-infiltrated ceramic, and polycrystalline ceramic.

Pressable Glass Ceramics

Pressable glass ceramics are composed of two main groups: the LRGCs and the lithium disilicate glass ceramics (LDGCs). They both contain a fluid glassy phase and crystalline components.

LRGC restorations such as IPS Empress (Ivoclar Vivadent), OPC (Pentron Ceramics Inc., Somerset, New Jersey), Finesse All-Ceramic (DENTSPLY Prosthetics), and Authentic porcelain (Jensen Dental, North Haven, Connecticut) have been in use for over 20 years. LRGCs are highly translucent so they are good for esthetic restorations. Another advantage is the ability to wax the restoration to full contour, check the shape and occlusion, and invest and press it to form, resulting in a restoration that covers the site and can be bonded. The restoration is natural looking with accurate margins. Copings can be fabricated by using either a lost wax–heat pressing technique or CAD-CAM technology.

The disadvantage of this material is its inability to hide a dark discolored core. Because of the material's high translucency, a discolored tooth, metal core buildup, or implant abutment will alter the final shade of the restoration. Anterior crowns made from a core material of this type have shown exceptional success rates. The flexural strength has been measured at 105 to 120 MPa, and the fracture toughness is 1.5 to 1.7 MPa $m^{0.5}$.

Materials such as these, with low strength, are best used in the anterior region. The strength of these restorations is supplemented by etching the internal surfaces with hydrofluoric acid, silanating, and bonding to treated tooth structure with resin cements (Figure 19-1).

LDGC restorations such as IPS Empress II, IPS Eris, and IPS e.max (Ivoclar Vivadent) have been in use since 1999. LDGCs are recommended for anterior and posterior crowns as well as for three-unit FPDs from the second premolar and forward. These materials are not recommended for posterior bridges with a molar abutment. Flexural strength is about 360 MPa for e.max CAD and closer to 400 MPa for e.max Press. Fracture toughness is about 2.25 MPa $m^{0.5}$ for e.max CAD and closer to 2.75 MPa $m^{0.5}$ for e.max Press.

Once again, the core is fabricated with lost wax and heat-pressure techniques. These restorations are etched with hydrofluoric acid and adhesively cemented, although they are strong enough to be conventionally cemented—another advantage.

In using LDGC to fabricate a bridge, large connectors are needed between the abutments and the pontic tooth in both

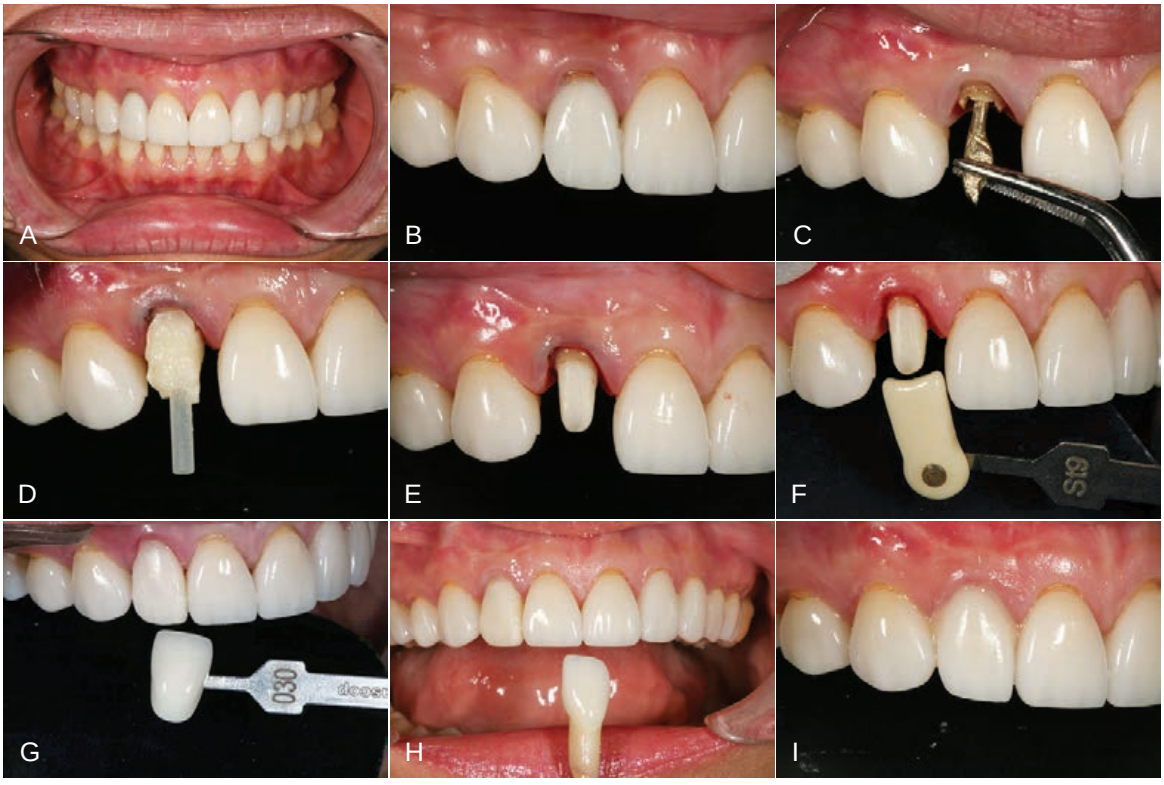


FIGURE 19-1 Fiber post, composite core, and Empress pressed-leucite porcelain crown used to match existing veneers. **A,** Retracted pre-operative view of discolored tooth No. 7. Anterior restoration is 10 years old. **B,** Close-up pre-operative view showing shine-through of metal post and microleakage. **C,** Removal of gold cast post and core after crown removal. **D,** Composite core buildup around cemented fiber post. **E,** Finished post and buildup and tooth preparation. **F,** Preparation shade selected after the acrylic provisional has been placed. **G,** The final shade of the crown is selected. **H,** The shade of the new crown is checked on the preparation die against the anterior teeth. **I,** Try-in gel used to check the shade of the new restoration.

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FIGURE 19-1, cont'd **J,** Hydrofluoric acid porcelain etch is used on the intaglio surface of the crown for 15 seconds and then rinsed off. **K,** Silane coupling agent is applied to etched porcelain for 1 minute and then dried. **L,** The tooth is etched for 15 seconds with 35% phosphoric acid. **M,** Bonding agent is applied to the moist tooth surface. **N,** Light-cured resin cement is loaded into the crown. **O,** The crown is seated and spot tacked in the center of the facial surface with a 2-mm tacking tip for 1 second. **P,** Excess cement removed from the margins with a rubber tip. **Q,** The contacts are flossed and the floss pulled through to the lingual. **R,** Glycerin is placed around the margins to ensure curing of the oxygen inhibition layer. **S,** The crown is light cured into place for 20 seconds per surface. **T,** A scaler is used to remove excess cured cement. **U,** A 32-bladed finishing bur is used to remove cement from the margins. **V,** The bite is checked with articulation paper. **W,** Contact must be light, and one should be able to drag shim stock through when in maximum intercuspation. **X,** Close-up postoperative view of the completed Empress crown. **Y,** Retracted postoperative view of the leucite crown restoration on tooth No. 7. **Z,** Pre-operative smile. Note the protected smile and asymmetrical upper lip dynamics. **AA,** Postoperative smile. Note the fuller smile and symmetrical upper lip dynamics.

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facial-lingual and incisal-cervical orientations. This material is not to be used for anterior bridgework when a 4.0-mm × 4.0-mm connector is not possible.

The earlier core materials made from lithium disilicate were originally not as translucent as the LRGCs. Both materials can be fabricated to full anatomic contour and characterized with surface stains, or the cores can be cut back and layered with feldspathic "effect" porcelains.

Like the LRGCs, the LDGCs have many indications and uses. The pressable lithium disilicate material (IPS e.max Press) is indicated for inlays, onlays, partial crowns, thin veneers, veneers, anterior and posterior crowns, three-unit anterior bridges, three-unit premolar bridges, telescope primary crowns, and implant restorations. In some cases in which minimal or no tooth preparation is desired (e.g., thin veneers), laboratories are able to press restorations as thin as 0.3 mm while still ensuring a strength of 400 MPa. Indications for the machinable lithium disilicate material (IPS e.max CAD) are inlays, onlays, veneers, partial crowns, anterior and posterior crowns, telescope primary crowns, and implant restorations. For a posterior crown fabricated to full contour using CAD methods, lithium disilicate offers 360 MPa of strength through the entire restoration. As a result, restorations demonstrate a "monolithic" strength unlike any other metal or metal-free restoration. With a flexural strength four times greater and a fracture toughness almost two times greater than those of LRGC, it is no wonder that use of LDGC core material in both its pressable and CAD-CAM versions (IPS e.max Press, IPS e.max CAD [Ivoclar Vivadent]) has grown in popularity (Figure 19-2).

LDGC is emerging as a restorative material of choice for single-unit all-ceramic indirect restorations. It is increasingly being integrated into North American and Western European dental practices. Being strong, versatile, and lifelike, it comes with a variety of translucencies and can be layered to maximize esthetics in select cases.

Glass-Infiltrated Ceramics

Glass-infiltrated ceramics are a product of infiltrating molten glass to partially sintered metal oxides such as alumina, magnesium alumina, and partially stabilized zirconia. Sintering is a method for making objects from powder, by heating the material in a sintering furnace below its melting point (solid state sintering) until its particles adhere to one another. Glass-infiltrated ceramics are part of the In-Ceram (Ivoclar Vident) family of restorations introduced in 1989.



FIGURE 19-2 **e.max lithium disilicate crowns used for anterior restorations. A, Retracted pre-operative view. B, Close-up pre-operative view. C, View of teeth Nos. 8 and 9 prepared for crown restorations. D, The teeth provisionalized with acrylic crowns made from a pre-operative PVS impression and cemented. E, Model of the preparations. F, View of the full-contour wax-ups of the anticipated restorations. G, The individual wax patterns sprued and invested. H, Cut-backs are completed after the fit of the restorations was verified and the incisal matrix is placed on the model to verify the proper reduction. I, All contours are shaped (using a variety of diamond burs), and the surface anatomy and morphology added to make the restorations blend with the surrounding teeth.**

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FIGURE 19-2, cont'd **J,** Small amounts of stain are applied where needed, and the restorations are fired. **K,** After the restorations have been fitted back on the solid model, contacts are checked, full embrasures are confirmed, and No. 2 pumice is used to finish the surface to the desired satin luster and reflectivity. **L,** View of the completed restorations on the master model at the dentist's office. **M,** The appropriate shade of luting cement is chosen. **N,** The restorations are tried in with glycerin try-in gel. **O,** The preparations are etched with 35% phosphoric acid. **P,** The crowns are seated, and excess cement is allowed to escape from the margins before cleanup. **Q,** Glycerin is placed around the margins to ensure curing of the oxygen inhibition layer. **R,** The crown restorations are light cured into place. **S,** Retracted postoperative view of the lithium disilicate crown restorations on teeth Nos. 8 and 9. **T,** Close-up pre-operative view of the completed restorations. **U,** Pre-operative smile. **V,** Postoperative smile. **W,** Pre-operative headshot. **X,** Postoperative headshot.

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Glass-infiltrated alumina has a high-temperature, sintered alumina glass-infiltrated infrastructure and is used in anterior or posterior crowns as well as three-unit FPDs in the anterior. It has a flexural strength ranging from 236 to 600 MPa, and the fracture toughness ranges from 3.1 to 4.6 MPa $m^{0.5}$. The coping or framework can be fabricated by the ceramist using either a slip-casting technique (in which a slurry is poured into a porous mold and the liquid is filtered out through the mold, leaving a layer of solid porcelain body) or CAD-CAM technology. The core is opacious and limits VITA In-Ceram ALUMINA's use as a highly esthetic material.

This lack of translucency in the core of glass-infiltrated alumina is what led to the development of glass-infiltrated magnesium alumina. Although it has lower flexural strength, about 283 to 377 MPa, the VITA In-Ceram SPINELL core material is almost twice as translucent as the In-Ceram ALUMINA core. It is mostly used for anterior crowns in situations where maximum translucency is required at the expense of strength. This risk has been demonstrated to be one worth taking, as VITA In-Ceram SPINELL's track record has proven to be successful over an extended period of time.

In-Ceram ZIRCONIA contains partially stabilized zirconia, which increases the core material's core flexural strength from about 421 MPa to 800 MPa. Fracture toughness ranges from 6 to 8 MPa $m^{0.5}$. This strong core allows the material to be used for posterior bridgework as well. The drawback of this material is its higher opacity, and because the main reason for using all-ceramic materials is to improve light transmission and translucency, the use of this core material is limited to the posterior dentition.

Polycrystalline Ceramics

Polycrystalline ceramics are machinable using CAD-CAM technology and include materials such as the Procera AllCeram system (Nobel Biocare), which is a densely sintered high-purity aluminum oxide. These cores are glass free and have a flexural strength of 500 to 650 MPa and a fracture toughness of 4.48 to 6 MPa $m^{0.5}$. The material is recommended for anterior and posterior crowns. However, its use is questionable for three-unit bridges.

The other polycrystalline ceramic system is made of Y-TZP. Y-TZP is the foundation for a number of high-strength systems, such as Lava (3M ESPE), Cercon (DENTSPLY Prosthetics), Cerec inLab (Sirona Dental Systems, Charlotte, North Carolina), and Procera AllZirkon (Nobel Biocare). The machinable Y-TZP blocks can be used for FPD frameworks as well as anterior and posterior crown copings. In vitro studies of Y-TZP demonstrate a very strong flexural strength of 900 to 1200 MPa and a fracture toughness of 9 to 10 MPa $m^{0.5}$. The strength of the Y-TZP is attributed to a process known as *transformational toughening* and to the material's small 0.3- to 0.5-µm grain structure. When a crack begins to spread through the ceramic, a high-energy stress state develops that causes the Y-TZP to repair itself by transforming from a tetragonal crystal configuration to a monoclinic configuration, stopping crack propagation within the framework.

The design of the Y-TZP substructure is achieved conventionally by some restorative systems using a wax-up and milling process and by others using CAD-CAM technology. The size of the partially sintered, milled infrastructures is increased to compensate for the 20% to 25% reduction in size that typically occurs with during final sintering. Pressed ceramics or layering porcelains can be used over the substructures to give the restoration the final desired esthetic outcome.

One of the main advantages of this material is that one can create long-span bridgework because the material is available in large blocks and in a horseshoe shape.

Zirconia-cored crowns are susceptible to chipping of the veneering ceramic. The fracture rate has ranged from 8% to 50% at 1 to 2 years. In comparison, the reported rate of chipping with PFM crowns is 4% to 10% after 10 years. The mechanism of chipping is not clear. It might be attributable to core flexure or bond failure.

Another possible cause of chipping is the lack of uniform support of the veneering ceramic by the core. A well-known principle for PFM restorations is that the metal core should support a uniform thickness of veneering ceramic and that there should be a maximum of 2 mm of unsupported porcelain. This is accomplished with an anatomic-contour wax-up and controlled cut-back.

Zirconia cores are made by dental laboratories by scanning the die and then milling a uniform core of 0.3 mm for anterior teeth and 0.5 mm for posterior teeth. Because of the bell-shaped nature of teeth that must be reduced to remove undercuts, uneven thicknesses of the veneering ceramic will result, some of which may exceed the industry standard of 2 mm of unsupported porcelain stacked on top of the zirconia core. The technician can correct this problem before he or she mills the core, by designing the uneven thicknesses into the core rather than relying on the layering ceramic to pick up the slack.

As far as most clinicians are concerned it does not matter how fracture resistant the core is—a restoration is only as good as its weakest link. If the layering porcelain fractures or breaks, the restoration must be remade or repaired.

The high-strength polycrystalline ceramic zirconia and alumina restorations cannot be etched and bonded readily. It is necessary to use materials such as a resin-modified glass ionomer cement (e.g., RelyX Luting Plus Cement [3M ESPE], GC FujiCEM (GC America, Alsip, Illinois). These cements are well known for their lack of associated postoperative tooth sensitivity, acceptable strength, and fluoride release.

A second option is to use a self-adhesive universal resin cement such as RelyX Unicem (3M ESPE) or MaxCem Elite (Kerr Corporation). These cements contain an incorporated self-etching bonding agent.

A third option is to use resin cements that require the use of a separate self-etching bonding agent such as PANAVIA F (Kuraray America, New York, New York) and Multilink Automix (Ivoclar Vivadent). Both of these resin cements have a two-component liquid self-etching bonding agent that is intended to be applied to the tooth preparation before the restoration is seated with the resin cement. The self-etching bonding agent is

همیار دندانسازان و دندانپزشکان

intended to seal the dentinal canals and provide bonding to both the enamel and the dentin.

Some authorities advocate the use of air abrasion on the intaglio surface of zirconia-cored restorations with a tribochemical silica coating (Rocatec or CoJet system [3M ESPE]) to increase the bond strength between the resin cement and the ceramic, whereas others feel that air abrasion inside the entire surface of the restoration can cause a transformational change that ages the restoration and reduces its life expectancy.

It is important to understand that simply placing an all-ceramic restoration instead of a metal-ceramic restoration will not guarantee outstanding esthetics. The clinician must ensure that there is proper tooth preparation with a good finish line. To attain ideal esthetics and an adequate amount of strength, the dentist must achieve sufficient reduction to give the ceramist room to create a restoration with physiological crown contours as well as excellent esthetics. The clinician must remove a minimal cross-sectional thickness of 1.2 to 1.5 mm of enamel and dentin circumferentially to provide sufficient room for these polycrystalline alumina or zirconia cores and veneering porcelains. These are aggressive preparations, and an increase in biomechanical risk is incurred for the sake of esthetics.

CURRENT BEST APPROACH

The higher-strength all-ceramic materials make many clinicians feel at ease with using them because of their improved esthetics and lower cost.

If esthetics is the main concern and the conditions are ideal, the best approach for anterior full-coverage restorations is a leucite-reinforced glass ceramic fabricated with the IPS Empress system. These restorations must be bonded adhesively with resin cement.

In the posterior, a lithium disilicate full-coverage restoration made with the IPS e.max system meets the requirement for strength and esthetics. These restorations can be bonded with resin cement or cemented conventionally with resin-modified glass ionomer or self-adhesive resin cements.

The use of zirconia full-coverage posterior restorations is acceptable if conditions allow for it and there is adequate tooth structure and retention.

OTHER CONSIDERATIONS

Using an all-ceramic restoration does not automatically guarantee esthetic success. Besides choosing the right material, it is important to choose a good ceramist and pay attention to the details regarding tooth preparation and cervical margin design, margin placement, soft tissue management, and quality of the impression. A thorough history is needed so the dentist knows which restoration is appropriate. It is necessary to assess whether the pulp of the tooth is healthy before the crown is prepared. Are endodontic procedures needed? If there is any reason to question the vitality of the pulp of a tooth receiving an all-ceramic crown, endodontic therapy should be considered before the tooth is prepared. With a metal-ceramic crown, it is very easy to put a hole on top of it, do the endoscopic work, close the hole, and not lose the crown. An all-ceramic crown is a little different because cutting a hole through it invariably results in a defect that can lead to catastrophic failure of the crown. In developing the margins of the finish line, it should be as smooth as possible. Polishing of the finish line is critical for the long-term heath of the restoration. Margins must be placed deep enough into the gingival sulcus that minor recession will not expose them. With these restorations it is not necessary to place the margins so deeply that the biologic width is violated, resulting in a chronic inflammatory response. In most instances the margin can be placed equigingivally or 0.5 mm subgingivally, so analyzing these soft tissues before tooth preparation is paramount with the all-ceramic restoration.

Understanding what the ceramist needs when preparing the teeth, performing shade-matching procedures, and using the correct cement material are all important. It is critical for patients to give informed consent and understand that long-term survival rates for all-ceramic restorations are likely to be slightly lower than for PFM restorations.

If the patient is a nocturnal bruxer, use of a night guard is recommended to lengthen the life span of these restorations.

INNOVATIVE ELEMENTS

Everyone is striving to make the ideal restoration. Applied scientific research is constantly seeking ways to make a hard-core full-coverage restoration that is esthetic, has great physical properties, and can be cemented conventionally. If it were possible to create an all-ceramic restoration with the track record and the positive aspects of a full gold crown, it would be ideal.

Technologically, research is ongoing into materials that are more translucent. The more translucent the material, the more glass there is, and the weaker it is. Researchers are working on materials that are hard enough but less opaque. The harder the material is, the more opaque it tends to be.

In addition, active CAD-CAM technology is being developed to mill cores made of harder materials that can be delivered to the dentist at a reasonable cost. Milling centers may reduce the cost.

The latest zirconia restoration to appear on the market is a solid monolithic zirconia crown or bridge restoration (BruxZir [Glidewell Laboratories, Newport Beach, California]) with no porcelain overlay. BruxZir is ideally suited for posterior molar crowns when the patient desires a tooth-colored restoration but lacks the preparation space for a PFM crown or has broken one in the past owing to bruxing. A shoulder preparation is not required, and a feather edge is acceptable. It is a conservative preparation similar to full-cast gold, so any preparation with at least 0.5 mm of occlusal clearance is satisfactory, although 1 mm is ideal.

Other innovative elements include digital impression systems such as Chairside Oral Scanner C.O.S. (3M ESPE) and iTero (Cadent, Carlstadt, New Jersey), which can optically scan the patient's teeth and bite. The digital impression is used to create

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a stereolithographic model, die, and wax coping for crown creation.

ARTISTIC ELEMENTS

One of the hardest tasks for a dentist is to match a single crown to an existing natural tooth. In the anterior region of the mouth, the task becomes more daunting as the patient wants an anterior crown to look exactly the same as the adjacent central incisor. In some instances, both teeth are done in order to meet the patient's expectations.

Some of the artistic elements that dentists must know include natural tooth shape and tooth anatomy, emergence profile, line angles, and tooth arrangement. In addition, dentists must understand color and be able to capture and translate the color and the details of that tooth into ceramic, whether by photography, by taking a study model, by taking a shade map, or by using shade-selection software. The dentist must be able to transfer this information correctly to the ceramist. If working with a ceramist locally, a dentist may have the luxury of doing custom shade matching. However, many dentists use laboratories that are in a different part of the city or state or often in another country.

A good knowledge of digital photography and the ability to translate all of this information to the laboratory are also artistic elements for the dentist. To learn these techniques requires looking at teeth a lot, studying a good tooth anatomy book, taking a waxing course, and understanding what ceramists look for. It is good to have an eye for detail when looking at teeth and to learn to observe embrasures, contact areas, outline forms, line angles, and reflective and deflective zones. It is important to understand what a tooth naturally looks like and to be able to copy it. This is the artistic component of working with teeth. Learning and practicing how to do direct veneers and direct resin mock-ups will accelerate one's skills and esthetic eye.

Most of the artistic elements that the patient sees in the final restoration depend on the talent of the ceramist. The challenge is finding a ceramist who has the skill to produce what dentists are looking for. A ceramist must understand how and have the ability to use different materials to create the perfect restoration. The ceramist must also be familiar with various materials so that the correct material may be chosen for the particular situation. He or she must be able to look at small things such as the mamelons, lobes, perikymata, and naturally occurring craze lines and must possess the talent to reproduce these in the finished restoration.

TREATMENT PLANNING

A good medical-dental history is essential. From this foundation, the clinician considers the following:

- Does the tooth need to be extracted?
- Is the tooth that needs a crown endodontically treated?
- Did the tooth have an existing post?
- If not, what type of post and core should be used?
- Is the tissue level at the right height, where the crown is needed?
- If the person fractured the tooth, was it right at the gum line?
- Did this tooth have a previous crown on it?
- When it was removed, was the tooth black? If so, is there a metal post in it?

The amount of ferrule on a crown preparation should be considered when planning an anterior all-ceramic crown. For example, a patient comes in with a crown from the upper right central incisor in hand; the crown obviously broke off at the gum line. The remaining tooth structure is less that 2 mm in height, and the dentinal wall is less than 1 mm thick. This tooth is at risk of not surviving longer than 5 years. Decisions must be made at the treatment-planning stage. Is it necessary to use orthodontics to extrude that tooth? Is crown lengthening needed, or is it best to extract the tooth and consider the option of an implant and an implant crown? These are some of the things dentists must consider when sequencing treatment. Before color, shape, and so on are contemplated, the viability and prognosis of the tooth must be determined.

Relative to the tissue around the tooth, is the tissue healthy? Is the gingival height the same on the two central incisors? Does it look natural next to the surrounding teeth and soft tissue? Is there tooth and gingival symmetry? Does any periodontal work need to be done before the crown is inserted?

Once the dentist has looked at the remaining tooth structure and assessed the specific situation and the surrounding tissue, the color of the final restoration is considered. Patients usually ask whether they can bleach the teeth. Should they do that before the crown procedure or after? In most instances when a person is going to bleach the teeth, it is best to do the whitening first, then wait 2 weeks before proceeding with crown preparation. If the color is not satisfactory to the patient, further whitening will be planned. If the tooth cannot be whitened to specifications, porcelain veneers might have to be included in the treatment plan along with the single crown.

Another thing to consider is the dark-tooth single crown in which the patient has undergone endodontic treatment but has received no post. If there is an endodontic access, should the dentist internally bleach the tooth to increase the color of the preparation shade? If internal bleaching is planned, it is accomplished before preparation of the entire tooth. If there is a metal post, can it be removed safely without causing iatrogenic damage to the remaining tooth structure or catastrophically fracturing the tooth?

TREATMENT CONSIDERATIONS

As an example, a dentist is planning to restore a maxillary central incisor, and the goal is to match the other one exactly. What steps must be taken from start to finish?

To begin with, it is helpful to mock up the tooth with composite to make it anatomically match the adjacent central. Soft tissues should be of the same height. If they are not, a soft tissue

همیار دندانسازان و دندانپزشکان

laser is used to correct any minor tissue discrepancies. A polyvinyl impression is taken and set aside for making an acrylic provisional restoration after tooth preparation. The patient is sent home, having seen the mock-up of the corrected tooth looking as good as possible and with the soft tissue architecture looking ideal.

A digital photograph of the desired shade of the final restoration is taken using a digital single-lens reflex (SLR) camera, making sure that the shade number is captured along with the shade tab. The shade tab is placed next to the tooth being restored, making sure the shades of the adjacent teeth are captured at the same time. This is a good time to take the photograph because the teeth are moist and the color is true. If the shade is taken after tooth preparation, a higher-value shade may be mistakenly recorded owing to desiccation of the teeth.

The patient is anesthetized with local anesthetic, and tooth preparation begins with a depth cut bur used to make depth cuts on the facial, lingual, and incisal surfaces of the tooth. Changing to a coarse bullet-nosed chamfer diamond bur (856-016), interproximal separation cuts are made so that the preparation is free of the adjacent teeth. Next the bur is used to scribe the buccal and lingual margins of the future crown supragingivally on the preparation. With all the depth cuts complete, the incisal, facial, lingual, and interproximal reduction is completed by "joining the dots" circumferentially. After the crown preparation is roughed out, a fine red-stripe diamond chamfer finishing bur (856-016) is used to define the finish line and to make certain everything is smooth. A football-shaped red-stripe fine diamond bur is used to finish the lingual wall of the preparation. The preparation is checked to ensure there is at least 1.0 to 1.5 mm axial reduction, 1.5 to 2.0 mm incisal reduction, 1.0 mm reduction at the gingival margin, and 1.5 mm lingual contact clearance. Sharp corners or edges are eliminated.

The healthy placement of the margin is important, so a periodontal probe is used to measure or "sound" the distance from the gingival margin to the osseous crest in the facial, midfacial, and interproximal areas to ensure the margin placement does not violate the biological width. Before impression taking, a two-cord technique is used for tissue retraction. A No. 0 or 00 cord is placed in the sulcus and an Astringident-impregnated No. 1 cord is placed circumferentially around the tooth and left in. The definitive margin is refined and finished.

To polish the preparation, a medium Sof-Lex disk (3M ESPE) is used, taking out all the sharp corners and making sure all is smooth. In a second check, adequate reduction is determined with the patient sitting up, and the angulation of the preparation is checked to make sure the long axis inclines slightly mesially to the midline.

In the impression part of the procedure, a bite registration is taken for the crown using polyvinyl bite registration material. The lower opposing arch impression is taken with alginate substitute or polyvinyl or alginate. For the upper restoration impression, self-retracting retractors are placed, then a stock crown and bridge tray is tried in to make sure there is plenty of room. The tray should not bind in the first or second molar region to be considered a good fit; if it does, it is too small. The tray is then painted with adhesive to make sure the impression material does not separate from the tray. There are many different materials for taking an impression. The author's preference is either heavy- or medium-body fast-set polyvinyl siloxane (PVS) and a wash using extra-light-body fast-set PVS.

Triple trays can be used cautiously for a single anterior crown; however, the full-arch impression will prevent any articulating inaccuracies. In the case of a single posterior crown when the crown preparation is not the most distal tooth, a triple tray can be used routinely. The tray should be a reinforced one that is unlikely to distort with impression taking.

The impression-taking process is begun by having an assistant load the heavier body impression material, either by hand or using a Pentamix device (3M ESPE), into the impression tray. Material does not have to be loaded on the palate portion of the tray. It is important to ensure there is an even depth of impression material in the tray.

As the assistant is filling the tray, the dentist removes the larger No. 1 cord, leaving the No. 0 or 00 cord in place as he or she syringes extra-light-body material with the tip all the way around the margin of the tooth preparation, on the adjacent teeth, and on the occlusal surfaces of the posterior teeth. When the assistant hands the dentist the tray, the small tip at the end of the mixing tip is removed, and some light-body material is injected on top of the heavier-body material in the tray. The impression is inserted into the mouth. The tray should not be moved back and forth or rotated after placement. The assistant holds the tray in place with light pressure over the posterior teeth. The retractors are removed, and the material is allowed to set. The impression is removed; verification is made that the margins and detail have been accurately captured. The impression is placed in a container with the opposing arch and bite registrations for the dental lab.

The color of the core and the preparation makes a difference in the restoration. Preparation shade is documented using a 35-mm digital photograph. This can be emailed to the laboratory. The picture of the preparation shade is taken, making sure the preparation shade number on the tab is recorded as well. All the details are listed on the lab slip and transferred to the laboratory, including the material to be used to make the crown, the final shade of the restoration (cervical, body, and incisal shades), the color and amount of incisal translucency, the degree of surface texture, and surface characteristics such as hypocalcification and maverick colors.

In order to make a provisional restoration, Luxatemp (DMG Chemisch-Pharmazeutische, Hamburg, Germany), Integrity (DENTSPLY Caulk, Milford, Delaware) or any self-curing acrylic can be used. The teeth are isolated with self-retracting retractors again. The remaining retraction cord is removed, and the preparation is cleaned with a 0.12% chlorhexidine solution, rinsed with water, and left slightly moist.

Acrylic is placed into the original triple-tray impression set aside earlier. A tip for injecting Luxatemp and not getting an air bubble or void when injecting into the polyvinyl impression is to keep the dispensing tip down and move it back and forth as the acrylic is being dispensed into the pre-operative impression of the crown. It is important to be generous with the acrylic and not to underload the impression.

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The tray is positioned over the arch with the prepped tooth. The patient bites into the tray, and after about 2 minutes, the triple-tray impression is taken out. The new provisional crown will either come out with the impression or remain on the tooth. If it comes out with the impression, the tray is re-seated and allowed to set for an additional 2 minutes. If it remains on the tooth, the dentist must ensure that the crown can be carefully eased off the tooth and not shrink-locked onto the tooth preparation. The temporary crown is replaced back on the tooth preparation and allowed to set.

The set provisional crown is removed from the mouth and checked to make sure the margins are intact and that there are no voids. If voids are present, a similar shade flowable composite resin such as LuxaFlow is used to make repairs.

The acrylic crown is trimmed with a 3M medium disk on a slow-speed handpiece. The same polishing tips such as those used for composite, such as Astropol, can be used for fine finishing. Polishing is done with a bristle brush to obtain a dull shine. A clear uncondensed resin is applied, such as BisCover (Bisco, Schaumburg, Illinois), LuxaGlaze (DMG America, Englewood, New Jersey), or G-Coat Plus (GC America). This clear unfilled resin allows one to achieve a surface that appears like glazed porcelain. The glaze is light cured with a curing light. The crown is cemented with dual-cure provisional luting cement such as Systemp.link or Telio CS Link (Ivoclar Vivadent). A self-curing provisional cement such as TempBond (Kerr Corporation) may be used; however, the opaque shade may not be desirable in the anterior region. TempBond Clear or any undetectable shade of provisional cement may be used as long as all of it is removed at the seat appointment and it does not hinder the seating of the final restoration.

The excess cement is removed and the restoration is light cured or allowed to self-cure. The occlusion is checked on the temporary crown after it is cemented in place. A final impression is taken of the provisional restoration so that the laboratory can copy the provisional's shape and position, especially if it had been mocked up.

In finishing the restoration, much communication goes on with the laboratory. The lab may want a gingival shade selection. The patient may go to the lab for a custom shade. The patient may also come back with changes to the provisional restoration that must be transmitted to the lab either by phone or through a new impression.

The definitive crown is made with the ceramic material of choice by the dental laboratory. The restoration is inspected on the cut die, the working model die, and the duplication of the uncut die. A soft tissue model may be sent with the case to check that the emergence profile of the anterior teeth looks good.

At the seat appointment, the provisional crown is removed to make sure that no food or bacteria are present on the tooth preparation. It is cleaned with 3% hydrogen peroxide and rinsed with water. The restoration is tried on to make sure that the margins can be observed. All margins should be tight, with no gaps. In checking the contact areas, the tooth contact location and tightness should be appropriate. Dental floss should pass through the contact with a nice snap. The occlusion is lightly and carefully checked in the restoration. The patient should be cautioned not to clench down. The restoration is never checked to see whether it is high enough this early in the seating process, to eliminate any chance of damaging the restoration. Adjustments are made as needed with a fine finishing diamond, and the restoration is polished with a porcelain polisher (CeraGlaze [Axis Dental, Coppell, Texas]).

The crown is then tried in with water or a clear glycerin to see what the actual shade would look like with transparent cement. This helps in selecting a final cement shade for the situation. The restoration is tried in and the tooth assessed under various different lights, for example, in the operatory light, under the halogen light, and in natural daylight. It is helpful to take a digital photograph of the crown to verify that the shade, shape, and surface texture of the crown are satisfactory to both the patient and the dentist. Various shades of glycerin try-in paste can be used to alter the color if the patient is dissatisfied. If a good color match is impossible using the try-in pastes and the restoration is too dark or too light, it is sent back to the lab for modification. It is easier to lower the value of a restoration in the incisal that is a bit too bright than to brighten a restoration that is too low in value. The restoration may have to be remade if the color or the value is completely off. Any remake may involve a different ingot or different porcelain shade to make it match. When everything looks acceptable, it is time to cement the restoration. If the intaglio surface of the crown was adjusted or heavily contaminated, it is etched with hydrofluoric acid porcelain etch for a minute and rinsed with water. If it was simply tried in with try-in paste or water, reactivating the surface of the restoration with 35% phosphoric acid for a minute and rinsing with water and drying are adequate.

Silane is painted on the intaglio surface of the crown and left in place for a minute before drying. Depending on the viscosity of the resin cement used, an adhesive resin bonding agent may or may not be needed. If the crown is to be luted with a low-viscosity cement like Variolink Veneer (Ivoclar Vivadent) or RelyX Veneer Cement (3M ESPE), a resin bonding agent does not need to be painted on the inside of it.

If possible, isolate the teeth with a rubber dam. The tooth preparation is etched for 15 seconds (dentin for 10 seconds and enamel for 15 seconds), taking care not to etch the teeth adjacent to it. The acid etch is rinsed off, leaving the tooth slightly moist. The adhesive bonding agent of choice is applied. The adhesive is scrubbed or rubbed on the tooth for 20 seconds. High-volume suction or the warm-air tooth dryer (A-dec, Newberg, Oregon) can be used to evaporate the solvent for 10 seconds. The adhesive on the tooth is light cured with a curing light for 10 seconds. If for any reason the gum starts to bleed, the bleeding can either be stopped with 35% hydrogen peroxide, a clear Astringident, or a diode laser. A repeat of the etching procedure is highly advisable because bleeding under an all-ceramic crown leads to microleakage from areas that are not bonded, and ultimately failure or discoloration of the restoration.

After the tissues are isolated and the tooth is etched, bonded, and ready, resin cement of the desired shade is placed inside the crown, making sure that the margins are covered. The crown can be held with a Pic-n-Stic (Pulpdent Corporation, Watertown, Massachusetts) or OptraStick (Ivoclar Vivadent) to facilitate its

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placement. Both of these are placement instruments that feature a flexible adhesive tip. The tip allows restorations and small objects of all kinds to be picked up.

The crown is placed onto the tooth preparation and seated. There will be an excess of cement. Today's curing lights are powerful enough to go through the entire restoration, so there is no need to use dual cure cement. Using an instrument such as a ball burnisher to keep the crown seated down, the center of the restoration is cured by spot tacking for 2 seconds with a 2-mm tacking tip. The excess cement can be cleaned off with Microbrushes and a Butler rubber tip (Sunstar Americas, Chicago, Illinois). Alternatively, one can wave the curing light for 2 seconds over the buccal and lingual margins to partially set the excess cement and then peel it off. Care is taken not to cure the cement interproximally.

Flossing is performed interproximally on both sides of the crown, pulling through the excess cement interproximally. Glycerin is injected around the margins to make sure the oxygen-inhibited layer will be cured. The restoration is final cured on the incisal or occlusal, buccal, and lingual surfaces for 20 seconds per side with conventional or light-emitting diode (LED) light curing. A curette or scaler can be used to chip off little bits of the cement that are left over. If needed, a 32-blade carbide finishing bur can be used to remove the excess and smooth the marginal area. Diamond burs are avoided because they tend to scratch the restoration, dentin, or cement.

A pencil can be rubbed along the surface of the porcelain, which will mark excess cement but not porcelain. A No. 15 Bard-Parker blade is used to remove the excess cement from the surface of the porcelain.

Occlusion is checked with articulation paper with the patient sitting up. The patient bites the teeth together to see where centric contact is. The contact is adjusted if necessary with a football-shaped fine diamond bur. The lateral and protrusive excursions are checked. Any streaks should be even and perfected. Floss is used to check interproximal contacts again. Any adjustments made on the crown are polished with porcelain point, wheel, and cup finishers and polishers such as CeraGlaze.

The patient is dismissed with instructions to return for occlusal adjustments if needed after the local anesthetic wears off.

EVIDENCE-BASED PRINCIPLES

A lot of the evidence in the literature involves studies with all-ceramic materials. Single crowns have been studied extensively. Most of the materials, especially the older materials, have 5 years of follow-up, which bodes well for the single crown. Clinical long-term studies have verified the usefulness of the various materials, including Empress, In-Ceram, and Procera. The zirconium restorations are new and seem to be the hot item in dental materials right now. Several longer-term studies involving zirconium restorations are being done. The concern for most people is whether the restorations will hold up over time. Lithium disilicates have been around since 1999, and over the past 10 years or so there have been a lot of long-term studies on single units. Evidence shows these are reliable materials. The only change now with the materials involves bringing the core to the occlusal surface. Studies show that the material is not abrasive to the opposing teeth.

CLINICAL CONSERVATION CONCEPTS

These restorations technically need a 1-mm reduction or a 1.5-mm occlusal reduction, and that is fairly conservative. The PFM could be made very thin but would never hide the gold. The average reduction is 1.2 mm, with 0.2 mm for the gold core and 1.0 mm for layering ceramic. Some other restorations require more ceramic to hide the core. The zirconium may necessitate more preparation, but it is possible to make the zirconium core as thin as 0.5 mm. These restorations on the whole are fairly conservative.

Gold is still the best choice in the posterior from a biomechanical conservation of tooth structure point of view. A gold crown can be 0.2 mm thick and be functional for a fairly lengthy period, which is not true of ceramic. However, few people want to have a full set of gold crowns on their anterior teeth!

MAINTENANCE

Patients should be advised to not do with these restorations what they would not do with their natural teeth. It is unwise to bend wire or fix jewelry with the restorations because of the risk of chipping. In terms of hygiene, brushing, and flossing, regular general maintenance is sufficient. Abrasive toothpaste, such as Pearl Drops, can take the glaze off. When patients come for hygiene, the hygienist should not use a coarse polishing paste. Instead a fine product such as Proxyt (Ivoclar Vivadent) should be used. These are designed to not remove the finish from the restoration.

The only controversy that exists with the increased use and popularity of all-ceramic restorations is that dentists are divided about them. "Old school" traditionalists feel that they should not base the use of all-ceramic restorations on what their patients want. They say all-ceramic crowns should not be used on molars because they will fail. Some of the controversy involves the facts that all-ceramic crowns can fracture and that they lack the depth of evidence-based research of PFM crowns. It is the longevity issue versus the esthetic issue.

However, the drive for esthetics and the desire to have teeth look like teeth lend good support to dentists who are willing to try the most esthetic restoration in the appropriate situation.

Empress restorations should not be placed in a high load area—they will break. The advantages of this material are its esthetics and its versatility in the anterior region. It is also a conservative restoration, as the total amount of tooth reduction is less than that of a standard PFM restoration.

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Near-Future Developments

Continued advances in dental laboratory CAD-CAM and chairside CAD-CAM are rapidly progressing. More than 10,000 dentists in North America are now using CAD-CAM and have the ability to mill all-ceramic restorations or restorations made of other materials chairside.

Currently the technology exists for dentists to make a digital impression and mill a crown chairside, or mill multi-unit bridges chairside. The dentist can choose to design a crown with the CERECi or E4D machine, mill the restoration out of a lithium disilicate block, place it in an oven to sinter for 35 minutes, add external stain, and have a good-looking e.max lithium disilicate posterior crown all fabricated chairside in about an hour. The possibilities are endless. Growth depends on whether the dentist chooses to give this work to a chairside auxiliary or ceramist or chooses to have a lab perform it. It is a major investment to have all this equipment, and an investment in time and money to do this chairside. If it is worthwhile or the dentist can assemble a team that does it, it can be very profitable and satisfying.

On the lab side, CAD-CAM continues to evolve, allowing dental labs to mill restorations and finish them in a more cost-effective and efficient manner.

Advances in ceramic science are focusing on development of materials that exhibit esthetics and translucency with good strength and physical properties. If the material can be bonded to the tooth, that would be a bonus.

The quest for the "Holy Grail," the perfect all-ceramic crown material, continues.

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Ceramics: Porcelain-Fused-to-Metal Restorations

Gary Radz

RELEVANCE OF PORCELAIN-FUSED-TO-METAL RESTORATIONS TO ESTHETIC DENTISTRY



FIGURE 20-1 Some examples of porcelain-fused-to-metal restorations.

Porcelain-fused-to-metal restorations provide the opportunity to restore damaged, nonfunctional teeth to proper function and esthetics (Figure 20-1). These restorations have been among the most popular and most heavily used restorations in dentistry over the last 50 years. Porcelain-fused-to-metal restorations have a long history of clinical success and provide the opportunity to give patients an esthetic option to rehabilitate damaged teeth. Any tooth can be restored with porcelain fused to metal.

For an esthetic approach to restoring a tooth, the dentist needs to consider the patient's concerns and desires. Most often the anterior teeth and those that are visible when a patient speaks or smiles are chosen for esthetic restorations. This not only includes the anterior teeth but in many patients includes teeth as far back as the maxillary first molar, which is still a tooth to be considered when overall smile esthetics are evaluated. Molar teeth, even mandibular second molars, are often considered for porcelain-fused-to-metal restorations. These restorations are more frequently requested and done than any other indirect restorations.

Photography provided by Gary Radz, DDS, (Vident, Brea, California) and Amos Harding, CDT, (Captek, Altamonte Springs, Florida).

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

Initially in dentistry, full-coverage restorations were performed using cast metals. About 50 years ago, as the demand for more esthetic restorations was developing, dentists started using acrylics and placing acrylic facings onto the cast metal restorations. For a period of time this provided a full-coverage restoration with some esthetic value. About 15 years later, new techniques were developed so it was possible to fuse porcelain to a metal casting and thereby provide a far superior, more esthetic full-coverage restoration. This began the advent of the porcelain-fused-to-metal restorations available today. As ceramics and techniques have improved, the porcelain-fused-to-metal restorations have become more and more esthetic.

RELATING FUNCTION AND ESTHETICS

When a tooth has been damaged to the point that it requires a full-coverage restoration, it is of primary importance that the tooth be returned to proper function. For patients who desire an esthetic final restoration, the use of porcelain fused to metal allows the dentist to create a final esthetic restoration that achieves the return to full function. The function of the crown is to protect the tooth from further damage and to restore proper anatomy so that the lost structure is restored. By using the porcelain-fused-to-metal restoration, the dentist can restore function with a tooth-colored esthetic replacement.

In some situations, proper restoration of function is difficult to achieve in an esthetic manner. For example, a patient who has a history of bruxing or clenching may demonstrate a lot of tooth wear. Some of these patients have the potential to fracture porcelain. With such patients, a full-coverage restoration in full cast metal is more appropriate because of the increased risk of fracturing a porcelain structure.

In addition, depending on the patient's occlusion, porcelain may be in the functional pathway and, because of porcelain's

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FIGURE 20-2 A lower first molar with a large restoration and a fractured distal buccal cusp.

abrasive nature, can cause wear on the opposing dentition. In these situations the dentist may be inclined to place metal as opposed to porcelain in the functional pathway.

CLINICAL CONSIDERATIONS

Indications

Any time teeth have been damaged by trauma, decay, or tooth fracture and/or heavily restored, those teeth are structurally compromised (Figure 20-2). These are good candidates for porcelain-fused-to-metal restorations. In addition, patients who have high esthetic demands or requirements may be treated with a porcelain-fused-to-metal restoration. This choice allows the dentist to create a restoration that can visually restore the tooth to its proper esthetics.

Contraindications

The primary contraindication would be if the crown preparation cannot achieve sufficient occlusal clearance. This means 2 mm for the porcelain-fused-to-metal restoration. Another contraindication would be concern about porcelain wearing the opposing dentition when functional occlusion is restored. Porcelain would not be appropriate in a functional pathway. Instead cast metal would be more desirable.

MATERIAL OPTIONS

Metals

There are a number of different material options for the metal substrate of the porcelain-fused-to-metal restoration. The major classes are base cast metals, high noble metals, and semi-precious metals. The advantages of each are partially based on cost. Base metals are inherently lower in price and tend to provide the structural integrity needed. These lower-cost restorations still provide for the patient's functional and esthetic needs. However, the dentist must carefully select patients in whom base metals are to be used. Dentists must be concerned about the biocompatibility of the metals. Base metals frequently contain nickel, which is associated with a high incidence of allergic reactions in patient populations.



FIGURE 20-3 A porcelain-fused-to-metal crown with a metal substructure that has a high gold content.



FIGURE 20-4 A powder-liquid mixture of porcelain is stacked onto the metal framework.

With high noble metals, restorations become a bit more expensive because of the cost of the material. These offer the advantage of better biocompatibility than base metals.

The semi-precious metals contain high percentages of gold, platinum, and palladium, all of which are even more biocompatible (Figure 20-3). These metals also tend to have a slightly better fit and even the potential for the margins to be burnished, which provides an enhanced clinical result.

Porcelains and Ceramics

Many different types of porcelain can be used. The industry standard for years has been the use of stacked porcelains, where a powder and liquid are mixed together on top of the metal to provide the final esthetic result (Figure 20-4).

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Numerous different ceramics are also available, with the selection often made based on personal preference of the dentist and/or on discussions with the ceramist.

Recently techniques have been developed wherein ceramics are actually pressed on top of metal. This provides another ceramic option to the dentist in obtaining an ideal end result. The pressed ceramics offer the advantages of ease of fabrication and slightly better strength.

Current Best Approach

The dentist must carefully consider the different options available for full-coverage restorations. Porcelain-fused-to-metal restorations are one of several different types of restorations available. Based on the patient's clinical needs, the dentist's experience, and the laboratory technician's input, the dentist must decide what type of full-coverage restoration to use. Often porcelain-fused-to-metal is an excellent choice to restore the tooth to proper function while fulfilling the esthetic requirements and demands of the patient. Depending on the dentist's experience and education and the ceramics used, porcelain-fused-to-metal restorations can be used for any tooth. Some dentists choose to use them more selectively in areas of high functional demand and functional stress. Porcelain-fused-to-metal restorations are also ideal for use as bridges and implant restorations (Figure 20-5). Porcelain-fused-to-metal bridge and implant restorations have a long history of clinical success.

OTHER CONSIDERATIONS

Other considerations for the use of porcelain-fused-to-metal restorations are based on the patient's esthetic demands and also depend on which teeth will be worked on, how many teeth will be restored, and the existing appearance of the teeth surrounding the one where the restoration will be placed. Porcelain-fused-to-metal restorations may or may not be the best choice. In today's dentistry, all-ceramic restorations have the potential to provide a slightly more esthetic final result. In cases of high esthetic demand, the clinician may decide that porcelain-fused-to-metal will not meet the requirements and choose an all-ceramic alternative.

INNOVATIVE ELEMENTS

Porcelain-fused-to-metal restorations have changed over the years to become more esthetic in nature. Improvements in available ceramics, which are more biocompatible, and the development of techniques that allow for stacking of porcelain have provided a more esthetic, more realistic, and more vital restoration. The ability to press ceramics on top of metal has allowed dentists to create a restoration that is stronger, has higher fracture resistance, and offers more durability in the long term. That development has allowed more predictable results in a system that was already highly predictable. Over the last 10 years the development of the metal coping itself has also contributed to the effectiveness of these restorations. The product Captek (Precious Chemicals Inc., Altamonte Springs, California) permits the use of a high–gold-content metal coping that is highly biocompatible and still offers high strength as a metal substructure. The Captek material has raised the esthetics and biocompatibility of porcelain-fused-to-metal restorations to an even higher level (Figure 20-6).

ARTISTIC ELEMENTS

For porcelain-fused-to-metal restorations to produce the best esthetic result and allow the artistic ability of the ceramist to contribute to this result, it is imperative that the dentist prepare the tooth properly. This means ensuring there is enough room to meet the requirements for a metal substructure that will support the weight of the porcelain and multiple layers of ceramic on top of the teeth. A primary aspect in achieving the final esthetic result is allowing the ceramist the room to artistically layer the porcelain in a way that creates vitality and natural color within the teeth.



FIGURE 20-5 Six-unit porcelain fused to metal bridge. Pink porcelain is used to simulate gingival tissue.

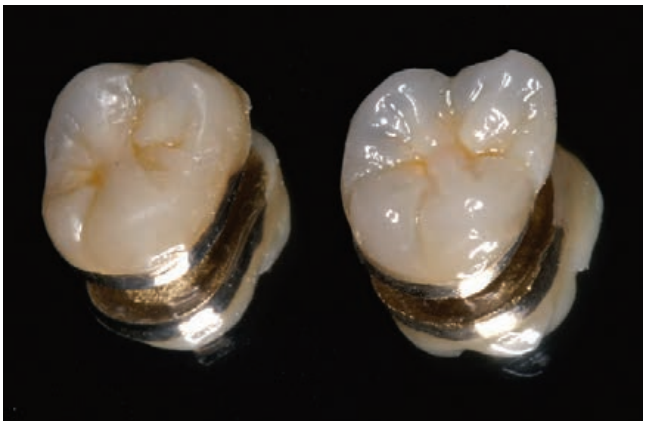


FIGURE 20-6 The high gold content of a Captek substructure offers excellent esthetics and biocompatibility.

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The dentist should also take advantage of the ability to share what is needed directly with the ceramist. This means using digital photography to ensure that the ceramist can see what he or she is trying to match. With good digital photographs, a dentist can communicate with any ceramist in any part of the world and show exactly what the adjacent teeth look like to convey the final desired esthetic outcome (Figure 20-7).

TREATMENT PLANNING

Options and Sequence

When a patient comes to the dentist with a tooth that is compromised or potentially compromised and requires a full-coverage restoration, first the dentist must determine what type of crown will be best. Several options must be reviewed, as the dentist seeks to understand the desired end result and how the patient's desires can mesh with current restorative materials. The different options in a crown restoration include cast metal, most often a full gold crown restoration; a porcelain-fused-to-metal restoration; or a restoration with a zirconium-based material. The dentist should also look at all-ceramic alternatives. Depending on the patient's desires, the clinical status of the occlusion, the amount of tooth left, and how much tooth can be reduced, the dentist must determine which specific material will provide the best end result. Assuming that the patient has chosen a porcelain-fused-to-metal restoration, the clinical requirements for preparation to allow for the appropriate fabrication are as follows:

- There must be a minimum of 2 mm of occlusal reduction.
- The axial walls of the teeth require 1.2 to 1.5 mm of reduction, depending on the tooth in question and the desired functional and esthetic result.

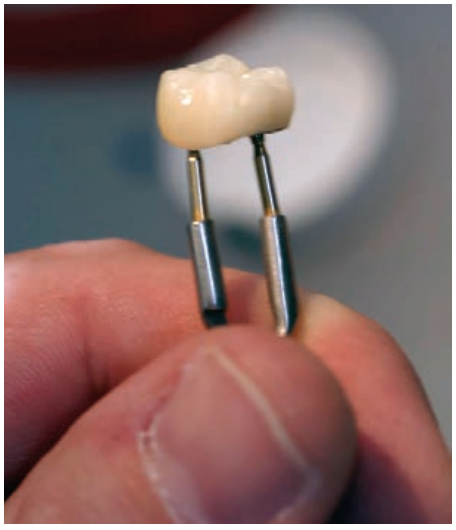


FIGURE 20-7 The ceramist creates the porcelain-fused-to-metal crown using a variety of shades and opacities to meet the dentist's requirements.

Several different margin designs can be used with porcelain-fused-to-metal restorations. One margin design is the use of a chamfer (Figure 20-8, *A*). When a chamfer arrangement is used, the margin can be in either metal or porcelain. The esthetic result is slightly compromised if the dentist tries to take porcelain to the chamfer margin because there will be a small area that tends to be slightly opaque. The chamfer design is an excellent design if the dentist wants to end the margin of the crown in metal.

Having the margins end in metal is desirable because it allows for an excellent, intimate marginal fit and permits excellent biocompatibility. However, it compromises the esthetic result of the crown.

If crown esthetics are imperative, a shoulder margin (Figure 20-8, *B*) should be placed on the facial or buccal surface so a minimum of 1 mm of porcelain can be stacked at the margin, thereby hiding the metal coping and providing a tooth-colored

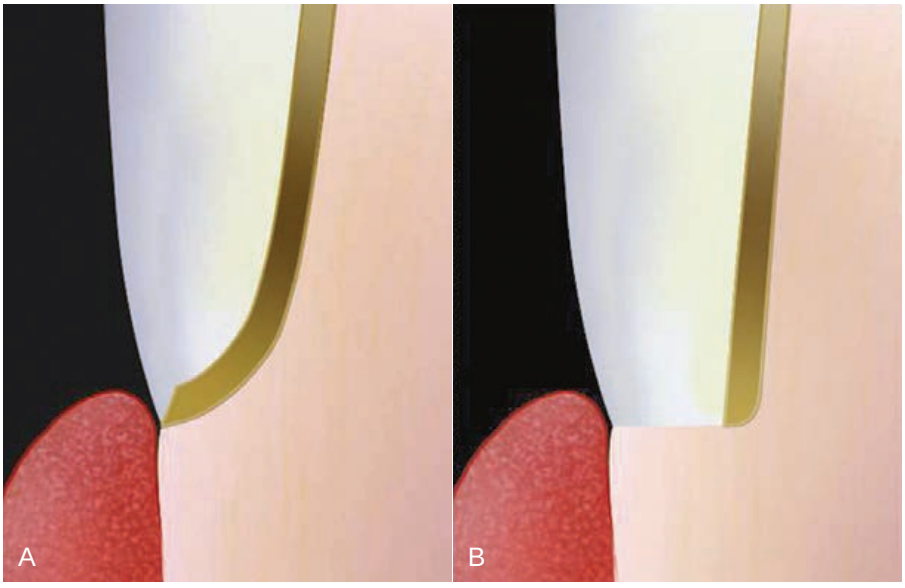


FIGURE 20-8 A, Chamfer preparation margin for a porcelain-fused-to-metal crown. B, Shoulder preparation margin for a porcelain-fused-to-metal crown.

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esthetic result that abuts where the porcelain crown meets the tooth preparation.



FIGURE 20-9 A premolar that has a post and core placed demonstrates a porcelain-fused-to-metal preparation where 2 mm of natural tooth are present at the apical aspect of the margin.

TREATMENT CONSIDERATIONS DURING PREPARATION, PROCEDURE, AND FINISHING

Preparation and Procedure

During preparation the dentist must create adequate occlusal clearance. Porcelain has the potential to fracture when it is too thin, so the dentist must take time to ensure that there are 2 mm of clearance between the opposing dentition from the top occlusal aspect of the final preparation. The inability to create adequate room will leave the restoration with an increased potential to fracture in the future.

Another important aspect of preparation design is proper axial reduction. For the final esthetic result an absolute minimum of 1.2 mm, and more ideally 1.5 mm, should be reduced around the tooth to provide adequate room for the ceramist to stack the porcelain and create an esthetic result. The dentist must look at the clinical situation and decide whether esthetics is the primary concern. If so, the shoulder margins should be placed slightly below tissue height. Using retraction cord the soft tissue should be displaced apically so the margins can drop slightly below the tissue height, then the shoulder preparation is performed. The shoulder needs to be a minimum of 1.0 mm deep in an axial direction.

For other marginal considerations in areas that are not of esthetic concern it is more ideal and more biocompatible to have a metal margin. One of the benefits of porcelain-fused-to-metal restorations is that the cast metal coping can be extremely thin at the margin. If there is a chance that the dentist will need to slice the margin, porcelain-fused-to-metal offers the ability to take the metal coping and allow for metal to be placed at the margin. This creates a better marginal fit and better biocompatibility.

The preparation design axially should follow the inclinations of the tooth, especially with anterior teeth that exist in more than one plane or aspect. The clinician should follow the different planes of the tooth in their preparation so that adequate reduction would be achieved at all three aspects—the cervical aspect, the mid-body aspect, and the incisal aspect.

With teeth that have been restored with a post and core, it is important, if not imperative, that adjacent to where the post and core meet the tooth there are 2 mm of natural tooth in the marginal aspect of the preparation (Figure 20-9). This is the cardinal rule and has been proven numerous times. This 2-mm width of natural tooth must be present apical to the tooth and where the post and core or core buildup has been placed.

Finishing

When the porcelain-fused-to-metal restoration is placed in the mouth, a critical aspect for its longevity is making sure ideal occlusion is achieved. The occlusion can be adjusted in the office. When adjusting an occlusion the dentist should use a fine diamond bur and water spray. Once the occlusion has been adjusted to the ideal, the adjusted areas need to be addressed in one of two ways. It is certainly possible, and to some people ideal, to reglaze the restoration in the dental office; or the restoration may be returned to the lab for glazing.

Haywood, Heymann, and Scurria demonstrated a simple in-office procedure that allows for repolishing of the porcelain to a surface that rivals a glazed surface. Using the following sequence the final polishing of porcelain can be equal to or possibly surpass the state of the glazed surface. The areas that have been adjusted are now polished by first using a No. 30 carbide finishing bur at high speed with no water spray. This is followed with a series of rotary rubber porcelain polishing systems at various levels. These polishing systems are available from several different companies. For repolishing, the dentist adjusts the porcelain with a series of rubber polishers to achieve a final surface equal to if not better than a glazed surface.

EVIDENCE-BASED PRINCIPLES

Fifty years of clinical experience and research using porcelain-fused-to-metal restorations has demonstrated excellent clinical success over time, whether the porcelain-fused-to-metal restoration is used as a single-unit crown, an implant restoration (Figure 20-10), or a multiple-unit bridge restoration. Porcelain-fused-to-metal restorations have excellent longevity and excellent clinical success, providing dentists with the confidence to prescribe this particular restoration at extremely high frequency. These restorations have also allowed for many patients to have a functional and esthetic replacement for a severely damaged tooth.

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FIGURE 20-10 An implant-supported porcelain-fused-to-metal bridge.

CLINICAL CONSERVATION CONCEPTS

With porcelain-fused-to-metal restorations the dentist can be conservative in areas that do not require ceramic coverage. These areas do not have to be prepared as deeply, conserving tooth structure. In an area where only metal will be on the restoration, a millimeter of reduction is all that is required. Porcelain-fused-to-metal restorations allow for dentists to be selective regarding where they need to prepare the tooth. Areas that will not be covered with porcelain will not require the same amount of reduction as areas that will be receiving porcelain. Specifically, this will involve posterior teeth that have very short clinical crowns. In these areas it is possible for the dentist to cover the occlusal surface with metal and the buccal surface in porcelain. The metal occlusal surface does not require as much reduction as it would if it were to be covered in porcelain.

MAINTENANCE

Patient maintenance of porcelain-fused-to-metal restorations should be very similar to what patients do for their natural teeth. This includes regular brushing and flossing and occasional professional attention to remove plaque buildup and/or calculus. The patient should be made aware that the porcelain surface can be scratched by certain toothpastes and other abrasive materials. This will leave the surface dull. The dentist or dental professional should inform the patient to choose tooth-cleansing materials carefully. For example, the dentist should highly discourage patients from using baking soda. Baking soda, although it was once a popular tooth cleanser, is a highly abrasive material and can scratch the surface of the porcelain. Toothpastes that promote their whitening capabilities also often contain abrasive materials that are used to scratch stains off the surface of natural teeth. Those same substances will also scratch and abrade the porcelain surface. Patients should therefore avoid abrasive cleansers such as baking soda and whitening toothpastes. Proper brushing and flossing will maintain the surface and color of the teeth as well as products that claim to whiten.

CONTROVERSIES

The porcelain-fused-to-metal restorations have a very long and successful history of providing replacements for damaged teeth. Concerns have been raised over the last few decades regarding esthetic concerns when these restorations are placed anteriorly and meet the soft tissue at the marginal area. This area can be un-esthetic and unacceptable to the patient. With the development of all-ceramic restorations, it is now possible to avoid this esthetic problem by eliminating the metal. All-ceramic restorations give dentists the ability to overcome that objection and offer a potentially more esthetic alternative. However, all-ceramic options are newer technology and are still being explored. The all-ceramic technology tends to be more controversial because it is compared with the "gold standard" of full-coverage restorations, which is the porcelain-fused-to-metal restoration.

With respect to clinical success, longevity, and predictability, porcelain-fused-to-metal restorations offer no controversy. They are proven to work well with the tooth and to withstand the test of time.

NEAR-FUTURE DEVELOPMENTS

The most exciting thing in porcelain-fused-to-metal restorations is the ability to press ceramics on top of the metal coping. Pressed ceramics are inherently stronger in all physical properties than stacked porcelain. The ability to press ceramics and create that stronger restoration is very exciting. The pressed ceramic also allows for faster fabrication of the restoration. Going forward in porcelain-fused-to-metal technology is the most exciting technologic development lately in an area that has been relatively stable for a long time.

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Porcelain-Fused-to-Metal and Zirconium Crowns and Bridges

Robert A. Lowe

RELEVANCE TO ESTHETIC DENTISTRY

To put things in perspective, this chapter looks first at the development of porcelain-fused-to-metal (PFM) restorations and then introduces zirconium as it was developed. PFM crowns in dentistry have been the mainstay of esthetic restorations since facings were first placed on the facial surfaces of gold crowns. In the 1960s and 1970s dentists did acrylic or ceramic facings in gold restorations as the esthetic alternative to a full-coverage crown for anterior teeth. They were also the mainstay for posterior teeth when crown restorations were needed. When it was discovered that porcelain could be fused to metal through an oxide layer, this offered a significant improvement in the esthetic quality of the restoration that could be delivered. PFM has been actively used as an anterior crown, posterior crown, and bridge restoration material for esthetic dentistry for several decades. About 70% of the laboratory work done for indirect restorative procedures is PFM, so this technique is probably the most widely used esthetic restoration offered. Since computer-generated materials and processes have come into vogue, specifically termed *computer-aided design and manufacturing* (CAD-CAM), laboratories have been able to mill both ceramic restorations and understructures out of metal and out of zirconium. Zirconium offers a benefit over conventional PFM in that it has a very light tooth like color and is dimensionally stabile during the firing process when the veneering porcelain is added. One of the challenges of PFM is hiding the color of the metal by layering ceramic on top of it. The goal is to produce a naturally colored, translucent tooth. Zirconium offers the dentist more leeway in the ability to create a beautiful, translucent, tooth-like restoration.

RELATING FUNCTION AND ESTHETICS

Dr Harold M. Shavell has stated that "if it looks good, it functions well; and if it functions well, it looks good." If this is the case, the requirements of dental restorative materials have been met. The materials must be strong enough to withstand masticatory forces yet still look tooth like and esthetic. The aim of every dentist using indirect restorations is to create a facsimile of natural tooth form while recreating or replacing lost function resulting from dental disease, caries, or extraction.

The advent of dentin bonding and high-strength microcrystalline porcelain has moved dentistry toward the ultimate goal of a long-lasting tooth-colored restorative material that can be micro-mechanically or chemically affixed to tooth structure. This helps create a restoration that resembles natural tooth structure and at the same time has strength and longevity.

CLINICAL CONSIDERATIONS

Indications

The indications for PFM and zirconium overlap, and the requirements for tooth reduction or preparation are quite similar. A full-coverage PFM restoration is indicated when the tooth structure is so badly broken down that it requires a complete crown. These teeth could be endodontically treated teeth with posts and cores or heavily restored teeth that were filled with amalgam or composite restorations but suffered recurrent decay or damage that could not be addressed by direct filling material. Whether the indicated indirect restoration will be an inlay or onlay, which conserves some surrounding healthy tooth structure, or whether it will be a full-coverage restoration, such as a crown, depends on the amount of healthy tooth structure that remains. The clinical indications for these restorations are to restore badly decimated posterior and anterior teeth with full-coverage restoration in an esthetic fashion.

Contraindications

The contraindications deal with the delivery and cementation when there is inadequate tooth structure for resistance and retention form. With conservative clinical preparation, dentin bonding and total etching increase the retention of the restorative materials. It is not possible to etch zirconium or PFM to gain the same micro-mechanical retentive quality seen with an all-ceramic restoration, although there is great promise with the addition of zirconium primers, which are helping to increase the bond strength of zirconium and metal to tooth structure. The author generally draws the line at a preparation height of 3 mm or higher. If the height from the exit of the gingiva to the top of the preparation (axial height) is shorter than 3 mm, it is preferable to use total etch and dentin bonding to gain

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additional retention and restore the tooth. (The limit is 2.5 mm of axial height remaining.)

MATERIAL OPTIONS

A range of materials is available, beginning on the laboratory end at the material from which the metal substructure is made. That metal substructure could be a non-precious metal, semi-precious metal, noble metal, or high noble metal. Higher noble metals with a higher gold content are more expensive, and non-precious metals are less costly. The cost of the fabrication for the PFM restoration is a factor of the metal used and the time ceramists need to build or stack porcelain on top of that metal. Zirconium restorations are more expensive than traditional non-precious or semi-precious metal or PFM restorations because of the CAD-CAM technology and the labor needed for milling. Once the zirconium or PFM understructure has been fabricated, the process of stacking the porcelain is virtually the same. Although many material options are available when ordering the standard PFM restoration, price and the specific laboratory used dictate many of the material choices.

Another PFM substructure with which dentists have considerable clinical experience is Captek (Precious Chemicals Company, Altamonte Springs, Florida). Captek composite metal is a combination of platinum, palladium, and gold. No oxide layer is needed for bonding to block out the metal. Captek offers several advantages over conventional PFM substrates such as a thinner, warmer substructure that has been shown to be more biologically compatible in the gingival sulcus.

In general, with PFM the metal substructure is dark and will not allow light transposition through it. Often it is difficult for the laboratory to create a cervical third of the restoration at a high enough value. When a brighter shade or higher value than A2 is needed, the technician faces the challenge of masking the low value of the metal without having the crown look too opaque or masking the gingival margins when light does not penetrate the metal substructure and illuminate the root. The marginal areas around PFM restorations create dark lines at the gingival area. For crowns in anterior areas and with patients who have high smile lines, this could be an esthetic problem.

Alumina and zirconium both have the advantage of being a substructure that is more tooth colored or lighter than the metal counterparts. Therefore the porcelain layered on top of it has less trouble blocking out the underneath color. These restorations tend to be more translucent and more lifelike and have less of a problem with dark lines at the gingival areas because of the lack of metal in the restoration.

OTHER CONSIDERATIONS

Alumina or zirconium can definitely be a more esthetic restoration than PFM, particularly in the gingival third and marginal area. The margin placement for esthetics is crucial for PFM, and that placement is usually subgingival or intracrevicular because these placements will mask or hide the dark line around the marginal area. This is much less critical with zirconium because there is no dark line. Clinically, the author uses an intracrevicular margin on the facial surface in two situations only:

1. If the tooth color or prep color is dark, as occurs with an endodontically treated tooth. In this case an intracrevicular margin is indicated to get a better esthetic result.
2. If the preparation is extremely short in the cervical incisal dimension, and an extra 0.5 or 1.0 mm of the axial surface is needed to increase the retentive property of the preparation.

In other cases an attempt is usually made to end the margins of the restoration either at the level of the gingiva or above. Both of those areas are much more esthetically pleasing with a zirconium than a PFM restoration.

INNOVATIVE ELEMENTS

From the scientific standpoint, PFM technology has changed little from the fabrication standpoint. There have been, however, advances in the types of porcelains that are used to cover the substructures. Today's porcelains shrink less, polish better, are more esthetic, and wear opposing dentition at a lesser rate than the older porcelain materials. Basically a PFM crown is constructed via the lost-wax technique to create the understructure. The dies are coated with wax and the understructure is designed in wax. That wax is invested on a refractory die and burnt out, then the metal is melted and spun via centrifuge into the investment to create the metal understructures or copings. Next the ceramic is stacked onto the coping, then that is placed in the ceramic oven. The heating of the metal creates an oxide layer, which allows the specific ceramic material to adhere to the outer surface. With PFM it is important to remember that the esthetic quality is highly dependent on the proper preparation design. Fit and longevity depend on an excellent impression, as noted in the clinical cases presented later in this chapter.

The creation of Captek involves two materials—Captek P and Captek G. Captek P is a blend of platinum, palladium, and gold suspended in a waxy medium that is press-fit over the die. This wax coping is put in a burn-out oven and the wax is burned away, leaving a honeycomb structure of platinum, palladium, and gold. The second layer, Captek G, is 97% gold suspended in a wax medium; it is press-fit on top of Captek P then placed in a burn-out oven. The 97% gold actually liquefies and fills all the capillary networks created in the original Captek P, forming a composite coping that is about 0.2 mm thick. The average conventional PFM coping is 0.3 to 0.5 mm thick. The newer, thinner Captek castings do not usually require opaquing because of the high value of the surface. Overall these require less tooth reduction, about 0.5 mm, so for younger patients and those who require high-value restorations the Captek PFM may be a good alternative to the conventional PFM.

Other innovative elements in the laboratory involve the use of CAD-CAM technology to mill understructures, frameworks, or complete restorations With chairside CAD-CAM units such as CEREC or E4D, dentists can create inlays, onlays, and

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single-unit ceramic crowns chairside for the patient. Typically the zirconium CAD-CAM approach from the laboratory is purely to mill the understructures for zirconium crowns and bridges. The laboratory CAD-CAM machine scans the dies; from that scanning the computer designs and mills a coping out of a solid block of zirconium. The technician then places that on the die and builds the ceramic on top of it. These innovative elements in the laboratory in both materials and techniques give the dentist several options in the types of restorations available.

ARTISTIC ELEMENTS

The artistic result of the ceramic restoration, in part, depends on providing enough space via tooth preparation, for the dental technician to create a beautifully esthetic restoration. For a PFM crown, zirconium crown, or bridgework created on either substrate, the technician needs a minimum of 1.0 to 1.5 mm of space for porcelain on top of the coping. This means the tooth in the axial dimension must be reduced at least 1.5 mm. For posterior crowns and bridges the opposing occlusion is also a consideration. There must be enough space or enough of a reduction of the occlusal portion of the preparation to allow for the proper thickness of metal and ceramic or zirconium-ceramic on the occlusal stress-bearing surface. For posterior teeth, long-lasting results require the amount of space to be 1.5 to 2 mm, which will then be taken up by the metal or zirconium coping and porcelain that stacks on top of that. This allows the technician to create all of the elevations and depressions inherent in posterior anatomic form without compromising the thickness of the ceramic underneath that form, which would reduce its strength. Often in failures of PFM crowns in posterior teeth, the ceramic breaks or separates from the metal substructure. Usually this is attributable to occlusal forces and lack of space for the proper thickness of porcelain. The dentist demonstrates artistry in the preparation design, which allows the technician proper space and dimension to create a natural-looking tooth in proper anatomic form.

The other artistic element goes beyond the scope of the dentist. This is the artistic technique needed for a technician to recreate a human-looking tooth. This requires much more than picking two or three shades of porcelain for some patients. It always requires the ceramist's eye for and knowledge of color—hue, value, and chroma—and his or her ability to mix the powders in the correct proportions to create the desired result. The ceramist must know and picture the end result while building this restoration to contour the various layers one at a time.

TREATMENT PLANNING

When planning treatment for full-coverage restorations, a good portion of the tooth structure is missing, previously filled, or decayed and the decay has been removed. Usually this area has been restored with a foundation restoration, possibly a resin-based buildup material, or, in older cases, amalgam, which uses a buildup material. It may also be an endodontically treated tooth or a post and core structure that was used to reestablish lost tooth form. For full-coverage options in PFM restorations, it is possible to use a wide variety of cements in a conventional cementation technique. In today's clinical practice of dentistry, usually PFM restorations are cemented with glass ionomer cements, resin-reinforced glass ionomer cements, or self-etching resin cements; there are many options.

An important consideration in treatment planning and deciding whether to use a PFM, alumina, or zirconium crown versus an all-ceramic restoration with acid etch, assuming the retentive properties of the preparation are not an issue, is the periodontal environment, the tissue, isolation, and the ability to keep the tooth surface clean, dry, and free of crevicular fluids and blood during cementation. If a full-coverage restoration is planned and it is difficult to maintain a field, the restoration of choice would be PFM or zirconium because they can be cemented with virtually anything. A pressed ceramic or stackable ceramic requires a totally dry field with acid-etch procedures and dentin bonding materials.

Cementation Criteria

First the dentist must evaluate the need for periodontal or endodontic therapy. Is there enough ferrule (clinical crown above the free gingival margin) on badly broken-down teeth? At least 2 mm of ferrule are required. Does the clinical crown need to be augmented using a post buildup or other type of foundation restoration? It is also necessary to consider whether the clinical crowns are in the correct position or whether orthodontics done before restorative therapy would create a better position for the remaining tooth structure. Another consideration in treatment planning occurs in large rehabilitative cases involving many teeth, considered occlusal reconstructions. These cases may require a period with temporary crown and bridge material such as acrylic or laboratory-processed provisional restorations to work out the correct functional occlusion and esthetics for the definitive restoration.

TREATMENT CONSIDERATIONS

Treatment considerations for the dentist basically focus on the preparation design. PFM and zirconium preparations both require 1.5 mm of axial tooth reduction, 1.5 to 2.0 mm of posterior occlusal reduction, and 1.0 to 1.5 mm of incisal reduction on the anterior teeth.

The procedure involves selecting the appropriate diamond instruments to create the desired shape for the preparation. A common diamond instrument to use for tooth preparation for these types of restorations is a rounded, tapered cylinder. It is also necessary to know the appropriate diameter of the diamond instrument tip. It is necessary to create depth cuts into the tooth structure following the natural anatomic form of the preparation and then remove the tooth structure between the depth cuts to ensure uniform reduction of tooth structure. The author usually accomplishes gross preparation with a rough or coarse diamond.

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The preparations are then smoothed using a 30-μm composite finishing diamond and Enhance points (DENTSPLY Caulk, Milford, Delaware). The goal is to have as smooth a preparation as possible with soft transitional, line, and point angles. The technician should not have to paint much die spacer onto the dies to make up for micro-undercuts, roughness, or sharpness and angles of preparation because that would compromise the final fit of the restoration. In comparing PFM and zirconium restorations, should there be a failure of the restoration at a subsequent time, necessitating removal, the PFM is much easier to cut through with high-speed rotary instrumentation. Zirconium is quite difficult, requiring several diamond instruments for a single crown to get through the understructure and down to the tooth structure. Zirconium understructures are extremely strong, more tooth colored, and more esthetic, and they produce a more lifelike restoration. The downside is that should they need to be removed, they are much harder to remove than conventional PFM restorations.

EVIDENCE-BASED PRINCIPLES

PFM restorations have withstood the test of time, with PFM crowns and bridgework serving as a mainstay of restorative dentistry for several decades. Patients have had useful service from their PFM restorations for 20, 30, or even 40 years. No further evidence is needed to show that these restorations are very good dental restorations. They still account for over 70% of the crown restorations made worldwide.

CLINICAL CONSERVATION CONCEPTS

Although conserving tooth structure through limited tooth structure removal during preparation is a goal, the controlling principle is making enough space so that the laboratory can make the appropriate conventional PFM or zirconium restoration. If the space is insufficient, the strength, longevity, and esthetics of the restoration will be compromised. An axial reduction of 1.5 mm is needed for good esthetics and function from either PFM or zirconium CAD-CAM restorations. Captek fits well as a clinical conservation concept because it is a PFM material that allows far less tooth preparation. The copings are thinner and require little to no opaquing, which saves about 0.5 mm of reduction in most cases—significantly less preparation. Comparing Captek, all-ceramic CAD-CAM zirconium-type, and conventional PFM restorations, the same results are obtained but the least preparation is needed for Captek.

MAINTENANCE

Maintenance for these restorations is similar to what is required for all dental restorations. No dental restoration is as good as the natural tooth. Anything dentists can do to repair or replace using restorative material will have a marginal interface between the natural tooth and the restorative material. Although 30 μm is quite acceptable as a restorative interface, bacteria are much smaller, so preventive maintenance is key. Patients must brush, floss, and perform regular home care and daily maintenance of their dental restorations whether the restoration is PFM or zirconium.

A common problem with PFM or zirconium-based porcelain restorations is fracturing of the veneering porcelain. Although the fractured porcelain does not necessarily cause a health problem, by exposing tooth structure to bacteria in the oral environment it can provide or cause an esthetic or functional problem. Unfortunately, few good long-term ways exist to repair veneering porcelain in a PFM crown intra-orally. Porcelain repair kits allow etching of porcelain, placement of bonding resin, and repair with composite materials, but this is never as good as the original porcelain. Regular recare maintenance schedules and visits on at least a 6-month schedule are the minimum requirements, but for many patients who have multiple PFM or zirconium restorations, a 3- or 4-month recare schedule is appropriate.

CONTROVERSIES

In considering crowns versus inlays or onlays and tooth conservation, the goal is to conserve as much healthy tooth structure as possible. Sometimes "teeth are sacrificed on the altar of false conservatism" (H.M. Shavell). Being conservative by prepping less—not creating enough space—can cause a functional and/or esthetic failure. It is then necessary to re-prepare the tooth and remake the restoration, which is not a conservative in the long term. The best choice is a conservative approach that creates good longevity and does not require another assault on the tooth with a rotary instrument.

Generally patients considering a crown versus an inlay or onlay can be approached through the "50% rule." If more than 50% of healthy natural tooth is missing because of decay, old fillings, and so on, the author recommends that a laboratory-processed restoration be made, whether an inlay or onlay or a crown. With less than 50% of healthy natural tooth missing, a high-quality direct restorative material will replace the missing part. Whether or not it needs an inlay or onlay or a crown depends on how large the missing part of the tooth is, whether the remaining part of the tooth is supported well with sound dentin, and whether there are internal stress fractures in the dentin from old restorative materials. The dentist must evaluate on a case-by-case basis whether or not to do an inlay or onlay or a crown. In general it is preferable to over-engineer and protect the tooth, particularly in compromised areas with much tooth loss or heavy occlusions in patients who do not have regular maintenance. In those situations it is best to choose a restoration that will be more predictable—a full-coverage crown. In a patient with good hygiene, recare, and a reasonable amount of healthy tooth left supported by dentin, inlays or onlays are better choices.

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NEAR-FUTURE DEVELOPMENTS

For in-office digital impressions a system called iTero (Cadent, Inc., Carlstadt, New Jersey) is useful. It is very comfortable for the patient and does not involve placing impression material in a tray with potential gagging, and so on. Impression materials, although excellent and able to create outstanding results, are being surpassed by digital impressions, which not only create consistent marginal accuracy but also generate models of polyurethane rather than dental stone, which can chip and break. The digital impression models created are excellent, and the restorations fabricated on them have consistent fit, and often require fewer adjustments. The chairside CAD-CAM systems, E4D (D4D Technologies, Richardson, Texas) and CEREC (Sirona Dental Systems, Charlotte, North Carolina), continue to improve, and others will follow.

Someday patients may be able to come into the office and in one visit have multiple crowns made. This would not include PFM restorations because their fabrication process is not easy and cannot be done in a day chairside. They may be of a CAD-CAM variety. Soon it may be possible to use CAD-CAM to create an entire full-mouth splint out of zirconium, which offers several benefits. Anybody doing a full-mouth restoration or a full-mouth splint knows that when a metal framework is placed back into the oven for a subsequent bake, distortion occurs, leading to problems with fit, marginal integrity, and so on. Dentists may eventually prescribe fewer PFM restorations because the cost of gold will be prohibitive and the CAD-CAM materials, whether zirconium or something else, will be more readily available. These will be produced in the laboratory via either digital or conventional impressions, and the restoration will be created without any metal understructures.

CLINICAL TECHNIQUES

Porcelain-Fused-to-Metal Crown on Anterior Tooth

Figure 21-1 shows the steps involved in sequential tooth reduction for a PFM crown on an anterior tooth.

Provisional Restoration on Posterior Teeth

Preparation of posterior teeth for the placement of a bridge to replace missing tooth No. 30 is shown in Figure 21-2.

Two Cord Retraction Technique

The process for making a master impression using the two-cord retraction technique is shown in Figure 21-3.

Complete Dental Reconstruction

The patient in Figure 21-4 has had previous orthodontic rehabilitation. He has very short clinical crowns, some large posterior amalgam fillings, and full-coverage PFM restorations. He needs occlusal vertical dimension recapture, creating space between the upper and lower teeth to make proper space for restorative

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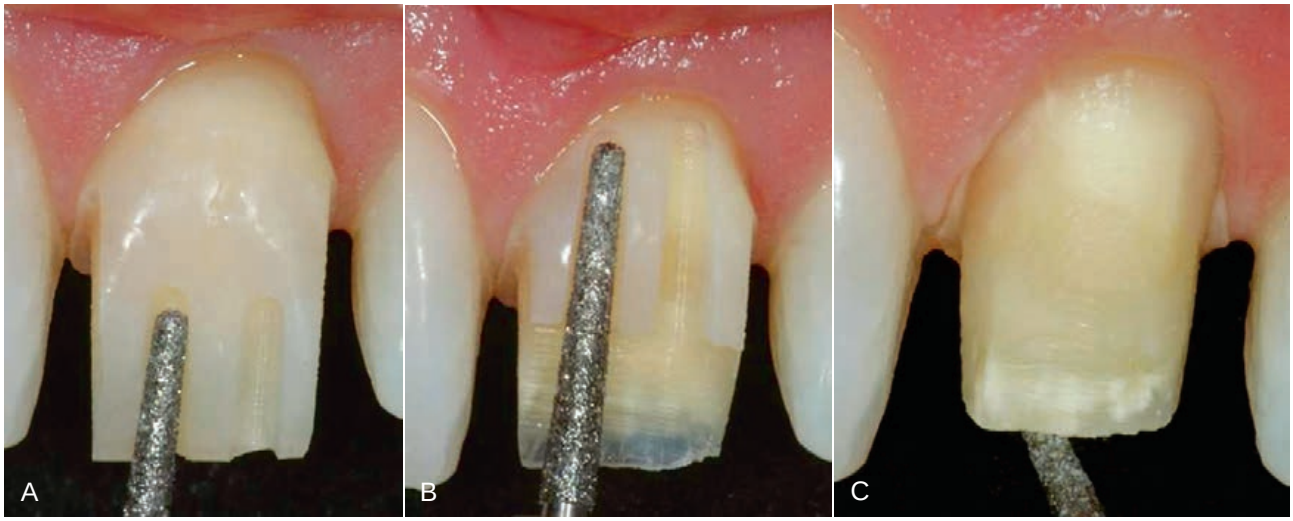


FIGURE 21-1 **A, Depth cutting the incisal half of the tooth on the facial aspect to the radius of the bur (which is about 0.6 mm). B, The tooth structure has been removed between the depth cuts in the incisal half, and the angle of the bur changed to the facial plain toward the cervical. The depth cuts are made slightly supragingival in the cervical half of the preparation. The reason the depth cuts are supragingival is that when the tooth structure is removed between the depth cuts, the final margin placement will be at the free gingival margin. C, The two facial planes of the central incisor prepared.**

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FIGURE 21-1, cont'd **D,** The arrows demonstrate that the facial surface has been reduced following the natural anatomic form in two planes, the cervical half and an incisal half. Note that the incisal edge is palatal to the position of the incisal edge of the lateral incisor adjacent to it. **E,** Proximal view of the lingual surface showing the three distinct planes on the lingual surface of the tooth. A depth channel is placed in the center of the tooth following those planes to ensure that when the surface is reduced there will be a uniform thickness following the anatomic form of the maxillary lingual concavity. **F,** An elliptical (or American football-shaped) diamond bur is used to remove the tooth structure on each side of the depth groove on the lingual surface of the preparation. The third plane at the cervical around the cingulum will be reduced using the rounded cylinder diamond to finish the third plane on the lingual surface. **G,** Facial view of the completed preparation. **H,** Lingual view of the completed preparation. Note that from the incisal view, rounded transitional line angles and smooth uniform preparation can be seen. **I,** View of the preparation in centric occlusion showing the clearance between the lower mandibular incisal edge and the lingual surface of the preparation. It is important not only to ensure that the patient has clearance in centric occlusion but also to check all functional movements to ensure that there is a uniformed reduction of the lingual surface.

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FIGURE 21-2 **A,** Pre-operative view of the mandibular right side where a bridge will be prepared to replace the missing lower right first molar. **B,** Depth grooves (*arrows*) placed on the facial cusps of the occlusal surface at the depth of the grooves, at the buccal groove, and at the heights of each cusp and at the marginal ridge to ensure uniform reduction of the occlusal surface following the natural anatomic planes. **C,** Occlusal depth grooves completed and the tooth structure between the depth grooves removed. **D,** The same procedure is followed on the lingual cusps, placing depth grooves at the lingual groove, marginal ridges, and heights of the mesial, lingual, and distal lingual cusps. The same has been done on the lingual surface of the occlusal aspect of the premolar or the lingual cusps of the occlusal surface of the premolar. **E,** Occlusal reduction complete. Arrows show the depth of the central groove. The cusps should be in the same facial, lingual position on the preparations as they are on the unprepared teeth. **F,** Facial depth grooves are made in the occlusal half of the preparation on the buccal surface of the molar and on the buccal surface of the premolar.

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FIGURE 21-2, cont'd **G,** The occlusal reduction is complete. The tooth structure is removed between the depth cuts on the facial surface. **H,** The next plane, the cervical plane, has been depth cut and reduced to create the two-plane reduction on the facial surface. **I,** The occlusal depth grooves on the lingual surface of the preparations. **J,** The occlusal half of the lingual surfaces of the preparations has been completed. **K,** The cervical plane on the lingual surfaces is complete. A verification of occlusal clearance with the patient closing in centric occlusion relation position can be seen. Note that 1.5 to 2 mm of space is needed between the preparations at the cusp tips and at the fossa depths as compared with the opposing dentition.

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FIGURE 21-2, cont'd **L, Occlusal lingual view of a provisional restoration after fabrication and custom staining. The teeth included in the restoration are the lower right mandibular cuspid, lower right first and second premolars, and lower right first molar. M, Facial view after custom staining with double deflecting contours on the facial surface at the cervical margin. N, The provisional restoration placed and cemented using polycarboxylate cement. Note that the gingival embrasures are adequately opened to allow the patient to use floss aids, brushes, and threaders to clean interproximally to maintain the health of the tissue. Although this is a splinted provisional restoration, the final restorations will be single units. O, The provisional restoration seated on the master dies. If the cement from the provisional restoration is cleaned out and the die spacer is cleaned off of the master dies, a well-fitted provisional restoration that fits on the master dies will ensure good tissue management emergence profiles, marginal integrity, and good occlusal contacts, all of which are important in the provisional restoration.**

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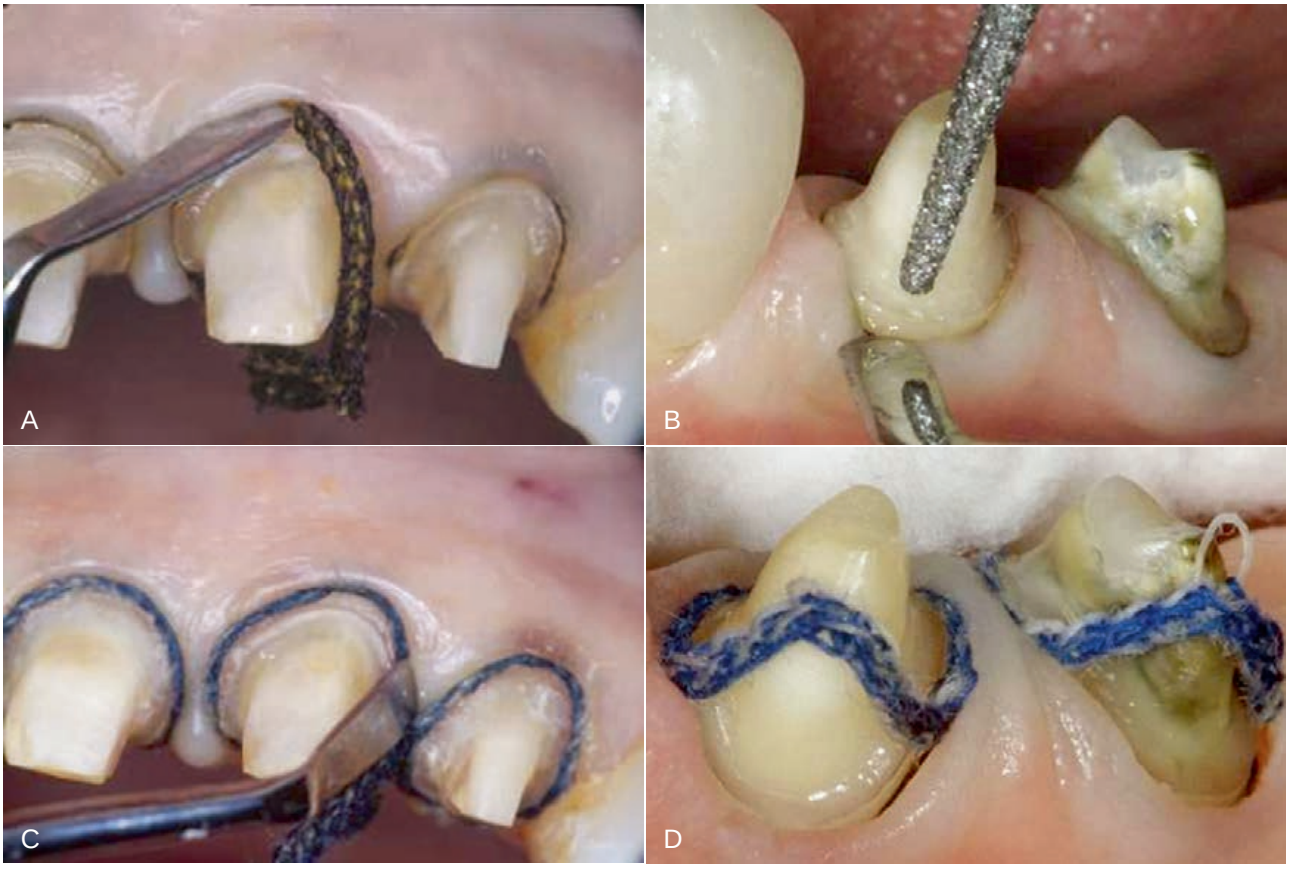


FIGURE 21-3 **A, In the two-cord retraction technique the first step is the placement of the double zero cord. The double zero cord is placed at the base of the sulcus and should not overlap when the cord is in position. B, Minor corrections are made at the marginal area after the placement of the double zero cord. Any little irregularities or lips created from the bur at the edge of the margin can now be seen and corrected after placement of the double zero cord. C, Placement of the top cord over a number one retraction cord at the level of the margin. In this case a knitted blue number one retraction cord is placed and should be visible circumferentially around the preparation to ensure that when it is removed there will be a wide-open patent sulcus 360 degrees around the preparation. D, Teasing of the number one cord with the tine of an explorer to evaluate the space between the tissue and the preparation to evaluate retraction. The goal of the final impression is to capture not only the margin but 0.5 mm of tooth or root surface apical to the margin to ensure that the laboratory will have an accurate die so that the emergence profile of the tooth can be duplicated precisely in the restoration.**

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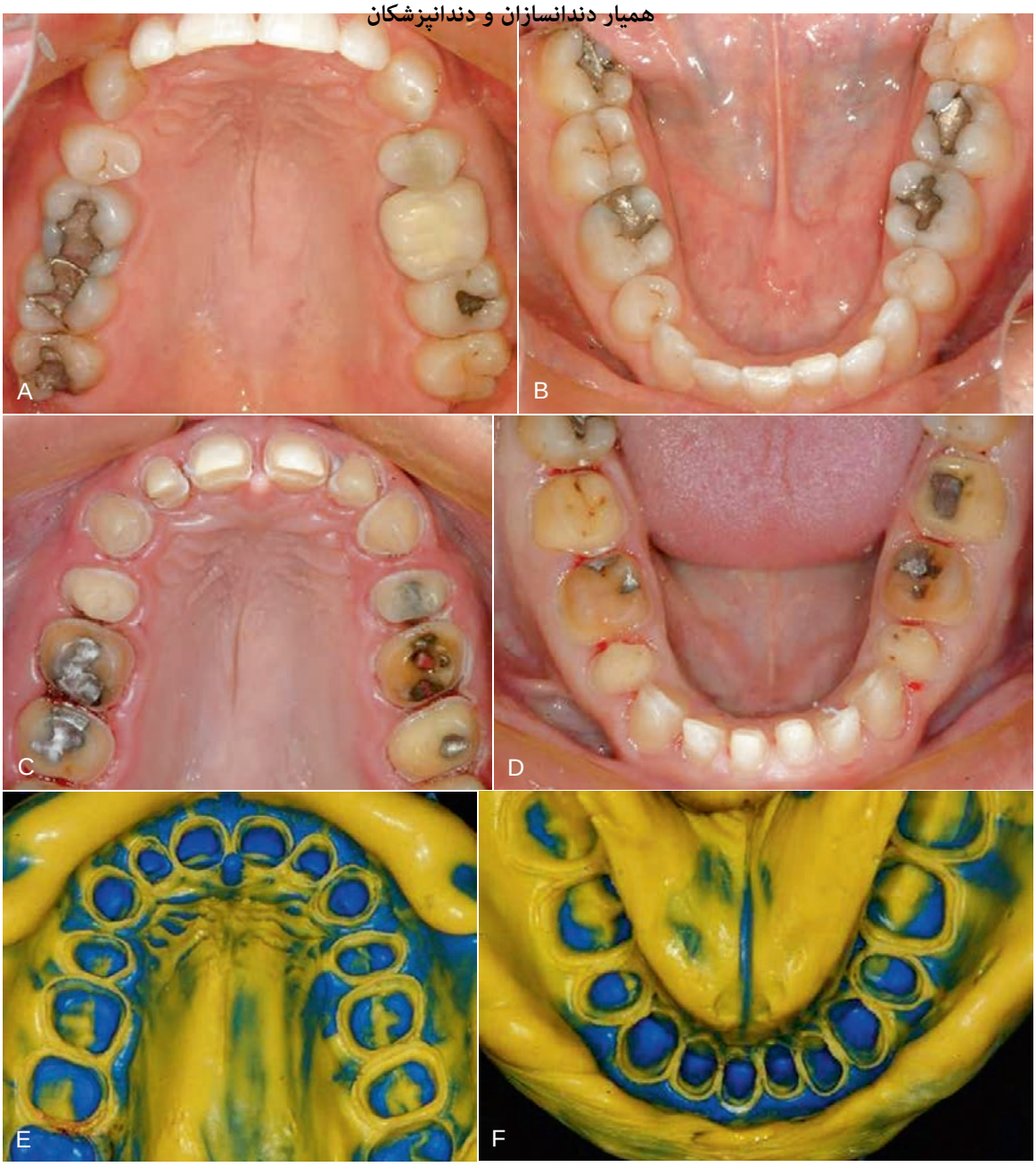


FIGURE 21-4 **A,** Pre-operative maxillary arch view of a class II, division I post-orthodontic reconstruction patient. **B,** Mandibular view of the class II, division I post-orthodontic rehabilitated patient before tooth preparation. **C,** Occlusal view of preparations completed on the maxillary arch. The posterior teeth are prepared for the porcelain to zirconium crowns, and the anterior teeth are prepared for the feldspathic veneers. **D,** The mandibular arch prepared for porcelain to zirconium crowns, and the mandibular anterior teeth prepared for porcelain laminate veneers. **E,** Full-arch maxillary master impression. **F,** Full-arch mandibular master impression. Note that both these impressions show margin and tooth surface beyond the margin so that when these are poured, the master dies will be an accurate reflection of the tooth preparation and the tooth surface apical to the margin.

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FIGURE 21-4, cont'd **G,** The patient in centric occlusion position with provisional restorations placed on the posterior left and right sides. Note that the posterior provisional restorations hold the patient's vertical dimension of occlusion so that the clearance in the anterior area of the preparations can be accurately assessed. **H,** A buccal view of the patient's right side in centric occlusion position with the provisional restorations in place. **I,** A buccal view of the patient's left side in centric occlusion with the provisional restorations holding the vertical dimension of occlusion. **J,** An occlusal view of the completed restorations (porcelain to zirconium) showing exquisite occlusal detail, morphology, and custom staining. **K,** Intaglio view showing the zirconium understructure of the two mandibular molar restorations. **L,** Self-etching resin cement being placed into the zirconium crown restorations before seating in the patient's mouth.

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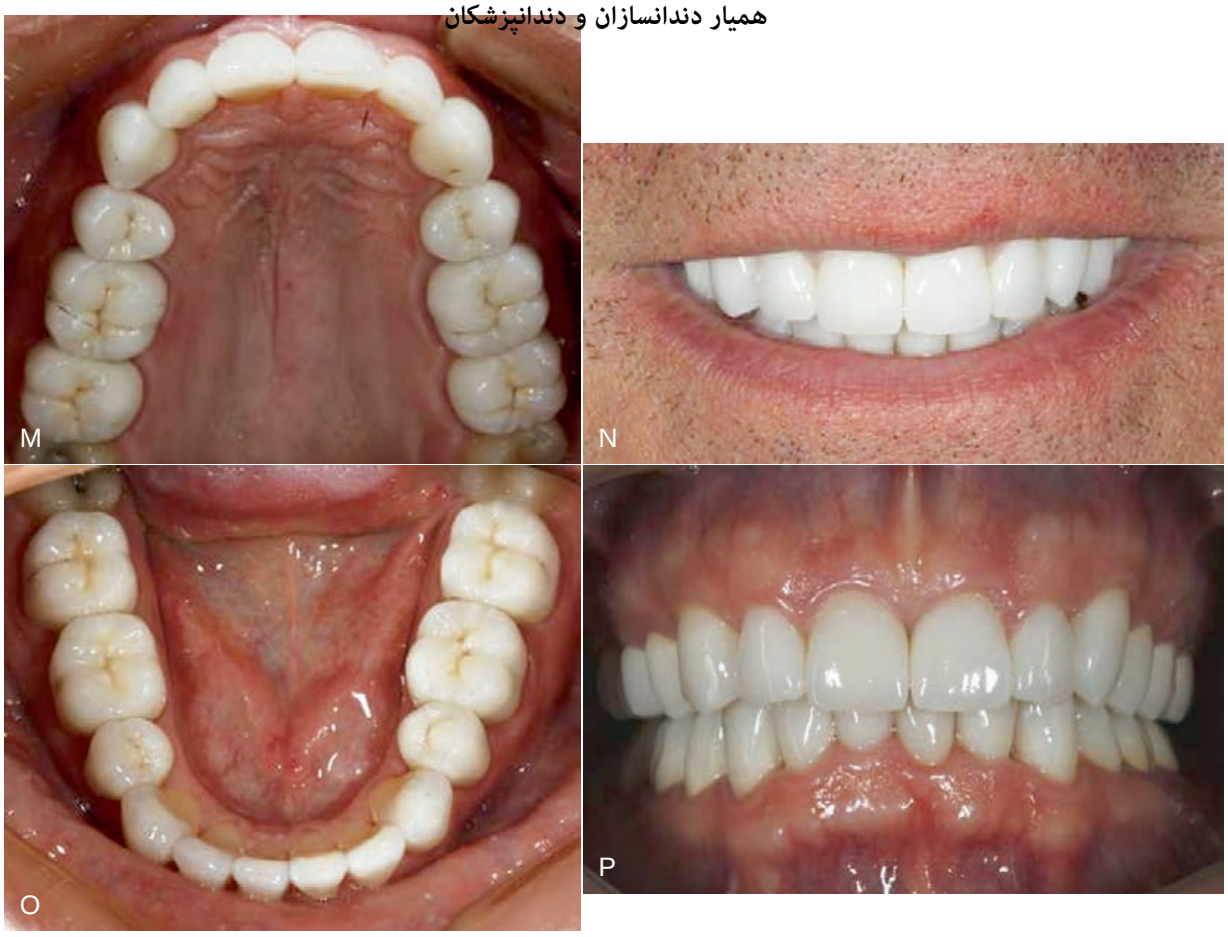


FIGURE 21-4, cont'd **M, Maxillary view of the completed Class II rehabilitation. N, Un-retracted smile view of the patient's completed restoration. O, Occlusal view of the mandibular arch of the completed restoration. P, Full-mouth retracted view in centric occlusion relation position of the patient's completed porcelain rehabilitation.**

material. This is important in the diagnosis because if these teeth are prepared at the present occlusal vertical dimension and a 1.5- to 2-mm space is created occlusally to make room for the restorations, there will be no axial height for retentive quality left in the preparations. The only way for this patient to gain sufficient space for restorative material is to recapture lost vertical dimension between the upper and lower arches.

Posterior Dental Reconstruction

The patient in Figure 21-5 has failing, old posterior amalgam fillings and fractured porcelain crowns that are in need of replacement. Porcelain fracture is common when inadequate occlusal reduction causes a lack of space for the material to an optimum thickness of 1.0 to 1.5 mm.

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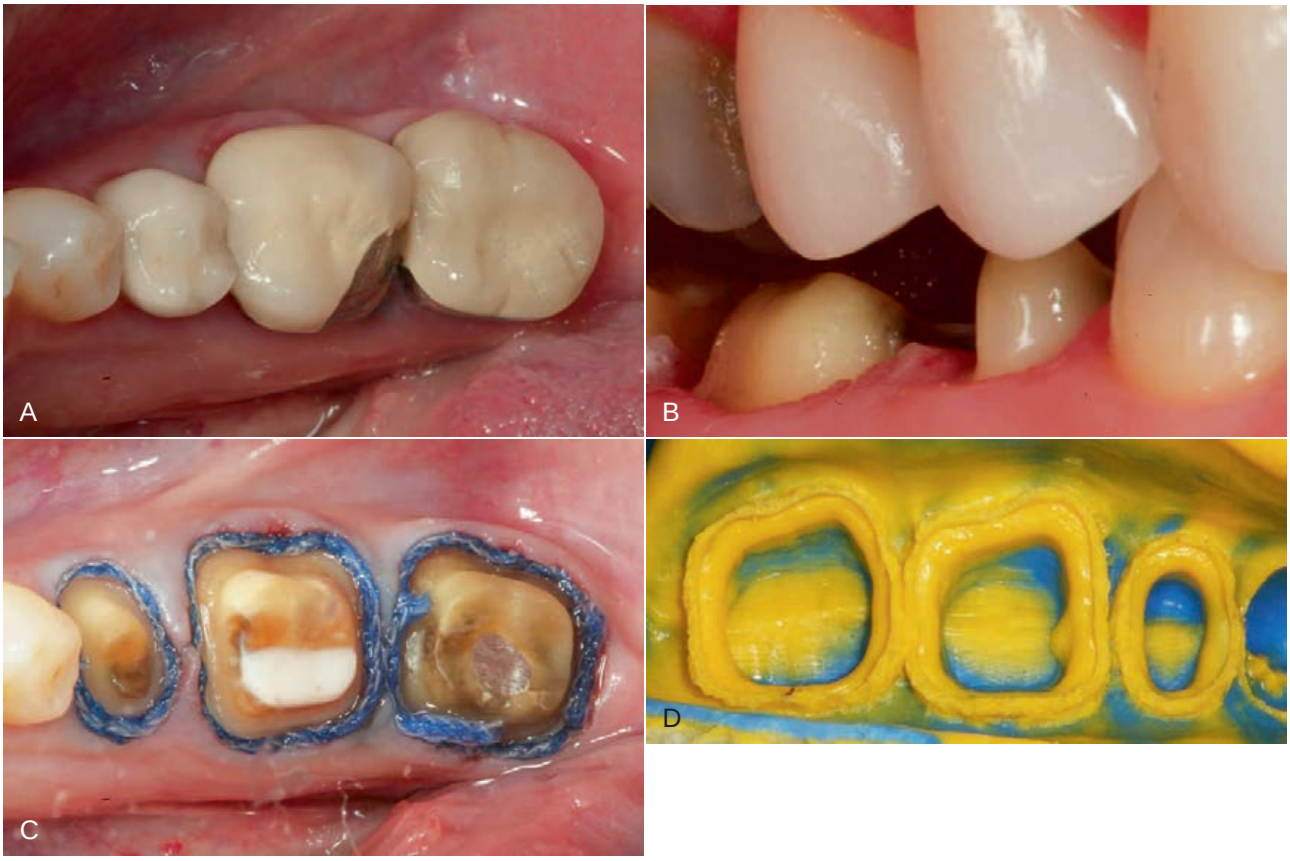


FIGURE 21-5 **A,** Pre-operative view of patient's right mandibular posterior quadrant. The teeth will be prepared to include the mandibular right second premolar, mandibular right first molar, and mandibular right second molar. A previous restoration on the mandibular first molar has fractured porcelain owing to lack of clearance between the preparation and the opposing dentition. **B,** Preparations after correction. Note the two-plane reduction on the facial surfaces of the premolar, the molar in view on the mandibular quadrant, and the amount of space between the preparations and the opposing dentition. **C,** Mandibular right quadrant after both the double zero and number one retraction cords have been placed around the preparations. **D,** Master impression made for the mandibular right posterior quadrant; there is a 360-degree cuff around each of the preparations, demonstrating clearly that not only has the margin been captured, but 0.5 mm of tooth or root surface apical to the margin has also been captured in the master impression.

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FIGURE 21-5, cont'd **E, Provisional restorations placed for the mandibular right second premolar, mandibular right first molar, and mandibular right second molar. Proper occlusal morphology has been carved as an exercise to test that there is proper thickness of provisional material, which will translate into enough space for the restorations to be made without duplicating the fracture seen in part A. F, Occlusal view of the patient's maxillary right posterior quadrant. G, Preparations completed for the maxillary right first molar and maxillary right second molar. The clearance can be seen between the preparations, and the provisional restorations have corrected the occlusal plane on the mandibular right posterior quadrant. H, Master impression for the maxillary right posterior quadrant including the maxillary right first molar and the maxillary right second molar. I, Occlusal view of the provisional restorations in place for the maxillary right first molar and the maxillary right second molar. A full-flap periodontal procedure was performed on the maxillary right first molar to lower the crest of the bone and free the gingival margin to create enough space or to create enough clinical crown to have a good fitted crown restoration with proper axial height to the preparation. The free gingival margin is more in harmony with the free gingival margins in the adjacent teeth and achieves overall correction of the occlusal and gingival planes. J, Quadrant view from the buccal aspect of the completed provisional restorations that have corrected the occlusal plane, corrected the gingival planes, and corrected tooth position for this posterior rehabilitation.**

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FIGURE 21-5, cont'd **K,** Inferior facial aspect of the provisional restorations on the master dies in centric occlusion, which shows the positions of the cusps and the fossae and the importance of integrating the provisional into the treatment as an interim esthetic and occlusal rehabilitation that will be used by the laboratory as a blueprint for the fabrication of the completed ceramic restorations. **L,** The completed ceramic restorations for the mandibular right second premolar, mandibular right first molar, and mandibular right second molar. **M,** Porcelain restorations cemented in the mandibular right posterior quadrant. The occlusion has been checked with Parkell AccuFilm II. Nice, small punctuate occlusal contacts can be seen. *A, B,* and *C* contacts exist on the occlusal surfaces of the restorations, indicating occlusal harmony with the opposing dentition. **N,** Maxillary right posterior quadrant, two molar restorations, and first and second molars after the occlusion has been checked with AccuFilm. **O,** Facial aspect of the completed ceramic restorations with the patient in the centric occlusal relation position. Compare this photo with the view of provisional restorations in part J. This comparison shows how important provisional restorations are when used as a blueprint to test out function and form. The best articulator in the world is the one between the patient's ears, and this information should be used in the laboratory to fabricate high-quality ceramic restorations.

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Dentist–Lab Technician Communications

Chuck N. Maragos, Jenny L. Wohlberg

RELEVANCE OF COMMUNICATION BETWEEN DENTIST AND LABORATORY TECHNICIAN TO ESTHETIC DENTISTRY

Communication among patient, dentist, and laboratory technician is one of the most important factors for a successful outcome in any case, from the relatively routine to the most complex. With thorough, accurate, and timely communication, all parties understand exactly what they are trying to achieve, what challenges they need to address, what options are available, and generally what to expect. The result is greater satisfaction all around. The technician has a satisfied dentist-client. The dentist has a happy patient who will refer family and friends. And the patient has a smile on his or her face—the smile that the patient wanted from the moment he or she walked in the dentist's door.

On the other hand, with inadequate or imprecise communication, even the most skilled professionals can fall short. Especially today, with so many options available at every stage of the restoration process, communication is the key to making decisions that lead to the excellent result everybody wants.

Communication has always mattered—to a point. But not long ago, the decisions to be made and the channels for communicating them were far more limited.

BRIEF HISTORY OF COMMUNICATION BETWEEN DENTIST AND LAB TECHNICIAN

In the past, communication was brief and simple. The dentist would specify a porcelain or metal crown, assign it a shade, and sign a work authorization for the laboratory. Today the material selection process is far more complex, and there are many more options. To make the optimal decisions in each case, the laboratory needs more information from the dentist (Box 22-1). At the same time, laboratories have evolved from simply filling orders to being an important resource to dentists, consulting on everything from materials to procedures. To take advantage of that resource, dentists are communicating with their laboratories closely and continually throughout the restorative process.

The channels for these communications have also broadened and deepened, with communications increasingly being handled digitally. The ease of transmitting photography—as well as work authorizations—digitally is improving the accuracy, thoroughness, and speed of all communications between dentists and laboratories, with correspondingly better results for patients.

CLINICAL CONSIDERATIONS

All esthetic cases require communication among the technician, dentist, and patient from the start. As the dentist begins discussing with the patient what he or she does and does not like about his or her smile, and what concerns the patient may be having with form, fit, and function, the laboratory can play an important collaborative role in designing the diagnostic aspects of the case. With implants and similarly complex restorative cases, dentist–laboratory technician communications are always essential. If orthodontic movement, periodontal therapy, or oral surgery is involved, the laboratory technician should always be part of that team to help facilitate a precise and esthetic outcome.

Even with a single tooth case, results can be compromised with inadequate communication. In fact, the laboratory needs as much information with a single central as with a full anterior restorative case. For example, it is important that the laboratory technician know the design of the preparation and the underlying tooth structure in order to properly select the suitable restorative material. If the crown is to cover a metal substructure, or a root canal with a metal post, some materials, such as zirconia, might not block out the metallic coloration sufficiently. A more opaque material or a porcelain-fused-to-metal restoration such as Captek (Altamonte Springs, Florida) would be a better choice.

ESTABLISHING PROPER FUNCTION AND ESTHETICS

The more time and effort that the dentist spends intra-orally on fine-tuning the provisionals, the better the template that the laboratory has to work from and the more closely aligned the outcome will be with the doctor's and patient's expectations. Skilled laboratory technicians can do much to enhance the quality of the restoration. But form, fit, and function should be

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BOX 22.1 Checklist for Cosmetic and Large Restorative Cases

The following items are needed to complete a cosmetic or large restorative case:

- Model of pre-operative dentition
- Model of diagnostic mock-up or MDM models
- Photos of pre-operative teeth with shade guide, 1:1, 1:2, from different angles
- Photos of prepped teeth with stump shade tabs
- Bite registration: right, left, anterior, segments of the provision left in place to maintain vertical while taking the bites in a tripod fashion
- A bite taken with the upper provisional in place against the lower preparations
- A bite taken with the lower provisional in place against the upper preparations
- Stick bite (horizontal plane parallel to interpupillary line)
- Photos of provisionals, full face including eyes, 1:2
- Photos of provisionals, eye to chin, relaxed lip position
- Models of provisionals
- Comments regarding the current provisionals
- Desired length of final restorations
- Detailed lab prescription expressing goals of patient
- Implant cases: indication of type and size of each implant to be restored
- Implant cases: indication of preference for type of part to be used (i.e., plastic or metal)

clearly established in the finished provisionals, which serve as the final blueprint for the laboratory's work.

Taking shortcuts at this crucial stage leads to communication problems that can seriously undermine the result. A dentist who changes laboratories in the middle of a case and requests that the new laboratory complete the restorations using provisionals based on the patient's old crowns will receive crowns that are both inaccurate and inadequate, with the resulting restoration satisfying neither the dentist nor the patient. The correct decision is to start again, with full provisionals, a Master Diagnostic Model (MDM), and ongoing communication among patient, dentist, and laboratory. Although it requires more time, the patient will be far more satisfied with the final result, and the dentist preserves or creates a valuable relationship.

CHANNELS FOR DENTIST–LAB TECHNICIAN COMMUNICATION

A great deal of information can be conveyed between dentist and laboratory verbally, and there is no substitute for conversation when it comes to discussing certain aspects of a case. Verbal communication is direct, open, and fast and conveys emotional as well as factual information. It is perhaps the ideal way for the laboratory technician to get a sense of the results that the dentist and patient want. On the other hand, conversation is easy to forget and open to interpretation, which is why it is crucial to have a written laboratory prescription and notes from consultations, as well as photographs. The technician should keep these records in the case file for 10 years, which means that if the laboratory should return to the case several years later, there will be no question about what was done, why it was done, and exactly which implant parts and ceramic materials were used.

Some dentists prefer to use handwritten prescriptions; others have progressed to handling them digitally. Digital records are generally easier for laboratories to use, because there is not an issue with hard-to-read handwriting. Another consideration is that dentists tend to convey their thoughts in a more organized and complete fashion when using preprinted guides. However, when laboratories receive handwritten notes that are unclear or incomplete, it is the technician's responsibility to communicate with the dentist for clarification, and to take comprehensive notes. Along with the work prescription, it is very helpful to have accompanying pictures, either emailed, as prints sent with the impressions, or on a disk. These are invaluable for showing the technician the patient's current state (Figure 22-1). In addition, many dentists include photos to suggest how the patient would like to look. All of this helps the technician to get a feel for the character of the patient. Taking shade photos and pictures of the dentin or enamel yields valuable coloration information; a full-face view can reveal other very important data. For instance, if the midline is canted, the lab technician can help to correct this malinclination. If the buccal corridor should be filled out more and the dentist did not mention it in the prescription, the lab technician can diagnose this condition on the photographs and then consult with the dentist about adjusting the restoration accordingly.

To be most effective, full-face shots should show a 1:1 or 1:2 straight-on view and right and left lateral views. Photos should include the eyes. Larger multimedia esthetic or specialty cases may be accompanied by a video of the patient and of the interview between dentist and patient. This is an increasingly popular way to communicate and once again reveals far more than a series of tooth-only pictures.

SHADE COMMUNICATIONS

In the past the process of shade selection was simple. Dentists held a printed shade guide up to the patient's mouth and chose the shade that seemed closest to the patient's teeth. Today, in addition to matching by eye, the dentist has a variety of electronic shade-matching devices—the VITA Easyshade (Vident, Brea, California), the Cynovad ShadeScan (Cynovad Inc., Montreal, Canada), and the X-Rite ShadeVision System (X-Rite, Inc., Grand Rapids, Michigan)—that can be used in combination with photography. A shade machine is useful because it takes human error out of the process, matching shades precisely regardless of surrounding color and light conditions.

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FIGURE 22-1 **Patient before treatment. A, Full-face picture of the patient. B, Close-up picture of the patient's smile. C, Retracted view of the patient's dentition.**

The LADDER (Laboratory and dentist digitally enhanced reference) is an excellent tool for helping dentists communicate with the laboratory. Showing surface texture, luster and incisal translucency, it allows patient and doctor to select images to use as a visual reference for the laboratory. Technicians find the Ladder images extremely helpful, as they provide a clear, objective shade baseline, particularly when working with a new patient.

TECHNICAL INNOVATIONS

The use of computers and the availability of email for digital photography communication has revolutionized cooperative contact in all professions, and dentistry is no exception. The digital platform allows laboratories and dentists to communicate in real time, any time. It has also enabled professionals to enhance their collegial communication through the sharing of more and better images.

Material improvements are playing a huge role in what can be done for patients—and what they expect in terms of results. Ceramics today are much more color stable and consistent than they were 10 or 20 years ago. Still, it is common to insert subtle nuances and to create illusions by using characterizing shades. Working from the gingival to the incisal, 10 or 11 different colors may be used to obtain certain desired effects. Although it is now much easier to create a simple shade and to obtain color stability, the result is more natural and esthetic when shades are combined. Again, the key to satisfaction for all parties is communication; both the patient's desires and doctor's expectations must be as clear as possible.

THE ARTISTIC ELEMENT

For the partnership between dentist and technician to yield consistent outcomes, it is important for dentists to communicate what they see in the oral cavity, from an artistic *and* a technical standpoint. Subtle nuances—such as striations, incisal translucency, and surface texture—may not be as apparent in photographs as they are in real-life. If technicians are aware of subtleties such as these, they can respond appropriately, using their extensive artistic skills. There is a friendly debate that compares how much of the case parameters the dentist needs to dictate, and how much should be left to the artistic discretion of the laboratory technician. Some practitioners prefer to maintain complete control, whereas others are comfortable giving more artistic license to the technician.

TREATMENT PLANNING

For every esthetic and extensive restorative case, the laboratory needs a number of items to successfully complete the task. The technician starts a case with an impression of the existing teeth in order to make a diagnostic mock-up, or MDM. Following the dentist's work authorization, the laboratory prepares the pre-operative models for either crowns or veneers. Then wax is added to simulate correct form, fit, and function according to the interocclusal records provided by the practitioner (Figure 22-2).

With the finished diagnostic models, a silicone mold of the wax-up is made, along with a clear stent that will be used for a reduction guide, and a stone model for the preparations. All of these materials go to the dentist, who is then ready for the

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FIGURE 22-2 Master Diagnostic Model (MDM) using wax to simulate the correct form and function.

patient's preparation appointment. This is the time to present the diagnostic mock-up to the patient, enabling the patient to see how the finished restoration could look, and to discuss any questions or concerns. By helping the patient visualize the outcome and making him or her part of the communication process at this crucial stage, the dentist helps ensure that the patient's expectations are being met, and that he or she will be satisfied with the end result.

After preparation and provisionalization, the dentist must obtain a tripod bite registration taken in three sections. First remove the right posterior provisional section, and inject bite registration material. Then place the right posterior provisional section back in the mouth, remove the left posterior provisional section, and continue the earlier technique. With right and left posterior sections in place, remove the anterior section and take a bite registration. This completes the tripod bite registration—an anterior bite registration and a left and right posterior bite registration, thus the tripod effect. In addition, it is important to do a temporary-to-temporary registration. Finally a stick bite is taken from the horizontal plane parallel to the interpupillary (eyes) line.

The laboratory technician also needs 1:2 photos showing the full face including the eyes. Photos of provisionals with the eye to chin in relaxed lip position are also helpful. Impressions of the provisionals provide an exact replica of the patient's mouth (Figure 22-3).

Comments regarding the current provisionals, noting what is good and what is undesirable, are helpful as well. These should reflect both the dentist's and the patient's perspectives. The dentist should indicate the desired length of the final restoration, and specifically if the final length is to be different from the existing length. And—very important—a detailed lab prescription should express the goals of both the patient and the dentist.

With all implant cases it is wise to indicate the type and size of implants to be restored, as well as the dentist's preference for plastic or metal parts.

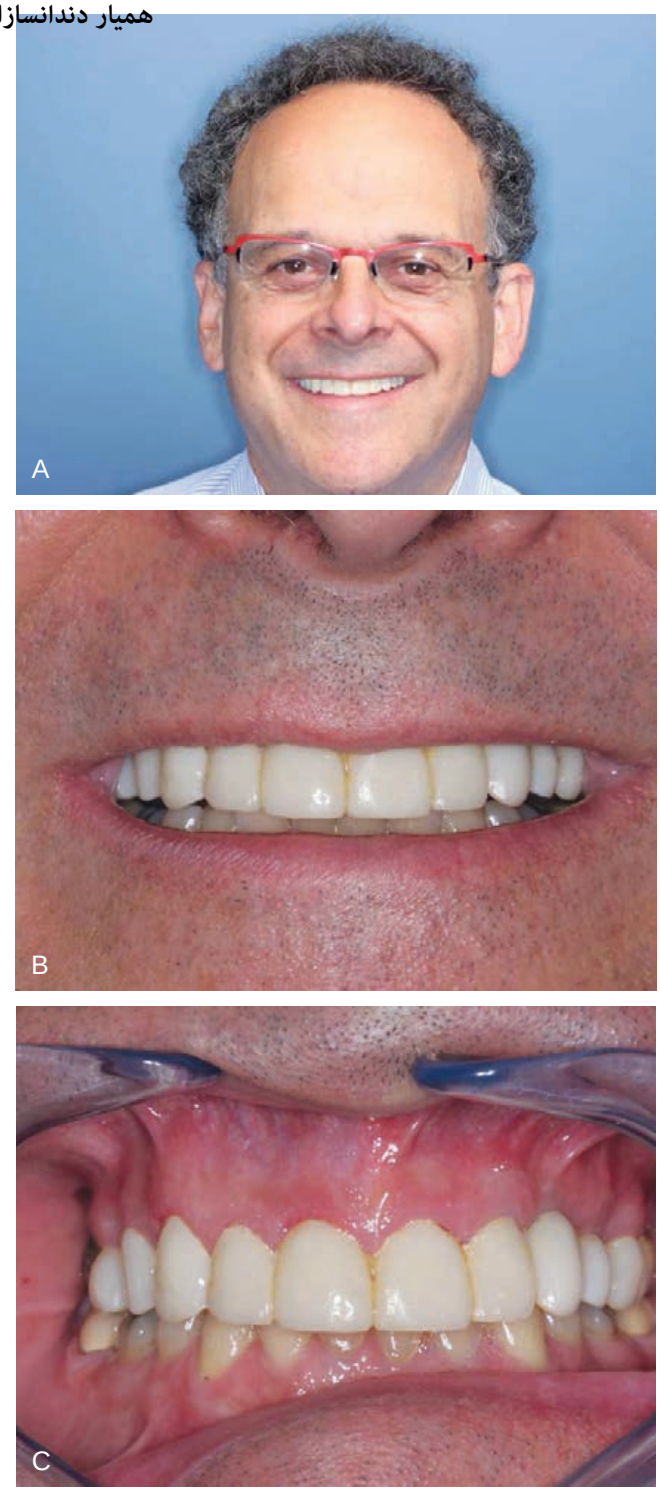


FIGURE 22-3 The provisional restorations. A, Full-face picture of the patient. B, Close-up picture of the patient's smile. C, Retracted view of the patient's smile.

The dentist should always call the laboratory for an itemized estimate for complex cases. This is important for keeping the patient informed about estimated treatment costs. If an abbreviated time schedule is needed for a particular case, the laboratory needs to know in advance, in order to accommodate (if possible) these restrictions.

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At this point, the doctor is ready to send all materials—MDMs, tooth impressions, impressions of the provisionals in the mouth, bite registrations, face-bow or stick bite, measurements, and photography—back to the laboratory. In implant cases a few additional items are needed, such as types and size of each damaged implant being restored.

Once the impressions have been poured and mounted, the laboratory technician can evaluate the case on an adjustable articulator. The temporary models are then mounted and cross-mounted to the prepped models. This is a good time to evaluate whether any additional reduction is required for the proper thickness of restorative material to duplicate the temporaries that are in the patient's mouth.

Then the technician reviews plans for the case with the dentist. This is called *protocoling the case*—an opportunity to talk about material options, unusual situations encountered during preparation, and issues that the patient may have been experiencing with the provisional. For complex implant restorations, the lab may white-wax the entire case and return it to the dentist to try in the patient's mouth for fit, form, and function. The dentist should also photograph it in the mouth. Then, when the case is returned, the lab matrixes the white wax. The wax is then removed from the frame, and the building process can begin.

In consultation with the dentist, the laboratory selects materials and proceeds through the finalization of the restoration, using all the models, impressions, photography, and other items noted in Box 22-1 to duplicate the smile that was presented to the patient during the diagnostic wax-up. In this way, the laboratory can ensure ongoing consistency and predictability of results (Figures 22-4 and 22-5). The final restorations are then sent to the dentist for cementation.

Communication between dentist and lab should continue, even after the final restorations are seated. Discussing what went well, what did not, and how techniques can be improved provides an excellent learning opportunity for all parties concerned, as does documenting and sharing the outcomes photographically (Figures 22-6 and 22-7).

CLINICAL CONSERVATION CONCEPTS

Although dentists generally favor minimizing preparation in order to preserve healthy tooth structure, laboratories often need to be consulted on the limitations of materials in order to create an esthetic and functional end result. Clearly dentists and laboratories want the best possible outcomes for patients, but occasionally their different perspectives on preparations collide. On these occasions, good communication often leads to an enhanced synergistic solution, particularly when the laboratory and dentist have an ongoing consultative relationship. For instance, in a case in which a two-shade shift is required, the laboratory can suggest that minimal prepping may be counterproductive, because very thin porcelain cannot accomplish this result. On the other hand, the lab may be able to successfully shift one shade if this is acceptable to the patient.

MAINTENANCE

A number of options can be chosen to provide easier, more accessible maintenance for the patient both at home and in the dental office. The dentist makes the decision as to which choice is best for the patient. Generally, supragingival margins are better than subgingival, because the patient cannot accomplish routine subgingival maintenance. Although many dentists are primarily concerned with how much tooth structure is reduced, the interface is potentially the weakest area of the restoration, and the key in determining its longevity. If there are marginal gaps—interface discrepancies where the cement seal is not complete—bacteria can access tooth structure and



FIGURE 22-4 The laboratory technician selects the materials and finalizes the restorations.



FIGURE 22-5 The labial view of the final restorations.

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FIGURE 22-6 **Post-treatment results. A, Full-face picture of the patient. B, Close-up picture of the patient's smile. C, Retracted view of the patient's dentition.**

cause recurrent decay. If the margins are not perfect, whether supragingival or subgingival, the chance of failure is much greater. All margins should be checked under the 10/20 microscope to ensure that proper marginal sealing has been achieved.



FIGURE 22-7 **Treatment chart summary of the patient's before and after appearance.**

NEAR-FUTURE DEVELOPMENTS

Within the next 5 years it is likely that paperless communication will become the standard of the profession. Dentists will use digital technology for everything from transmitting photography to writing prescriptions to creating virtual MDMs. This migration to digital communication will offer many benefits. Nevertheless, there will always be a need for the give and take of verbal communication among patient, dentist, and laboratory as the entire team works closely together to achieve optimal results.

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CHAPTER 23

CEMENTS

SECTION A

Contemporary Dental Cements

Howard E. Strassler, Eric Levine

RELEVANCE TO ESTHETIC DENTISTRY

The number of choices for laboratory-fabricated restorations has increased significantly over the past decade. When planning treatment to replace missing teeth with fixed or removable partial dentures or implants, full-coverage crowns, or partial-coverage inlays and onlays and when restoring the endodontically treated tooth with cast posts and cores and prefabricated posts, the options include cast metals, ceramics, metal-ceramic, and computer-aided design and manufacture (CAD-CAM)–based restorative materials. With these developments, the types of cements have also changed. The cementation or luting of restorations is an extremely critical phase in placing laboratory-fabricated restorations. The surface treatments for the various adhesive cements differ, so it is critical that the clinician and the chairside assistant understand the requirements and steps needed to optimize clinical success with any given cement.

In the past (and still), the term "permanent cement" has been used to describe the use of a cement for final, definitive cementation of indirectly placed laboratory-fabricated restorations. Unfortunately the term as it relates to restorative procedures is inaccurate and gives patients a false sense of security and expectation. In the future of fixed prosthodontics, cementation in restorative dentistry should focus on the placement-cementation so that the restoration *cannot* be removed later. Currently, a more proper term for cementation is "definitive cementation."[1]

RELATING FUNCTION AND ESTHETICS

This chapter describes all types of dental cements for definitive cementation and includes their composition, properties, and indications. A class of dental cements used for cementation of provisional restorations is described but not covered in detail. Currently the most widely used dental cements, glass ionomer and resin, adhere to the dentin for full-coverage restorations and to the enamel and dentin for partial-coverage restorations and porcelain veneers. These same cements can be used successfully to cement cast metal posts and cores, ceramic posts and cores, prefabricated metal posts, and resin-fiber–reinforced posts.

Clinical Considerations

The treatment procedures for laboratory-fabricated restorations generally require two or more patient visits and a series of treatment decisions to achieve the final restoration. During treatment the clinician will spend significant time with tooth preparation (or implant placement), soft tissue management, impression making, fabrication of provisional restorations, and selection of the tooth shade for esthetic restorations. At a later appointment the clinician will perform the try-in and adjustment of the restoration and cementation. Preparing for these restorations might also involve a diagnostic wax-up to preview and plan the case, or more involved occlusal therapies may be needed during the provisional restoration phase. Over the course of treatment, cementation of the restoration requires less than 5% of the overall time spent on clinical steps. In terms of cost for these restorations, whether single crown, inlay or onlay, a more involved multi-unit fixed partial denture or multiple restorations for numerous teeth for esthetic reasons (such as a large porcelain veneer case), the practitioner may use an adhesive cementation system costing less than $20 (US), or for a single unit less than $2 (US), yet the durability of the restoration depends on this agent.

Improper and incorrect cement selection for the restorative material being cemented or poor technique during cementation can lead to premature failure of the costly restoration. Financial considerations include the cost to the practitioner in laboratory fees, cost to the patient for the restoration, and sometimes cost to the practitioner's reputation and the staff's perception of the success or lack of success with certain procedures.

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Other factors are equally as vital as the selection of cement type for clinical success. For example, during the laboratory fabrication of cast and ceramic restorations, some steps can lead to marginal discrepancies and gaps between the restoration and tooth preparation. Today's contemporary cements provide excellent marginal integrity to compensate for these discrepancies.[2-5] An inherent aspect of retention is the taper of the tooth preparation with different cements.[6] Zidan and Ferguson[6] found that the retentive values of the adhesive resin cements for a tooth preparation with a 24-degree taper were 20% higher than the retentive values of the conventional cements (zinc phosphate and conventional glass ionomer) for a tooth preparation at a 6-degree taper. The use of resin luting agents yielded retention values double those of zinc phosphate or conventional glass ionomer cement. The type of bur or diamond rotary instrument used to prepare for crowns can also affect the retention of a crown placed with different cements.[7]

A significant issue after cementation is the presence of postoperative sensitivity. Conventional glass ionomer cements have higher rates of postoperative sensitivity than other cements,[8] although reports show that when a manufacturer's recommendations are followed, postoperative sensitivity is the same for zinc phosphate cement and glass ionomer cement.[9-11] Before cementation, the tooth must be clean and dried to a level compatible with the cement being used. To err on the side of caution, some recommend avoiding desiccation of the dentin surface of the preparation before cementation[12] to decrease the likelihood of postoperative sensitivity after cementation. Other studies describe the use of desensitizing agents and dentin sealers as part of the cementation process.[13-17] However, certain desensitizing techniques can have a negative impact on adhesion. Although use of a 5% glutaraldehyde sealer[15,16] or a resin desensitizer-sealer[14,16,17] is not detrimental to multistep etch and rinse adhesive resin cements or glass ionomer cements, oxalate desensitizers are incompatible with glass ionomer luting agents.[18]

MATERIAL OPTIONS

If there were one cement for all clinical situations, it would have to be easily mixed and go through its setting reaction either quickly for a single crown or inlay or onlay or be adjustable to set more slowly for multi-unit, more involved cementation cases. Unfortunately this "holy grail" of cements is not available. However, certain factors and properties can guide the choice of cement for a given situation. In the search for an all-purpose cement, specific physical properties and handling characteristics have been quantified.[19-21] The ideal properties of an all-purpose cement include the qualities listed in Box 23-1.

BOX 23.1 Desirable Properties of an All-Purpose Cement

- Low viscosity for easy seating
- Easy to mix
- Extended working time
- Short setting time
- Film thickness compatible with complete seating of a restoration
- Insolubility in the mouth
- High shear strength
- High tensile strength
- High compressive strength
- Bondable to tooth and restoration specific for the restorative material of the restoration
- Biocompatible with pulp and soft tissue (no postoperative sensitivity)
- Translucent
- Radiopaque
- Easy post-cementation cleanup

CLASSIFICATION OF DENTAL CEMENTS

Dental cements can be classified based on their chemistry and applications[19-21] (Table 23-1). All cements must have a film thickness and consistency compatible with cementation, as described in American Dental Association (ADA) specification No. 96 and International Organization for Standardization (ISO) specification 9917. The three categories of dental cements are water-based, resin-based, and oil-based definitive and temporary cements. Examples of each cement type are listed in Table 23-2. This chapter focuses on glass ionomer and adhesive composite resins.

Water-based cements typically undergo an acid-base setting reaction and are acidic during cementation. These cements are either non-adhesive or have a low bond strength to tooth structure. Some water-based cements provide for fluoride release. Examples of water-based cements are glass ionomer, resin-modified glass ionomer, zinc phosphate, and zinc polyacrylate.

Resin-based cements are chemically similar to composite resins. They have higher bond strengths to tooth structure when bonded to dental adhesives. In some cases these cements are self-adhesive to dentin. For some resin-based cements, surface treatments of the restoration combined with primers and monomers allow adherence to dental metallic alloys or ceramics. Although these cements have stronger physical properties, they are generally more technique sensitive to use.[22]

Oil-based cements are typically used for the cementation of temporary (provisional) restorations. In the past most contained eugenol, but there are now eugenol-free oil-based cements. Typically these cements have a greater film thickness than water-based and resin-based cements and much lower physical properties. In cementing provisional restorations with these agents, the tooth must be thoroughly cleaned before the definitive cement is applied.

Each category of cement presents challenges to achieving clinical success. Within each class, these cements have physical properties that allow for a consistency favorable to cementation and a film thickness that will allow for complete seating of a

همیار دندانسازان و دندانپزشکان

TABLE 23-1 Cement Types and Restorative Applications

TYPE OF CEMENT	APPLICATIONS
Water-Based Cements	
Conventional glass ionomer	All-metal crowns, fixed partial dentures
	Porcelain-metal crowns, fixed partial dentures
	Zirconia substructure (core), all ceramic
	Metal posts
	Cast metal inlay or onlay
	Implant-supported crowns, fixed partial dentures
Resin-modified glass ionomer	All-metal crowns, fixed partial dentures
	Porcelain-metal crowns, fixed partial dentures
	Zirconia substructure (core), all ceramic
	Metal posts
	Cast metal inlay or onlay
	Implant-supported crowns, fixed partial dentures
Zinc phosphate	All-metal crowns, fixed partial dentures
	Porcelain-metal crowns, fixed partial dentures
	Metal posts
	Cast metal inlay or onlay
Zinc polyacrylate	All-metal crowns, fixed partial dentures
	Porcelain-metal crowns, fixed partial dentures
	Metal posts
	Cast metal inlay or onlay
Resin-Based Cements	
Etch and rinse composite resin	All-metal crowns, fixed partial dentures
	Porcelain-metal crowns, fixed partial dentures
	Zirconia substructure (core), all ceramic
	Metal posts
	Cast metal inlay or onlay
	Implant-supported crowns, fixed partial dentures
	Fiber posts
	Porcelain veneers (light cure only)
	All-ceramic inlay, onlay, crown
	Composite inlay, onlay, crown
	Maryland bridge
Self-etch self adhesive composite resin	All-metal crowns, fixed partial dentures
	Porcelain-metal crowns, fixed partial dentures
	Zirconia substructure (core), all ceramic
	Metal posts
	Cast metal inlay or onlay
	Implant-supported crowns, fixed partial dentures
	Fiber posts
	Porcelain veneers (light cure only)
	All-ceramic inlay, onlay, crown
	Composite inlay, onlay, crown
	Maryland bridge
Compomers	All-metal crowns, fixed partial dentures
	Porcelain-metal crowns, fixed partial dentures
	Zirconia substructure (core) all-ceramic
	Metal posts
	Cast metal inlay, onlay
	Implant-supported crowns, fixed partial dentures
	Fiber posts
	Porcelain veneers (light cure only)
	All-ceramic inlay, onlay, crown
	Composite inlay, onlay, crown
	Maryland bridge
Oil-Based Cements	
Zinc oxide–eugenol	Provisional crown restorations
	Provisional inlay or onlay restorations
	Provisional veneer restorations
Non–eugenol–zinc oxide	Provisional crown restorations
	Provisional inlay or onlay restorations
	Provisional veneer restorations

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TABLE 23-2 Partial Listing of Contemporary Cements

BRAND NAME	MANUFACTURER
Conventional Glass Ionomer	
Ketac-Cem	3M ESPE
Fuji I	GC America
Aqua Meron	VOCO
Meron AC	VOCO
Riva Luting	SDI
GlassLute	Pulpdent
CX-Plus	Shofu
Resin-Modified Glass Ionomer	
RelyX Luting Plus	3M ESPE
RelyX Luting	3M ESPE
Fuji Plus	GC America
FujiCEM	GC America
Zinc Phosphate	
Hy-Bond zinc phosphate	Shofu
Zinc phosphate	Bosworth
Polyacrylate	
Durelon	3M ESPE
Hy-Bond polycarboxylate	Shofu
Etch-and-Rinse Resin Cement (Can Be Dual-Cure or Self-Cure)	
Infinity	Den-Mat
ResiLute	Pulpent
RelyX ARC	3M ESPE
C&B-METABOND	Parkell
Calibra	DENTSPLY Caulk
COMSPAN	DENTSPLY
Twinlook	Heraeus Kulzer
Nexus 2	Kerr
NX3 Nexus	Kerr
Cement-It	Pentron Clinical
Lute-It	Pentron Clinical
C&B Cement	Bisco
DUO-LINK	Bisco
Illusion	Bisco
CLEARFIL ESTHETIC and DC BOND	Kuraray
PANAVIA F2.0	Kuraray
Variolink II	Ivoclar Vivadent
Dual Cement	Ivoclar Vivadent
ParaCem	Coltène/Whaledent
Duo Cement Plus	Coltène/Whaledent
PermaFlo DC	Ultradent
Self-Etch Self-Adhesive Resin Cement	
iCEM	Heraeus Kulzer
SmartCem2	DENSTPLY Caulk
Multilink	Ivoclar Vivadent
RelyX Unicem	3M ESPE
MonoCem	Shofu
MaxCem	Kerr
MaxCem Elite	Kerr
Embrace	Pulpdent
Breeze	Pentron Clinical
BisCem	Bisco
G-CEM	GC America
Veneer Cements (Light Cure)	
Choice 2	Bisco
Illusion	Bisco
Calibra	DENTSPLY Caulk
Variolink veneer	Ivoclar Vivadent
RelyX veneer	3M ESPE
Ultra-Bond Plus	Den-Mat
NX3 Nexus	Kerr
CLEARFIL ESTHETIC CEMENT	Kuraray
Compomer Cement	
Principle	DENTSPLY Caulk

restoration. There is variability in the handling characteristics of each class of cement and even differences within the same class of cement. A recent survey of usage of definitive fixed prosthodontic cements noted that conventional glass ionomer was used 24% of the time, resin modified glass ionomer 46% of the time, composite resin cements 8% of the time, zinc phosphate cement 10% of the time, and zinc polycarboxylate 12% of the time.[23] Generally the clinician should not assume that cements within the same class are mixed and manipulated in the same way. The dentist and chairside assistant must read the manufacturer's instructions relative to material dispensing and mixing before using any cement on a restoration.[1,18,23]

Water-Based Cements

Glass Ionomer Cement

Glass ionomer cements are classified as either conventional glass ionomer cements, which are water-based without any resin, or resin-modified glass ionomer, which has about 10% resin added to improve physical properties. Both types of glass ionomer cements are adhesive to enamel and dentin via ionic bonding of the glass ionomer to the calcium and phosphate ions of the tooth. It usually takes 24 hours for the final adhesive values to be attained. Besides being self-adhesive through chemical bonding to tooth structure, glass ionomers have the additional

همیار دندانسازان و دندانپزشکان

benefit of leaching fluoride to the adjacent tooth structure, which provides some protection against recurrent caries. Both types of glass ionomer cement have low solubility.

Conventional glass ionomer is provided as a powder and liquid that can either be hand dispensed for mixing on a mixing pad with a cement spatula or used in a preloaded capsule that is mixed on a mechanical mixer (amalgamator, triturator). The capsule has a dispensing tip, and the cement is syringed using an applicator gun onto the restoration and preparation. Applicator guns are usually manufacturer specific. When using a conventional glass ionomer cement, the excess cement at the margins should be protected from moisture and dried using a coating agent or an unfilled bonding resin. It is advisable not to clear away excess cement until it is fully set.

Resin-Modified Glass Ionomer Cement

Resin-modified glass ionomer (Figure 23-1) (also referred to as *resin-reinforced* and *hybrid ionomer*) is supplied as a powder-liquid, a paste-paste, or a unit-dose mixing capsule with a dispensing tip. It is easier to mix than the conventional powder-liquid glass ionomer and has improved physical properties while retaining the properties of self-adhesion and fluoride release. Some resin-modified glass ionomer cements provide a dentin conditioner to improve adhesive bonding. It is acceptable to clear away excess resin-modified glass ionomer cement when it reaches the gel stage or after complete setting. Resin-modified glass ionomer cements are less vulnerable to the effects of early moisture.

Indications for Water-Based Cements

The primary clinical indications for either type of glass ionomer cement are all-metal and porcelain-metal restorations, alumina or zirconia core-type all-ceramic restorations, implant-supported crowns and fixed partial dentures, and metal posts. It is this author's primary cement for use in cementing all-metal and porcelain-metal restorations. The tooth must not be overly desiccated and dried when using this class of dental cement. One usually wets the dentin using a microapplicator or a damp cotton pellet so the dentin is slightly glossy with no water pooling on the surface. When glass ionomer cements were first introduced there was concern for postoperative sensitivity after cementation,[7] but not all studies have found this to be a problem.[8-10]

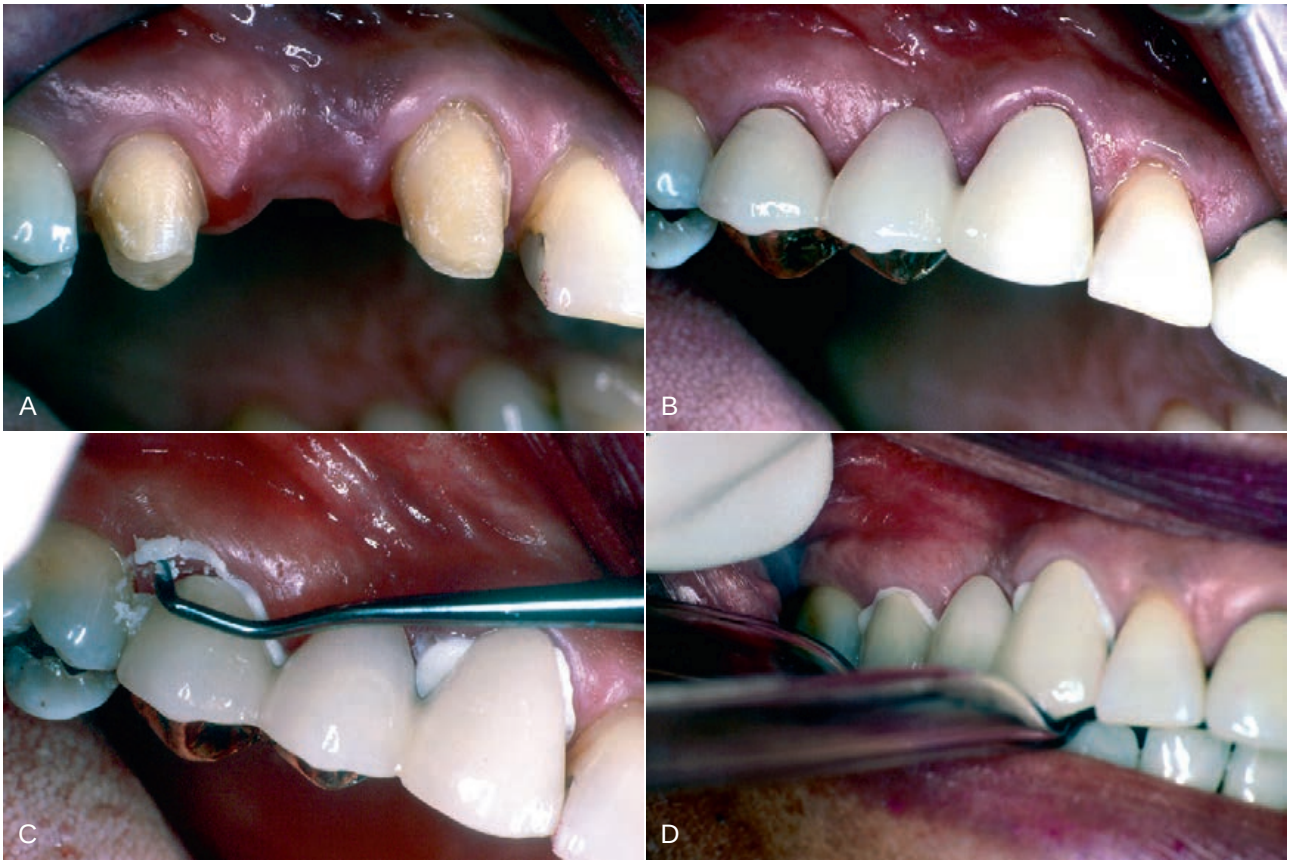


FIGURE 23-1 **Step-by-step cementation of a porcelain-metal fixed partial denture with a resin-modified glass ionomer cement. A, Preparations for porcelain-metal fixed partial denture. B, Porcelain-metal fixed partial denture being cemented with resin-modified glass ionomer cement (FujiCEM, GC America, Alsip, Illinois) using an active force when cementing by having the patient bite down on a saliva ejector. C, Cleaning away the set cement from the crown margins. D, Completed cementation of porcelain-metal restoration.**

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Resin-Based Cements

Composite Resin Cements

In recent years the number of composite resin cements has grown significantly. Within this class of resin-based luting agents are those that require a separate adhesive application and those that are self-adhesive. In most cases the indications for these types of dental cement are the same, but the ease of application differs. Adhesive resin cements typically use an etch-and-rinse bonding adhesive, whereas self-adhesive resin cements eliminate the need for the separate phosphoric acid etching and application of a separate resin adhesive to tooth structure before cementation. Various initiators and packaging are used to promote resin polymerization. Composite resin cements are supplied as powder-liquid and paste-paste hand-mixing formulas, a double-barreled syringe with automixing tips, and a unit-dose dispensing and mixing system.

All cements in this category are relatively insoluble compared with other dental cements. They have the highest mechanical physical properties, including high compressive strength, high flexural strength, good fracture toughness, low coefficient of thermal expansion and contraction, and highest stiffness of any dental cement.[1,18,23] Composite resin cements are based on the chemistry of direct placement restorative composite resins and are resistant to wear and abrasion.

This class of cement offers more toothlike translucency. These cements are often available in several shades to permit better matches to adjacent tooth structures. Adhesion of this class of cement to not only tooth structure but also etched porcelain and sand-blasted metal has been demonstrated.[24-27] The interface and bond between etched porcelain and composite resin when the porcelain has been treated with a ceramic primer (silane) strengthens the porcelain and eliminates the propagation of microcracks and fractures between the porcelain, composite resin, and enamel.[28,29] In terms of handling, composite resin cements have easy flow, spread readily over the surface being cemented, are not tacky, can be polished, and have a chameleon effect relative to surrounding tooth structure.

Etch-and-Rinse (Total-Etch) Adhesive Resin

The resin cements in this category require the use of separate tooth etching with phosphoric acid combined with the application of a separate resin bonding agent. When bonding to dentin, these cements use the adhesive as the bonding interface with the composite cement. The cements can be classified as self-cure (autopolymerizing), dual-cure (light cure and self-cure), and light cure. Autopolymerizing and dual-cure composite resin cements can be used for all cementation applications, including all-metal, porcelain-metal, and all-ceramic (fritted porcelain, pressed porcelain, alumina and zirconia porcelain cores) restorations (Figure 23-2).

The use of etch-and-rinse adhesive light-cure composite resin (Figure 23-3) cements should be limited to porcelain veneers and pressable ceramic crowns that allow the curing light to penetrate the porcelain so photopolymerization of the cement under the translucent veneer or crown occurs. The differences in the polymerization mechanism are based on the chemical type of initiator. Self-cure composite resin cements use a peroxide-amine initiator-accelerator; dual-cure composite resin cements use a combination of amine and photoinitiator; and light-cure resin cements use a photoinitiator only. Self-cure composite resin cements can be used to cement all types of indirect restorations, but because of potential problems with color stability, translucent all-ceramic restorations and all-ceramic crowns and veneers should be placed with light-cure composite cements.[30-32] When light-cure-only composite resin cements are used with all-ceramic veneers or crowns, the light-curing time should be increased when polymerizing through porcelain thicknesses of 0.5 to 2.0 mm.[19]

There has been concern that self-cure and dual-cure composites are chemically incompatible with light-cure-only adhesives.[33-38] Currently, changes in the chemistry of different systems and the addition of self-cure activators to fifth-generation adhesives (etch-and-rinse single-bottle adhesives, e.g., Prime & Bond NT, DENTSPLY Caulk, Milford, Delaware; OptiBond Solo Plus, Kerr Corporation, West Orange, California) appear to have solved this problem. Also, many of the latest generation of self-etch adhesives are now compatible with dual-cure and self-cure composite resin cements. Each practitioner must read the instruction sheet to guide the use of the resin cement and adhesive supplied. No agreement on the use of self-cure and dual-cure resin cements and etch-and-rinse and self-etch adhesives yet exists. When a dual-cure resin cement is used, the light-curing capability offers the added benefit of easy cleanup. The excess resin cement is readily removed from the marginal areas after light curing. Whenever any etch-and-rinse adhesive resin cement is used, care must be taken to inspect and remove excess resin cement. Unlike more traditional cements, where the excess can be easily removed with a scaler or curet, a rotary diamond or finishing bur is often required to remove set resin cement.

Self-Adhesive Resin Cements

Self-adhesive resin cements (Figure 23-4) are approaching the requirements of a true all-purpose cement. Although their use is not advisable with translucent ceramic restorations (pressed ceramic crowns and porcelain veneers), in which a color change in the cement could affect the restoration's color and a separate ceramic primer and adhesive are needed to reinforce the porcelain, they can be used for all other applications. This includes zirconia and alumina core ceramics, cast metal, porcelain-metal, and cementation of cast post and cores and prefabricated posts. These cements are dual-cure and have an easy cleanup at the gel phase.

Many of the cements in this category are available in dual-tube automixing configurations or in preloaded capsules that are mixed on a high-speed mixer (triturator) (G-CEM, GC America, Alsip, Illinois; RelyX Unicem, 3M ESPE, St Paul, Minnesota). These cements are especially useful in the cementation of fiber posts. RelyX Unicem provides a special tip for delivering the cement into the root canal for post cementation. Other cements can be easily placed into root canals for post cementation with needle tip–like delivery using either Jiffy Tubes (Water Pik, Inc., Fort Collins, Colorado) or AccuDose NeedleTubes (Centrix, Inc., Shelton, Connecticut). This type of needle delivery

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FIGURE 23-2 **A porcelain-metal crown cemented with a dual-cure composite resin cement A, Porcelain-metal crown preparation being cleaned with a prophylaxis cup with a pumice-water paste. B, Inside of porcelain-metal crown being air abraded to improve adhesion of composite resin cement. C, After 15 seconds of etching with phosphoric acid, rinsing, and drying, a dual-cure adhesive resin (Tenure, Den-Mat, Santa Maria, California) was applied to the tooth preparation. D, Cementation of porcelain-metal crown with a dual-cure composite resin cement using a Profin reciprocating handpiece (Dentatus USA, New York, New York) with a wooden insert and PDS/MJ2 tip (Dentatus) to fully seat crown with mechanical force. E, Completed cementation of porcelain-metal crown.**

is more effective at filling the root canal than a Lentulo spiral.[41] Even though these cements are self-adhesive using the mechanisms of the self-etch class of adhesives—for example, RelyX Unicem, G-CEM, BisCem (Bisco, Inc., Schaumburg, Illinois)[39,40]—some cements require a separate primer on the tooth surface before the cement is applied (Multilink, Ivoclar Vivadent, Inc., Amherst, New York).[42] Before using a self-adhesive cement, one should be familiar with the steps required.

Recommendations for Resin Cements

The physical properties of resin cements have been well researched.[5,42-44] Resin cements bond well to abraded base metal.[27,45] Research shows that resin-based cements and resin-modified glass ionomers are thixotropic, meaning that because they are viscous liquids there is a shear-thinning of the fluid phase of the cement that takes a finite amount of time to reach an equilibrium. The various physical characteristics and properties

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FIGURE 23-3 Restoration with pressed ceramic crowns and veneers, using an etch-and-rinse (total-etch) light-cured composite resin cement. **A,** Preoperative view before tooth preparations for pressed porcelain veneers and pressed all-ceramic crowns. **B,** Completed tooth preparations: maxillary canines, lateral incisors, and central incisors. **C,** Porcelain veneers (canines and lateral incisors) and porcelain crowns (central incisors) returned from laboratory. **D,** After 15 seconds of etching with phosphoric acid, rinsing, and drying, a light-cure adhesive resin was applied to the tooth preparations. **E,** Crowns and veneers have been seated with a light-cure composite resin cement (NX3 Nexus Cement, Kerr Corporation). **F,** Light-curing of facial surface of crowns and veneers. **G,** Completed all-ceramic crowns (IPS e.max CAD, a lithium disilicate glass ceramic, Ivoclar Vivadent).

همیار دندانسازان و دندانپزشکان



FIGURE 23-4 The use of a self-adhesive composite resin cement with alumina core ceramic crowns (NobelProcera, Nobel Biocare, Zurich, Sweden). **A** and **B**, Preoperative facial (**A**) and lingual (**B**) views of a patient with a history of bulimia. **C**, Completed crown preparations of maxillary lateral and central incisors. **D**, All-ceramic, alumina core crowns (NobelProcera) returned from laboratory. **E**, Self-adhesive resin cement (BisCem, Bisco, Inc.) being placed into the all-ceramic crown using an automixing tip. **F**, Completed all-ceramic crowns for the maxillary lateral and central incisors.

of these cements influence the seating of crowns during cementation.[46-48] Using force allows the cement to flow when the restoration is being seated completely on the tooth preparation. In fact, sustained seating pressure during luting procedures, up to 3 minutes, increases bond strength and improves marginal integrity of the interfacial margins.[49] A clinical technique to ensure complete seating of the restoration (not for ceramic inlays or onlays or pressed ceramic crowns) is to have the patient bite down on a saliva ejector.[50] The hydraulic forces needed to completely seat a crown, metal inlay or onlay, CAD-CAM–fabricated ceramic inlay or onlay using a resin-based cement or resin-modified glass ionomer require the use of a mechanical advantage.

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Dual-Cured Resin Cements and Esthetic Supragingival Margins

George Freedman

RELEVANCE OF CEMENTATION TO ESTHETIC DENTISTRY

Many dental restorations are fabricated indirectly outside of the mouth. As such they must be affixed to the tooth structures in some manner. Over the years, various cementation techniques have been used. Although adhesive cementation is not universally accepted as the only method to fix restorations to tooth structure, it has been gaining popularity and is increasingly the choice of both the patient and the dentist (Figure 23-5). Adhesive cements tend to perform more effectively than older luting cements, making restorations stronger and more resistant to marginal breakdown and failure. Because they can be manufactured in various shades, resin cements can match the color of the restoration and the tooth more accurately. In esthetic dentistry, a shade-matched intermediary material positioned between the tooth and the restoration is of paramount importance (Figure 23-6).

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF CEMENTATION

Generally, cements can be classified into two categories: luting cements and adhesive cements (Box 23-2). *Luting cements* rely on mechanical retention and are typically based on water and reactive alkaline fillers. They do not adhere to any surfaces. *Adhesive cements* are stabilized by adhesive bonding to both tooth structure and restoration. They are based on anhydrous and silanized nonreactive filler materials.

The luting cement's reliance on mechanical retention places tremendous clinical demands on the dentist's skills (Box 23-3). The preparation that is to receive the restoration must have long axial walls. Ideally there is a slight 6-degree gingival to incisal taper to the preparation three dimensionally circumferentially around the tooth, and the restoration must have a precise fit of about 30 to 100 µm. Conventional cements simply fill the gap between the tooth and the restoration. Much, if not all, of the retention depends on mechanical attributes: both the external surface of the tooth preparation and the internal surface of the restoration must be precise *and* complementary. If there is any significant variation from this adaptation model, the restoration will be lost rather quickly.

Adhesive restorations are stabilized by the adhesive bonding to both the restoration and the tooth (Box 23-4). This adhesion depends on adhesive surfaces and the materials that can adhere to them: the tooth surface, the internal surface of the restoration, and the intermediary cement. Adhesive cementation also depends on a controlled environment. The earlier resin cements required that moisture be strictly controlled by effective isolation. Any moisture diminished or totally eliminated the bond strength, and led to an early catastrophic failure of the adhesive interface, causing loss of the restoration. Adhesive cements also fill the gap between the tooth and the restoration, but unlike luting cements they bond to both the restoration and the tooth, creating a monobloc. In the monobloc, the strengths of the adhesion at the various component interfaces, such as the tooth-cement, and cement-restoration, are all greater than the cohesive strength of the dentin itself. When force is applied to the restored tooth, the force is dissipated evenly over the entire remaining tooth structure by the monobloc rather than being focused on a particular stress spot, better protecting the entire remaining tooth structure.

The dental profession has used a number of cements over the past century. The oldest cement still in use is *zinc phosphate cement* (Figure 23-7). Its advantages are that it can be used for both all-metal full crowns and bridges, and with porcelain-fused-to-metal restorations. It has excellent compressive strength and a good film thickness. Disadvantages are its low hardness and high solubility in oral fluids, low tensile strength when it is stressed, and lack of chemical bonding to either the tooth or the overlying restoration. Immediately after mixing, zinc phosphate is very acidic; when applied to vital teeth, there is an excellent likelihood that the acidity of the cement on application, which is about pH 2.0 or less, could be irritating, particularly if no anesthesia is used. Once the zinc phosphate has completely set, it maintains a pH of 4.5 -5.0. This is still quite acidic and may cause short-, medium-, and even long-term sensitivity of vital abutments and possibly necessitate post cementation endodontic treatment. Zinc phosphate cement is called a "permanent" cement but offers no adhesion to enamel, dentin, metal, or ceramic. Crowns cemented with zinc phosphate can be "recovered" or knocked off the abutment in most cases if the pressure

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FIGURE 23-5 **A, Tooth prepared with a supragingival margin. B, Esthetic crown cemented with the adhesive cementation method.**



FIGURE 23-6 **An esthetic restoration showing the effect of a shade-matched intermediary material between the tooth and the restoration.**



FIGURE 23-7 **Hy-Bond zinc phosphate cement.** *(Courtesy Shofu Dental Corporation, San Marcos, California.)*

BOX 23.2 Two Categories of Cements

Luting Cement
- Relies on mechanical retention
- Based on waters and reactive alkaline fillers

Adhesive Cement
- Stabilized by adhesive bonding
- Anhydrous and silanized non-reactive fillers

BOX 23.3 Luting Cement
- Relies on mechanical retention
  - Long axial walls
  - Slight taper of preparation (6 degrees)
  - Precise fit (30-100 µm)
  - Conventional cements fill the gap between the tooth and the restoration.

BOX 23.4 Adhesive Cement
- Stabilizes by adhesively bonding to both restoration and tooth
  - Adhesive surfaces
  - Controlled environment (no moisture)
  - Adhesive cements fill the gap between the tooth and bond to both restoration and tooth, creating a monobloc.

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FIGURE 23-8 Hy-Bond polycarboxylate cement. *(Courtesy Shofu Dental Corporation, San Marcos, California.)*



FIGURE 23-9 Glass ionomer cement. *(Courtesy Shofu Dental Corporation, San Marcos, California.)*

is applied carefully in on occlusal direction at the margin. Unfortunately, they also occasionally experience cement failure.

Zinc polycarboxylate cements (Figure 23-8) were introduced to overcome the high rate of sensitivity found with the zinc phosphate cements. They have been used for more than 25 years and have the ability to release fluoride. There is little evidence that the tooth surface actually incorporates any of the fluoride released, however. A major advantage with polycarboxylate cements is the lack of postoperative sensitivity; the pH of application and setting are higher (closer to pH 7) than that of zinc phosphate. These cements are useful for metal and porcelain-fused-to-metal crowns and bridges but have a lower compressive strength than zinc phosphate. The negatives of this material include high solubility and low hardness. The film thickness can be problematic, particularly if the mixing is not ideal. The product exhibits low tensile strength and can deform under loading, leading to de-cementation under extreme loads. Today, zinc polycarboxylate cements are considered excellent for long-term provisional indications but not long-term permanent ones. They are used quite often to cement implant superstructures where recovery on a regular basis is important.

Glass ionomer cements have been available for about 30 years (Figure 23-9). They also release fluoride but are of only medium adhesive strength to tooth structures. Their weak bond to enamel and dentin are compensated for by excellent biocompatibility. The negatives of glass ionomer cements include frequent postoperative sensitivity caused by the cement's acidity. Glass ionomers can be compromised by the presence of moisture during setting as well as the moist environment of the mouth. They are also sensitive to mechanical loading and tend not to support high stress. Their low tensile strength precludes them from use under extended bridges. Glass ionomers are popular as cements, but their properties are relatively weak. Their major drawback is their solubility in oral fluids, an obvious disadvantage in the oral cavity.



FIGURE 23-10 Resin-modified glass ionomer cement. *(GC Fuji Plus, GC America, Alsip, Illinois.)*

Resin-modified glass ionomers (Figure 23-10) have been available since the 1990s. They release fluoride, have medium bond strength, cause little postoperative sensitivity, and can be used under metallic and porcelain-fused-to-metal full crowns and bridges. These cements often exhibit very high bond strengths and are not particularly technique sensitive, making them relatively easy to use in dental practice. The powder, however, is moisture sensitive. Even after mixing and setting, the cement

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FIGURE 23-11 Composite resin cement. *(Calibra; courtesy DENTSPLY Caulk, Milford, Delaware.)*



FIGURE 23-12 One-step resin cement. *(Embrace WetBond; courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

may absorb moisture and swell three-dimensionally. When this occurs underneath metal restorations, there is not much of a problem. However, under more friable ceramic restorations, the expanding resin-modified glass ionomer cement often exerts greater forces than can be withstood by the ceramic, which is stressed and can fracture. Although resin-modified glass ionomer cements can be used for metal full crowns and porcelain-fused-to-metal full crowns and bridges, they are definitely contraindicated for all-ceramic restorations and veneers.

Composite resin cements have been used since the early 1990s (Figure 23-11). They may be self-cure or dual cure and have high adhesion to both the pretreated tooth structure and the restoration. Their high hardness prevents torquing, especially in the case of a bridge. They exhibit low solubility in oral fluids and good mechanical properties. Furthermore, when they are correctly applied, they can contribute to the overall esthetics of the restoration. Earlier composite resins required separate etchers, primers, and adhesives, necessitating many steps, and did not release fluoride. Because they hardened so well and quickly, it was important to remove any excess cement quickly, prior to complete polymerization. Etching of the tooth structure occasionally caused postoperative sensitivity. Composite resin cements are indicated for indirect restorations: metal, porcelain-fused-to-metal, ceramic, high-strength ceramic and composite resin. Their major drawback is the need for separate etching, primers, adhesives, and a large number of skilled hands to accomplish all these procedures, which become very technique sensitive and thus, problematic. They have little or no fluoride release, and can be moisture sensitive during placement. Generally composite resin cements have good mechanical properties, but their clinical moisture sensitivity is a drawback, particularly in situations where the restorative margins are subgingival.

The most recent addition to the cement families is the *one-step composite resin cement* (Figure 23-12). These cements were first introduced in the early 2000s and show high adhesion to restorative and enamel dentin surfaces, high hardness, and very low solubility; excellent mechanical properties; and when shade selection is correct,, excellent esthetics. The major advantage of one-step composite resin cements is that no etch, primer, or adhesive are required. There is a release of fluoride, and removal of excess cement is easy when undertaken immediately after application. Because there is no etching of vital tooth surface, no postoperative sensitivity develops. One-step composite resin cements are indicated for all restorations: metal, porcelain-fused-to-metal, ceramic, and composite resin.

The recent development of alumina and zirconia crowns and bridges has made many of the existing cements obsolete. The simple problem is that the most current resin materials do not adhere to either the alumina or zirconia, and thus become luting rather than adhesive cements. A new category of resin-based cements has been developed for these restorations and they provide full confidence for the dental practitioner. These A-Z cements include ResiCem (Shofu Dental Corporation, San Marcos, California) (see Figure 23-12). The basic kit includes the innovative two-component pre-mixed A-Z primer for the alumina and zirconia surfaces and the dual-cure ResiCem. This cement is compatible with the treated restorative surface and the remaining enamel, dentin, or composite buildup of the abutment.

One important note to remember is that zinc phosphate and polycarboxylate cements can be classified as *retrievable.* Under the right circumstances, and with special care taken to prevent damage to the remaining abutment, a cemented restoration can be removed if the tooth underneath must be accessed or the restoration repaired. Glass ionomer cements may be retrievable, but compomer and composite resin cements, both multistep and single-step formulations, are not. For crowns affixed with these latter cements, if the restoration must be removed from the tooth, it must be cut off; to physically knock it off in the fashion

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used to remove zinc phosphate–cemented crowns often fractures the tooth, eliminating the natural crown abutment as well as the fabricated crown.

RELATING FUNCTION AND ESTHETICS

Stronger and more resistant cements provide better retention for functional restorations. Because the restorations placed in the patient's mouth are typically expected to last many years, it is important that they are able to withstand normal function and para-function. Whereas this was the only required property for cements years ago, today the restoration not only has to function as a tooth but must look like a tooth as well. Preferably, from a patient's perspective, it should be indistinguishable from the natural tooth.

The cement is located at the interface between the restoration and the natural tooth structure, called the *margin.* Typically, the crown implies previous damage or disease in the natural tooth; the remaining tooth structure is often significantly darker or colored differently than the restoration, which is designed to resemble the original natural tooth. The esthetic issue involves the management of the marginal area where these differently colored materials are in close proximity, highlighting their chromatic differences. The easiest solution is to locate the margin subgingivally, because this places the margin out of sight, leaving the more esthetic part of the crown visible. There are some drawbacks to this:

1. More tooth structure must be removed to position the margin subgingivally.
2. Because of the surface roughness of the marginal interface in comparison with the natural tooth structure, the margin is often an area where bacteria tend to congregate, along with deposits of plaque and subsequent gingival irritation. Gingival irritation causes the gingiva to recede, eventually allowing the margin that was so meticulously located subgingivally to be seen.
3. Thus even when the margin is carefully placed in a subgingival location, all too often within a short span of 3 to 5 years it will be fully visible as a result of aging, gingival irritation, or lack of home maintenance on the patient's part.

Another important consideration for cements from an esthetic perspective is their actual color. There are various choices. The cement can be chosen to match the color of the remaining tooth root structure, to match the color of the crown, or some intermediate shade in between Translucent cements often offer the best, and easiest color matching across the margin; (Figure 23-13). The right cement color makes it possible to bridge the interface between the restoration and the tooth esthetically, allowing the margin to be located supragingivally. This is very advantageous because the marginal cement does not pose an esthetic liability and can be readily maintained by the patient (Figure 23-14).

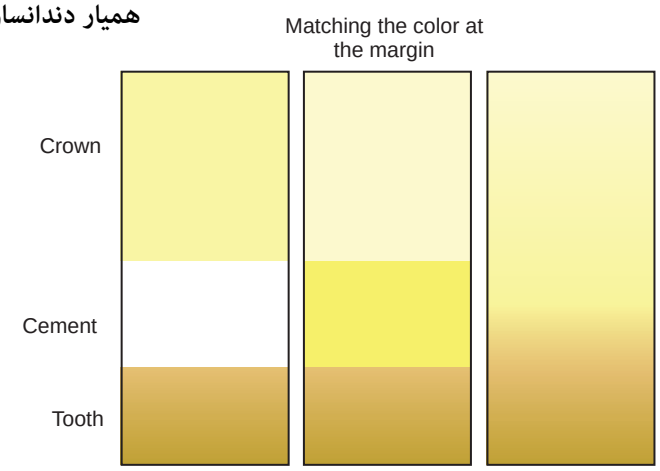


FIGURE 23-13 The cement can be chosen to be the color of the remaining tooth root structure, the color of the crown, some intermediate color, or possibly a translucent color to bridge the interface between the restoration and the tooth esthetically.



FIGURE 23-14 Supragingival margin showing a cement color match at the crown-tooth interface.

CLINICAL CONSIDERATIONS

The indications for dual-cure resin cements include crowns, inlays, onlays, and bridges. The contraindications include veneers, provisionals, and implants. A dual-cure resin cement will, after mixing, cure to hardness with or without light polymerization within 5 to 7 minutes, depending on the product and the manufacturer. If it is initiated by a curing light, the surface material (1 to 2 mm) that is directly accessible to photo-activation will cure within several seconds, depending on its color and thickness. The remaining dual-cure cement, unaffected by direct light, will continue to polymerize within the following 5-7 minutes; since the marginal areas are generally more exposed to photo-activation, the marginal cement polymerizes first, creating an effective moisture-proof seal for the

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remaining cement and allowing it to cure under relatively ideal conditions.

In considering the cementation of crowns, inlays, onlays, or bridges, particularly metal or porcelain-fused-to-metal restorations, it must be remembered that the curing light cannot pass through metal. The metal blocks all the polymerization rays. If the resin cement in the areas that are not directly reachable by the curing light is to harden, there must be a dual-cure component. The dual-cure initiator is typically based on phosphene chemistry, which, once initiated by light, will continue to polymerize the entire cement volume even in the absence of direct light. It is incorrectly assumed that light-cure resin cements can be used with all-ceramic restorations, even if they are thick and opaque; the actual amount of light that passes through an all-ceramic restoration thicker than 0.5 to 1.0 mm is virtually nil, even with the most translucent porcelains. Whether an indirect restoration is resin, ceramic, metal, or a combination thereof, as long as there is no direct light access to all areas of the cement, the cement used *must be* a dual-cure resin cement. Using the curing light at the margins (Figure 23-15, *A*), ideally for only 1 to 2 seconds, allows those margins to be set immediately, preventing contamination by moisture, blood, and other materials and allowing the excess resin cement at the margin to be scaled away while it is still relatively malleable (Figure 23-15, *B*). The hardened resin cement can be polished once it is completely set or polymerized. This is not difficult at the more accessible buccal and lingual surfaces. However, in the interproximal areas, a hardened resin cement can be quite difficult to remove without damaging surrounding structures, and may be inadvertently left in place; long-term, this can cause tissue damage and gingival recession. Provisionals, of course, should not be cemented with a permanent cement. Implants must be recoverable as well, in case the retention screw must be tightened for repair, replacement, or addition to the implant-borne restoration. Veneers are best cemented with light-cure resin cements (Figure 23-16). Phosphenes, the components that catalyze the dual-cure cement to polymerize to completion even in the absence of light, also tend to yellow the cement with time. This is not a desirable situation for veneers; therefore phosphene-free or light-cure resin cement should be used for these restorations.

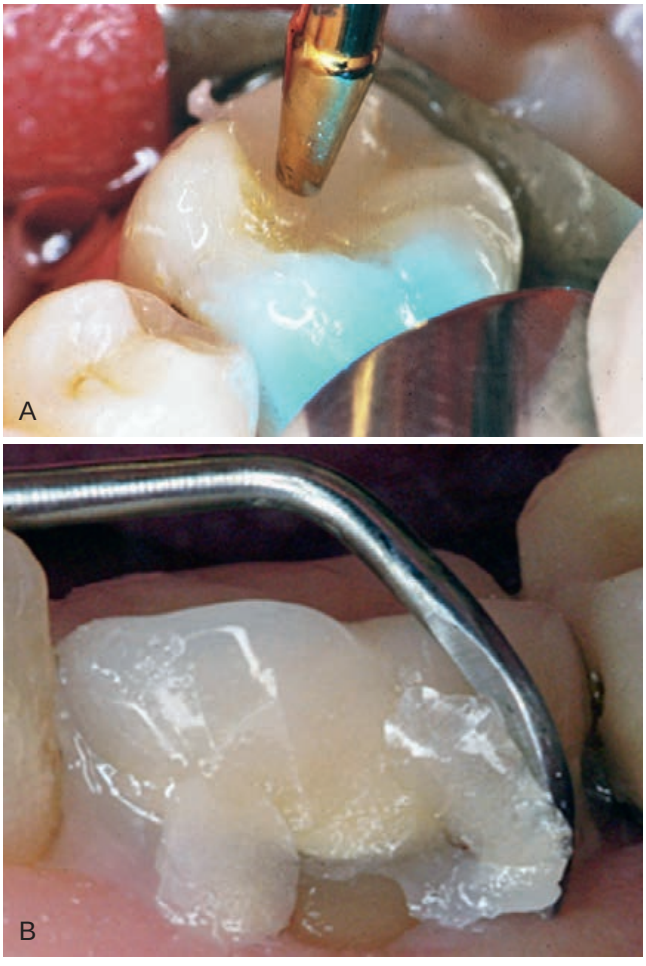


FIGURE 23-15 A, Tack curing the margins to prevent fluid contamination at the tooth-restoration interface. B, Tack curing allows easier removal of excess cement while it is still not fully polymerized.

MATERIAL OPTIONS

Advantages

The advantages of using composite resin cements are (1) they are the strongest available; (2) they have excellent adhesion to enamel, dentin, ceramic, and metal; and (3) all the interfacial bonding strengths are higher than the cohesive bond strength of dentin to itself; the overall interface between tooth and restoration is actually stronger than the natural tooth. Thus a force that is great enough to break the tooth will usually fracture the tooth structure cohesively, often the dentino-enamel junction (DEJ), leaving the tooth-restoration interface intact.

Resin cements have high hardness. When resin cements are used for an extended bridge, the torque created by occlusal



FIGURE 23-16 Light cure veneer cement. *(Kleer-Veneer; courtesy Pulpdent Corporation, Watertown, Massachusetts.)*

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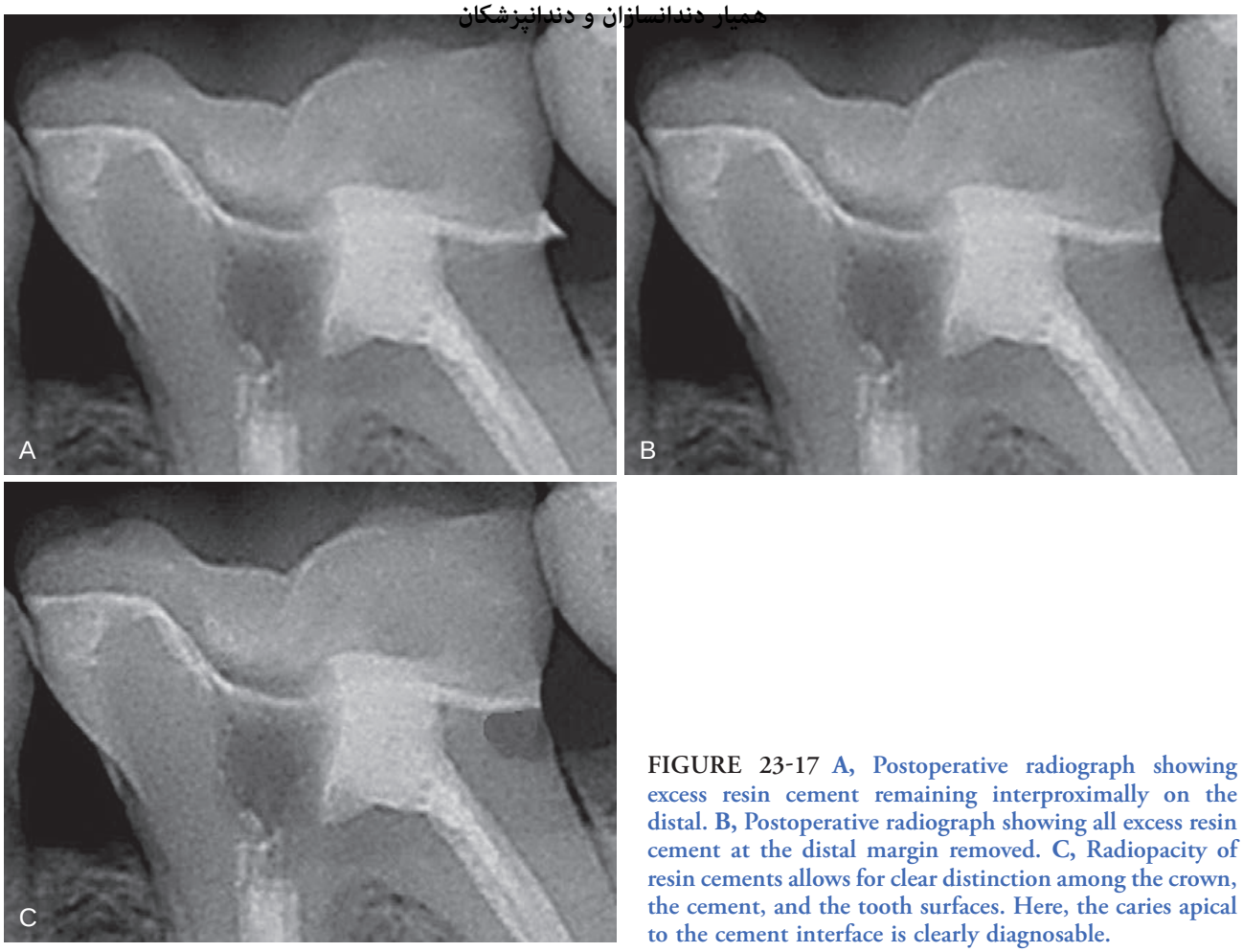


FIGURE 23-17 A, Postoperative radiograph showing excess resin cement remaining interproximally on the distal. B, Postoperative radiograph showing all excess resin cement at the distal margin removed. C, Radiopacity of resin cements allows for clear distinction among the crown, the cement, and the tooth surfaces. Here, the caries apical to the cement interface is clearly diagnosable.

pressure on one part of the bridge is not likely to debond an abutment at a location distant from the occlusal force. Because the bond strength is so high, occlusal forces, even if placed unevenly on a bridge, will tend to be redistributed in a more balanced fashion by the resin cement–bonded bridge to *all* the abutments. The low solubility of the resin cements ensures that they are truly permanent adhesive agents. Their solubility, measured over many years in the oral cavity, is a fraction of 1%. With the proper selection of cement and the development of a natural and esthetic emergence profile, the practitioner can achieve an imperceptible interface between the tooth and the restoration.

The relative absence of postoperative sensitivity with the self-adhering one-step composite resin cements is a major advantage. Many vital teeth require extensive restorations, such as when large amalgams are being replaced. It is important to maintain the pulpal health of these teeth and the patient's comfort at all times. Another major advantage of the one-step resin cements is that they involve a single clinical step. No etching, primers, or adhesives are required. Therefore the cementation procedure is simple and straightforward, and the dentist requires minimal assistance during the process.

It is important that dual-cure resin cement be radiopaque. When an immediate postoperative radiograph is taken, any excess resin cement left interproximally will be clearly visible (Figure 23-17, *A*) and can be eliminated (Figure 23-17, *B*). Over time, secondary decay may develop beneath a restoration. If the cement is radiolucent, it is difficult to differentiate the radiolucency of decay from the radiolucency of the cement. The professional must rely on the irregularity and shape of decay radiolucency to make an indirect diagnosis. Dual-cure resin cements that are radiopaque (have radiopaque filler particles included in their chemistry) clearly show up on radiographs, usually at the margin. It is easy to distinguish the presence of the cement between the crown and the tooth; radiolucent areas of decay at the margin or elsewhere at the interface are similarly clearly identifiable (Figure 23-17, *C*).

Disadvantages

Generally, resin-cemented restorations are not recoverable from the tooth without concomitant destruction of the restoration itself. The bond of the cemented crown to the tooth is so strong that attempting to remove it by force often fractures the remaining tooth structure. Therefore these restorations must be cut away from the tooth structure with diamond and carbide burs rather than knocked off.

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Current Best Approach

The current best approach to dual-cure resin cementation is the use of self-adhesive one-step resin cement. One-step resin cement has minimal technique sensitivity. There are far fewer components, far fewer steps, and a reduced likelihood of the dentist or the auxiliary making an error. Multi-step resin cements require multiple pairs of hands, two or ideally three team members, to mix the various components required, to apply them, and to maintain the mouth in a dry state so that no moisture contamination of the abutment occurs while awaiting the placement of the cemented restoration. For one-step resin cements, only one to two pairs of hands are required. Two sets of hands are ideal but even one pair, the operator working solo, will suffice.

The typical process is for the dentist to isolate the tooth to be cemented (Figure 23-18, *A*) and, after it has been cleansed, to moisten it with water (Figure 23-18, *B*). The auxiliary, having cleansed the internal surface of the crown, simply activates the dual-cure resin cement by pushing a single plunger that presses the two components through an auto-mixing tip and injects the cement into the prepared crown (Figure 23-18, *C*). The crown is then seated on the moistened abutment, the margins are verified, and the cement is light initiated (Figure 23-18, *D*). The excess resin cement is removed with a scaler (Figure 23-18, *E*) and with floss interproximally (Figure 23-18, *F*). Within 6 to 7 minutes, after a final check, the patient is completed (Figure 23-18, *G*).

The number of component procedures required for the earlier multistep resin cements is typically five or more, including etching (Figure 23-19, *A*), conditioning (Figure 23-19, *B*), priming (Figure 23-19, *C*), bonding, mixing, filling (Figure 23-19, *D*), and insertion (Figure 23-19, *E*). Each step includes the nagging possibility that errors of improper sequencing or improper timing will occur. The one-step resin cements are simply injected directly into the crown, which is then placed onto the prepared tooth and photo-initiated.

Another significant clinical consideration is the chairtime involved. Multistep resin cement procedures take 15 minutes or more per cementation. One-step resin cements require 5 or 7 minutes; at this time, the interface-initiated cement has completely polymerized, and the excess cement has been removed interproximally, buccally and lingually.

OTHER CONSIDERATIONS

There are several differences between light-cure, self-cure, and dual-cure resin cements. *Light-cure resin cements* are polymerized by curing light activation only. *Self-cure resin cements* are activated by mixing two components and do not require a curing light. They are not affected by exposure to a curing light. *Dual-cure resin cements* are manufactured in two components. Once mixed, they will polymerize to completion within several minutes; applying the curing light, however, will polymerize any exposed surfaces, allowing the setting process to continue below the cured material until all the cement is self-cured. The advantage of the dual-cure resin cements is that the practitioner can polymerize the exposed marginal surfaces, hardening them immediately and preventing potential moisture or blood contamination. This also allows immediate cleanup of marginal areas. Generally, light-cured resin cements should be used for porcelain veneers. Dual-cure or self-cure resin cements are useful for all other indirect restorations.

INNOVATIVE ELEMENTS

Clinical Elements

A number of innovations have accompanied one-step dual-cure resin cements. Scientifically, manufacturers have made them easier to use and more convenient for both dentist and patient. They are also much less technique sensitive. These cements are self-adhesive to both moist enamel and moist dentin. This eliminates numerous tooth and restoration conditioning steps, the need to desiccate the remaining dental structures, and decreases the likelihood of post-cementation acid-induced sensitivity of vital teeth.

Most recently, totally translucent dual-cure resin cements have been introduced. These resin cements are effectively transparent and allow the color of the underlying natural tooth or core restoration to shine through. They eliminate the distinct visual boundary between the various materials at the margin. These materials allow the well-fabricated crown to blend in imperceptibly to the tooth structure at the gingival margin. As a result, translucent resin cements can make the marginal area look entirely natural, and allow the margin to be placed supragingivally while respecting the patient's demand for esthetic results.

Scientific and Technologic Elements

Technological innovations in single-step dual-cure resin cements include the chemistry that allows them to bond to moist enamel and dentin. In the rather moist environment of the mouth this makes the practitioner's task much easier. He or she will not need to work against all the odds to keep the tooth surfaces completely dry. Moisture is allowed, but preferably water, not saliva, for ideal cementation whether subgingival or supragingival. In situations where deeply subgingival margins are inescapable, and moisture (crevicular fluid) at the interface is unavoidable, the moisture-tolerating one-step dual-cure resin cement is likely to result in better, if not ideal, restorative margins.

The comparison between older, more traditional composite resin cements and newer one-step resin cements is straightforward and rather dramatic. Unlike the older resin cements, the one-step resin cements require no etching, no bonding, and only one clinical step versus multiple steps for the older resin cements. The newer products are usually available in the automix format, eliminating the inaccurate and bubble-incorporating pad mixing required for the older resin materials. Cleanup on the tooth at the crown margins is quite fast and easy.

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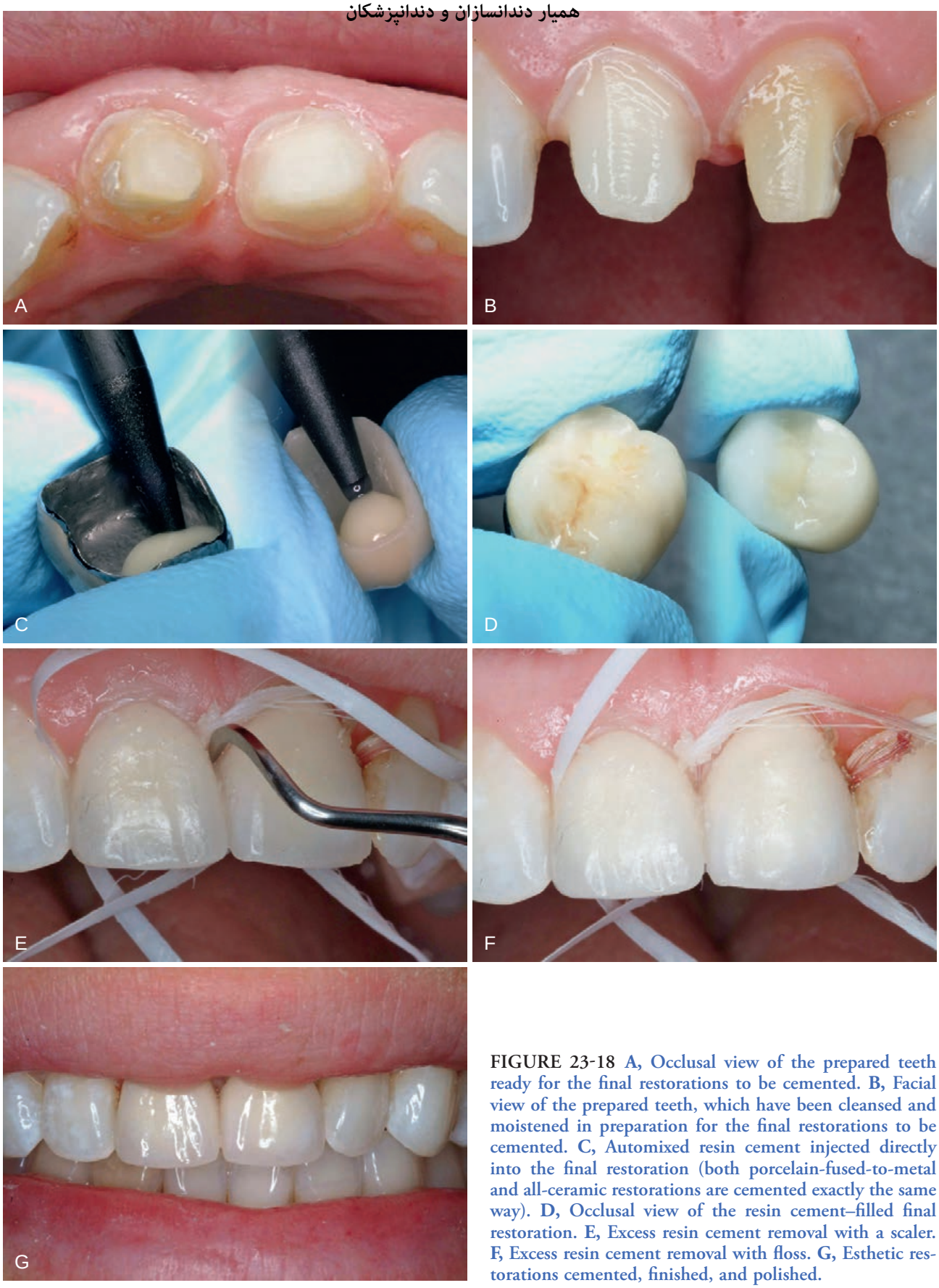


FIGURE 23-18 **A,** Occlusal view of the prepared teeth ready for the final restorations to be cemented. **B,** Facial view of the prepared teeth, which have been cleansed and moistened in preparation for the final restorations to be cemented. **C,** Automixed resin cement injected directly into the final restoration (both porcelain-fused-to-metal and all-ceramic restorations are cemented exactly the same way). **D,** Occlusal view of the resin cement–filled final restoration. **E,** Excess resin cement removal with a scaler. **F,** Excess resin cement removal with floss. **G,** Esthetic restorations cemented, finished, and polished.

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FIGURE 23-19 **A, Prepared teeth. Etching the preparations. B, Conditioning the preparations. C, Application of primer in the restoration. D, Mixing cement on the pad, risking the incorporation of air bubbles. E, Loading the restoration with the mixed cement.**

ARTISTIC ELEMENTS

The artistic elements of tooth cementation are virtually infinite. Any number of shades can be used alone or in combination to create various effects. The minimal thickness of the cement layer does not permit a *major* color change to be implemented, however. Even at the minimal ceramic thickness of the margins, often only a slight color variation can be introduced by the filler coloration of the cement. In examining the options available, using a translucent cement with a well-fabricated crown, preferably with all-ceramic and/or translucent margins, is the easiest way to achieve superlative esthetics and an imperceptible margin.

TREATMENT PLANNING

In planning the restorative procedure, it is important to consider which cement will be used. If the cement is to be un-esthetic, it is best to place the margin subgingivally, recognizing that this will eventually, owing to aging, recession and gingival irritation, become supragingival. When a subgingival

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margin is planned, there is less clinical concern for the color shift between the restoration and the tooth or for the color of the cement itself. "Out of sight" can be "out of mind", even though this might not be a permanent or even a long-term situation.

If the practitioner uses truly esthetic cements, the margin can be placed virtually anywhere, even in full view. Thus the restoration can be far more conservative. The margin can be supragingival and can be blended with any natural tooth coloration. If the practitioner uses this knowledge to plan the procedure, much healthy tooth structure can be preserved, and a more conservative restoration can be recommended. Less invasive restorations can be selected, and esthetic concerns have less of an impact on the definitive restoration.

Cementation is the penultimate step for indirect procedures. The only procedures required after cementation are the polishing of the margins and the verification of the occlusion. All steps that lead up to the process of cementation must be accomplished accurately if the cementation process is to succeed. Even though cementation is nearly the final step in indirect restorations, it is important to include cementation objectives and planning at the stage of initial treatment planning.

Preparation

Use of dual-cure resin cement is much easier clinically than it used to be. The preparation must be accomplished with minimal removal of tooth structure, but it is also important to provide adequate thickness for the ceramic to create the proper shade for the final restoration. Whereas tooth preparation in terms of parallelism and axial wall surface available for retention is not nearly as critical with adhesive resin cements as with zinc phosphate luting agents, it is still preferable to provide the laboratory technician with a strictly defined preparation: tapering walls without undercuts, smooth and rounded surfaces, and no acutely angled areas of the tooth that could stress the overlying ceramic after cementation. Generally, the rule is to remove as little as possible and only as much as needed.

Although the ideal luting thickness (and the required thickness for resin cements) may be as low as 10 to 15 μm, realistically the accuracy of most laboratories is more likely to be in the 30- to 100-μm range. Fortunately, the dual-cure resin cement creates a monobloc from the natural tooth to the restoration; the entire cement volume, whether 10 or 100 μm, consists of a material that is (1) stronger than the natural tooth structure, (2) adhesively bonded to surrounding structures, and (3) unlikely to be a functional liability.

Procedure

The procedure for using one-step resin cements is very straightforward. Once the abutment tooth has been thoroughly cleaned and moistened, the one-step resin cement is mixed and expressed by slightly depressing the plunger, providing exactly the right amounts of both components. After disposing of the first bit of cement (which may not be totally mixed) as it exits the auto-mixing tip, the cement is injected directly into the restoration. The cement-filled crown is then fitted onto the tooth.

Finishing

The finishing of the dual-cure resin cement is accomplished immediately after the initial light cure (1 or 2 seconds) while the resin is still relatively easy to remove, particularly in the interproximal regions. This best instruments for this task are scalers and/or floss. It is essential that positive pressure by means of a finger or an instrument be maintained on the crown until the dual-cure set is complete at 5 to 7 minutes. Otherwise the pressure of the scaling instruments or the floss can actually dislodge the partially cemented crown at a juncture where the resin cement between the restoration and the tooth has not completely polymerized and cannot offer much retention. Furthermore, trapping cement between the crown and the tooth results in fluid pressure that tends to push the crown off the tooth, away from a complete seating. Positive pressure during the polymerization phase eliminates this problem. Once the cement has completely polymerized, within 5 to 7 minutes, the remaining excess resin cement at the margins is removed, and polishing is done as necessary (Figure 23-20, *A,* Jazz composite polishing system for margins; Figure 23-20, *B,* Jazz ceramic polishing system for ceramic), and a radiograph is taken to verify that there is no resin cement left in the more difficult-to-reach interproximal areas. Interproximal flash is highly irritating to the soft tissues if left in place, and can sever periodontal damage.

EVIDENCE-BASED PRINCIPLES

The monobloc principle ensures that the forces placed on cemented crowns are distributed as evenly as possible to the underlying tooth structures. The key to this concept is that each interface between the tooth and the restoration is at least as strong as, or stronger than, the cohesive forces in the natural tooth structure. In this model, the interfaces are no longer the weak points at which excessive forces can break the crown off the tooth. The forces are transmitted through the remaining tooth and root, which together are best equipped to handle excessive occlusal and lateral forces. If enough force is applied, of course, the tooth *can* fracture, usually cohesively, within the dentin but not at the restorative interface.

When comparing various cements, it is important to compare them equitably. The clinically established "pull" adhesive strength measurement is the best indicator of the long-term success of a resin cement. Shear strength measurements and compressive strength measurements mean little in terms of the retention of a restoration. The periodontal considerations for margin placement are universally accepted. Since the 1950s the periodontal literature has pointed to the benefits of a supragingival margin. However, patient demands for esthetics did not permit the placement of the then-unesthetic restorative margins supragingivally. Patients were focused on esthetics first and tooth conservation second. Today, however, the profession can deliver both esthetic *and* supragingival margins within the same restoration.

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A B

FIGURE 23-20 A, Jazz composite polishing kit. B, Jazz porcelain and metal polishing kit. *(Courtesy SS White Burs, Lakewood, New Jersey.)*

Esthetic supragingival adhesive margins are far more effective than the older luting cement interfaces. Crowns are far more retentive and require less axial wall preparation. Bonded indirect restorations are less critically dependent on the preparation shape; thus, tooth structures can be conserved and the esthetic aspirations of patients can be served within the same procedure.

CLINICAL CONSERVATION CONCEPTS

Supragingival margins preserve marginal and subgingival tooth structure. Placing margins supragingivally requires less tooth structure to be removed. Because less tooth structure must be removed, more natural tooth is retained, leaving a stronger abutment that is more able to withstand vertical and lateral forces and functional and para-functional stresses. This is evident in preparing for a bridge. The angulations of the tooth preparations and the limitations of parallelism that must be respected necessitate far less removal of tooth structure when the margins are supragingival. More retained tooth structure means a more resistant tooth. A more resistant tooth implies that the restoration will last longer, be more effective, and function better for the patient. With clinical conservation and supragingival margins, it is far more likely that dentists can provide a restoration that will be functionally useful for the patient's entire life.

MAINTENANCE

Maintenance issues have always been problematic with dental restorations. It is important to consider that although most patients brush once or twice a day, few patients floss their teeth on a regular basis. The likelihood of a patient being able, or motivated enough, to cleanse a *subgingival* margin is virtually nil. There is no access to this area, no visibility, and little awareness in the patient's mind that an unseen, unfelt location must be kept clean. Ultimately subgingival margins attract plaque, bacteria, and calculus, restarting the tooth-destructive process that was the reason that a crown was needed in the first place. Thus the subgingival margin simply recreates the very same problems that it is intended to solve and simply moves these problems more apically to a less accessible location on the root surface and forward to a point in the near future.

In contrast, supragingival margins are very easy to clean. They are readily visible, readily accessible, and readily cleansable. Even patients who only brush are likely to cleanse most of the exposed margins on a fairly regular basis. Margins that are supragingival rarely exhibit decay or breakdown (Figure 23-21, *A*). They often do stain with time, but these surface discolorations are easily polished off. The only clinical question is whether the supragingival margin can be made esthetically acceptable to the patient (Figure 23-21, *B*). Posterior supragingival margins are out of sight and are less esthetically critical (Figure 23-21, *C*). Anterior supragingival margins are in full view, and appearance is very important.

CONTROVERSIES

Although many controversies have swirled over the use of zinc phosphate cement versus adhesive resin cement, these issues have largely been resolved. The resin cements have proved to be successful in the short and long term and are used by a majority of dentists on a regular basis worldwide. The current questions compare the traditional multi-step resin cements

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FIGURE 23-21 **A, Supragingival margins rarely exhibit decay or breakdown. B, Esthetic supragingival margin in the posterior region. C, Esthetic supragingival margin in the esthetic zone.**

and the newer one-step resin cements. Because the older resin cements have so many more steps, are so much more technique sensitive, and are less clinically efficient, it is simply a matter of time before the use of one-step resin cements becomes the mainstream cementation procedure. Most controversies seem to occur when new techniques are introduced. Not all new techniques succeed. When a new technique is better than an older one, it will, within a short time, supersede it. When it is not, it will fall by the wayside. Controversies at any given time are simply the new battling against the old. Within an educated profession, it is the better technique or material that ultimately rises to mainstream acceptance and use.

SUGGESTED READINGS

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Complete Denture Esthetics

Joseph Massad

RELEVANCE OF COMPLETE PROSTHETIC DENTURES TO ESTHETIC DENTISTRY

Because the goal is meeting the esthetic desires of patients who have lost their teeth, complete dentures are probably the most relevant area for esthetics in dentistry. Patients who are completely edentulous generally have poor self-esteem, generalized soreness, and difficulty in effectively chewing many foods. With complete dentures, a patient's self-esteem and self-worth can be improved to such a degree that these deprived people will feel much better about themselves and become a part of society, able to communicate easily. Some surveys have estimated that approximately 15% of the global population is edentulous. In the United States alone, this accounts for 36,000,000 Americans, or approximately 12% of the U.S. population. When a patient loses all of his or her teeth, one of the options is complete denture therapy, provided that the patient is a good candidate. The practitioner must take into account not only function, but how the final prosthesis will fill the void from the loss of teeth and much of the surrounding bone structure. Replacing the void from inside the oral cavity will assist in recreating (or shaping) the outer facial contours by restoring the inner structure, thereby replacing the mass supporting the external muscles and allowing an overall natural smile to be presented to the patient and his or her beholders.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT OF COMPLETE DENTURES

The history can be prefaced with a brief quote by Dr John Anderson, who once said, "If you're going to quote what I said or write, please put a date on when I said [May, 1980] or published it." I think that we are all aware that education is always in motion. In the days of George Washington, dentures were carved out of wood, stone, and ivory. The dentists of that time sculpted and shaped teeth by looking into people's mouths and matching the natural dentition of most humans. Over the years, numerous sources pertaining to the art and science of denture creation were made available to the profession to aid in fabricating complete dentures. In the last century, many in the profession were guided by the influence of great professors such as Dr Carl Boucher (and others of the same philosophy) who authored textbooks on complete denture fabrication. However, dentists in other parts of the country chose to follow alternative methods and techniques with somewhat different opinions for preparing dentures. Public curricula were generally based on one or two of the major textbooks written by the most prestigious professors of their time. The textbooks documented methods that they had personally performed, not once or twice, but hundreds of times. This was essentially the first evidence-based dentistry.

Beginning in the 1990s, compilations of many of the major textbooks and published articles over the previous 50 years began to be published to create an additive effect, whereby teachings began to be modified by combining parts that lead to predictability. The earlier, less predictable denture outcome, compounded with patient dissatisfaction, influenced an evaluation of all the current methods and an overhaul based on an analysis of each reported problem, with development of a solution with a consistent predictable result. New protocols and methods were developed that incorporated improved materials and a better understanding of the effects of the aging population's role in prosthetic dissatisfaction. It was even more important to apply the current understanding of the entire stomatognathic system when creating a valid solution to the reported problems.

EVOLUTION OF COMPLETE DENTURE PROCEDURES

Historically dentures were predominately designed according to valid anatomical landmarks. Different methods of designing a prosthesis were employed based on different landmarks. For example, the boundary of the upper denture base between the hard and soft palates and around the tuberosities was designed mostly from anatomical landmarks. From approximately the 1940s to 1980s, the use of landmarks not only was accepted but had reasonably successful outcomes. However, as time passed, the life span of the population began to increase significantly owing to improved healthcare, a better understanding of how factors affecting the body also affect health, and the new age of pharmaceutical drugs. Even though the predominant anatomical approach was extremely effective for a time, the fact could not be avoided that denture procedures needed to be reevaluated and updated to address modern realities—realities that frustrated

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both dentists and patients. Considering that life expectancy at the time the majority of the textbooks were published (from the 1940s to the 1980s) was close to 16 years less than today's average life expectancy, the need for updated procedures can be easily understood.

So why did it take dentistry so long to update the complete removable prosthesis process? Because the mission of dentistry was to stop total edentulism in the world by research. Dentistry began to flourish in other areas, with new ideas and techniques, new materials and machinery, and better education in ways to maintain a patient's dentition. At that time, dentistry was on the right track to try to maintain and educate patients on how to keep their teeth over their lifespan. No one today ever anticipated that there would be, in the year 2011, 36 million Americans who are edentulous and are denture wearers. It was thought that by improving both education and new technologies, dentistry would be able to defeat the loss of total dentitions within the population. However, what was not taken into account was that as patients grow into their 70s, 80s, and 90s, the dentition may wear out, resulting in an increased number of denture wearers in the aging population but not necessarily because of loss of more teeth. In all fairness, dentists need to look back at the forefathers of dentistry and thank them for all they did to assist their students, who have grown into the new age of knowledge, science, and evidence-based medicine.

So what can be taken from this? Creation of dentures based on anatomical and functional musculature and other physiological aspects results in more predictability and less dissatisfaction. A purely singular concept of anatomical design may have worked nicely on a 50-year-old who still had good muscle tone; however, the same design might not have been appropriate for an 80-year-old because of the loss of muscle tone and alterations in anatomy, physiology, and function. Some patients, often those taking certain medications, may have artificially lost muscle tone and may also have had complications of xerostomia, or dry mouth. These particular situations effectively resulted in less predictability until dentists began to understand that older patients have a different set of rules than those that applied when they were much younger.

In the last century the anatomically designed prosthesis was the standard, and in making definitive impressions, border molding procedures were predominantly dictated by the dentist. This method did not necessarily take into consideration all the possible functional maneuvers patients may perform when in their own environments.

For example, patients will suck strongly through a straw, smile a moderate to full grin, and vigorously laugh, which will alter the shapes of the peripheral anatomy of both the maxillary and mandibular sulcular form. It is also understood today that the post-palatal zone is asymmetrical, and the maneuver taught by Valsalva was enhanced by being able to use impression materials that respond to resistance 10 to 12 mm (a viscosity heavy enough to properly measure the degree of forward movement of the soft without the need to have a long posterior perimeter of the tray) and extend beyond the tray border without distortion. This allows the practitioner to use an impression tray that is significantly short of the functional zone and allows the patient to vigorously cough while the dentist occludes the nostrils with a rigid impression material extending beyond the posterior border of the tray, allowing the soft palate to move forward and thereby shaping the left and right post-palatal zones accurately.

RELATING FUNCTION AND ESTHETICS TO COMPLETE DENTURES

In making a complete denture prosthesis for a patient who has lost all the teeth of both arches, the patient's vertical spacing must be reestablished. This vertical spacing, among other functions, is what makes the patient look younger or older. Patients with a significant loss of vertical dimension generally will have the lower chin protruding slightly past the upper face. Reestablishing the appropriate vertical spacing will improve the patient's appearance by decreasing the sunken and aging appearance. This vertical space must be not only esthetically pleasing but also compatible with the typical mandibular joint apparatus, including the muscles of mastication. The outer surfaces of the prosthesis should be built to support the facial muscles, thereby giving the patient a natural, healthy appearance. A patient exhibiting flaccid or very weak muscular tone will generally require a prosthesis cameo surface to fill the horizontal vestibular void, whereas the patient with stronger muscular tone would demonstrate less horizontal projection of this cameo surface.

It is also necessary for the cameo portion of the complete denture prosthesis to be compatible with musculature action to support the facial muscles and decrease food entrapment around and under the natural peripheral borders of the sulcular space. Patients should achieve improved efficient chewing capabilities through appropriate fabrication of the proper cameo prosthetic surface.

The position of the teeth from labio-buccal and linguo-palatal and within the confines of the musculature action of the lips and cheeks contracting inward and the tongue muscle moving forward and laterally outward will guide the bolus of food to remain on the occlusal chewing surfaces of the teeth during mastication. This space is what was described as the *neutral zone* by Beresin and Schiesser in their 1973 textbook. This is one of the clinical considerations that was not popular from the 1970s to the 1990s as the anatomical approach dominated education. However, it should be apparent that combining the anatomical, physiological, and functional aspects of the muscles, along with the proper spacing between the upper and lower jaws, allows modern dentists to use the ideas of their prestigious forefathers to create a new model for the complete removable prosthesis.

Contraindications

Patients who should not receive complete removable dentures include those who are psychologically phobic about having any foreign objects placed into the oral cavity. Also, patients who have extremely sensitive gag reflexes may not be appropriate candidates for a full maxillary prosthesis.

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Patients who do not want to wear any type of detachable prosthesis are not candidates. Patients with chronic parafunctional habits, including erratic tongue movements, have severe difficulty with any type of removal detachable prosthesis, as patients with chronic erratic spitting problems and those who cannot control their tongue movements and have habitual movements of both the tongue and the jaw. Such parafunctional habits generally are considered a contraindication for a complete removal denture. Patients who have neurological deficiencies, such as those occurring after a stroke, involving greater numbness on one side than on the other have difficulties in chewing, especially with any appliance that is not secured in the mouth. Patients who indicate that they want only teeth that "do not come out" are not good candidates and should not be encouraged to have a complete denture unless they are willing to have psychological help to alter their desires.

Also among the contraindications are patients who are chronic bruxers and who generally grind their teeth with heavy forces. These patients are liable to breaking the denture and can also sustain severe tissue abrasions.

MATERIAL OPTIONS

The materials used in complete removable prostheses are generally acrylics or methyl methacrylate. Generally the bases of the prosthesis are made of acrylic resin and the denture teeth of a very similar acrylic, which aids in chemical bonding. Other choices of materials for denture bases include urethane materials, which do not have any free monomer and may be indicated for patients who have hypersensitivity or allergic reactions to acrylic materials. Options for the teeth include composite and porcelain materials. It is generally thought by many practitioners that if the occlusion is fully balanced, then porcelain teeth have a much longer wear factor. However, there is also controversy because porcelain teeth can sustain damage if the occlusion is not always in balance. Generally, porcelain teeth are more esthetic because they can be layered and have a more crystalline or toothlike appearance. In the profession today, the composites, even though they have been reported to fracture, are being improved and have properties that fall between those of acrylic and of porcelain. Acrylic teeth generally are relatively strong when they are chemically cross-linked with fibers. Thus fractures are less likely than with porcelain, which is a much harder material—consider, for example, a ceramic floor versus a tile floor. Ceramics generally have a higher propensity for cracking but are more natural in appearance; the double cross-linked fibered acrylic teeth have less chance of fracture than porcelain teeth.

It is extremely important for the dentist and the patient to have a mutual understanding of the end result. Giving the patient appropriate alternative treatment is of the utmost importance in allowing him or her to choose from the many options available in dentistry today. It is important in discussing treatment with patients who have lost all of the teeth owing to either periodontal disease or caries that the dentist make the patients aware that even with an artificial prosthesis, they may still have some difficulty unless they are able to change health and hygiene habits. Patients should also be aware that once the prosthesis is completed, maintenance will still be necessary. It is both ethically and professionally appropriate for the dental practitioner to discuss with the patient the financial considerations associated with the type of prosthesis the patient is choosing. If a patient receives a complete prosthesis on the maxillary arch and a partial prosthesis on the mandibular arch, the patient will still be responsible for maintaining the remaining teeth on the mandibular arch. Patients should be made aware of the fact that once the lower teeth are deemed to be non-restorable, then the lower prosthesis will need to be either added to if possible or replaced completely, depending on the severity of the failing dentition.

It was thought at one time that patients with severe bone loss were not candidates for a complete removable prosthesis. However, it has been shown that even with bone deficiencies patients can wear a complete removable denture if the practitioner understands that he or she must take into account the anatomy, physiology, function, and esthetic considerations in combination and must use a tested protocol to fabricate the prosthesis. When the prosthesis is created in this fashion, the patient will have the best opportunity for a successful result. It has also been thought by many practitioners that implants will "fix" denture problems; however, this has not been the overall consensus. Patients who have not been happy with a complete denture prosthesis and are then converted to an implant-retained prosthesis report satisfaction owing to the retention of the prosthesis. However, over the last 20 years, patients who were initially satisfied with the conversion have made other complaints. These complaints generally have involved food entrapment in and around the prosthesis, breakage of the prosthesis, maintenance of the prosthesis, and an unnatural feeling with the prosthetic device in the mouth.

These complaints support the concept of designing the complete denture differently than was done in the 1970s. Implants are not a "fix" for ill-fitting dentures. Once the denture model has been analyzed and reconfigured to today's standards, then implants become a partner in the successful result.

Current Best Approach

The current best approach is to use porcelain denture teeth for the anterior portion for optimal esthetics combined with hardened acrylic teeth for the posterior area. The patient should be made aware that porcelain teeth have a more natural appearance; however, there is a higher incidence of cracking if the prosthesis is dropped or if the patient eats hard candies or brittle foods. However, in most cases, dentists use all acrylic and/or composite prosthetic teeth. This approach has been favored because of the ability to easily adjust occlusal interferences. However, the present method of recording occlusion and equilibrating in vivo using an intra-oral Gothic arch tracing device stabilizes the denture bases; if the occlusion is precise, this may alter the choice of prosthetic tooth materials. This improved method prevents the prosthetic bases from rotational movement, which alters the base position, prevents proper evaluation of bilateral balanced occlusion, and prevents the practitioner from

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achieving accurate equilibration to eliminate any balancing interferences. This method, if done correctly, would lend support to using all porcelain teeth. As the method is improved and the new denture model is standardized, porcelain teeth may return as the preferred material.

There is also the consideration of the practitioner's experience level. If a practitioner does not use the methods in which detailed occlusal records are made and equilibration procedures are performed, then the use of acrylic teeth may present a safety net; acrylic teeth will wear faster and are more flexible (thus less brittle and less likely to crack), and if the occlusion is not balanced, then the present thinking is that there will be less harm to the residual bone and tissues, along with less breakage from unbalanced occlusal forces. This is not to say that the predominant method is flawed; however, one must take into consideration each individual practitioner's ability to perform certain functions with precision.

The choice of the materials for denture bases is also relevant today. Acrylic bases have been used for many years. Their advantages include high bond strength to the acrylic teeth. The chemical bonding of compatible materials increases the ease of processing and improves retention between the prosthetic teeth and the denture base. The composite or urethane-based materials are preferable for patients who have allergies to methyl methacrylate or its monomers. Composite bases offer good strength; however, they will have diminished chemical bonding when acrylic teeth are used. If a composite or urethane base is used, it would then be suggested that composite teeth be used because the two would achieve a chemical bonding and improved strength. Improvements with composite prosthetic teeth include primers and bonding agents that increase the composite base's strength even when acrylic teeth are used. However, de-laminations and separation from the base occur more readily when specific bonding agents are not used. Acrylic bases are generally easier to repair because the chemical bond between the teeth and the base is superior to composite or porcelain prosthetic teeth.

SCIENTIFIC ELEMENTS

Muscle performance differs from patient to patient, and varying degrees of muscular tone can be expected. It is necessary that the practitioner record each patient's unique muscle performance during chewing. This is essential to provide a comfortable and functional prosthesis. The concept of the neutral zone described by Beresen and Schiesser is a proven method of measuring the muscles of mastication and facial expressions to define the optimal position of posterior tooth to coordinate with the muscles and improve the efficiency of chewing.

TECHNOLOGICAL ELEMENTS

The methods used to obtain the recording of the patient's vertical and horizontal spacing have been updated. The occlusal vertical dimension has two component parts. The vertical position, when measured from a point on the patient's chin to a point on the patient's nose, can be recorded as the distance between these two points when the patient is relaxed. A method that permits easy measurement is called the *exhaustive technique;* when done correctly, it assists the patient in becoming relaxed and at rest for the practitioner to make a vertical measurement. This rest position can be measured by a divider positioned to the markings on the face to give a relative reading that tests for repeatability. The patient is instructed to breathe inward and exhale outward until the lower jaw muscles become fatigued. The lower jaw is observed as it drops open, and the distance is recorded. With the use of the newly designed Gothic arch tracing device, this vertical spacing can be held intra-orally and then adjusted to allow for free way space, also called *speaking space.* These Gothic arch tracing devices are made of materials that can be adjusted to virtually any tooth and/or ridge configuration. The older devices were made of metal, and it was extremely difficult to adapt to either the edentulous ridge on a baseplate, the dentate, or combination dentate and edentulous situations. The newer devices are easily adjusted to fit the various teeth and ridge sizes and allow alteration of the vertical pin to be positioned for paralleling the maxillary striking plate with the mandibular vertical pin in a perpendicular axis. This prevents rotational movement of either a maxillary or mandibular base while the patient's jaw is closed and moving forward, backward, and excursive. Once the vertical position has been established, the vertical pin is fixed and the patient can easily slide the jaws forward and backward and side to side. Forward is a protrusive position, backward is an unstrained retrusive position, and side to side is an eccentric position. The patient should be able to slide the jaws several times, thereby creating a crisp arrow where three lines come together. At the apex of the arrow the patient is at a physiological centric relation. Once this area has been identified, it is extremely simple for the practitioner to place a receiving plate at the apex so the teeth can be fixated at the physiological centric relation position with the use of a bite registration material injected between the two surfaces holding this position. This method, initially developed in 1876 and abandoned some years later, has been reintroduced to the profession because the principles were valid; however, the mechanics were extremely discouraging for the practitioner in the early years.

ARTISTIC ELEMENTS

Preparing a complete removable denture involves building a patient's complete dentition. The practitioner can develop a smile design specific to a particular patient, so that each patient exhibits a unique look. The final appearance partly depends on how the teeth are arranged. The goal is to achieve a youthful look while still capturing the facial features of every patient. Artistically, very natural-looking prosthetic teeth have been created that can be shaped to each patient's mouth to produce individuality among patients.

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TREATMENT PLANNING

Options

After evaluating the patient's particular needs, the dentist can devise options for patients to choose from. The recommended computed tomography (CT) scan yields the appropriate three-dimensional views of the patient's maxillary and mandibular arches and allows the practitioner to determine the three-dimensional architecture of the remaining bone before deciding whether or not implants can be suggested. If the patient's anatomy and functional tonicity are adequate, many patients may do very well without implants. However, it has been found that the use of implants not only will make the prosthesis more retentive but will decrease progressive bone and tissue resorption.

Sequence

Once the practitioner sits down with the patient and completes a thorough assessment, the complete clinical evaluation is performed. It is suggested that a CT scan be taken if the patient has significant clinical requirements. However, a panoramic two-dimensional radiograph accompanied by a full series of periapical radiographs will be sufficient in most cases. Once all the images have been taken and reviewed by the practitioner, the patient is then provided with an explanation of the findings and treatment options, which are dependent on the patient's specific needs and desires. On patient acceptance of the treatment, an informed consent is presented to the patient to read; any questions are discussed; and the consent is signed before commencement of the appropriate procedures. The patient is asked specifically if there are any questions whatsoever, including those regarding possible complications or failure of treatment. Once the patient has agreed and signed the appropriate informed consent, the practitioner then lays out a specific protocol to be followed for the prosthetic fabrication. Midway through the treatment, if possible, the patient is presented with a cosmetic try-in to review and comment on before completion.

Once cosmetic acceptance has been obtained from the patient, another consent form is given to the patient and discussed, verifying that at this point the prosthesis will be sent for final fabrication.

If the patient has any questions regarding the cosmetic portion of the prosthesis, it is at this time the patient has an opportunity to comment and make alterations.

Additional Treatment Considerations

Patients who have acute issues requiring immediate treatment will have initial therapy performed before fabrication of any definitive restorations. All patients should be given hygiene guidelines to adhere to for optimal health of the oral cavity; it is important to stress that a successful outcome is dependent on vigilant oral care.

EVIDENCE-BASED PRINCIPLES

It is important that the practitioner follow treatment guidelines based on sound principles following the optimal standard of care. However, some methods are not always supported by science; therefore following evidence-based principles is highly recommended when other supporting documentation is not available.

CLINICAL CONSERVATION CONCEPTS

The initial goal is to ensure that the patient's particular needs and wants are addressed. Although it is not always possible to satisfy all the wishes of patients, it is, however, necessary to be extremely clear when discussing with the patient what can and cannot be done. A clinically conservative approach, for example, may be to use two implants to support a removable prosthesis instead of four or more implants. This is, however, dependent on many factors, including the status of the opposing arch. If the opposing arch is completely edentulous and treated with a complete removable denture, then it is not as necessary to place four to six implants on the opposing arch unless there is some future consideration for placing implants on the maxillary arch. The optimal treatment should be recommended but should allow for alternatives from which a patient may choose. Ethically, the dentist does not want to bias a patient's decision according to the practitioner's wishes, but instead the patient should be offered appropriate alternatives and given the opportunity to decide on the final treatment.

MAINTENANCE OF COMPLETE DENTURES

It is recommended that edentulous patients wearing complete removable dentures be evaluated twice a year. This is necessary to re-evaluate the patient's tissue condition and prosthesis condition. Once patients have completely adjusted to a complete removable prosthesis, he or she may still have irritations from time to time depending on their eating habits. It is suggested that patients soak the mouth using recommended solutions to improve the health of the tissues and, with a soft-bristled toothbrush, begin to brush the tissues in a massaging motion to help improve blood flow and decrease accumulated biofilm. Patients will still continue to have some bone resorption once the prosthesis has been completed. With age, the tissues generally will become less elastic, and it is not uncommon that patients will need to have refitting procedures done possibly each year or at least every 2 to 5 years, depending on their particular overall health. It is also suggested that a patient be informed before prosthetic fabrication that the life expectancy of the complete removable prosthesis is generally 5 to 8 years. Patients who have severe parafunctional habits such as grinding or bruxing generally will have far more wear compared to a patient who does not have parafunctional habits.

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NEAR-FUTURE DEVELOPMENTS

In our high-tech world today, we have seen many advancements in dentistry. Even though scan techniques are becoming commonplace in dentistry, the total edentulous patient will likely need to have impressions, as opposed to having the mouth scanned. This is essentially because in order for a definitive impression to be made, the patient needs to go through different maneuvers, such as coughing, sucking, smiling, laughing, yawning, and to make tongue movement such as licking. Scanning inside the mouth for this application is still not possible. It is extremely difficult to scan while the patient is going through all of the muscular movements. However, the impression itself can now be scanned, and the stone cast can be digitally printed. It all comes down to this: Will the new technology create more cost to the patient at this time? Once the technology has improved to the extent that that the price can be distributed among millions of patients, then it will be affordable. However, at this time, conventional methods appear to be much less costly, because of the high cost for research and development.

Text continued on p. 574

THE CLINICAL TECHNIQUE

CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space

A male patient came to the office in good health after being referred by another dentist. He wanted to improve both the looks and function of his maxillary and mandibular prostheses that were in need of replacement owing to severe discoloration and wear. The patient had excess gingival show with his upper prosthesis, and his chief complaint was that he did not like his appearance and wanted a better-fitting prosthesis (Figure 24-1).



FIGURE 24-1 **A, Initial photograph of the patient demonstrating an excess amount of gingival display. B, Panoramic radiograph showing the patient's significant bone height. C and D, Class I maxillary (C) and mandibular (D) ridges.**

Continued on next page

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CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

The patient had significant bone structure on both arches, and adequate retention was noted (see Figure 24-1, *B*).

It was decided that implants were not necessary at this time, nor were they desired by the patient. It was agreed that a new prosthesis would be fabricated; however, the optimal conservative approach would be to fabricate the prosthesis without implant retention. It was then necessary to determine whether or not the patient's desired esthetic improvements were possible. With that much bone structure present, it was wise to analyze the amount of space between the ridges at rest. That would determine if there was sufficient space between the maxillary and mandibular ridges for a conventional acrylic denture prosthesis (see Figure 24-1, *C* and *D*).

In this particular case the patient had insufficient interridge distance; this, compounded by the distance between the maxillary lip at rest and the premaxillary ridge crest, measuring 7 mm, definitely compromised the overall esthetics and was the primary reason that the patient presented with excess gingival display.

The treatment plan was formulated, the patient was accepted, and it was recommended that definitive impressions be made, followed by all necessary records required to fabricate a new prosthesis. Definitive impressions were made using a layering technique. The material used was polyvinyl siloxane (PVS) impression material. The advantage of this material was that it would allow the practitioner to match the character of the tissue and the mobility of the tissue, the freni, and the sulcus. Figure 24-2 shows the moldable viscosity of the material. These viscosities co-laminate when applied properly.

After the impressions were made, capturing both the anatomical and functional aspects, the decision was made to fabricate a metal casting to allow the prosthesis base to be thin in the area of high esthetics leaving more room for proper tooth position. An open window was left on the maxillary arch for ease of setting anterior teeth and to address the inadequate vertical dimension, which contributed to the patient's excess gingival smile. A metal casting was fabricated to allow sufficient space between the arches when the prosthetic teeth were set. The fact that the patient had inadequate interridge distance made it extremely difficult to make a conventional prosthesis. Therefore the metal casting was used to add strength to the base, which needed to be very thin in order to fit within the physiological vertical space (Figure 24-3).

The open window in the maxillary metal casting allows the technician to position the teeth higher up to reduce the amount of gum display. A metal casting was also made on the mandibular ridge for strength. The casting as fabricated was made short of the borders, so that the finished prosthesis around the peripheral borders could be adjusted easily in acrylic, see Figure 24-3, *B*.

The wax rim was tried in the patient's mouth, and the patient was asked to smile (Figure 24-4, *A*). This waxed rim, also called the *esthetic blueprint,* outlines how the teeth will look when the patient is at repose or animating to a full smile. In this patient's case, the goal was to avoid the excess gum display that had made the patient unhappy with his appearance. The esthetic blueprint was adjusted to the patient's smile, including the high-lip position, the midline position, and the cuspid position. This provides a roadmap for the technician to set the teeth in the esthetic zone.



FIGURE 24-2 Definitive impressions demonstrating the layering of various viscosities to match the ridge character.

همیار دندانسازان و دندانپزشکان

CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

Figure 24-4, *B*, shows a comparison of the height of the esthetic blueprint *(left)* that was adjusted in the patient's mouth with the patient's existing denture *(right)*. The patient's existing denture was measured to be twice the height of the adjusted esthetic blueprint.

Figure 24-5, *A*, demonstrates the making of the face-bow. It is necessary to make a face-bow to allow the practitioner the ability to offer the vertical at the end of try-in if necessary, without taking a new occlusal record.

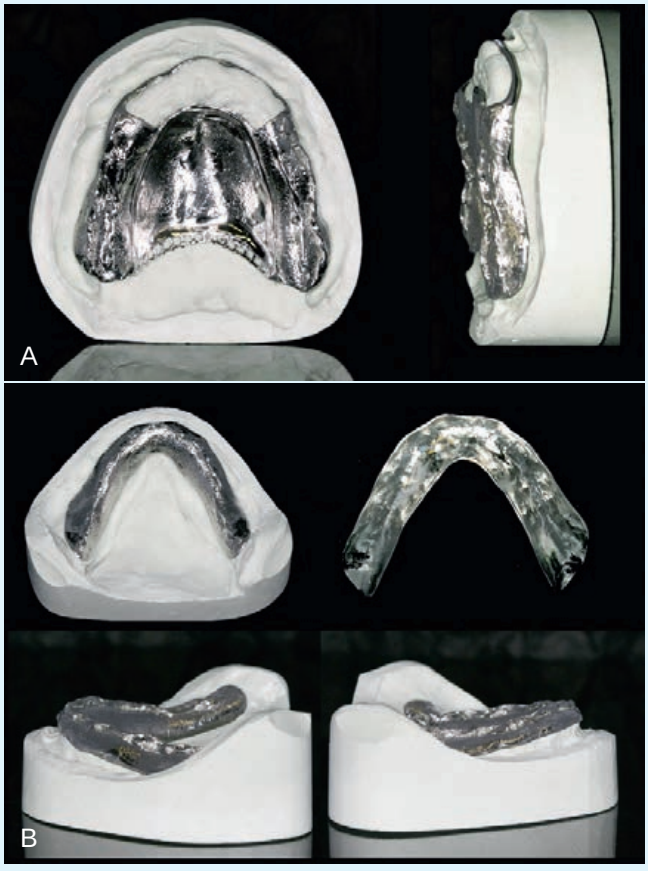


FIGURE 24-3 **A, Maxillary metal casting with open anterior window allowing ease of tooth placement. B, Mandibular tissue-borne metal casting made short of peripheral borders.**

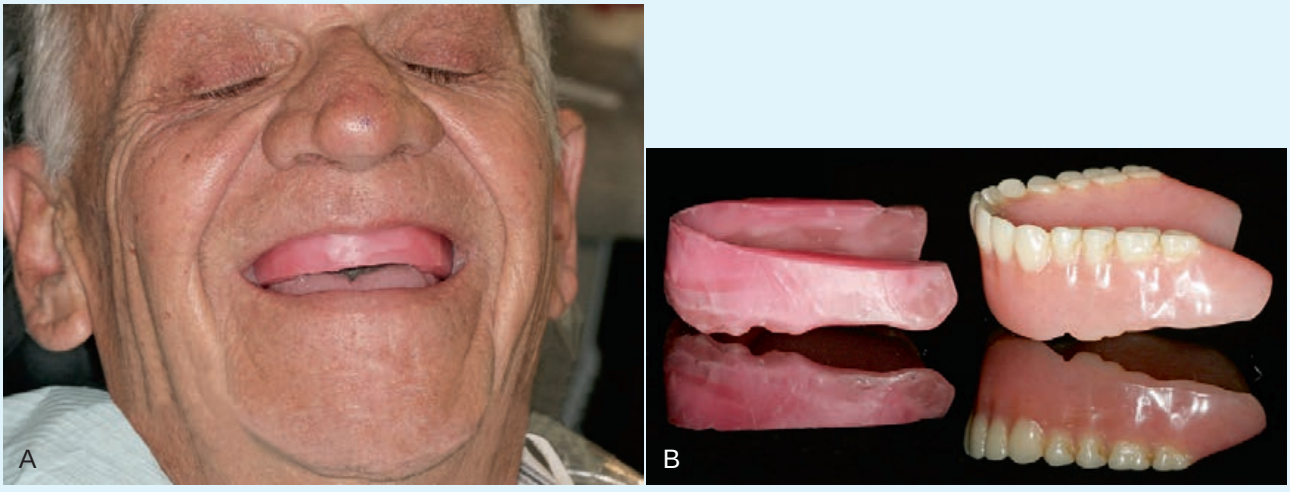


FIGURE 24-4 **A, Patient smiling to mark esthetic blueprint (EBP) to set teeth. B, Comparison of the height of the EBP *(left)* with the existing denture *(right)*.**

Continued on next page

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CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

If it is necessary to alter the vertical space at the try-in stage to enhance esthetics, this can be done without making a new occlusal record on the articulator, provided that the face-bow record was made. The existing lower denture was used (Figure 24-5, *B*) to help hold the upper esthetic blueprint in the mouth while the face-bow record was made.

Next, the physiological centric relation is made using a Gothic arch tracer. Figure 24-6, *A*, shows a neutral zone record base in the patient's mouth. The neutral zone record base consists of an acrylic-based plate that is made over the ridge and with compound wax added to the occlusal portion of the rim. Compounding wax can be heated to 60°C, when placed into the mouth, it softens to allow the muscles to shape the wax as they contract and records muscle pressures. Once the compound base is placed into the patient's mouth, the patient is instructed to swallow, thereby allowing the muscles to shape the softened compound wax (Figure 24-6, *B*). While the compound is soft, the patient swallows several times until the compound has hardened. As the patient swallows, the cheeks move inward and the tongue moves outward and laterally while the lips are moving inward. This normal muscle action defines the posterior tooth position.

Physiological-centric relation was recorded using a disposal Gothic arch tracing apparatus. Figure 24-7, *A*, shows the maxillary and mandibular base separated by the Gothic arch tracing apparatus, which is attached to

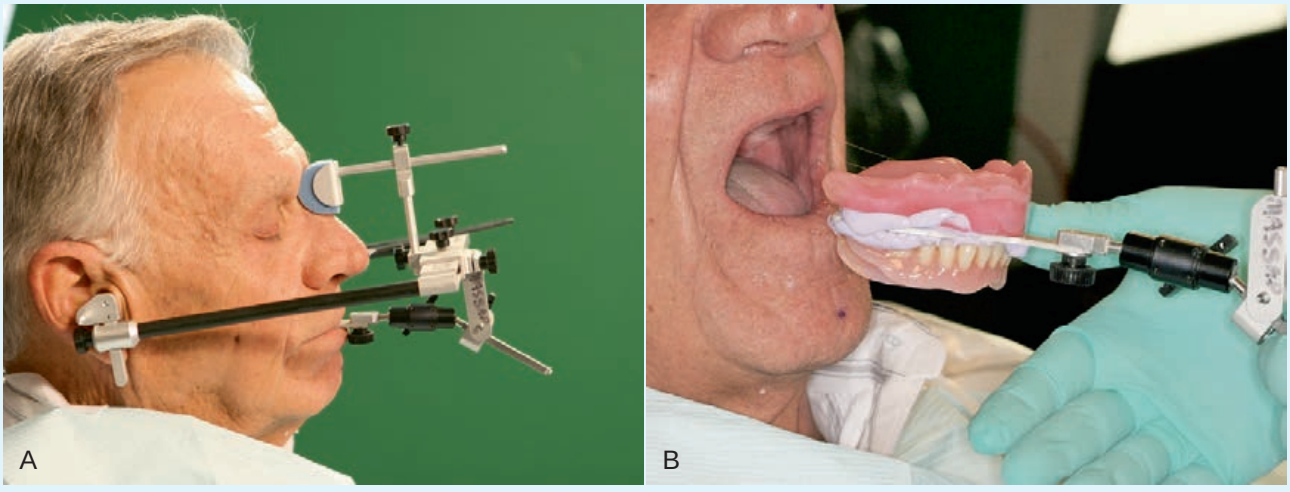


FIGURE 24-5 A, Ear-bow with glabellar support. B, The ear-bow held steady using the patient's existing denture.

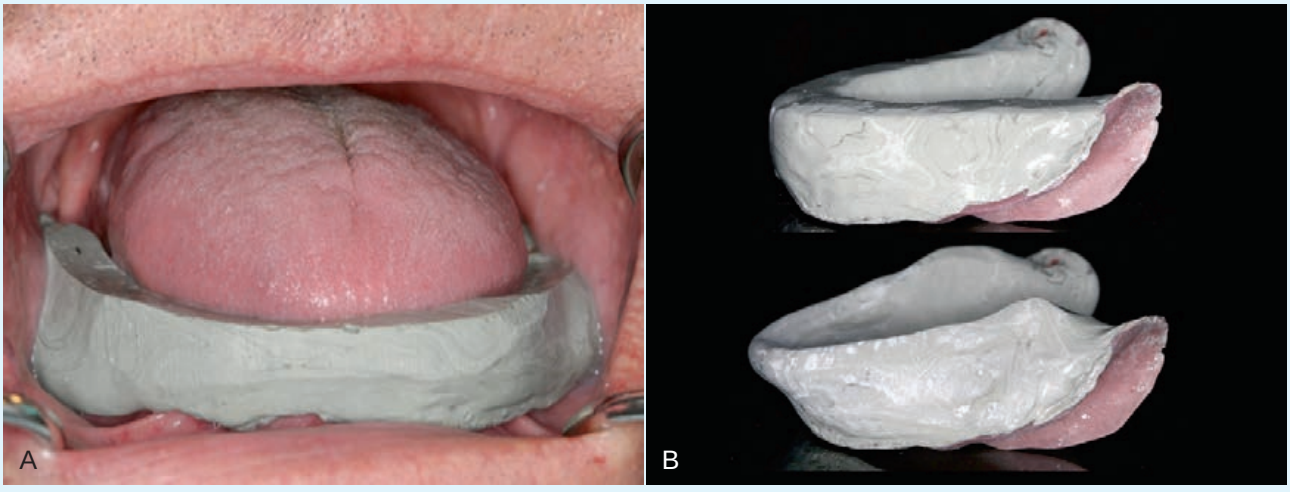


FIGURE 24-6 A, Heated compound wax over record base to take functional neutral zone recording. B, Before *(top)* and after *(bottom)* neutral zone recording.

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CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

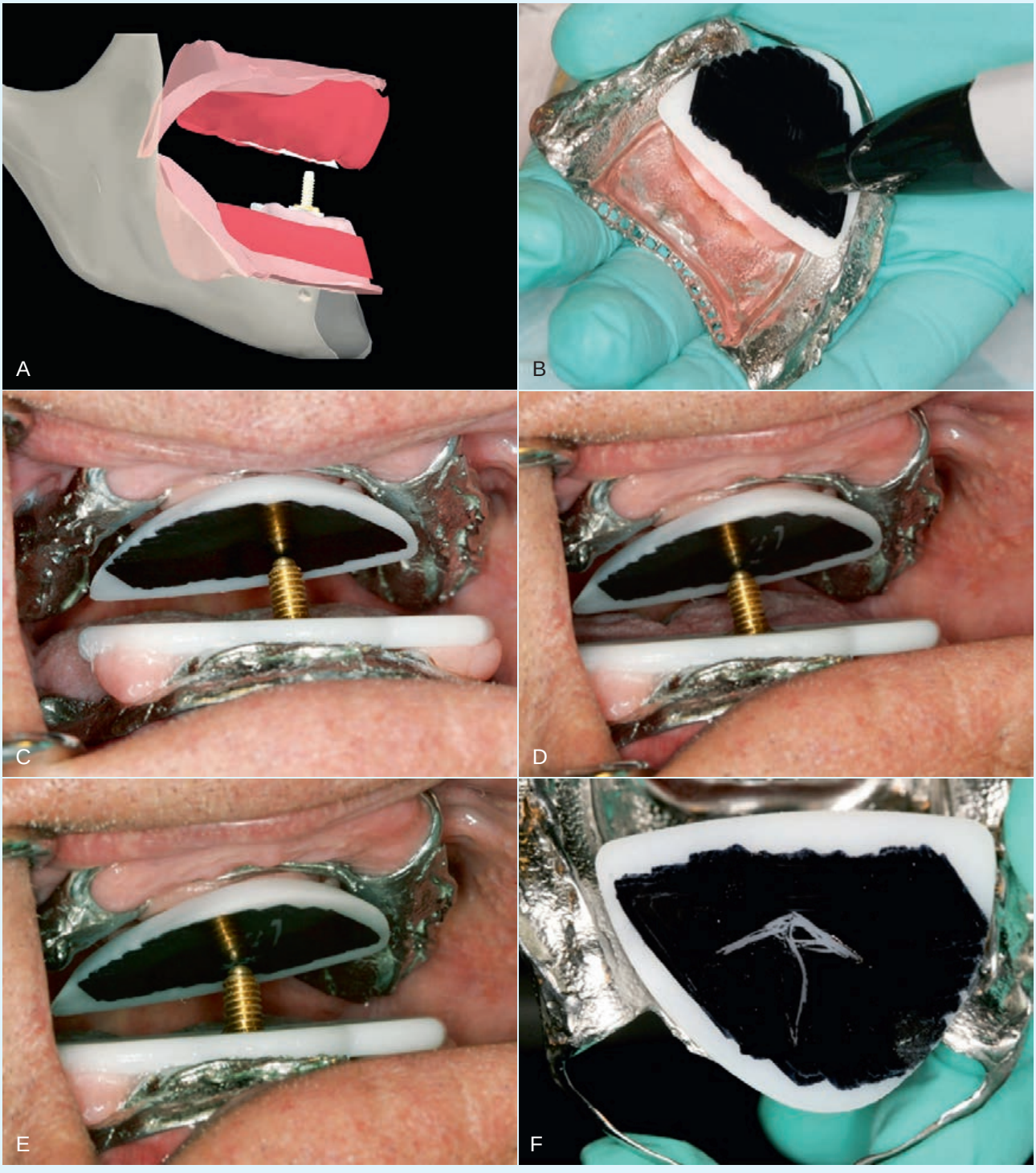


FIGURE 24-7 A, Jaw recorder mounted to record bases. The pin is adjusted to proper vertical. B to E, Ink is placed on striking plate (B); patient slides jaw forward, backward, and side to side (C to E). F and G, Arrow depicts centric relation (F), and pin receiver is secured over apex (G).

Continued on next page

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CASE Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

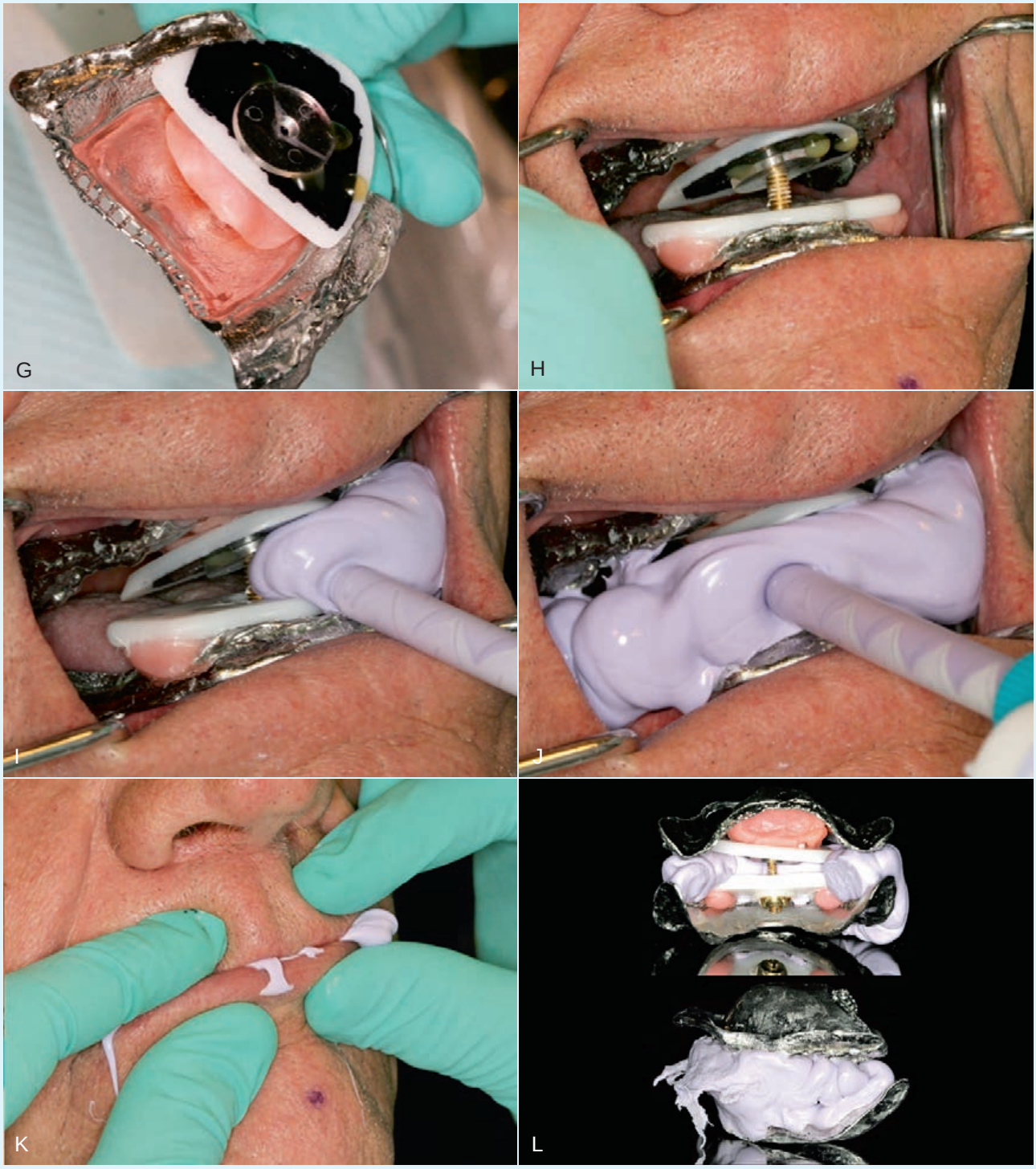


FIGURE 24-7, cont'd H to K, Patient's jaw closed into centric relation (H), and polyvinyl siloxane bite registration placed (I to K). L, Complete jaw relation recording.

همیار دندانسازان و دندانپزشکان

CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

the acrylic bases. On the maxillary base, an inked striking plate (Figure 24-7, *B*) is mounted; on the mandibular base a vertical pin apparatus is placed, altering the patient's vertical spacing and holding it in position. Once the appropriate vertical position is obtained, the patient is asked to close, making sure that the pin strikes the plate perpendicular to the maxillary arch, thereby eliminating rotational forces of either the maxillary and/or mandibular base when the patient is moving. One of the prime rationales for using the Gothic arch tracing device is to stabilize the bases and to eliminate rotational forces of the bases, thereby obtaining an accurate recording. The patient was asked to close so the pin strikes the maxillary plate, and then he was instructed to slide the jaw forward, backward, and side to side (Figure 24-7, *C* to *E*).

As the patient moves the jaw forward, we note that this is a protrusive movement. As the patient moves the jaw backward, this is a retrusive movement. Then the patient is asked to move the jaw side to side, which is an excursive movement.

An apex is formed when the patient moves the jaws forward, backward, and side to side. The apex allows the practitioner to visualize the position of the physiological centric relation, which is where all three lines come together and is located at the tip of the apex (Figure 24-7, *F*).

Note that the patient's jaw is not pushed by the practitioner, but rather the patient is asked to move the jaws forward and backward and side to side repeatedly without straining.

To secure the physiological centric relation position (Figure 24-7, *G* and *H*) a PVS material is injected between the spaces of the bases (see Figure 24-7, *I* to *K*). This registration material is very light viscosity, thereby eliminating any pressure against the ridges. However, it sets quickly to a hardened record (Figure 24-7, *L*). Once this record has been completed, all of the records are sent to the prosthetic laboratory for complete setup. The metal casting structure supports have the teeth secured with dental wax (Figure 24-8, *A*). They were tried into the mouth for the patient's approval (Figure 24-8, *B* [the mandibular wax try-in]). Note: There is an absence of wax around the cameo surface. There is only enough wax to hold the teeth in position. Figure 24-8, *C (left)* shows the patient's existing denture, and Figure 24-8, *C (right)* shows the patient's new prosthesis still in the waxed form. The patient was asked to review this new prosthesis closely. This was the patient's opportunity to make esthetic changes. If satisfied, the patient is then asked to sign the form accepting the appearance of the



FIGURE 24-8 **A, Wax try-in with metal and tissue areas shown. B, Occlusal and tissue view of wax try-in with wax only supporting teeth. C, The patient before *(left)* and after *(right)* treatment.**

Continued on next page

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CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

prosthesis, including the midline position, the high-lip position, and the shape and shade of the teeth. If patients decide to have something changed *after* the denture has been completed, then they will be responsible for paying additional fees. Figure 24-9, *A*, shows the preparation for taking the cameo impression (external impression) by ensuring that the wax is off the baseplate above the necks of the teeth. Impression material will be placed where the wax has been removed. Adhesive has been applied to this surface to ensure that the impression material will not separate. As noted, the wax has been removed everywhere except around the necks of the teeth (Figure 24-9, *B*). A physiological recording is now made in this space to prevent food entrapment around and underneath the prosthesis and to capture the appropriate horizontal position of the muscle. PVS material is injected around this surface, and the patient is asked to pouch out and smile and then open wide, thereby shaping the PVS material to the appropriate horizontal position, making a customized cameo surface,



FIGURE 24-9 **A,** Wax try-in ready for external impression. **B,** Maxillary view of wax try-in ready for external impression. **C,** Completed external impression using polyvinyl siloxane impression material (front view). **D,** Completed external impression (left view). **E,** Completed external impression (right view).

همیار دندانسازان و دندانپزشکان

CASE

Esthetic Enhancement in the Fabrication of Complete Dentures for a Patient with Minimal Interridge Space (cont'd)

which will be part of the final prosthesis (Figure 24-9, *C* to *E*). This shape will ensure that the cameo surface is compatible with each individual patient's muscular action. The patient achieves both the functional and the esthetic support needed so that the face does not appear to be sucked in. Figure 24-10, *A*, shows the prosthesis completed and ready to be delivered to the patient. Figure 24-10, *B* shows the shape of the acrylic at the finished stage. Note: The shape is not conventional but is specific to each individual patient's muscle tonicity and function.

Photographs show the patient in this case before (Figure 24-10, *C [left]*) and after (Figure 24-10, *C [right]*). He was able to take the prosthesis home with him on the day of delivery.

In summary, the patient desired a decrease in the amount of vertical spacing to have a less gummy appearance. A metal casting was made for strength, then the occlusal vertical space between the maxillary mandibular jaws was decreased from a physiological rest position to allow for approximately 3 mm of speaking space. The improved occlusal vertical spacing was at the optimal centered relation position. The patient looked much better and had improved function because the vertical and horizontal spacing were now compatible with his particular physiological situation.







FIGURE 24-10 **A, Completed mandibular processed prosthesis. B, Completed processed maxillary prosthesis. C, Before *(left)* and after *(right)* treatment.**

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Precision and Semi-Precision Attachments

George E. Bambara

RELEVANCE OF PRECISION AND SEMI-PRECISION ATTACHMENTS TO ESTHETIC DENTISTRY

Precision and semi-precision attachment dentistry allows for esthetic removable partial dentures that do not display the metal clasps that can make traditional removable clasped cast partial dentures unesthetic. The attachment itself becomes the clasp, rest, reciprocating and stabilizing element and is hidden inside the partial denture, which renders it invisible. The attachment also provides the retentive element necessary to retain the partial in the mouth at rest and during masticatory function (Figure 25-1). Attachments are also used in segmented fixed partial denture and overdenture prosthetics on natural roots and implants. There are two parts to the attachment: a male and a female. In planning a removable partial denture, one part is incorporated into the casting or root on the crown, bridge, or splint, and the other part is incorporated into the removable partial framework or acrylic. As a result, the partial denture becomes highly esthetic and appealing to patients. Esthetically speaking, from a patient's perspective, they smile with confidence, knowing that they have functioning, beautiful, natural-looking teeth.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF THE PROCEDURE

The use of attachments as connectors was popularized in the twentieth century by Dr Herman E.S. Chayes. He fabricated dental bridgework in segments that were connected by a key and keyway attachment (Figure 25-2). The attachments allow for micro-movement between segments and provide stress relief to the connected abutment teeth. His philosophy was to provide a physiologic tooth movement similar to that of natural teeth by using dental attachments in treatment planning prosthetics. This concept eventually led to the development of various rigid or resilient stress-relieving or stress-breaking attachments. Acting as a fixed bridge, Dr Chayes's slot type of dental attachment was quite rigid and provided for removability and cleanseability. Over the years, attachments were fabricated to accommodate a wider range of controlled micro-movements and are now selected on a case-by-case basis, according to how the final prosthesis is planned to function on the remaining supporting elements.

Various types of attachments have been developed. The *precision attachments* are very precise, and are milled out of alloy. The male and female parts fit together with tolerances of about 10 microns. They are purchased as a finished product and are soldered or cast to the final prosthesis (Figure 25-3). They are incorporated within the contours of the crown or splint and direct the forces of occlusion down the long axis of the tooth. They are generally rigid attachments in that the prosthesis is able to transfer most of the occlusal force to the teeth in which the attachments are incorporated, and less to the tissue-bearing areas.

The *semi-precision attachments* are much less precise in their fit and usually have much more resiliency than their precision attachment counterparts. These attachments are cast from refractory patterns, and the male or female parts may be made of nylon, polymer, or metal. These attachments can allow up to 15 degrees (or more) of rotational movement and up to 600 microns (or more) of vertical movement. Some offer hinge and/or lateral resiliency. In removable partial denture cases, they are cast with the crown or splint and are placed outside the contours of the teeth (Figure 25-4). In overdenture prosthetics, they are either cast on top of copings, incorporated onto posts which are cemented into the roots or abutment teeth or incorporated into overdenture implant abutments. Their resiliency allows the prosthesis to transfer most of the occlusal load to the tissues and away from the abutment teeth to which they are connected.

The choice of which attachment to use depends on the patient and all the data that is gathered during the treatment planning process. This allows the dentist to make decisions that will build longevity into the prosthesis and satisfy the needs of the patient.

RELATING FUNCTION AND ESTHETICS

The treatment planning process often places both dentists and patients in a dilemma between function and esthetics. Removable cast partial dentures are fabricated with clasps, rests, and reciprocating elements that can create visibly unpleasant esthetics as well as wear and torque on the abutment teeth.

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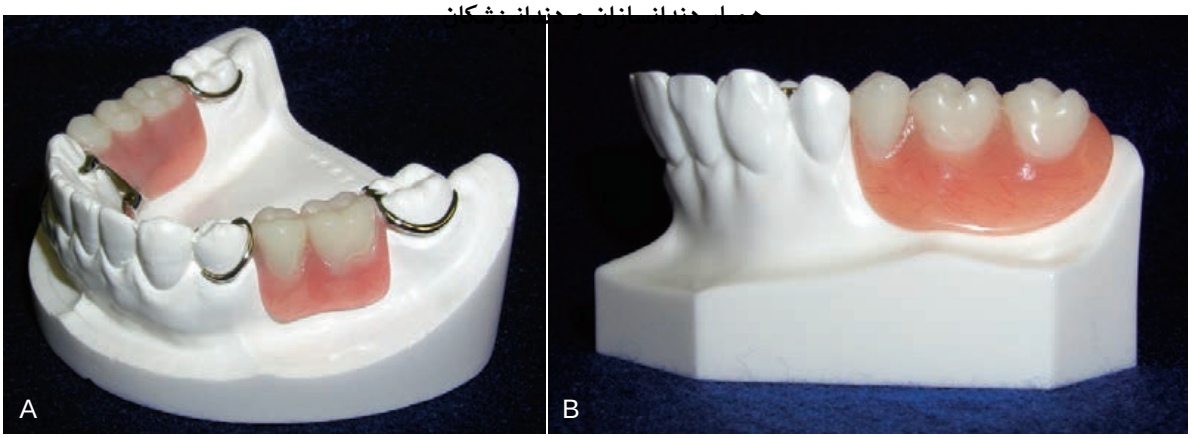


FIGURE 25-1 A, Clasped cast partial denture. B, Precision attachment partial denture.

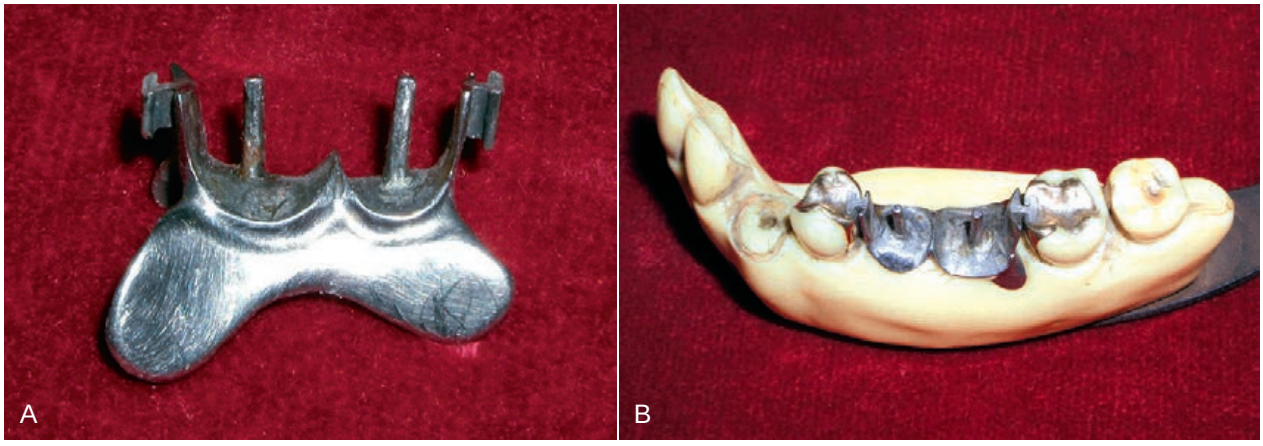


FIGURE 25-2 A, Chayes attachment. B, Chayes attachment in place.



FIGURE 25-3 Sterngold precision attachment.



FIGURE 25-4 Sterngold ERA semi-precision attachment.

Overdentures can be fabricated directly over cast copings or implant healing caps. Wthout the use of attachments however, the retentive and protective elements that attachments provide are lost. As a result, undue stress can be placed on the remaining roots or implants. Long-span fixed bridgework, fabricated in one piece, can be difficult to cast and fit properly. Attachments that will allow fixed bridges to be segmented can solve these problems. Diverse root or implant angulations may not be able to be corrected easily unless a segmenting attachment is used. (Figure 25-5). The use of dental attachments can obviate many of these problems as well as provide the desired esthetics. The typical Kennedy class 1, 2, or 4 clasped partial denture relies on teeth and soft tissues for stability and support. The use of Class 2 clasped lever designs with properly placed and designed clasps

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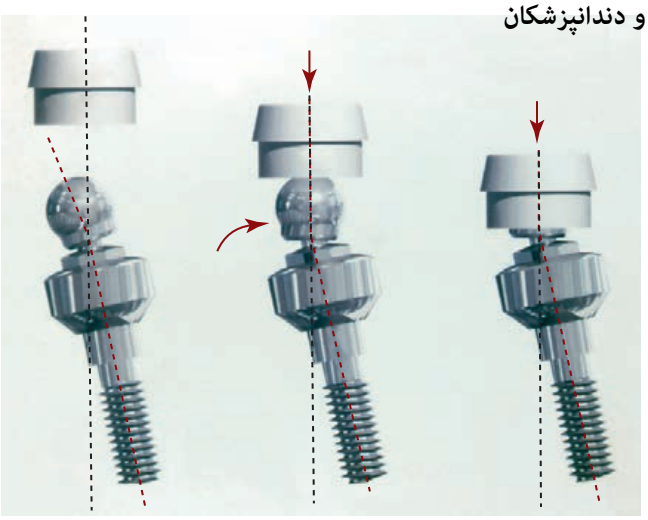


FIGURE 25-5 Sphero Flex (Rhein 83 USA Inc., New Rochelle, New York).

direct occlusal forces along the axial length of the supporting teeth and minimize torque to the abutment teeth. Clasps do not provide a resilient mechanism for forces to be redistributed to other areas of the mouth without causing movement or wear to the connected abutment teeth or supporting tissues.

Attachments provide the mechanism that solves many of the treatment planning problems while offering the esthetics that create natural-looking smiles.

CLINICAL CONSIDERATIONS

Indications

Dental attachments can be used in treatment planning all aspects of dentistry because they provide cosmetic and functional alternative adjuncts to traditional prosthetic approaches. The indications for using attachments are as follows:

- Esthetics
- Redistribution of forces
- Minimization of trauma to soft tissue
- Control of loading and rotational forces
- Non-parallel abutments–segmenting
- Future salvage efforts–segmenting
- Retention
- Stabilization
- Proprioception

The purpose of using precision and semi-precision attachments is that they function as the retentive and supporting elements while redirecting the occlusal forces onto the areas that can support or share the masticatory loads. Keeping natural teeth or roots allows for proprioception and maintains alveolar bone levels. Proprioception is a protective neurologic feedback mechanism provided by the periodontal ligament. Proprioception allows for the awareness, feeling and perception of where things are in the mouth and between the occlusal surfaces of the teeth. Attachments are simply rigid or resilient connectors that redirect the forces of occlusion. The redistribution of occlusal forces improves the function and longevity of the natural teeth, roots, ridges, and implants while maintaining bone height and width. The attachment is, or can essentially be, "invisible." In designing fixed segmented bridges, a small amount of the metal attachment shows on the occlusal. Should this present an esthetic problem, the attachment can be reversed and placed on the gingival aspect of the bridge, rendering it invisible. Care must be taken not to close the embrasure spaces. Beside esthetics, attachments are indicated in removable partial denture design to redirect occlusal forces onto or away from the remaining residual ridges, thereby offering protection to the remaining teeth or implants. In the overdenture prosthesis, attachments are used to attenuate occlusal forces onto or away from the remaining residual roots or implants, protecting roots that remain or implants that have been placed. With enough roots or implants serving as abutments, the prosthesis can be fully supported and retained without soft tissue. Attachments are indicated in certain fixed bridges when there is a concern for the loss of posterior abutments. In these cases certain attachments should be selected that allow for convertibility to a removable prosthesis should the posterior abutments be lost. Segmented attachments are also indicated when mesially tipped molars are to be used as abutment teeth in fixed bridges when a favorable path of insertion cannot be achieved and/or the abutment may need intentional root canal therapy. Segmenting obviates this problem because the abutment teeth do not have to be parallel to each other. The dental laboratory surveys the prosthesis and parallels the attachments to create a favorable path of insertion.

Attachments are classified according to how they function in prosthetic designs:

- Class 1A—solid, rigid, non-resilient
- Class 1B—solid, rigid, lockable
- Class 2—vertical resilient
- Class 3—hinge resilient
- Class 4—vertical and hinge resilient
- Class 5—rotational and vertical resilient
- Class 6—universal, omni-planer

Attachments are selected after treatment planning is complete, with the dentist having a thorough knowledge of the stability and integrity of the remaining teeth, roots, and/or implants.

Contraindications

Contraindications to using attachments in treatment planning are poor oral hygiene, poor manual dexterity, dry mouth, insufficient number of abutment teeth that can be splinted if necessary, and cost. Patients should be willing to commit to 3-month recalls, meticulous oral hygiene, and the use of fluoride rinses. The patient's manual dexterity is also a consideration; attachment-retained dental prostheses require a degree of adroitness for insertion and removal. Medications that cause dry mouth are always a serious concern because patients lack salivary flow raising the caries index. Finally, precision or semi-precision attachments, along with innovative prosthetic designs, increase the total cost of dental treatment.

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MATERIAL OPTIONS

Precision attachments are milled from high noble metals and must be cast to high noble metal frameworks. They are obtained as finished products ready for the laboratory to use. Their tolerances are so precise that errors in the casting process may prevent the final prosthesis from fitting well. Because of the preciseness of fit, they are considered to be rigid attachments. Laboratory technicians should have a good working knowledge of attachments and attachment retained prosthetic fabrication techniques.

Semi-precision attachments can be cast in semi-precious or base metal. Because they are cast, their tolerances are not as precise as those of their precision counterparts. One element is generally made of plastic and cast along with the framework. The other element can be made of metal or has a metal housing with a nylon or polymer insert. Because of the nature of the material, the use of spacers in the curing process which create vertical resiliency, and other design factors, semi-precision attachments are very versatile in their function and are considered resilient.

Current Best Approach

Treatment planning consists of cast mounted models, radiographs, periodontal charting, mobility assessments, thorough evaluation of the remaining teeth and condition of the residual ridges, arch form, esthetics, and patient desires. These are all used to determine the prosthetic design and the use of specific attachments. Cases are planned on an individual basis and determinations are made as to whether the prosthesis will be implant or root supported and retained, implant or root and tissue supported and retained, or soft tissue supported and implant or root retained. Attachments allow dentists to vary treatment planning. There is no one attachment prosthetic plan that fits all. The goal is to have a salvageable plan should prosthetic failure occur in the future.

INNOVATIVE ELEMENTS

Scientific Innovations

Attachment manufacturers have created resilient and rigid attachments, allowing the dentist to choose which attachment best serves the treatment plan. New polymers allow increased retention and less wear on the component parts, and various degrees of resiliency can be obtained through the use of these materials. Attachments come with angulation corrections that allow for more parallel paths of insertion of the prosthesis. Implants have been designed with attachment abutments incorporated into a one-piece structure, allowing for various loading protocols. Smaller implant diameters of less than 3 mm with attachments incorporated on them have become popular and have contributed to reduced costs. Certain overdenture attachments have special designs that allow for easier insertion and removal of the prosthesis by the patient.

Technological Innovations

Attachment wear must be checked on a periodic basis because a worn out attachment may not allow the prosthesis to function as it was originally intended. Titanium nitride coatings are placed on some attachments to resist wear (Figure 25-6). New, smaller designs have been introduced to be used in areas where space may not be sufficient. Ridge atrophy and loss of vertical dimension may necessitate prosthetic relines.

Easily interchangeable parts with varied degrees of retention have been introduced over the years. Patients experience greater comfort, eating pleasure, feeling and looking better, wearing their prostheses, experiencing less trauma to their natural teeth, roots, soft tissue, and implants, returning periodically for regular checkups, and being more conscious of their oral hygiene. Manufacturers have made oversized parts that fit into, or onto, worn male and female components. This has obviated the need to recreate new frameworks and allows patients to continue to use what was originally fabricated. Some attachment companies have created kits that allow dentists to successfully convert one type of attachment-retained prosthesis to another chairside. The use of threaded attachment options has allowed dentists to easily remove attachments for placement. New instrument designs have facilitated the attachment-removal process for the dentist and allow for precise replacement (Figure 25-7).

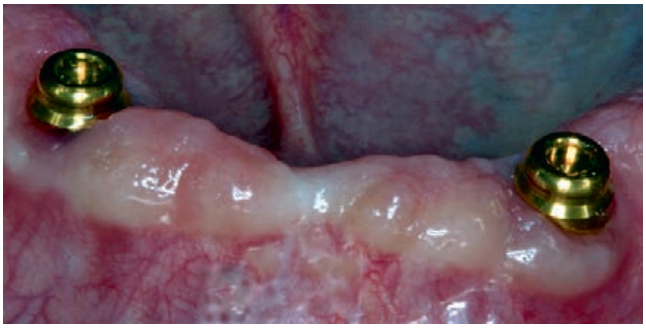


FIGURE 25-6 LOCATOR implant attachments (Zest Anchors, LLC, Escondido, California).

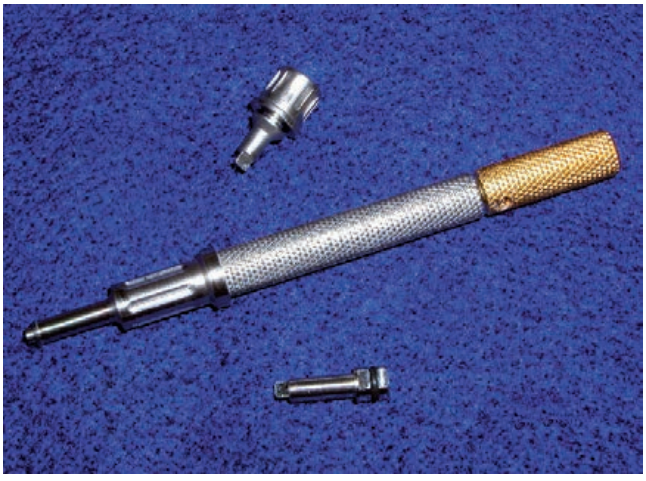


FIGURE 25-7 LOCATOR placement and removable tool.

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ARTISTIC ELEMENTS

Attachment dentistry is an esthetic and functional discipline, allowing the dentist to create prosthetic designs that have longevity and protection built into their treatment plan. Attachment dentistry utilizes the true artistic talents of the dentist to create claspless smiles.

TREATMENT PLANNING

The choice of whether to use an attachment retained or attachment supported prosthesis must be made in the early stages of the treatment planning process and discussed fully with the patient. Once the decision has been made, a plan that harmonizes esthetics and function must be developed. Removable or fixed partial dentures, root or implant retained or root or implant-supported overdentures, and segmented fixed bridges all require considerations. Occlusal schemes must be considered and setups must be made so that the prosthetic plan can be verified and the patient satisfied with the proposed result. If implants are considered, a stent must be made for the surgeon so that the occlusion can be maintained (Figure 25-8). Prosthetics drives the surgical component if success is to be achieved with the fewest compromises.

The next step is to decide whether the remaining teeth can bear the occlusal load of the planned prosthesis or whether these loads will be shared, or redirected to the supporting tissues. Rigid attachments will redirect the occlusal forces to the remaining teeth, whereas resilient attachments will redirect those forces to the soft tissue. Careful evaluation of the study models, radiographs, periodontal charting, amount of usable soft tissue, and consideration of what the opposing dentition will determine attachment selection.

The next consideration in planning is to determine if the planned prosthesis will be tissue supported and root or implant retained, tissue and root or implant supported and retained, or root or implant supported. Once this has been determined, attachments can be selected by functional classifications, facilitating attachment selection. The more resilient an attachment is, the more the prosthesis will rely on soft tissue for support, redirecting occlusal forces to the tissues and away from the teeth, roots, or implants. The more rigid the attachment is, the more the prosthesis will rely on hard tissue for support. Rigid attachments redirect occlusal forces away from soft tissue and onto supporting teeth, roots, and implants. It is wise to consult with the attachment companies to explore the various types of attachments available.

Sequencing of Tooth Implanting

Implant dentistry starts with a thorough medical history, mounted study models, and a tentative treatment plan based on occlusal considerations and the desires of the patient. The next step is to have appropriate radiographs and scans to see if the quantity and quality of bone to verify the patient is a candidate for implants. Bone-grafting procedures and sinus augmentation may be a part of the protocol. If implants can be placed, the type of prosthesis design must now be considered. The number and placement of the implants will dictate whether the restorative plan will include fixed, non-removable or removable overdenture prosthetics. Depending on the number of implants placed, a determination must be made as to whether the prosthesis will be implant supported and retained, implant and tissue supported and implant retained, or totally tissue supported and implant retained. Facial esthetics must be considered, along with proper lip support and jaw relationships, before a decision can be made regarding fixed or removable prosthetics. Arch form and anterior-posterior spread will determine reasonable cantilevering from the terminal abutments. It is mandatory at this time to set up an occlusal scheme that will serve to verify the esthetics as well as vertical dimension (Figure 25-9). With the setup used as a guide, a clear plastic duplicate denture, that will act as a surgical guide or stent, can be made.



FIGURE 25-8 Occlusal implant stent.



FIGURE 25-9 Occlusal setup in wax.

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The restoring dentist can cut out a lingual channel or section exposing the residual ridge, leaving the facial surfaces of the teeth intact. Knowing where the teeth need to be helps the surgeon in the placement of the implants and ensures successful prosthetic restorations.

TREATMENT CONSIDERATIONS

Preparation

Incorporating dental attachments into treatment planning requires a basic working knowledge of how attachments work and how they can be used to create successful results by redirecting occlusal forces onto areas that can better handle increased stress. Precision attachments incorporated within the confines of the crown need more tooth reduction to create a restoration that is not bulky and overcontoured. Semi-precision attachments are incorporated outside the crowns so there is no difference in the preparation of the abutment teeth. Precision attachments incorporated into posterior teeth should be wider and bulkier than those chosen for anterior teeth. Interarch and interocclusal space requirements are a consideration, with many attachments needing 3 to 5 mm of space to be incorporated into the prosthesis. It is best to obtain reference manuals and catalogues from the various manufacturers and distributors to make sure the proper attachments are selected.

During the Procedure

In extraction cases, it is important to allow adequate healing time of several months before fabricating a new prosthesis. Long-term temporaries and transitional dentures or partials will hold the occlusion and vertical dimension, as well as providing for esthetics during this interim period. Once the final prosthesis has been inserted, it is important to allow time for it to settle in place. During this period, all adjustments can be made. Once the patient is comfortable, the attachments are cured into the overdenture or partial denture. This is done for tissue-supported cases as well as cases that are tissue and root supported or implant supported. The time to place the attachments in the prosthesis is once it has settled, with all adjustments made, and the patient is comfortable. If attachments are placed before this time, the proper relationship between the prosthesis, the soft tissue, and the attachments will not be established. In cases that are totally root or implant borne and do not rely on soft tissue, it may be best to have the laboratory cure the attachments into place as the support mechanism has been accurately established in the impression-taking and fabrication stages.

Finishing

Attachment dentistry requires the same attention to detail as any of our general dental procedures. It is important to periodically recall these patients to check the attachments for proper function and wear, as well as checking the occlusion for any deviations that need adjustment and polishing.

EVIDENCE-BASED PRINCIPLES

This process continues to develop, and much research has been done to demonstrate how protective and esthetic precision and semi-precision attachments can be. Research has shown that healthy teeth in their alveoli can move from 30 to 50 µm occluso-gingivally and 50 to 100 µm bucco-lingually, and possibly more, depending on their support mechanisms. This natural physiologic tooth movement will vary slightly depending on the teeth in question. It occurs because the root is attached to the alveolus by vital and mobile periodontal ligaments. Implants osseointegrated into bone display no movement since there is no periodontal ligament. Measurable movement with implants is a result of the compressibility of the surrounding and supporting bone. As a result, implant movement is far less than the movement of natural teeth. Attachments allow for various degrees of movement along three different planes of space. Using attachments to attenuate occlusal forces by redirecting them to better load-bearing areas has proved to be successful.

CLINICAL CONSERVATION CONCEPTS

The use of attachments in treatment planning allows patients to experience greater comfort, eating pleasure, a better self image, less trauma to their natural teeth, roots, soft tissue, and implants, and a greater consciousness of their oral hygiene. Patients wear attachment-retained prosthetics almost 100% of the time. They have a good sense of psychological security and do not feel esthetically compromised. The prosthesis functions much like the natural teeth and provides them with a greater degree of comfort than traditional partial dentures or overdentures.

Our goals are to preserve the soft tissue and bone and provide retention and outstanding esthetics. This translates to successful dentistry and many satisfied patients.

MAINTENANCE

Patients are required to come in for 3-month scaling, prophylaxis and examinations. Routinely patients are given instructions on how to clean their teeth and their prostheses at home. A standard regimen of brushing and flossing is followed up with a fluoride mouthrinse, particularly for patients with fixed appliances. Removable appliances require fluoride to be placed in the attachment before it is inserted in the mouth. Patients are instructed to remove and clean their appliances before they go to bed in addition to maintaining their existing teeth, roots, or implants.

During the visit, the prosthesis is checked in the mouth for retention and stability and the need for possible relining. Attachments are checked for wear and may need to be replaced. Attachment-retained overdentures may need relining. In this case, new male or female components have to be ordered and picked up during the relining process, or as a separate proceedure. Attachments are also checked for the presence of plaque

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or calculus, which can lead to attachment failure, loss of the tooth, root, or implant.

Oral hygiene cannot be overstressed and the patients leave the office with written instructions on home care.

NEAR-FUTURE DEVELOPMENTS

In the near future, stronger, lighter materials will be developed that will allow for smaller attachments. Research with magnets has shown some positive results. Newer, stiffer or resilient polymers can redirect occlusal forces with less wear. Highly viscous relining materials can act as a retentive element, eliminating the male or female attachment and providing a great amount of retention, support, and stability.

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26 CHAPTER

Technology and Esthetics

A SECTION

Minimally Invasive Dentistry: Dental Procedures and Technology

Edward Lynch, Fay Goldstep, George Freedman

RELEVANCE OF MINIMALLY INVASIVE DENTISTRY TO ESTHETIC DENTISTRY

The less destruction of tooth structure, the more conservative the preparation. The more of the original tooth structure that can be maintained, is generally more esthetic. In dealing with a carious occlusal pit and fissure lesion that extends into dentin, management with a minimally invasive approach is preferable—for example, using the SS White fissurotomy burs (SS White Burs, Inc., Lakewood, New Jersey) (Figure 26-1, *A*) and exposing the dentin, plus subsequent treatment with ozonation of tooth surface and rinsing with ozonated water (Figure 26-1, *B*). The disinfection of remaining carious dentin is possible as long as the lesion is relatively superficial. An acid-etching technique (Etch-Rite, Pulpdent Corporation, Watertown, Massachusetts) is then used on the enamel (Figure 26-1, *C*), followed by a use of single-bottle seventh-generation system (Bondforce, Tokuyama Dental America, Inc., Encinita, California) for bonding to enamel and dentin (Figure 26-1, *D*). After light polymerization (Figure 26-1, *E*), an appropriate flowable composite resin (BEAUTIFIL Flow Plus, Shofu Dental Corp., San Marcos, California) can be inserted into the cavity (Figure 26-1, *F*). This is a very minimally invasive approach that produces end results that are esthetically pleasing for the patient (Figure 26-1, *G*).

Patients who are esthetically oriented are generally more up-to-date with modern health concepts and philosophies. Dentistry has moved away from the destructive template approach that involved cutting prescribed shapes into the teeth (Figure 26-2). Modern dental practice is much more focused on a disease-oriented approach, in which the diseased tissues are removed and only those modifications that are absolutely necessary to improve the longevity of the restoration are made to the cavity site (Figure 26-3).

BRIEF HISTORY OF CLINICAL DEVELOPMENT OF MINIMALLY INVASIVE DENTAL PROCEDURES AND TECHNOLOGY

The earliest perhaps inadvertent attempts at esthetic dentistry or minimally invasive dentistry were made by Michael G. Buonocore in the 1950s (see Figure 8-16). He was the first to etch teeth and to begin the process of bonding to tooth structure, which is inherently more conservative of teeth than preparing shapes that physically retain amalgam. As this approach progressed from enamel etching to the inclusion of dentin etching/conditioning in subsequent years, it became more widely used, so that by the turn of the twenty-first century over 50% of North American posterior restorations were performed with adhesive procedures. Subsequently the single-bottle, seventh-generation adhesives were developed. Other innovative technologies helped to ensure that the surface to be restored was relatively free of bacteria that cause decay, or at least less inclusive of those bacteria (Figure 26-4).

The philosophy is now even more conservative. The infected dentin is managed with ozone and photoactivated disinfection (PAD). This allows the operator to dramatically reduce the number of microorganisms remaining in the retained dentin, which can then be infiltrated with adhesives that bond to this surface. This process is most conservative with direct composite restorations. Ozone can penetrate to a somewhat deeper subsurface level than PAD. Ozone is available in a gaseous form, such as that provided by the HealOzone system (Curozone GmbH, Wiesbaden, Germany) (Figure 26-5) in action and in aqueous form with ozonated water.

PAD is available commercially as well. The most common system used is Aseptim Plus (SciCan, Ltd., Toronto, Canada) (Figure 26-6, *A*). A dye that attaches to microorganisms (Figure 26-6, *B*) is placed on the prepared tooth surface then is

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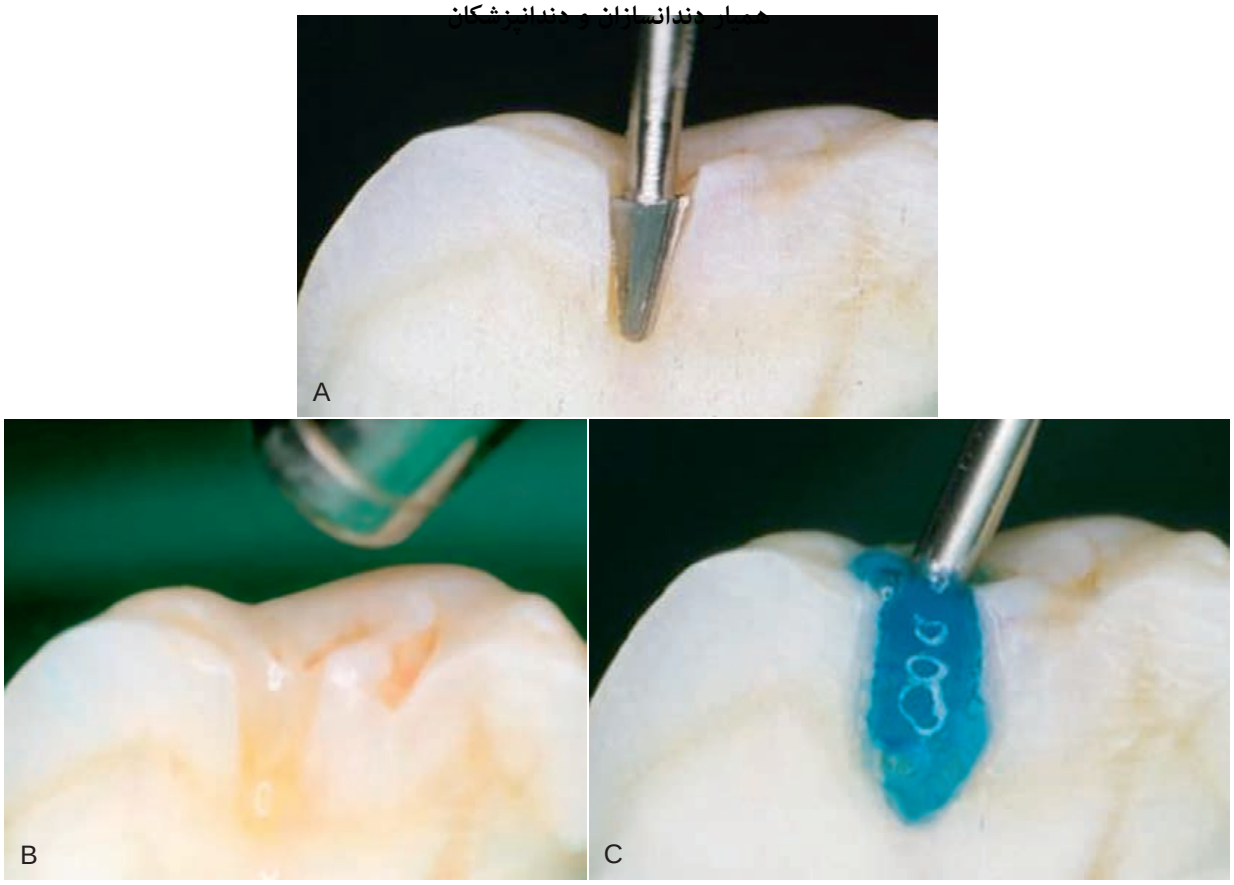


FIGURE 26-1 **A, SS White Fissurotomy bur in fissure to the depth of the dentin. B, Rinsing the tooth surface with water. C, Etching the tooth surface.**

Continued

irradiated with a light-emitting diode (LED) light to effectively kill the microorganisms near the surface (Figure 26-6, *C*).

The history of minimally invasive dentistry has been a process whereby the surgical approaches of the past that focused on removing all *diseased* or *questionable* tissues and replacing them with restorative materials have been replaced by a philosophy that allows the on-site *management* and *treatment* (where possible) of diseased tissues. Increasingly treatment is aimed at retaining as much natural tissue as possible as an integral part of the permanent restorative process.

RELATING FUNCTION AND ESTHETICS

Maintaining the natural tooth structure assists in both function and esthetics. For example, if an operator is removing caries from a mesial-occlusal-distal (MOD) cavity in the upper first premolar, and if the base of the retained buccal cusp is supported by more conserved tissue, clearly that buccal cusp has greater strength than that allowed by the traditional invasive approach of cavity preparation, which undermines and weakens the remaining cusp (Figure 26-7). Natural tooth structure is better than the best restorative materials available and supersedes any synthetic material the dentist can place. Generally, if the dentist can maintain the natural occlusion, the natural form and shape of the tooth, and the functional outline of the dentition and soft tissues, the health of the patient's oral environment will be better and more easily maintained over a longer term.

CLINICAL CONSIDERATIONS

Indications

The indications for minimally invasive dentistry include every preparation and intervention that an operator carries out. Minimally invasive techniques are not solely applicable to pits and fissures but also deal with overall health and patient management. Even deep carious lesions can be managed to avoid traumatic exposure of the pulp or even potential further damage to the pulp through additional heating, desiccation, or trauma associated with operative procedures in close proximity to the pulp (Figure 26-8).

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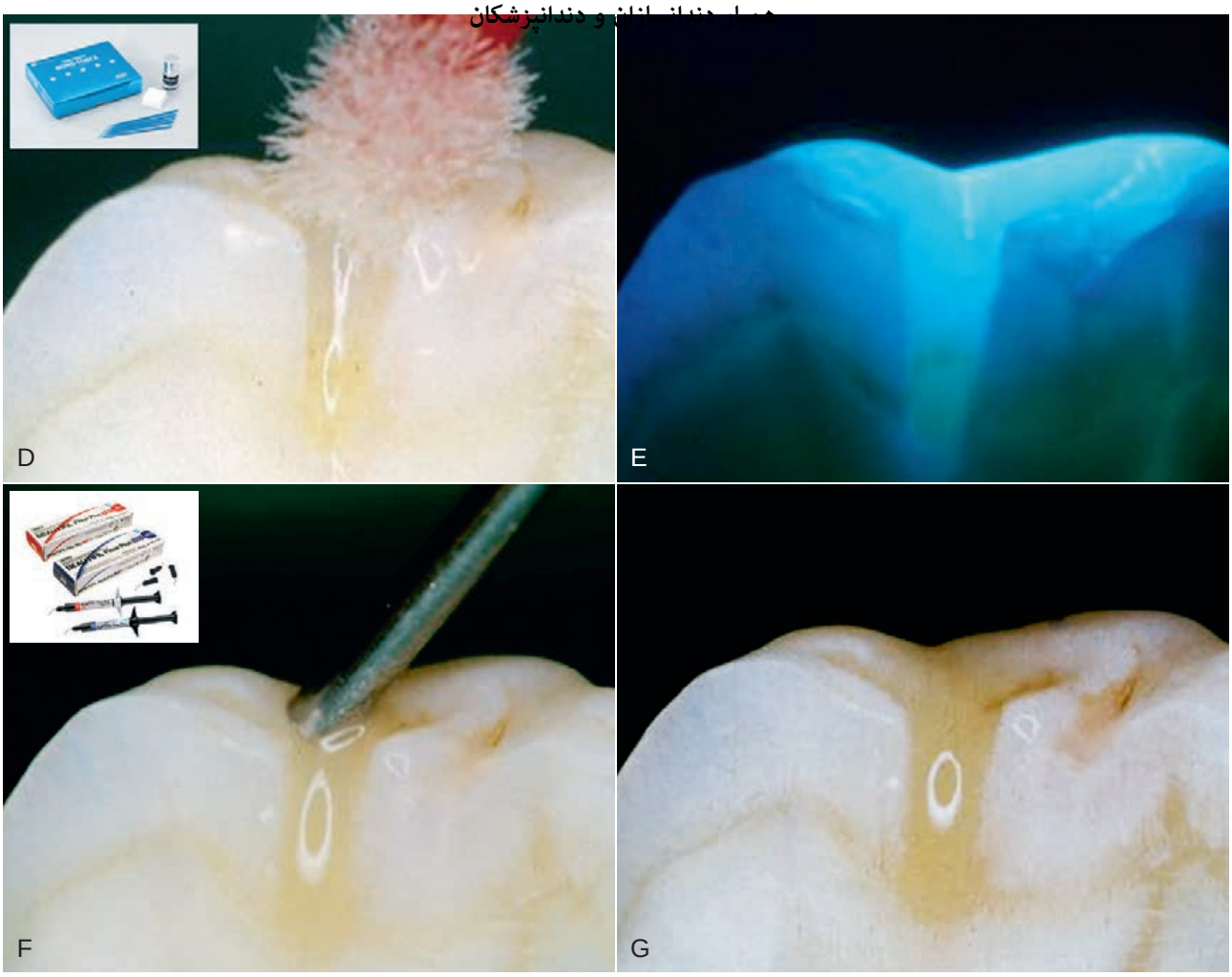


FIGURE 26-1, cont'd D, Applying the adhesive (Tokuyama Bond Force). E, Light polymerization. F, Restoration with BEAUTIFIL Flow Plus. G, Completed fissure restoration. *(Inset **D** courtesy Tokuyama Dental America, Encinitas, California. Inset **F** courtesy Shofu Dental Corporation., San Marcos, California.)*

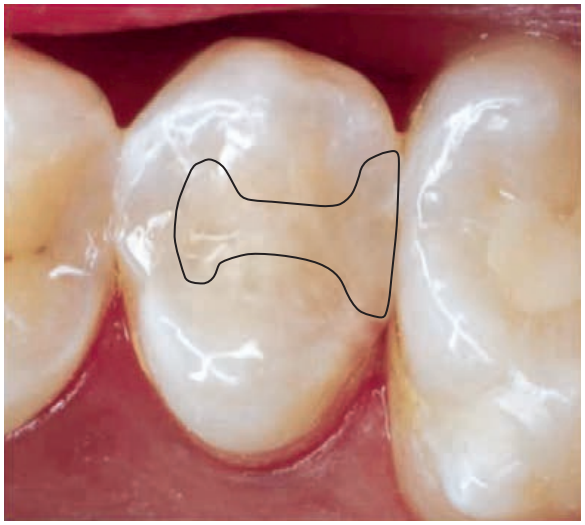


FIGURE 26-2 Traditional preparation class II form.



FIGURE 26-3 Conservative Clark class II preparation.

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Contraindications

Minimally invasive dentistry is both a clinical approach and a philosophical one. In practical terms, it is a clinical approach because it is something that every dentist aims to achieve for every preparation for each patient. However, the philosophical approach of *non*–minimally invasive dentistry has been predominant for over a century within the dental profession. It predated the modern pharmaceutical approach to managing infected tissues. In the past, a number of studies have shown that any infection remaining in the tissues could progress, thereby leading to ongoing problems beneath restorations (Figure 26-9). Caries may progress, with all the attending implications. Of the pharmaceutical approaches to management, the two most notable are ozone (gas or ozonated water) and PAD. These approaches destroy or reduce the pathogenicity of the cariogenic flora remaining beneath cavity preparations. This allows a much more minimally invasive approach. This



FIGURE 26-4 Consepsis syringe. *(Courtesy Ultradent Products, Inc., South Jordan, Utah.)*

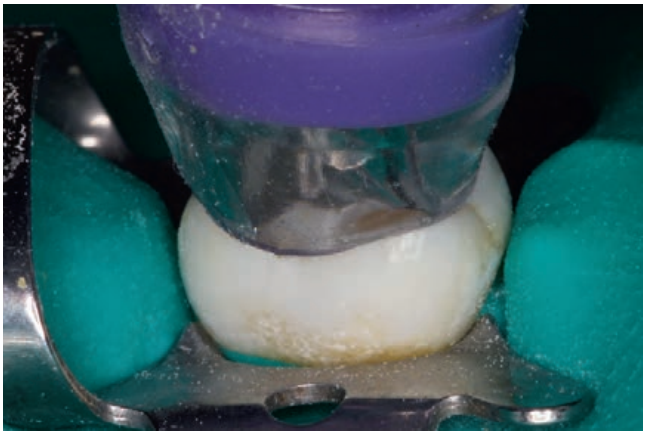


FIGURE 26-5 HealOzone system on tooth.



FIGURE 26-6 A, Aseptim Plus. B, The dye that will be placed on the prepared tooth. C, Tooth irradiated with a light-emitting diode (LED) light to kill the microorganisms near the surface. *(A courtesy SciCan, Ltd., Toronto, Ontario, Canada.)*

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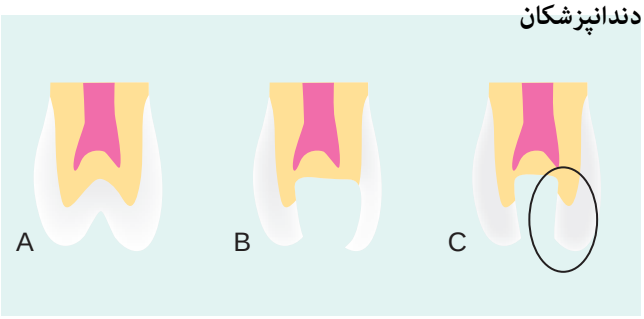


FIGURE 26-7 A, The unprepared tooth has the greatest strength. B, The undermined buccal cusp of the traditional invasive cavity preparation is rather weak and can fracture under pressure even after restoration. C, The conservative preparation leaves more supportive tissue under the buccal cusp, making pressure fracture after restoration less likely.

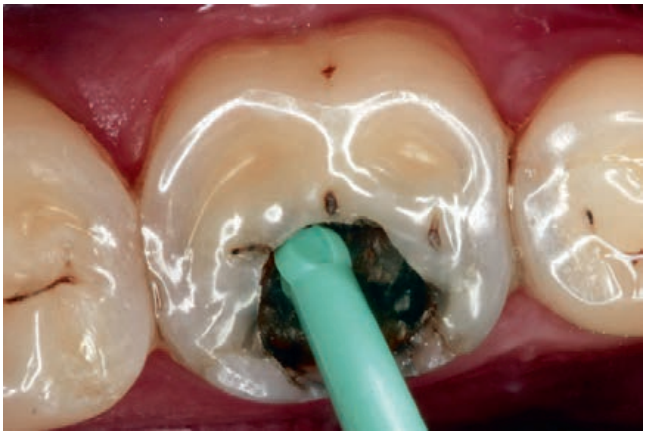


FIGURE 26-8 Removing deep caries with the Smart Bur II (Wehmer Corporation, Lombard, Illinois).

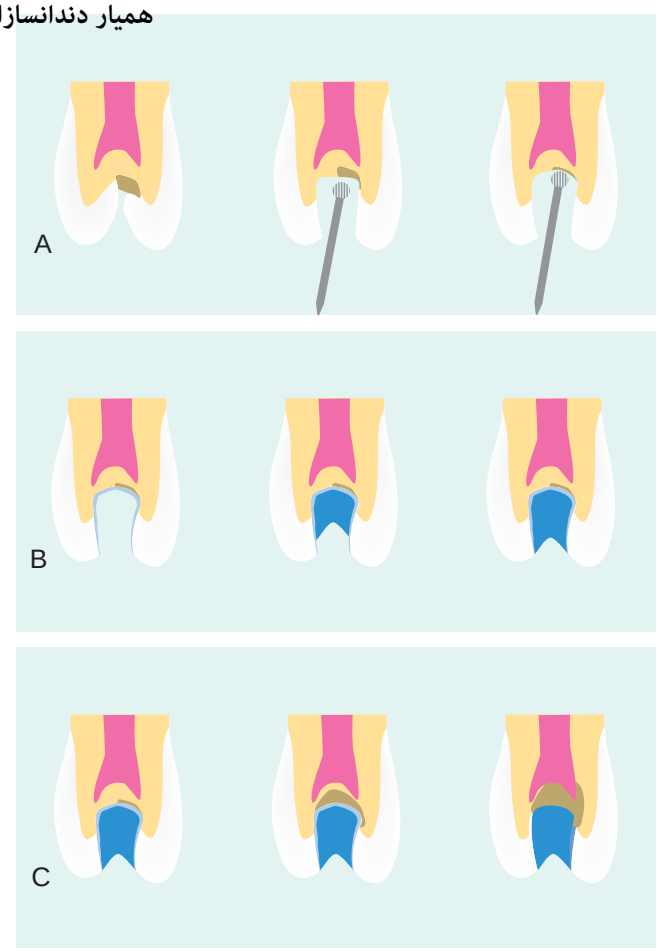


FIGURE 26-9 A, Occlusal decay is removed with high-speed and low-speed burs, inadvertently leaving healthy-appearing but affected dentin toward the buccal area of the cavity floor. B, The affected dentin is sealed over by the layered steps of the composite restorative material. C, The affected dentin, still harboring bacteria, begins to re-decay along the tooth-restorative interface, eventually expanding and infecting the pulp.

treatment modality is not limited to the management of caries or cavity preparations; it can be used in endodontics, periodontal therapy, and other areas.

MATERIAL AND ASSESSING OPTIONS

Ideally the dentist must properly isolate the operative area, which requires selecting from the various available isolation methods, including the rubber dam technique where appropriate. It is also necessary to develop effective visualization access, typically involving magnification and illumination.

The dental team, including every single professional member, has both a responsibility and a desire to deliver the best care possible to each and every patient. The experience of clinical practice and continuing education tends to improve the quality of this care throughout the dentist's career. The clinical success in the delivery of dental care, however, is dependent on many factors including visual acuity and manual dexterity. Enhancing the diagnostic and clinical armamentarium in ways that enhance the eyes and hands of the operator benefits both patients and dentists tremendously.

Clinical dentistry can be a rather difficult occupation. The oral cavity is not a treatment-friendly space; it is small, has restricted access with numerous interfering oral structures, and is generally quite dark. Seeing minute details (during diagnosis or treatment) and visualizing procedures in progress can be both difficult and stressful. The improperly positioned patient's head can cause significant physical discomfort to the practitioner seeking better visual access and may in time cause the dentist physical damage that may impede the continued practice of dentistry (Figure 26-10).

همیار دندانسازان و دندانپزشکان

Magnification

Magnification provides the means to alleviate many of these problems and concerns and allows the dentist to practice more comfortably while ensuring that dental procedures can be delivered at the most exacting level (Figure 26-11).

The most significant advantages offered by magnification loupes are visualization, illumination, isolation, and preparation.

Visualization

Improved visualization of minute yet significant dental detail simplifies diagnosis and enhances clinical treatment. The dentist using magnifying loupes can examine both hard and soft tissue surfaces in more exacting detail, thus often diagnosing problems at an earlier stage than previously possible. Earlier diagnosis benefits the patient through more conservative, less invasive treatment (Figure 26-12).

Fortuitously, magnification loupes force the operator into a more **ergonomic posture**, reducing back and neck strains (Figure 26-13). A dentist who is using properly fitted magnification loupes is required to view the oral cavity and to operate from a more ergonomic and healthier sitting position. There is less stress on the back and neck muscles, reducing strain and contributing to more comfortable and productive working sessions. Magnification is responsible for reducing eyestrain by providing a clear and magnified view of the working area. Decreased eye fatigue contributes to a more satisfying clinical practice, particularly toward the end of a working day or a long working week. In addition, the improved clinical visualization allows more precise and less invasive treatment.

Esthetic and cosmetic procedures call for invisible margins and tooth-restorative interface transitions. These technique-sensitive, yet critical, features are far easier and less demanding to develop when the visual working field is enhanced to twice normal (or greater) size. If the margin seems to "disappear" when magnified, then it will certainly not be visible to the naked eye. The fine internal and external colorations and characterizations

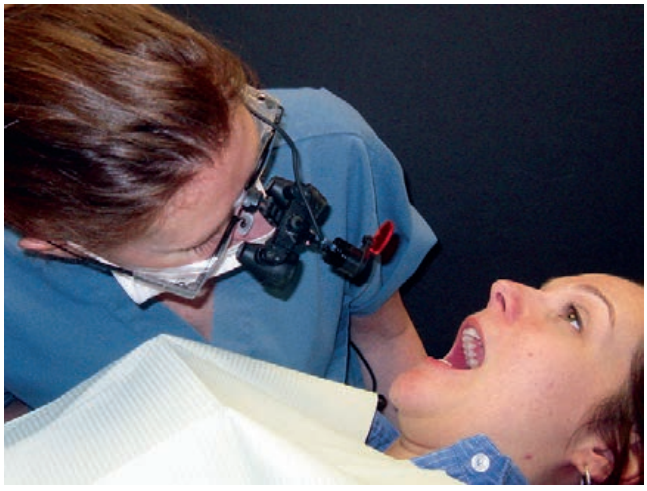


FIGURE 26-10 Dentist leaning over patient at an awkward angle.



FIGURE 26-11 Practitioner wearing magnification loupes. *(Courtesy Orascoptic, Middleton, Wisconsin.)*

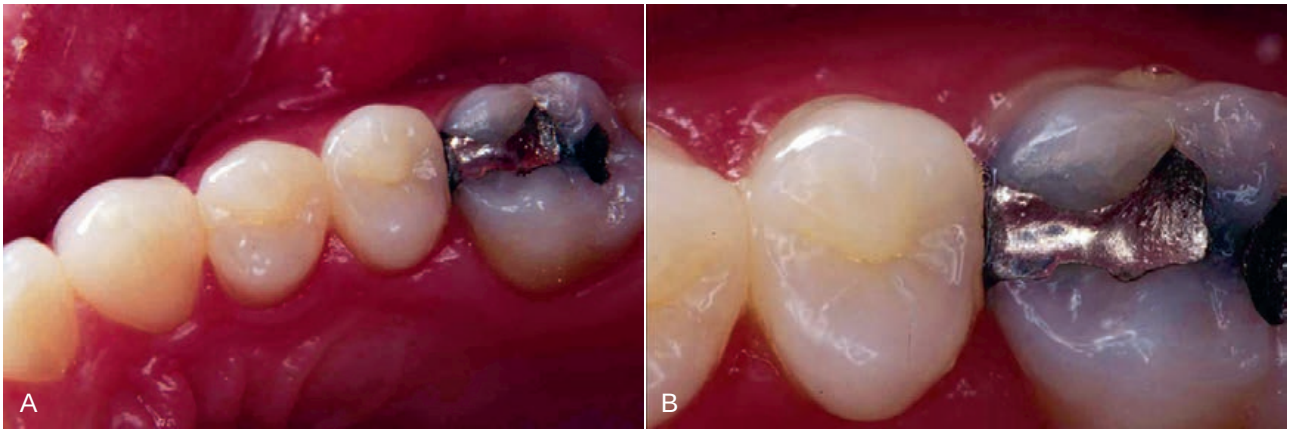


FIGURE 26-12 Distant (A) and close-up (B) views of the same structure.

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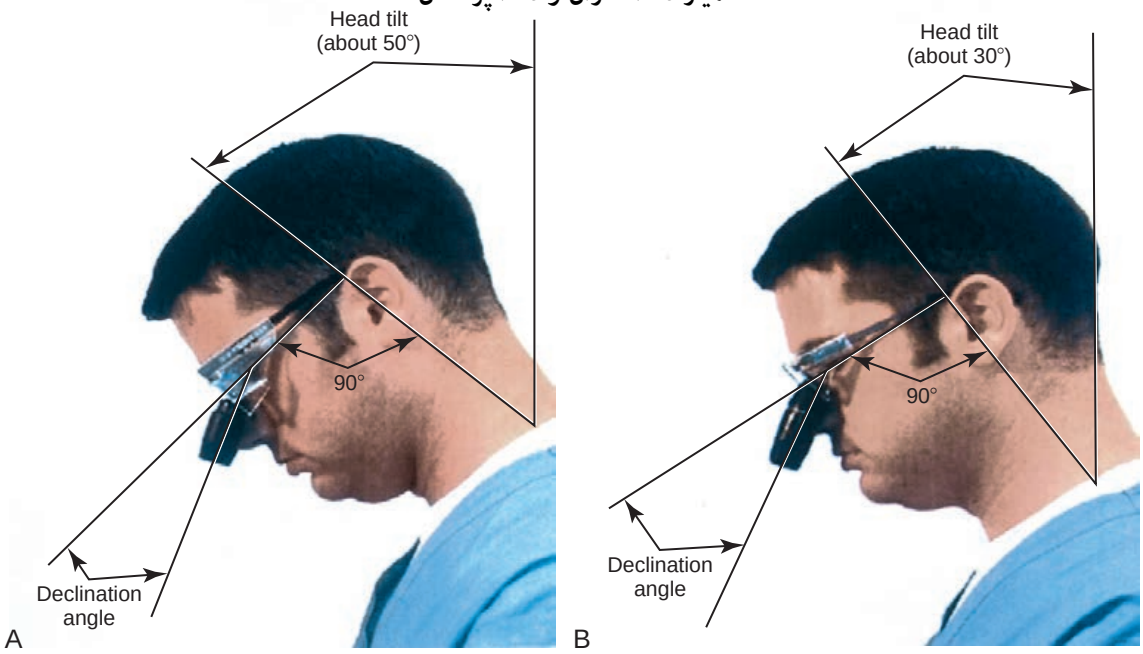


FIGURE 26-13 Good (A) and bad (B) posture of a practitioner.

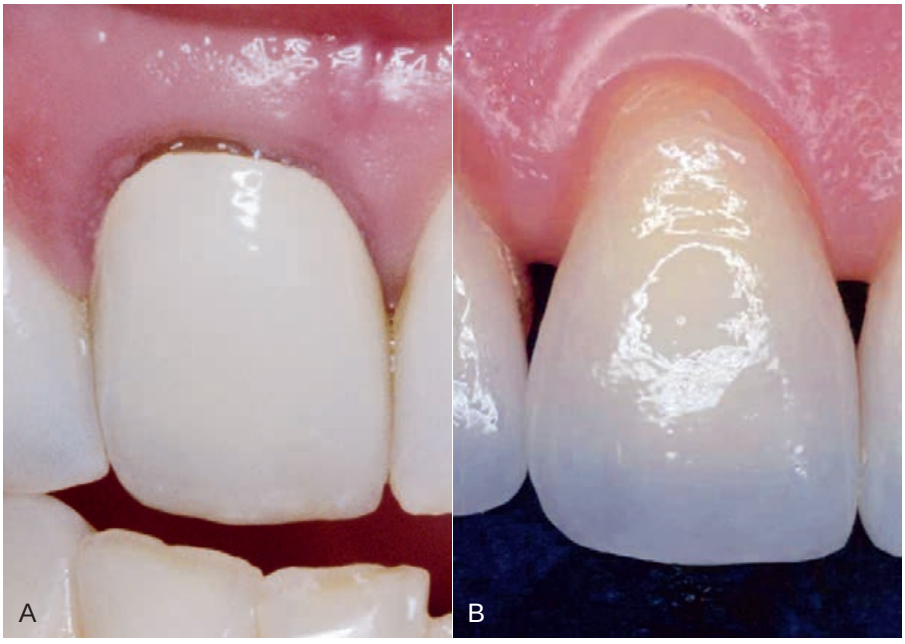


FIGURE 26-14 Close-up views of visible (A) and invisible (B) margins.

that are required for "invisible" margins are virtually impossible to achieve without appropriate magnification (Figure 26-14).

A generation ago, magnification was primarily targeted at older practitioners whose age-related eyesight changes were making routine clinical procedures increasingly difficult to accomplish. These individuals required mechanical vision modification in order to keep practicing dentistry, and loupes, such as they were at the time, fit the bill. Then, cosmetic dentists, who were fanatically fussy about margins and other minute clinical details, began to avail themselves of the esthetic advantages offered by working under magnification. Periodontists and endodontists quickly followed suit. Today magnification is routinely introduced to dental students while they are in their formative years of dental school.

As magnification has become more mainstream in the dental profession, it has raised the bar in the assessment of restorative procedures. Current standards of care demand better materials, better techniques, and better self-evaluation. The twenty-first–century practice finds dentists at every age and stage, in general practice and in specialties, using magnification to enhance their

همیار دندانسازان و دندانپزشکان



FIGURE 26-15 Practitioner wearing loupes with illumination.



FIGURE 26-16 Fiberoptic handpiece.

visual acuity, to see more easily, and to diagnose earlier, more effectively, and more accurately. Today, clinical treatment under magnification is part of the design concept for most new materials and techniques.

Illumination

The science and art of illuminating the operative site have advanced rapidly in recent years. Dentists, like medical surgeons, have found that maximizing visual acuity at the work site not only is important, it is essential (Figure 26-15). Suitable lighting provides much-improved diagnostics, greatly enhanced treatment opportunities, and better treatment outcomes. Vision and visibility in the oral cavity are always major concerns. Hands, instruments, or even a slight movement of the patient's head can often obstruct the overhead dental light. Fiberoptic light handpieces have been the standard of care for several decades, and most dentists will not consider high-speed tooth preparation without targeted illumination of the operative site (Figure 26-16). Although in-handpiece lights are effective in



FIGURE 26-17 A, Odyssey Mini 3 Watt LED. B, DentLight Nano Loupe Light. *(A courtesy SurgiTel, Ann Arbor, Michigan. B courtesy DentLight, Richardson, Texas.)*

illuminating the immediate working area, often a larger sphere of visibility is needed (Figure 26-17). In addition, as dental professionals get older, their eyes require more light to see and work effectively. Increasingly they have begun to use illuminating headlamps. Earlier lighting models were heavy, bulky, wired (to the battery), and cumbersome. The innovative and very convenient solutions to illumination problems inside the oral cavity consist of LED bulbs that provide 500 foot-candles of light intensity or more. Best of all, the headlight's weight on a standard clip is less than 1 oz. Headlights are also effective clinical treatment adjuncts for hygienists as well as others on the dental team.

Isolation

There are typically three major problems when working in the mouth: (1) the lack of visibility of the teeth or soft tissues, (2) the physical interference of the tongue and cheeks in the work areas, and (3) the presence of copious amounts of saliva that tends to flood surfaces just when they need to be dry. In fact, most of the benefits of four-handed dentistry involve improved isolation and moisture control in the working area. The Isolite system (Isolite Systems, Santa Barbara, California) (Figure 26-18, *A*) isolates the working field by keeping away the tongue and cheeks. It is attached to the high-volume suction port and aspirates both excess saliva and coolant water from the

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A



B

FIGURE 26-18 A, Isolite system provides continuous illumination, aspiration, and retraction. B, Lighting the patient's oral cavity from within the mouth. *(Courtesy Isolite Systems, Santa Barbara, California.)*

handpiece. It also provides bright, shadowless illumination inside the mouth through the light distribution system in the Isolite mouthpiece (Figure 26-18, *B*). The light source is external, and the brightness can be adjusted as per the needs of the operator. The single-use mouthpiece is readily inserted into the patient's mouth, and patients find the mouthpiece very comfortable as resting the teeth on the bite block makes it easier to keep the mouth open for extended periods during procedures. The illumination is delivered into the mouth using an LED light source; there is no electrical current or any danger of shock in the mouth. The continuous aspiration of both the buccal and lingual sulci keeps the field dry and the working area clean and clearly visible. The Isolite mouthpiece is flexible and acts as a single-unit replacement for numerous isolation, illumination, and aspiration devices.

Preparation

Clearly the tools that are used to prepare the cavity are very important. Air abrasion must be well directed and aimed into the cavity with appropriate high-aspiration suction so as not to produce excessive debris around the rim of the preparation (Figure 26-19, *A*). The PrepStart H_2O (Danville Materials, San Ramon, California) (Figure 26-19, *B*) and the RONDOflex (KaVo Dental, Charlotte, North Carolina) (Figure 26-19, *C*) are the two highest-ranked air abrasion systems for use in cavity preparations, particularly in pits and fissures (Figure 26-19, *D* and *E*).

The SS White Fissurotomy bur (Figure 26-20) is a novel approach to ultraconservative dental treatment. The shape and size of the bur are designed specifically for the purpose of treating small, incipient, and pit and fissure lesions. The head length of the bur is 2.5 mm, the average thickness of occlusal enamel, allowing the dentist to limit the bur tip to cut to just below the dentino-enamel junction (DEJ) and not further into the dentin (conservation). The tapered shape of the bur (visualization) allows the cutting tip to encounter very few dentinal tubules (patient comfort) at any given time and has been designed to minimize heat buildup and vibration. Because the cutting of the Fissurotomy bur is restricted largely to enamel, patient discomfort is minimized and the need for local anesthetic is eliminated in most cases. The Fissurotomy bur is far less invasive than similar length carbide and diamond burs. Traditional cutting burs remove far more enamel at any depth of cut and are designed to access caries that has progressed well beyond the DEJ, whereas the Fissurotomy bur has been anatomically designed to enlarge the fissure and eliminate small caries without removing excessive healthy enamel or dentin.

The SS White Great White bur (Figure 26-21) is an excellent instrument for generating conservative preparations, particularly in posterior teeth. Its highly dentated surfaces quickly and effectively cut tooth structures, amalgam and composite resin, and restorative metals. Its geometric configuration is highly suitable for developing ideal cavity preparations for class I and II posterior composite resins. The Great White bur does not grab, catch, stall, or break in harder-to-cut materials such as amalgam, composite, and semi-precious and non-precious castings.

The HealOzone system (Curozone, Wiesbaden, Germany) (Figure 26-22) produces ozone that safely kills cavity-causing bacteria in and on the tooth (Figure 26-23). To prevent potential lung inhalation, it is important to follow manufacturer directions. Ozone treatment (as seen in the HealOzone system) is highly effective in managing superficial infected dentin.

The restoration process involves the effective elimination of remaining bacteria on and in the dentinal surface, followed by a single-component adhesive system that can manage enamel and dentin simultaneously. The restorative material buildup for the single-surface occlusal cavity is well documented.

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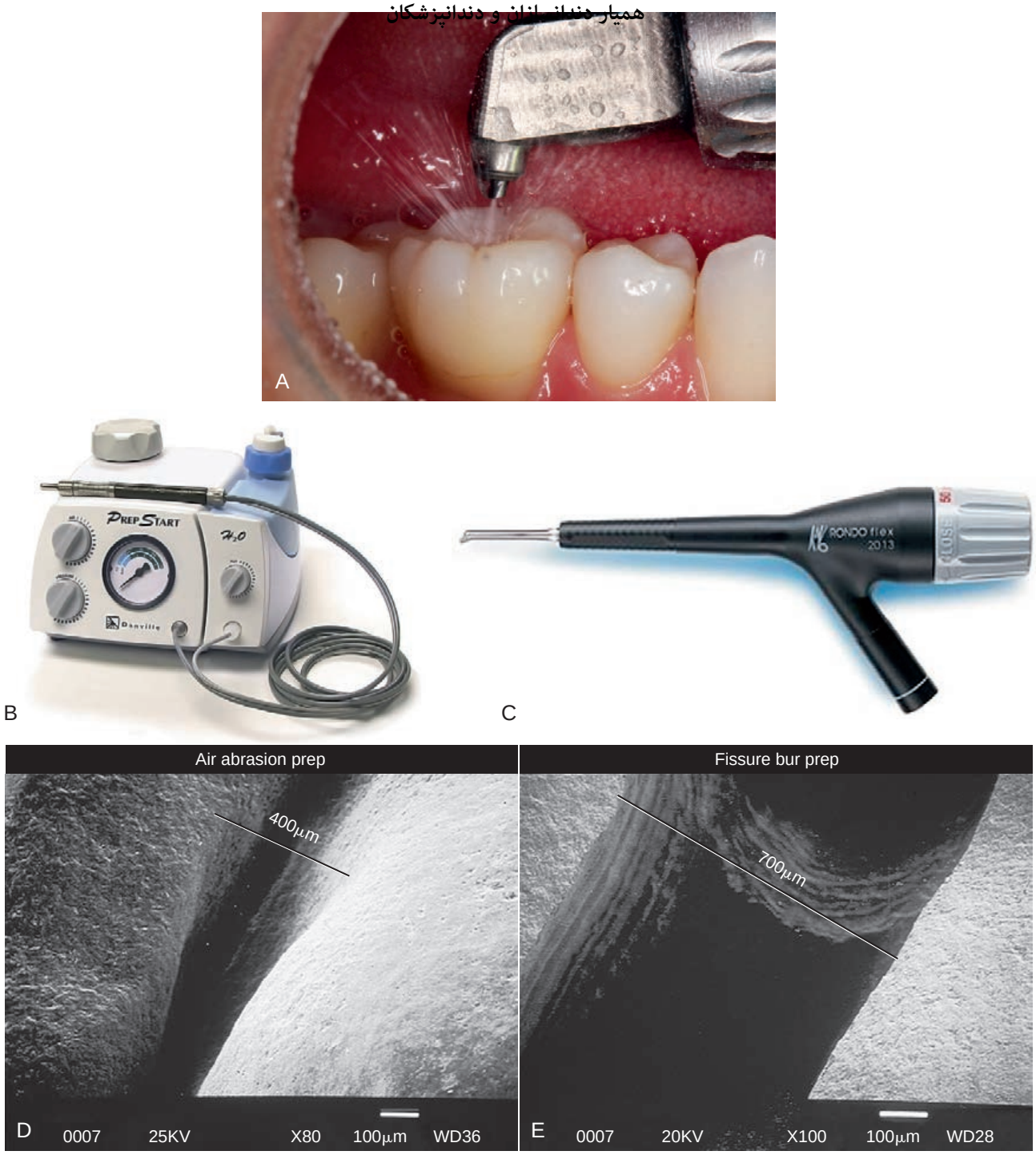


FIGURE 26-19 A, Air abrader on teeth. B, The PrepStart H_2O. C, The RONDOflex. D and E, Comparison of air abrasion preparation and fissure preparation. *(**B** courtesy Danville Materials, San Ramon, California. **C** courtesy KaVo Dental, Charlotte, North Carolina.)*

Single Surface Occlusal Cavity As previously documented in Figure 26-9, *A*, the majority of the decay is removed. Often, undetectable surface bacteria remain that can cause further decay after the restorative process (Figure 26-24, *A*). Ozone gas can be used to kill bacteria in the surface dentin layers (Figure 26-24, *B*). Alternatively, PAD can also be used to destroy the remaining bacteria (Figure 26-24, *C*). After either of these treatments or independently, ozonated water can be used in rinsing the cavity preparation to provide a bactericidal effect (Figure 26-24, *D*). Then a seventh-generation adhesive is applied to the prepared surfaces, air dried, and polymerized (Figure 26-24, *E*). The composite restorative material is placed into the cavity in small increments (up to 2 mm) and polymerized (Figure 26-24, *F*). The composite material is built in increments to the occlusal

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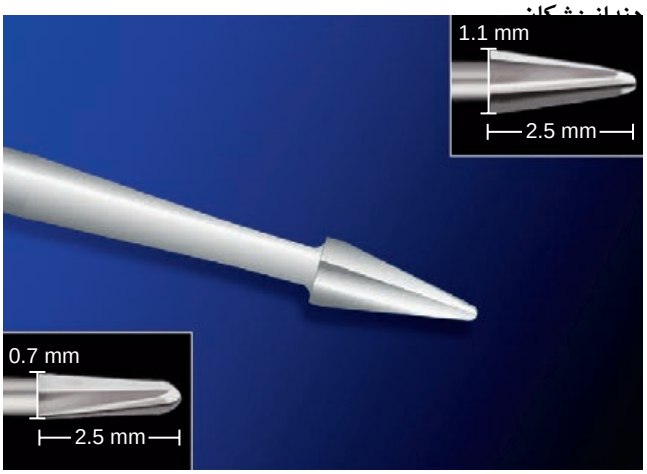


FIGURE 26-20 The SS White Fissurotomy bur.

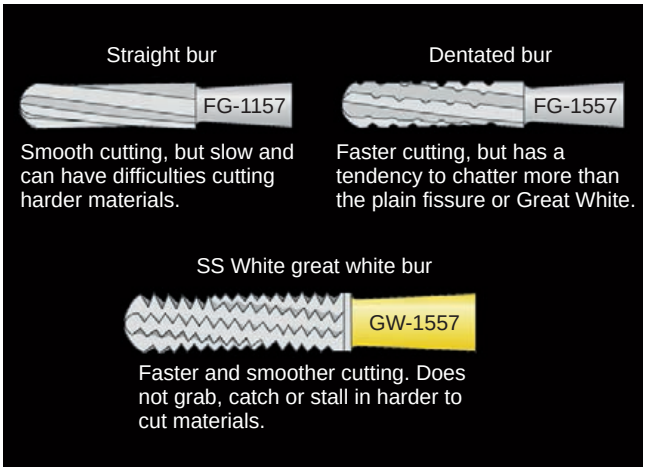


FIGURE 26-21 SS White Great White bur.



FIGURE 26-22 The healOzone ×4. *(Courtesy Curozone GmbH, Wiesbaden, Germany.)*

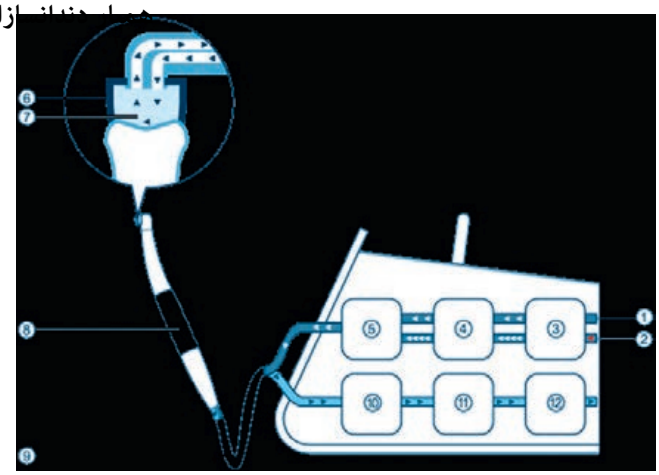


FIGURE 26-23 Principles of operation for healOzone ×4. *1*, oxygen suppy; *2*, air supply; *3*, air dryer; *4*, differential pressure sensor; *5*, ozone generator; *6*, tooth cup; *7*, ozone; *8*, handpiece; *9*, tubing; *10*, moisture trap; *11*, ozone neutralizer; *12*, vacuum pump. *(Courtesy CurOzone GmbH, Wiesbaden, Germany.)*

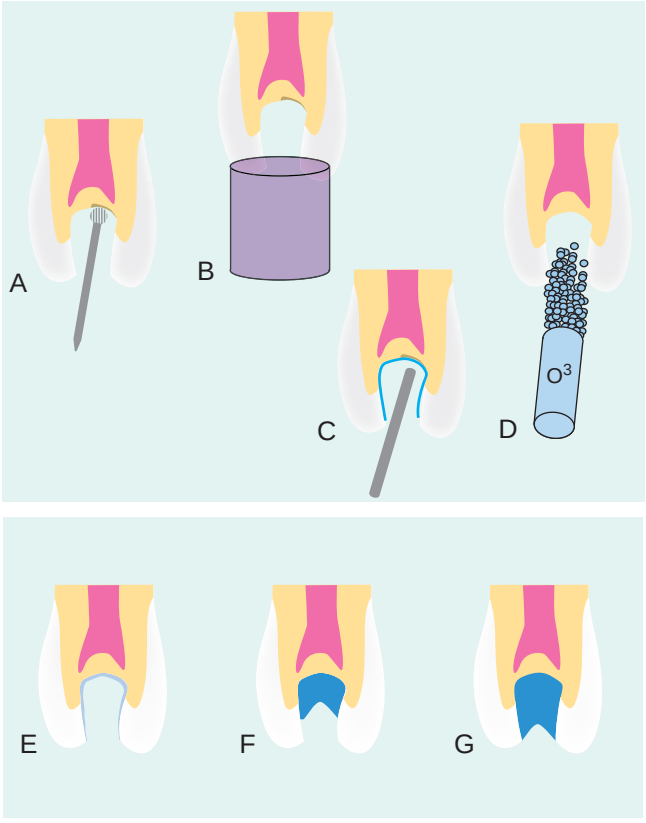


FIGURE 26-24 A, The visible decay is removed with high-speed and low-speed dental burs. Affected dentin may remain in spite of the best preparation efforts. The cavity preparation is disinfected with ozone gas (B), photoactivated disinfection (C), and/or ozonated water (D). The disinfected cavity (E) is now restored with adhesive and layered composite materials (F and G). Because there are no live bacteria left in the formerly affected dentin, this step reduces the incidence of re-decay.

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surface, polymerized at every step, and then finished to full occlusal contour and esthetics (Figure 26-24, *G*).

The Aseptim Plus unit (see Figure 26-6, *A*) is a PAD device that infiltrates the cell wall using tolonium chloride dye. PAD is discussed thoroughly in Section D of this chapter.

INNOVATIVE ELEMENTS

The innovative elements include all the new technologies in magnification, illumination, and isolation.

Magnification

Lighter, more comfortable, and easier to adjust loupes have made magnification a practical operation for the practitioner. Improved optics with shorter focal lengths and thinner glass lenses make the wearing of the magnification apparatus convenient and tolerable for the entire day.

Illumination

The development of diode light sources that are both lighter and consume less energy have made loupes-based illumination possible in the dental practice. The significantly decreased heat production of diode light bulbs is also more comfortable for the dentist's forehead.

Isolation

The convenient combination of devices to isolate, illuminate, and evacuate the oral cavity into a single unit frees up valuable operative space inside the oral cavity and makes four-handed operation far more productive and two-handed treatment possible.

Air Abrasion

With respect to cavity preparation, innovations involve the use of water with the air abrasive stream, which reduces the dust that would otherwise spread around the mouth and the operatory (Figure 26-25). The traditional handpiece methods used by dentists to prepare teeth for restoration, combined with their associated sounds and sensations, can have a tremendous impact on the image of the practice, its marketing potential, and treatment acceptance by patients. Most patients dislike the noise and the vibration of the drill during the cavity preparation, often commenting on the need for alternative treatment options. Drill-less techniques have been used in dentistry for more than half a century. In the last two decades, novel abrasion technologies and improved adhesive restorative materials have made these options practical and effective.

The operating principle of this technology is based on translating the velocity of the alumina particles that are propelled through the abrasive system into abrasive energy at the surface of the tooth. Although the alumina particles have a very tiny mass, their velocity on exiting the nozzle is very high. The kinetic energy stored in this velocity is directed at the tooth surface. When the particles strike the tooth surface, the energy of the alumina micro-abrades small particles of decay, enamel and dentin, layer by layer, from the tooth. Continued air abrasion can quickly prepare the cavity, readying it for adhesive restoration. The nozzle is not supposed to touch the tooth surface, and therefore tactile feedback is severely limited. However, the dentist has good visual control and can directly observe the elimination of decay on a real-time basis. The fine focus of the stream of alumina particles exiting the nozzle permits pinpoint, ultraconservative cavity preparation.

Air abrasion is useful for direct-access occlusal, buccal, and lingual cavity preparations. It can be used to remove existing composite restorations and selectively repair composite margins. Air abrasion roughens bondable surfaces such as tooth, porcelain, metal, and composite resin, offering improved adhesion for direct and indirect, resin-cemented restorations. It can also effectively clean away permanent or temporary cements, providing a contaminant-free surface for permanent bonding. Air abrasion is used to explore pits, fissures, and small cavities to remove any remaining decay and bacteria before the application of sealants and flowables.

Ozone

Ozone technology (as discussed earlier for the HealOzone system) is a documented safe treatment modality.

With the HealOzone system, ozone is delivered inside a cup directly into the lesion being treated (Figure 26-26). If the cup loses its seal, the cup simply sucks air into itself and ceases to deliver ozone. Radical ozone ions can be quite damaging to the lungs and should not be inhaled in significant dose. The HealOzone system has been proven in many studies to be absolutely safe to use. Even when it is inadvertently misused, there is no danger of any damage occurring to the lungs of the patient, the operator, or assistants because of the safety mechanisms that have been built into the technology (Figure 26-27).

Water Ozone Systems

Ozonated water systems are also very safe. Any ozone not delivered into the water bottle is converted into oxygen by the safety mechanisms, which is then blown into the dental operatory. The ozonated water is produced in total safety. The ozonated water can be used directly in irrigating syringes, ultrasonic scalers, cavity preparation rinses, root canal irrigation, or mouth rinsing for patients before, during, and after treatment to promote healing (Figure 26-28).

Innovative Elements of Fissurotomy

The SS White Fissurotomy bur (Figure 26-29) uses shapes as narrow as 0.7 mm and a cutting side as small as 2.5 mm long. The 2.5 mm relates to the average depth of the occlusal enamel. The operator can control the preparation with the Fissurotomy bur to ensure that it continues to cut enamel only, never entering the dentin. This eliminates the likelihood of patient discomfort.

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FIGURE 26-25 The use of water with the air abrasive provider (A) helps to reduce the dust that can otherwise spread around the mouth (B) and the operatory (C).



FIGURE 26-26 HealOzone delivers ozone gas directly and exclusively into the lesion.

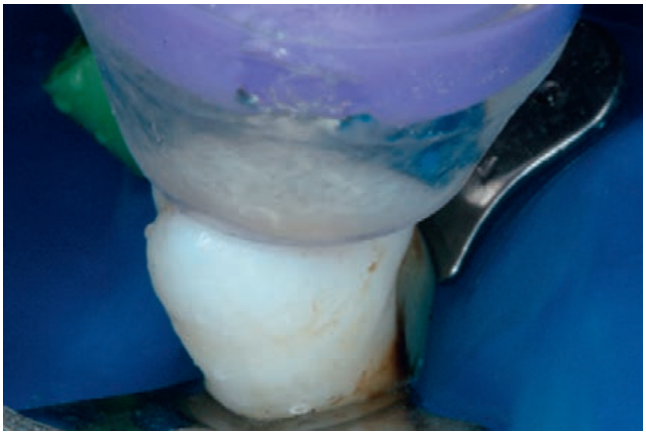


FIGURE 26-27 HealOzone generates therapeutic doses of ozone at the sight of application.

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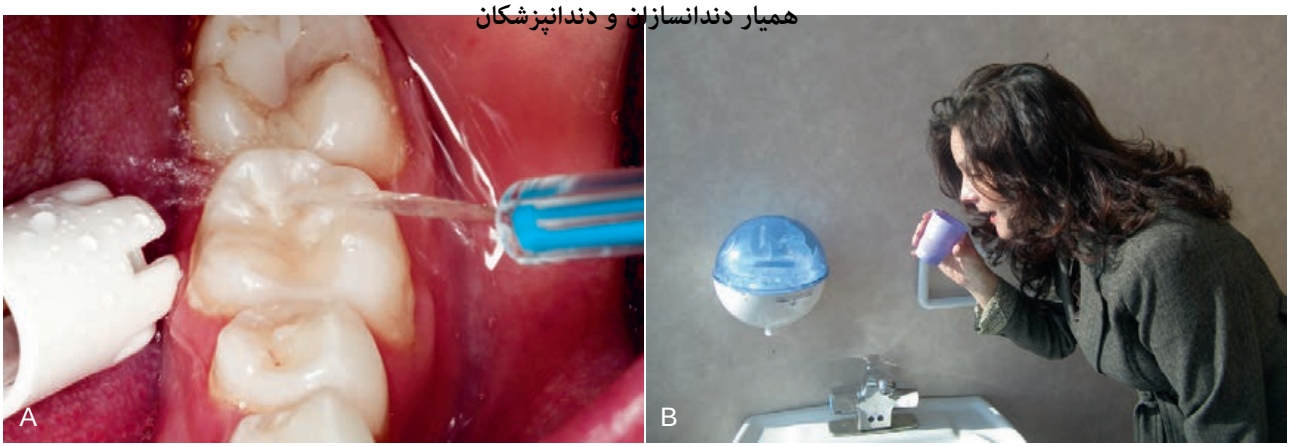


FIGURE 26-28 Ozonated water can be used in irrigating syringes (A) and or mouthrinses (B).

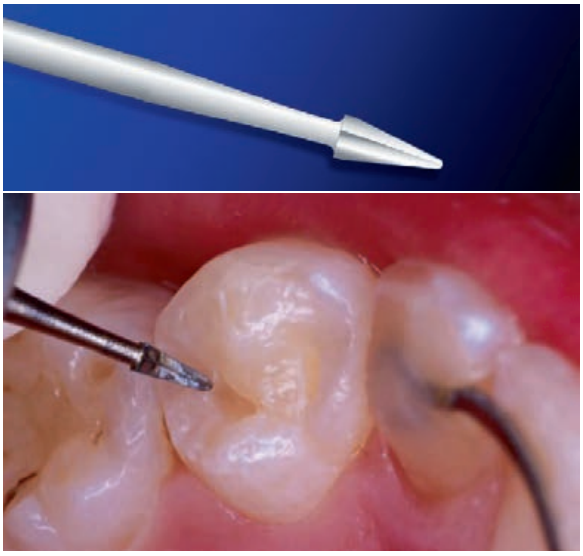


FIGURE 26-29 The tapered, depth-limited SS White Fissurotomy bur is used to control conservative preparation of the dentino-enamel junction (DEJ).

The conical shape of the Fissurotomy bur permits comprehensive visual access to any remaining carious material.

TREATMENT PLANNING

The dentist should not "add" minimally invasive approaches to the armamentarium. These modalities should be very much an integral part of every treatment plan. In the diagnosis of a carious lesion, every minimally invasive parameter should be included as part of the standard treatment evaluation. Minimally invasive approaches should be built into the psyche of the operator as the first determination of every treatment plan.

In the treatment process, operators typically provide pain relief first. For example, if the patient has pulpitis associated with a deep carious lesion in a particular tooth, the minimally invasive approach is to first manage the pulpitis if symptoms indicate that it may be reversible. A minimally invasive approach uses an ozone treatment as an initial step. The caries is then removed, leaving as little as 1 mm (or less) of infected dentin over the roof of the pulp chamber. Ozone treatment disinfects the tooth before the provisional or definitive restoration of the tooth, using a method that allows the pulp to heal over time. The aim is to keep the pulp vital and avoid root canal therapy. This is an integral part of the stabilization phase for pain relief.

For a patient with numerous carious lesions and clinical symptoms of pulpitis, the dentist can stabilize all of these lesions with a minimally invasive provisional approach using either gaseous or aqueous ozone or PAD as an intermediate step to definitive restoration. At the end of the stabilization phase, the dentist reviews what additional treatment, if any, may be required. This might include composite restorations, crowns, and bridges.

TREATMENT CONSIDERATIONS

Operative Considerations

Restorative Dentistry

A patient has the symptom of pain brought on by a cold stimulus that lasts only a matter of seconds and does not keep the patient awake at night. It is not a spontaneous pain, but it is always precipitated by cold. Radiographs reveal a carious lesion in close proximity to the pulp, but there is no loss of lamina dura around the root. The operative treatment plan immediately focuses on a minimally invasive approach, aiming to conserve tooth structure and to cause minimal damage to pulpal tissues. The operator proceeds to remove the caries without overdesiccating, dehydrating, or heating the dentin. The goal is to leave less than 1 mm, a very thin layer of possibly infected dentin over the roof of the pulp chamber. To verify this, a sharp probe is used with very light pressure. If the probe enters the infected dentin on the cavity floor and then can be withdrawn without any resistance, this indicates that more than 1 mm of infected dentin is present. If the probe enters the lesion with

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FIGURE 26-30 A, CarieScan PRO. B, THE CANARY SYSTEM dental caries detection system. *(A courtesy CarieScan, Ltd., Charlotte, North Carolina. B courtesy Quantum Dental Technologies, Toronto, Ontario.)*

very light pressure and the cavity floor is leathery, sticky, or resistant to the withdrawal of the probe, this indicates that less than 1 mm of infected dentin is present. Holding the probe up to the radiograph to estimate the extent of the caries with respect to the location of the pulp is fraught with the usual dangers of trying to interpret three-dimensional structures using two-dimensional radiographs.

The electrical caries monitor (ECM) is used to objectively quantify the severity of the root caries index (Figure 26-30). Previously, primary root lesions were classified by color, texture, hardness, cavitation, size, and severity. The ECM can be used to determine the severity of primary carious lesions because it is a less invasive but equally accurate way to detect carious lesions when compared with tactile methods.

When infected dentin remains in a lesion, it is desirable to destroy the viability of the remaining bacteria. One management approach includes ozonation with water as part of the preparation phase. The ozone gas is delivered for about 60 seconds into the cavity before the restorative steps are begun. An alternative is to use a PAD system. Since dyes have less penetrating ability than gases, photoacticated disinfection is more effective when there is less infected dentin remaining.

This technique is appropriate for pit and fissure carious lesions. For all other carious lesions, the same principles apply regarding conservation of the pulpal floor of the cavity, but the periphery of the cavity should have all infected tissue removed so that the adhesive can find purchase on solid tooth structure, whether enamel or dentin. Where no infected tissue remains, a very good seal can be achieved. For crowns and bridges, the same principles apply to manage deeper caries more conservatively. Ozone is one of the most powerful antimicrobial agents used in dentistry. To be effective, all the active ingredients must be in sufficient doses and delivered via the most appropriate method. Ozone will react immediately with reductants in culture media. The recommended use is to deliver the ozone under pressure directly into a lesion by pressing the delivery tube onto the carious surface so that it is encouraged to penetrate the lesion.

Periodontal Treatment

Periodontal disease is an infective process usually associated with pathogens such as *Actinobacillus actinomycetemcomitans* or *Prevotella intermedia.* Gram-negative anaerobes have developed a selective ecologic niche that leads to the destruction of periodontal tissues. The use of pharmaceutical agents can dramatically reduce the number of these pathogens and is of great benefit in periodontal therapy. Many hygienists currently use ozonated water instead of regular water in their ultrasonic scalers. This ozonated water not only reduces the number of pathogens, but assists with healing. For periodontal surgery, ozonated water also dramatically reduces the number of pathogens and promotes healing. In managing root caries, ozone has been shown to reverse shallow noncavitated lesions when used as part of the full preventive care regimen. This includes reducing the frequency of consuming fermentable carbohydrates, increasing the use of fluoride-containing products, and improving oral hygiene. Ozone is not effective in managing deep root caries. The outer carious lesion must be removed, leaving a maximum of 1 mm of caries over the pulpal floor before ozone is applied. Common sense must be used in determining how much infected tissue can be penetrated by the ozone, and disinfection or at least a dramatic reduction of the microorganisms is needed before restoration.

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Endodontic Treatment

With respect to ozone and endodontics, studies in which a sufficient dose of ozone is used clearly show that it dramatically reduces the numbers of microorganisms present in the canals. When extremely low concentrations in very low volumes of liquids or gases have been used, results have been mixed. Ozone used in sufficient doses achieves an excellent result, however. Ozonated water can be used as a routine final irrigant within the ultrasonic device. The use of ultrasonics in the root canal produces very effective acoustic streaming and ozonated water that penetrates into many portions of the intraradicular anatomy, well beyond what conventional filing methods can achieve. The end stage is ideally placed with the root canal containing ozonated water and ozone gas bubbled to further increase the concentration of ozone and reduce microorganisms inside the root canal.

Ozone works best when there is less organic debris remaining. The recommendation is to use either ozonated water or ozone gas *after* cleaning and shaping. Conventional irrigants can be used during the early phase. Ozonated water is then used to irrigate using ultrasonics. Ozone gas can also be bubbled into the ozonated water, and ozonated oil can be used as a medicament.

Several studies have investigated the bactericidal effect of ozone compared with sodium hypochlorite (NaOCl) as irrigation solutions in **endodontic therapy**. Sodium hypochlorite is not as biocompatible as aqueous ozone for human oral epithelial cells, gingival fibroblast cells, or periodontal cells.

Disinfected root canals were tested for antimicrobial presence then sealed and incubated for a week before bacterial growth was then retested. The absolute bacterial count was significantly diminished after disinfection, with equal results for NaOCl, a mixture of tetracycline an acid and a detergent (MTAD), and HealOzone. Ozone was shown to have great potential for endodontic antimicrobial use. Conventional irrigation (including with NaOCl) should be used during cleaning and shaping. Ozonated water, preferably accompanied by ozone gas, is recommended as the final irrigant with ultrasonication.

In vivo root canal contents and caries, unlike artificial biofilms, contain many molecules, including iron, that can increase the antimicrobial effectiveness of ozone and can help produce hydroxyl radicals that can further potentiate the antimicrobial effectiveness of ozone. Ozone gas has toxic effects on both human oral epithelial cells (BHY) and hepatocyte growth factor (HGF-1) cells. Aqueous ozone demonstrates no cytotoxicity and is highly biocompatible compared with other antiseptics. Ozone gas performs well compared with the established endodontic irrigants, which have equal or higher cytotoxic potentials. Ozone irrigation of the root surface of avulsed teeth has shown no negative effect on periodontal ligament cell proliferation. The ozone gas applied into the moist root canal, as delivered through the HealOzone device, dissolves in canal fluids, producing aqueous ozone, which comes into contact with tissues.

Ozonated oils were investigated histologically and histobacteriologically for their usefulness in infected root canals. These were compared with calcium hydroxide in camphorated paramonochlorophenol (CMCP) as intracanal medications and were applied either in a single visit or two visits. Analysis after 6 months found that control root canals treated in a single visit had a success rate of 46%. The success rates for CMCP and ozonated oil were 74% and 77%, respectively. Ozonated oils were also the most effective agent against bacterial species commonly associated with periradicular disease.

The transcription factor NF-κB is critical in the processes of inflammation, immune function, and apoptosis. It may also regulate periodontal and periapical inflammatory reactions and the pathogenesis of periodontal disease and apical periodontitis. Aqueous ozone exerts inhibitory effects on the NF-κB system, indicating possible anti-inflammatory and immune-modulating abilities.



FIGURE 26-31 Jazz Supreme polishing system. *(Courtesy SS White Burs, Inc., Lakewood, New Jersey.)*

Surface Finishing and Polishing

For finishing, the least invasive and the most rapid procedure is generally the best. The SS White Jazz Supreme polishing system (Figure 26-31) is a one step, one instrument polishing system that provides a highly successful clinical approach. Most polishing systems offer a series of progressively smoother polishing instruments, from coarse to medium to fine, but with the Jazz System a single instrument is used throughout the polishing process. The progressive abrasiveness depends on the pressure that the operator places on the instrument during the polishing of the tooth surface. With greater pressure, the effect is more abrasive, actually removing or smoothing the surfaces. As less pressure is applied, the bur's action tends to buff and produce a final luster. Within seconds an acceptable anatomy can be molded, shaped, and polished to a high-gloss, high-luster surface that will last for many years.

EVIDENCE-BASED PRINCIPLES

Research has demonstrated that cariogenic bacteria can be killed by directly applied ozone in gas or liquid form and by visible light after they are photo-sensitized. The ozone technique involves the flooding of a dental structure with ozonated air or water. As the ozone bathes the tooth structure, ozone ions

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penetrate it to various depths and disrupt the cell walls of any bacteria that are encountered, destroying them. The PADS technique involves applying a photoactive solution that is absorbed selectively by cariogenic bacteria to the operative surfaces. This sensitizes them to the application of visible illumination, which causes cytotoxic bacterial reactions that result in selective destruction of the target microorganism.

CONTROVERSIES

Cochrane standards have been applied to the assessment of ozone only as an alternative rather than in addition to current methods for managing and treating dental caries. Ozone should not be applied in isolation; it is designed to be used in conjunction with current caries management methods. Because ozone is much easier, cheaper, and faster than existing treatments, it should be assessed on its overall effectiveness. Instead of being compared with conventional drilling and filling approaches, it should be compared with similar antimicrobial and oxidant treatments for caries.

NEAR-FUTURE DEVELOPMENTS

An interesting area of future development is the use of adhesive resin technologies that can infiltrate infected dentin. If these can be managed with ozone or PAD first, infiltration resins will contribute further to truly minimally invasive dentistry.

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Diode Lasers: The Soft Tissue Handpiece

Fay Goldstep, George Freedman

Although dental lasers have been commercially available for several decades and their popularity among patients is unparalleled, the dental profession has taken to this treatment modality rather slowly. Lasers have been thoroughly documented in the dental literature. They are an exciting technology, widely used in medicine, kind to tissues, and excellent for healing. So why have they not been more widely embraced by the practicing dentist? There is a wide perception in the profession that somehow the dental laser is not useful, is too complicated, and is too expensive. These concerns have changed forever with the arrival of the diode laser onto the dental scene. There is now a convergence of documented scientific evidence, ease of use, and greater affordability that makes the diode laser a "must have" for every dental practice.

DIODE LASERS: THE SCIENCE IN BRIEF

The word *laser* is derived from the acronym for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation. Lasers are commonly named for the substance that is stimulated to produce the coherent light beam. In the diode laser, this substance is a semiconductor (a class of materials that are the foundation for modern electronic devices, including computers, telephones, and radios). This innovative technology has produced a laser that is compact and far lower in cost than earlier versions. Much of the research has focused on the 810-nm diode laser. Energy of this wavelength is ideally suited for soft tissue procedures because it is highly absorbed by hemoglobin and melanin. This gives the diode laser the ability to precisely cut, coagulate, ablate, or vaporize the target soft tissue.[1]

Treatment with the 810-nm diode laser (Figure 26-32, Picasso diode laser, AMD Lasers, Indianapolis, Indiana) has been shown to have a significant long-term bactericidal effect in periodontal pockets. *A. actinomycetemcomitans,* an invasive pathogen associated with the development of periodontal disease and generally quite difficult to eliminate, responds well to laser treatment.[2,3] Scaling and root planing outcomes are enhanced when diode laser therapy is added to the dental armamentarium. The patient is typically more comfortable during and after treatment, and gingival healing is faster and more stable.[4,5]

DIODE LASER: EASE OF USE

Early adopter dentists thrive on new technologies. They enjoy the challenges that come with being the first to use a product. Most dentists, however, are not early adopters. Over the past two decades, lasers have intimidated mainstream dentists with their large footprint, lack of portability, high maintenance profile, confusion of operating tips, and complex procedural settings. Common questions have included the following: When do I use which tip? What setting works for which procedure? Why do I need a laser when I have been managing well without one?

Enter the diode laser. It is compact. It can easily be moved from one treatment room to another. It is self-contained and does not have to be hooked up to water or air lines. It has one simple fiberoptic cable, which can function as a reusable operating tip. The units come with several presets, although after a very short time the operator becomes so comfortable that they are rarely needed. The power and pulse settings are quickly adjusted to suit the particular patient and procedure.

One of the authors is a dentist who does not thrive on the challenge of brand new high-tech, high-stress technology, having tried many lasers in the past that were said to be user friendly but were found to be anything but. The 810-nm diode laser provided a totally different experience; after a brief in-office demonstration, the laser handpiece felt comfortable enough for the author to perform some simple clinical procedures. Further online training and lecture courses enhanced both clinical comfort level and competency.

DIODE LASER: AFFORDABILITY

Laser technology has always come with a high price tag. Manufacturing costs are high, and cutting edge technology commands steep pricing. Diode lasers are less expensive to produce. Breakthrough pricing for this technology has now reached under

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FIGURE 26-32 The Picasso diode laser. *(Courtesy AMD Lasers, Indianapolis, Indiana.)*

$5000. At this level the diode laser becomes eminently affordable for the average practicing dentist.

DIODE LASER: WHY DO I NEED THIS TECHNOLOGY?

The 810-nm diode laser is specifically a soft tissue laser. This wavelength is ideally suited for soft tissue procedures because hemoglobin and melanin, both prevalent in dental soft tissues, are excellent absorbers. This provides the diode laser with broad clinical utility: it cuts precisely, coagulates, ablates, or vaporizes the target tissue with less trauma, improved postoperative healing, and faster recovery times.[6-8] Given the incredible ease of use and its versatility in treating soft tissue, the diode laser becomes the "soft tissue handpiece" in the dentist's armamentarium. The dentist can use the diode laser soft tissue handpiece to remove, refine, and adjust soft tissues in the same way that the traditional dental handpiece is used on enamel and dentin. This extends the scope of practice of the general dentist to include many soft tissue procedures.

The procedures discussed in the following sections are easy entry points for the new laser user.

Gingivectomy, Hemostasis, and Gingival Troughing for Impressions

The diode laser (Picasso) makes restorative dentistry "a breeze." Any gingival tissue that covers a tooth during preparation can be easily removed, as hemostasis is simultaneously achieved (Figure 26-33). The restoration is no longer compromised because of poor gingival conditions. There is no more battling with unruly soft tissue and blood. Excess gingival tissue can be readily managed (Figure 26-34) for improved restorative access for class V preparation (ezLase, Biolase Technology, Irvine, California).

Gingival troughing before an impression is taken (see Figures 26-33, *E* and 26-34, *A* [Picasso]) ensures an accurate impression (particularly at the all-important margins) and an improved restorative outcome. Packing cord is no longer necessary.

Diode lasers make restorative dentistry less stressful, more predictable and more enjoyable for the dental team and the patient.

Operculectomy, Excision and/or Re-Contouring of Gingival Hyperplasia, and Frenectomy

Operculectomy, excision and/or re-contouring of gingival hyperplasia, and frenectomy are not commonly offered or performed by the general dentist. These procedures are examples of the expanded range of services readily added to the general practice. The dentist becomes more proactive in dealing with hyperplastic tissues that can increase risk of caries and periodontal disease (Figure 26-35).

A frenectomy is now a simple and straightforward procedure (Figure 26-36 [ezLase]).

LASER-ASSISTED PERIODONTAL TREATMENT

The use of the diode laser in conjunction with routine scaling and root planing is more effective than scaling and root planing alone. It enhances the speed and extent of the patient's gingival healing and postoperative comfort.[4,5] This is accomplished through laser bacterial reduction (Picasso), débridement, and biostimulation (Figure 26-37).

A. actinomycetemcomitans, which has been implicated in aggressive periodontitis, may also be implicated in systemic disease. It has been found in atherosclerotic plaque,[9] and recent data have suggested that it may be related to coronary heart disease.[10] The diode laser is effective in decreasing *A. actinomycetemcomitans*[2,4] and thereby indirectly improving patients' heart health.

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FIGURE 26-33 Hemostasis is simultaneously achieved with the laser when gingival tissue covering a tooth (A) is removed during preparation (B to D). E, One week post-op. *(Courtesy Dr Phil Hudson.)*

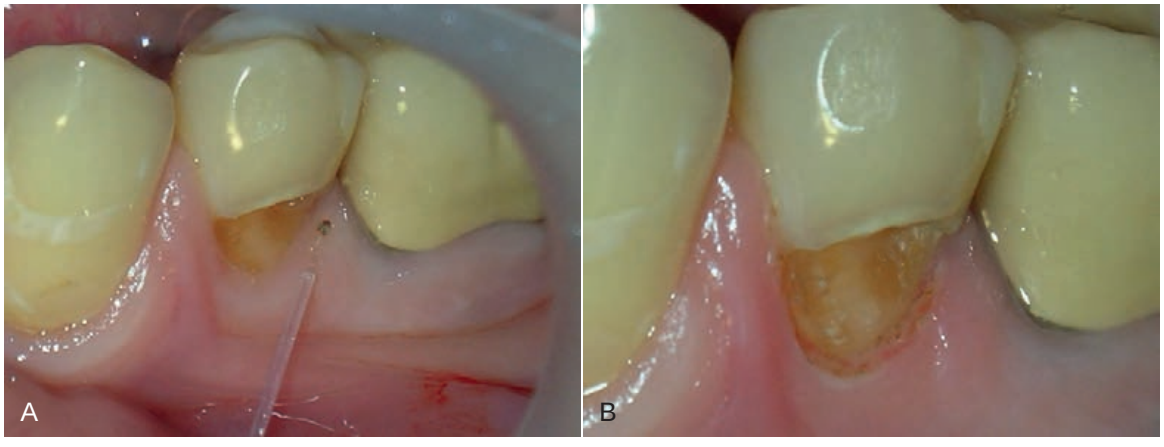


FIGURE 26-34 Excess gingival tissue can be readily managed with the laser (A) for improved restorative access to class V preparations (B). *(Courtesy Biolase Technology, Irvine, California.)*

همیار دندانسازان و دندانپزشکان

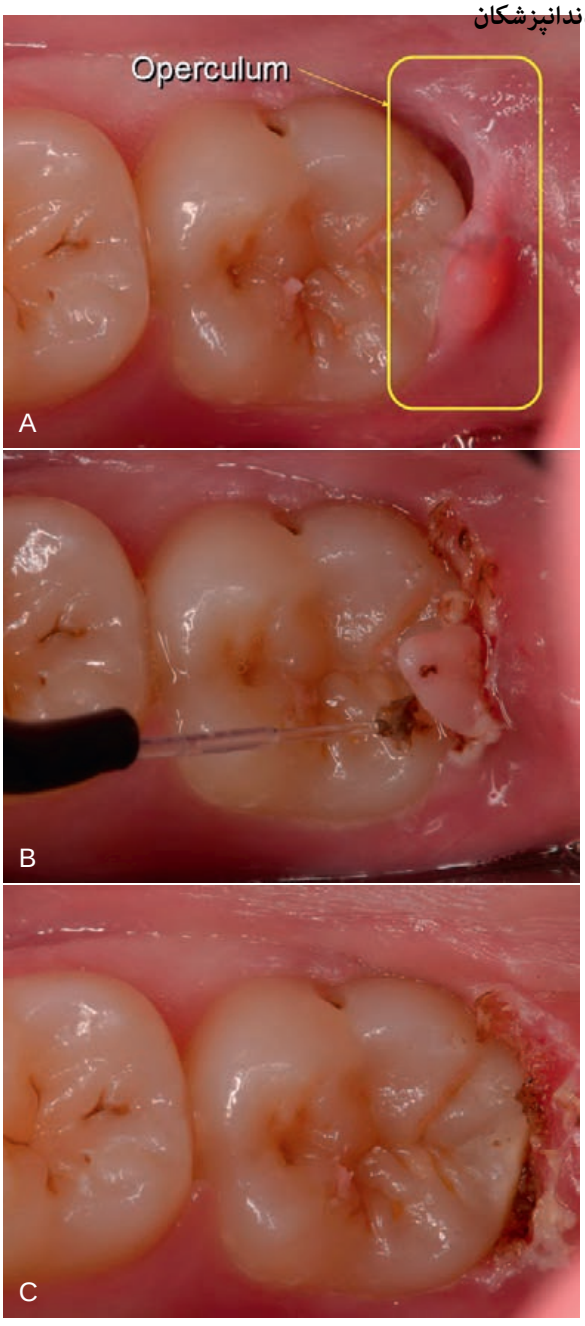


FIGURE 26-35 **Hyperplastic tissues (A) that can increase risk of caries and periodontal disease are easily removed with the laser (B and C).** *(Courtesy Dr. Glen van As, Vancouver, BC, Canada.)*



FIGURE 26-36 **Lasers make frenectomies simple and straightforward.** *(Courtesy Biolase Technology, Irvine, California.)*

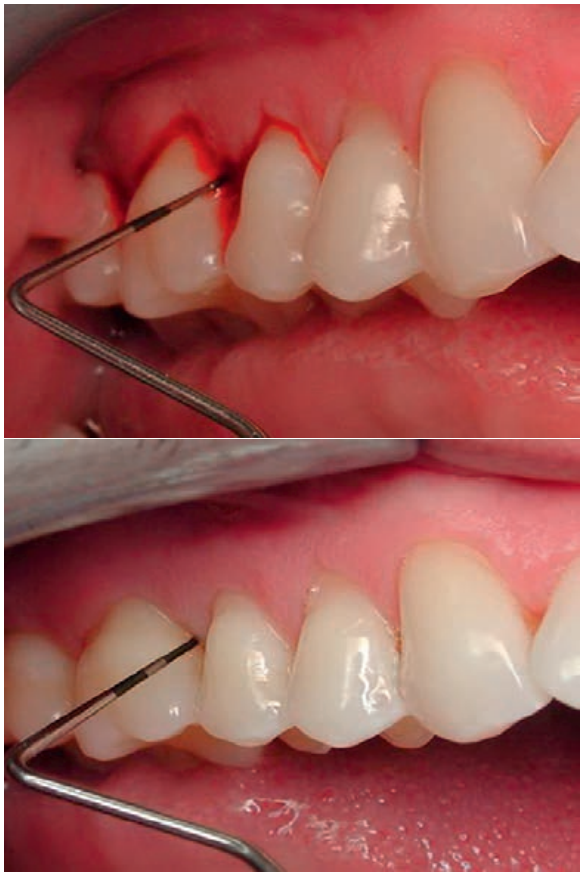


FIGURE 26-37 **When used in conjunction with routine scaling and root planing, a laser enhances the speed and extent of the patient's gingival health and postoperative comfort through improved bacterial reduction, débridement, and biostimulation.** *(Courtesy Dr William Chen.)*

LASER EDUCATION

Most diode laser manufacturers provide some education to get the new user started quickly and effectively. The most comprehensive online diode laser introductory course with certification (including the science and safety and clinical procedures) can be found at the International Center for Laser Education, www.dentallaseredu.com (877-522-6863). This course provides everything necessary to get started with soft tissue diode laser therapy. Advanced courses are available for more complex procedures.

The soft tissue diode laser has become a "must-have" mainstream technology for every general practice. The science, ease of use, and affordability make it simple to incorporate. The laser

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is now the essential "soft tissue handpiece" for the practice. In fact, a case can be made for having a diode laser in each restorative and each hygiene treatment room. Restorative dentistry becomes easier, more predictable, and less stressful. Laser therapy expands the clinical scope of practice to include new soft tissue procedures that keep patients in the office. Patients' gingival health is improved in a minimally invasive, gentler manner. Every time the dentist picks up the diode laser the question is, "Where have you been all my life?"

DIODE LASERS FOR PERIODONTAL TREATMENT: THE STORY SO FAR

The concept of using dental lasers for the treatment of periodontal disease elicits very strong reactions from all sides of the spectrum. Everyone has an opinion. Everyone is certain that his or her own opinion is correct. But the only certainties are confusion and the lack of clear direction in the concept of laser-assisted periodontal therapy (LAPT).

Much of this uncertainty stems from not comparing "apples to apples" in terms of the type of lasers used and the way that studies are designed. Certain lasers are used specifically for soft tissue treatment. These include the carbon-dioxide (CO_2), neodymium:yttrium-aluminum-garnet (Nd:YAG), and diode lasers. Others can be used for both soft and hard tissue applications. These are the erbium:YAG (Er:YAG) and erbium, chromium-doped yttrium, scandium, gallium, and garnet (Er, Cr:YSGG) lasers. They must be compared within their own category.

Many of these lasers have been shown to provide periodontal treatment benefits. In order to achieve an element of clarity and simplicity on this very complex topic, the following discussion exclusively addresses the use of the diode laser for periodontal treatment.

A SPECIFIC INSTRUMENT

The diode laser has become an important tool in the dental armamentarium owing to its exceptional ease of use and affordability. It also has key advantages with regard to periodontal treatment. The diode laser is well absorbed by melanin, hemoglobin, and other chromophores that are present in periodontal disease.[11] Hence the diode *specifically* targets unhealthy gingival tissues. The laser energy is transmitted through a thin fiber that can easily penetrate into deep periodontal pockets to deliver its therapeutic effects.

The 2002 American Academy of Periodontology statement regarding gingival curettage[12] proposes that "gingival curettage, by whatever method performed, should be considered as a procedure that has no additional benefit to SRP alone in the treatment of chronic periodontitis." Also stated is that all the methods devised for curettage "have the same goal, which is the complete removal of the epithelium" and "none of these alternative methods has a clinical or microbial advantage over the mechanical instrumentation with a curette."

This was the science in 2002. More recent studies have shown that instrumentation of the soft periodontal tissues with a diode laser leads to complete epithelial removal, whereas instrumentation with conventional curettes leaves significant epithelial remnants.[13]

AN EFFECTIVE INSTRUMENT

Bactericidal Effects

Periodontal disease is a chronic inflammatory disease caused by a bacterial infection. Hence the bactericidal and detoxifying effects of laser treatment are advantageous in periodontal therapy.[14] The diode laser's bactericidal effectiveness has been well documented.[3,15-17]

Moreover, there is a significant suppression of *A. actinomycetemcomitans,* an invasive bacterium that is associated with aggressive forms of periodontal disease that are not readily treated with conventional SRP. *A. actinomycetemcomitans* not only is present on the diseased root surface, but it also invades the adjacent soft tissues, making it difficult to remove by mechanical periodontal instrumentation alone.[16,18,19] This necessitates the use of adjunctive antibiotic therapy.[19] The diode laser provides a non-antibiotic solution. *A. actinomycetemcomitans* has also been found in atherosclerotic plaques,[9] and there has been evidence to suggest that subgingival *A. actinomycetemcomitans* may be related to coronary heart disease.[10] This makes it even more compelling to seek methods to control this aggressive pathogen.

Wound Healing

Diode lasers are very effective for soft tissue applications including incision, hemostasis, and coagulation.[20] Many advantages of the laser versus the scalpel blade have been discussed in the literature. These include a bloodless operating field, minimal swelling and scarring, and much less or no postsurgical pain.[21,22] When laser surgical procedures are carried out, the surface produced heals favorably as an open wound, without the need for sutures or surgical dressings.[14] Studies have shown enhanced, faster, and more comfortable wound healing when the diode laser is used in conjunction with SRP.[16]

An Adjunct to Scaling and Root Planing

There is very compelling evidence in the dental literature that the addition of diode laser treatment to scaling and root planing (SRP) (the gold standard in nonsurgical periodontal treatment) will produce significantly improved results. After SRP, the diode laser is used on the soft tissue side of the periodontal pocket to remove the inflamed soft tissue and reduce the pathogens.[23] Research has demonstrated better removal of the pocket epithelium compared with conventional techniques.[13] Many studies have shown increased reduction of bacteria (especially specific periopathogens) when diode lasers are used after SRP.[2,3,5] Significant improvement in decontamination and effective treatment of peri-implantitis also occur with the addition of diode laser therapy.[24]

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Gingival health parameters are significantly improved with the addition of the diode laser to SRP. Studies have shown decreased gingival bleeding[2,25] decreased inflammation and pocket depth,[2,23] as well as decreased tooth mobility and decreased clinical attachment loss.[23] This improvement in gingival health remains more stable than with conventional SRP treatment alone and tends to last longer.[4] Moreover, patient comfort is significantly enhanced during the postoperative healing phase with the addition of diode laser therapy.[16]

The research thus shows diode laser periodontal treatment to be an effective procedure. It is also a minimally invasive procedure. Patients are demanding less surgery, and the diode laser provides the general dentist with an excellent means of keeping periodontal treatment in the general practice.

A SAFE INSTRUMENT

Histological testing of roots where the diode laser was used after SRP has demonstrated no detectable surface alteration to root or cementum. There were no signs of thermal side effects in any of the teeth treated.[26] Many studies have specifically indicated no adverse tissue events, demonstrating the safety of the diode laser.[2,3,17,27]

The diode laser's very effective bactericidal action on periodontal pathogens makes the adjunctive use of antibiotics unnecessary.[19] This eliminates the problem of bacterial resistance and systemic side effects engendered by antibiotic use.[15] The laser is a safer, more effective treatment.

THE PROTOCOL SO FAR

The research cited earlier has demonstrated that the use of the diode laser after conventional SRP is superior to the use of SRP alone. Various protocols have been developed by clinicians to incorporate this treatment into the busy dental practice.

These protocols may be performed by the dentist and/or the hygienist as determined by the regulating organization in the geographic location of the dental practice.

Individual parameters vary depending on the clinician and the particular diode laser that is being used. However, most protocols *do* follow a simple formula. The hard side of the pocket (tooth and root surface) is first débrided with ultrasonic scalers and hand instrumentation (Figure 26-38, *A*). This is followed by laser bacterial reduction and coagulation of the soft tissue (epithelial) side of the pocket (Figure 26-38, *B* and *C*).[11]

The laser fiber is measured to a distance of 1 mm short of the pocket depth. The fiber is used in light contact with a sweeping action that covers the entire epithelial lining, from the base of the pocket upward.[1] The fiber tip is cleaned often with damp gauze to prevent the buildup of debris.

Re-probing of treated sites should not be attempted for 3 months postoperatively (Figure 26-38, *D*), because healing starts

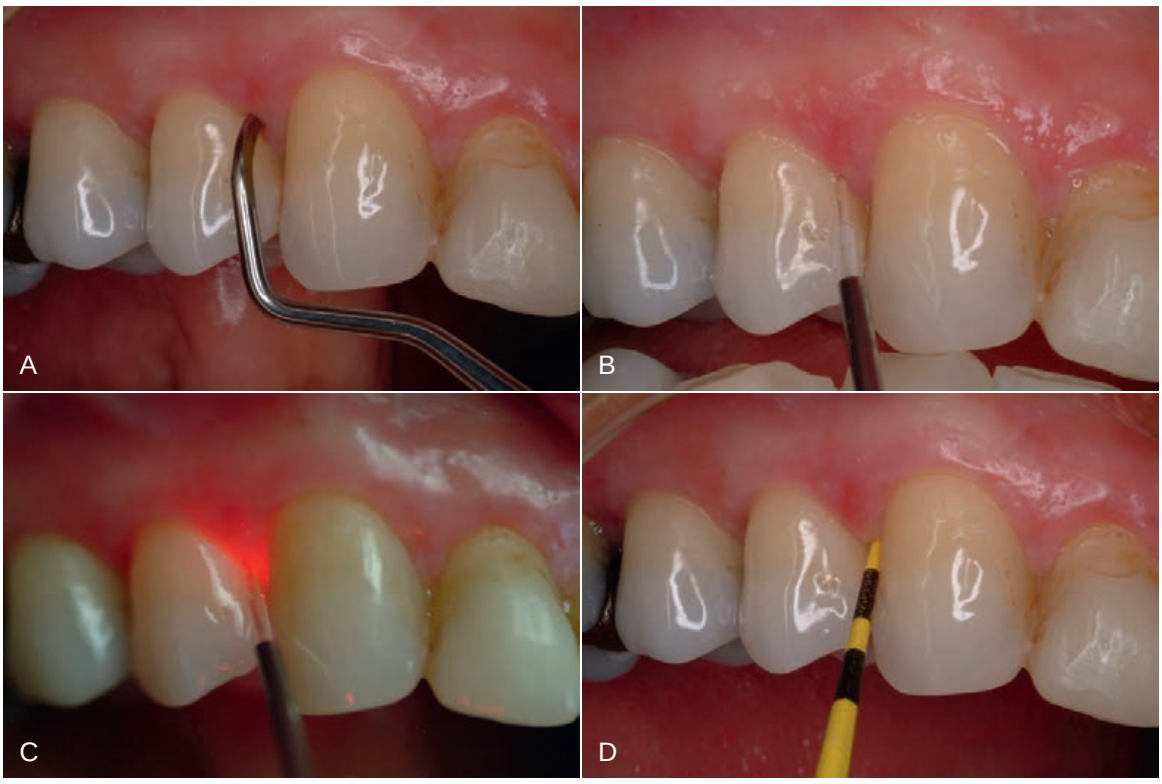


FIGURE 26-38 **A, Hard side of the pocket débrided. B and C, Laser bacterial reduction and coagulation of the epithelial side of the pocket. D, Re-probing of the treated site 3 months post-treatment.**

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at the base of the pocket and the new tissue remains fragile for this period of time.[11]

The power settings and time parameters are determined by the particular laser used. The diode laser clinician *must* undergo training on the specific laser in the practice to be fully able to implement with LAPT. With experience, the user will feel comfortable enough to adapt the protocol to his or her particular practice.

In the future, protocols will be modified and fine-tuned by various laser user groups after discussion of their experiences and results. These results will be incorporated into new procedures that will bring LAPT to a newer, more effective level.

THE TIME HAS COME

The time has come to embrace the routine use of lasers for the treatment of periodontal disease. The diode laser has been shown to be effective and safe for this purpose. If not now, when? Patients need treatment. LAPT is non-invasive. With the diode laser there is a reduced need for systemic or locally applied antimicrobials. This leads to fewer allergic reactions and antibiotic resistance.

There is significant proof that the addition of LAPT to conventional SRP improves outcomes. This is particularly compelling when considering the periodontal health–systemic health link. It is time to embrace laser technology and apply the treatment that is in the best interests of patients.

DIODE LASERS FOR PERIODONTAL TREATMENT: THE STORY CONTINUES

Lasers have been a part of the dental scene for over 25 years. Unfortunately, they have tended to be big, clunky, hard-to-use, expensive machines that were largely ignored. Affordable, effective, user-friendly diode lasers have only recently arrived on the scene. In fact, the diode laser, in a very short time, has proven itself to be the ideal soft tissue handpiece.

The diode laser functions as the essential handpiece for all soft tissue procedures, just as the dental handpiece is essential for all hard tissue procedures. The advantages of the diode laser for soft tissue applications include surgical precision, bloodless surgery, sterilization of the surgical site, minimal swelling and scarring, minimal suturing, and virtually no pain during and after surgery.

What about using the diode laser for the treatment of periodontal disease (LAPT)? An early version of the diode laser was used effectively in the treatment of periodontal pockets in 1998.[2] So why is there so much confusion and controversy regarding the use of lasers in the treatment of periodontal disease today? There is need for clarification and simplicity.

First, as the name *laser*-assisted *periodontal therapy* implies, the laser is only part of the treatment equation. Laser use should not be viewed as a stand-alone treatment for periodontal disease. Second, the laser may not be of any help in very advanced cases of periodontal disease. These cases may require a surgical approach.

Third, when discussing the benefits of LAPT, one must specify the particular type of laser used. Several categories of lasers have shown positive results. For the sake of clarity and simplicity, the following discussion deals exclusively with the diode laser, because its ease of use and affordability have made it the predominant laser in dentistry.

DIODE LASERS FOR PERIODONTAL TREATMENT

Two types of diode lasers have been studied for their effects in LAPT: the diode laser (which emits high levels of light energy), and the low-level diode laser (which emits low-intensity light energy).

There is very compelling evidence in the dental literature that the addition of diode laser treatment to SRP will produce significantly improved and longer lasting results.[28] SRP is the gold standard in nonsurgical periodontal treatment.

Low-level lasers for biostimulation have been used in medicine since the 1980s. The therapeutic technique is non-cutting and of low intensity and covers a much wider area than the traditional laser. Low-level laser therapy (LLLT) is treatment in which the light energy emitted by the laser elicits beneficial cellular and biological responses. On a cellular level, metabolism is increased, stimulating the production of adenosine triphosphate (ATP), the fuel that powers the cell. This increase in energy is available to normalize cell function and promote tissue healing.[29,30]

The functions of the diode and low-level diode laser have remained separate until recently. With the introduction of the biostimulation delivery tip, the diode laser is able to provide both cutting *and* therapeutic effects. When the low-level tip is used, the laser energy is delivered over a wider area, decreasing the energy level and producing the low-level therapeutic effect. Two laser companies have made these auxiliary tips available (Figure 26-39).

Used together, these two laser treatment modalities provide benefits that help to heal the chronic inflammatory response in the periodontal pocket. This works well in treating mild to moderate periodontitis. Patients can be treated in a minimally invasive way, without surgery, in the general practice. There is time to try the surgical approach, if needed, at a later date.

The Periodontal Pocket

Periodontal disease is a chronic inflammatory disease caused by bacterial infection. The inflammation is the body's response to destroy, dilute, or wall off the injurious agent.[31] Unfortunately, if the situation remains chronic, this protective mechanism of the body to defend itself against injury becomes destructive to the tissues.

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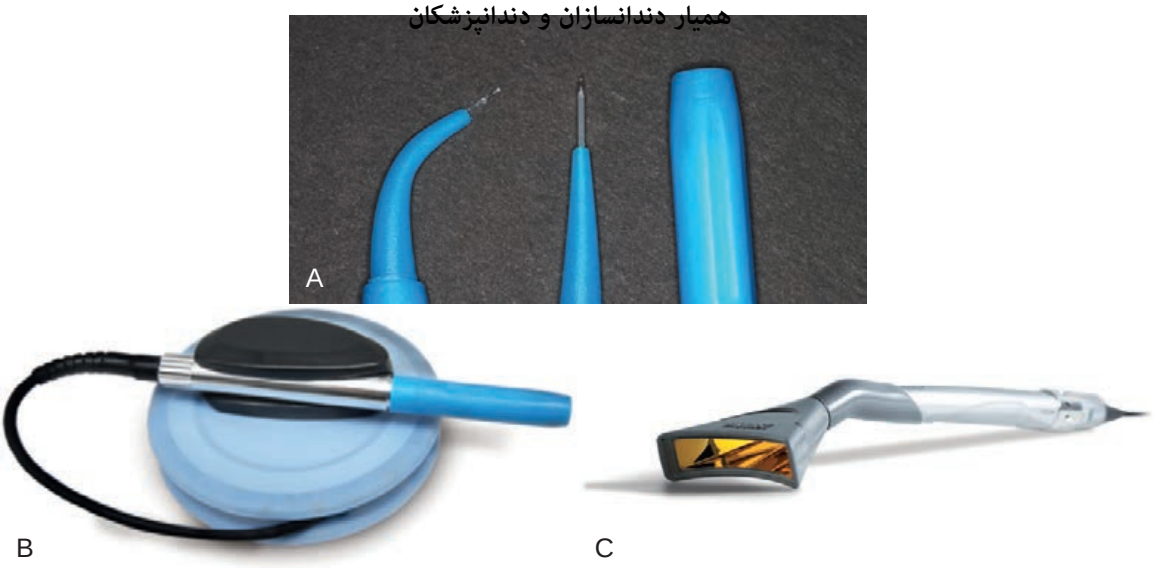


FIGURE 26-39 A, Picasso high-energy tip (left and middle) and biostimulation tip (right). B, Picasso biostimulation tip. C, ezlase biostimulation tip. *(B courtesy AMD Lasers, Indianapolis, Indiana. C courtesy Biolase Technology, Irvine, California.)*

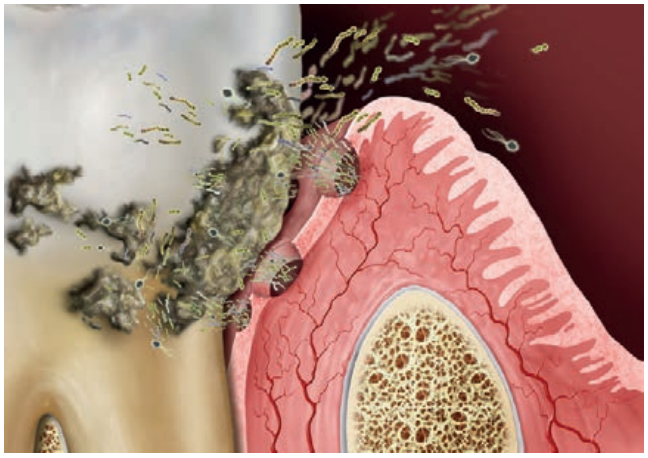


FIGURE 26-40 The periodontal pocket containing calculus, bacteria, and granulation tissue.

The periodontal pocket in periodontal disease contains several substances that contribute to the continuation of the unhealthy condition (Figure 26-40):

- Calculus and plaque on the tooth surface
- Pathogenic bacteria
- An ulcerated, epithelial lining with granulation tissue and bacterial byproducts

What is needed for healing of the pocket?

- SRP: Elimination of calculus, plaque, and other debris on the tooth to create a totally clean surface
- Decontamination: Elimination of all pathogenic bacteria dispersed throughout the pocket
- Curettage: Elimination of granulation tissue, bacterial products, and ulcerated areas to create a clean, even epithelial lining without tissue tags (epithelial remnants)
- Biostimulation: To kick-start the healing process

The following is a sequence to show how this can be easily accomplished in a minimally invasive, nonsurgical way:

1. Calculus is removed with SRP. This procedure has been well documented throughout the dental literature as the gold standard of care for nonsurgical periodontal treatment.

   The diode laser and the low-level diode laser are ideal for the remaining steps:
2. Because a bacterial infection is the initiator of the chronic inflammatory response of periodontitis, the bactericidal and detoxifying effect of laser treatment is advantageous.[14] The diode laser's bactericidal efficacy, particularly against specific periopathogens, has been well documented.[3,16-18] Moreover, there is a significant suppression of *A. actinomycetemcomitans,* an invasive bacterium that is not easily treated with conventional SRP. *A. actinomycetemcomitans* not only is present on the diseased root surface but also invades the adjacent soft tissue, making it virtually impossible to remove with mechanical means alone.[17,19,20] The diode laser energy is able to penetrate into the soft tissue to eliminate this pathogen.
3. The diode laser is a specific instrument well suited to dealing with diseased soft tissue. The diode laser energy is well absorbed by melanin, hemoglobin, and other chromophores that are present in periodontal disease.[11]

   The 2002 American Academy of Periodontology statement regarding gingival curettage[12] proposes that "gingival curettage, by whatever method performed, should be considered as a procedure that has no additional benefit to SRP alone in the treatment of chronic periodontitis." However, the diode *specifically* targets unhealthy gingival tissues, performing an effective curettage that produces a clean, even epithelial lining without tissue tags.

   Also stated is that all the methods devised for curettage (including lasers) "have the same goal, which is the

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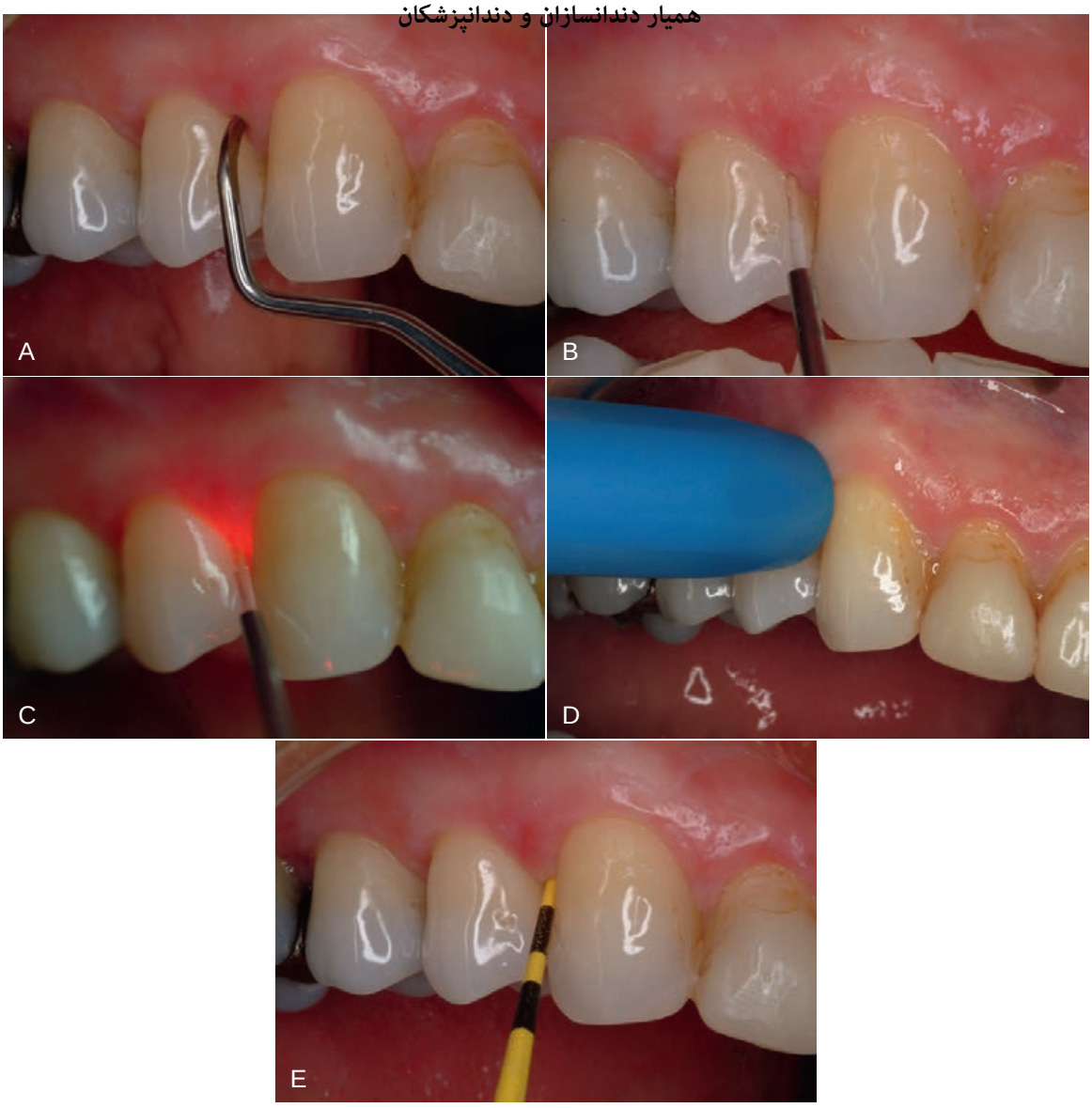


FIGURE 26-41 **A, Scaling and root planing are performed first. B, The diode laser tip is placed into the pocket. C, Laser energy is applied into the pocket to decontaminate and coagulate the soft tissue. D, The biostimulation tip is applied at right angles to the external surface of the pocket E, Pocket depth is measured pre-treatment and 3 months post-treatment.**

complete removal of the epithelium" and "none of these alternative methods has a clinical or microbial advantage over the mechanical instrumentation with a curette."

This was the science in 2002. Currently, this American Academy of Periodontology statement has not been updated. Studies have shown that instrumentation of the soft tissues in the diseased periodontal pocket with the diode laser leads to complete epithelial removal, whereas conventional instrumentation with curettes leaves significant epithelial remnants.[13] Thus, in fact, the diode laser *does* have a clinical advantage over mechanical instrumentation with a curette.

4. This step requires the low-level laser tip. Studies have shown that low-level laser light affects damaged but not healthy tissue. Laser biostimulation normalizes cell function and promotes healing and repair.[32]

Secondary effects include increased lymphatic flow, production of endorphins, increased microcirculation, increased collagen formation, and stimulation of fibroblasts, osteoblasts, and odontoblasts. This stimulates the immune response, pain relief, and wound healing.[30]

Studies have shown that LLLT performed in conjunction with SRP in patients with both mild periodontitis[33] and chronic advanced periodontitis[34] can significantly improve treatment outcomes and the long-term stability of periodontal health parameters.

These four steps create the ideal environment in the periodontal pocket for healing to take place.

Use of lasers is an adjunct to SRP, not a stand-alone procedure. On the other hand, SRP is not a stand-alone procedure. All the pieces of the puzzle are needed to create health.

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THE PROTOCOL SO FAR

Now that it is clear what is needed, how can it be achieved?

The protocol must incorporate the four steps discussed earlier to create the ideal environment for periodontal healing to occur: a clean, calculus-free hard tissue surface; no pathogenic bacteria; a smooth, clean soft tissue surface; and biostimulation.

Biostimulation tips are at present available for only two diode lasers: the Picasso (AMD) and the ezlase (Biolase).

Individual parameters vary depending on the clinician and the particular diode laser used. However, most protocols follow a simple formula:

1. The hard tissue side of the pocket is first débrided with ultrasonic scalers and hand instruments (Figure 26-41, *A*).
2. This is followed by laser bacterial reduction and coagulation of the soft tissue side of the pocket[11] (Figure 26-41, *C* and *D*). The laser fiber is measured to a distance of 1 mm short of the depth of the pocket. The fiber is used in light contact with a sweeping motion that covers the entire epithelial lining, starting from the base of the pocket and moving upward.[1] The fiber tip is cleaned frequently with damp gauze to prevent debris buildup.
3. The low-level laser tip is applied at right angles and with direct contact to the external surface of the pocket (Figure 26-41, *D*) for biostimulation.
4. Re-probing of the treated sites should be performed no earlier than 3 months after treatment to allow for adequate healing (Figure 26-41, *E*). The tissue remains fragile for this period of time.

The power settings and duration are determined by the particular laser used. The manufacturers should be consulted for the proper parameters to achieve the best results. With experience, the user will feel comfortable enough to adapt the protocol to his or her particular practice.

This protocol may be performed by the dentist and/or hygienist as determined by the regulating organization in the geographic location of the dental practice.

THE DIODE LASER AND PERIODONTAL TREATMENT: THE STORY IS CLEAR

Many patients have periodontal disease, but they want to be treated in a minimally invasive way. They are not rushing out to the periodontist to have "gum surgery." Their disease must be treated before it spirals out of control, especially given the link between periodontal health and systemic health.

There is significant proof that the addition of LAPT to SRP improves outcomes in mild to moderate periodontitis. The treatment is not invasive. It is not uncomfortable.

The tools and protocols are now available to treat periodontal patients with an effective procedure that they are ready to accept. What are we waiting for?

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SECTION C

Soft and Hard Tissue Lasers

Scott D. Benjamin

RELEVANCE OF LASERS TO ESTHETIC DENTISTRY

In esthetic dentistry, lasers allow complete control of the interactions with hard and soft tissues. This enables minimally invasive procedures to be done with extreme precision, facilitating care that is not only of high quality but of minimal discomfort and conservative of tooth structure. Postoperative complications are minimized and appropriate tissue management accomplished. Soft tissue management in esthetic dentistry is extremely important, enhancing care, managing tissues appropriately, maintaining control of esthetic outcomes as well as retraction, and managing hemostasis. Hard tissue procedures performed using the laser to prepare or properly condition the dentin and enamel for composite restorative materials exhibit greatly increased bond strength compared with those done with traditional rotary instruments, and this is a primary goal. With lasers, dentists can control the amount of power used, the temporal emission mode, and the total interaction time while causing minimal consequences to the surrounding tissue.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF DENTAL LASERS

The concept of laser interaction with tissue was first postulated by Niels Bohr in the early 1900s and employed spontaneous emission. Between 1916 and 1920, Albert Einstein postulated stimulated emission. From there, the concept has been moving forward, with Theodore Maiman inventing the ruby laser in 1960 using a ruby rod and photographic flash lamp.

In 1964 a laser was first used in a laboratory setting on enamel and dentin. Leon Goldman actually used the laser clinically for enamel and dentin in 1966. In the early 1980s, the carbon dioxide (CO_2) laser, which is used for soft tissue surgery, was developed. The neodymium-doped yttrium-aluminum-garnet (Nd:YAG) laser first received U.S. Food and Drug Administration (FDA) marketing clearance for use in dentistry in 1987, facilitated by Terry Myers, a dentist from Michigan. In 1988 it was used for desensitization and in minimally invasive soft tissue procedures.

The diode laser came into use in dentistry in 1996. The diode laser brought the cost of lasers down significantly from the Nd:YAG. In 1997 the erbium:YAG (Er:YAG) laser received marketing clearance from the FDA for the preparation of teeth and later for osseous recontouring.

When lasers were first introduced into healthcare, the uses were left fairly generically wide open. For the first surgical lasers the indications were for incisions made by a general surgeon. As a result, hospitals required a general surgeon to accompany the cardiac surgeon when doing laser cardiac surgery.

Indications

Uses—basically laser tissue interaction with biologic tissue—fall into two major categories: ablating (vaporizing) or stimulating the tissue. When tissue is stimulated with photonic energy, the process is often referred to as *photobiomodulation.* Tissue ablation is accomplished by using the technique of incising, or excising, or vaporizing the targeted tissue. All laser procedures are accomplished by using one or more commonly a combination of these techniques to obtain the desired treatment objective. This allows for an extremely wide variety of procedures to be performed using a laser treatment modality. One of the most relevant and valuable aspects of laser usage is its antibacterial applications, including periodontal pocket débridement laser therapy (PDLT) to assist in the decontamination and maintenance of a healthy periodontal sulcus and attachment apparatus. Additional applications vary depending on the clinician's focus and procedural expertise. An incisional biopsy is a form of excision, and the destruction of a lesion is considered an ablative or vaporizing technique. Photobiomodulation includes procedures with low-level laser energy, which actually stimulate the cells to facilitate an enhanced healing or reparative response. Laser-induced auto-fluorescence technology is used in caries detection; the photonic energy actually induces a fluorescence response from the bacterial endotoxin (porphyrin), which emits a different wavelength than the light energy it absorbed (was stimulated with) (Figure 26-42). Light energy absorbed into soft tissue can also produce an auto-fluorescence response from the tissue, which assists in discerning tissue composition and

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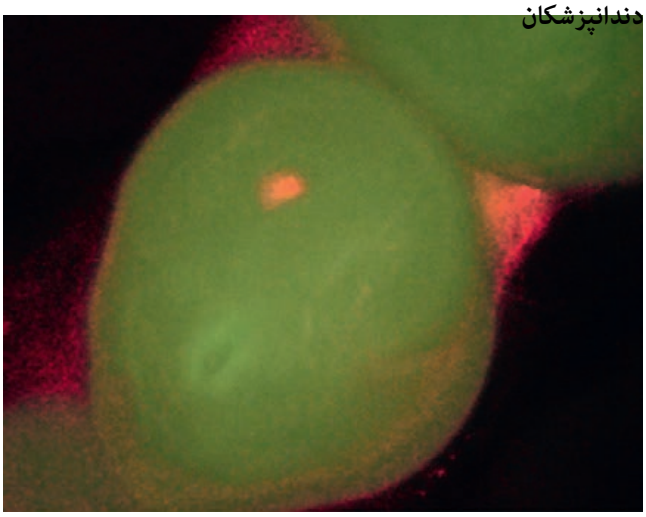


FIGURE 26-42 The orange area in the occlusal surface indicates the presence of porphyrin in caries. This fluorescence response is emitted from the endotoxin porphyrin when it is excited with light energy.



FIGURE 26-44 A 980-nm diode laser being used for bacterial decontamination and débridement of a periodontal pocket.

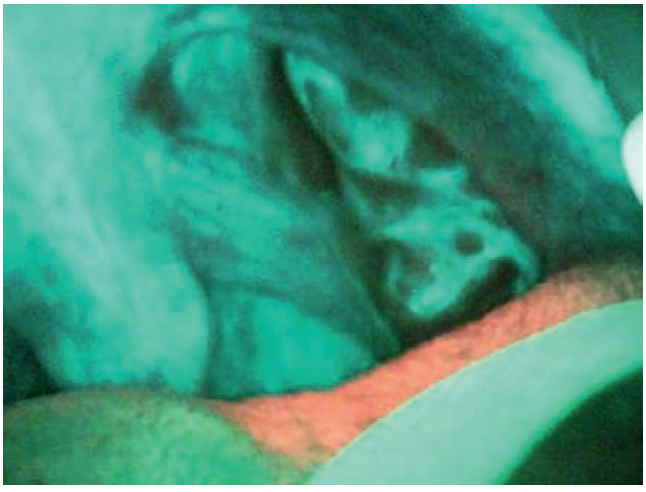


FIGURE 26-43 Soft tissue fluorescence image of normal tissue in the tonsillar region. Note the variances in the tissue response depending on the composition of the tissue.



FIGURE 26-45 A 980-nm diode laser being used to create a trough for a digital impression using water cooling to maintain the healthy gingival contours.

abnormalities (Figure 26-43). Depending on the device and evaluation objective, the emitted fluorescence response may be detectable by either the human eye or various types of sensors. The use of light energy in dentistry is exploding at an exponential rate. Applications for using lasers extend to almost anything that can be imagined.

RELATING DENTAL LASERS TO FUNCTION IN ESTHETICS

Soft tissue lasers today are increasingly being used to maintain and manage the periodontal tissues (Figure 26-44), whether the goal is to promote health through bacterial control, to establish the appropriate and desired tissue contours and architecture, or to create the desired environment and/or space to allow an impression to be obtained. As technologies are advancing, the digital (sometimes referred as "virtual") impression is becoming routine, and the lack of an impression material to displace tissue necessitates precise soft tissue management. The precision of the soft tissue laser makes it an indispensible instrument to manage these situations (Figure 26-45), whether the clinician is using one of the new technologies or the more traditional techniques with materials such as the polyvinyls or polyethers.

The soft tissue laser approach gives the clinician simple and efficient techniques with predictable results to manage the impression process—**what you see is what you get (WYSIWYG)**. With use of dental lasers, unlike electrosurgery or radiosurgery, and with proper laser techniques, minimal to

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FIGURE 26-46 **A, Note the liberal amount of water being used for convection cooling of the remaining tissue. This is accomplished by using a "high fluence technique" with the 980-nm diode laser. B, Controlling the temperature of the tissue is accomplished by flowing water across the surgical site. This type of convection cooling and tissue management also assists in minimizing patient discomfort, enabling the procedure to be performed with the use of just topical anesthetic.**

no recession accompanies tissue removal. Radiosurgery and electrosurgery have a long history of causing collateral damage to soft tissues extending 2 or 3 mm or more beyond what is ideally removed. Lasers today, especially with the use of the high-fluence techniques, can significantly minimize if not eliminate, the amount of collateral destruction in these situations. A 980-nm class laser with high power can be used with convection water cooling to facilitate the ability to ablate tissue by keeping it hydrated because the primary chromophore is water. The convection water cooling of the tissue surrounding the excised or troughed tissue keeps the collateral spread of heat and its related thermal necrosis to an absolute minimum or eliminates it (Figure 26-46).

The ability to manage tissue with a soft tissue laser has far exceeded anything done in the past and helps expedite treatment. The same philosophy is also applied doing a simple class V procedure that extends subgingivally or placing a veneer or crown in an anterior region that is below the gingival crest; it is possible to completely control the tissue and achieve a highly predictable result, maintaining an appropriate gingival contour that is desired both by the clinician and by the patient.

Tissue maintenance procedures are arguably some of the most valuable uses of soft tissue laser. Being able to establish the desired tissue contours and emergence profile of the anatomic crown is essential for esthetic outcomes. Being able to discover precancerous or potentially malignant lesions with the aid of light-based florescence technology at its earliest stages, and guiding tissue sampling (biopsies) and conservative treatment with a laser holds great esthetic promise for patients. Disfigurement is minimized and restorative or replacement procedures avoided.

Hard tissue applications for dental lasers facilitate conservative preparations. Hard tissue lasers such as the 2940-nm Er:YAG laser can minimize the amount of tooth structure that is removed, enhance the retention of the replacement materials, and yield a very favorable outcome (Figure 26-47). The erbium class of lasers really shines in controlling hard tissue interactions. Bone recontouring is achieved to create appropriate and healthy architecture for the dentition and support the restorative procedure. Practitioners with an erbium-class laser and the appropriate visualization and access are able to perform a closed osseous recontouring procedure without reflecting a soft tissue flap to achieve access. This minimizes the discomfort to the patient and enhances reattachment of the soft tissue to the dentition.

Lasers used in periodontal therapy can perform procedures that have been shown in some situations to create environments that may facilitate the redeposition of bone and stabilize tissue previously thought to be questionable in prognosis or even hopeless. This allows dentists to maintain the dentition for a much longer and hopefully indefinite period of time. This approach becomes extremely valuable for establishing conservative treatments and case results, especially with the aging population of today. More and more geriatric patients have a complete or nearly complete complement of teeth and would like to maintain their natural dentition throughout their entire life. The laser approach gives the clinician and the patient very conservative treatment alternatives with reasonably predictable results.

CLINICAL CONSIDERATIONS

The dental laser, because of the fine control over tissue interactions, enables dentists to do many procedures with a minimal amount of anesthetic. Often soft tissue procedures are done with nothing more than a topical anesthetic such as compounds of 14% to 20% benzocaine in the liquid and gel forms. This allows clinicians to minimize the amount of injectables needed for patients and assists in alleviating a major source of worry for patients, the fear of "the needle." With the selection of the proper laser and controlling its energy, healing is improved and there is a minimal amount of postoperative inflammatory discomfort. With lasers, dentists also have control over hemostasis. Soft tissue lasers in particular help patients who may have compromised health issues. It may be no longer necessary to take patients off their anticoagulants to attain pre-treatment

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FIGURE 26-47 **A, Pre-treatment image of dentition with cervical breakdown, to be restored with the assistance of an erbium:YAG (Er:YAG) laser, without the use of a local anesthetic. B, The end firing functionality of the Er:YAG laser enables the clinician to retract the gingival tissue to access subgingival breakdown with the laser tip without causing any soft tissue damage during the preparation. C, The most efficient removal of enamel and tooth structure is accomplished, aiming the laser energy parallel to the enamel rods and dentinal tubules (at a right angle to the tooth surface). D, Note the surface texture of the partially prepared tooth structure; this roughened surface texture has been shown to greatly enhance the bonding strengths using conventional bonding techniques. E, Immediate post-treatment appearance of the restored teeth that were prepared with an Er:YAG laser without the use of any anesthetic.**

objectives (Figure 26-48). More and more patients today are taking multiple medications, so in minimizing the amount of anesthetic, postoperative complications, and patient discomfort, the degree of interference with systemic health is also minimized, and esthetic case acceptance is possible and desirable.

One disadvantage attributed erroneously to lasers is their lack of speed. This compares the active treatment phase only of lasers versus other techniques. The true measure of efficiency requires considering the time from the start of the procedure until the time the procedure has ended, including pre-operative measures and postoperative complication management. The laser function is a bit slower because of the fine control it allows. This is a benefit because such control means dentists do not have to (1) wait until an anesthetic takes effect or (2) wait for the anesthetic to wear off afterward. Procedures can be started as

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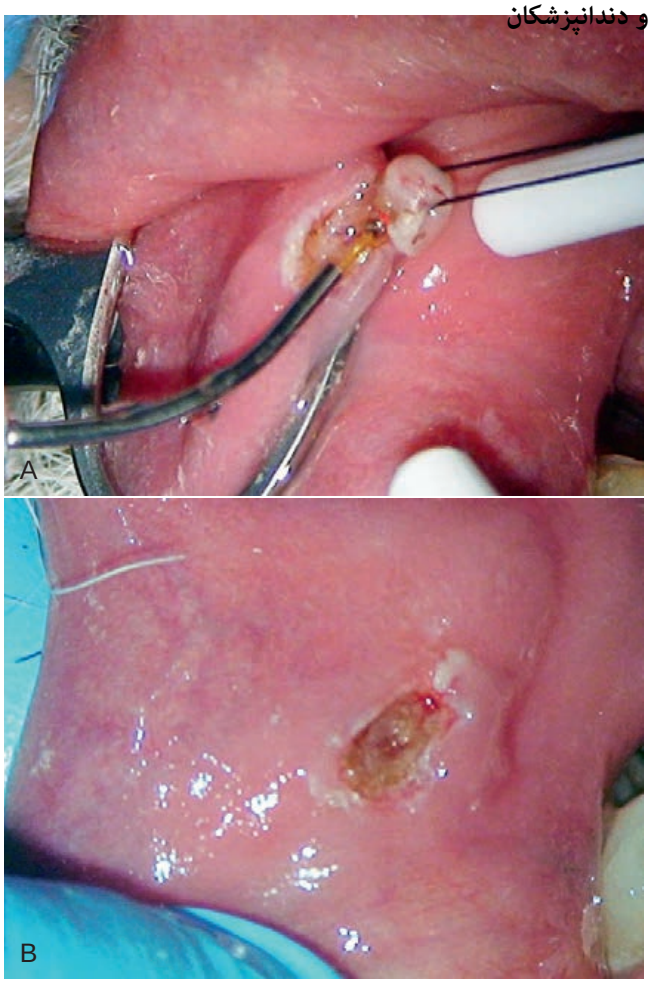


FIGURE 26-48 **Removal of a fibroma with a diode laser for a patient on 10 mg of Coumadin (warfarin) per day. Because of the hemostatic control that the laser provides, the anticoagulant therapy was not altered for the treatment. Note the lack of bleeding both during the procedure (A) and immediately after it was completed (B).**

needed, and minimal waiting time or disruptions are required to meet treatment objectives or address complications. Problems can be handled immediately without changing the overall protocol and while obtaining a predictable outcome as quickly and easily as possible.

MATERIAL OPTIONS

Lasers fall into two basic categories. The first consists of hard lasers—those that basically have the laser energy absorbed into the target tissue, heating it to its vaporization point and converting it to a gas and then vaporizing it. The second category comprises soft or cold lasers that are used for photobiomodulation using photonic energy to stimulate the cells to facilitate healing responses and improve outcomes, without removing or vaporizing the target tissue. Much research is being done, focusing on everything from facilitating hydrogen peroxide release of the cells, to mitochondrial stimulation for improving outcomes and reducing healing times.

The hard laser category is often broken down into hard tissue lasers and soft tissue lasers. Hard tissue lasers interact specifically with bone, osseous structures, and dentition. Because of the relatively low amount of water in these structures, an extremely high absorption in water is needed. The hard tissue erbium-class lasers presently used in dentistry use wavelengths of light energy of 2780 nm for erbium, chromium:yttrium-gallium-garnet (Er,Cr:YSGG) lasers and the Er:YAG lasers, which have a light output of 2940 nm. These wavelengths have a very high amount of absorption of light energy into water, causing its vaporization and facilitating the ablation of the hard structures of the oral cavity, the dentition, and the osseous structures. In the future the 9600-nm laser may be the ideal laser for cutting both dentition and bone. Not only does it have a very high absorption in water, but it also has a very high absorption in hydroxyapatite, the main component of both these structures. This addresses an additional chromophore that today is considered minimal with the erbium class (2780- to 2940-nm) lasers. The 9600-nm lasers are in research and development, but the future looks promising.

With soft tissue lasers there are multiple classifications. The CO_2 laser operates at 10,600 nm and is often thought of as a surgical laser. This laser is often used in skin rejuvenation and by oral and head and neck surgeons to ablate dysplastic tissues. Nd:YAG lasers operate at a parameter of 1064 nm. Nd:YAG lasers are ideal for periodontal work because they are free-running lasers that allow for an extremely high amount of peak power and control over relaxation time. Nd:YAG lasers have been traditionally thought of as lasers for de-epithelialization, and débridement of the periodontal pocket.

A disadvantage of the Nd:YAG laser in soft tissue is that it does not have the same coagulating effects achieved with the smaller and less expensive diode lasers. The diode lasers on the market today fall into two basic groups. The 980-nm diode lasers with a peak power of 12 watts or greater take advantage of a peak absorption in water in the near infrared range. This increased absorption enables the clinician to use water cooling when desired during procedures. As mentioned previously, this ability to use water for convection cooling allows the practitioner to control the laser's effects on the surrounding and remaining tissue to achieve the desired outcome. Diodes with wavelengths below 950 nm and others that require "fiber initiation" operate on a principle of blocking the light energy at the end of the fiber tip so that the fiber becomes a hot glass probe. These lasers function by ablating the tissue with conductive heat transfer by contacting the tissue with the hot fiber rather than by photoirradiation using radiant light energy. All of the diode lasers have great coagulation functionality, especially around tooth structures and preparations. They are ideal for procedures such as gingivectomy and soft tissue troughing to access subgingival margins for restorative procedures as well as many other soft tissue procedures. Depending on their wavelengths and temporal emission modes, they have varying ability for contouring tissue interactions and the management of the remaining soft

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tissue. A high-power 980-nm class laser that gives the clinician complete control of the laser's duty (emission) cycle and pulse duration might be considered the ideal laser at the present time.

OTHER CONSIDERATIONS

Both training and skill are required for the clinician to successfully integrate laser therapy into his or her practice, and there is no substitute for the importance of clinical experience. One of the most underestimated, overlooked, and expensive aspects of any new technology is the time and education required to learn how to properly use the technology. Device-specific education is critical and must be appropriately considered as these technologies are being evaluated. Also of primary concern is the high initial cost of the laser devices themselves. They range in price from a few thousand dollars to sums approaching $100,000 depending on the laser, the accessories, and the education that is necessary to use it. All this must be considered as the clinician moves into the realm of laser therapy and patient care.

Understanding the use of energy on the electromagnetic spectrum and the principles of laser physics involved is also essential. The laws of physics do not change from devices to device; however, how each device capitalizes on these principles may be significantly different. All lasers, and even all diode lasers, are not the same. Having a comprehensive, thorough understanding of the science makes all of the devices much easier to use. It makes it possible to adapt to specific parameters and techniques to compensate for the scientific interactions occurring in the biologic interactions with tissue.

INNOVATIVE ELEMENTS

Among the innovative elements is the ability to do caries detection. It is hoped that in the future a laser will be used to stop the progression of decay or perform preventive measures rather than just the destructive surgical procedures that are commonplace today. It is desirable that areas prone to breakdown might be able to undergo light therapy in the future to change chemical composition or the external interface to make the area significantly more resistant to long-term breakdown.

Another innovative element in the use of lasers involves the soft or cold lasers for photobiomodulation. These devices can be used to improve healing and promote health, as in bone rejuvenation. An example of this use has been demonstrated at the University of Texas, Houston, showing that exposing edentulous areas to certain wavelengths of light repetitively will increase the quality of bone, which in turn makes the site more suitable to receive dental implants.

ARTISTIC ELEMENTS

The ability for a laser to sculpt both hard and soft biologic tissue, gives the clinician the ability to perform various types of procedures that cannot be done with any other technologies. It is possible to conservatively prepare a dental restoration or re-contour osseous structures with the removal of minimal biologic structures to attain the desired outcomes. Restorations prepared with the use of an erbium-class laser have enhanced bonding strength when compared with techniques involving rotary instrumentation. Not only do lasers obtain the hard tissue results that are wanted, but it is also possible to manipulate the soft tissue elements and achieve increased longevity of the outcome. In gingivoplasty procedures, it is possible to use soft tissue lasers to actually sculpt the contours of the gingiva to achieve the desired esthetic effect.

A major misconception of light energy is that this energy has a significant impact on bleaching, specifically accelerating bleaching. Many articles show that light enhancement *insignificantly* increases the effectiveness of bleaching and has no significant impact on the outcome of bleaching procedures.

TREATMENT PLANNING

In treatment planning the clinician must assess what technology will be available over the course of treatment. Knowing what goals are obtainable with the various types of lasers and other technologies that are available allows the clinician to plan treatment all the way through to the obtainable outcome. Laser treatments can minimize the number of appointments needed. The ability to perform many procedures with a reduced amount of anesthesia or none at all enables treatment in multiple areas of the oral cavity in the same appointment. In many situations the periodontal component does not have to be complete before the restorative phase of treatment is started.

Knowing and understanding what can or cannot be corrected at any phase of the plan is essential. Dental lasers in some situations enable to possibility of performing some re-contouring of both hard and soft tissue structures even in the final stages. Lasers permit this to be nicely finessed to obtain the best possible results. Whether the approach will involve open flap or closed flap surgery, lasers can help in facilitating patient care. Most soft tissue laser surgeries are done without the need for placing a periodontal dressing. Being able to plan treatment thoroughly facilitates the patient being able to plan out his or her role. Patients will know how the treatment will affect their everyday life and their normal work schedule or daily activities. Knowing what options are available and where laser therapy fits appropriately into the sequence becomes very valuable to the clinician. Having various lasers available opens up myriad possibilities to achieve the best treatment goals.

Options in the Sequence

It is possible to sequence treatment planning slightly differently today because of the use of lasers. These tools allow minor tissue control at the time of preparation and at the time of seating or final placement of the restorations as well as anywhere in between. The bulk of what is planned for soft tissues is aimed at being able to be performed before the placement of

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provisional restorations, giving the clinician the opportunity to make some minor adjustments in the provisional stage and then, after the case has been completed, to make any needed adjustments in the soft tissue. With lasers it is possible to sequence steps without being locked into a certain timeframe, which is an improvement over the past, before these options were available.

TREATMENT CONSIDERATIONS

Studies show that bonding after laser surface preparation is possible to get significantly stronger than after rotary instrument preparation. As a result dentists can do minimally invasive preparations. Minor gingival touching up after a procedure is possible to address problems that arise because of a lapse in home care. Dentists would like their patients to be more compliant than they normally are with home care, but when patients do not respond as desired, lasers allow corrections as soon as problems arise.

EVIDENCE-BASED PRINCIPLES

Hundreds of articles in peer-reviewed journals show the value of lasers. It all comes back to the physics and the science, which enable the clinician to be confident in performing what is planned. The basic principles of periodontal care have not changed, but the laser modality literally allows the accomplishment of goals more conservatively and with less discomfort to the patient. The science is showing extremely desirable outcomes. Laser procedures are well supported and documented in the literature with regard to their efficacy and effectiveness.

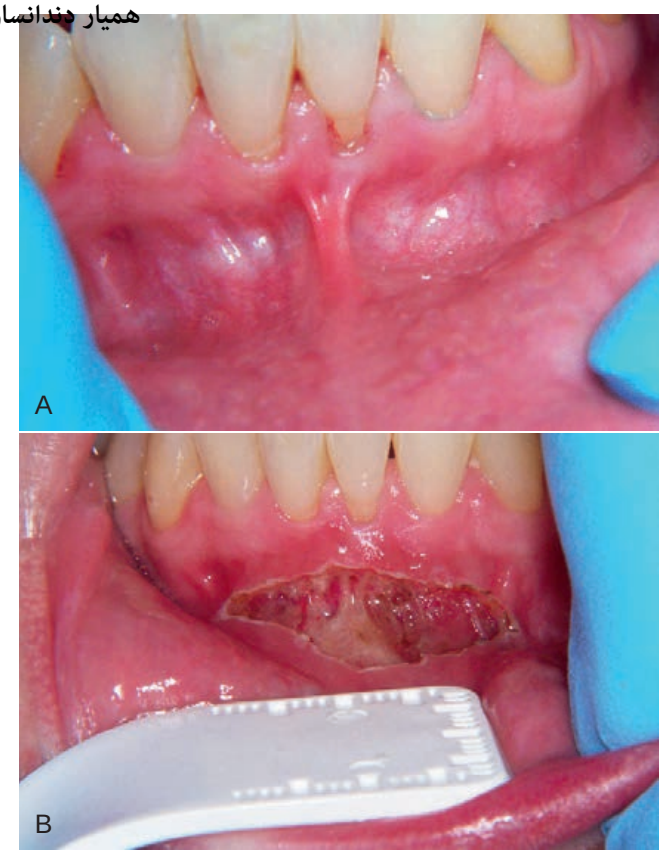


FIGURE 26-49 **In the pre-treatment image (A) note the pull and destruction that are occurring in the periodontal tissue of the lower left central incisor. In the post-operative image (B) note the immediate improvement in the health and esthetics in that area.**

CLINICAL CONSERVATION CONCEPTS

In the past many clinicians would monitor the effects of the overtly strong muscle pull on the periodontium until there was damage to the gingival structures before referring the patient for a surgical frenectomy, which required multiple appointments and caused a fair amount of patient discomfort (Figure 26-49). Lasers allow dentists to very conservatively intervene and stop the destruction before it reaches a pathologic state with minimal or no discomfort. This is also accomplished in a single appointment with a procedure that often takes less than 5 minutes. Examples of early interventions to hopefully halt the progress of disease include vestibuloplasties, frenectomies, and preventive rather than restorative procedures. The goal of all oral healthcare is to minimize the need for dentistry. This is even more ideal than performing dentistry in a minimally invasive way; it is best to eliminate the need for the procedure and end the disease state in the first place. Prevention of disease and the preservation of health are the true goals for all healthcare providers.

MAINTENANCE

Patient Maintenance

Homecare and maintenance for laser procedures for the most part are the same as for other treatments. However, because no significant inflammatory response is created for many procedures, the patient needs to be reminded that he or she has had a surgical treatment and to take extra care in the area treated. For the most part when a dentist is done with the procedure, the dentition is at a point at which the patient can maintain it properly. Most postoperative instructions after laser soft tissue surgery are the same as for any other form of soft tissue surgery. Basically patients should avoid food that will be irritating to the tissue such as spicy and acidic food and beverages. The patient should also be informed that he or she might notice a white yellowish fibrin clot forming over the area of soft tissue treatment. This is a normal appearance and is part of the healing process and should not cause concern. Thus the care and maintenance after a laser procedure are for the most part no different from the care and maintenance after any other type of dental intervention.

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Maintenance of the Laser Equipment

The maintenance and infection control of light-based technology are not significantly different from the maintenance of other kinds of dental equipment. However, some special care must be performed and special considerations must be taken into account. The electronics of the laser devices cannot be placed through an autoclave, but laser handpieces are autoclaved in the same way as other handpieces. Laser fibers and tips should be removed from the handpiece or the device and go through the appropriate sterilization cycle or be properly disposed of. Asepsis barriers are often used over user interface screens and switches to prevent cross-contamination between patients. All appropriate infection-control considerations and concerns must be addressed in a prudent manner. Maintaining a good service contract through the equipment provider is essential. Laser devices should be inspected, calibrated, and routinely aligned to make sure that they are functioning properly. It is important to ensure they are operating within the specified tolerances for which they were designed, as for all the equipment in a dental practice.

CONTROVERSIES

The daily controversy in laser dentistry stems from a lack of understanding of the science behind it. In periodontal care, the concepts of care with lasers are the same as what has been done for many years. The concept of the disease process and treatment has not changed, although the modalities have, with lasers being used to simplify techniques and improve outcomes.

Clinicians must determine if incorporating a laser into their armamentaria is truly cost-effective. It is important to understand where and when it will enhance and promote quality of care and how laser technology will improve the efficiency of the way that care is delivered.

NEAR-FUTURE DEVELOPMENTS

Traditionally the diode lasers were always considered to have a minimal amount of control over their temporal emission modes with a fairly low amount of power, 2 to 4 watts. More and more high-powered diode lasers with expanded control over their temporal modes are being introduced and used. The goal of these efforts and enhancements is to have diode lasers perform and function more like free-running lasers in addition to the tissue interactions that they already have. This means using very high peak power and controlling the thermal relaxation time of the tissue so tissue can be vaporized or ablated with minimal to no collateral damage to the surrounding tissue.

The future of light-based technology is almost limitless. The scope will extend to diagnosis, healing, and minimally invasive procedures at a cellular level. Some of the diagnostic light-based modalities being developed include tissue and cellular auto-fluorescence, optical coherence tomography (OCT), near-infrared (NIR) imaging, and sidestream dark-field (SDF) imaging.

With auto-fluorescence, light energy absorbed into a target tissue or substance produces a specific fluorescence response from the target to assist in discerning the tissue composition, morphology, health, and abnormalities.

NIR imaging uses specific wavelengths of light energy to make dental enamel become basically invisible. Unfortunately, these wavelengths of light are outside the range of visible light that can be detected with the human eye. However, with the use of appropriate receptors, internal abnormalities in dentition such as caries can be detected with NIR trans-illumination of the teeth without using ionizing radiation.

OCT is also a near-future technique. With OCT it will be possible to perform point spectroscopy. This is basically an optical biopsy in which clinicians noninvasively investigate and sample cells to evaluate the chemical and morphologic composition without having to remove any intact structures. This information will assist clinicians in determining when and where tissue sampling or removal would be most beneficial.

In the area of photodynamic therapy (PDT), in the near future it may be possible to use laser energy with the aid of an induced chromophore to attack abnormal cells and selectively destroy cancer or other diseased cells while leaving the adjacent healthy cells intact. Extensive research is being done at several institutions (such as the Roswell Park Cancer Institute in Buffalo, New York; the MD Anderson Cancer Center in Houston, Texas; and the British Columbia Cancer Institute in Vancouver, British Columbia) on how to formulate this process.

Photobiomodulation, or low-level laser therapy, is also coming into the realm of healthcare. It is often looked at very similarly to the way in which Eastern medicine, such as acupuncture, is viewed by adherents of Western medicine. In large part this is because the study mechanisms for double-blind, randomly controlled investigations are difficult to apply. However, more and more high-quality research from places such as Harvard University and Uniformed Services University of the Health Sciences in Bethesda, Maryland, are studying photobiomodulation. The focus is on how to heal a wound rather than surgically treat it.

Increasingly, lasers and light-based technologies are being incorporated into dental practice, as well as all forms of healthcare, to assist in attaining better outcomes for patients' well-being and esthetic appearance.

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SECTION D

Photoactivated Disinfection

George Freedman

The preparation of the tooth is complete. The walls of the cavity seem hard to the explorer. There is no telltale brown decay visible, even under magnification. Therefore the cavity must be clean and ready for restoration (Figure 26-50). *Or is it?*

If cariogenic bacteria are retained at or below the tooth-restorative interface, the long-term health of the remaining tooth structures, as well as the longevity of the restoration will be compromised. For the practitioner this is a significant issue that will determine short- and long-term clinical success and one that is not readily diagnosable with currently available tools and technologies. Ozone has been proven to be an excellent antimicrobial agent and is now in use in many thousands of practices around the world.

Photoactivated disinfection (PAD) is an innovative technology that uses two nontoxic components, a photoactivating liquid, and a light-emitting diode (LED) light source to selectively tag and destroy cariogenic bacteria and periodontal pathogens. PAD instruments have been evolving for two decades, and the Aseptim Plus system (SciCan, Ltd., Toronto, Ontario, Canada) represents the current state of the art in the photoactivation treatment category (Figure 26-51).

CURRENT CLINICAL PROBLEMS

Dental Caries

Dental caries is a disease that initially demineralizes the enamel and then progresses slowly into the dentin. The advancing zone of demineralization is preceded by a layer of partially demineralized dentin infected with bacteria. During clinical evaluation and/or treatment, it is difficult to differentiate these two zones, and as a result, significant quantities of sound but demineralized tooth tissue are removed during cavity preparation.

It is conservatively advantageous to retain the partially demineralized dentin, but only if the bacteria can be reliably eliminated.

There are two possible approaches to conserving remaining sound tooth structure:

1. The use of bacterial detection agents that assist in the removal of the infected (and only the infected) tissue
2. The use of PAD to eliminate bacteria and then to remineralize the partially infected dentin

Given the high levels of bacteria in the oral environment, the general assumption must be that even cavities freshly prepared to the level of sound tooth structure have microorganisms lurking in the dentinal tubules and enamel lattices.

Research has recently demonstrated that photo-sensitized cariogenic bacteria can be killed by directly applied visible light (see Figure 26-51). The technique involves applying a photoactive solution that is absorbed selectively by cariogenic bacteria to the operative surfaces. This sensitizes them to the application of visible illumination, which causes cytotoxic bacterial reactions that result in selective destruction of the target microorganism.

Periodontal Therapy

A similar problem exists in periodontal pockets; scaling and root planing (SRP) can remove the calculus and plaque but have little effect on the acidogenic and aciduric bacterial presence that is the cause of these deposits, and the ensuing periodontal disease that has been associated with numerous systemic health problems. As soon as traditional SRP is completed, the bacteria resume their damaging activities.

Additional research has indicated that an identical PAD mechanism combats the bacteria that are largely responsible for periodontal disease. In fact, it has been observed that PAD treatment can reduce bone loss.

PHOTOACTIVATED DISINFECTION: MODE OF ACTION

Scientific Model

Photosensitization is a treatment that involves the interaction of two non-toxic factors, a photoactive compound (tolonium chloride) and a directly applied visible light (LED illumination at 635 nm). The photosensitization consists of the formation of metachromatic complexes with lipopolysaccharides that can be photoactivated by visible light illumination to cause oxygen ion release. The oxygen ions are specifically toxic to a vital structural component of the target bacterial cells. The interactions between the phenothiazine dyes, including tolonium chloride and methylene blue, and many bacteria are well documented.

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FIGURE 26-50 **A, Tooth showing decay. Tooth prepared (B) and ready for restoration (C)—but is it really clean and free of bacteria?**

Bacterial cells are typically composed of a variety of cytoplasm materials enclosed by a cell wall. Many "traditional" antimicrobial substances must enter and accumulate inside the bacterium in order to destroy their targets. Because this process requires a transport mechanism through the cell wall, it gives the bacteria an opportunity to build up a resistance by modifying the transport mechanism required by the drug. This also applies to photoactivated drugs that must accumulate within the cell.

Some PAD compounds, on the other hand, target the cell wall structures and membranes and do *not* need to enter the cell. Only specific adhesion to the targets is required for the light-activated destruction of the cell. As a result, target cells cannot develop resistance by stoppage of uptake, metabolic detoxification, or increasing exportation of the drug.

Clinical Model

In Figure 26-52, *A,* the bacterial cytoplasm is enclosed by the cell wall. The microorganism must have both in order to survive. Magnification of the cell wall (Figure 26-52, *B*) indicates the substructures in the cell wall. Further magnification (Figure 26-52, *C*) identifies that some of theses substructures are liposomes. Figure 26-52, *D*, is a stylized liposome that has been magnified further still and sectioned to illustrate what occurs within.

The dissolved tolonium chloride is released by the practitioner in the general environment of the area to be disinfected (Figure 26-53) and worked into the tissues for up to 60 seconds. The target areas may be hard or soft dental tissues or both. The photoactivator is a good wetting agent and quickly flows to all accessible areas, including surfaces (gingiva) and penetrable structures (enamel and dentin). The absorption is very selective into bacterial wall structures, however. No absorption of the photoactivator can be seen (and therefore no adverse effects from light application) on adjacent healthy tissues. The tolonium chloride is selectively and rapidly absorbed into the liposomes in the bacterial cell walls, as indicated by the small blue circles within the liposome. In looking at the cell wall again, it can be seen that many liposomes throughout the structure have absorbed the tolonium chloride dye.

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FIGURE 26-51 **A to C, Aseptim Plus photoactivated oral disinfection system. D and E, Disposable tips.** *(A courtesy SciCan, Ltd., Toronto, Ontario, Canada.)*

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Then the tolonium chloride–specific 635-nm LED is applied to the photoactivated surface (Figure 26-54). This relatively intense light not only photoactivates at the surface of application but can penetrate to a certain depth within dental structures as well. A 60-second irradiation is sufficient to release the bactericidal oxygen ions from the photoactivated metachromatic complexes for carious and periodontal applications. The liberated oxygen ions are shown within the liposome and, in a more distant view, within the magnified cell wall.

The oxygen ions are toxic to the liposomes and hence the cell wall. The photoactivation begins to break down the bacterial cell walls (Figure 26-55). The oxygen ion activity continues as the cell membrane is ruptured. The cell contents escape, killing the bacterium.

Photoactivated disinfection is very specific to bacterial cells and will not affect healthy tissues, even those that are immediately adjacent to or surrounding the offending bacteria.

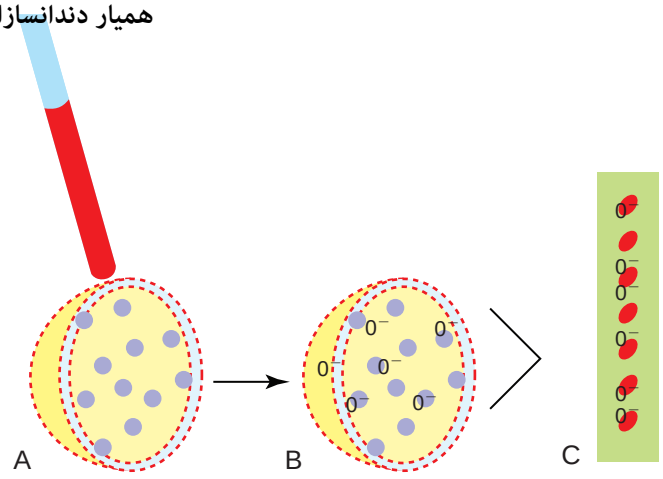


FIGURE 26-54 **A,** A 635-nm light-emitting diode (LED) light source is applied to the surface to photoactivate the tolonium chloride inside the lipsomes. **B,** Liberated oxygen ions shown within the liposome walls. **C,** Distant view shows oxygen ions within the magnified cell wall. Oxygen ions are toxic to the cell wall.

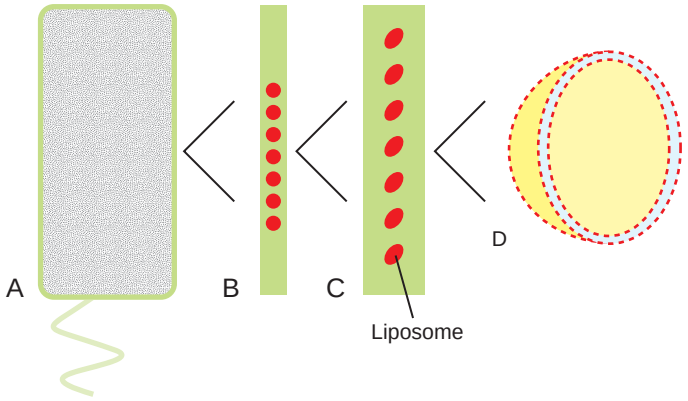


FIGURE 26-52 **A,** Bacterial cytoplasm enclosed by the cell wall. **B,** Magnification of the cell wall shows substructures. **C,** Further magnification identifies certain substructures in the cell as liposomes. **D,** Further magnified sectioned of a stylized liposome illustrates what occurs within.

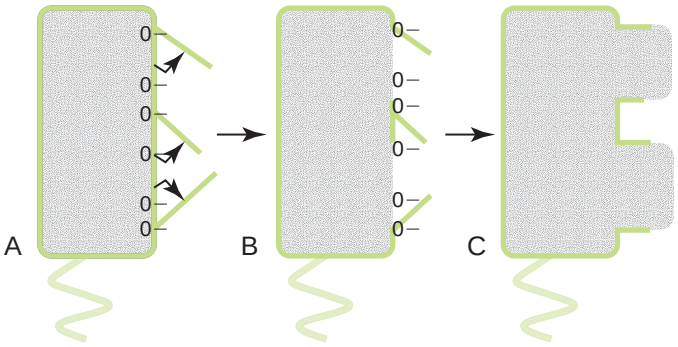


FIGURE 26-55 **A,** Oxygen toxicity ruptures the bacterial cell membrane. **B,** Cell membrane ruptured by oxygen ions. **C,** Cell contents escape, killing the bacterium.

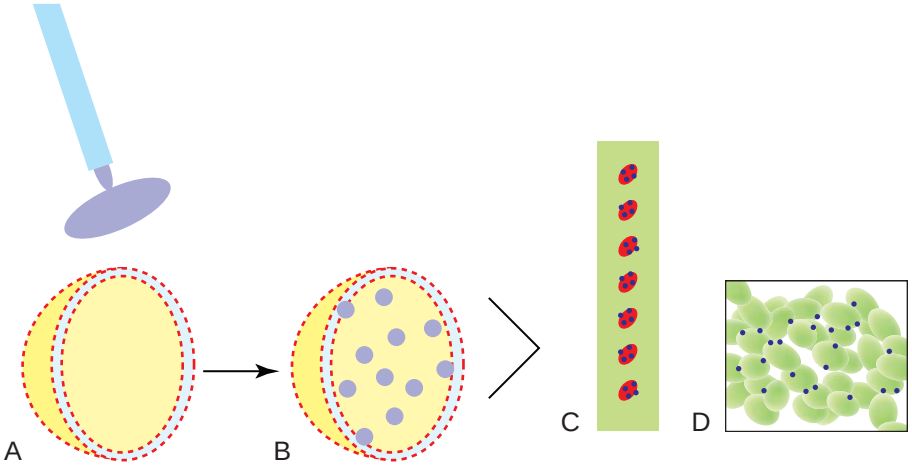


FIGURE 26-53 **A,** Dissolved tolonium chloride applied to surface. **B,** Tolonium absorbed into the liposome in the bacterial cell walls *(blue circles).* **C** and **D,** A significant number of liposomes have absorbed the tolonium chloride dye.

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PHOTOACTIVATED DISINFECTION TECHNIQUES

Conservative Photoactivated Disinfection Caries Treatment (Early Decay)

1. Appropriate anesthesia and isolation are applied to the carious tooth. The sectional matrix system is the Triodent V3 Ring and Matrix (Triodent, Katikati, New Zealand), a very effectively designed set of instruments for creating predictably tight interproximal contacts and contour.
2. The carious lesion is accessed and removed (Figure 26-56, *A*).
3. The Aseptim solution is applied to the entire lesion with an applicator for 60 seconds (Figure 26-56, *B*)
4. The Aseptim Plus diode handpiece tip is held close to the tolonium chloride–treated tooth surfaces (Figure 26-56, *C*).
5. The diode light is activated for 60 seconds, penetrating the illuminated tissues and disinfecting the remaining tooth structures (Figure 26-56, *D*).
6. The cavity is treated with a remineralizing agent.
7. The cavity is restored permanently with a resin ionomer or composite resin (Figure 26-56, *E*).

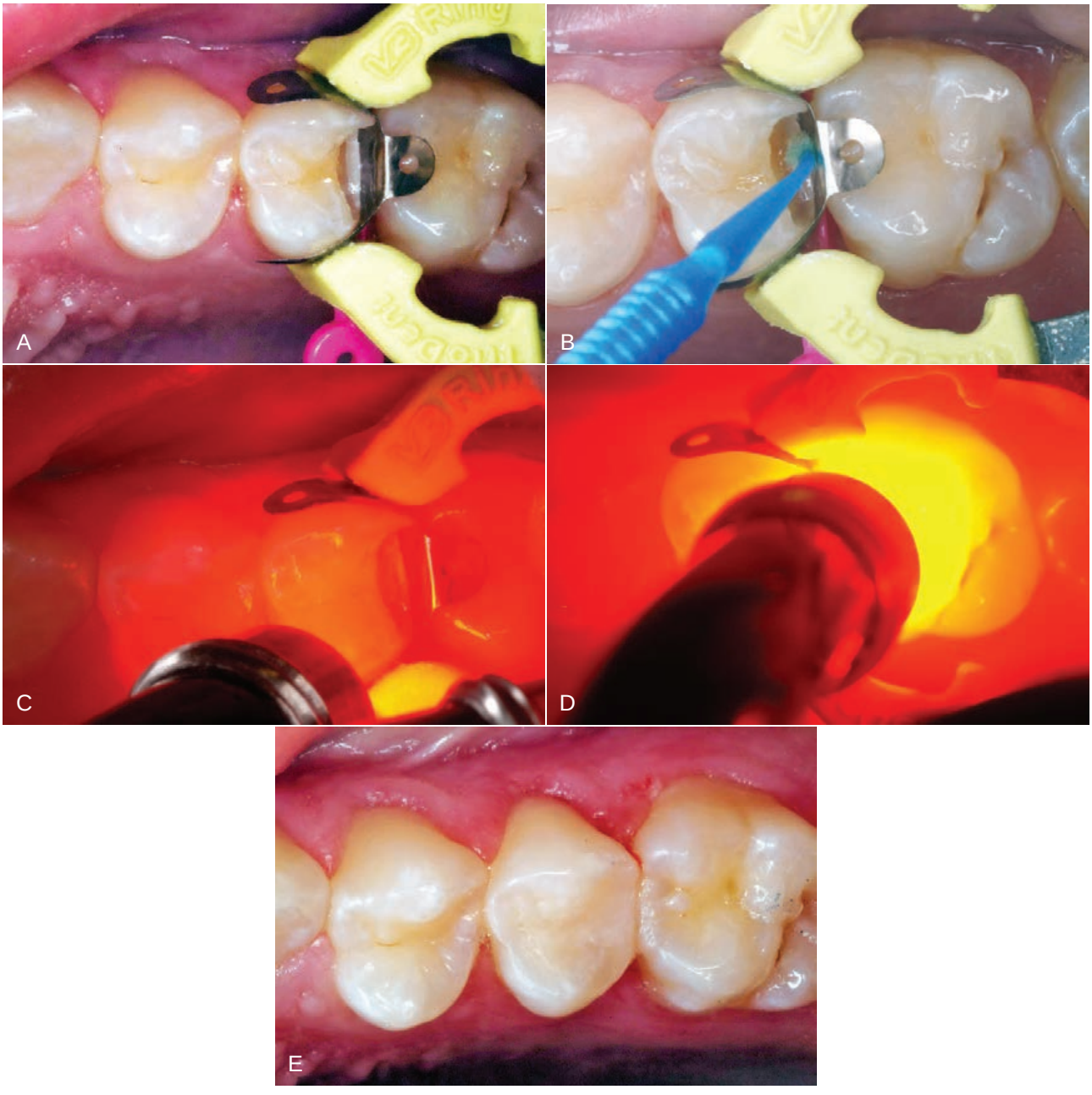


FIGURE 26-56 Conservative treatment of caries (early decay) using photoactivated disinfection. **A,** Caries lesion has been accessed and removed. **B,** Aseptim Plus solution applied to the entire lesion. Aseptim Plus diode handpiece tip is held close to the tolonium chloride–treated tooth surfaces (**C**), and the light is activated (**D**). **E,** Permanent restoration of the cavity.

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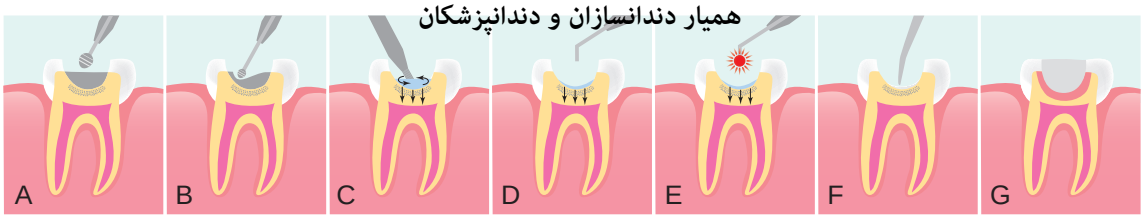


FIGURE 26-57 **Application of Aseptim Plus in caries treatment (advanced decay).** *(Courtesy SciCan, Ltd., Toronto, Ontario, Canada.)*

Conservative Photoactivated Disinfection Caries Treatment (Advanced Decay)

1. Appropriate anesthesia and isolation are applied to the carious tooth.
2. Only sufficient enamel to access the carious lesion is removed (Figure 26-57, *A*).
3. The remaining infected tissue is removed with an excavator or slow dental handpiece until resistance is felt (Figure 26-57, *B*).
4. The Aseptim solution is applied to the entire lesion with an applicator for 60 seconds (Figure 26-57, *C*).
5. The Aseptim Plus LED handpiece tip is held close to tolonium chloride–treated tooth surfaces (Figure 26-57, *D*).
6. The LED light is activated for 60 seconds, penetrating the illuminated tissues and disinfecting the remaining tooth structures (Figure 26-57, *E*). (If two interproximal surfaces are involved, they must be disinfected separately.)
7. The cavity is treated with a remineralizing agent (Figure 26-57, *F*).
8. The cavity may be restored permanently with a resin ionomer or composite resin or restored temporarily with a remineralizing agent for later definitive restoration (Figure 26-57, *G*).

The restorative protocols presented are very similar to currently established ones, with one major difference: with PAD treatment, the remaining tooth surfaces are disinfected and therefore are far more likely to remineralize effectively. Aseptim Plus is used with both routine and deep carious lesions to increase the probability of long-term clinical success.

Conservative Photoactivated Disinfection Periodontal Therapy (Figure 26-58)

1. Routine, thorough SRP debridement is completed, and bleeding is controlled (Figure 26-59, *A* and *B*; see also Figure 26-58, *A*).
2. The tolonium chloride photoactivator solution is inserted to the depth of the pockets (Figure 26-59, *C*; see also Figure 26-58, *B*).

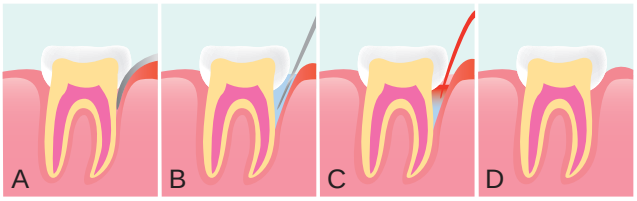


FIGURE 26-58 **Application of Aseptim Plus in periodontal treatment.** *(Courtesy SciCan, Ltd., Toronto, Ontario, Canada.)*

3. The Aseptim Plus handpiece with the light guide is inserted to the bottom of the pocket (Figure 26-59, *D*; see also Figure 26-58, *C*).
4. The Aseptim Plus LED light is activated for 60 seconds to eliminate bacteria in the periodontal pocket (Figure 26-59, *E*; see also Figure 26-58, *C*).
5. The patient's periodontal status is reviewed at 4 weeks (see Figure 26-58, *D*). Repeat PAD treatment if necessary.

The elimination of periodontal pathogens from the depths of the pockets promotes the gingival health far more effectively than SRP débridement alone can. Aseptim Plus periodontal therapy is clinically straightforward, simple to carry out or delegate, and an excellent adjunct to routine SRP. Used together, these treatments offer more predictable long-term clinical results.

CONCLUSION

Practitioners and patients have had understandable qualms about the level of disinfection that can be practically and realistically achieved during routine dental procedures. Given the high levels of ambient bacteria in the oral cavity and the difficulty of isolating surgical treatment sites during and after procedures, it is evident that additional disinfection modalities are welcome additions to the dental armamentarium.

PAD offers a heightened level of disinfection during and after operative and periodontal procedures (in addition to endodontic and peri-implant treatments that were not discussed earlier). A relatively rapid and simple system that is readily inserted into the treatment routine, the Aseptim Plus destroys bacteria both on the surface and underneath to provide healthier periodontal tissues and more predictable and longer-lasting restorative interfaces.

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FIGURE 26-59 **Conservative treatment of periodontal disease using photoactivated disinfection. Débridement (A) completed and bleeding controlled (B). C, Toluidine chloride photoactivator solution inserted into the depth of the pocket. D, Handpiece inserted to the bottom of the pocket. E, Light-emitting diode (LED) light activated.**

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SECTION E

Soft Tissue Screening

Scott D. Benjamin

RELEVANCE OF SOFT TISSUE SCREENING TO ESTHETIC DENTISTRY

The goal of soft tissue screening is the goal of dentistry. As healthcare providers, dentists aim to promote and achieve an enhanced quality of life for their patients. Dentists evaluate patients appropriately to make judgments about the status of the patient's health and to identify any disease process at the earliest possible stage. Then they inform the patient of their findings and an appropriate course of action. In the dentition, the focus is on pre-carious, carious, and pulpal pathology; long-term wear; and/or traumatic lesions or injury. In the periodontium, dentists assess infections related to bacteremia. With the surrounding soft tissues of the oral cavity, providers look for a combination of bacterial infections, traumatic injuries, developmental pathology, and inflammatory reactive responses to identify disease at the earliest possible stage, before it becomes critical. Too often the goal has been to identify disease after it has developed into a pathologic condition rather than managing it in the earliest stages.

Looking at disease processes in the body, there are reactive lesions caused by outside stimuli; malignant abnormalities, which are tissues growing in an abnormal pattern; and congenital defects. Specific to the soft tissues, the goal is to identify any condition at the earliest possible stages so that a healthy condition can be reestablished. Many situations in the mucosal tissues can be reversed, allowing dentists to function as healers rather than surgeons.

The disease processes that affect the human body develop over time. By routinely evaluating patients, dentists have the opportunity to identify diseases at an early stage. Undergoing routine evaluation is comparable to women going for an annual gynecological examination. That is the accepted standard of care today, and women understand that their annual examination is crucial to their quality of life. This is the same message that oral healthcare providers need to convey.

Dentists' knowledge of oral soft tissue diseases can be described as a *use-it-or-lose-it* phenomenon. The practitioners who are most proficient at doing a thorough soft tissue examination tend not to be the experienced clinicians but the ones who have most recently completed their training programs.[1] The further away a clinician is from his or her courses in oral medicine and oral pathology and from formal education, the less he or she tends to remember. This is probably no more evident in dentistry than in managing soft tissue and mucosal abnormalities. Over 50 diseases or conditions mimic oral cancer, which by itself becomes a very confusing factor. When an abnormality is present, the dentist must establish not only the appropriate differential diagnosis but the appropriate management.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF SOFT TISSUE SCREENING IN DENTISTRY

Soft tissue screening until recent years has been almost nonexistent. A sad fact is that the incidence and morbidity of oral cancer have not significantly decreased in 50 years.[2] It is the only form of cancer in North America that is actually increasing in incidence rather than decreasing. Much of the increase has to do with the fact that basically for 150 years, until 2001, how dental patients were screened did not change. The assessment was strictly a visual and tactile examination with no other assistive modality. In recent years, things like magnifying devices, which are now being worn by more and more clinicians, have been developed, significantly improving the dental assessment of soft tissue conditions. Digital cameras have also significantly helped by allowing dentists to perform photographic documentation of how a disease or condition manifests in the oral cavity; photography then assists in assessing the progression or regression of the abnormality, as well as how effective therapies and management have been.

In 2001 the first improvement in oral screening was made; until then the only adjunctive technology that was used was a toluidine blue (nuclear) stain. It was applied after an area of concern had been identified; the stain could possibly be used to further identify its location and mark it. This technology had little to no application in the opportunistic screening of an asymptomatic patient with no obviously apparent lesion. In 2001 an aceto-whitening system, which used acetic acid, was introduced. With this white-lesion detection system, the patient rinses with a very mild acetic acid solution. For the cervical

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region, research has shown that 5% acetic acid was the most effective way to improve the visualization of white lesions.[3] However, 5% acetic acid was too strong to use in the oral cavity, so it was downgraded to a 1% solution, which is basically vinegar. The acetic acid desiccates the patient's tissues and allows a visibly white lesion to stand out against the pink mucosal background. For the first time an adjunctive technology helped oral healthcare providers move forward with soft tissue evaluations. This technique was used in conjunction with a chemically reactive glow stick, which emitted a light for a short amount of time. Drawbacks included the following:

1. The light lost intensity over time, decreasing its effectiveness in illuminating the oral cavity.
2. Patients' objections to the taste of the acetic acid were substantial.
3. Introduction of another solution during the dental appointment interfered with antimicrobial mouthrinses, fluorides, and other procedural steps.

That technology has not progressed significantly over the years. A study from Virginia Commonwealth University showed a slight value to using acetic acid mouthrinse, but use of the illumination device was problematic because the acetic acid caused increased salivary function and the increased illumination produced reflections off the saliva.[4] This was confusing to look at. More recently, this same concept has been partnered with an electronic version of the device that is significantly better as a light source. This approach still has the disadvantages of a bad aftertaste and confounding factors.

However, the battery-powered broad-spectrum white-light devices are very valuable in illuminating all areas of the oral cavity, helping facilitate the visual inspection of the previously difficult-to-see structures with the operatory light (Figure 26-60). These instruments have proved valuable for better performance of white-light examinations but do not enhance the tissue response.

The first major enhancement in the area of visual inspection of the oral cavity is the use of tissue auto-fluorescence. With tissue auto-fluorescence, energy in the form of a very narrow band (or range of wavelengths) of visible light is directed at and is absorbed by the tissue to be examined. This excitation light energy in the tissue is then converted or transformed to an emission light created by the tissue itself. This allows the clinician to observe the fluorescence response of the tissue, which is based on chemical and morphological composition of the target tissue.[5] The fluorescent response of the tissue gives the clinician additional information to be used in conjunction with other findings to assess the patient's current status. If the fluorescent response is normal tissue for the region and other examination findings are within normal limits, it gives the dentist more confidence that the soft tissue is in a healthy state. However, if the fluorescent response is not what would be expected of the tissue in that region, there is probably an abnormal process present, whether inflammatory, reactive, potentially malignant, or malignant. The introduction of the VELscope (LED Dental, Inc., White Rock, British Columbia, Canada) has combined auto-fluorescence and filtration to allow the clinician to focus on and assess the patient's well-being.

A field-of-view screening, in which dentists look at the entire oral cavity, is very similar in concept to what is displayed or viewed in a panoramic radiograph. By using a field-of-view survey of the entire oral cavity under a visual white-light examination, performing a tactile examination, and then adding any data from a fluorescence examination, the clinician is able to discover conditions that may not have been detected previously. These assessments allow the practitioner to detect all sorts of mucosal abnormalities that range from a cheek bite or an irritation caused by a sharp restoration or dentition to a disease process that may be benign, such as geographic tongue, to even an invasive condition such as a malignancy that otherwise may have gone unnoticed. Once such a condition is discovered, the practitioner is able to further investigate it, its present status, its potential causes, and interventional processes to manage the situation. These adjunctive tools are invaluable in accessing the patient's health status.

When a fluorescence visualization device such as the VELscope (Figure 26-61) is used, if an abnormal area is discovered,



FIGURE 26-60 Using the Microlux/DL device (AdDent, Inc., Danbury, Connecticut) to enhance the white-light illumination of the floor of the mouth.



FIGURE 26-61 Clinician using the VELscope to perform a fluorescence screening of the oral mucosa.

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Oral Mucosal and Soft Tissue Evaluation Form

Patient's Name: _____ Date: _____

Date of Previous Exam: _____ Condition Duration: _____

Relevant Medical History / Status: _____

Medications: _____

Relevant Social History / Status: _____

Relevant Dental History / Status: _____

Extent of Involvement: _____

General Visual Appearance: _____

Region of Soft Tissue: _____ Location / Dentition Reference: _____

Visual Color: _____ Visual Size Dimensions: _____

VELscope / Fluorescence Visualization (FV): _____ FV Size Dimensions: _____

Overall Configuration: _____ Surface of Lesion: _____

Margin Configuration: _____ Mode of Attachment: _____

Consistency: _____ Mobility of Lesion: _____

Pain / Symptoms: _____

Extraoral Head Neck Findings: _____

Photodocumentation: _____

Clinical Impression / Preliminary Diagnosis: _____

Action(s) Taken: _____

Status / Recommendations: _____

Other Comments: _____

_____

_____

Reviewed By: _____

FIGURE 26-62 Oral mucosal and soft tissue evaluation form.

it should be re-evaluated with white-light examination and the findings from examination with both illumination sources (fluorescence and the broad-spectrum white light) should be compared. When an area of concern is being evaluated, several observations should be made and recorded (see sample soft tissue evaluation form [Figure 26-62]). Some of the basic questions the dentist should consider are as follows: Does the shape or size seem different when comparing the white-light versus the fluorescent image? How does the area respond to diascopic pressure (blanching)? Is it raised or flat? What is the surface texture? What do the borders of the area of concern look like? What is the shape of the area of concern? Where is it located in the oral cavity? Is it painful?

An extremely important part of this process is a focused dialogue between the clinician(s) and the patient on the history and possible solutions discussing the appropriate courses of action to manage the condition. This discussion needs to include the patient's systemic health history and present status, including medications—both those prescribed by all healthcare providers and any over-the-counter self-prescribed treatments and supplements. Also the delivery mechanism for these treatments, such as inhalers, dissolving in the oral cavity, elixirs, and rinses, needs to be considered.

Other adjunctive techniques may also be helpful when assessing the tissues of the oral cavity. There are minimally invasive technologies that can be used to explore an area of

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concern. Clinicians can brush the area and collect cells in a disaggregated form and then send the sample to a pathology lab for evaluation. This process is often referred as a *brush biopsy*—a somewhat inappropriate term. The more accurate description of the process is *transepithelial cytology collection;* the procedure is very similar to the Papanicolaou (Pap) test that has been used since the 1950s to assess the female cervix. The clinician collects the cells of the oral epithelium by repetitious brushing over the area of concern, collecting cells from all three layers of the oral epithelium, with the goal of harvesting cells all the way to and including the basement membrane. After the cells have been collected on the brush, either they can be smeared on a glass slide, followed by an application of a fixative to prepare the slide for viewing, or the cells can be suspended in a liquid solution that is sent to the oral pathology laboratory for processing. When the cells are placed in a solution, the process is referred to as *liquid cytology.* This procedure has been done in the cervical region for many years and is now routine for the cervical Pap test. With this method the cells in the liquid solution are placed in a cytospin and filtered to remove the debris and artifacts. The cells are then applied in a monolayer to a glass slide, stained, and slipcovered for the oral pathologist to read. Slides prepared in this manner present a better representative collection of lesional cells and allow for an easier interpretation because the monolayer of cells eliminates the blood and other obscuring debris. This can assist in decreasing the number of false-positive and false-negative findings when the cells are evaluated by the oral pathologist for atypical or abnormal cells.

Besides evaluating the collected material for cellular abnormalities, liquid cytology can be used to test for the presence of other conditions and organisms such as fungal infestations, herpetic viruses, the various genotypes of the human papillomavirus (HPV), and even DNA abnormalities with a ploidy analysis—the measurement of DNA content within the cells' nuclei.

Salivary evaluation and screening processes have also been developed to assist the dentist in non-invasively assessing a patient for the presence or risk of several oral conditions. These tests range from measuring the rate and type of salivary flow, to determining the presence, concentration, and types of bacteria responsible for both cariogenic and periodontal conditions, to establishing the presence of various viruses, as well the patient's genetic risk for various oral diseases.

An important consideration to remember for all the screening technologies is that they are not designed to be a definitive diagnostic modality. They are designed to assess a patient who is basically asymptomatic and assess the possible risks of having any disease process. The only way to confirm a condition, such as oral cancer, is with a surgical biopsy so the oral pathologist can look at the intact architecture and determine what cellular processes are present (Figure 26-63). The surgical biopsy of tissue with an intact architecture is the gold standard for diagnosing oral cancer, and all other processes and technologies are adjunctive modalities to supply additional information to assist in the diagnostic process.[6] Their role is to enable the accurate diagnosis as early as possible in the disease process. The role and the goals of a surgical biopsy are not necessarily to "confirm" a malignancy but rather to "rule out" a cancer or malignancy and then to establish a diagnosis for the disease or condition that is present.

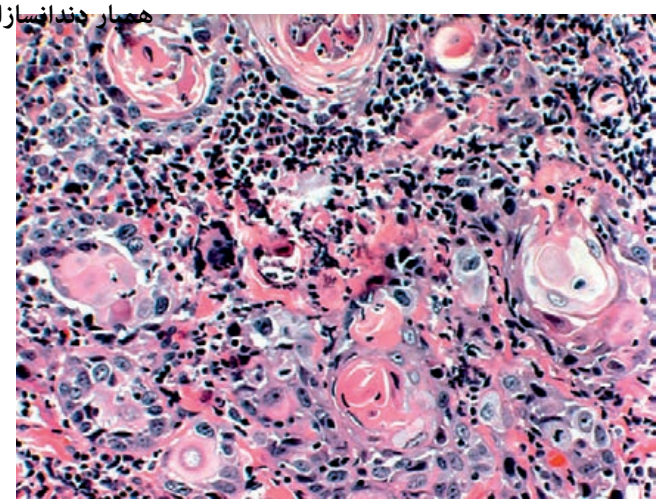


FIGURE 26-63 **Histological micrograph of a lesion that the oral pathologist diagnosed as a well-differentiated invasive squamous cell carcinoma.**

RELATING SOFT TISSUE SCREENING TO FUNCTION AND ESTHETICS

Dental clinicians design their cases to create a beautiful appearance for each patient—not just pretty teeth or esthetic looking teeth, but a very pleasant esthetic oral presentation. Without healthy soft tissue it is impossible to have healthy hard tissues, that is, the dentition and supporting structures. In addition, it is desirable to identify disease and stop it from becoming disfiguring to the patient's overall appearance. Just like everything else, the foundation of the healthy soft tissue and supporting structure environment is important. Clinicians assess whether tissues are symmetrical as they are supposed to be and maintain health within the proper context.

CLINICAL CONSIDERATIONS

A comprehensive enhanced mucosal examination should be done on all adult patients. The statistics on oral disease are quite alarming. Over the past few years the incidence of head and neck cancer has increased at the rate of approximately 10% per year.[7] Traditionally, most clinicians were taught that the causes of oral cancer and other mucosal abnormalities were tobacco and alcohol use combined with the aging process. Today, 25% of oral cancer cases involve people who do not have any of these traditional risk factors and instead are

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occurring in patients under age 40 years who are not regular users of tobacco. This is a fivefold increase in the last few decades in these types of patients.[8] The majority of these lesions occur in areas along the lateral border of the tongue and the floor of the mouth, from the ventral surface of the tongue and the soft palate complex. A 2002 study done by the Centers for Disease Control and Prevention showed that 25% of 15-year-olds had already engaged in conventional intercourse and/or oral sex. By age 19 years, that number had jumped to over 75%.[9] This trend is alarming because studies now show that there is a correlation between the presence of HPV and oral cancer as well as cervical cancer. Studies show that 70% of all cervical cancers are caused by the HPV genotype number 16 or 18. These correlations are being mirrored in the oral cavity. Studies from Johns Hopkins[10] and other places show this to be an area of concern. All adult patients are at risk, not just those who use tobacco and alcohol.

Oral cancer is the sixth most prevalent cancer globally, yet few people are aware of it. A survey done by the Mouth Cancer Foundation in 2008 in the United Kingdom showed that less than 50% of the people in the United Kingdom had even heard of oral cancer.[11] This is a frightening statistic and has significant implications for the dental profession. Oral healthcare professionals need to actively inform patients about their risks and to what they may be exposed. The use of an oral health risk factor questionnaire (Figure 26-64) is an excellent mechanism to obtain relevant information and facilitate a discussion between the patient and practitioner on potential risks and concerns.

A study published in a 2000 showed that less than 15% of the adults in the United States over age 40 years claimed to have had an oral cancer screening ever. Less than half of those had had it done in the previous 12 months.[12] These are disheartening statistics. The incidence of oral cancer is three times that of cervical cancer in North America.[13] The incidence of oral cancer in a female is almost identical to that of cervical cancer; with this in mind, a comprehensive oral examination at the dental hygiene visit is as important for a woman as a visit to her gynecologist. Men presently have twice the incidence of oral cancer as women, so for male patients the comprehensive oral evaluation is actually twice as important as it is for the female patient. Despite these facts, more women seek routine dental care and evaluation than men. The incidence and the 5-year survival rate of oral cancer have not significantly changed in many decades. The 5-year survival rate still hovers around 50% to 55%,[14] which is unacceptable. This high morbidity rate is related to late diagnosis. To ensure the patient's overall health and quality of life, clinicians must establish and maintain the health of all oral tissues and structures to ensure a good-looking, attractive, esthetic smile.

A visual and tactile oral cancer evaluation has no contraindications, although clinicians may err by stating that what they are doing is an oral cancer examination and inadvertently alarm their patients when there is any area of concern. Clinicians should tell patients that they are performing a comprehensive oral evaluation looking for everything from cavities to periodontal disease to a cheek bite to cancer. In doing this they will look at all of the structures in the oral cavity, not just the dentition. The value of stating it this way is that the word *cancer* is mentioned and patients understand that they are receiving an *enhanced comprehensive examination,* not just a cancer examination. The chances of finding cancer are very slim compared with those for other mucosal diseases. By telling patients it is comprehensive, the soft tissue evaluation is seen in the appropriate context. The patient now understands that the value of the dental appointment is to have not just the teeth taken care of, but the entire oral cavity. This is a significant message.

The implications of this are fairly intriguing, as the great majority of soft tissue abnormalities are not malignant or potentially malignant. A study presented at the American Dental Association annual session in 2001 focused on the oral evaluation of dentists and hygienists. Of the over 1000 dentists and hygienists, who in theory have the best quality of oral healthcare, 10% had had some sort of mucosal abnormality.[15] A research project based in the author's office retrospectively looked at a 2-year period. A total of 1317 patients had been examined, and 460—over a third—had had some sort of mucosal abnormality. Of those, there had been 21 dysplasias that had been confirmed with a surgical biopsy.[16] Dysplasia is a potentially malignant condition that has the ability to transform into cancer in about 25% to 35% of cases.[17] Being able to discover the disease or condition at an early stage allows clinicians and patients to take appropriate action early in the disease process and hopefully prevent progression into a more advanced stage that can involve surgically removing fairly large areas of tissue. Treatment may be a simple matter of changing controllable risk factors, informing the patient of risks, encouraging tobacco cessation, suggesting better dietary practices, and using increased surveillance and monitoring.

Properly performed noninvasive examinations have no contraindications or negative side effects, thus enabling a screening to be done on every adult patient at every hygiene visit. Individuals under age 18 years who engage in behaviors such as inner oral piercing, tobacco use, or recreational drug use should also undergo an enhanced comprehensive mucosal examination. In this situation it might be best if they are told that this is specifically an oral cancer examination to motivate them to stop unhealthy behaviors. The incidence of oral cancer today in people under age 18 years is very rare but not insignificant. Checking these young patients aids in controlling unhealthy behaviors and their progression into chronic habits. It is not only a diagnostic or screening process but also an educational process. Other patients under age 18 years who are of concern are those who have had any form of systemic neoplastic or cancerous lesions. A genetic predisposition makes them potentially more at risk for having oral malignancy. A thorough oral evaluation is done routinely to ensure that they are healthy. The goal of the cancer evaluation in the oral mucosal examination is to ensure health rather than discover disease. In the past, dentists waited until lesions were large, very visible, and very frank before intervening. The goal today is to find problems when they are minor, possibly only a

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Oral Health Risk Factors

Patient's Name:_____

1. **Do you smoke or have you EVER smoked?** **Yes** **No**
(If No, proceed to question 2)

The amount that you are presently smoking (Check ALL that apply)

___ None (quit smoking completely) ___ Less than 1 pack of cigarettes per day ___ An occasional cigar
___ An occasional cigarette ___ 1-2 Packs of cigarettes per day ___ Cigars on a daily/regular basis
___ A few cigarettes per day ___ 2 or more packs of cigarettes per day ___ Occasional pipe smoker
___ A pipe on a daily/regular basis

If you have quit smoking, when did you quit?

___ Less than 6 months ago ___ 6 months to a year ago ___1 to 3 years ago ___Over 3 years ago

How many years have you or did you smoke?

___ Less than 2 years ___2-5 years ___5-10 years ___ 10- 20 years ___ Over 20 years

2. **Do you/have you EVER chew/chewed tobacco or use/used snuff or other similar substance?** **Yes** **No**
(If No, proceed to question 3)

Are you STILL using smokeless tobacco or snuff? **Yes** **No**

If No, WHEN did you quit?

___ Less than 6 months ago ___ 6 months to a year ago ___ 1 to 3 years ago ___Over 3 years ago

How many years did you use or have you used smokeless tobacco?

___ Less than 1 year ___1-2 years ___ 2-5 years ___ Over 5 years

3. **Approximate average amount of alcoholic beverages presently consumed per week:**

___ None ___ Less than 1 per week ___ 1-5 drinks ___ 6-11 drinks ___11- 20 drinks ___Over 20 drinks

4. **Do you have or have you ever had a substance abuse problem?** **Yes** **No**

Describe _____

5. **Do you presently use any recreational drugs?** **Yes** **No**

List _____

6. **Do you have or have you ever had an eating disorder?** **Yes** **No**

If Yes, Please Specify: _____

7. **Do you have or have you ever had any head, neck or mouth piercing(s)?** (Other than ears) **Yes** **No**

List _____

8. **Do you have or have you ever been informed that you have been infected with an oncogenic strain (possible cancer-causing) of the Human Papilloma Virus (HPV)?** **Yes** **No**

9. **Please list your history or any family member's history of cancer :**

_____

10. **Other concerns and considerations:**

_____

CONSENT—To the best of my knowledge, all of the preceding information is correct and if there is ever any change in health or medications, this practice will be informed of the changes without fail. I also consent to allow this practice to contact any healthcare provider(s) and to have the patient's health information released to aid in care and treatment. I also hereby consent to allow diagnosis, proper health care and treatment to be performed by this practice for the above namedindivi dual until further notice. I understand there are no guarantees or warranties in health or dental care

Signature _____ Date _____
(Parent or guardian, if patient is a minor)

Reviewed By: _____

FIGURE 26-64 Oral health risk factors form.

millimeter or so in diameter and restricted to a few cells. If the dentist can identify lesions at an early stage and manage them, he or she can make a significant difference in the disease process. A patient does not go to bed at night healthy and wake up in the morning with cancer. It is an ongoing disease process. The ultimate in esthetics is establishing overall health for the patient.

MATERIAL OPTIONS

The options available today include an aceto-whitening process (e.g., ViziLite Plus [Zila Inc., Fort Collins, Colorado], Microlux/DL, Orascoptic DK [Orascoptic, Middleton, Wisconsin]) in which the patient uses an acetic acid mouthrinse to make white lesions slightly more visible. However, the

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aceto-whitening process does not help detect an erythroplakia (a red lesion). Although all lesions are of concern, only a small percentage of white lesions will progress into a dysplasia or a malignancy. However, 80% of erythroplakias are predisposed to becoming dysplastic. Thus the lesions of most concern are the red lesions, which are not well picked up by the aceto-whitening process.

An improved adjunctive approach for assessing the tissues is the use of the tissue's auto-fluorescence properties by means of what is referred to as *fluorescence visualization technology* (VELscope, Identafi [DentalEZ Group, Malvern, Pennsylvania], and DentLight Dental Oral Exam [DOE] System [DentLight, Inc., Richardson, Texas]). With auto-fluorescence the excitation light energy penetrates into the tissue; the tissue converts the energy from the excitation light and emits the light from the tissue at different wavelengths. The light emitted is created by the tissue itself from the energy it absorbed; the change in the wavelength from that of the light that is absorbed to the longer-wavelength light that is created by the tissue is called a *Stokes shift.* The wavelength of the emitted light created by the tissue is determined by the chemical and morphological composition of the fluorophores within the tissue itself.[5] A fluorophore is an absorber of light that uses that light energy to create a light of a different wavelength.[18]

The operator uses the device to excite the tissue with a high-intensity blue light of a narrow-band wavelength. The light emitted by the tissue goes through a series of filters to help discriminate between healthy and abnormal tissue. This yields the best overall field-of-view perspective. If a sensitivity, an area of concern, is discovered, it can be more thoroughly evaluated. Site-specific observations and technologies are employed and recorded (see Figure 26-62). How does it feel under a tactile examination? How does it appear under a white-light examination? How does it look under a fluorescent examination? Things to consider are surface texture and how the borders appear: Are they well defined? Are they diffuse? Regular in shape? In inflammatory responses, the collection of blood in one area tends to have an oval pattern. Dysplastic changes tend to have an irregular shape. Is the area bilateral or unilateral? These are all issues that must be considered.

Using fluorescence technology is part of a multimodal examination process. The clinician needs to combine all the information available to determine what the next course of action should be. It might be appropriate to simply keep the tissue under surveillance with watchful waiting. It also may be appropriate to take some corrective measure and observe the area for a specified period of time or even immediately obtain a sample of the tissue and send it for a histologic analysis. Epithelial tissue on the average takes 21 days for a cell to form and to be exfoliated into the oral cavity. By re-evaluating the patient in 2 to 3 weeks, the clinician should detect changes that indicate if it is a reactive or traumatic lesion that has improved. If there is no improvement, some other disease process may be going on and a surgical biopsy may be needed. It is a matter of seeing what options are available and managing a case as appropriate. It is important to view things in context, as part of the evaluation, and not take any one of these processes alone. The tactile examination, the white-light examination, and the fluorescence examination all work together. None of them should be taken as a stand-alone procedure.

OTHER CONSIDERATIONS

Clinicians must consider the patient's risk factors. Has the patient ever smoked or used other forms of tobacco? How much? How long? Does he or she have an occasional alcoholic beverage? What is his or her alcohol consumption? Has the patient ever been told that he or she is carrying an oncogenic strain of the HPV virus? Years in the future, dentists will have to ask whether the patient has been vaccinated for HPV. The HPV vaccine on the market will help vaccinated young people in the future but has no benefit for adults who did not have the opportunity to be vaccinated before exposure to the HPV strains it covers. Dentists must also consider other aspects (Figures 26-64 to 26-66): What are the patient's occupational risks? What are his or her systemic health and pharmacological background? Is the patient taking medications that can cause this condition? Is there an immunocompromise concern? All of these are part of assessing the patient's overall well-being.

INNOVATIVE ELEMENTS

Tissue auto-fluorescence is the most innovative technology currently available. With auto-fluorescence the clinician uses light energy to stimulate the tissue. In using lasers the primary targets are chromophores, which are substances that absorb the light energy. With auto-fluorescence the target are fluorophores, which are substances that absorb light energy and emit light back out in return. The purpose is to look at the concentration of the fluorophores in the tissue and how they relate. The common fluorophore in relation to the oral epithelium is flavin adenine dinucleotide (FAD), which is a component of the mitochondria and is in the cytoplasm of the cell. As a condition progresses to a neoplastic state, there is a change in the cytoplasmic to nuclear relationship. Mitochondria decrease along with a decrease in the percentage of FAD contained in the cell and a loss of fluorescence.[18] Also, a large amount of the tissue's fluorescence also comes from below the basement membrane in the stroma from the collagen, in particular the elastin and the cross-links that bind the collagen together. When neoplastic activity begins, there is a breakdown of that collagen matrix and an increase in metabolic activity. These changes cause a significant decrease in the natural fluorescence of the tissue, and it appears darker because of this loss in fluorescence. This is evidence of abnormal metabolic processes. One of the other elements or substances that fluoresce is fibrin, a clot fiber that develops during healing after biopsy or in aphthous ulcer, for example. A fibrin clot will fluoresce very strongly, as will a salivary stone and keratin. These substances will have a gain in fluorescence that

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Health Information and History

Today's Date: _____

Patient's Name: _____ **Date of Birth:** _____

If you are completing this form for another person:

Your name: _____ Phone: _____ Relationship: _____

Emergency Contact: (If not listed above)

Name: _____ Phone: _____ Relationship: _____

Primary Physician: _____ Phone: _____ City & State: _____

Date of last physical examination: _____ Date of last blood test/work-up: _____

Other Physicians and Specialists

Name: _____ Specialty: _____ Phone: _____ City & State: _____

Name: _____ Specialty: _____ Phone: _____ City & State: _____

1. With in the last 3 years, have you been hospitalized or had surgery? ☐ **Yes** ☐ **No**

If Yes, please give reasons and dates: _____

2. Have you ever been instructed to take ANY medications or take ANY special precautions before any dental appointments*? ☐ **Yes** ☐ **No**

If Yes, please explain: _____

3. Are you taking ANY drugs, medications, or treatments at this time? ☐ **Yes** ☐ **No**

(If you brought a complete written list with you, give that to the receptionist instead)

Prescribed: _____

_____

Over-the-counter (OTC) medications (such as Aspirin, Advil, allergy medication, sleeping aids, etc):

_____

Vitamins, natural or herbal preparations and/or dietary supplements:

_____

Are you having or have you ever had radiation or chemotherapy treatments*? ☐ **Yes** ☐ **No**

If Yes, for how long? _____ Name of facility performing the treatment : _____

4. Are you taking or have you ever taken / been treated with a Bisphosphonate (Fosamax)? ☐ **Yes** ☐ **No**

5. Are you allergic to or have you ever experienced an unusual reaction to:

___ Latex ___ Metals or jewelry ___ Dental anesthesia (local)

___ Fluoride ___ Nitrous oxide (laughing gas) ___ General anesthesia

6. Are you allergic to or have you ever had any reaction to any of the following drugs?

___ Penicillin (or related drugs) ___ Tranquilizers (Valium) ___ Tetracycline ___ Codeine

___ Aspirin / Ibuprofen (Advil, Motrin, Nuprin) ___ Keflex (Cephalexin) ___ Sulfa drugs ___ Iodine

___ NSAID (Celebrex, Vioxx, Anaprox) ___ Clindamycin (Cleocin) ___ Erythromycin

7. Have you had an allergic reaction or unusual response to ANY other medications, drugs, pills, or treatments? ☐ **Yes** ☐ **No**

If Yes, please list : _____

Continued on next page...

Reviewed By: _____

FIGURE 26-65 Health information and history form.

makes them look significantly brighter (Figures 26-67 to 26-69). The presence of a combination of substances that fluoresce and adding in others that will absorb the light, such as hemoglobin, oxyhemoglobin, and melanin, produce the fluorescent response that is observed by the clinician. Seeing and understanding the normal anatomical variances are extremely important. If the observed tissue does not respond with a normal appearance, an abnormal process is going on. The fluorescence pattern observed may be categorized in several different ways. One would be the normal fluorescence pattern, a second would a loss of fluorescence, a third would a loss of fluorescence that returns to a normal pattern under diascopic pressure, and another would be a gain in fluorescence that is observed with an increase in keratin or the presence of fibrin (Box 26-1). Further evaluation should be performed whenever there is a fluorescence response that is not normal in the tissue that is being examined, and appropriate corrective action or management should be undertaken by the clinician.

TREATMENT PLANNING

The comprehensive oral soft tissue evaluation should be done as part of every examination in the office. When the patient comes in for an initial consultation and work-up, this should be the

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Health Information and History (continued)

Patient's Name: _____

8. Do you have, or have you ever had, any of the following? (Please check Yes or No for each question)

	Yes	No		Yes	No
Congenital heart defects	___	___	Asthma	___	___
Angina or chest pains	___	___	Hay fever, skin or food allergies	___	___
Atherosclerosis	___	___	or allergies in general		
Congestive heart failure	___	___	Sinus problems	___	___
Coronary artery disease	___	___	Tuberculosis, emphysema or lung disorder	___	___
Heart surgery	___	___	Skin problems	___	___
If Yes, type and date _____			A sore or wound that bleeds easily	___	___
Heart attack	___	___	or does not heal		
If Yes, date _____			A thyroid problem or disease	___	___
Rheumatic heart disease / rheumatic fever	___	___	Arthritis	___	___
Infective Endocarditis*	___	___	Glaucoma or any eye diseases	___	___
Heart valve(s) damage / Mitral valve prolapse	___	___	Epilepsy or other seizure disorder	___	___
Artificial heart valve	___	___	Any kidney problems	___	___
Pacemaker	___	___	Ulcers, acid reflux, or stomach problems	___	___
Stroke or CVA	___	___	A compromised immune system	___	___
High blood pressure	___	___	(lupus, HIV, AIDS, radiation immune problem, etc.)		
Low blood pressure	___	___	An active sexually transmitted disease (STD)	___	___
Anemia	___	___	Any mental health issues	___	___
Hemophilia or bleeding disorder	___	___	Been treated for any psychiatric condition	___	___
Excessive bleeding from any cut or incident	___	___			
Diabetes or blood sugar problems	___	___	**Women Only:**	**Yes**	**No**
Any artificial joint, joint surgery, or prosthesis	___	___	Are you pregnant?	___	___
If Yes, what joint or area? _____			If Yes, what is your due date? _____		
When was operation done? _____			Do you think you might be pregnant?	___	___
Hepatitis, jaundice, or other liver problems	___	___	Are you presently nursing?	___	___
Any form of cancer	___	___	Are you using birth control medication?	___	___
An organ transplant	___	___	Are you taking hormone replacement therapy?	___	___

9. Do you have any other conditions, diseases, or medical problems, or is there ANY other information that you would like us to know about, or that we should be made aware of? ☐ **Yes** ☐ **No**

If Yes, please explain: _____

_____

_____

CONSENT — To the best of my knowledge, all of the preceding information is correct and if there is ever any change in health or medications, this practice will be informed of the changes without fail. I also consent to allow this practice to contact any healthcare provider(s) and to have the patient's health information released to aid in care and treatment. I also hereby consent to allow diagnosis, proper health care and treatment to be performed by this practice for the above named individual until further notice.

I understand there are no guarantees or warranties in health or dental care.

Signature _____ Date _____

(Parent or guardian, if patient is a minor)

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FIGURE 26-65, cont'd

foundation for all treatment. Once the case is completed and the patient established, the patient will be seen at ongoing recare appointments. Continuous surveillance of the mucosa is extremely important. As part of the process of life, human bodies undergo changes. A major part of treatment planning and case presentation is understanding the role these changes may play. If patients exhibit some sort of hypersensitivity to certain materials or xerostomia, it may exert a strong effect on treatment planning. An important concern is how the patient will be able to maintain the dentition and oral cavity after treatment. Those types of considerations are extremely important, requiring careful patient education.

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Dental and Oral Health Information

Patient's name: _____ **Date:** _____

Please describe any specific dental problem or discomfort you are having at this time: _____

_____ How long has it been present? _____

If you have had any of the following dental care please list the dentists and approximate dates:

Periodontal (gum) treatment or surgery: _____

"Braces" or any type of orthodontic treatment: _____

Dental implants: _____

Any other type of oral surgery: _____

Do you have/have you had/have you noticed any of the following signs or symptoms in your head, neck, or mouth?

(Please check Yes or No for each question)	**Yes**	**No**		**Yes**	**No**
Teeth that are sensitive to:			A clicking, snapping or difficulty when chewing	___	___
Hot, cold, sweets, or biting pressure	___	___	Difficulty opening or moving the jaws	___	___
An unpleasant taste or persistent bad breath	___	___	Difficulty speaking or changes in your voice	___	___
Does food catch between your teeth	___	___	Difficulty moving your tongue or "tongue tied"	___	___
Do your gums bleed when brushing	___	___	Loose or separating teeth	___	___
Red, swollen, tender, bleeding, or sore gums	___	___	Changes in the way your teeth fit together	___	___
Gums that have pulled away from the teeth	___	___	A color change of the tissues in your mouth	___	___
Pus between the teeth and gums	___	___	Pain, tenderness, numbness, or earaches	___	___
Avoid any area when brushing or chewing	___	___	Any lumps, swelling or swollen glands	___	___
You clench or grind your teeth	___	___	Sores, ulcers, or rough spots in your mouth	___	___

Your Dental Health:

How do you rate your overall dental health? **Good** **Fair** **Poor**

How many times a day do you brush your teeth? _____ **How many times a week do you floss your teeth?** _____

Do you use any of the following? (Please check Yes or No for each question)	**Yes**	**No**
Mechanical (electric) toothbrush If Yes, what type or brand? _____	___	___
Flossing aids (floss holders, threaders, etc.)	___	___
Oral irrigating device (Waterpik)	___	___
Fluoride treatments or supplements at home. If Yes, which ones: _____	___	___
Mouthwashes or oral rinses. If Yes, what brand? _____	___	___
Do you have any missing teeth that have not been replaced?	___	___
Why have you not had them replaced? _____		
Do you wear any removable dental appliances?	___	___
If Yes, what type and for how long? _____		
Have you ever had your teeth whitened or bleached?	___	___
Would you like to have your teeth whitened or bleached?		

How do you feel about the appearance of your smile and what would you change if you could?

_____

Are you concerned about the finances required to return your mouth to excellent health?	___	___
Are you frustrated because you always need something treated or repaired when you visit a dentist?	___	___
Do you feel you will eventually wear artificial dentures?	___	___
Have you ever had any complications from an extraction or dental treatment?	___	___
If Yes, please explain: _____		
Have you ever had any other dental conditions, major trauma or injury to your head, neck, or mouth?	___	___
If Yes, please specify: _____		

If you are a new patient to this practice:

Date of last dental visit _____ Dentist's name _____ City and State _____

Reviewed By: _____

FIGURE 26-66 Dental and oral health information form.

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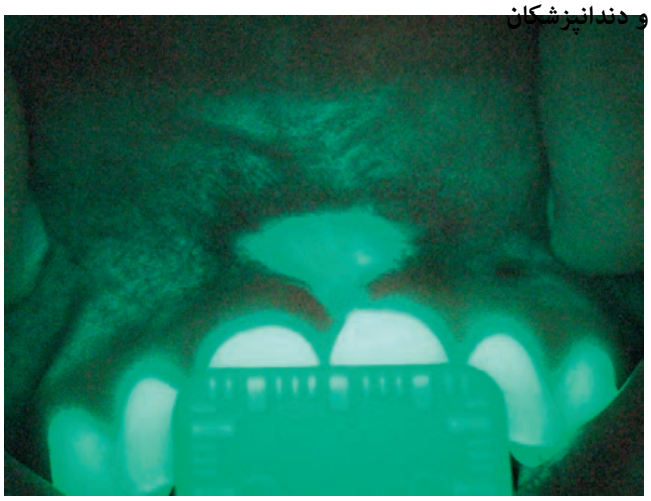


FIGURE 26-67 Fluorescence image of a fibrin clot. Note the strong gain (increase) in the fluorescence of the fibrin formed as the area heals from a frenectomy surgical procedure. Also note the strong fluorescence response from the dentition.

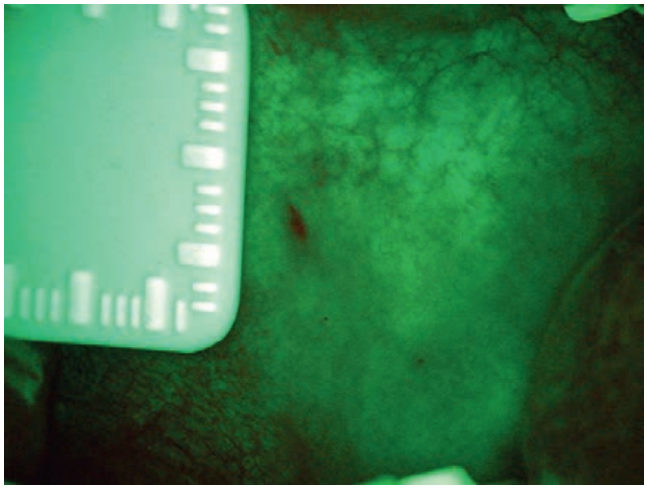


FIGURE 26-68 Fluorescence image of a small salivary stone. Note the gain in fluorescence of the stone, with its brighter appearance compared with the surrounding tissue.

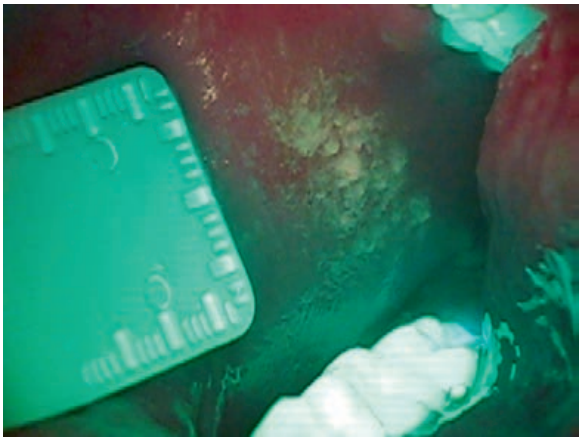


FIGURE 26-69 Fluorescence image of hyperkeratosis of the buccal mucosa. Again, note the gain in the fluorescence when compared with the surrounding tissue.

BOX 26.1 Descriptors of Fluorescence Tissue Response

Retained fluorescence—Tissue has a normal fluorescence appearance.
Loss of fluorescence—Tissue appears darker because of changes in the chemical and morphological composition, indicating the possibility that an abnormal situation may be present.
Diascopic fluorescence—Tissue appears to have a loss of fluorescence but returns to normal fluorescence on diascopic pressure. (Often referred to as *blanching*.) May indicate that an inflammatory process is present.
Gain in fluorescence—Tissue appears brighter than normal because of an increase in the amount of fluorophores that are present with the tissue.
Porphyrin fluorescence—Appearance of a reddish orange glow from porphyrin; indicates an increase in bacterial activity.

TREATMENT CONSIDERATIONS

For an esthetic case it is important to consider whether the soft tissue has any complications that will alter the treatment plan. Over 400 medications cause xerostomia[19] or decreased salivary function. Such a decrease is strongly associated with serious abnormalities of both the soft tissue and the dentition. Problems with the dentition and the periodontium must be understood and corrected or altered where appropriate. Part of long-term treatment planning includes considering what happens if the patient's condition progresses. Beta-blockers can have an effect on some patients' gingival component, restorations, and esthetic results. Managing these concerns becomes crucial. The overall health of the soft tissue must be a strong component in the treatment considerations for the patient.

PROCEDURAL STEPS TO A COMPREHENSIVE ORAL SOFT TISSUE EXAMINATION

The sequence of events in a soft tissue examination is quite simple. Clinicians are trained to do this as part of routine dentistry (Box 26-2). First, the patient is informed that he or she is receiving a thorough oral examination and oral health assessment, including a comprehensive oral mucosal and soft tissue examination. This demonstrates that the practitioner is concerned about the patient's overall well-being and that the patient is not there for "just a cleaning" but is having more than just the teeth evaluated. The patient is informed that the dentist is looking for everything from a cheek bite to cancer.

Second, the clinician reviews the patient's overall systemic condition, looking for any disease processes or conditions that

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BOX 26.2 Ten Steps of an Oral Mucosal Examination

1. Inform the patient that he or she is receiving a thorough oral examination and oral health assessment, including a comprehensive oral mucosal and soft tissue examination.
   - It shows that the practice cares about their patients' well-being.
   - Inform the patient that you are looking for everything from a cheek bite to cancer.
   - Assures patients that they are receiving the best possible overall oral health care.
   - It's not "just a cleaning"!
2. Comprehensively review the patient's medical, pharmacologic, and dental history.
   - Past history of cancer, dermatologic or mucosal abnormities in the patient and his or her family.
   - Present medical conditions and treatments.
   - Medications.
   - Dental and other oral habits.
     - Bruxism, cheek biting, gum chewing, finger habits, and so on
   - Discuss tobacco and alcohol use along with social habits and history.
3. Perform visual examination and assessment of the face, head, and neck.
   - Look for lumps, bumps, patches, color changes, asymmetry, and so on.
4. Perform extra-oral tactile examination (palpation) of the head and neck.
   - Look for abnormal lumps, bumps, nodules, and bilateral symmetry.
5. Perform intra-oral and transoral tactile examination (palpation) of hard and soft tissue.
   - Look for abnormal lumps, bumps, nodules, and bilateral symmetry.
6. Perform visual examination of intra-oral structures with magnification.
   - Pay particular attention to the high-risk areas:
     - Lower lip
     - Ventrolateral tongue
     - Floor of the mouth
     - Soft palate complex
       - Lingual retromolar trigone, anterior tonsillar pillar, soft palate proper, uvula
   - Look for:
     - Induration—Abnormal hardness of a lesion or area on palpation
     - Ulceration—Loss of continuity of the mucosal or any soft tissue
     - Fungation—Verrucous, cauliflower-like surface
     - Elevation—Part of lesion is raised above the normal level of the surrounding tissue
     - Enlargement—Areas of increased size, especially when compared with contralateral side
     - Fixation—Attachment of normally mobile tissues to underlying structures with loss of mobility
     - *Any* changes from normal tissue
       - Especially red areas and red and white patches
       - Changes in surface texture
7. Perform visual intra-oral examination with fluorescence visualization.
   - Repeat previously described visual examination of intraoral structures using the VELscope.
8. Perform photographic documentation of any areas of concern.
   - Both with visible light and with fluorescence visualization.
9. Record and document all findings.
   - Record that no areas of concern were observed ("within normal limits" [WNL]) if appropriate.
   - If an area is discovered, the "Oral Mucosal and Soft Tissue Evaluation Form" and "Oral Schematics Form" can be used or referred to for assistance.
10. Inform the patient of all findings and the recommended course of action.
    - State that no areas of concern were observed (WNL) if appropriate.
    - If an area of concern is noted:
      - Seek a probable cause and treat or manage appropriately:
        - Traumatic or irritational, infectious, developmental, nutritional, caused by systemic disease, or unknown cause
      - If only of mild concern:
        - Encourage removal of all potential causes of the lesion and schedule a recall appointment for re-evaluation in 2 weeks.
        - Consider using adjunctive techniques such as a transepithelial (brush) biopsy.
      - If particularly concerned by the lesion's appearance or growth behavior:
        - Perform full-thickness scalpel biopsy or refer patient for a biopsy.
          - Recommended follow-up
          - Patient instructions

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may have oral consequences or affect any treatment outcomes. This includes evaluating all medications being taken or treatments being received that may have oral manifestations. Several computer programs, such as Lexi-Comp drug interaction software, are available to assist the clinician in deciphering the myriad medications that many patients are taking today. Many of today's medications have a significant effect on the oral cavity as well as the treatments that dentists are performing. This evaluation also includes a review of the patient's dental history and oral habits. Is there a history of dry mouth? Have apical amalgams been placed? Are there any dental situations, concerns, or problems present?

Third, once the medical and dental history has been reviewed, a visual extra-oral assessment of the patient is performed. This begins with looking at the patient's face, head, and neck. If the patient is wearing glasses, they are removed so the clinician can look for facial asymmetry and other problems that they may be covering up. This goes along with the basic principles for any esthetic case and includes patient color and the patient's external appearance.

Fourth, an extra-oral tactile examination is done. The clinician palpates the tissue and lymph node areas from the clavicle to the occipital regions, looking for an enlarged node or any other abnormalities—anything that is atypical.

Fifth, after the external palpation, a transoral and intra-oral palpation is done by compressing the tissues between the clinician's fingers or against the osseous structure. After a quick cursory examination of the oral cavity, the soft tissues of the cheek are squeezed between the fingers. After looking to see any abnormalities, such as blocked salivary glands, lumps, or bumps, the dentist palpates the floor and roof of the mouth and the alveolar ridge, trying to identify anything that feels abnormal.

Sixth is a comprehensive visible white-light examination. All examinations should be done with the highest magnification the clinician is comfortable wearing. As with all examinations, it should be performed in a consistent systematic manner to help ensure that all the oral structures are thoroughly evaluated. For efficiency, the visible white-light examination may start with the patient still reclined in the supine position after the completion of the intra-oral tactile examination. As mentioned, the clinician should use magnification and proceed systematically, starting in a region and working through the entire oral cavity. An important component is the use of a 2×2 gauze to hold the tongue and pull it out as far as possible so the posterior region and base of the tongue can be inspected. This is extremely important, as it is the area of the oral cavity most prone to developing a malignancy. At the end of the white-light examination the patient needs to be placed in an upright sitting position for inspection of the oropharyngeal region. This area is very difficult to examine with the patient in a reclining position, as the tongue will tend to fall back and block this area. Many clinicians have great difficulty seeing the oropharyngeal region through magnification and will look over their magnification or remove it to inspect this area. Having the patient stick out the tongue and say "Ah" helps visualize much of the oropharynx and tonsillar region.

Seventh, once the white-light examination has been completed, the fluorescence visualization examination is performed. Again, this examination should begin with the patient in the same position as at the end of the visible white-light examination, for efficiency and to enable a comparison of the white-light to the fluorescence findings if an area of concern is detected. With these concepts in mind the oropharyngeal and tonsillar region that was just inspected should be reexamined first in the fluorescence examination. If everything appears normal, the patient is returned to a reclining position and the entire visual examination is repeated using fluorescent visualization. The clinician then uses the fluorescence device to reexamine the entire oral cavity for anything that appears out of context. If something does not appear normal with fluorescence it should be reexamined with visible white light and the findings compared to assist in determining the proper course of action.

Eighth, if an area of concern warrants further care or monitoring, it should be photographed under both fluorescence and white light as a benchmark of the patient's condition, enabling monitoring and comparison of the progression or regression of the disease process. This photo-documentation also helps in communicating with specialists, pathology labs, and any interested third party. Photo-documentation is also an invaluable tool for educating and discussing the findings and appropriate course of action with the patient. Whenever possible when photographing a soft tissue lesion, the clinician should try to include a measuring device (see Figures 26-67 to 26-69) and a distinguishable anatomical area for reference. The "Oral Mucosal Soft Tissue Evaluation Form" (see Figure 26-62) and "Dental and Oral Health Form" (see Figure 26-66) can be used to assist in identifying the lesion's location.

Ninth, documenting the findings is an integral part of the examination process. It is extremely important for medical-legal reasons that all of the examination findings be recorded in the patient's clinical record. An electronic health record helps facilitate the documentation and communication of the findings, allowing the clinician to be very specific concerning the findings and technologies used. If an area of concern is discovered, the potential cause—such as traumatic, infectious, developmental, or nutritional; caused by systemic disease; or unknown cause—should be noted. Also, the recommended course of action also needs to be charted in the patient's clinical record. If a biopsy is recommended or required and the clinician is not going to perform it personally, it is still the practitioner's responsibility to make sure that all necessary recommendations have been followed by the patient. If an area is discovered, the "Oral Mucosal Soft Tissue Evaluation Form" (see Figure 26-62) and "Dental and Oral Health Form" (see Figure 26-66) can be used or referred to for assistance.

If the examination reveals that everything is healthy and appears within normal limits, it should also be noted in the patient's record.

Tenth and last, it is very important to inform and discuss with the patient all of the findings and the appropriate course of action and postoperative instructions. If all of the structures appear to be healthy and within normal limits, the patient should also be informed of that finding. If an area of concern is noted, the clinician should seek out and question the patient for a probable cause and treat or manage it appropriately. If an area

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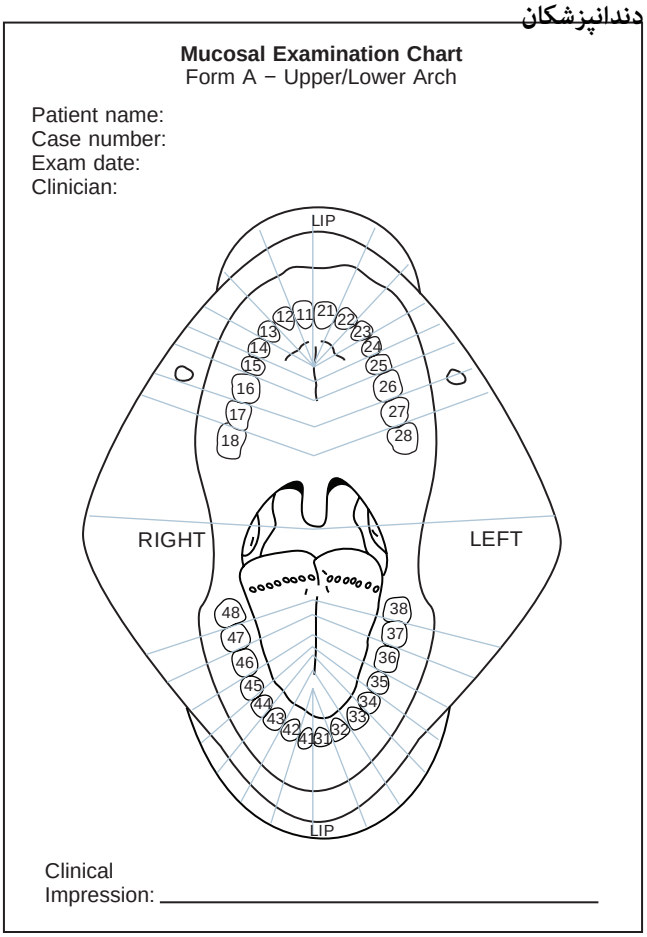


FIGURE 26-70 Oral cavity mucosal recording schematic.

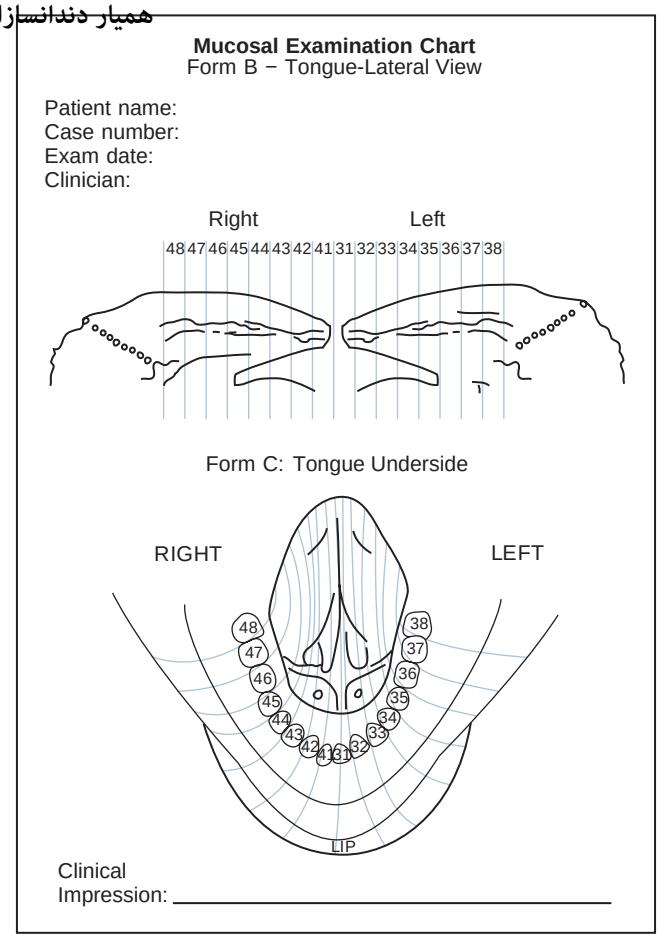


FIGURE 26-71 Tongue and floor of mouth recording schematic.

is detected but it is not of particular concern, encourage removal of all potential causes of the lesion and schedule a re-care appointment for re-evaluation in two weeks to ensure that it has resolved as expected.

These procedures should be part of every examination appointment.

EVIDENCE-BASED PRINCIPLES

The visual examination is the oldest examination in the history of medicine. More enhanced examinations, the enhanced fluorescence evaluation, are supported by over $60 million of research medicine. This technology not only is used in the oral cavity but has been used in the lungs and various other body areas. In 2005 the American Association for Cancer Research gave a scholar award for the research done to help surgeons delineate the extent of a disease process with this device.[20] Many peer-reviewed medical journal articles document the value of fluorescence in the oral cavity. Most research on auto-fluorescence has been in the medical literature versus the dental literature, so many dental clinicians have not been exposed to it. Clinicians should be encouraged to share this information with their medical counterparts. They can become an excellent referral source and can better understand that dental professionals are an integral part of the medical community and that esthetic procedures have more value than just creating a beautiful smile.

CLINICAL CONSERVATION CONCEPTS

The value of the soft tissue examination is that it is completely noninvasive so there are no harmful side effects, unlike a radiographic examination, in which the patient is exposed to ionizing radiation. In a comprehensive oral mucosal evaluation the dentist is using 100% safe, noninvasive technologies. The blue light being emitted by the VELscope is simply a 420-nm wavelength, which is in the middle of the visible blue light spectrum so there are no mutagenic effects. There are no harmful side effects so there is no reason not to perform this examination on every patient.

The value of soft tissue screening in terms of early interception of a disease is that the disease management becomes tremendously simplified. Trying to control and treat a condition

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when it is in its early stages and not widespread throughout or across regions helps the patient maintain a level of comfort and quality of life. By finding a dysplastic lesion in its earliest possible stages, treatment is easier on the patient with better outcomes. In theory, cancer is caused by irritations and stimulants causing an inappropriate turnover of cells. If areas that could be causing problems for the patient can be identified and corrected, it might be possible to handle or control disease progression. This yields a better quality of life for patients. If the patient has a history of oral cancer or oral dysplasia, a comprehensive fluorescence evaluation should be done at every appointment even if the patient was just seen 2 weeks earlier. By keeping these patients under appropriate surveillance, it is possible to better control disease progression and improve outcomes.

MAINTENANCE

The maintenance of the technology includes infection control considerations, which for most diagnostic technologies are either disposable or are identical to those for other dental instrumentation such as composite curing lights. Maintenance of the VELscope and the DentLight DOE System, for example, is minimal to none. However, as with all dental equipment and instrumentation, the devices must be properly handled and kept in good repair.

CONTROVERSIES

There is no controversy concerning the value of soft tissue screening. The biggest controversy is in determining the next step for patients with a diagnosed dysplasia. It is believed that 25% to 35% of dysplasias may progress to cancer over time.[23] The controversy is whether they should be excised, oblated, or just watched. The other controversy is whether the grading system of the dysplastic lesion truly reflects how the disease will progress. These are more often medical than dental issues.

NEAR-FUTURE DEVELOPMENTS

Some of the near-future developments will involve how to improve detection and photo-documentation. In addition to the fluorescence technology of the VELscope, other field-of-view and site-specific screening modalities such as enhanced salivary diagnostics, optical coherent tomography (OCT), and point spectroscopy are among some of the technologies that are presently being developed. Many of these technologies are being designed to enable detection without surgical intervention. With all screening technologies the goal is to identify the disease process as early as possible and to intervene appropriately, ensuring that cases needing surgical biopsy are sent for that process. On the flip side, dentists want to be able to identify areas that do not need biopsy and appropriately manage those also. The rule is to not ever rule anything out.

Among the advancements is diagnostic software that guides the clinician to ask appropriate questions and make appropriate choices when information has been obtained. This includes the specific words to use to describe the lesion and images of the lesion or area of concern. The description is run through an algorithm to determine the most appropriate way to proceed and what clinical signs and symptoms to look for, and the potential causes. These technologies are being developed now and will hopefully be available in the near future.

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Minimally Invasive Implant Esthetics

Joe L. Carrick

RELEVANCE OF MINIMALLY INVASIVE IMPLANT STABILIZATION TO ESTHETIC DENTISTRY

All cosmetic principles are based on the tooth setup. With dentures, because of the loss of bone, the teeth must be placed close to the residual ridge to create a stable prosthesis. This often means they cannot be placed in an esthetic position. If, however, these dentures are supported and stabilized with implants, then the teeth can be placed in a more ideal position to achieve the desired esthetic look. Not only is the smile improved, but the lower third of the face is redeveloped from the extreme collapse of the vertical dimension. This approach contributes to the esthetics of the teeth that create the desired smile and facial proportions.

Effect on Facial Proportions

The nose and the chin begin to approximate one another because of the loss of vertical dimension. When the teeth are placed back to where they were before bone loss and once stability is achieved via implants, the facial proportions become more normal. With a typical denture look as a result of significant lost vertical dimension of occlusion, the nose becomes larger proportionate to the face. Reestablishing the proportion between the nose and other structures actually recreates the lost vertical dimension, giving the patient a proportional lower third of the face relative to the nose, eyes, and so on.

Forces Placed on the Jaws and Restorations

In proper position, the front teeth can be compared with the wheel of a wheelbarrow and the condyles act as the handles of the wheelbarrow. When vertical dimension is lost, it is akin to a flat front tire on the wheelbarrow, which puts extra strain and stress on the condyles, creating reduced function and increased muscle fatigue. Reestablishing the vertical dimension and putting the teeth where they are supposed to be reestablishes the condyle in proper position in relation to the base of the skull, thus allowing the muscles of mastication to function more ideally.

The patient with a conventional denture is able to generate only a fraction of the biting force of the patient with his or her own teeth. Through use of small implants for stabilization of the denture, patients gain a significant increase in function. The denture is stable, no longer moving, and no longer relying on the tissue for support. This approach achieves greater function, yields better esthetics, and in many cases positively affects phonetics.

Opening of the Vertical Dimension

The face of the patient whose nose and chin look like they are about to touch has the appearance of a chronic frown when viewed straight on. The corners of the mouth turn down because of the position of the mandible in relation to the maxilla as a result of significant bone loss. If the denture can be stabilized with implants, it is no longer necessary to rely on tooth position to create stability. The implants allow the teeth to be set in a more ideal position to reestablish the patient's appearance, eliminating the frown look because the denture is supported by the implants. This also places the teeth so that they support the lip, rather than the lips supporting themselves. Denture patients may look as though they have a wad of tobacco underneath their lower lip because the upper lip is supporting the lower lip and causes it to curl. These people also experience communication problems beyond esthetics. In addition, there is a quality-of-life issue. The first impression they project is that they are unhappy people because of their facial appearance. Once these structures return to a position in which the teeth are in the right place, the lips are supported, the frown look is gone, the lower third of the face is reestablished, and the phonetics are cleaned up. Everything returns to a more ideal functional and esthetic state.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT OF MINIMALLY INVASIVE IMPLANT STABILIZATION

Implants have been in active use for 40 to 45 years. Initially the people who needed the implants the most did not have adequate bone to support the implants available at the time. The typical implants were made of titanium alloy. To use these implants, patients had to undergo very invasive grafting procedures that

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were only occasionally successful. The implants then evolved into mini-implants, which were not really different from the previous implants as they were still made of titanium and had the same shape. Early attachments were only good if the implants were placed parallel to each other. In most cases this eliminated maxillary treatment because it is almost impossible to place all the implants parallel owing to the anatomic realities. If it was necessary to use attachments that allowed the path of insertion to be altered when implants were not parallel. Thus, due to the superior position of the attachments the bar created, the implants were exposed to increased detrimental lateral forces of mastication. The denture that was supported by a bar (implant supported and implant retained) was exposed to the same forces as any fixed restoration. The bar essentially negated the ability to use a smaller implant because the surface area was lacking for this fixed application. When regular-sized implants were used in a bar-retained overdenture, bone loss would occur after only a few years, primarily because the lateral forces transmitted to the implants were not addressed. The development of an attachment that could alter the path of insertion on divergent implants and minimize lateral forces without a bar was the solution to the overdenture challenge. This new over denture technique produced a tissue-supported, implant-retained prosthesis that reduced the forces enough to make the smaller implants a predictable option.

The ERA® attachment (Sterngold Dental, Attleboro, Massachusetts, Figure 27-1) has been available for many years and was miniaturized and adapted to these smaller implants. The ERA® mini implant (an ERA abutment incorporated onto a 2.2 or 3.25 mm diameter implant) enables the clinician to place implants in areas that are too atrophic for traditional implants. Thus making it possible to treat many more patients in whom the remaining bone width is insufficient to support conventional implants without extensive bone grafting. The ERA® mini implant's ability to alter the path of insertion and negate the need for a bar in the maxilla, has opened the door to these smaller implants in the maxilla where minimal bone is present, often without additional bone grafting. The success rate of the ERA® mini implants is equal to that of the larger implants in the over denture application primarily due the ability of the ERA® attachment to alter the path of insertion which significantly reduces forces placed on the implant. The ERA® supported denture, whether on conventional or smaller ERA® mini implants, creates a tissue-supported implant-retained prosthesis. Patients who were not eligible for the treatment previously can now proceed with a less invasive and significantly more economical technique. Once a stabilizing platform has been achieved (implant support) and the teeth can be replaced on a denture, the limitations previously caused by a lack of stabilization for the dentures no longer apply.



FIGURE 27-1 **The resiliency of the ERA attachment is accomplished by using A, ERA male component with the black processing insert that occupies the entire metal housing. B, The white male insert *(arrow)* creates 0.4-mm space for resiliency and hinging inside the metal housing.** *(Courtesy Sterngold Dental, LLC, Attleboro, Massachusetts.)*

RELATING FUNCTION AND ESTHETICS

The clinician's goal is to place the teeth in the proper position for function and esthetics whether the case is fixed or removable. The approach in establishing tooth position for function and esthetics is basically the same for dentures as it is for natural dentition. Phonetics are used to help identify the position where the anterior teeth should be relative to one another first and then the posterior teeth are addressed. The ERA® denture patient, because he or she has implants now has a stable platform. It is possible to use the same criteria (with a few exceptions) to reestablish where the teeth provide maximum function. The practitioner is relatively free to have the patient participate in establishing esthetics once position of functional stability has been achieved.

Once the esthetic end result has been determined, the practitioner can proceed to a wax try-in stage. Stabilization via implants at this stage allows the patient to test the phonetics and observe their own esthetics. Rather than proceeding to the finished case and hoping that the patient's needs are addressed, the patient becomes an active participant, leading to better patient acceptance at the end of the case.

CLINICAL CONSIDERATIONS

Indications

Minimally invasive implant procedures are indicated for patients who have unstable dentures and want to have the increased quality of life that stable dentures can provide. There must be a minimum of 8 mm vertical height and 3 mm width of bone. These parameters are achieved in about 95% of all denture patients. Relating this to a conventional implant, the minimums are 8 mm height and 5 mm width parameters, which are not seen in most long-term denture patients.

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It is important to note that most patients are in their 50s, 60s, and 70s. Because they tend to have a multitude of medical problems, dental practitioners must consult these patients' medical care providers. With few exceptions, most persons at these ages can be treated with guidance from the primary health-care giver.

Contraindications

It is unlikely that a good result will be achieved if the patient has severe osteoporosis and minimal bone. A subject with osteoporosis but adequate bone could be treated successfully. Hemophilia is a contraindication for any kind of surgery, and certain medical and heart conditions may preclude elective procedures as can radiation treatment of maxilla or mandible.

MATERIAL OPTIONS

Advantages

It is better to place a smaller implant in adequate bone than to place a larger implant where the bone is very thin. Because the maxilla is addressed and bars are not being used, it is necessary to use an attachment that will allow for alteration of the path of insertion. Currently only the ERA® Attachment System (Sterngold Dental) has the ability to alter the path of insertion (Figure 27-2) and create vertical resiliency with multiple retentive strengths (see Figures 27-1 and 27-2). The other small attachments on the market are appropriate only in situations in which the implants are parallel. If the implants can be positioned parallel, almost anything can serve as an attachment. If the osseous contour makes it impossible for the implants to be placed parallel, only the ERA® attachment will alter the path of insertion sufficiently to enable it to be made parallel.



FIGURE 27-2 This figure illustrates the female portion of the ERA® attachment and the way that the path of insertion is altered. *(Courtesy Sterngold Dental, LLC, Attleboro, Massachusetts.)*

The technology has expanded, so these implants are starting to be used widely as an orthodontic tool to move teeth and grow bone in lieu of grafting. They are also being used for intruded molars. The primary use for the ERA®mini implant still remains to be in the overdenture applications.

Disadvantages

This technology should not be used to support a single tooth restoration, a bicuspid or molar, as this would certainly lead to failure. It is not meant to be used in a fixed application, but primarily for overdenture application when there is insufficient bone to accommodate larger implants.

Current Best Approach

The goal is to enlighten general dentists to treat their denture patients with ERA®mini implants. There are two different protocols, one for the maxilla and the other for the mandible, owing to the different quality of bone in each. If the bone quality or quantity is difficult to determine with routine radiographs, then a scan appliance with fiduciary markers is created; it is important to make the appliance stable and carefully inserted prior to taking a computed tomography (CT) scan. The information from this scan is entered into one of many computer programs that allow the clinician to view the available bone three-dimensionally and virtually place implants until the result is satisfactory. The plan is recorded along with implant size and sent to be made into a surgical guide appliance. The guide allows placement of the implants in the precise position identified on the computer during the virtual placement. This approach removes anxiety and provides accuracy within a 0.5 millimeter.

OTHER CONSIDERATIONS

Eighty-five percent of patients with bad dentures have already spent a lot of money without comfort or satisfaction. Often it becomes an issue of expense. It is possible to retrofit the existing denture to keep the cost lower. If the patient wants to take the process a step further, this can be achieved in steps. Initially stabilization of the denture provides the comfort the patient is seeking. Once this has been accomplished, the patient is often more open to looking at the esthetics that a new stable, implant supported denture can provide.

INNOVATIVE ELEMENTS

Scientific

The attachment used has resiliency, allows alteration of the path of insertion, and has multiple retentive strengths. This innovation makes it is possible to retrofit the existing denture or a new denture. The implants continue to function as long as the patient needs them. The ERA®mini implant was created by combining a micro ERA® attachment with a smaller implant of the same

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material makeup as the conventional implant and an aggressive self-tapping thread design. Where the bone is not dense, undersizing the osteotomy, an effect much like squeezing a sponge (making the sponge denser), is achieved. In maxillary areas where the bone is not of good quality, better bone quality is created by condensing the bone around the implant as it taps its way into the spongy bone. The implant-bone interface is much denser then the surrounding bone and provides stability during the healing phase. Altering the path of insertion, without incorporating detrimental forces of mastication, will correct for misalignment (see Figure 27-2).

Technologic

The use of CT technology is a major advance. The software has been made more user friendly and provides points of reference that were not previously available. The CT scan is taken with three metal markers that enable a three-dimensional point of reference. Even without extensive training, it is possible to virtually place the implant on the computer's three-dimensional representation of a specific patient's mouth. It not only gives the location but provides a relative bone density, maximizing implant placement in the densest bone available. The scan also allows the practitioner to view and avoid areas such as the neurovascular bundle in the lower jaw and the sinuses in the upper jaw, allowing greater predictability and increases the comfort zone for the general dentist.

Using the CT scan prepared guide allows the practitioner to spend less time in the patient's mouth, increases efficiency, and reduces overhead. With less overhead, the patient may face a reduced cost for the procedure, and making it an option for more patients. Everybody wins because the technology permits greater efficiency and effectiveness in a shorter amount of time. It also makes the procedure less invasive because of the reduced time in the mouth and the lowered potential for post-operative swelling, infection, and so on.

ARTISTIC ELEMENTS

Cosmetic dentistry is both an art and a science. With dentures, the art has basically been eliminated because the teeth cannot be placed exactly as desired without creating an unstable platform and unstable dentures. With the smaller implants and the ability to precisely place them using CT technology, the artistic aspect returns without compromising stability or function. For example, in replacing an anterior tooth in a patient with teeth, photographs are used to characterize the replacement tooth to match the natural teeth next to it; the soft tissue is not part of the treatment. Dentures however present an additional challenge because the tissue is replaced with a resin supporting the teeth that often does not match the patient's natural soft tissue, making it look very artificial. Once a stable platform has been accomplished, the process can be taken into a different arena. The patient's soft tissues are photographed, and the photos are sent to the lab. Dentists are no longer limited to a purple or gray modeling of the soft tissue because the lab technician can color-match an accurate photograph of the soft tissue. It is mimicked so that it becomes difficult to see where the soft tissue ends and the denture base begins. Artistically, something totally artificial is made to look natural.

TREATMENT PLANNING

Sequencing

The sequencing establishes the number of visits that will be needed, based on the patient's initial presentation, and the laboratory technician's work. All patients are asked about their **chief complaint**. The practitioner may see other things that need to be done first, but all factors are thrown into the mix. The denture patient usually wants a stable denture and may not even consider the esthetics. The clinician's job is to encourage patients to look beyond the immediate complaint. Once a stable denture has been created, the patient can be asked how he or she would like the teeth to appear. A list of options can be offered. To achieve a more stable denture usually requires implant placement at some point. If the patient's other chief complaint is about the plastic on the roof of the mouth, addressing this will require the placement of more implants to provide the support needed. All of these elements enter into the treatment planning process.

So the process is (1) identifying all the chief complaints, (2) obtaining radiographs, and (3) offering treatment options, some of which will require implants. Along the way it is important to take into account the patient's medical status. In most cases, after the dental practitioner has done a thorough work-up, the proposal and medications are sent to the primary care physician with an assurance that the procedure will be minimally invasive. The patient must be deemed medically able to undergo the procedure. If the primary care physician has any suggestions, such as medication changes, these are accommodated as the procedure unfolds.

After the work-up, consultation is completed and the patient accepts treatment the **first phase** begins. The patient's current dentures are evaluated and the most serviceable set for retrofitting identified. Remaining focused on the patient's chief complaint, which is a stable denture, the clinician places the implants and retrofits the existing denture making sure the primary implants have no loading forces. On the lower denture, several implants may be placed to stabilize the prosthesis along with the primary implants during the healing phase. These primary implants and stabilizing implants can be identical in size and shape. The stabilizing implants undergo immediate loading forces and are meant to last only the 3 to 4 months of healing, during which it is necessary to protect the primary implants from loading forces. In many cases, due to the denser bone in the mandible and reduced forces placed on the implants by using the ERA® attachment, these implants survive.

After 3 to 4 months of a stable and retentive denture, the patient can start looking at what a desirable end result would be. Photographs are used to help the patient choose the mold

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and position of the teeth. It is best to prepare a composite of five or six photographs, noting the various factors. Working with the patient's choices, a wax try-in is prepared. This can lessen the number of visits because it is an advanced starting point.

The **restorative phase** begins with obtaining occlusal records, reestablishing a functional occlusion, and obtaining the esthetics the patient desires. During the 3 to 4 months of the healing phase, the vertical dimension of occlusion is opened gradually. Resin is added to evaluate the vertical dimension the patient can tolerate. Over this period of time, the centric record the positioning of teeth is clarified. This planning reduces the amount of chair time and the number of visits.

The **final stage** comes very rapidly. The patient and laboratory are active participants in the end result as they have been since the first day. This makes the process a win-win situation. The clinician supports this because he or she is receiving sufficient remuneration for service, the patient is aware of the financial commitment, and he or she is extremely happy to have a functional denture. The fact that the replacement looks good is an added benefit.

TREATMENT CONSIDERATIONS

The treatment considerations basically follow the sequencing. In the surgical phase the goal and destination are established. During the treatment phase the needed implants are placed. There are two protocols, one for the maxilla and one for the mandible. The maxillary protocol requires under-sizing the osteotomy in most cases because the maxillary bone is not nearly as dense as the mandibular bone. The density is increased as described earlier, providing a more stable position of the implants.

During healing, integration takes place. In the mandible, transitional implants are generally used to stabilize the denture and protect the primary implants while they osseointegrate. These transitional implants can be the same size as the primary implants, but they are immediately placed into function. Although many of these implants will go on to integrate, because of the dense bone in the mandible they do not integrate with the same success as the primary implants that have no load placed. Transitions are also used to stabilize the denture, but they seldom integrate, owing primarily to bone being less dense than that of the mandible. Whereas placement of the implants in the mandible can follow that of the maxilla as far as using a punch technique to access the bone, it differs considerably from the bone level on. The amount of keratinized tissue present and the awareness of the location of the neurovascular areas will determine whether the punch technique is appropriate. In the mandible it is usually necessary to make an incision to maintain the attached tissue and avoid areas such as the nerve. A negative mandibular ridge will affect the sequencing of the treatment plan because the patient will not have the denture retrofitted to the transitional implant until after the soft tissue has healed. In the restorative phase, the occlusal scheme is a consideration. If a stable platform is achieved but the occlusal scheme is not addressed and excessive forces are placed on these implants, they have the potential to collapse as the teeth and bone did before them. The functional occlusion must be accurate. If a patient was unable to maintain the natural dentition and lost the teeth through neglect, it must be impressed on him or her that this is the last option. The patient requires instruction about cleaning the at-risk places in particular because many of these patients do not go to the dentist unless they have a problem. Appointments should be made every 3 to 4 months to maintain a normal cleansing cycle. This way, problems are identified before they develop very far. Once the patient can maintain good oral hygiene, the occlusal scheme is verified to be within accepted parameters. The implants can then be placed under adverse forces and they will be successful, just like their larger versions.

Because these small implants are placed within the bony confines, there is no need for grafting in most cases. Grafting is an added invasive procedure that requires additional expertise and additional expense. Avoiding it benefits the patient.

EVIDENCE-BASED PRINCIPLES

The "big brother" to these mini-implants has been around since the late 1980s and has been used for at least 20 years in the United States. It has proven itself useful as the most widely used attachment in the world. Although the ERA® abutment has been made smaller, to conform to the smaller implant (ERA®mini implant) that allows it to be used in areas with minimal bone, it maintains the same retentive strength as the regular its larger predecessor.

CONTROVERSIES

There are objective ways of measuring the ability of an attachment to alter the path of insertion without subjecting it to lateral forces. The ERA® attachment is the only one that can function well beyond 10 degrees. The controversy is a marketing issue. If the divergence of the implant measures beyond 5 to 10 degrees, which is not unheard of in the maxilla, the clinician faces the choice of using a bar, which elevates the plane of rotation and subjects the implant to significantly higher lateral forces. Until about 10 years ago the only option was a bar, and the success rates in the maxilla and mandible differed significantly. Maxillary implants failed considerably more often because (1) the bone is less dense and (2) implants are in places that allow lateral forces on them and the implants cannot continue to sustain the pressure. The lateral forces are eliminated by bridging the gap with a tissue-supported implant-retained prosthesis, which is what the ERA® is, rather than an implant-supported implant-retained prosthesis, which is what the bar is. The success rate in the maxilla over the last 8 years is comparable to the rate in the mandible with the ERA attachment.

The other controversy is that a smaller implant cannot do the same job, which on paper is true. The small implants work

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because the forces are minimized. This is a win-win situation for many patients financially, is less invasive, is easier on the patient, and gives predictable results.

NEAR-FUTURE DEVELOPMENTS

The smaller implant can be used in other applications because it is a tool, not just an implant. It is possible to place these implants in a position that will allow the orthodontist to move maxillary bicuspids posterior and bring the bone with them when no molars exist. This will then achieve a height and width of bone better than can be achieved with grafting the sinus area. These smaller implants can also be placed such that they can provide the orthodontist with and anchor that provides the ability to intrude molars that have super erupted.

CASE STUDY

Patient History

The patient was a very energetic 72-year-old woman from Central America who had just lost her husband of 40 years and was re-entering the social arena. She did not look or act her age. Her husband had accepted her with her ill-fitting prosthesis, but she was not sure she would be accepted by others and was looking for a change from her cumbersome denture, basically a denture with two second molars to help hold it in place. She wanted an esthetic and functional change that would include removal of some of the denture base on the palate and alter her significant reverse smile (Figure 27-3, *A*).

Examination revealed a maxilla with an extremely narrow ridge (less than 3.5 mm in most areas) and a bone quality that was poor (Figure 27-3, *B* and *C*). A Panorex (Figure 27-3, *D*) shows the remaining dentition and alveolar bone status. CT scans of the maxilla and mandible indicate the proposed treatment. The proposed maxillary treatment can be viewed in two dimensions (Figure 27-3, *E*) or three dimensions (Figure 27-3, *F*). The proposed mandibular treatment can be viewed in two dimensions (Figure 27-3, *G*) or three dimensions (Figure 27-3, *H*). She had severe premature posterior occlusal interferences along with significant hyper-eruption of the lower anterior teeth and bone that was responsible for the accelerated bone loss in the maxilla. This compromised the occlusal plane three-dimensionally to such a point that an ideal smile design would be impossible without first addressing these factors in the diagnostic work-up.

Treatment Plan

One possible treatment option to achieve the change she wanted would have involved extensive grafting bilaterally at both sinuses and an onlay graft to supply sufficient width bone, additional implants, and close to a year of treatment. The cost would have been 10 times greater than that of the overdenture.

Another treatment option suggested to her, which she accepted, was to construct an implant-retained, tissue-supported overdenture that would remove the plastic in the roof of her mouth, one of her main treatment objectives. With this alternate approach she would see no wires and it would reestablish her appearance when she was younger, based on pictures she had brought in. The photographs she provided showed an esthetic scheme that was not what would be considered ideal because of the soft tissue architecture in the maxillary lateral incisor area, but it was what she had had when her teeth were still present. This is much like someone not wanting to close a diastema between two maxillary central incisors; it is a personal preference.

The fixed option was ruled out owing to the expense and the invasiveness of the procedure. The final plan that was accepted was to create an implant-supported removable prosthesis with an open palate. The lower arch needed to be completely redone and the crowns had to be removed and refabricated to establish an occlusal plane proper for both function and esthetics. A thorough diagnostic work-up was completed. Occlusal records were obtained, models were mounted on an articulator and a graphic survey was done. A CT scan with an appliance that contained fiduciary markers was also taken.

Clinical Step-by-Step

Pre-surgical Phase

The pre-surgical phase involves three steps: what the patient and dentist have decided on as a destination, what obstacles have been identified, and how the clinician will achieve the foundation to support the restorative phase.

With this patient, the occlusal plane was askew and the patient had one molar with decay that required a crown. The goal was to alter her upper denture to eliminate her significant occlusal interferences. The overdenture had to be stabilized to prevent it from exerting undue force on the bone around the implants. A temporary restoration was placed on the upper left molar, and an impression of both arches was obtained and used to make a CT scan appliance. The CT scan guide for the maxilla was taken with the temporary crown in place; otherwise the CT surgical guide would not fit if the permanent crown were placed prior to the scan. It was decided that all of her crowns on the mandible would need to be redone at some point to achieve an ideal arch form and a functional occlusion.

Two implants were to be placed on the lower left at the same time the upper implants were being placed; this would allow crowns in that area instead of a lower partial. An ERA® abutment with a mesial guide plane was incorporated on the crown that was to be delivered after the implants had been placed; to place the final crown on the upper molar prior to surgery would have made the surgical appliance unstable and thus inaccurate. This would, along with the molar on the other side of the maxilla and two mid-palatal transitional implants, stabilize and protect the primary implants. The CT scan appliance was sent back to the lab along with the treatment plan, and a surgical guide was created that included removable metal sleeves that would allow

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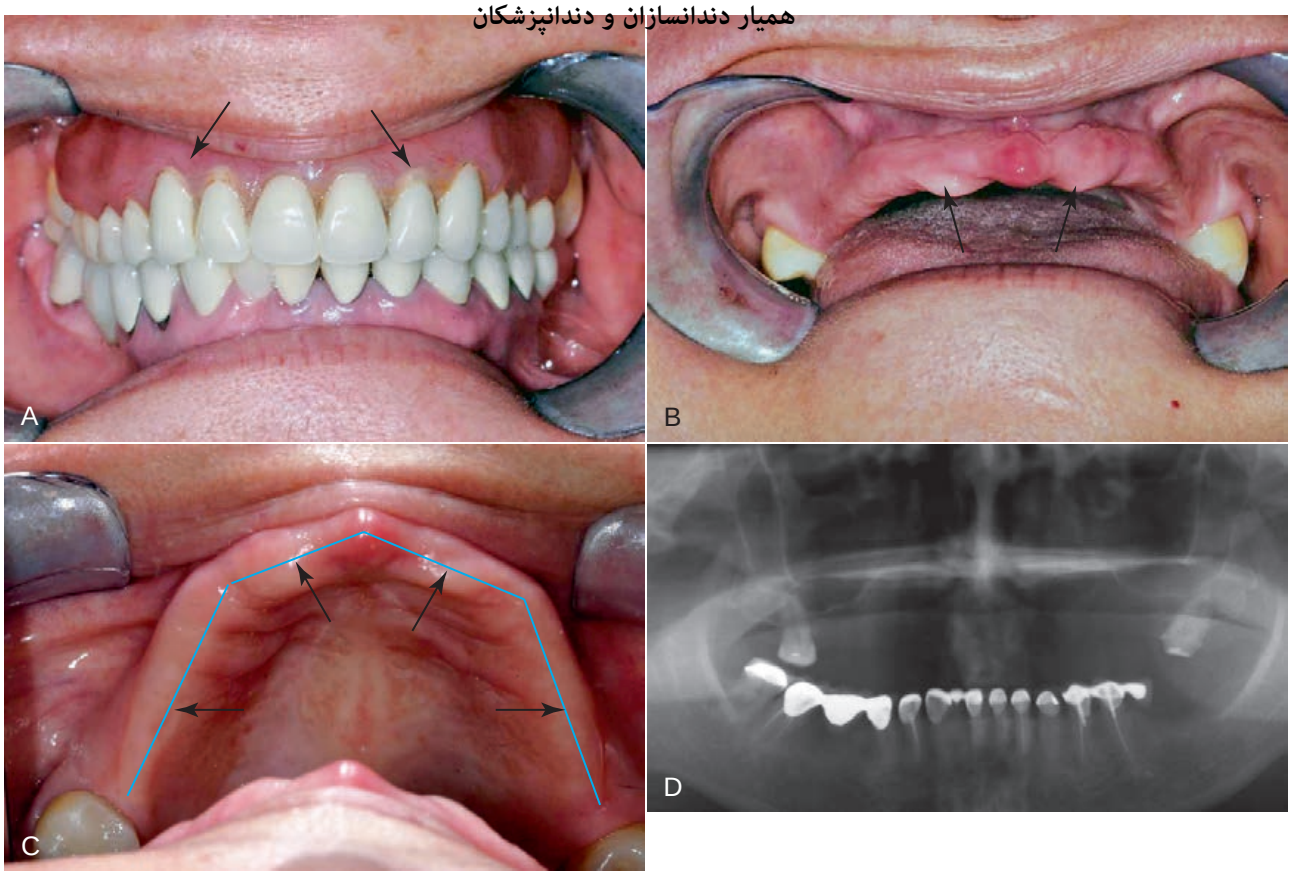


FIGURE 27-3 **A,** This illustrates the patient's two remaining teeth attempting to secure her existing tissue-borne prosthesis *(arrows)* with the exaggerated occlusal plane. **B,** Clinically, the ridge is very deceiving. There is 6+ mm of flabby tissue *(arrows),* and the remaining bone is very narrow and of poor quality. **C,** Location of the actual ridge *(blue line)* surrounded by 4 to 6 mm of flabby tissue *(black arrows).* **D,** The panorex illustrates poor density and a very narrow ridge in the maxillae.

Continued

the osteotomies and implants to be placed directly through this surgical guide (Figure 27-4).

Surgical Phase

Using a CT scan that was taken with an appliance with fiduciary markers along with the implant placement software, a CT-generated surgical guide was created (Figure 27-5, *A* and *B*). The implants were placed using this guide, which allowed for a minimally invasive procedure, and no sutures were required (Figure 27-5, *C* to *M*). Seven implants were placed, including two in the midline of the palate, along with a crown on the upper right molar to aid in denture stability (Figure 27-5, *N*). The white alignment handles (Figure 27-5, *O*) illustrate the path of insertion based on the molar. Thus the appropriate angle corrections for the midline implants were cemented in position to provide the parallel path of insertion based on the molar crown that was cemented immediately after implant placement. Once these implants had been placed, the crown and angle corrections were inserted and cemented (Figure 27-5, *P*). Two implants were placed in the lower left mandible to support a fixed application in that area. While the implants were being placed, the laboratory technician was altering the patient's old prosthesis to relieve the areas where the primary implants were placed and allow the prosthesis to be secured to the palatal implants for stability (Figure 27-5, *Q*). A clasp was also placed that would secure the prosthesis on the upper left molar (Figure 27-5, *R*).

The removable prosthesis was seated to ensure that there was adequate relief over the primary implants, which were 2.2 mm in diameter and only 10 mm in length. Once this had been accomplished, the proper abutments on the midline implants (2.2 mm in diameter, 8 mm in length) were placed to alter the path of insertion that was compatible with that of the second molars. The undercut areas were blocked with polyvinyl impression material to prevent subsequent engagement of the pickup material (Figures 27-5, *S*). Then the male ERA® component of the right molar and the midline implants were attached to the removable prosthesis to provide stability with an auto-cure bis-acryl resin to provide stability (Figure 27-5, *T*). The black processing male components were replaced with white retentive male components on the molar, and one anterior midline was inserted into the metal housings, leaving the posterior midline metal housing empty to be engaged when the anterior midline implant became mobile and had to be removed (Figure 27-5, *U*). The black male attachments were removed and the denture relined with a resilient non porous silicone-based material that

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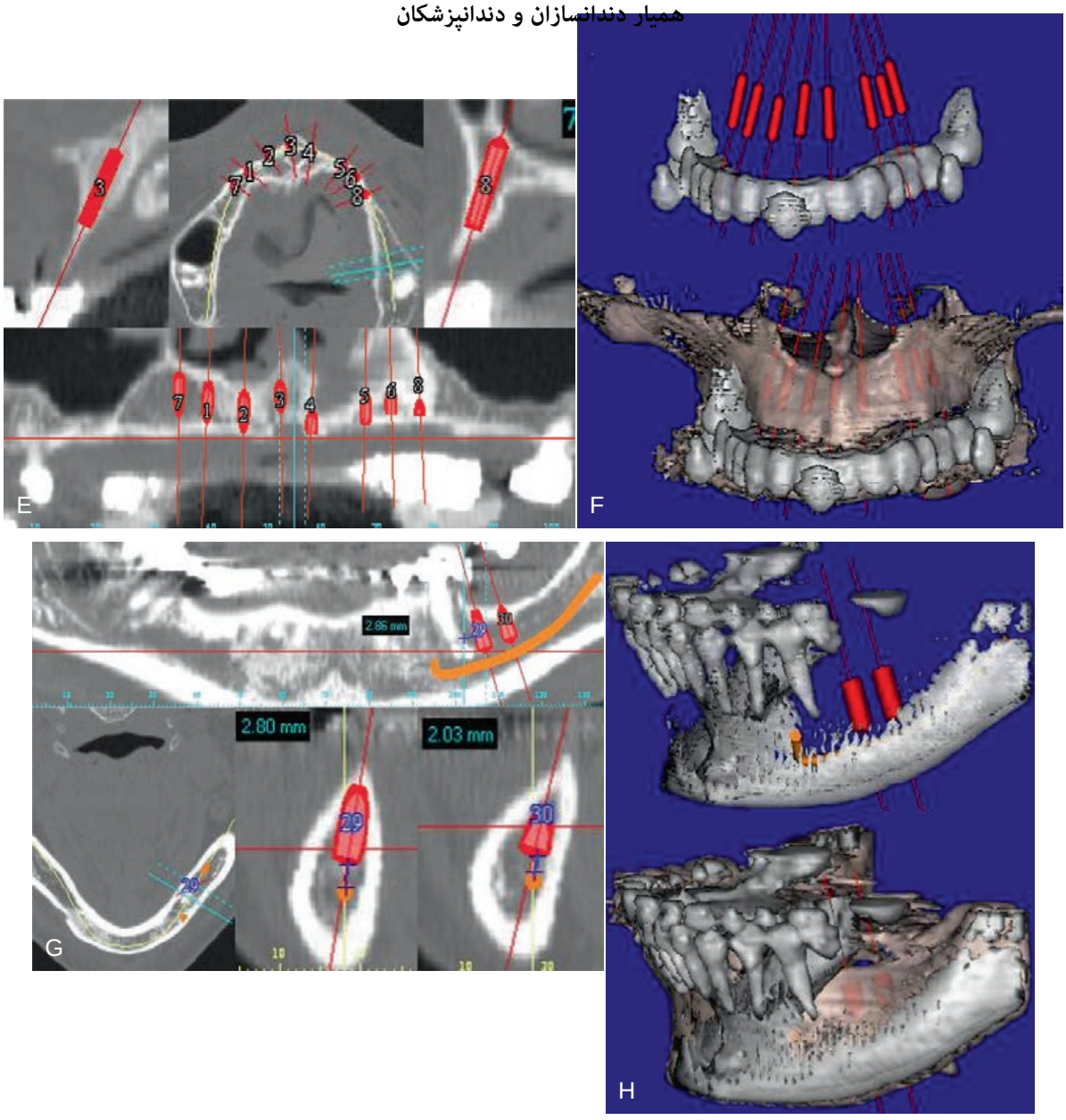


FIGURE 27-3, cont'd E, The pre-operative maxillary computed tomography (CT) scan showing all three views. F, The CT scan view of maxilla with proposed implant placement. G, The pre-operative mandibular CT scan shows the three dimensional views that facilitate treatment planning. H, The CT scan shows mandible with proposed implant placement.

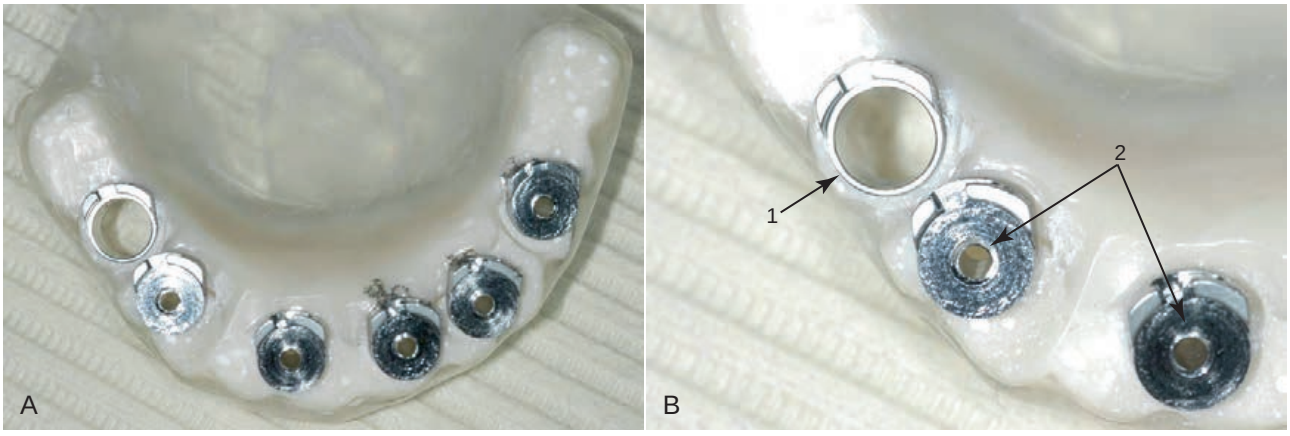


FIGURE 27-4 A and B, Surgical guide produced from the treatment plan using VIP Treatment Planning Software (Biohorizons, Inc., Birmingham, Alabama) and a computed tomography scan. (1) Sleeve removed to allow for appropriate countersink of bur as determined by abutment height; (2) Guide for 1.6 bur.

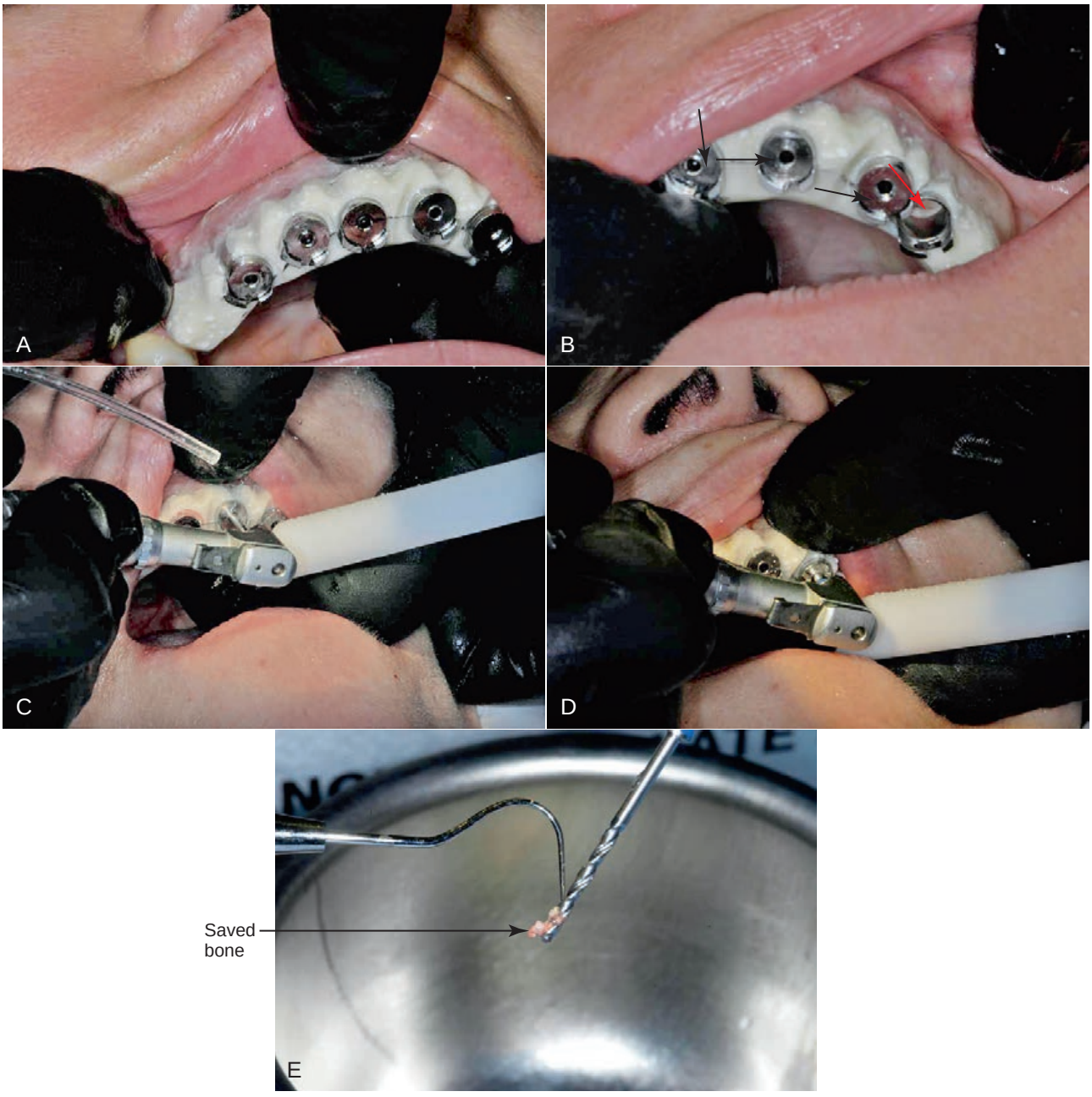


FIGURE 27-5 Try-in of the surgical guide. **A,** Surgical guide in place with 1.6-mm inserts locked in position. **B,** Surgical guide in place with 1.6-mm inserts *(black arrows)* and one area with insert removed to allow for the appropriate countersink bur *(red arrow).* The osteotomies are placed through the guide, tissue, and bone. Seven implants are placed around the arch. **C,** Working around the arch using the 1.6-mm bur in the guide to 4 mm short of the final implant depth density. The implant, due to poor bone quality was then used as a tap, which allowed it to reach final depth with greater stability. **D,** The 1.6-mm bur and depth guide. It took only 7 minutes to create six osteotomies, including the countersink bur for the 2.2-mm-diameter ERA® mini implants. **E,** Saving the bone from the osteotomy.

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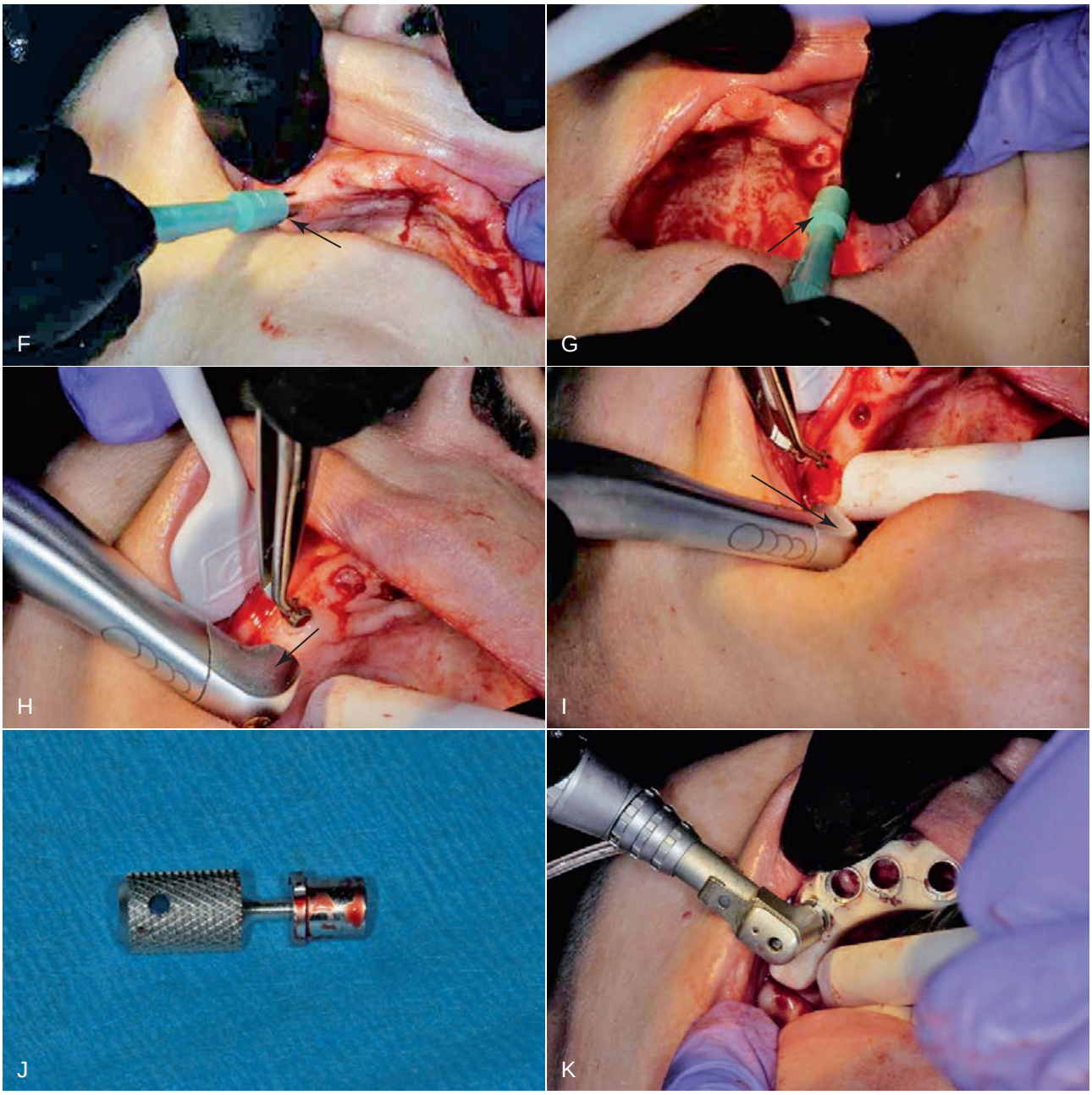


FIGURE 27-5, cont'd **F to I,** Using a tissue punch (**F** and **G** *[arrow]*) and laser (**H** and **I** *[arrow]*) to remove the residual tissue before using the 1.6-mm countersink which is the final bur for the 2.2-mm ERA® mini implant protocol in the maxillae. **J,** Insertion tool and 1.6-mm guide removed it from the surgical guide. **K,** Countersink bur guided into position to be used via the surgical stint.

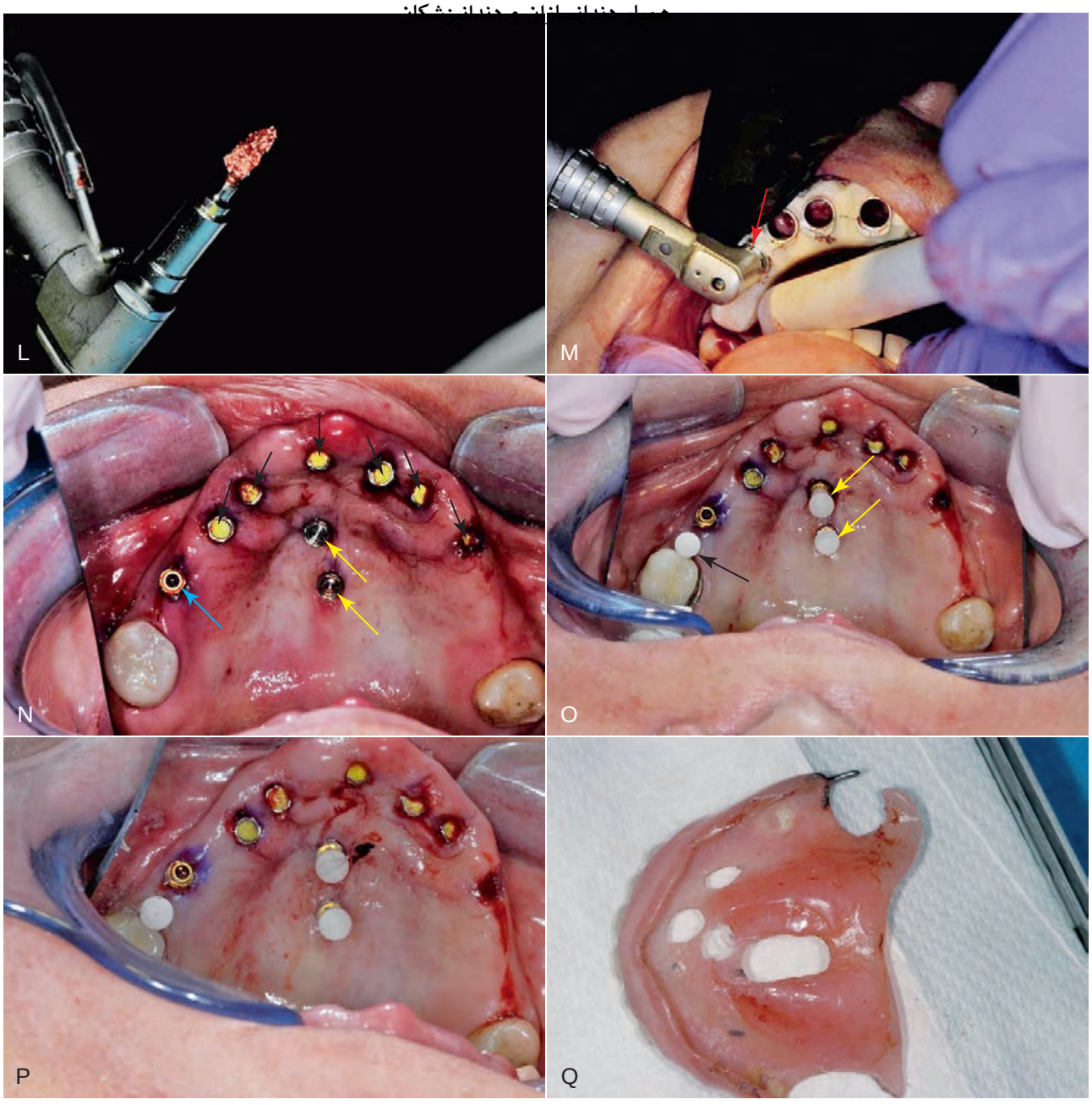


FIGURE 27-5, cont'd **L,** Insertion tool with 2.2- × 10-mm implant with graft material ready to be inserted back into the guide and placed into maxillae using a torque-limited surgical motor. **M,** A 2.2- × 10-mm ERA® mini implant *(arrow)* seated using insertion tool and surgical motor. **N** and **O,** Seven primary implants placed with the computed tomography (CT) guide. Two transitional implants are in the midline. **N,** *Black arrows:* six 2.2- × 10-mm ERA® mini implants after insertion shown with polyvinyl material used to seal the female portion of the attachment during healing phase. *Blue arrow:* one 3.25- × 10-mm implant placed without guide. *Yellow arrows:* two 2.2- × 8-mm implants placed in the midline to be immediately loaded act as vertical stops to protect the primary implants during the healing phase. **O,** *Black arrow:* a previously prepared crown with an ERA® partial attachment and alignment sleeve. *Yellow arrows:* a 5° and 0° angle correction cemented and also an alignment sleeve. **P,** The path of insertion is parallel. The partial will be retrofitted. **Q,** Relieved partial denture with new clasps altered to achieve a passive fit before picking up the male ERA® black attachments in their metal housings.

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FIGURE 27-5, cont'd **R,** The tissue-supported prosthesis needed to use the molars for support. Posterior vertical stop clasps *(arrow)* were added while the implants were being placed. An ERA® attachment was placed on the right molar and a clasp was placed on the left molar to hold the denture in place. This model was produced using an alginate impression and Mach Slow produced by Parkell (sets in 45 seconds). **S,** Polyvinyl bite registration material *(arrows)* placed in the undercut areas, then the metal housings were picked up. **T,** InstaTemp auto-cure resin (not "acrylic") injected around male ERA® housings and into the denture. **U,** Denture removed and one of the black male processing inserts is replaced with a white retentive male attachment *(black arrow)*. The prosthesis is tried back in to ensure fit, then the other two black male inserts *(white arrows)* are replaced with white, but one of the midline white inserts will be removed before the patient leaves. **V,** The black male inserts have been removed and the denture relined. The resin is removed and replaced with a silicone-based material that does not pick up blood and tissue. The soft liner is placed. The denture is polished and seated and the patient dismissed. **W,** One day post-operatively. The patient was instructed on how to place the prosthesis and was told to leave it out at night.

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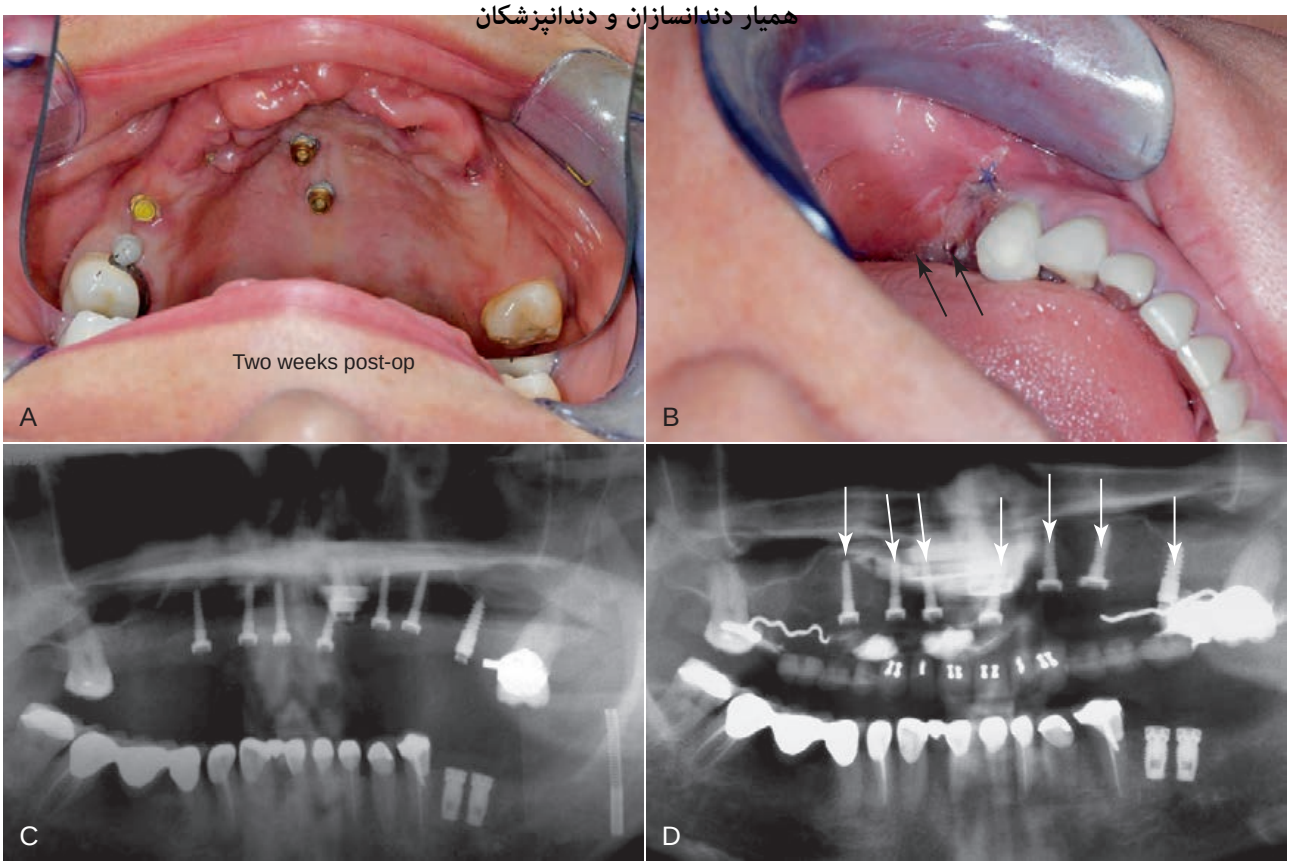


FIGURE 27-6 Two weeks post-operatively. **A,** Position of implants in the lower arch to be used for a fixed application later. **B,** Area *(arrows)* where two conventional implants were placed to provide a first molar fixed solution. **C,** Panorex of all the implants. The implants were almost completely covered by the soft tissue, which was the desired outcome. The denture base was no longer touching those areas. If a line is drawn from the two molars to one implant at a time, it shows a tripod effect. When the patient bites down in the front, those implants prevent the denture from digging into the primary implant; when she bites down in the back, the teeth prevent the denture from digging into the implant. **D,** Panorex 1 month post-operatively. Palatal implants *(arrows)* and the molars provide vertical stops and retention to protect the 2.2-mm ERA® mini implants and one 3.25-mm ERA® mini implant that will eventually support a denture without palatal acrylic.

would not trap blood or other fluids (Figure 27-5, *V*). The upper removable prosthesis was adjusted significantly to remove the occlusal interferences until the restorative phase, when a new upper denture and lower crowns could be fabricated. Although this gave the upper prosthesis greater esthetic disharmony in the short term, the patient decided that a new transitional denture would not be worth the cost because it could not significantly eliminate the esthetic disharmony until the lower arch was addressed. She was sent home with the denture in her mouth for first night. The patient was seen the next day to show her how to place the removable prosthesis using the proper path of insertion that had been established (Figure 27-5, *W*). She could no longer pop it into her mouth and bite it into place; she needed to line things up and snap it into place. The denture stability was evaluated to ensure there was adequate relief over the primary implants. The soft tissue was already visibly growing over those implants, which was an indication there was no pressure in these areas.

Healing Phase

A portion of the molars in the lower dentition was removed. The posterior teeth were adjusted so the patient's occlusal scheme no longer demonstrated a premature contact. Previously the patient's posterior teeth, because of passive eruption and mesial drift, had caused significant occlusal interference, thus forcing her mandible forward and creating adverse loading forces on the denture. This accounts for the significant bone loss in the anterior maxillae and loss of the lower left posterior teeth.

A little over 4 months was allowed for osseointegration, with the patient returning in 2 weeks (Figure 27-6, *A* to *C*), 1 month, and 3 months (Figure 27-6, *D*) for post-operative care and 4 months for the restorative phase.

Restorative Phase

The restorative phase consisted first of uncovering the implants on the upper and placing the appropriate female ERA® angle correction to allow for a path of insertion that was established

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with the upper right and left second molars (Figure 27-7, *A* to *C*).

The male metal housings with appropriate retentive insert were retained in the removable transitional appliance. After this had been accomplished, occlusal records were taken and a final impression for a new transitional was taken using the transitional with the male components in place (Figure 27-7, *D* and *E*). Because the patient was from out of state and travel was a concern, a wax try-in was made the same day. The laboratory technician then proceeded to fabricate the new maxillary transitional denture using an ideal arch form and did a wax-up on the mandibular to accommodate the new maxillary appliance. The upper and lower prostheses were mounted (Figure 27-7, *F*).

The alignment handles show how all the implants are aligned to be parallel with the molar on the upper left side (Figure 27-7, *G*).

Impressions were taken using the provisional denture that had been worn for 4 months as the impression tray. The mounted case shows where the male housings should be in order to facilitate the wax try-in (Figure 27-7, *H*).

An acrylic base plate was then constructed on the mounted model and the teeth were set up for the wax try-in. This allowed for a stable platform to evaluate the placement of the teeth from which the new provisional denture was produced (Figure 27-7, *I* to *K*).

After completing the wax-up on the upper denture to determine position of the teeth in the new transitional denture, the lab technician prepared the diagnostic wax-up on the lower arch. The lower wax-up allowed the technician to create a record of the shape and position of the teeth which would facilitate the construction of the new lower temporaries. The next day, all the crowns were removed from the mandible and temporaries were constructed based on the diagnostic wax-up and occlusal records (Figure 27-7, *L* to *N*). The maxillary provisional prosthesis was relieved to accommodate the male ERA® attachments, and InstaTemp was injected around the male abutments (Figure 27-7, *O* to *Q*). Due to the rapid turnaround of the new upper transitional denture, the base plate shade was not refined to blend in with the patient's natural tissue but this was corrected on the final prosthesis (Figure 27-7, *R*). The excess InstaTemp material was removed from the maxillary transitional denture, and it was delivered with the metal housings and appropriate retentive inserts (Figure 27-7, *S*).

The tooth preparations on the lower teeth were refined and abutments were placed on the two lower posterior implants. The new fixed resin temporaries on the mandible were relined and cemented on the teeth and abutments (Figure 27-8). The patient returned on the next day to refine her occlusion.

The patient was seen five or six more times in a span of 2 months until occlusal harmony was satisfactory and the patient

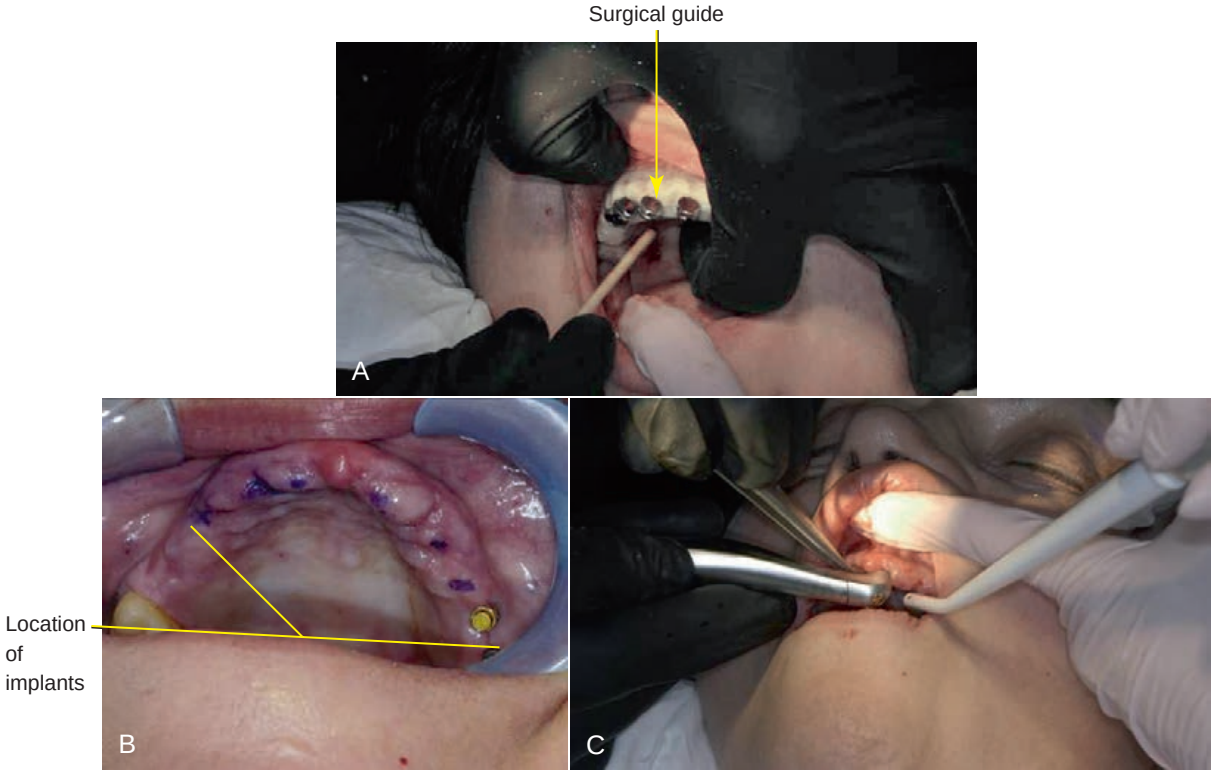


FIGURE 27-7 A to C, Tissue appearance 4½ months post-operatively. Surgical guide (A) is used to locate implants (B) and remove tissue covering them (C).

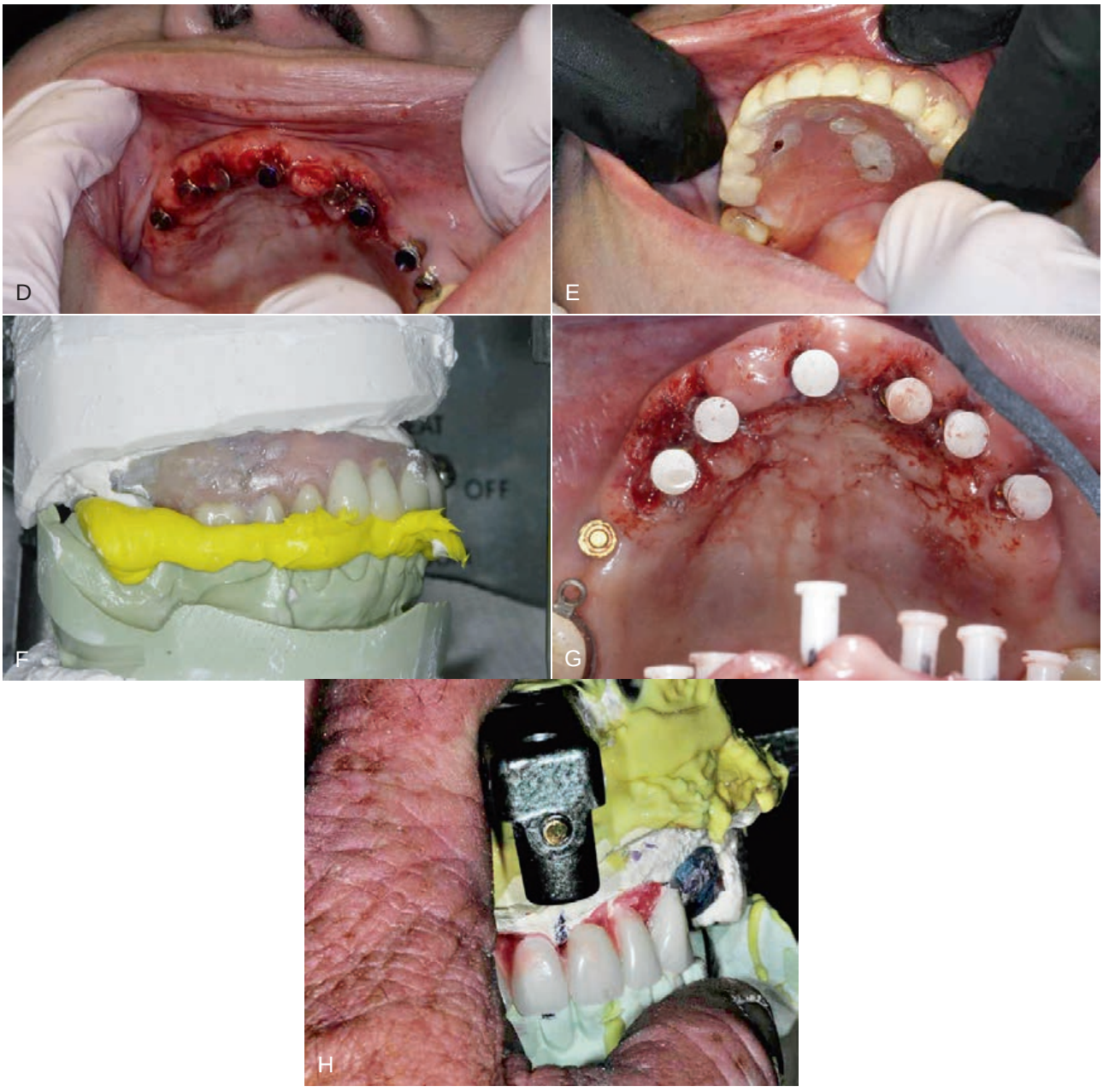


FIGURE 27-7, cont'd **D and E, The implants are uncovered, the angle corrections are cemented, and the male ERA® housings are picked up in the patient's old denture. Little remained of the retrofitted denture, but it had served its purpose. Occlusal records were taken along with a reline impression, analogs were placed in the male attachments and the case was mounted with proper centric relation. F, Impressions taken using the denture that the patient had worn for 4 months as the impression tray. The mounted case shows where the male housings should be. G, Starting to work toward a wax try-in. The alignment handles show how all the implants are aligned to be parallel with the molar on the upper left side. H, The day after the attachments were picked up, a wax try-in was completed. Wax set-up for new overdenture based on occlusal records using altered original denture.**

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FIGURE 27-7, cont'd I to K, The appropriate corrections were made and a new transitional overdenture was fabricated. L to N, A wax-up was done lower arch based on the correct position of the teeth on transitional denture (L). The next day all the crowns were taken off the lower teeth (M) and temporaries were placed based on the diagnostic wax-up and occlusal records (N).

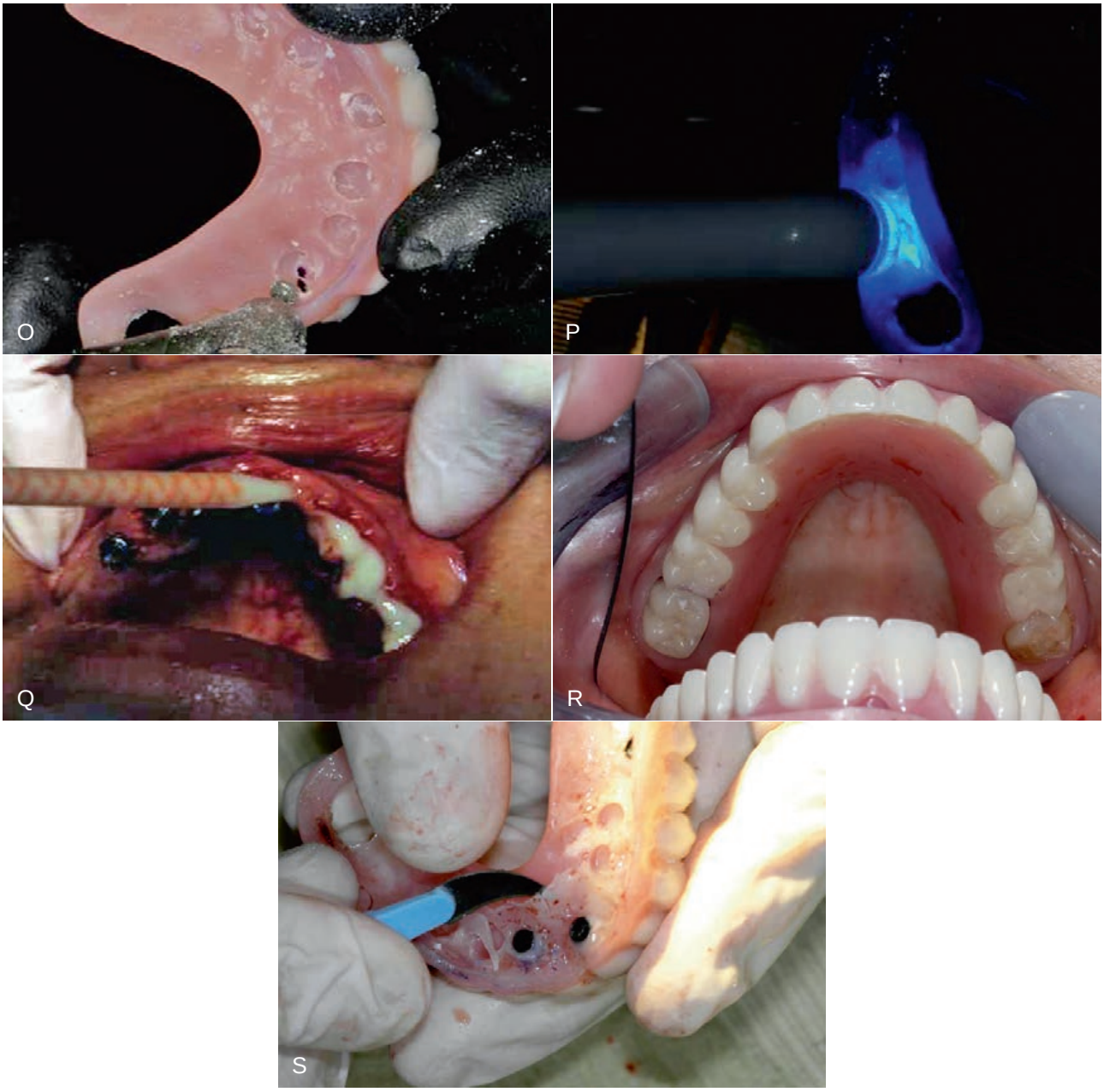


FIGURE 27-7, cont'd **O and P, The maxillary prosthesis is reduced to accommodate the male ERA attachments. Q, Insta-Temp is injected around the male abutment. R, Transitional denture in place. The base plate is not the same shade as her natural tissue, and this was corrected in the final prosthesis. S, The ERA® male attachments were picked up in the new transitional denture.**

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FIGURE 27-8 **A, The day of delivery of the temporary restoration. The patient has temporaries on the bottom and a transitional denture on top. B to D, The transitonal denture and lower resin crowns day of delivery (finished with transitional phase). The occlusal scheme was corrected, and a month was allowed for healing.**

was happy with the esthetic outcome. The occlusal scheme can be elaborated on later, but is different from that of a tooth-supported fixed case because in this case a denture was involved.

The final stage was to have the patient return for impressions for the new final upper prosthesis, and to rebase and reline her existing transitional prosthesis as a back-up denture with the improvements that were incorporated into the final prosthesis. When the new final prosthesis was delivered, the lower anterior 6 temporaries were removed and impressions for the porcelain crowns were taken.

Two weeks later the lower anterior porcelain crowns were delivered and impressions were taken for the posterior final restorations bilaterally. Three to four weeks after the impressions were taken the posterior final restorations were cemented (Figure 27-9). The patient was placed on a 3-month recall.

Conclusion

This patient was able to achieve the appearance she wanted without an invasive grafting procedure (Figure 27-10, *A*). If a fixed restoration had been used, it would have been less accurate and more expensive. The patient's needs for this case were choreographed, and the implants were placed appropriately. The final esthetic result was based on the photograph of the patient when she had her natural teeth. The occlusal plane was altered to create a functional occlusion which was lost due to years of neglect. Although the irregular tissue levels were not what many would consider esthetically ideal, they reflected the patient's desire to reproduce her desired end result. The changes in her function were made slowly and initiated in the surgical phase. The refinements in her occlusion took into consideration the

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FIGURE 27-9 A, Finished transitional phase 1 week after insertion. B and C, Note the new transitional upper and lower resin crowns. D to F, Retracted view of the new upper denture and the final prosthesis on the lower. The denture base goes halfway up the anterior region. Posteriorly the denture base stops halfway up and the natural tissues starts; note the match.

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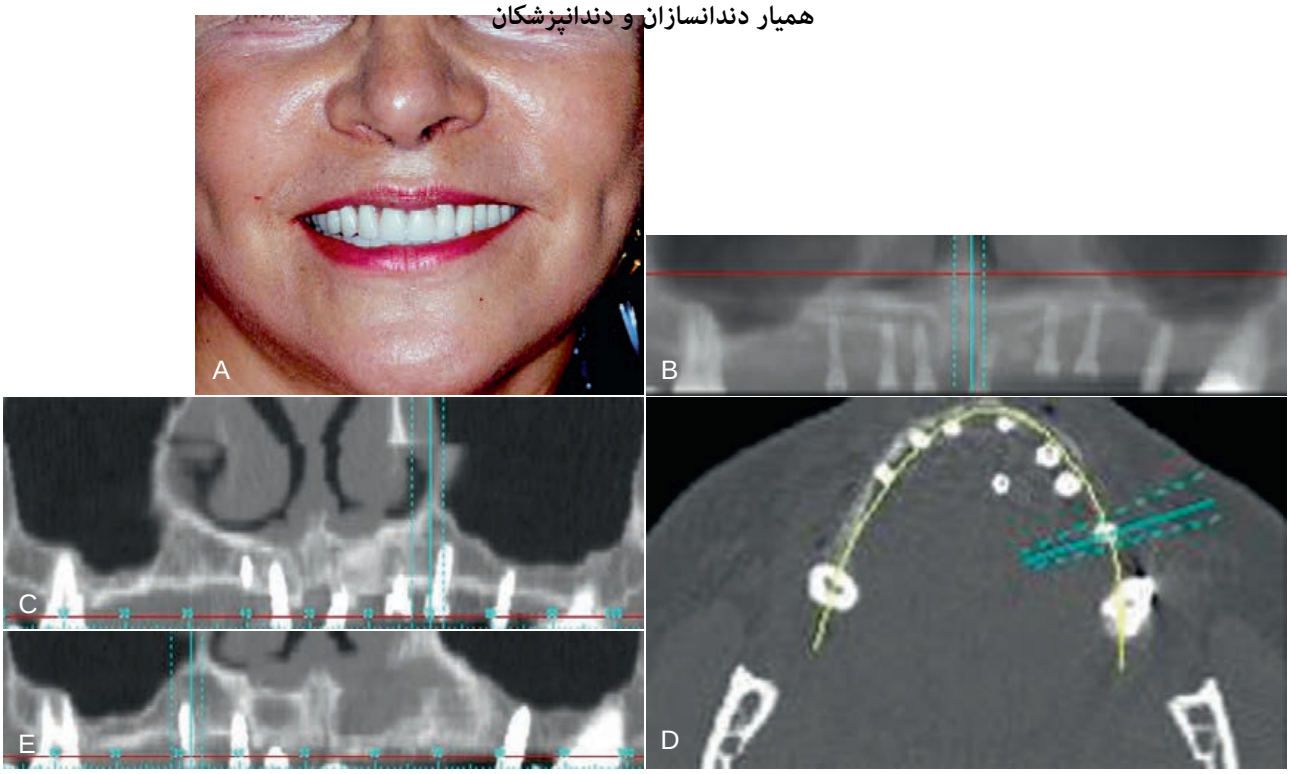


FIGURE 27-10 **A, Facial view of the finished case the day of delivery. B, Finished case after 4 months. The CT scan shows the implants in place. Lateral views (C and E) and sagittal view (D).**

patient's esthetic desires and that her upper denture opposed lower natural dentition. Her new realigned occlusion was tested in her final maxillary transition prosthesis and mandibular temporaries for a period of time to verify that the desired result had been achieved.

The CT scans at 4 months indicate the position and the integration of the implants (Figure 27-10, *B* to *E*).

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CHAPTER 28

PERIOESTHETICS

SECTION A

Periodontal Esthetics and Periodontal Plastic Surgery

Jon B. Suzuki

RELEVANCE OF PERIODONTAL ESTHETICS AND PERIODONTAL PLASTIC SURGERY TO DENTAL ESTHETICS

Therapy for periodontal diseases includes treatment for inflammation of the gingiva, regeneration of the periodontium, and maintenance of the dentition. The primary emphasis for initial periodontal treatment should be the reduction and control of inflammation. Erythematous, edematous gingiva contributes a very un-esthetic quality to the dentition and therefore should be primarily addressed during the initial phase of treatment.

Among the first stages of periodontal therapy are oral hygiene instructions, conservative scaling and root planing, and ultrasonic or piezoelectric débridement therapies. Antibiotics may be given systemically (usually not indicated) or locally as necessary. The second link between esthetics and periodontal therapy includes contouring crowns, improving the esthetic presentation of prostheses, and minimizing gingival overgrowth patterns that can develop around dental implants or prosthetic devices. A third relevant association between periodontal therapies and esthetic dentistry is the maintenance or establishment of adequate zones of keratinized gingiva around crowns, bridges, and dental implants.

HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF THE CONCEPT AND PROCEDURES

The clinical recognition of periodontal therapy developed at least a half a century ago when studies first equated bacterial plaque with gingival inflammation. These studies were published in the 1960s and 1970s. Control of inflammation was primarily targeted at managing disease and preventing gingivitis and did not address esthetic qualities. Concomitantly with the development of esthetic dentistry and the dental materials associated with it, clinicians began to address the minimum clinical qualities of the periodontium needed to enhance the esthetic profiles of a restoration.

As periodontal procedures evolved, surgeries for clinical management of disease became more refined. For example, some medications contributing to gingival hyperplasia were managed with gingivectomy and other gingival resective procedures to ensure esthetically acceptable restorations. The recognition of the importance of keratinized gingiva modified periodontal treatment planning and surgery. More recently, dentists have become aware of the importance of keratinized gingiva for dental implants and crown and fixed prostheses. Clinical research has not fully supported the concept of keratinized gingiva for dental implants, but it is clear to most clinicians who place dental implants that it is preferable to have keratinized gingiva to manage rather than alveolar mucosa.

RELATING FUNCTION AND ESTHETICS

The two primary goals in periodontal esthetics are to (1) reduce gingival inflammation and erythematous, edematous gingiva and (2) manage the keratinized gingiva. Reduced inflammation eliminates un-esthetic edematous or bleeding gingiva, especially when the patient speaks or smiles. Enhancement of keratinized gingiva improves esthetics around dental implants, especially in the anterior region. In addition, function is improved for toothbrushing and other cleansing habits. There can be a dramatic improvement in periodontal support of the dentition with improved keratinized gingiva as well as reduced gingival inflammation.

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CLINICAL CONSIDERATIONS

Indications

The diagnosis of periodontal disease is one indication for reducing gingival inflammation. Redness, bleeding on probing, and the patient's report of signs and symptoms of periodontal disease, such as sour taste in the mouth, odor, and shifting of teeth, are additional indications for proceeding with periodontal therapy. To the clinician, arresting bone loss and regenerating bone and attachment are also indications for proceeding with periodontal therapy.

The indications for enhancing keratinized gingiva include a lack of keratinized gingiva, which is established in the periodontal literature as 1 to 3 mm of keratinized gingiva. Amounts less than that or concerns about zones of inadequate keratinized gingiva related to oral hygiene suggest that periodontal therapy, including periodontal surgery, should be planned.

Contraindications

The contraindications for periodontal therapy are very few, but they include any medical and medication influences on wound healing or systemic health. For example, during the first trimester of pregnancy, an obstetrician-gynecologist may warn against more aggressive periodontal therapy.

Contraindications for mucogingival surgeries (which the American Academy for Periodontology now refers to as *periodontal plastic surgery*) include medical and medication considerations as already noted and the presence of anatomic structures in the mouth that mitigate against surgical treatment planning. Some of these anatomic landmarks include a coronally positioned mental foramen or a prominent mandibular ramus or other structures that may interfere with periodontal surgical procedures.

MATERIAL AND TECHNIQUE OPTIONS

Among the material and technique options available for the different stages of periodontal therapy related to esthetic dentistry are optimal management to reduce gingival inflammation and control of periodontal disease. This includes the initial therapy phase. Generally, oral hygiene instructions with a wide variety of devices should be included in the treatment plan. Progression to ultrasonic or piezoelectric débridement of the dentition and implants should also be included in the periodontal treatment plan, followed by hand scaling and root planing. This is especially important if pockets exceed 3 to 5 mm and there are deposits on the teeth when dental implants are considered. These are the primary approaches available for débridement of the dentition and implants.

Other alternatives for treatment include local drug delivery devices such as doxycycline-impregnated spheres (Arestin, OraPharma, Warminster, Pennsylvania). This type of delivery system permits local antibiotic release in periodontal pockets for the purpose of controlling gingival inflammation (off-label use per the U.S. Food and Drug Administration [FDA]). Enhanced keratinized gingiva for prosthetics and dental implants can be obtained by using autogenous soft tissue grafts such as from the palate or the distal area of the most terminal molar as donor keratinized gingiva.

Alternatively, the clinician can use allograft material such as AlloDerm (BioHorizons, Birmingham, Alabama), which is freeze-dried human skin. The distinct advantages of allograft products include not requiring a second surgical site, greater patient comfort during the procedure, reduced time for the procedure, and improved postoperative management. The major disadvantage is cost; the estimated charge per square centimeter of allogeneic skin is about $150 (US), which may be prohibitive for some patients and may not covered by insurance. Other disadvantages are patient reluctance regarding use of freeze-dried allogeneic products and the learning curve required for the clinician to be able to handle these products.

Current Best Approach

It is the author's opinion that the current best approach is to use allogeneic skin products to enhance keratinized gingiva.

OTHER CONSIDERATIONS

With regard to esthetics, the clinician should be aware of the position of the area of keratinized gingiva. In the anterior part of the mouth, the clinician should ensure that the smile line is accurately recorded, perhaps with clinical photographs. Most important are the patient's chief complaints and concerns regarding enhancement of keratinized gingiva. Another consideration is any patient concern related to oral hygiene. For example, are there areas of the dentition where the patient experiences gingival sensitivity owing to a lack of keratinized gingiva?

Further considerations also include medical and medication complications related to surgery, including periodontal therapy débridement procedures. Patients who have a history of cardiovascular disease may be taking "blood thinners," resulting in increased bleeding risk. Frequently cardiologists will comply with the dental clinician's request to either reduce or suspend the patient's medication for the duration of periodontal or dental therapy.

INNOVATIVE ELEMENTS

Scientific Elements

One of the most exciting scientific approaches in periodontal therapy as it relates to esthetics involves the use of lasers. Research continues, but the FDA has approved several laser products for

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limited soft tissue management of periodontal tissues. This includes soft tissue débridement and control of inflammation.

Technologic Elements

Currently both the ultrasonic and piezoelectric approaches can be used to control inflammation. The tips and qualities of these devices have improved significantly. Most recently, a new ultrasonic tip (Cavitron THINsert, DENTSPLY Professional, York, Pennsylvania) was introduced that is about the size of a periodontal probe. This new tip permits deeper access into periodontal pockets and interproximal areas of teeth.

Another technologic approach for both ultrasonic and piezoelectric instruments is the use of plasticized or rubber tips with dental implants. Controversies remain regarding the use of metal tips on dental implants. However, the potential to scratch implant surfaces and enhance colonization of the plaque biofilm exists. Many companies have made technologic advances in this area, and the scientific literature supports the use of non-metal tips (Implacare, Hu-Friedy Mfg. Co., LLC, Chicago, Illinois) for the maintenance of dental implants.

ARTISTIC ELEMENTS

With respect to the artistic elements involved in the control of periodontal disease and gingival inflammation, any reduction or elimination of redness around the teeth will improve the artistic qualities. This makes it pragmatic for the dental clinician to use "nature" and the healing process to reduce gingival inflammation.

With regard to the artistic qualities specific to the enhancement of keratinized gingiva, the dentist's eye and clinical experience must be used to develop the shape, thickness, and quality of the gingiva to be transplanted into the site where keratinized gingiva is lacking. This would include use of the proper thickness ("biotype") of either tissue taken from the palate (autogenous grafts) or allogeneic freeze-dried dermal matrix skin to enhance keratinized gingiva. Other artistic qualities could include the scope of the procedure and the mesial-distal width and apical coronal height of the keratinized gingiva in the periodontal plastic surgical site. Artistic techniques would include blending the periodontal graft into the existing gingiva to make it appear as if they are confluent with each other.

TREATMENT PLANNING

Treatment planning is completed in two different areas based on the esthetic procedure to be performed. The treatment planning for conventional periodontal therapy has not changed over the past several decades. The periodontal treatment plan to control inflammation includes (1) a review of medical, medication, and dental history, (2) the accurate diagnosis and consultation with the patient, and (3) initial therapy, also termed *nonsurgical therapy* or *phase one periodontal therapy.* Initial therapy includes oral hygiene instructions, periodontal débridement including ultrasonic and piezoelectric approaches, hand scaling and root planing, occlusal control (if necessary), evaluation of initial therapy 4 to 6 weeks after the conclusion of the last débridement procedure, and periodontal surgical procedures (if necessary). The result is a reduction of gingival inflammation and arresting of disease progression.

When planning for the enhancement of keratinized gingiva, especially when this includes dental implants and crowns and bridges, one must include periodontal surgical treatment planning as already outlined. The enhancement of keratinized gingiva is referred to currently as *periodontal plastic surgery.* This includes the enhancement of keratinized gingiva by autogenous grafting from the palate or by allografts using freeze-dried human skin from a tissue bank. Other periodontal plastic surgical procedures in treatment planning are root coverage for teeth with exposed roots *(connective tissue grafts).* The two choices for such procedures are autogenous gingival and allograft freeze-dried skin.

TREATMENT CONSIDERATIONS DURING PREPARATION, PROCEDURE, AND FINISHING

The most important preparation with regard to treatment planning considerations is an accurate medical and dental history of the patient. That includes ruling out any medical contraindications to therapy and also considering medications that may influence periodontal therapy, such as blood thinners or medications that would cause gingival hyperplasia. Three recognized drugs and drug types are phenytoin (e.g., Dilantin), calcium channel blockers (e.g., nifedipine), and drugs that prevent organ transplant rejection (e.g., cyclosporine). Use of these medications should be considered during preparation for treatment. The procedure itself requires timing. Some patients, such as those with early periodontitis, require two appointments for débridement and initial therapy, whereas other patients with moderate to advanced periodontitis need four or five appointments. This includes patients with periodontitis with furcation involvement.

The evaluation of initial therapy takes place 4 to 6 weeks after the last débridement procedure. Included is an assessment of the patient's oral hygiene and wound healing. If the periodontal soft tissues are not healing or responding to therapy as anticipated and the patient's oral hygiene is satisfactory, a medical consultation may be needed to rule out the influence of systemic diseases.

The results of plastic periodontal surgical procedures depend on wound healing, typically 2 to 5 weeks after surgery. Evaluation includes the number of millimeters of enhancement of keratinized gingiva, the blending of the color, and the size and shape of the grafted tissues.

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EVIDENCE-BASED PRINCIPLES

There is overwhelming support in the literature for periodontal therapy to reduce general inflammation, beginning in the 1960s and 1970s. Clinical research shows that the removal of bacterial plaque and débridement of the dental root surfaces result in improved gingival health; reduced redness, which is an esthetic concern; and, most important, management of the attachment surrounding the teeth.

Studies on enhanced keratinized gingiva around the dentition and dental implants have been conducted for several decades. Recently the keratinized gingiva principle has been applied to dental implants, although the literature is still sparse regarding how much keratinized gingiva is needed for a healthy dental implant. This is probably where the evidence-based principles are somewhat lacking. The strong clinical opinion of many clinicians is that they prefer keratinized gingiva during suture and soft tissue management when placing dental implants.

CLINICAL CONSERVATION CONCEPTS

The conservation of the periodontium and the supporting structures around the teeth is essential to the esthetics and function of the patient. Although these procedures have worked for many patients, for others loss of periodontal attachment continues, bone is lost, and other soft tissue problems exist. The conservation concepts related to periodontal therapy are critical in maintaining the overall periodontal health and attachment apparatus. For example, the concepts of periodontal surgery have, over the last 10 to 20 years, emerged in regeneration procedures. The use of bone grafts, whether autogenous, allograph, or synthetic bone materials, or the use of membranes, resorbable or nonresorbable, to regenerate periodontal tissues is a primary method of conserving, preserving, and regenerating lost periodontal tissues. For conservation of the periodontium, these clinical concepts have shifted dramatically toward regeneration rather than resective surgery.

MAINTENANCE

Maintenance for esthetic purposes is extremely important. There are strong evidence-based principles that a periodontitis patient must be monitored and undergo follow-up a minimum of four times per year, every 90 days, throughout his or her lifetime. Such patients need clinical examination and scaling and root planing to maintain the periodontal attachment. If the diagnosis is gingivitis, the recommendation is maintenance procedures twice a year. With regard to esthetics, especially with dental implants, no evidence-based research, clinical or scientific, currently gives recommendations for the ideal maintenance periods for follow-up care. Therefore the projections for implant maintenance have been adapted from the literature in reference to natural teeth. If patients have dental implants, they should be monitored and evaluated using a plastic periodontal probe to look for pocketing or signs of inflammation around implants or other prosthetic devices, and to reveal other signs of inflammation. Radiographs should also be taken, although the frequency and interval of radiographs or implant maintenance has not been established. The author's recommendation is to perform radiographic follow-up of dental implants after 6 months and 1 year to monitor peri-implant bone loss, and then examine dental implants at least every 1 to 2 years radiographically (unless a problem develops earlier). Oral hygiene must always be monitored at each recall appointment.

CONTROVERSIES

The controversies relate to the use of plasticized instruments versus metal instruments in terms of implant care. Although many clinicians continue to use metal instruments on implants, others prefer to use titanium metal instruments for débridement. There is a growing acceptance of plasticized tips. Hu-Friedy makes a set of three implant instruments. Plasticized or rubber ultrasonic tips are also commercially available and are recommended.

The second controversy relates to the interval and frequency of maintenance care. Periodontitis follow-up is established to be four times per year of maintenance for the rest of the patient's life. After gingivitis treatment, patients are checked twice per year. Currently there are no evidence-based principles for implant follow-up care. The controversy surrounds the frequency at which implant patients should be monitored. Currently, the author advocates four times per year as a follow-up schedule for implant maintenance.

A third controversy surrounds the use of local drug delivery systems such as minocycline-impregnated microspheres (Arestin), doxycycline-impregnated polymer (Atridox), or chlorhexidine-impregnated collagen strips (PerioChip). The controversy surrounds the off-label application of these local drug delivery systems to periodontal pockets. The FDA has approved these products for reducing inflammation and managing periodontal health. Whether these local drug delivery systems can be applied to clinical situations involving dental implants and peri-implantitis remains untested. The FDA has not approved these products for peri-implantitis. However, two evidence-based peer-reviewed studies indicate that selected local drug delivery devices (Arestin, chlorhexidine gel) improve inflammation around dental implants and in treatment of peri-implantitis.

NEAR-FUTURE DEVELOPMENTS

With regard to future developments, the author predicts that periodontal therapy will be more focused. For example, lasers, improved scaling and root planing, and perhaps root preparation using laser therapy may become common time-saving approaches. The laser appears to offer greater patient comfort as well.

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Other future developments should address the area of keratinized gingiva. Currently, stem cells from the patient can be grown in cell culture in a laboratory to produce autogenous mats of keratinized gingiva. After several weeks or months, the "tissue-engineered" autogenous graft will be placed into the patient's mouth surgically. Also on the horizon is enhanced growth of the gingiva either by different molecular- and cellular-induced methods of development or by use of other enhancements to improve areas of root recession. This is an exciting area especially applicable to esthetic dentistry. Surgical procedures may not be required in the future. Instead there will be cell culture and stem cell approaches to grow gingiva in the oral cavity.

CLINICAL CASES

CASE 1 Fractured Incisor

A 24-year-old healthy white man had a fractured maxillary right lateral incisor (tooth No. 7 Universal system; tooth No. 1-2, FDI World Dental Federation notation). The treatment plan featured a surgical crown lengthening without osseous re-contouring in order to enhance the sound tooth structure for prosthetic replacement with a crown. At least 5 to 7 mm of sound tooth structure can be seen immediate postoperatively.

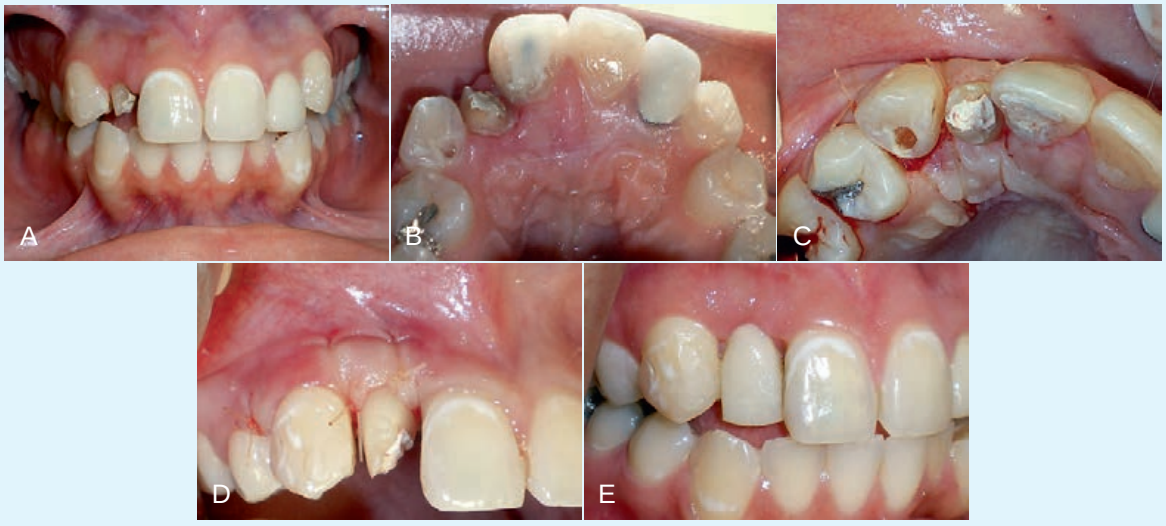


FIGURE 28-1 **A to D, Fractured maxillary right lateral incisor. Surgical crown lengthening (without osseous re-contouring) completed to enhance tooth structure for prosthetic replacement with a crown. E, Postoperative view shows 5 to 7 mm of sound tooth structure.** *(Clinician, Dr Kevan Green.)*

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CASE 2 Esthetic Improvement of Maxillary Anterior Dentition

A 20-year-old African American woman was referred by orthodontics for esthetic improvement of the maxillary anterior dentition. An external bevel gingivectomy procedure involving soft tissues was performed. The postoperative image shows improved maxillary anterior teeth.



FIGURE 28-2 **A, Maxillary anterior dentition requiring esthetic improvement. External bevel gingivectomy involving soft tissues completed. B and C, Improved maxillary anterior teeth shown postoperatively.** *(Clinician, Dr Ann Chernyak.)*

CASE 3 Esthetic Improvement of Gums

An 18-year-old healthy white female patient's chief concern was improved esthetics of her gums. An external soft tissue gingivectomy was performed. Six-month postoperative images are shown.



FIGURE 28-3 **A, Gums requiring improved esthetics. An external soft tissue gingivectomy was performed. B, Six-month postoperative photograph.** *(Clinician, Dr Justin Zalewsky.)*

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CASE 4 Esthetic Improvement of Gum Line

A 24-year-old African American woman has full-banded orthodontics and an interest in improving the "esthetics of her gum line." External bevel gingivectomy was performed using a prefabricated stint to result in the images shown at 1 month and 1 year.



FIGURE 28-4 **Patient with full-banded orthodontics requiring improvement of the "esthetics of her gum line." Pretreatment facial (A), radiographic (B), and intraoral views (C). D to F, External bevel gingivectomy performed using a prefabricated stint. G, Treatment results at 1 month *(top)* and 1 year *(bottom).*** *(Clinician, Dr Kevin Suzuki.)*

SUGGESTED READINGS

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B SECTION

Relating Function and Esthetics

David L. Hoexter

RELEVANCE OF PERIOESTHETICS TO ESTHETIC DENTISTRY

The link between health and appearance in the oral cavity is highly relevant. Without a healthy periodontal status, no matter what has been done with the teeth—crowns, veneers, whitening—the results will not last. Oral esthetic results need a background of health to enhance the image desired. For example, if the patient has a long-appearing tooth owing to excessive recession, and the desire is to create a more symmetrical illusionary smile line, it is necessary to move the tissue with its pink keratinized tissue background and then reattach it over the recession, which will make the tooth appear beautiful in a smile, depending on the patient's lips and exposure of teeth. It is essential for health and esthetics to support the results achieved restoratively, and that means healthy soft tissue, good color, and proper maintenance by patient and dentist.

Role of Periodontics in the Enhanced Smile

There is no improved smile without a symbiotic relationship between periodontics and restorative dentistry. To achieve an enhanced smile one first develops an image of the desired outcome and then physically tries to achieve that restoratively. The soft tissue must be present in the correct proportion if that outcome is to be achieved. For example, if the tissue level is altered, it may result in spaces between the teeth—the so-called "black diamonds." No matter how wonderful the restorative work is, the eye will be drawn to these dark spaces. It is necessary to have a picture surrounded by a frame. Periodontics becomes the frame that helps visualize what is desired in the smile. Dentists can alter or enhance the frame. The results will be predictable if periodontic treatment achieves a healthy foundation. Then the smile not only looks good but can be maintained.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF PERIOESTHETICS

Periodontal surgery can move tissues up and down and/or left and right to preserve a tooth, disregarding the esthetic component. Society today, however, demands an overall standard of appearance, so periodontal esthetic surgery aims to achieve an overall outcome that can be maintained using the periodontium's shape, form, and color.

An early periodontal esthetic technique was called the *curtain procedure* because often surgeons just cut away the palatal aspect. It was one of the first compromises in esthetic surgery involving the maxillary anteriors in which the pocket was not removed. Surgical procedures were done strictly from the palate, then the surgeons scaled into the labial covering so the tissue level did not expose the interproximal areas. This technique avoided exposing the roots but left pathology. Arthur Zentler was perhaps the first periodontist in the United States, and he cut all the soft tissue horizontally, exposing the roots, regardless of the type of tissue. That approach is the opposite of what is really wanted today. The goal is to preserve the pink-colored keratinized tissue and recognize other colored non-keratinized mucosa.

Initially, practitioners must recognize appropriate tissue colors. Anatomically there is a horizontal line, the mucogingival junction, that appears to separate the bluish-red alveolar mucosa from the attached keratinized pinkish gingiva (Figure 28-5). The alveolar mucosa is reddish purple, movable, and not keratinized. The tissue around the teeth, from the mucogingival junction toward the teeth's cemento-enamel junction (CEJ), is keratinized, having the same epithelium with keratin as the outside layer. That keratin should be a pinkish-white color. Some people have different melanin pigmentation, causing a different color (Figure 28-6), but the pinkish-white keratin is very important. For an esthetic periodontal background it is necessary to have horizontal symmetry of keratinized gingiva and to cover the CEJs. The pinkish-white background emphasizes and enhances the foreground. It is the only background with which the patient can maintain the teeth's health by performing correct oral hygiene. The pinkish-white background establishes the foundation for esthetics in the oral cavity and is needed to maintain health.

In 1956, Grupe and Warren described a procedure they called a "sliding flap." They were the first to recognize the ability of the attached gingival to move laterally. This technique is now referred to as a laterally positioned pedicle graft. Grupe modified this technique in 1966.

The first article recognizing the two different gingival zones was written by Claude Nabers in 1954. He described keratinized attached gingiva versus non-keratinized alveolar mucosa, which had not been distinguished earlier. While Groupe developed sophisticated ways to move the tissue from left to right,

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FIGURE 28-5 The teeth surrounded by pink attached gingiva, separated from the bluish-red alveolar mucosa by the mucogingival junction.



FIGURE 28-6 Keratinized attached gingiva with different color because of different melanin pigmentation.

Abrams used it esthetically in a more vertical fashion. This author also has contributed articles about taking the depressed labial tissue and building it out. The labial tissue is built out labially to eliminate a previously concave depressed area (Figure 28-7). Free gingival grafts using a connective gingival component are used. Through initial release of the recipient area tissue from the inside, the keratinized tissue is preserved. The connective tissue graft is placed inside the flap, which has a full blood supply. It is used to build out the labial definition so there is an appropriate physiological background for pontics. The results in this situation are that the location of the depression will not be visible and there will not be a large unphysiologic pontic that is unattractive and collects food.

Raising the tissue vertically and exposing the proper amount of tooth structure to prepare for a crown in an area that is not pathologic is called *crown lengthening*. When pathology is present, the same technique is called an *apically repositioned flap*. The apically repositioned flap is a technique that results in an existing pocket removal and ends with keratinized attached gingiva surrounding the area. An esthetic enhancement of the vertical movement of the tissue is the growing enamel technique (Figure 28-8). It will lengthen the appearance of the maxillary anterior teeth by taking the keratinized tissue and vertically manipulating to the CEJ, when there is excessive tissue. Doing that exposes the beautiful natural length of the teeth while keeping a healthy wide zone of attached gingiva as their background.

In esthetic tissue grafting, the goal is also to use color to obtain a symmetrical appearing background in addition to a keratinized attached zone of health. The tissue is manipulated laterally, apically, and coronally. A specific technique for coronal repositioning is used when there is recession. With recession, on a few teeth a difference of color can be seen—the white of the enamel and the yellowish brown of the exposed root. It is not desirable for the root to show, so the tissue is grafted in a coronal position. The result is the covering of the previously exposed root with healthy tissue of the same color as the surrounding tissue (Figure 28-9).

To support the teeth, practitioners use bone grafts, such as autogenous bone grafts. Bone grafting is basically taking bones from different sources and not repairing but regenerating support for the tooth or the edentulous ridge. By doing that, one achieves a strong base for the tissue to be maintained with a good blood supply for health. Bone grafts do two things: they increase tooth support, and they provide a base in which healthy tissue can be placed to achieve the background needed for an esthetic result or which can support future implants.

Brief History of Implants

Implants have been used since ancient Egyptian times. Endosseous oral implants made of different sizes, shapes, and materials became quite popular in the 1960s. Also, in the early 1960s titanium began to be used in implants. The titanium alloy implant came in various sizes and shapes. Retention of the implant and its crowns could now be considered predictable, and such restorations replacing lost teeth could be considered non-removable.

By using implants, practitioners could restore vertical dimension and tooth length, achieving the correct height between the maxillary and mandibular arches with support from a non-removable prosthesis. This changed the facial component, restoring and eliminating the commissures at the corners of the mouth and restoring the vertical dimension. Having the correct height of the teeth between the arches results in more youthful teeth because the actual vertical space has been resurrected.

RELATING FUNCTION AND ESTHETICS

Blending physiology and function is a natural way to create a pleasing appearance. In periodontics there should be symmetrical blending of hard and soft tissue structures so they maintain each other symbiotically. When dealing with perioesthetics and periodontics, the image is emphasized by producing a restorative structure that can be maintained. For that, a healthy hard structure is needed underneath. The hard structure (the bone) maintains the integrity of the soft structure, which maintains the background of the smile.

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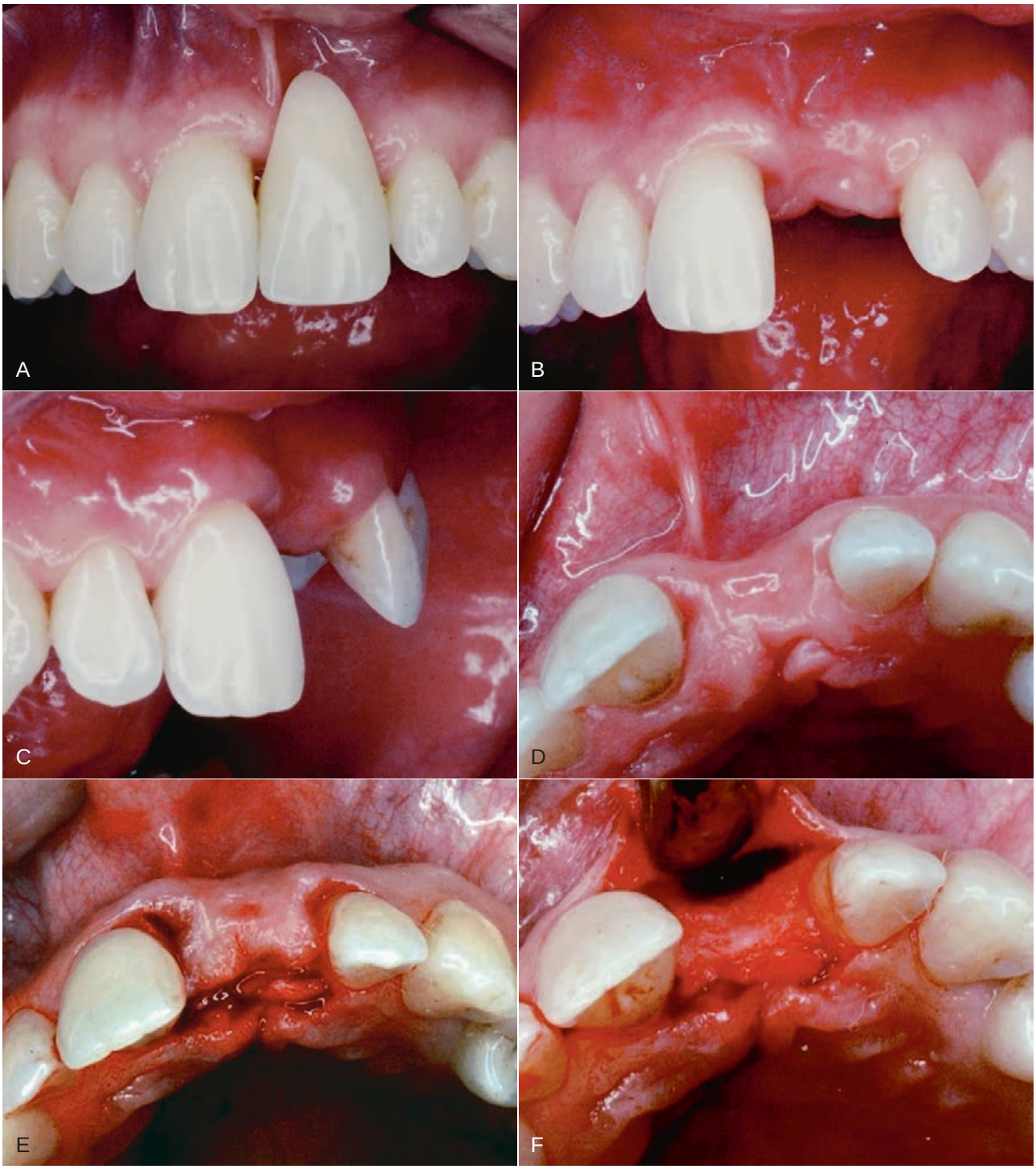


FIGURE 28-7 **A,** Labial view of a maxillary arch with the No. 9 tooth missing, replace with a removable "flipper." **B,** Labial view without the flipper, showing depressed ridge. **C,** Lateral view showing extreme concavity of the depressed area of tooth No. 9. **D,** Occlusal view of depressed ridge. **E,** Occlusal view of flap design including palatal keratinized tissue. **F,** Flap released toward the labial, exposing the osseous defect.

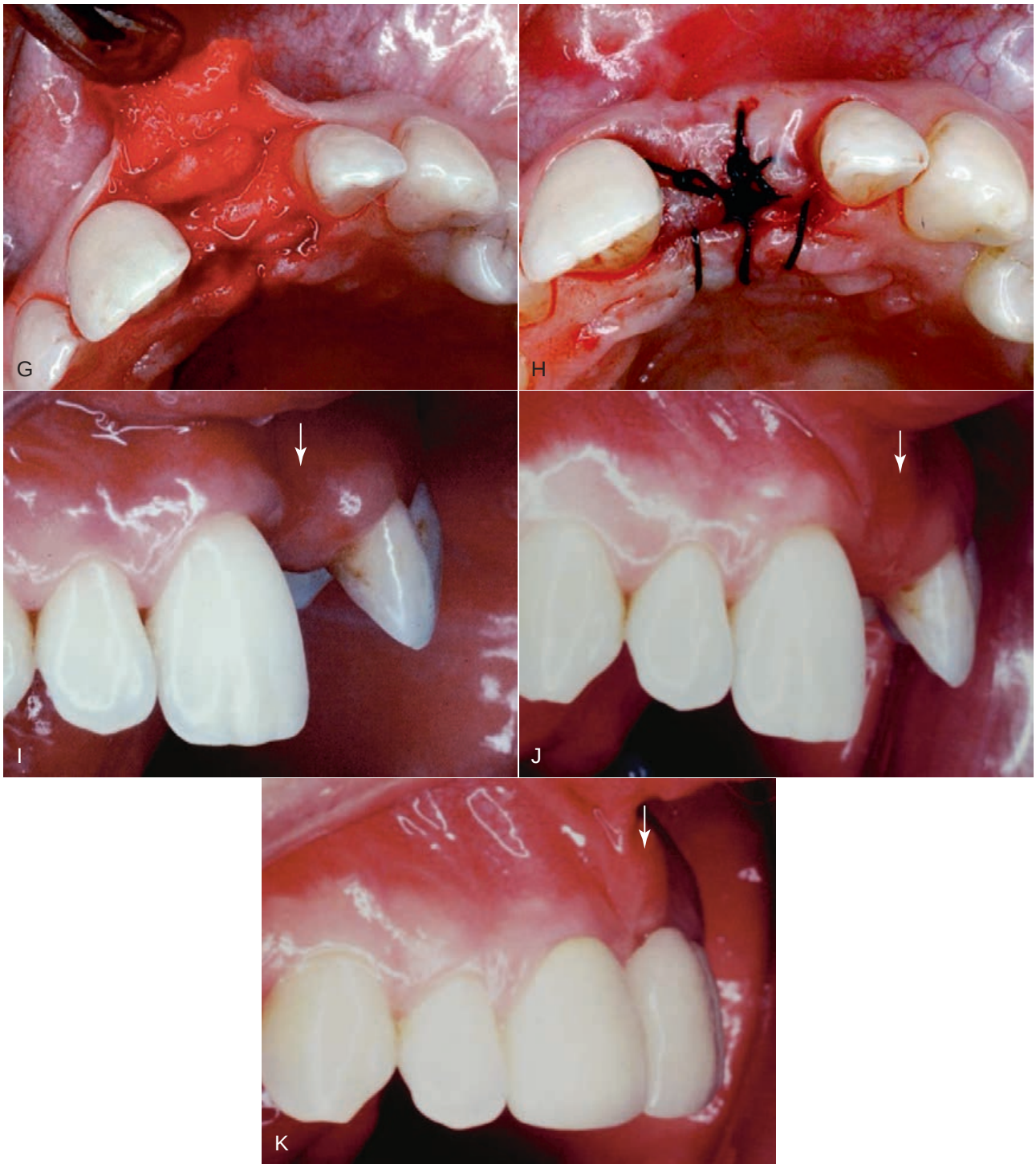


FIGURE 28-7, cont'd **G,** Connective tissue (CT) graft from the palate, inserted in defect area. **H,** Flap sutured in desired position with CT graft. **I,** Lateral view before, with depression (*arrow*). **J,** Lateral view after, healing with ridge built out (*arrow*). **K,** Final lateral view with prosthesis after ridge augmentation (*arrow*).

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FIGURE 28-8 **A, Initial labial view. B, Growing enamel technique sutured in position, exposing the length of natural enamel crown. C, Final view of healed area showing the entire teeth without exposing any root.**

CLINICAL CONSIDERATIONS

Indications

What is needed is a healthy keratinized attached gingival zone that is symmetrical. It should be symmetrical vertically as well as horizontally, with a pinkish keratinized gingival color. It should be symmetrical so that it acts as a background for the restorative work. A good healthy zone must be in place because it is the only tissue that the patient can keep clean and free of bacteria.

There can also be a concavity from the labial aspect, especially after extraction. This is usually a result of bone resorption. To achieve a normal-appearing tooth, the tooth and the labial bone must be built up. The convexity emphasizes the natural root. There is a nice slope, and the pink keratinized tissue is on top of it. If the tooth is lost, the alveolar bone resorbs, typically toward the lingual, creating a concavity. If a pontic is to be placed, the concavity must be filled. A depressed background adds to a large unsightly pontic tooth that stands out and collects all sorts of food and plaque. It is undesirable to see a depression in the labial tissue, which causes an unsightly shadowy area that draws attention to itself. Techniques are used to build out the tissue from the inside with connective tissue grafts or artificial bone or bone replacements. These also appear when the results of an extraction site are too resorbed to place an immediate implant. One should not put an implant in the socket of an extracted tooth if there is inadequate buccal bone, because it will be in a lingual position, the crown will add shadows, and food will collect in that area. These ridges are built out for esthetics and to add bone support for future implants.

New instruments from Hu-Friedy Mfg. Co. (Chicago, Illinois) are designed to aid in preventing resorption of the alveolar ridge after an extraction. These instruments will help avoid a depression, will preserve the osseous ridge to allow for success of the future implant, and will enhance the esthetic appearance of the area.

Another indication for periodontal esthetics is the *color of the attached gingiva.* Color is based on melanin pigmentation, which may differ in color within the gingiva locally. Some people have gingivae that are more symmetrical and pinkish white, some are darker brown, some are pink and brown—it depends on natural heritage (see Figure 28-5) and has little to do with health. In seeking a gorgeous smile, if the patient has a sporadic dark

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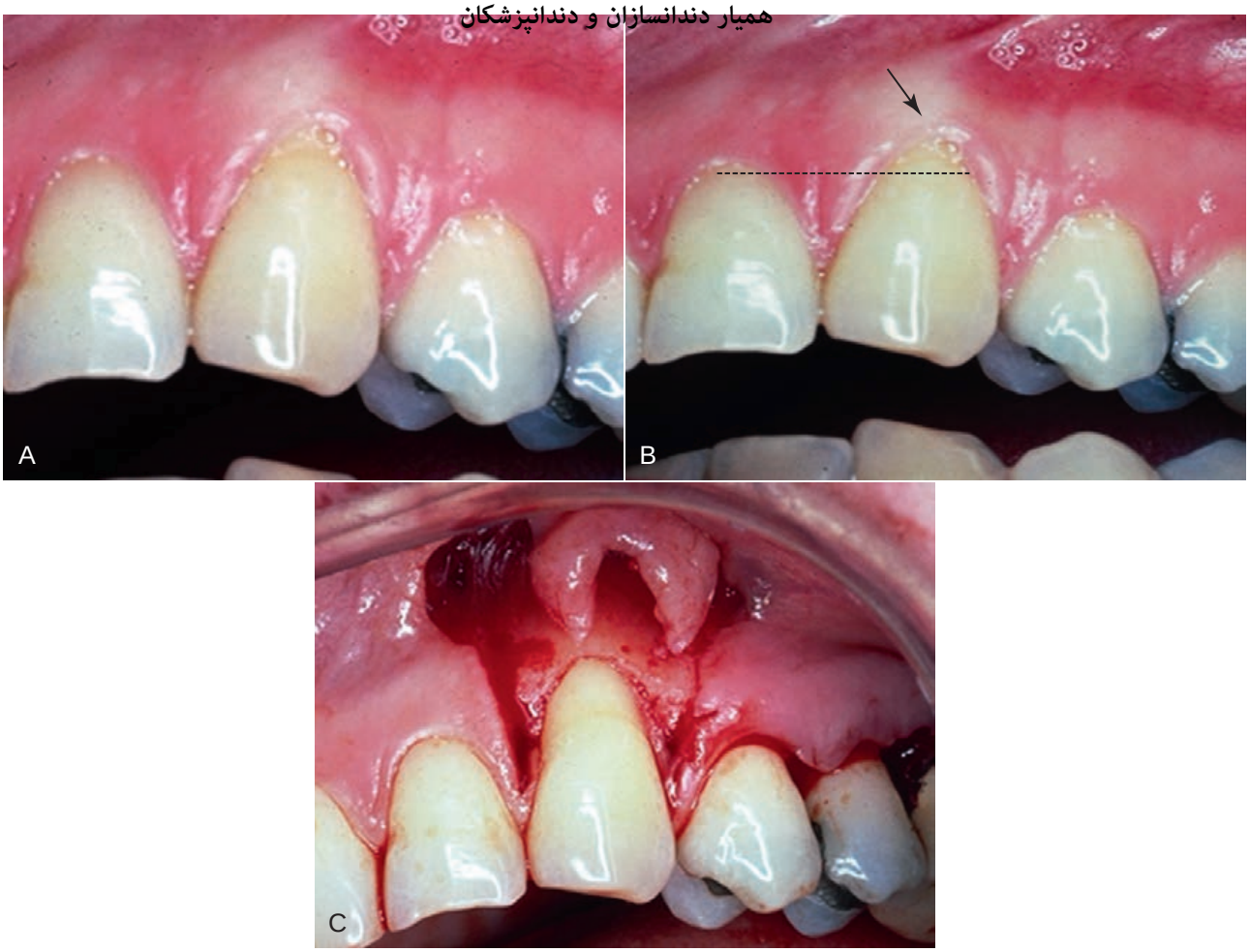


FIGURE 28-9 **A, Exposed root recession of tooth No. 11. B, Arrow pointing to recessed area. Horizontal line emphasizing the amount of recession with adjacent tooth No. 10. C, Labial flap reflected, showing larger amount of recession.**

Continued

melanin pigmentation and if surgery such as trim scalloping or gingivectomy is performed, the result is often a keratinized scar that is a solid pinkish color, called a *keloid,* which is not desirable. The optimal outcome is a natural pinkish white attached gingiva or symmetry in color, size, and form—incisal-cervical as well as horizontal. Gingival grafts using specifically keratinized tissue or lateral sliding grafts are done to avoid a non-smooth background of melanin pigmentation.

Hyperplasia, or *overgrowth,* of the fibrous keratinized tissue can be caused by medical factors or physical positioning. Medically, it can be induced by some blood pressure medications, as well as phenytoin (Dilantin). However, these drugs cause hyperplastic overgrowth only if the area is not kept clean, reflecting a bodily reaction to the irritant. If the mouth is kept clean, the odds are that overgrowth will not occur. However, hyperplastic keratinized tissue can lead to a pseudo-pocket. Esthetically, this makes the tooth look smaller or longer (Figures 28-10 and 28-11). The clinician begins to see part of the tooth covered, without the natural scalloped shape. Excess keratinized tissue is removed surgically to create a scalloping effect that resembles the cervical flow of natural teeth.

Recession of the tooth can be either introduced iatrogenically or produced physically. Physically, it occurs when teeth are moved orthodontically in a labial direction beyond the bone's physiological limit, by unphysiologic occlusal trauma (TFO), or excessive oral habits. It may also reflect a natural growth in today's heterogeneous societies, in an arch that lacks space. There might be nothing pathologic about recession, as the local area adapts physically. Nonetheless, the recessed area contributes to an appearance of being old, or timeworn—hence the term *long in the tooth.* The appearance also makes patients sensitive about their looks—there is a glistening white smile and then a sharp contrasting brown zone of exposed root. The patient adapts and learns to keep his or her lip down to hide the recession area. Various periodontal cosmetic surgical techniques can be used to correct these visual defects, such as lateral sliding, coronal repositioning using membranes, and connective tissue free gingival grafts using tissue from the palate. A very predictable method is to use barrier membranes for guided tissue regeneration.

With respect to membranes, this author prefers resorbable ones. Use of resorbable membranes avoids the need for a second surgical procedure. There are three groups of these resorbable

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FIGURE 28-9, cont'd **D, Acellular membrane in place for the guided tissue regeneration (GTR) technique. E, Flap sutured in a coronal repositioned position. F, Final view showing complete gingival coverage regeneration of the previously exposed recession.**



FIGURE 28-10 **Single lesion of hyperplasia.**



FIGURE 28-11 **Multiple hyperplastic lesions creating non-esthetic teeth.**

membranes: polyglycolic, polylactic, and collagen. The *polyglycolic membrane* has the advantages of being malleable and resorbable. The most popular member of this group is GUIDOR. The *polylactic membranes* such as Vicryl and Resolute are resorbable as well but sometimes have inconsistent resorbability. They may resorb sooner or later. Clinicians like to maintain the membrane for 6 to 8 weeks so that the blood supply becomes present. With natural connective tissue, there is no definite time for tissue graft resorption with a secure blood supply. Collagen membranes offer ease of use, availability of materials with a good shelf life, and less expense. Tranzgraft (CK Dental Industries, Orange, California), an acellular membrane, is an excellent example for use in this category.

همیار دندانسازان و دندانپزشکان



FIGURE 28-12 **A, Recession of the gingiva, exposing tan root color of tooth No. 11. B, Recession covered after regenerative root coverage treatment.**

If it is desired by the operator to use connective tissues from the patient's palate, we should remember that natural tissue is not easy to obtain, and the technique creates a second wound for the patient. The patient will undergo local anesthesia in two different places, the graft does not necessarily mean predictability, and this sort of wound actually hurts. There are easier ways to do this today without two wounds. All of the techniques move toward the goal of eliminating recession and regaining a youthful appearance while restoring health (Figure 28-12). The esthetics achieved are definitely a great reward.

Contraindications

Medically, there are restrictions. Some people may not be well enough to undergo perioesthetic treatment. For people taking Coumadin, it is necessary to work with a physician and usually have the patient taken off the medication for 3 days before the procedure. It is also essential to check medically whether a local anesthetic such as lidocaine can be used**.** Questions such as the following arise: Can epinephrine be used with the local anesthesia or not? Should a local anesthetic such as Carbocaine be used? What are the drawbacks of compromises necessitated by the medical health of the patient? Obvious results of not using a vasoconstricting medication would include the shorter period of no bleeding. The operator should curtail the length of the procedure owing to the bleeding; several operations of shorter duration might be required. One might consider referring the patient for a hospital procedure. In addition, the recommendations for antibiotic premedication have changed recently, as reported by the American Heart Association. Anytime oral medication is necessary, the compliance of the patient is always a variable.

Whatever the medical or surgical involvement in perioesthetic treatments, dentists should use common sense and never cause restriction of the healing. Some patients may take longer to heal than others. For example, the diabetic patient usually takes longer to heal, so this must be considered in the surgical postoperative healing time expectations.

Another contraindication, primarily for all patients, is poor oral hygiene. Before any esthetic surgery is commenced that requires regeneration or if a blood supply is lacking, poor oral hygienic habits must first be corrected or new ones instilled. The initiating factor of periodontal disease must be eliminated or it will reappear. If the patient has poor oral hygiene before the procedure or had poor periodontal status, that is likely to recur because of destructive local bacteria. Poor manual dexterity is the main reason that power toothbrushes were first created in the 1960s, but the key to power toothbrushes or hand toothbrushes is the type of bristles being used. The bristles, if not polished at the tip, might become an irritant themselves.

MATERIAL OPTIONS

Bone Regeneration

Autogenous bone is probably best for regeneration because there is no antigenicity and there is excellent bone morphogenetic protein (BMP) because it is from the same patient. The downside is the amount of bone that can be accessed. One major source of bone is the hip, which supplies a lot of bone. This requires a wound in the hip, which is painful and often must be performed by an orthopedist. Sometimes if the bone from the hip is put around the tooth to regenerate the bone, root resorption develops. It is preferable to take the bone and freeze it. Freezing helps to avoid root resorption. A second major source of bone is intra-oral site and this requires a second intra-oral wound. It is important to determine the cause of the initial bone loss first. Was it poor oral hygiene or an infection of some type?

There are also dispensable bone graft materials or "bottled bone." The three types are xenograft, alloplastic, and allograft.

Xenograft bone comes from another species and is usually dried. It is quite good and has the same proteins and same size as human bone. It is processed through treatments and sterilized, but once the antigenicity has been sterilized out of it there

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is diminished induction quality. Despite this, it has been shown to be quite positive in aiding regeneration.

Alloplastic bone is an artificial material, not taken from another living source. For example, ceramic is popular to use as a bone fill. It performs well for ridge augmentation but does not induce bone. It is used for ridge augmentation when dealing with esthetic restorations. Alloplastic bone allows one to build out the ridge because it causes no inflammatory response and it usually does not resorb.

Allograft bone is from another human being, and there is worry about antigenicity. The material is sterilized, but it is resorbable, so it does not last forever. Freeze-dried bone whose source is a human cadaver is considered the gold standard in allograft materials. Yet it is impossible to know how much conductive quality remains for induction, so it is an unpredictable, inconsistent, yet very useful source for bone, acting also as a matrix for bone regeneration. It is also readily available and requires no second wound site.

Tissue Regeneration

The gingival tissue is one of the few places in the body where complete regeneration is possible. *Repair* does not mean the same thing as *regeneration*. It does not include return to the actual nature of the structure. Dentists try for regeneration in the tissues of the periodontal ligament, but it is not possible to grow cementum predictably, so the option is tissue regeneration. This technique may aid in regeneration of the ligament because it is being stimulated and given a place to grow. With the ligament comes cementum, which means reattachment of the tooth. Regeneration of the Sharpey fibers always occurs, and the periodontal ligament attaches the Sharpey fibers to the cementum; that is true regeneration of the lost alveolus.

It is possible to regenerate the color by transferring the melanin pigmentation or the connective tissue from the palate. It is a bonus that should be taken advantage of in perioesthetics because it is not possible to regenerate enamel, dentin, or tooth. It is possible to regenerate the support and its color. If the gingiva is incised correctly, guided tissue regeneration can be used to get reattachment and color. Some companies tout regeneration by an artificial collagen material, but that does not regenerate and can cause a keloid (scar tissue). True tissue is needed to generate true color. One does not want to take the chance of using artificial material for an epithelial gingival graft because the color can come out pinker and brighter. It does not regenerate in the color desired—only connective tissue can do that. It is possible to regenerate the tissue if it is available, and it may be regrown someplace else if the blood supply is adequate.

Autogenous Tissue Grafts versus Autogenous Bone Grafts

Autogenous grafts are accessible because they are obtained from the patient. Rejection is minimized because of the lack of antigen-antibody or allergic reactions. In addition, the blood supply is the same. It is inexpensive for the amount available, and the color regeneration will be correct. The disadvantages of tissue regeneration are the limited supply and the need for a second surgical site in most cases. The process is technique sensitive, and learning the procedure, although not difficult, requires time. The patient must deal with an uncomfortable second surgical site and wait for both sites to heal.

Xenografts are from other species, specifically bovine and porcine species, and no antigen or antibody reactions are anticipated because they have been sterilized so much, but these membranes do not reproduce by themselves. Usually a piece of the host's tissue must be propped on top of a xenograft to regenerate the color. The xenograft offers an excellent blood supply, but color regeneration is not always predictable. So it is used in guided tissue regeneration (GTR) as a blood supply barrier. This GTR technique prevents the connective tissue and epithelium from growing into this recipient area, thus allowing the recipient site blood supply to come through and regenerate a blood supply to the donor site; that becomes the bed for the covering tissue. The desired new tissue can be placed and maintained on top as long as a base blood supply is available. Acrylic material membranes have also been used in these techniques but all too often provoke an allergic reaction and cause necrosis and sloughing at the wound site. Then the wound site has to regenerate by secondary intention. The healing area is unpredictable in its healing time and size, besides being uncomfortable, and might undergo some further resorption.

Allografts come from a human source other than the patient and may be freeze-dried tissue. They can be manipulated and are malleable. The disadvantages of the allograft are cost and color inconsistency. It is likely that one will obtain a more bland pink tissue rather than one that appears natural. The allograft resembles scar tissue reaction and is solid pink. That is undesirable labially in the anterior areas. There will probably not be an allergic reaction as long as sterilization is performed, but rejection of the material is possible.

To perform these techniques involves a learning curve. The materials are not difficult to handle, but there is a learning period for the surgical technique. Additional time is needed to do these techniques compared with gingival apical or crown repositioning. The techniques do, however, take more time to correctly place the membranes and to put the tissue correctly over the membrane.

TREATMENT CONSIDERATIONS

The three major factors in treatment are the patient, the restorative dentist, and the periodontist. There must be a coordination of all three. There must be mutual acceptance, one goal, and a plan. There should also be one person directing the process. The patient does not know dentistry. The restorative dentist has the treatment plan, has laboratory connections, and can coordinate with the referring dentist as well. The restorative dentist also knows the timing, determines the desired tissue level, and knows the colors desired in the final restoration. All three practitioners should contribute input, but one person should be in charge,

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captaining the team and keeping all participants informed and aware of the treatment schedule.

The treatment plan must be chosen and coordinated, and the patient must contribute input into how he or she sees the process. All participants should relate their desires and goals. A schedule should be written, noting the sequence that will be required. Elements that affect scheduling include allowing time for the periodontist to coordinate healing and use of provisionals during that time. This is the patient's smile but it is also a team effort that requires a team approach. Although one leader should take charge, that professional also constantly reinforces the others, and each practitioner should know the techniques used by the other practitioners. The perioesthetic phase should be coordinated with the restorative operator toward the team goal. It can be divided into three phases: preparation, procedure, and finishing.

Preparation

The preparation phase should also include the patient being educated about the technology of the approach so he or she can be prepared. This can involve juggling social events, travel, or working events. For example, when restoratives are done, provisionals should always be provided. A *provisional* means an interim prosthesis, and that term should be used rather than *temporaries.* The restorative dentist should be prepared to place provisionals according to the treatment to maintain the forthcoming esthetic and healthy periodontium.

Preparation of the area includes in periodontics a nonsurgical treatment period. It is important to ensure that whatever is being fixed will not recur. So the nonsurgical treatment is preventive and includes periodontal treatments such as scaling, curettage, and oral hygiene techniques. Each patient is different, and the techniques reinforce what should become part of a normal oral hygiene regimen. The technique is not difficult, but some people will never be able to floss or use a floss threader. Other techniques can be substituted. Esthetics must allow the maintenance and reachability of all surfaces of the tooth, so they can be kept clean by the patient. That does not mean that constant reinforcement will not be required. The periodontist and dentist should alternate reinforcing with continuous maintenance, with appointments at least four times a year.

Procedure

The procedure phase relates to all treatments involving the soft tissues. This includes getting rid of all inflammation and having the patient maintain the health of the tissues. Then the dentist can consider doing provisionals. If the provisionals are physiologic, surgical techniques can be used, including bone treatment planning or implant placement. All healing phases are considered in the treatment plan timing. Constant scaling and hygiene reinforcement are necessary until the final prosthesis is in place and the patient is able to accept the responsibility of maintaining the achieved healthy smile. The key to treatment is coordination and maintenance. The patient must be comfortable and able to maintain the teeth. The periodontist must make the restoration maintainable and, esthetically, ensure that the correct tissue is in the background. The restorative dentist must make it all usable. They must make the margins accessible so the patient will not catch on them and will be able to keep them clean. The dentist needs the tissue to do that and the correct esthetic background so that it is possible to create a picture of health that can be maintained. Constant maintenance must be performed by the periodontist. Constant reinforcement must be supplied by the restorative dentist until the total healing phase is completed and the patient can maintain the result. The periodontist then transfers the patient back to the restorative dentist. All involved parties must be coordinating care. When one phase of treatment is done, phone calls are made to transfer the patient for the next phase.

Finishing

The finishing phase should be coordinated with the general dentist. At all phases the coordination of communication is imperative. Constant reinforcement is needed. Information must be constantly reinforced for the participants. Complications such as personal schedules, healing times, medical interruptions, business interruptions, or vacation schedules can create distractions, so it is imperative to cooperatively schedule and maintain a knowledgeable, informed team. There is no maintenance of the illusion of good health if a team approach is not used.

INNOVATIVE ELEMENTS

Scientific innovations have been improving because the public wishes to look better and because better materials make that achievable. In past years, innovations adapted hard and soft tissue grafts and materials so they are better accepted by the body. Artificial tissues help in gaining gingiva. Color discrepancies may happen but can be overcome through guided tissue regeneration. The hard tissues are accepted by the body because they do not cause inflammation. However, not all these materials induce the body to produce regenerative bone. Key factors are stability, an accessible blood supply, and asepsis. The blood supply must be large enough that it is possible to not only use the materials as a scaffolding, called *conduction,* but also use them inductively. Whether there are any inductive qualities in the graft depends on the material being used. Some materials are resorbable and some are nonresorbable. Ideally, one wants inductive material that lasts about 8 to 12 weeks. The term *inductive* means exactly that. It induces the hematopoietic blood supply coming in to regenerate and develop into the patient's own new bone. It induces the blood supply to develop into the bone design. More inductive qualities come from autogenous bone than anything else.

The newer scientific bone graft materials, although not proven yet, refer to the production of the bone morphological proteins (BMPs) being accessible to the dental field. Currently the only bone graft stem cell material with that abundance of BMP is called *Infuse* (Medtronic, Inc., Minneapolis, Minnesota).

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It, so far, has been approved by the U.S. Food and Drug Administration (FDA) to use in sinus area regeneration. Many studies in progress use allograft materials. Infuse uses an actual liquid placed in a bovine collagen membrane, which is then placed in the sinus. Urist was the first one to use the term BMP, which stimulates the blood to aid the differentiation into bone.

Demineralized freeze-dried bone from cadavers is the gold standard of allografts. Others promise inductive qualities. Alloplastics, although artificial, try to emulate real bone but do not have pure inductive qualities. They have more of a conductive quality or a scaffolding effect that does not produce inflammation. These are very helpful in regenerating ridge augmentations. Many of these bone materials are resorbable, so in 5 to 10 months they probably will resorb and be replaced, it is hoped, by bone—but not predictably. Ridge augmentations are achieved, however. One disadvantage of these nonresorbable, noninductive or conductive materials is that if bone or a ridge of partial bone is regenerated and implant has been placed, no endosseous integration occurs throughout all of the implant surfaces. This makes it not as osseointegrated. The more surfaces attached naturally to bone, the more retention and the more protection an implant achieves.

Bone graft materials have pluses and minuses. They aid in regenerating the bone, and they are the materials that must be resorbed. Materials that are nonresorbable are more conductive. They help biocompatibility but do not always induce the body to produce more bone. Compromises have to be made. Currently the availability of bone is greater than ever before. The buyer must be aware that these bone materials must be approved by the FDA, they are sterile, and sometimes they are frozen. Each time they are sterilized, they lose some of their viability. The clinician must also know if the material is demineralized freeze-dried bone and if the cadaver from which it was taken was young or older. He or she must also know the laboratory or company from which this bone was obtained because some use older cadavers that have less BMP potential than younger ones.

There has never before been so much resorbable or nonresorbable bone. This bone is found in different forms, not only particulate forms that can be transferred very easily but also gel forms, which are premixed and can be added to a gelatin mix. Bone can also be in liquid form and dropped into the actual membrane when it is placed.

ARTISTIC ELEMENTS

The artistic elements of tissue changing are important. When changing tissue contours, the clinician must know the size and shape of the final prosthesis. If dentists contoured according to what would be liked, they sometimes would end up with an embrasure that is missing, creating a space that unfortunately requires a larger crown. That is why the prosthesis should be in provisional form, so operators can work together and shape it beforehand, then the final prosthesis can be completed.

Vertical height is very important, and positioning of the interproximal tissues is key. The height of the interproximal tissues clinically represents where the CEJ will be in the prosthetic component. In a tooth adjacent to a tooth, the interproximal height of the contact points of the teeth are 5 mm higher than the peak of the interproximal bone. Tarnow and Fletcher brought these facts to awareness in their publication. The dentist should contour the crown according to height of the interproximal bone. With an implant, however, the crest of the interproximal bone is sometimes less than 3 mm higher than the contact. The difficult esthetic component is when an implant is next to a tooth and the implant gingival height is 2 to 3 mm, whereas the interproximal height is 2 to 3 mm higher than the crestal bone. The tooth side might be 5 mm. This is where the dentist's artistic ability comes in. Either one lowers the tooth side and makes it equal to the implant side or one raises the implant side. The interproximal gingival margin height is very important to the restorative dentist to achieve the desired flow or scaffolding effect that does not draw the eyes to an unattractive area.

When the dentist has an excess amount of keratinized tissue, esthetic periodontal treatment can be accomplished to enhance the result. If just a marginal amount of keratinized tissue is present and the marginal ridges are then re-contoured, there will then be no keratinized tissue remaining. The result will be a different color background and an unprotected zone. In scalloping a resultant bevel, a thin gingival margin should be permitted and the integrity of the color of the gingival background should be preserved, enhancing its chance of maintenance.

As mentioned, everyone involved in restoring a smile must be coordinated. Options must be directed toward the goal. The options must be known by all the practitioners as well as the patient. They do not have to be able to do the procedures, but they have to know what is available. Since 1985 the implant replacement of teeth has been a viable option that is now well accepted by the public as a way to manage missing teeth. The term *endosseous implants* refers to replacing teeth with support inside the bone. These implants have been popular since the early 1960s, with Rafael Cherchève, Leonard Linkow, and Isaiah Lew pioneering the field, but the materials were different. Eventually titanium was used in the 1960s. Before that the materials varied with inconsistency. The forms of the implants varied as well. Commonly seen were forms called *blades, root forms,* and *subperiosteals.* Root-formed shapes had been used since the late 1940s, but with the acceptance of Per-Ingvar Brånemark (the father of modern implantology), the root-form implant on a universal platform became socially accepted and in demand. The public today wants to live longer with a better quality of life. Orally, foods are better handled with implants, so people with dentures are not limited to mush. As a matter of social acceptance, people do not want to take their teeth out if they can help it. With a population that is living longer, there is also the desire to look better. Brånemark showed what was known for years—that titanium is an excellent material that is accepted by the body and remains viable, releasing an oxide.

Shapes of the endosseous implants have changed. There have been what were called *press-fits,* in which the dentist drilled a preparatory site exactly the size of the implant and the implant was pressed gently into the prepared site. At the same time a screw-fit implant was done. The dentist used very slow-speed

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instruments so they would not burn the bone and screw, twisting the implant in slowly so the body would not get insulted and resorb.

On the outside of the implants, efforts have been made to get more surface area for the original implants. Smooth surfaces gave way to indentations. Then the implants changed. The manufacturers put small dots of titanium on the implants, called *plasma spray.* At the same time hydroxyapatite, one of the alloplastic materials alluded to earlier, was sprayed on as well. All these external advances were to gain more of a surface area for more bone contact. The outside surface of the implant was sprayed with hydroxyapatite because this material also was purported to speed healing. The surface area of the implant has changed many times. It also changed to what was called an acid etch or resorbable blasting media (RBM). Different surface treatments have been used by different companies in attempts to increase the surface area so that the bone would have more integrative abilities. All such treatments have positive and negative aspects.

There are hollow chambers inside the implants into which a piece of pre-engineered metal, an abutment, fits exactly. There are many ways to achieve this, but impressions can be taken or direct pre-made posts, called *abutments,* are made to fit inside the implant after it is integrated; restorative crowns are then put on top. They can be screwed or cemented on. The cemented ones offer the advantage of more positive occlusal direction because more anatomy is available. The screw-on ones are said to be *retrievable* because if the porcelain chips, it is possible to unscrew it and take it out. *Retrievable* does not really allude to the implant not working; rather, it refers to changing of the crown. Implants also must be attached to the abutment. Screws hold the implant in place. The more connections, the more possibilities for weakness. The advantage of cementing is avoiding the screw connection of the crown to the abutment. Screws—gold screws and titanium screws—loosen. There are pluses and minuses to each phase. The bottom line is that if the body accepts the implant, called *intergration,* then it can be built up. Esthetically the implant, which has a different shape than a natural tooth, has the emergence profile of a natural tooth. Restoratively the emergence profile of the crown should look like that of the natural tooth, but the implant is not bucco-lingually as wide as the natural tooth. Many techniques profess to build out. The author uses the same technique as with the ridge augmentation. *Build-out* or *ridge augmentation* is the general term for the building of a ridge. This results once again in pink keratinized gingiva appearing as a tooth ridge background.

To achieve an esthetic ridge augmentation, dentists prefer nonresorbable materials so they stay in place. Inductive resorbable materials offer bone support. Using a GTR membrane to do this makes it more predictable. It would be optimal to use Hu-Friedy's new instruments to help in the removal of the tooth initially so there is no resorption. It is important not to extract the tooth bucco-lingually but to prevent bucco-lingual pressure, which causes ischemia, which leads to the resorption, and to extract the tooth while preserving all sides of the extraction site, because that is where the blood supply comes from (Figure 28-13). Using inductive, high-quality bone supplements in that extraction site preserves the ridge. It gives more of a bony ridge to choose the best place to position the implant. This increased bone gives more predictability for an integrated implant and esthetically avoids the depressed labial view, which makes crowns stand out and produces shadowing in the submerged portion of the implant. Also, implants have a metal collar. One of the improvements for esthetics is a light abutment collar. All different types of commercial abutments prevent a poor esthetic view from showing through the gingiva if an abutment is used anteriorly for esthetics.

If the implant site is predictable, oral practitioners should be able to place the implant. If it is not predictable and the procedure will be more technique sensitive, practitioners with a lot of experience may be required. Implants generally are not limited to specialists, but they are limited to technique-sensitive, experienced dentists. With the implants being made today—with accessibility and interchangeable shapes—it is just a matter of diagnosing with a good computed tomography (CT) scan before measuring, using mountings, and using surgical trays to increase the predictability.

Not all teeth should be extracted to place implants, but endodontically involved teeth that have more than half the bone may be considered for extraction while preserving the bony ridge. Predictability and longevity are well integrated into the procedure, and there will be no caries in the future. Replacing problem teeth permanently with implants is a large part of esthetics, not only for the visual but also for the emotional and mental improvement of the patient.

The various grafts used to replace bone and the treatment options must be understood. Which materials are resorbable, and which ones are not? Which ones induce the bones to regenerate, which ones do not? These things must be known before use. One type does not replace all. There are different indications depending on the results desired.

Ridge augmentation is used for esthetics; nonresorbable bone is appropriate. If ridge augmentation and placement of an implant are desired, then nonresorbable bone grafts must be avoided. The goal is to have a ridge with as much bone as possible.

Tissue grafts are predictable. Esthetic results depend on where they originate from as much as what they have to do functionally. A free gingival graft from the palate using the epithelium and connective tissue will regenerate well and predictably. Usually these have a whiter color and stand out starkly. That is undesirable. If autogenous gingival grafts are needed, a connective tissue graft is best. It is also possible to achieve the same color gingiva by using the tissue adjacent to it. Using a lateral pedicle graft will achieve the goal, yet there will be just one wound site—not two sites as with a palatal graft. It is impossible to use membrane tissues to replace gingival grafts because they do not predictably regenerate in the color desired. They will aid in regeneration of the blood supply if the correct adjacent tissue is placed on top of it and the blood supply is adequate for the tissues to be replaced. It is possible to manipulate the tissue coronally. It is possible to replace the tissue apically if keratinized tissue is present. It is possible to manipulate it vertically and laterally, but the blood supply is essential.

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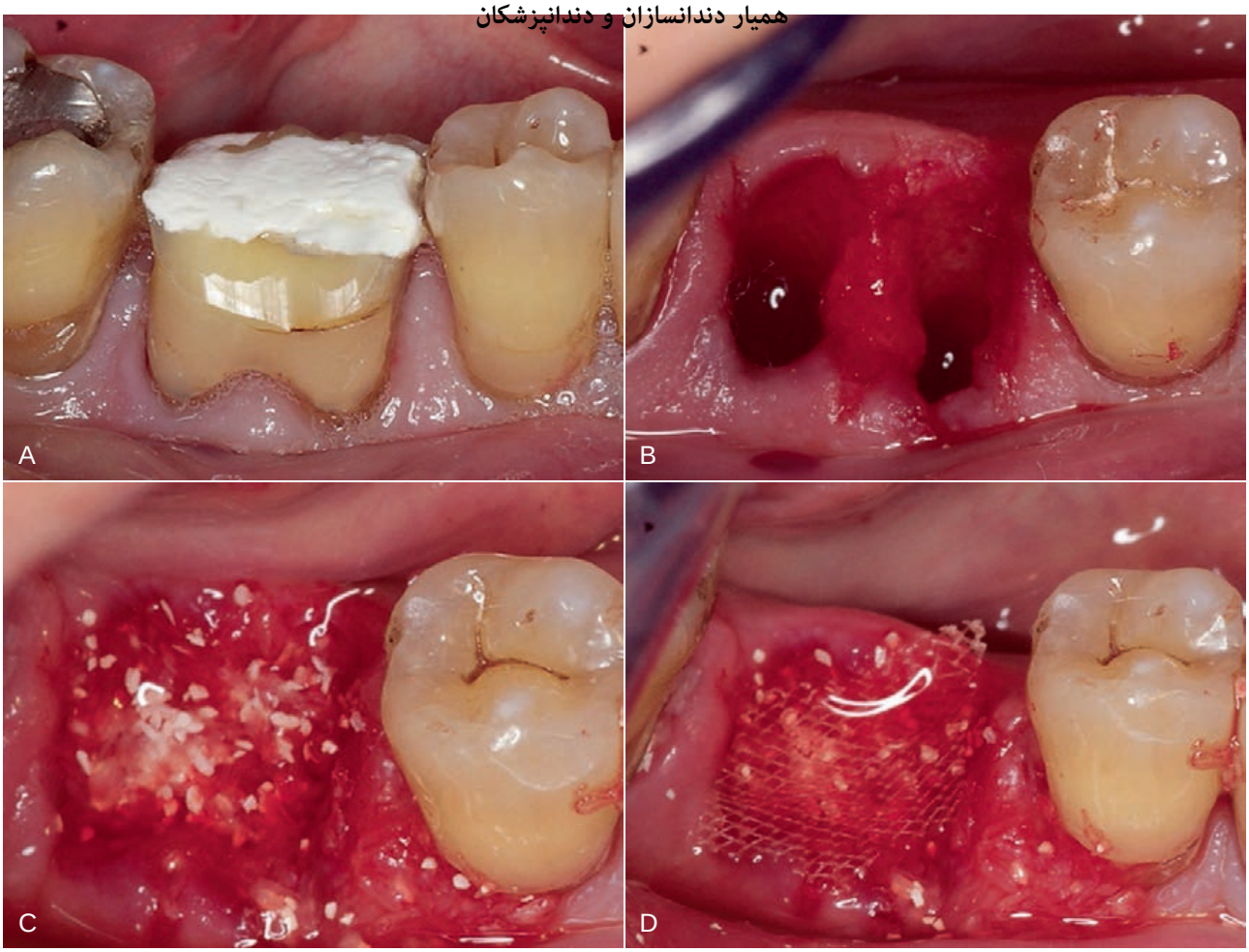


FIGURE 28-13 **A, Fractured tooth before extraction. B, View of socket after extraction. Note the preservation of the socket bone walls, especially the buccal, as well as the preservation of the septum. C, Bone particulate graft placed in osseous socket. D, Resorbable barrier membrane placed over bone graft.**

Resorbable membranes are used to achieve a healthy blood supply so the shifted gingival graft will stay in place and regenerate. If the donor site is healthy, it always regenerates without scarring.

EVIDENCE-BASED PRINCIPLES

Clinical evidence-based principles depend on the actual individual. There are many studies, but they do not apply to all individuals, and each culture has a transitional resistance. People from certain cultures never get caries, owing to their diet and lifestyle. Research shows there are substitutes to aid the host to regenerate more predictably than ever before. The final result is determined by the oral cavity. It depends on an individual antigen-antibody reaction, the allergy reaction to it, the teeth, and what caused it. There are many products available with clinical support and many products that are not supported, but the true result is a reflection of the oral cavity. No product that comes from outside the mouth works 100%, so the goal is to regenerate within the individual's body itself. The future is wide open. The key to evidence-based principles will result in how we can prevent the need for invasive corrections.

CLINICAL CONSERVATION CONCEPTS

In esthetic periodontal surgery compared with periodontal surgery itself, dentists are trying to achieve an esthetic goal and there is usually a healthier environment. When dealing with a pathological situation in which an esthetic result is the goal, it is necessary to take more chances than are desirable. The aim of clinical conservative concepts is to conserve as much natural tissue as possible. That includes the restorative conservative replacement of the natural tooth and conservative enhancement of the natural teeth. People wish to have a wonderful white enduring smile. If it is possible to conservatively enhance the natural tooth, then the tissues can be regenerated rather than simply enhanced. More than ever before the natural health of the oral cavity can be preserved, resulting in not only more

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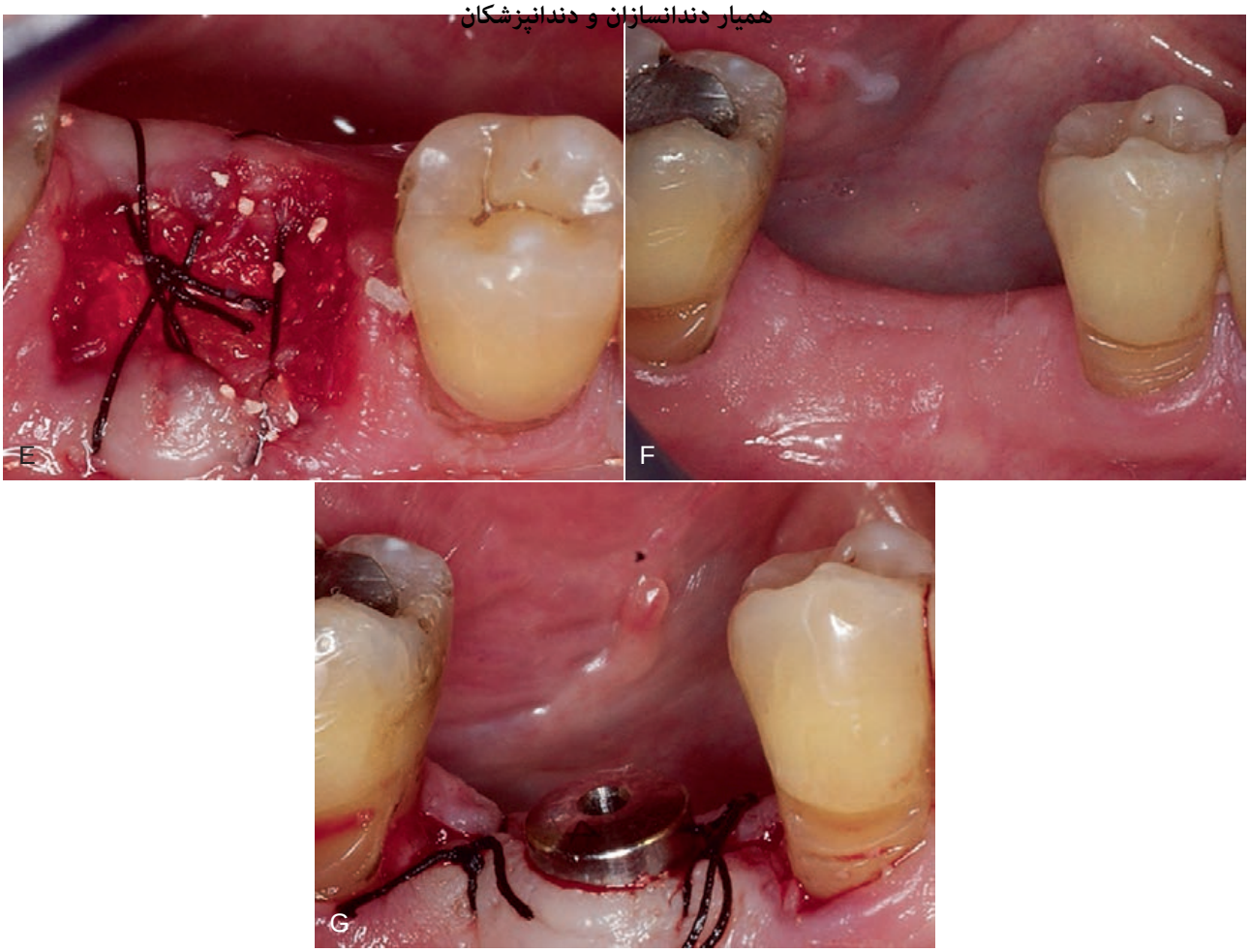


FIGURE 28-13, cont'd **E, Area sutured, with the graft as well as the membrane. F, Healed area with regenerated bone ridge as well as keratinized tissue. G, Implant inserted as well, emphasizing esthetic return of the buccal ridge.**

material with which to achieve the desired goals but also a better chance of achieving and maintaining them.

MAINTENANCE

Maintaining a beautiful healthy smile should be made as easy as possible. The way it is maintained is by avoiding local bacteria retention. Hygiene is just as important during and after restoration. The shape of the prosthesis should allow the patient to maintain good oral hygiene. The periodontal work should be done to allow the patient to maintain future good oral hygiene. Everything is done on a physiologic basis so the patient can effectively remove concretions and plaque. Many objects are available for use, and clinicians should identify what is best in each individual case.

A conservative approach will help the patient achieve good hygiene, but he or she will always need the help of dental professionals, not only to get rid of local concretions but also to provide constant reinforcement. The motivational contribution is as important as the plaque removal. Dental professionals should not only tell the patient that he or she has nice clean teeth but also reinforce proper hygiene methods and reward patients. Each professional sees the patient through his or her own eyes. It is better to have four or six eyes seeing the areas than just one person looking and maybe missing something. A team effort was needed to get the excellent results and a team effort is needed to maintain it. The patient should at least alternate between seeing the general practitioner and the periodontist. The minimum standard for professional maintenance for most people is four times a year, but visits can alternate between the periodontist and the restorative dentist. This schedule of maintenance is in the patient's best interest and definitely yields a positive reward. If the final result cannot be maintained, there is no reason to put the patient, the restorative dentist, and the periodontist through all these techniques. Some people's bacteria are more active, and some patients need more motivation or dental support.

CONTROVERSIES

Rather than view approaches as radical (surgical) or conservative, it is more accurate to see them as predictable or not predictable. The goal is to perform as predictably as possible. The use of

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scaling techniques is fine. The use of surgical techniques is always fine. But overall the outcome must be more predictable. Dr Saul Schluger, one of the grandfathers of periodontics, said that when someone was only scaling the teeth in an area in which scaling itself would not be able to eradicate disease or maintain a healthy periodontium, it was *supervised neglect.* One of the advantages of a "conservative" approach is maintenance of the area.

Among the advances in the past 15 years is the use of local rather than systemic antibiotics. No long-term proof is available, but the use of local timed-release chemotherapeutic agents has been popular. The antibiotic used is a form of tetracycline, either doxycycline or minocycline. It is released in a base over a period of less than 2 weeks. The antibiotic is placed under the pocket in the gingiva. If no pocket is there, the material will not stay in place. To maintain a pocket while avoiding root exposure, especially in the maxillary interiors, atraumatic techniques would include the use of local antibiotics. They last just a short period of time, but they do release the antibiotic over a period of 10 to 12 days, changing the flow locally. The key to eliminating bacteria is the accessibility of area, allowing the patient to rub it all of the time, and these are in compromised situations.

Another form of local systemic chemotherapeutic agent is chlorhexidine, which does not last as long—only about 11 days. It must be placed in a definite pocket; the little sliver of carrier releases chlorhexidine over a couple of moments. The chlorhexidine does not induce bactericidal properties; it just kills the bacteria for a short period of time. So the antibiotic treatment lasts longer but is not predictable.

Controversies also relate to where the bone in the grafting material comes from. Will the bone be viable? Will the donor site be a viable one? Will the bone be from a cadaver that has been there for 5 years, which means it has lost its viability? Will the material be usable, or was the body infected and used and not prepared? How many times has the bone been sterilized? So many that it has no viable inductive qualities? These are controversies that are addressed by knowing the source of the material. If allograft or alloplastic material is used, does the material do any good? Does it have inductive qualities, or is it just conductive?

Controversies occur because people present different sides of techniques. For example, Sture Nyman was the first to ask if alloplastic materials, which look white (radiopaque) on radiographs, cause regeneration of missing bone or just fill spaces up. An example was hydroxyapatite, which is non-inflammatory and fills spaces wonderfully whitely on radiographs but does not have any inductive or regenerative quality. Questions to ask concern inductive or conductive qualities, longevity, source, and viability.

Questions also arise about the future condition of the blood supply in the interproximal tissues because they are the last place that becomes regenerative. The interproximal tissues do not obtain any blood supply from the adjacent teeth, so the blood supply comes only from the alveolar bone. How far away from the alveolar bone is the peak of the gingiva? How can it be maintained? It would be a shame to have an unhealthy gingiva with restorative appliances cemented there. The ischemic effect of the crowns causes resorption of the interproximal tissue, resulting in the aforementioned black diamond space.

Going back to those important studies by Dennis Tarnow and Paul Fletcher, they stated that the height of the crestal bone as it relates to the height of the peak of the interproximal tissue and teeth contacts must be consistent. It is usually about 5 mm tooth to tooth. The height of the bone to the interproximal contact is only 3 mm with an implant. The materials used by the restorative dentist will not supply any maintainable viability to the tissue. It confers cleansability, which is just as important.

NEAR-FUTURE DEVELOPMENTS

Currently, attempts are being made to emulate the natural tooth. Nature is not always kind and does not give people perfect teeth or perfectly sized jaws to support these teeth. It is hoped that there will soon be predictable natural tooth implants to replace all missing teeth. Current methods fail to regenerate new cementum on teeth with the fibers attaching to it, so with today's implants the periodontal ligament is not attached, resulting in an ankylosis type of attachment. There is not total regeneration when a tooth is lost. Regeneration is possible with periodontal tissue if the tissues can be rebuilt. To return the tooth to its ideal state is yet in the future and involves dealing with stem cells and genomes. In certain animals it is possible to take a pure tooth and embed it into the oral cavity. Researchers can also take the actual gene and embed it in the bone so that it will grow into a tooth in the human jaw. Some of the downsides are rejection, the pain of teething, and the inability to know what size the tooth will be or its shape. Dentistry also needs to better understand the different genes that can reproduce teeth.

Another gene being used is the bone gene. If there is bone loss around the tooth, it may be possible to use stem cells, stimulate the correct genomes to produce bone, and regenerate the ligament around the natural tooth. This is being done in animals now. However, it is costly and the results are not predictable.

Stem cells are being taken from extracted third molars and extracted deciduous teeth today. If these cells can be stored in containers in a reserve bank, there could be plenty of stem cells banked. Is this practical in the dental office? The more the public demands stem cell procedures, the more proficient dentists will become with research and the more practitioners will ultimately use the technology. Until stem cell procedures are practical and reproducible, they are not predictable.

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Ortho-Esthetics

Relevance of Functional Appliance Treatment to Esthetic Dentistry and Temporomandibular Joint Health

Brock Rondeau

In *esthetic dentistry,* it is vital to establish a stable relationship for the temporomandibular joint (TMJ) before treatment. The author's treatment philosophy is to establish a correct relationship between the maxilla and the mandible to ensure proper condylar position within the fossa before any restorative, orthodontic, or prosthetic treatment. Functional jaw orthopedic appliances and philosophy enable one to achieve treatment goals consistently.

BRIEF HISTORY OF FUNCTIONAL APPLIANCES

Functional appliances are used to develop arches and to move mandibles or maxillae forward. They employ a non-extraction technique and were developed in Europe in the early 1900s. For over 100 years, clinicians worldwide have been using these appliances to improve facial esthetics in patients. Extracting teeth is very common in many countries, but when one extracts the bicuspid teeth, which are 8 mm wide, the upper arch is left 16 mm smaller, making for narrow smiles. Often if the teeth are retracted, the result is an un-esthetic retrognathic profile. Functional appliances were originally used to bring the lower jaw forward and thereby improve the patient's esthetics. More recently, bringing the lower jaw forward has been shown to improve TMJ health as well as prevent snoring and sleep apnea later in life. Not only do the patients look better, but they are healthier, which should be one of the most important treatment objectives. Practitioners of esthetic dentistry, orthodontics, prosthodontics, or restorative dentistry should strive to improve patients' health *and* their appearance.

In orthodontics, one moves the teeth, originally mostly using metal brackets. In the 1980s clear brackets became available. In the author's practice, 90% of the adults want clear brackets because of esthetic considerations. More recently, manufacturers have developed self-ligating clear brackets that do not stain and are highly esthetic. Clear brackets have encouraged many adults to choose orthodontic treatment.

About 20% of the orthodontists worldwide use functional appliances, with higher percentages in Europe and South America. In South America general dentists learn, in dental school, how to use functional appliances for treating children early while in dental school, then patients are referred to an orthodontist for tooth straightening and fixed braces. Dental schools in North America should start offering courses for general dentists regarding early orthodontic treatment for children. General dentists worldwide need to embrace the philosophy of developing arches at an early age.

When the patient has dental crowding, there are two options: (1) view the teeth as too large for the size of the jaws and extract some teeth, or (2) view the upper or lower arches as too narrow and use an orthopedic appliance that moves the bone. Orthodontic clinicians alter the shape of the bone and the shape of the arch by expanding the arch. This is easily accomplished in children. The mid-palatal suture widens and fills in with bone, it is a true orthopedic change that allows patients to keep all their teeth.

As far as facial esthetics is concerned, the primary goal is a broad, attractive smile. The actors and actresses on TV are often the standard used to evaluate everyone's smile and smile width. When teeth are extracted, the result is a narrow smile, rather than the broad smile sought through esthetic dentistry. Some clinicians who do not do orthodontics can still create a broader smile by putting veneers on the bicuspids and cuspids, trying to widen the look of the arch. That is not quite the same as developing the arch early on.

Techniques and appliances now exist that allow practitioners to develop adults' arches. These include self-activating, nickel titanium coil springs that use 150 grams of force to develop adult arches. Although it is amazing what can be accomplished,

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the key is improved health for the patient. First, practitioners should create a proper-sized maxillary arch without any extractions, and then relate the mandible properly to the maxilla. That ensures a healthy TMJ and an improved appearance. Patients who have unstable TMJs have unstable occlusions, with the mandible often moving to a retrognathic position, which is not considered esthetically pleasing. A straight profile is preferred to either a retrognathic or a prognathic look.

Functional appliances are the key to success in early orthodontic treatment. Children should be seen before age 7 years to detect problems with the arches. These include arches that are too narrow, the lower jaw being too far back, the presence of a deep overbite, or habits such as thumb sucking or tongue thrusting. Those must be corrected early when patients are more cooperative.

In Europe and South America, functional orthopedic appliances have been used to establish the correct relationship between the maxilla and mandible transversely, sagittally, and vertically. In North America an increasing number of orthodontists and general dentists have used fixed and removable functional appliances to treat younger patients. A reason for this is that mothers are constantly asking general dentists to treat the orthodontic problems of their children at an early age, before the permanent teeth erupt. Another reason is that patients are more likely to cooperate when wearing fixed functional appliances.

RELATING FUNCTION AND ESTHETICS

Patients want three things: straight teeth, white teeth, and broad arches. When functional jaw orthopedic appliances are used in young children and teenagers, clinicians can obtain broad arches and therefore broad smiles.

From an orthopedic (bone) standpoint, the seven keys to TMJ health are as follows:

1. The maxilla must be the proper width.
2. The maxilla must be positioned correctly anteroposteriorly.
3. A proper relationship must be present between the maxilla and the mandible.
4. The maxillary incisors must be properly inclined.
5. There must be no unilateral or bilateral crossbite.
6. Lower posterior teeth must be upright over the basal bone.
7. There must be a proper vertical dimension.

CLINICAL CONSIDERATIONS

Proper Maxillary Width

In developing the maxilla to its correct width using functional appliances, the simplest apparatus is the Schwarz appliance, which consists of two pieces of acrylic with a midline screw and four retaining clasps, i.e. Adam's clasps, on both sides. These appliances are extremely comfortable and can be used to treat patients as young as age 5 years. The midline screw of these appliances is activated twice a week, which equals 0.5 mm per week or 2 mm per month. They are well tolerated by children and teenagers alike, as there is no discomfort involved. The appliance should be worn at all times except when cleaning or for active sports. If a 6 mm expansion is required, then the appliance is activated for 3 months and held for 6 months to prevent a relapse. Statistics show that the results are extremely stable in patients who are nasal breathers and have no airway obstruction (Figure 29-1).

There are basically two theories regarding how to correct the problem of crowded teeth in a dental arch:

1. *Retractive technique.* This involves treatment of the permanent dentition and recommends extraction of teeth, usually the bicuspids, to eliminate crowding. Proponents believe the teeth are too large for the arches so permanent teeth are extracted to solve the crowding problem. The consequence of this can be a narrow smile and a posteriorly displaced condyle with resultant internal derangement (temporomandibular dysfunction [TMD]).
2. *Functional technique.* This involves treatment of the mixed or permanent dentition using functional appliances to expand and lengthen the arches so all the permanent teeth fit. Proponents believe the problem results from the arch being too small for normal-sized teeth, so the arch is expanded to a normal width. Patients treated with a functional philosophy routinely have normal, symptom-free TMJs.

The advantages of using functional appliances to expand constricted maxillary arches include expanding the nasal cavity transversely and vertically (when the palate subsequently drops), which encourages nasal breathing; making more room for the eruption of the permanent teeth; and gaining more space for the tongue, which helps ensure proper speech. Some children with narrow arches have speech impediments. The treatment of choice might be to develop the upper arch to normal first, which in the vast majority of cases provides more room for the tongue, which solves the speech problem. The expanded upper arch is the first key to achieving long-term health and also ensures that the patient will have a broad smile.

One important fact that must be recognized is that if the maxilla is too narrow and the mandible is deficient and requires advancement, the case will not be stable because the maxillary teeth will be in buccal crossbite. The retrognathic mandible must be advanced to improve facial esthetics and to move the condyle downward and forward to its proper position in the glenoid fossa. Therefore the first step in the treatment of patients with Class II skeletal malocclusion with narrow maxillae and retrognathic mandibles is to expand the maxillary arch with a fixed or removable functional appliance.

Another important point is to never attempt any cosmetic procedures, such as crowns or veneers, if the patient has a bilateral or unilateral posterior crossbite. This problem must be corrected first with functional appliances to expand the maxillary arch to normal before restorative treatment.

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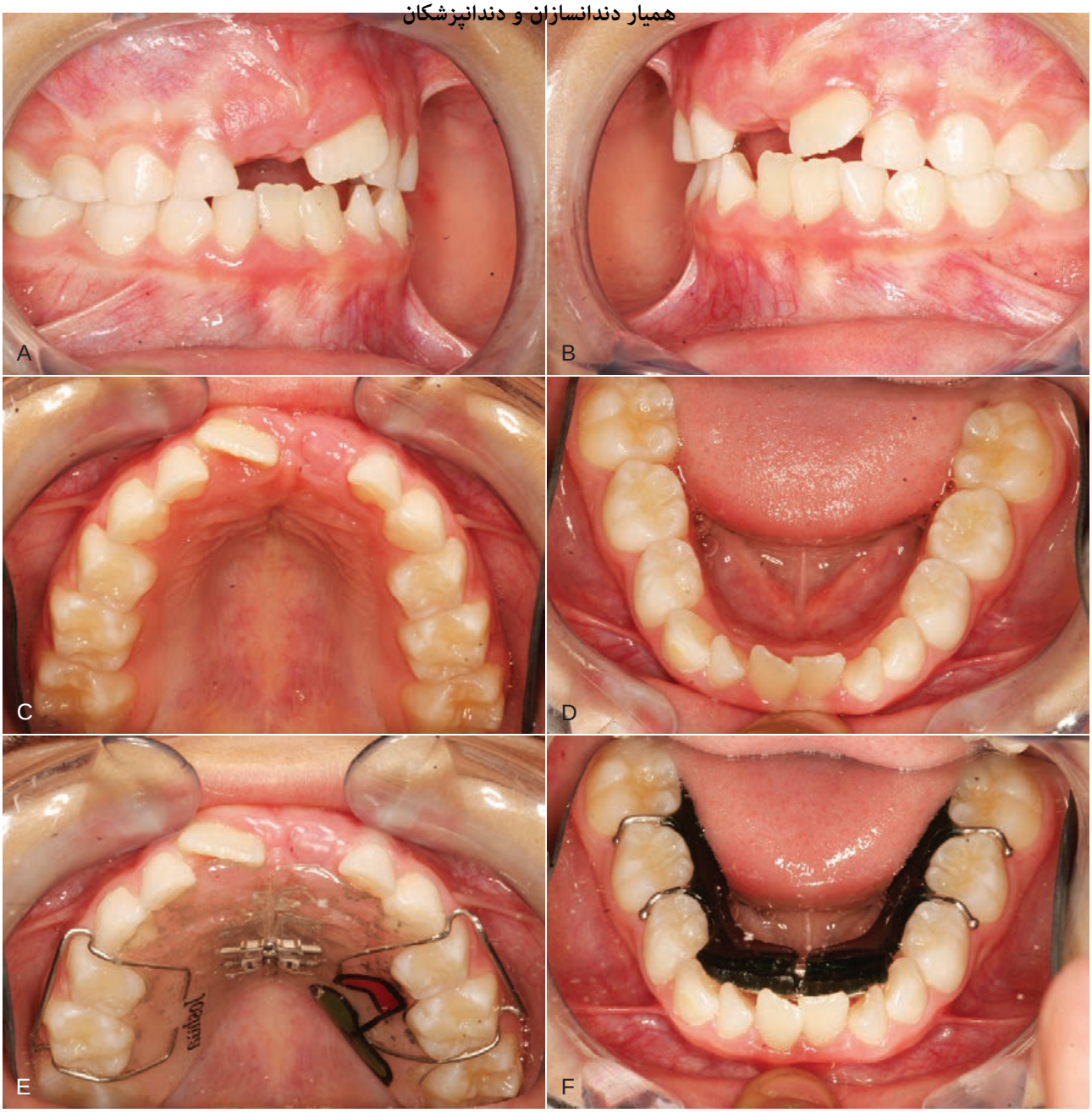


FIGURE 29-1 **A, Constricted upper arch, no room for lateral incisors. B, Traumatic occlusion upper left central incisor. C, Constricted upper arch, no room for upper central and lateral incisors. D, Constricted lower arch, no room for lower central and lateral incisors. E, Upper removable Schwarz appliance, one midline expansion screw, two double Adam's clasps for retention. F, Lower removable Schwarz appliance, one midline expansion screw, four ball clasps for retention.** *Continued*

Maxilla Positioned Correctly Antero-posteriorly

Despite the fact that only 5% of malocclusions are Class III skeletal, approximately 80% of these younger patients in the mixed dentition stage have retrognathic or underdeveloped maxillae. The ideal time to treat these patients using functional appliances is at ages 5 to 12 years to improve their facial esthetics.

One of the most popular fixed functional appliances for children is the Tandem Appliance, which effectively advances the entire maxilla. Patients with TMDs caused by anteriorly displaced disks and posteriorly displaced condyles must have the maxilla properly positioned anteriorly first. Once the maxilla is moved forward with a functional appliance, such as the Tandem Appliance, and an overjet has been created, the mandible can be advanced, moving the condyle down and forward. Hopefully, this will recapture the anteriorly displaced disk and eliminate the signs and symptoms of TMD (Figure 29-2).

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FIGURE 29-1, cont'd G, Upper removable Schwarz appliance, one midline expansion screw, two double Adam's clasps for retention. H, Schwarz appliance midline screw opened 6 mm. Adequate space for upper centrals and lateral incisors. I, Constricted upper arch, no room for upper central and lateral incisors. J, Broad arch, upper centrals and lateral incisors have erupted. K, Traumatic occlusion, upper left central incisor. L, Broad arch, normal overjet, normal overbite. M, Constricted arch, no room for upper and lower central and laterals. N, Broad arch, adequate space for upper and lower centrals and lateral incisors.

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Proper Relationship between Maxilla and Mandible

An estimated 70% of all malocclusions are Class II, and approximately 80% are Class II skeletal malocclusion with normally positioned maxillae and retrognathic mandibles. These patients traditionally have narrow maxillary arches, moderate to large overjets, and deep overbites. Routinely, these patients have internal derangements (problems within the jaw joints), evidenced by posteriorly displaced condyles and anteriorly displaced disks. Condyles that are posteriorly displaced frequently compress the nerves and blood vessels in the bilaminar zone distal to the condyle. Functional appliances effectively reposition the lower jaw forward, which results in the condyle moving downward and forward, away from the nerves and blood vessels.

Two methods of determining whether the condyles are in a pathologic position are described in the following sections.

Tomographic Radiographs of the Temporomandibular Joint

The tomogram shows the position of the condyle in the fossa when the patient is occluding in centric occlusion. In a recent article in the *Journal of the American Dental Association,* the correct position of the condyle in the fossa was identified as downward and forward, not rearmost and uppermost, as reported in many old textbooks. The ideal position of the condyle in the fossa in centric occlusion is to have a larger posterior joint space than an anterior joint space. The posterior joint space should be at least 4 mm to allow room for the nerves and blood vessels in the bilaminar zone plus a 2 mm superior joint space to allow room for the posterior ligament and a 2 mm anterior joint space to allow room for the disk (Figure 29-3).

Joint Vibration Analysis

The joint vibration analysis (JVA) device measures vibrations within the joint. Each of the five stages of internal derangements has a distinct vibration that indicates to the clinician just how serious the problem is before treatment. A normal healthy TMJ makes no noise, causes no pain, and makes no vibrations. The JVA diagnostic device can also be helpful during treatment with anterior repositioning splints (adults) or with the Twin Block appliance or Mandibular Anterior Repositioning Appliance (MARA) in children or adults to confirm that the disk has been recaptured (Figure 29-4).

The treatment of choice for a patient with a retrognathic profile, in order to improve the appearance, is to reposition the lower jaw forward using a functional appliance such as a Twin Block (removable appliance) or MARA (fixed functional



FIGURE 29-2 **A,** Male age 5, anterior crossbite, deep overbite. **B,** Anterior crossbite, deep overbite, Class III skeletal malocclusion, class III molars. **C,** Anterior crossbite, class III cuspid, class III molar. **D,** Tandem Appliance, move maxilla forward, class III elastics.

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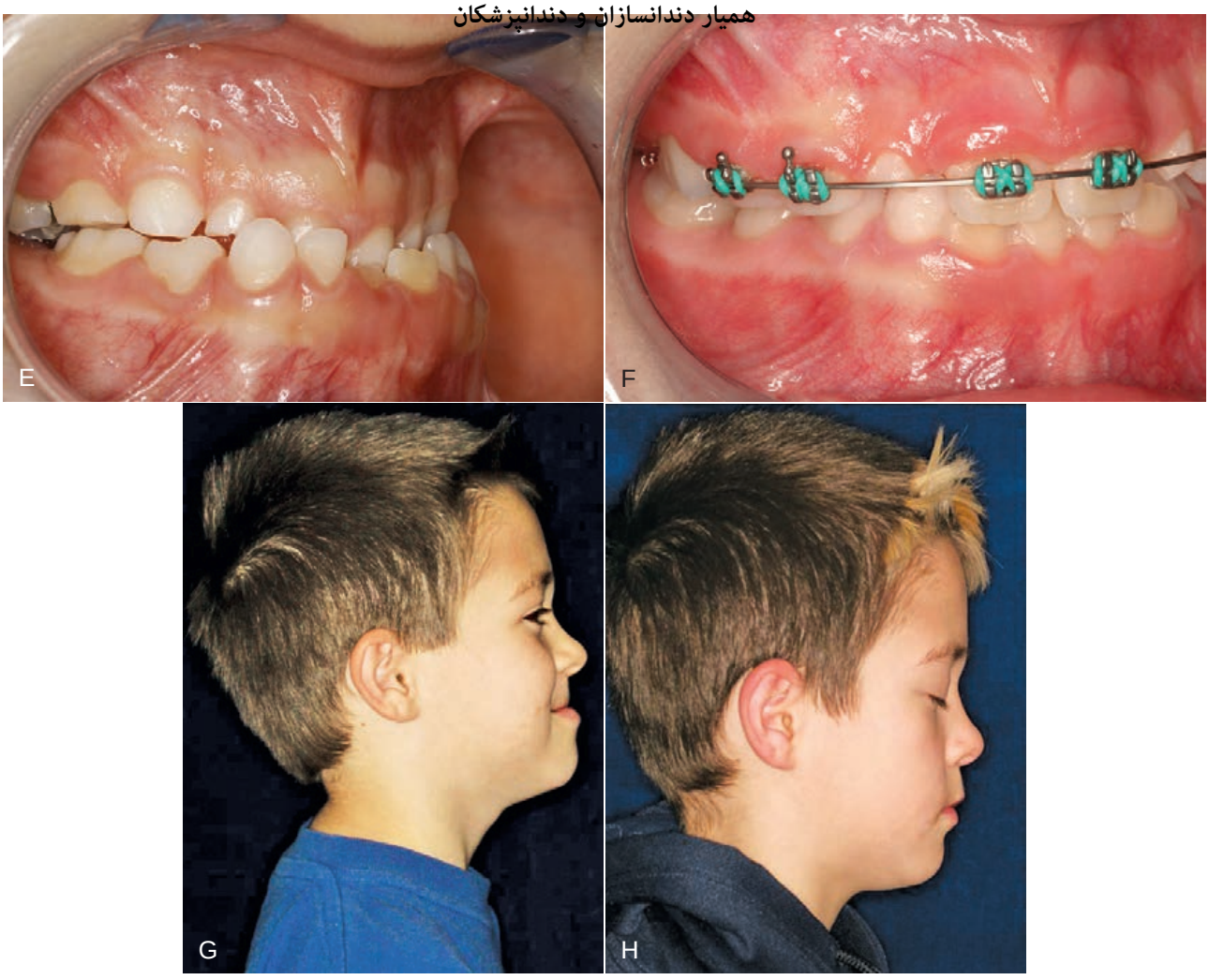


FIGURE 29-2, cont'd **E, Anterior crossbite, class III cuspid, class III molar. F, Anterior crossbite corrected, Tandem Appliance at 7 months, maxilla moved forward. G, Pre-treatment, 5-year-old boy, Class III skeletal malocclusion, deficient maxilla, normal mandible. H, Tandem Appliance at 7 months, maxilla moved forward, normal maxilla, normal mandible.**

appliance). The literature is clear that if the disk can be recaptured with the functional appliance that moves the mandible forward, then most patients have a significant reduction in the signs and symptoms of TMD. The treatment objective for these patients is to improve not only the facial esthetics but also the TMJ health (Figure 29-5).

Clinicians who are concerned with esthetic dentistry must be concerned first and foremost with the health of the TMJ. Patients go to dental offices for straight teeth and white teeth. The solution may be orthodontics followed by tooth whitening, or, alternatively, some patients may prefer porcelain veneers, porcelain crowns, or implants. It is important for the clinician to first properly evaluate the patient's existing occlusion and malocclusion.

Patients who were treated orthodontically previously may or may not have stable TMJs after treatment. This is particularly true if the guidelines for a healthy TMJ, as outlined previously, were not followed.

Proper Inclination of Maxillary Incisors

If the maxillary central incisors are too vertical, or, in the case of patients with Class II, division 2 malocclusion, if they are lingually inclined, this frequently results in trapping of the mandible so that it cannot come forward to its correct position. These patients, who also routinely have a deep overbite, often exhibit signs and symptoms of TMD. This is particularly prevalent in women age 20 to 40 years. It is virtually impossible to correct the TMD using crowns and veneers. These patients must be referred to an orthodontist or general dentist trained in orthodontics to correct the malocclusion and TMD before restorative or prosthetic work is preformed.

Dentists who fabricate crowns and bridges for patients with Class II, division 2 malocclusion must be extremely careful to diagnose and treat the TMD that exists in most cases before treatment. When the maxillary central incisors are lingually inclined, this frequently traps the mandible and causes the

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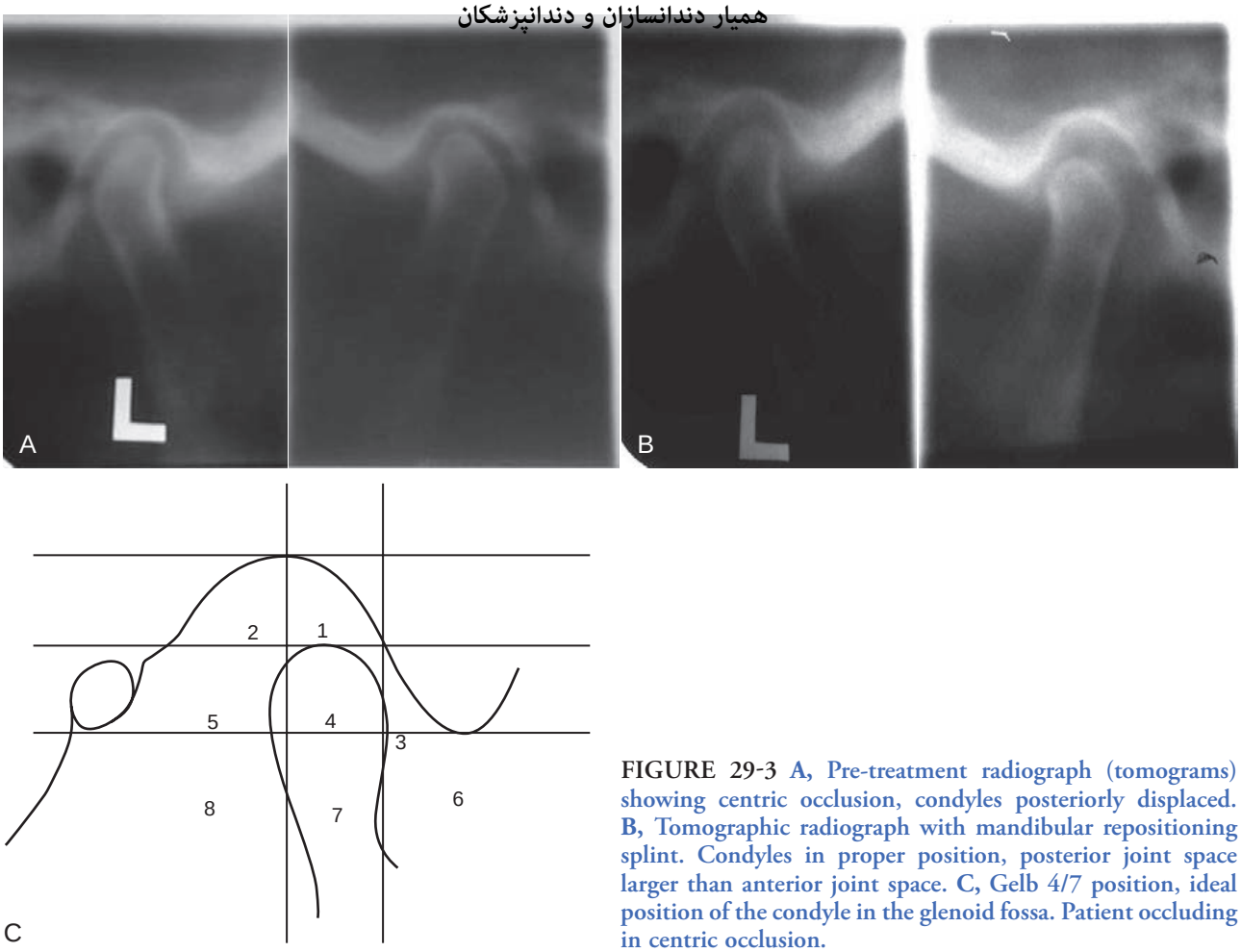


FIGURE 29-3 **A, Pre-treatment radiograph (tomograms) showing centric occlusion, condyles posteriorly displaced. B, Tomographic radiograph with mandibular repositioning splint. Condyles in proper position, posterior joint space larger than anterior joint space. C, Gelb 4/7 position, ideal position of the condyle in the glenoid fossa. Patient occluding in centric occlusion.**



FIGURE 29-4 **Joint vibration analysis diagnostic device to evaluate the health of the temporomandibular joint (TMJ). The device measures vibrations within the TMJ when the joint opens and closes.**

condyles to be posteriorly displaced and the disks to be anteriorly displaced (internal derangement) (Figure 29-6).

The treatment of choice is to orthopedically (using functional appliances) or orthodontically (with fixed braces) torque the maxillary centrals forward, thereby creating an overjet. Functional appliances that can torque lingually inclined maxillary central incisors forward include a removable appliance, Maxillary Anterior Sagittal, or fixed appliance (Barrel Three-Way Fixed Sagittal). This sometimes allows the mandible to come forward to its proper position and permits decompression of the TMJ, relieving, it is hoped, the TMD. Sometimes, however, it is necessary to use a functional appliance such as a Rick-A-Nator to advance the mandible slightly using an incisal ramp and to allow for the eruption of the lower posterior teeth to increase the posterior vertical dimension. Clinicians who are contemplating treating patients with Class II, division 2 malocclusion by endodontically treating the lateral incisor and then placing crowns on all four incisors should reconsider their treatment options. The author has seen cases where dentists have placed crowns on lingually inclined central incisors that increased the thickness of the restored teeth on the lingual, causing the mandible to be distalized further and increasing the TMD. Therefore the author recommends that general dentists consider an orthodontic or orthopedic treatment option before placing crowns

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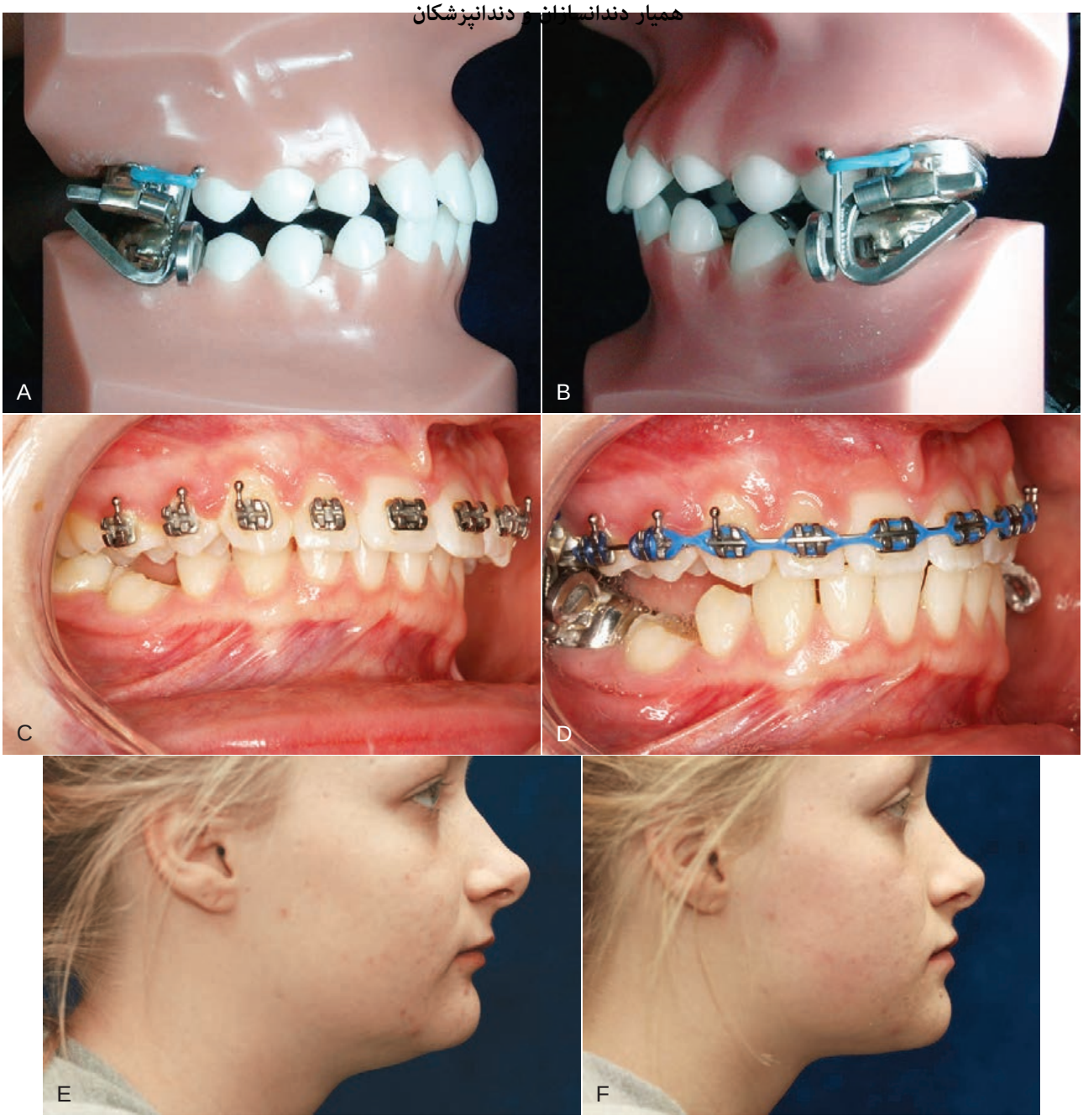


FIGURE 29-5 **A, Mandibular Anterior Repositioning Appliance (MARA) on model; lower arm is attached to lower first molar S.S crown. Upper elbow attached to upper first molar S.S crown. Lower arm in front of upper elbow holds the mandible forward. B, MARA. Lower arm in front of elbow holds mandible forward. C, Patient with Class III skeletal malocclusion with deficient mandible, deep overbite, class II cuspid, overjet 6 mm. D, MARA after 7 months. Mandible advanced 5 mm, normal overjet, normal overbite. E, Pre-treatment Class II skeletal malocclusion, normal maxilla, retrognathic mandible, retrognathic profile. F, MARA after 7 months. Normal maxilla, normal mandible, Class I skeletal malocclusion, straight profile.**

on patients with Class II, division 2 malocclusion with TMD. The treatment of choice for Class II, division 2 malocclusions is to torque the crowns and roots of the four incisors, ideally using either functional appliances or fixed braces. Then the mandible is advanced with a functional appliance such as a Rick-A-Nator to establish a normal maxillary-mandibular relationship. This stabilizes the TMJ before any cosmetic procedure.

Correction of Unilateral Crossbite

Patients, young and old, can have unilateral posterior crossbites caused by the shifting of the mandible to one side when the patient closes in centric occlusion. This is usually the only position in which the patient has maximum intercuspation. This causes a facial asymmetry that results in the condyle becoming

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FIGURE 29-6 **Class II, division 2 malocclusion. The maxillary incisors are lingually displaced, restricting forward movement of the mandible, causing posterior displacement of the condyles and temporomandibular joint dysfunction.**

posteriorly displaced on the side to which the mandible shifts during closing. This posterior displacement of the condyle can actually lead to osteoarthritis of the condyle as it continues to break down and to shorten in length. Posteriorly displaced condyles can often lead to anteriorly displaced disks and internal derangement within the TMJ. This problem should be corrected as soon as possible to avoid further damage to the condyle and to prevent TMD.

The treatment of choice is to treat these patients at an early age (4 to 12 years) with a Schwarz appliance (removable) or a Hyrax appliance (fixed) to expand the maxillary arch. Both of these appliances accomplish this with midline screws adjusted twice per week. This bilateral expansion allows the mandible to center itself within a properly developed maxilla. Treatment is usually completed successfully within 3 months, including correction of the unilateral crossbite, TMD, and facial asymmetry. The patient is then encouraged to wear the appliance for 6 more months to prevent relapse (Figure 29-7).

Uprighting of Lower Posterior Teeth over the Basal Bone

When the lower posterior teeth are lingually inclined, it is very difficult to obtain a proper occlusion. Certainly, it is not the ideal situation in which to fabricate crowns or bridges; it is preferable to have the teeth upright over the basal bone so that the direction of forces can be along the long axis of the teeth and not in a lingual direction, which tends to alter the occlusion. Lower posterior teeth that are lingually inclined can be uprighted with functional appliances to help ensure a proper occlusion and TMJ health. This uprighting of the posterior teeth widens the lower arch and increases posterior vertical dimension, which is one of the keys to TMJ health. This increased width of the lower arch also makes more room for the tongue, which ensures proper speech (Figure 29-8).

Establishment of Proper Vertical Dimension

Clinicians who routinely treat patients with TMD are well aware of the fact that patients with teeth that are overclosed vertically, evidenced by short lower face heights, large submental creases under the lower lips, and deep overbites, commonly have TMD. The cause of the deep overbite can be traced back to mouth-breathing problems, which cause the tongue to assume a lower position in the mouth and depress the lower posterior teeth. This causes a deep curve of Spee. Obviously, the solution to the problem is to solve the airway constriction that caused the mouth-breathing problem and then to erupt the lower posterior teeth back to their original heights, reestablish correct posterior vertical dimension, and eliminate the deep overbite. This improves not only the TMD symptoms but also the patient's appearance from the front by increasing lower face height. It also improves the appearance of the profile by helping to eliminate the submental crease.

Patients with deep overbites routinely have their condyles posteriorly displaced, which compresses the nerves and blood vessels distal to the condyle in the bilaminar zone. This compression can cause many symptoms, such as headaches, earaches, dizziness, neck pain, ringing in the ears, pain behind the eyes, ear congestion, tingling of the hands and arms, difficulty swallowing, and even shoulder and back pain. Depression of the lower posterior teeth by the tongue often causes the muscles to become shortened as the lower face height decreases. This can lead to excessive contraction of the muscles of mastication and other surrounding muscles.

One of the causes of bruxism is TMD caused by unstable TMJs (internal derangement). Frequently, patients who brux all night end up with headaches in the morning. Shortened muscles and bruxing can also increase muscle soreness and, in many cases, cause the formation of trigger points. A trigger point is a knotted part in a muscle and is extremely painful. These trigger points often refer pain to different parts of the body, including the head, neck, ear, and shoulder areas.

The solution to the problem is to use a functional appliance such as a Rick-A-Nator with an incisal ramp to stabilize the lower jaw. The incisal ramp prevents the eruption of the anterior teeth and encourages the eruption of the lower posterior teeth. When treating in the mixed dentition, the ideal treatment is to reline the incisal ramp with Triad Provisional Material (DENTSPLY International, York, Pennsylvania) to an ideal overjet and overbite (1 mm overjet, 1 mm overbite).

Patients with deep overbites now have a posterior open bite, making it extremely difficult to chew and causing the TMJ to

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FIGURE 29-7 **A, Seven-year-old girl with mandible shifted right in centric occlusion and facial asymmetry. B, Patient occluding in centric occlusion, with constricted upper arch causing the mandible to shift 3 mm to the right. C, Constricted upper arch with lack of space for the central and lateral incisors. D, An upper removable Schwarz appliance used to expand the upper arch, with one midline expansion screw and two double Adams clasps for retention. E, Upper expansion appliance widened the upper arch in 3 months and corrected the midline shift.**

be unstable. The solution is to build up the first and second lower primary molars with composite to allow the patient to chew and to stabilize the TMJ. This is the treatment of choice for children who brux, have headaches, or experience ear symptoms such as ringing or congestion in the ears. Clinicians must take a complete TMJ history for each patient, regardless of age, to determine whether or not these younger patients have a problem. This technique leaves a space between the upper and lower first molars. Within 2 to 3 months the lower first molars will passively erupt to contact the upper first molars and close the posterior open bite. A new occlusal plane has now been created for the patient. The composite is left on the lower first and second primary molars to support the posterior vertical dimension. When the primary molars are exfoliated, hopefully the lower bicuspids will erupt to the level of the new occlusal plane. The author cannot overemphasize the importance of

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FIGURE 29-7, cont'd **F, Photograph showing the lower jaw shifted to the right, causing a facial asymmetry. G, After 3 months, the upper arch has expanded. The lower jaw has been centered and facial symmetry achieved. H, Profile view of 7-year-old girl with thin upper lip. I, Profile view of patient at age 9 with full upper lip. A removable orthodontic appliance, an upper Anterior Sagittal Appliance, was used to advance the pre-maxilla. Treatment time was 5 months.**

establishing proper vertical dimension in achieving TMJ health (Figure 29-9).

TWO-PHASE ORTHODONTIC TREATMENT

Functional jaw orthopedic appliances can significantly change a patient's profile and hence facial esthetics (Table 29-1). The ideal time to implement treatment is between ages 6 and 11 years, while the child is actively growing. The treatment of choice is two-phase orthodontic treatment, the objective being to solve the orthopedic problems early in the mixed dentition before the eruption of the permanent teeth. The objective in Phase I is to treat all Class II and Class III skeletal malocclusions with functional appliances to a normal Class I skeletal occlusion in the mixed dentition. Therefore, when all the permanent teeth erupt, the orthopedic (bone or skeletal) problems have been corrected, and the only concern will be orthodontics (crooked teeth). The advantage of this type of treatment is that it produces excellent facial esthetics and drastically shortens the treatment time in fixed braces.

Phase I (Orthopedic Phase)—Mixed Dentition (Ages 6 to 11 years)

The objective of Phase I (the Orthopedic Phase) is to treat children early so as to prevent the malocclusion from worsening and to shorten the treatment time in fixed orthodontic braces.

TABLE 29-1 Two-Phase Orthodontic Treatment

Phase I (Orthopedic Phase) Mixed dentition	**Ages 6-11 years**
Functional appliances	
Phase II (Orthodontic Phase) Permanent dentition	**Ages 12-14 years**
Fixed orthodontic braces	

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FIGURE 29-8 **A, Seven-year-old boy with constricted lower arch and no room for central or lateral incisors. B, Lower Schwarz appliance, a removable orthodontic expansion appliance, with one midline expansion screw and four ball clasps for retention. C, Lower Schwarz appliance with one midline expansion screw inserted. No room for lower central or lateral incisors. D, Lower Schwarz appliance with midline screw expanded 4 mm 6 months later, allowing adequate space for lower centrals and lateral incisors. E, Lower arch expanded through use of lower Schwarz appliance 6 months later; lower incisors erupted.**

Treatment is designed to solve all functional problems such as constricted airways as well as skeletal problems. The causes of constricted airways include narrow maxillary arches, high palates, enlarged tonsils, deviated septa, enlarged turbinates, allergies, and enlarged adenoids. Other functional problems are habits such as tongue thrusting or thumb sucking. Functional appliances, fixed and removable, are used to correct skeletal problems, including constricted arches and retrognathic (underdeveloped) maxillae and mandibles.

Phase II (Orthodontic Phase)—Permanent Dentition (Ages 12 to 14 years)

Orthodontic braces are used in the permanent dentition to correct dental problems such as crooked teeth, to close spaces, and to correct rotations. It must be emphasized that phase II orthodontic braces address only dental concerns and are not

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FIGURE 29-9 **A, Ten-year-old boy with 6 mm deep overbite, headaches, Temporomandibular Dysfunction. B, Deep overbite, Class II malocclusion, condyles posteriorly displaced, overjet 4 mm. C, Normal overbite, normal overjet, Rick-A-Nator, composite buildups, eliminate TM dysfunction. D, Rick-A-Nator, fixed appliance to correct deep overbite and move lower jaw forward. Two molar bands, .045 S.S connector wires, incisal ramp (indexed). E, Normal overbite, normal overjet, Rick-A-Nator, composite buildups, eliminate TM Dysfunction.**

Continued

designed to significantly improve skeletal problems. Clinicians who are concerned with overall facial esthetics and not just straight teeth need to incorporate early treatment techniques for children with skeletal Class II and Class III malocclusions.

If the causes of the airway constrictions are not resolved, instability and relapse are likely. If the airway is constricted and the patient becomes a mouth breather, the maxilla will constrict and the teeth will become crowded again. During normal swallowing in a nasal breather, the tongue expands the maxilla 2000 times per day. With mouth breathers, the tongue assumes a lower position in the mouth and does not expand the maxilla during swallowing, causing maxillary constriction. Growing patients with dentofacial deformities must be diagnosed and treated early for maximum results. Most Class III malocclusions in the mixed dentition result from midfacial deficiencies caused by the underdeveloped maxilla.

Treatment for these patients involves wearing a removable functional appliance such as an Anterior Sagittal Appliance,

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FIGURE 29-9, cont'd F, Normal overbite, normal overjet, Rick-A-Nator, composite buildups, eliminate TM dysfunction. G, Lower jaw comes forward because of Rick-A-Nator. The patient occludes in front of the incisal ramp. Composite buildups are created on lower primary molars to help patient chew. Lower first molars passively erupted to correct deep overbite, 3 mm in 3 months. H, Class II skeletal malocclusion, normal maxilla, retrognathic mandible, TMD headaches, retrognathic profile. I, Rick-A-Nator after 6 months. Class I skeletal malocclusion, normal maxilla, normal mandible, no headaches, straight profile.

which moves the upper incisors forward to correct an anterior crossbite. More serious malocclusions involving deficient maxillae require the Tandem Appliance (fixed functional appliance). When these functional appliances are used during active growth, these dental deformities can be easily corrected, and the need for orthognathic surgery at age 17 years is eliminated.

It is vital to the health and normal development of the child to achieve nasal breathing. Mouth breathing can be the first sign of many problems, including snoring, obstructive sleep apnea, and malocclusions such as posterior crossbites, anterior open bites, and retrognathic (under-developed) maxillae and mandibles. Orthodontic authorities such as Dr Edward Angle and Dr Donald Woodside have stated that the cause of skeletal Class II malocclusions is primarily airway obstruction, which causes the maxilla to slowly constrict and then the mandible to subsequently assume a more posterior position to occlude with the narrow maxilla. Therefore clinicians who are concerned with facial esthetics must be concerned with airway obstructions and their negative ramifications.

As mentioned previously, the orthodontic profession is divided about the use of two-phase orthodontics for early treatment with functional appliances to treat Class II skeletal malocclusions versus waiting until all the permanent teeth have erupted and treating the case with bicuspid extractions or cervical face-bow headgear (retractive technique). The decision to treat patients with Class II skeletal malocclusions with TMD, narrow maxillae, and retrognathic mandibles either with the functional technique or the retractive philosophy has far-reaching health ramifications quite apart from the psychological and profile considerations.

Functional appliances open the nasal airway by expanding the maxilla, which increases the width and height of the nasal airway, located directly above the palate. Functional jaw

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repositioning appliances increase the pharyngeal airway by moving the lower jaw and tongue forward. Treatment of children with Class II skeletal malocclusions with underdeveloped mandibles using functional appliances to reposition the lower jaw forward can help prevent problems with snoring and obstructive sleep apnea along with their negative health ramifications. Patients with obstructive sleep apnea may develop high blood pressure, increased risk of heart attacks and strokes, type 2 diabetes, and gastroesophageal reflux disease (GERD). How children are treated orthodontically and orthopedically can affect them as they grow older. What the author has found clinically is that everything done to improve facial esthetics using functional appliances also positively affects the patient's overall health.

One of the main problems seen in an orthodontic-TMD practice is Class II skeletal malocclusions. There are basically three main ways to treat Class II skeletal malocclusions with normally positioned maxillae and retrognathic mandibles. These patients frequently have narrow maxillary arches, moderate to large overjets, and deep overbites, and the teeth are skeletally overclosed (reduced vertical dimension). Also, as previously mentioned, these patients often have posteriorly displaced condyles and anteriorly displaced disks with internal derangements resulting in TMD.

TREATMENT CONSIDERATIONS

Orthodontic Treatment Philosophies

There are basically two main philosophies in orthodontics. The *retractive philosophy,* often referred to as the *bicuspid extraction philosophy,* treats mainly patients in permanent dentition. The *functional philosophy* treats children in the primary or the mixed dentition with functional appliances. The functional philosophy is mainly a non-extraction, nonsurgical approach to orthodontic treatment. Depending on the type of treatment instituted, there will be a profound effect on the patient's facial esthetics. Therefore it is important for all general dentists to understand the advantages and disadvantages of both philosophies so they can make the appropriate referrals for orthodontic treatment.

Orthodontic Treatment Options for Class II Skeletal Malocclusions

Retractive Philosophy

The retractive philosophy is still extremely popular among orthodontic clinicians worldwide who do not use functional appliances. The retractive philosophy usually involves the extraction of upper bicuspids and treating patients in permanent dentition with fixed orthodontic braces. This is a common technique when patients have a moderate to large overjet. After the extraction of the upper first bicuspids, the six anterior teeth are retracted back into the extraction sites to correct the overjet. This is an acceptable technique if the patient has no signs or symptoms of TMD and has a prognathic maxilla or a protrusive upper lip. Some proponents believe that the overjet is primarily a result of a protrusive maxilla.

In the author's clinical experience, there are few prognathic maxillae in Caucasian patients (less than 5% of Caucasians have prognathic maxillae). In view of this fact, the routine extraction of upper first bicuspids in the majority of Caucasian patients who have moderate to severe overjets is not in the best interests of the patient. If the maxilla is in the correct position, it is not appropriate to extract bicuspid teeth, causing a retraction of the maxilla and negatively affecting facial esthetics. The extraction of upper bicuspids and subsequent retraction of the maxillary anterior teeth of patients who have normal maxillary lip support cause retraction of the upper lip, making the nose appear more prominent, a condition that many patients do not want.

The extraction of 16 mm of tooth structure also causes constriction of the maxillary arch, resulting in a much narrower smile because of the loss of two upper bicuspids. The author believes that this constriction of the upper arch resulting from bicuspid extraction is in violation of the first key to TMJ health, which is to establish a properly sized maxillary arch. As teenagers grow older, their noses grow and their chins move forward. When teeth are extracted, this has a negative effect on the patient's profile approaching adulthood. The midface becomes more flattened as a result of the extractions, and the profile becomes more concave with age, unacceptable to many patients. The other major consideration is that in the case of most Class II skeletal malocclusions the mandible is retruded and the condyles are posteriorly displaced and as the patient grows older will gradually compress the nerves and blood vessels distal to the condyle. When the anterior teeth are retracted to correct the overjet, the mandible becomes trapped and unable to come forward to decompress the joint and to correct or prevent the TMD, which usually gets worse with age (Figure 29-10).

However, the author is not opposed to bicuspid extractions in the following situations:

- African American and Asian patients often have prominent maxillae and mandibles and a malocclusion known as a *bi-maxillary protrusion.* These patients have extremely full upper and lower lips and want this fullness reduced as part of their treatment. The extraction of upper and lower first bicuspids is the treatment of choice for this type of malocclusion.
- The extraction of bicuspids would be an alternative treatment in cases with severe crowding, with no TMD, and when the patient in permanent dentition refuses to wear a functional appliance to either expand or lengthen the arch.

Surgical Technique (Orthognathic Surgery)

In the surgical technique, the lower jaw is repositioned forward to correct the overjet in Class II skeletal malocclusions with retrognathic mandibles. Orthognathic surgery usually takes place after age 17 years, at the end of most patients' growth spurt. The downside of this technique was reported by two prominent orthodontists, Drs Sabine Ruf and Hans Pancherez, who treated 46 Class II skeletal malocclusions with orthognathic

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FIGURE 29-10 **A,** Fifty-two-year-old woman after orthodontic treatment and bicuspid extraction. The patient had temporomandibular joint dysfunction (TMD) and was unhappy. **B,** Patient after orthodontic treatment. The condyles are posteriorly displaced, and the patient has TMD. **C,** Patient after orthodontic treatment and extraction of four bicuspids, with the maxillary incisors lingually inclined and a deep overbite (5 mm). **D,** Patient after orthodontic treatment and extraction of four bicuspids, showing the concave profile and thin upper lip. **E,** Patient after orthodontic treatment. Tomographic radiograph of the left temporomandibular joint shows that the condyle is posteriorly displaced and severe osteogenic breakdown of the head of the condyle is present.

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surgery and 23 similar patients with a fixed functional appliance (Herbst appliance). They reported that their patients who had pre-existing TMD (articular disk displacement—internal derangements) did not have a resolution of their TMD when the mandibles were surgically advanced. Ruf and Pancherez also reported that 50% of the patients treated with orthognathic surgery experienced neurosensory disturbances of the lower lip. Other complications included nonunion or malunion of the bony fragments and condylar resorption. They were highly successful in improving TMJ health with the fixed functional Herbst appliance. Therefore patients with Class II skeletal malocclusions with TMD must be treated with a jaw repositioning appliance such as a Herbst appliance or MARA in order to resolve the TMD problem and to prevent any post-surgical complications.

Functional Philosophy

It has been estimated that 70% of all malocclusions are Class II, and the majority of these patients have normally positioned maxillae and retrognathic mandibles. If the patient had a moderate to severe overjet and the mandible was retrusive, it would seem obvious that the treatment of choice would be to use some type of functional jaw repositioning appliance to advance the mandible to a more normal position. From an esthetic standpoint, the most acceptable esthetic result is transformation from a Class II skeletal malocclusion with a retrognathic profile to a Class I skeletal malocclusion with a straight profile using functional appliances.

The functional philosophy involves treating patients in the primary, mixed, or permanent dentition using functional jaw orthopedic appliances to develop the maxillary and mandibular arches transversely and to reposition the deficient lower jaw forward to correct the moderate to severe overjet. The use of functional appliances at an early age, while the child is actively growing, enables the clinician to develop the arch transversely, sagittally, and vertically to make room for all the permanent teeth and to improve nasal breathing. Children and their parents prefer early treatment, which in the majority of cases eliminates the need for extractions and orthognathic surgery.

The treatment of choice under age 11 years would be to use the Twin Block, which was developed by an orthodontist, Dr William Clark, from Fife, Scotland over 30 years ago. The Twin Block is a removable appliance that consists of two blocks, upper and lower, that interlock at 70 degrees mesial to the lower first molars. These interlocking blocks hold the mandible in a more forward position, and this corrects the overjet (Figure 29-11).

To correct the overbite, the clinician reduces the acrylic on the upper block covering the lower first molars, which are then allowed to passively erupt. When the first molars erupt, this corrects the deep overbite. When this appliance is worn for 7 to 9 months, the lower jaw stays forward as long as the following criteria have been achieved: normal overjet and overbite, first molars in contact, and absence of a dual bite.

For patients over age 11 years the MARA would be the appliance of choice to reposition the underdeveloped lower jaw forward. The MARA was developed by an orthodontist, Dr Jim Eckhart, Manhattan Beach, California. The advantage of these two functional appliances, the Twin Block and the MARA, is that patients can be treated nonsurgically (Figure 29-12).

Parents and patients much prefer treatment with functional appliances for 7 to 9 months when the patient is actively growing, rather than orthognathic surgery. In the latter case, treatment involves both orthodontic treatment and orthognathic surgery at age 17 years when the majority of the patient's growth is complete. It sometimes involves wiring the jaw shut for 6 weeks, as well as considerable discomfort and risk that some nerves could be damaged, causing permanent paresthesia.

The author's experience and that of many other clinicians who evaluate TMJ health before, during, and after orthodontic treatment confirm that if there is an existing TMD before orthodontic treatment, neither the retractive nor the surgical method



FIGURE 29-11 **Seven-year-old boy with Class II skeletal malocclusion, normal maxilla, retrognathic mandible, and retrognathic profile. Nine months after treatment with the Twin Block (a removable functional appliance that repositions the mandible forward) patient has Class I skeletal occlusion, normal maxilla, normal mandible, and a straight profile.**

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FIGURE 29-12 Twelve-year-old girl before treatment: Class II skeletal malocclusion, normal maxilla, retrognathic mandible, retrognathic profile. After use of MARA appliance, 8 months later, patient has Class I skeletal occlusion, normal maxilla, normal mandible, and a straight profile. Before treatment Class II malocclusion, forward head posture, neck pain after treatment head uprighted over cervical spine, neck pain relieved.



FIGURE 29-13 Twelve-year-old girl with Class II skeletal malocclusion, normal maxilla, retrognathic mandible, retrognathic profile. Nine months after treatment with the Herbst appliance, patient has Class I skeletal occlusion, normal maxilla, normal mandible, and a straight profile.

solves the problem. Conversely, when the lower jaw is repositioned anteriorly either with a Twin Block (for patients under age 11 years) or the MARA or Herbst appliance (for teenagers or adults), there is a significant reduction in the signs and symptoms of TMD. This can be confirmed by employing a TMJ health questionnaire, range-of-motion measurements, muscle palpations, JVA, and TMJ radiographs (tomograms) before, during, and after orthodontic treatment (Figure 29-13).

It is important that general dentists who make referrals to orthodontists for the treatment of Class II skeletal malocclusions with deficient lower jaws be aware of the treatment options available. The author recommends that general dentists either take courses to learn how to use functional jaw repositioning appliances or find orthodontists who are familiar with the Twin Block, Herbst appliance, and MARA so they can make the appropriate referrals. This is particularly critical if the patient has any pre-existing TMD, indicated by TMJ signs, including clicking, jaw locking, bruxism, clenching, crepitus, lack of adequate range of motion, restricted interincisal opening, and so on. Additional TMJ symptoms include headaches, earaches, neck pain, ringing in the ears, pain behind the eyes, ear congestion, and shoulder or back pain. According to Ruf and Pancherez, patients with pre-existing articular disk displacements (TMD) who are treated with orthognathic surgery actually have their symptoms worsen post-surgically. Therefore it would seem to be in the best interests of the patient's overall health to advance the

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mandible nonsurgically with functional appliances before age 17 years to avoid orthognathic surgery and its unfavorable complications. Parents do not want their children to have Class II skeletal dysplasia through high school if the children can be treated with functional appliances before they reach high school. Children with large overjets and underdeveloped mandibles are often teased and called hurtful names such as "buck teeth" and "Bucky beaver." This can have an extremely negative effect on a child's self-esteem.

Conversely, the author has found that when functional appliances are used early in the child's development, the significant improvement in the profile and the correction of the overjet have a positive effect on the child's self-esteem. Certainly most parents agree that the earlier this problem is corrected, the better it is for the patient both from a self-esteem standpoint and from an overall health standpoint. As mentioned earlier, when jaw repositioning appliances are used, this has a positive effect on the health of the TMJ as well as increasing the size of the airway. This movement of the tongue forward helps to prevent snoring and sleep apnea in children and eventually in adults.

A thorough history must be taken for any patient who requests porcelain veneers or crowns as a finishing technique. Patients treated with either the retractive technique or orthognathic surgery (Class II skeletal malocclusions) must be evaluated carefully before any permanent restorations are begun. The TMJ problems must be corrected first, and only patients with stable TMJs should be offered porcelain crowns or veneers. Patients with unstable TMJs will clench and brux all night and will slowly destroy the restorative dentist's work. When the crowns and veneers fail, this poses a major problem for the dentist, whose objective is to satisfy the patient. Always stabilize the TMJs first and then proceed with restorative, orthodontic, or prosthetic treatment.

OBSTRUCTIVE SLEEP APNEA AND ATTENTION-DEFICIT/ HYPERACTIVITY DISORDER

One of the serious consequences of snoring and obstructive sleep apnea in children is a lack of oxygen because of the obstructed airway, which can often lead to attention-deficit/hyperactivity disorder (ADHD). Airway obstructions reduce the amount of oxygen in the blood, resulting in frequent interruptions in breathing during sleep, causing the brain to become aroused and waking up the child several times per night. These incidents are called *arousals* and are effectively measured with hospital and sleep clinic overnight sleep studies called *polysomnograms.* They can also be evaluated using home sleep studies such as the Embletta X100 (a portable polysomnography [Embla Systems, Thornton, Colorado]). When the child sleeps in his or her own bed and therefore the environment is much more favorable to a normal night's sleep.

Children with ADHD often become hyperactive and aggressive in school and frequently pose a problem for teachers. These children are referred to medical doctors to try and calm them down so they will not be so disruptive in the classroom. Their medical doctors frequently prescribe a central nervous system stimulant called *Ritalin* or a similar drug to calm them down. In some cases this causes the children to become too subdued and almost listless and unresponsive. ADHD is extremely common and affects 1 in 12 children. Earlier research showed that children who snore because of airway obstructions, such as enlarged tonsils, are four times as likely to have ADHD as children who do not have enlarged tonsils.

Dentists must assess airway obstructions using cephalometric radiographs and then communicate this information effectively to otolaryngologists so that the patient's tonsils and adenoids, if obstructing the airway, can be removed. The cephalometric film must be properly analyzed so that the upper airway (adenoid area) is 6 to 10 mm wide and the lower airway (tonsil area) is 10 mm wide. The diagnosis of enlarged adenoids can be made by viewing the obstruction on the cephalometric film, as discussed, or by having an otolaryngologist use an endoscopic device through the nose to illuminate the adenoid tissue located above and behind the uvula on an enlarged screen, similar to the intra-oral camera used in dentistry. The tonsils can be viewed by pushing the tongue down with a mouth mirror and determining the size of the tonsils on either side of the uvula (Figure 29-14). The tonsils are graded as follows:

- Grade 1—Covers one quarter of one side
- Grade 2—Covers one half of one side
- Grade 3—Covers three quarters of one side
- Grade 4—Covers the entire side

Grade 3 and 4 tonsils effectively block the posterior pharyngeal airway, and the patient should be referred to an otolaryngologist for removal. The ideal treatment would be for dentists and otolaryngologists to work together to diagnose and then remove the cause of the obstructed airway (enlarged tonsils and/or adenoids). This is preferable to just treating the symptoms of ADHD with drugs. The removal of the tonsils and adenoids also helps to eliminate snoring and obstructive sleep apnea. Ritalin and similar drugs do not assist with the treatment of snoring and obstructive sleep apnea.



FIGURE 29-14 Eighteen-year-old male patient with severely constricted airway causing snoring and sleep apnea. He has enlarged grade 4 tonsils and a large uvula.

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Elden and colleagues, citing a short-term follow-up study of children who underwent adenotonsillectomy for obstructive sleep apnea, reported that symptoms disappeared in 80% of the cases. In a study conducted by Dr Ronald Chervin, Director of the University of Michigan Sleep Disorders Center, Ann Arbor, Michigan, of 22 children diagnosed with ADHD, the problem was eliminated in 11 children after a tonsillectomy.

In a study involving 105 children aged 5 to 12 years, children with enlarged tonsils had their tonsils removed. The study showed at the onset that the children with enlarged tonsils had far more behavioral and sleep problems than children without enlarged tonsils. However, after surgery the two groups were the same.

Although tonsils are one of the main problems causing airway construction, other problems include nasal allergies and structural abnormalities such as constricted maxillary arches, high palates, and Class II skeletal malocclusions with retrognathic mandibles. As mentioned previously, functional appliances can be used in children to prevent and indeed treat patients with ADHD as well as snoring and sleep apnea.

The use of functional appliances can maintain a patent airway, which ensures that the patient receives an adequate amount of oxygen to achieve a normal restful sleep. Functional appliances open the airway by expanding the maxilla, which increases the width and height of the nasal airway located directly above the palate. These appliances also increase the posterior pharyngeal airway by repositioning the lower jaw and tongue forward (Figure 29-15).

Airway obstruction can also have a damaging effect on the growth of the child. Growth hormones are secreted by the pituitary gland when the child reaches the deep stages of sleep. When a child has an airway obstruction, causing sleep apnea and numerous arousals, these arousals prevent the patient from obtaining deep sleep and therefore, interfere with the secretion of growth hormones by the pituitary gland. Many of these children are smaller in stature and weigh less than their classmates who are not mouth breathers and do not have airway obstructions.

Another sign indicating a child may have an airway obstruction is the inability to concentrate in school, which adversely affects grades. This also causes trouble competing at a high level in sports because of the inability to breathe properly. The frequent arousals when children have obstructive sleep apnea can lead to an extremely serious social problem for the child in the form of a bedwetting habit. It is almost impossible for the child to control this because bedwetting occurs during sleep after all the arousals caused by sleep apnea. This is of major concern to both parents and children during sleepovers at other children's homes.

FUNCTIONAL APPLIANCES AND IMPROVED ESTHETICS

The use of functional appliances helps improve esthetics. If the teeth are lingually inclined (tipped back) the ability to put a functional appliance behind those teeth and advance either with nickel-titanium coil springs or expansion screws allows one to tilt those teeth out and be more artistic. The author does not try to do everything with braces alone but recommends using different orthodontic appliances. The appliances today can expand arches, move the front teeth forward, and move the back molars back. They can do many things that improve the look of the arches and the appearance of the patient.

Team Approach for the Best Artistic and Functional Result

Orthodontics involves movement and straightening of teeth. Restorative or prosthetic dentistry involves the placement of crowns and veneers, but these procedures should be done after

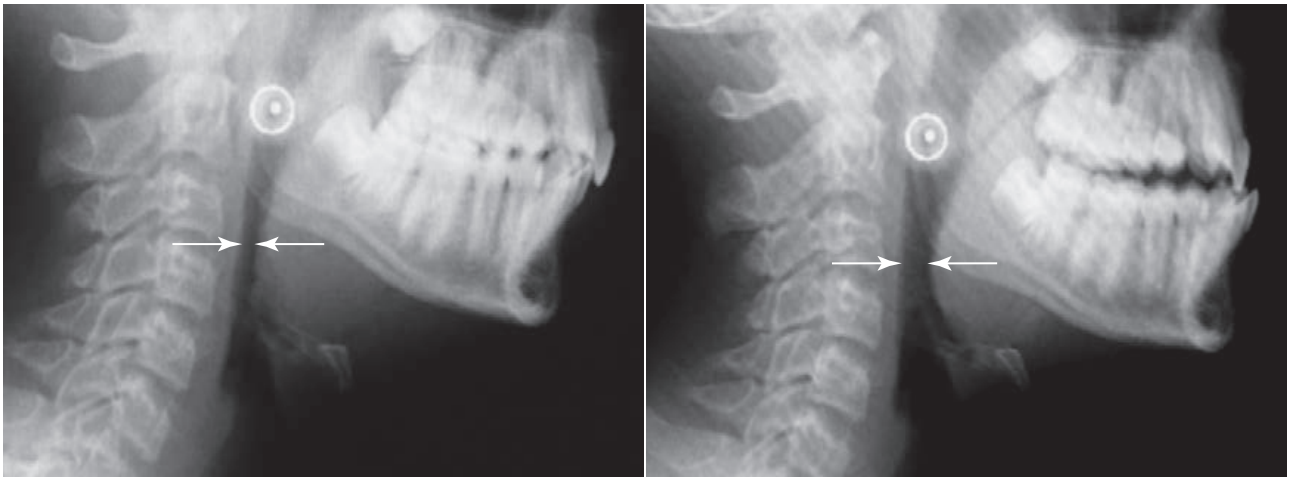


FIGURE 29-15 **A, Pre-treatment radiograph, overjet 2 mm, small posterior pharyngeal airway. (Angle of mandible.) B, When the mandible was advanced to 3 mm protrusive, the size of the posterior pharyngeal airway doubled.**

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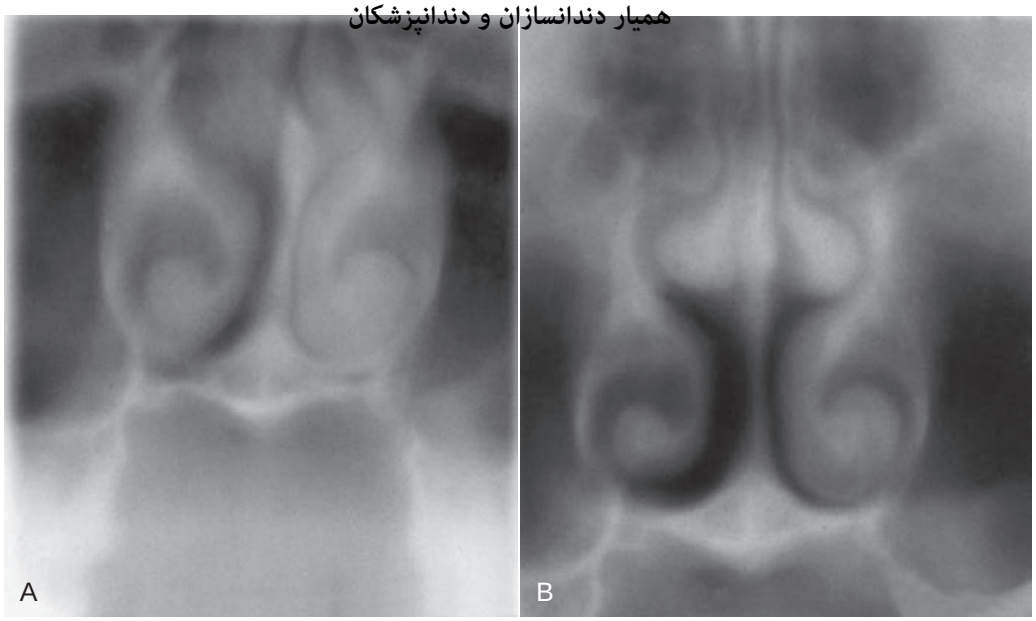


FIGURE 29-16 **A, Pre-surgical radiograph of nasal cavity obstructed by enlarged turbinate bones. Patient has severe obstructive sleep apnea according to the apnea-hypopnea index (AHI): 76 times per hour. B, Post-surgical radiograph of nasal cavity after resection of the inferior turbinates. There was a 50% reduction in obstructive sleep apnea.**

orthodontic treatment. The important thing is setting up the foundation. The foundation would be making the jaws wide enough, both upper and lower, and positioning the lower jaw forward so that there is no overjet, which helps to stabilize the TMJ. If the TMJ is not stable, the patient may look good with the new veneers but could have headaches for the rest of his or her life, hardly an acceptable result. Achieving a healthy TMJ is the first step that must be accomplished before the dentist can get any kind of satisfactory result with the patient. The functional jaw orthopedic approach is used with children and adults and creates a stable and healthy TMJ.

Before beginning, it is vital to eliminate airway constrictions, problems with large tonsils or adenoids, a deviated septum, or large turbinates (Figure 29-16).

The patient must be able to breathe through the nose, not the mouth. Next the dentist develops the upper arch to a normal shape and size so all the teeth will fit. Sometimes it is necessary to move the front teeth forward and the back teeth back and to lengthen the arch. Sometimes the arch must be widened and lengthened. That can be done at any age, but it is better if it is done when the child is actively growing. If the patient has an overjet and an underdeveloped jaw, proper treatment would be to bring the lower jaw forward with the functional appliance. If the patient is under age 11 years, a Twin Block is used. For patients over age 11 years, a MARA is used. These functional appliances were both developed by orthodontists. The lower jaw is brought forward to improve facial esthetics. If the face has a retrognathic profile, it can be made straight. The dentist also brings the condyles down and forward away from the nerves and blood vessels in the bilaminar zone, which helps improve TMJ health. Some orthodontic clinicians disagree with this approach or do not treat this way when the patient has a deep overbite. Some orthodontic clinicians will try to intrude the anterior teeth to correct the overbite, which the author believes is not as good for the TMJ as erupting the posterior teeth. Instead one should insert an appliance such as the Rick-A-Nator or a Twin Block II or some type of anterior bite plate to prevent the anterior teeth from over-erupting. When one erupts the posterior teeth, this significantly improves TMJ health. That is the functional philosophy. If this functional philosophy is followed before the application of any cosmetic dentistry, veneers, or crowns and the TMJ is stabilized first, the outcome will be a healthier patient. Once the jaw has been stabilized, the dentist can offer patients crowns and bridges as a secondary finishing technique. The author now uses CEREC crowns or CEREC overlays on the lower posterior teeth to take the place of the splint after phase I splint therapy or orthodontics. In the author's practice, more and more adult patients want to have porcelain onlays put on their posterior teeth. Another alternative is to have the porcelain onlays fabricated by a commercial lab, which is a nice way to finish some cases. The author's practice has evolved from strictly orthodontics to include treatment of patients with TMJ dysfunction, snoring, and sleep apnea. The patient who has a mild, moderate, or severe overjet, a retrognathic mandible, and a deep overbite frequently has a Class II malocclusion and TMJ dysfunction. The mandible is back and the condyles are up and back. The patient snores and has sleep apnea because the mandible is back, allowing the tongue to fall back and block the airway. This functional approach makes it possible to help all three problems. The author feels that not only does this approach make patients look better, but it significantly improves their health.

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There is a strong correlation in the medical literature, particularly over the last 3 to 4 years, and most notably in cardiology journals, between obstructive sleep apnea and an increased tendency for heart attacks, strokes, type II diabetes, and GERD. These are all serious health considerations that need to be addressed by the medical and dental professions. Through the functional approach the author can lower the blood pressures of these patients with oral appliances just by bringing the jaws forward. It is very rewarding not only to stop the patient's snoring but also to improve his or her quality of life.

TREATMENT PLANNING

Early Orthodontic Treatment and Childhood Development

It is vital to the health and normal growth and development of the child to achieve nasal breathing. Mouth breathing can cause many problems, including snoring and obstructive sleep apnea, malocclusions such as posterior crossbites, anterior open bites, deep overbites, and retrognathic (underdeveloped) mandibles. The cause of skeletal Class II malocclusions has been previously attributed to airway obstruction (nasal, oral, or throat), which causes the maxillary arch to slowly constrict and the mandible to move posteriorly to try and find a position of maximum intercuspation (centric occlusion).

Snoring is caused when the tongue falls back and partially obstructs the airway (Figure 29-17). The air vibrates on the soft tissue at the back of the throat creating the sound of snoring. Obstructive sleep apnea occurs when the tongue falls back and completely blocks the airway for 10 seconds or longer and more than 5 times per hour. *Apnea* is defined as a cessation of breathing for 10 seconds or more. *Hypopnea* is defined as a reduction of 4% in oxygen desaturation. Together, they are measured on a scale of severity called the *apnea-hypopnea index* (AHI) (Table 29-2).

It has been estimated that approximately 580,000 children in North America may have sleep apnea. In a set of guidelines, the American Academy of Pediatrics stated in 2002 that all routine checkups for children should include questions about snoring and sleep apnea. These sleep disorders can have serious health implications, including high blood pressure, bedwetting, stunted growth, and chronic fatigue that often translates into hyperactivity and learning disabilities.

Obviously, patients who have retrognathic mandibles with already retruded tongue positions are more susceptible to airway obstructions, which can lead to snoring and obstructive sleep apnea. Functional appliances that advance the mandible, which subsequently moves the tongue forward, are therefore effective in eliminating the possibility of snoring and obstructive sleep apnea in children and adults.

Early Orthodontic Treatment

In the author's opinion, despite the fact that 70% of children by age 12 years have some form of malocclusion and could therefore benefit from orthodontic or orthopedic treatment, the majority are not being treated earlier than age 12 years. The main reason for this is that there is a great deal of controversy within the orthodontic profession today regarding the importance of treating children early.

Most orthodontic clinicians prefer to treat patients after all the permanent teeth have erupted. The conclusion that many general dentists offer when they refer their patients for treatment is, "No treatment is indicated at this time. The patient is too young. The malocclusion will be observed and treated when the permanent teeth erupt." For some orthodontic clinicians (orthodontists and general dentists) who are trained with a preventive philosophy, this approach appears irrational when statistics prove that these malocclusions left untreated worsen over time.

Two leading orthodontic researchers, Drs Donald G. Woodside and James A. McNamara, Jr., working extensively with adolescent monkeys and functional jaw repositioning appliances, reported that condylar changes occurred when the monkeys were actively growing. Why condylar position is so essential for TMJ health and stability has already been explained. If the research clearly demonstrates that the clinician will obtain

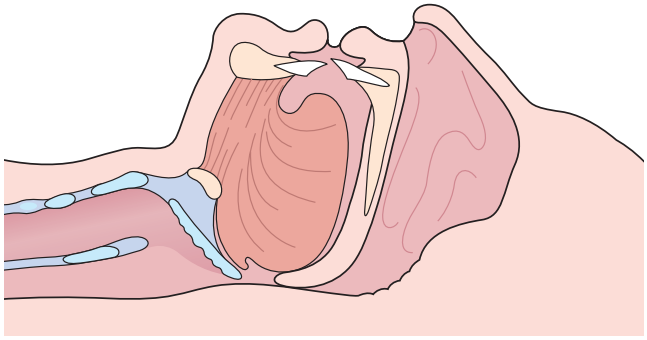


FIGURE 29-17 Patient lying on the back; the tongue falls back and completely blocks the airway (obstructive sleep apnea). *(From Albert RK, Spiro SG, Jett JR:* Clinical respiratory medicine, *ed 2, Philadelphia, Mosby, 2004.)*

TABLE 29-2 Apnea-Hypopnea Index (AHI)

AHI SCORE	INTERPRETATION
Adults	
AHI 0-5	Normal
AHI 6-15	Mild obstructive sleep apnea
AHI 16-30	Moderate obstructive sleep apnea
AHI 31+	Severe obstructive sleep apnea
Children	
	AHI greater than 1 can be severe obstructive sleep apnea

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the greatest response when the patient is still actively growing, one wonders why most patients are left untreated in the mixed dentition. The term *supervised neglect* seems appropriate.

In North America, few dental schools make an effort to include early treatment orthodontics in their curricula. Therefore general dentists graduate without the basic knowledge to either diagnose or treat children with orthodontic (dental) or orthopedic (bone or skeletal) problems. In some cases, not only is the general dentist not given an adequate education, but he or she is also discouraged from ever wanting to learn about orthodontics. There is no doubt that general dentists can learn to treat easy orthodontic cases and can become extremely competent in treating the mixed and permanent dentition in children.

There are many reasons why early orthodontic treatment is good for a child's self-esteem and overall health. Each year more orthodontic clinicians (orthodontists, general dentists, and pediatric dentists) are treating younger patients with functional appliances. A positive sign is the fact that for several years the American Association of Orthodontists has promoted early treatment on its website by recommending that all children be screened by age 7 years.

FACIAL ESTHETICS

When clinicians think about esthetics, they must consider facial esthetics. What is it that makes patients appear attractive facially, and what facial types are less attractive? Dentists, orthodontists, and prosthodontists have a profound effect on facial esthetics. Consider a patient who is edentulous and appears overclosed vertically, with a short lower face height and prognathic mandible and profile. The fabrication of new dentures with an increase in posterior vertical dimension can significantly improve the patient's appearance. When the vertical is increased, the mandible rotates downward and slightly backward, which results in a straight profile and a normal lower face height. The patient is now more attractive from the frontal view as well as the profile.

In orthodontics the same principle applies. If a young child has a Class III malocclusion profile, normal mandible, and deficient maxilla that is also overclosed vertically, the treatment of choice would be to advance the maxilla with a functional appliance such as a Tandem Appliance and increase the posterior vertical dimension by either adding composite to the lower primary molars or by allowing for the eruption of the lower first permanent molars. This treatment can have a profound effect on the facial esthetics of the child as well as an extremely positive effect on his or her self-image and self-esteem (Figure 29-18).

Early orthodontic treatment in children with Class III malocclusions can also prevent the probability of orthognathic surgery at age 17 years. It is preferable to use functional appliances to modify the growth of children while they are actively growing. Because 90% of the face is developed by age 12 years, it is critical that treatment be initiated early.

Patients who have the most pleasing faces esthetically have Class I skeletal occlusion with normally positioned maxillae and mandibles and normal lower face heights. Less attractive patients have short or long lower face heights. The use of functional appliances and orthodontic fixed braces increases short lower face heights to normal. Patients with Class II skeletal malocclusions with normally positioned maxillae and underdeveloped mandibles are less attractive than those with Class I skeletal occlusions with straight profiles.

There are literally hundreds of articles in the literature written by well-known orthodontists that substantiate functional jaw orthopedics. This treatment modality has been around for over 100 years, and there are numerous appliances that can be used, both removable and fixed, to solve these problems. From a clinician's standpoint, if a technique works, one keeps doing it; if it does not work, one stops doing it. The author's practice is getting good results or he would not keep doing it. There is a high level of success with patients using the functional philosophy who have these malocclusions, TMJ problems, snoring, and sleep apnea.

In treating children and adults, the goal is to choose a nonextraction technique as often as possible. Patients are advised that the arches will be developed without extraction of teeth. If the patient has an overjet of 7 mm and if from the side view the maxilla is perfectly positioned, the upper lip is in perfect position, and the nose looks good, but the patient's chin is insufficient, the treatment of choice is obviously to reposition the lower jaw forward with a functional appliance. If that patient has the two upper first bicuspids removed and the upper six anteriors brought back, that will have a devastating effect on facial esthetics. The upper lip will go back at least 4 mm and the nose will appear longer because there is no more support for the upper lip when the bone and teeth are moved back. That is very un-esthetic, and as the patient grows older, the nose continues to grow and the chin continues to grow until growth is complete, while the face becomes more concave and unattractive. That is not the look that patients want, and it also has a devastating effect on the TMJ. Many of these patients later in life will start clicking as the condyles move posteriorly and the disks become anteriorly displaced, a clinical sign of TMD. As mentioned previously, some patients later in life will develop obstructive sleep apnea because their lower jaw is back too far and their tongue is blocking the airway. Had they been given a functional appliance for a deficient lower jaw, it would have moved the lower jaw forward, improved facial esthetics, and possibly prevented snoring and sleep apnea in the future, especially if the patient becomes overweight. A snoring appliance moves the jaw forward and helps correct the problem. Anyone with children who have underdeveloped jaws should consult an orthodontist or general dentist who uses functional appliances, perhaps Twin Blocks or MARAs or other appliances, and have the jaw moved forward while the child is actively growing and the face is developing.

Early treatment and functional philosophy are key, along with non-extraction orthodontics. If general dentists or orthodontists embrace this philosophy, mothers will want them to treat their children. When parents see a malocclusion, either crooked teeth or crooked or narrow jaws, they do not like being told to wait and come back when all the permanent teeth have erupted. Dentists treat periodontal pockets and carious lesions

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FIGURE 29-18 Six-year-old boy with Class III skeletal malocclusion, deficient maxilla, and deficient upper lip. Eight months after use of Tandem Appliance, patient has Class I skeletal malocclusion, advanced maxilla, and full upper lip.

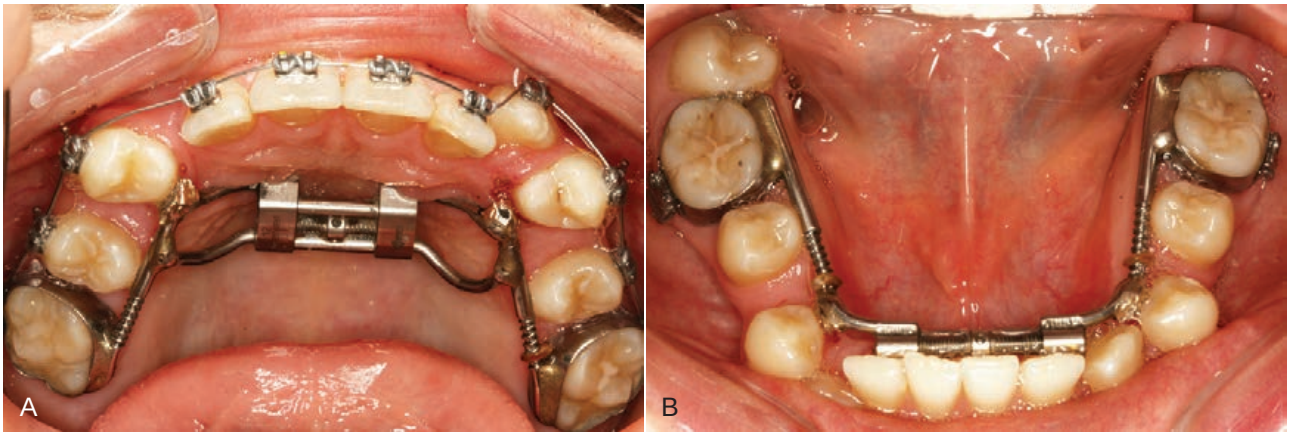


FIGURE 29-19 **A,** Thirteen-year-old patient with upper fixed expansion, molar distalization appliance, Hyrax expansion screw, and two self-adjusting nickel titanium coil springs to distalize the upper molars. The upper arch expanded 7 mm, and the molars distalized 4 mm. **B,** Thirteen-year-old patient with lower fixed expansion, molar distalization appliance, one Hyrax expansion screw, and two self-adjusting nickel titanium coil springs to distalize lower molars. The lower arch expanded 7 mm, and the molars distalized 4 mm.

when they are small. Why wait to treat a malocclusion when it is developing? Dentists should not wait but should treat early and embrace the functional philosophy.

LATEST INNOVATIONS IN ORTHODONTICS

Arch Expansion in Permanent Dentition

Dr Michael Williams of Gulfport, Mississippi, and Dr Neil Murphy of University of California, Los Angeles, have recently conducted studies using nickel-titanium coil spring appliances. The nickel-titanium coil springs were used on adults to slowly develop the upper arch and lower arch. Samples taken from the alveolar process showed that there was new bone growth in the buccal portion of the alveolar process. This new bone was called *woven bone.* This was a revolutionary innovation because previously some orthodontists felt it was impossible to expand the arches of adults once the suture had closed. The author has been developing adults' arches for 25 years, and very few have not been able to develop. With this new appliance it is possible to cement the appliance using molar bands and bicuspid bands. The nickel-titanium coil springs expand the upper and lower arches. The treatment of choice is to develop the narrow arches to normal with these or other arch development appliances before any cosmetic procedures such as veneers, crowns, or implants. Many patients want a broad smile and white teeth. These new orthodontic appliances ensure that when the arches are expanded the patient can achieve that broad esthetic smile (Figure 29-19).

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Clear Braces for Adults

As mentioned previously, from an esthetic standpoint, the clear brackets that have appeared in the last 20 years have also been a major improvement. Clear brackets are very popular with adults. Invisalign has done a great job of marketing to adults who thought they would never want braces because only metal brackets were available. It is now possible to encourage adults to use the plastic aligners to move the teeth. Plastic aligners are fine if the case involves minor crowding, but for severe crowding, brackets and wires are needed to straighten the teeth, as they are much more effective. Invisalign (Align Technology Inc., Santa Clara, California) has caused many adults to ask for treatment. If they come to the office with minor crowding, the author recommends plastic aligners. Owing to the high cost of the Invisalign system, many orthodontic labs are now fabricating these plastic aligners at a much reduced cost to the dentist and the patient. If there is more crowding, it is possible to offer clear brackets. These patients often are willing to try them because they look much better than the metal brackets.

The dental profession has done a poor job of marketing such services to the public. The only two esthetic practices the public really knows about are tooth whitening, which is often not advertised by dentists but by whitening companies, and Invisalign. It is television makeover programs that have done the best job of promoting esthetic dentistry to the public. The author believes the dental profession should do more. The combination of orthodontics and restorative procedures is extremely important. General dentists need to work together with specialists. The foundation must be laid by developing arches and lining up all the teeth. If the dentist is fabricating a crown or a bridge, the roots need to be lined up, which is sometimes not possible unless brackets are placed first. Then the crown and bridge procedure can be done. Orthodontic clinicians have to work with prosthetic and restorative dentists. A general dentist who is also good at cosmetic dentistry, prosthodontic dentistry, and orthodontics can do the whole case alone. It really helps to be knowledgeable in all three areas (Figure 29-20).

Colorless Wires

BioMers (Bothell, Washington) has created colorless wires made of composite. Adults much prefer the esthetic appeal of clear brackets and clear colorless wires. This has increased the number of adults who seek orthodontics. This has proved to be an excellent alternative to Invisalign. The disadvantages of Invisalign are that the clear aligners are very expensive, do not effectively correct moderate or severe crowding problems, and are incapable of adequately moving the roots of teeth. Conversely, the BioMers wires with clear orthodontic brackets (NeoLucent clear brackets [Ortho Organizers, Carlsbad, California]) do an excellent job correcting crowded teeth and moving the roots.

Temporary Anchorage Devices

Another new device in orthodontics is the temporary anchorage device (TAD), the mini-implant. These have recently become available and make orthodontics easier because they help control anchorage and tooth movement. If the clinician wants to make sure a molar does not move forward, the TAD is placed and tied to the molar so the molar cannot move. These devices also help to intrude a molar; the TAD is placed into the bone above the molar, intruding the molar with an elastic power chain. TADs can also be used for uprighting molars, retracting cuspids, distalizing molars, and intruding incisors. At the end of the treatment the TAD is unscrewed and discarded. They are very easy to use. They go only about 7 mm into the bone and are about 1.5 mm wide. They resemble a little pin, and they do not osseointegrate and are therefore not like regular implants. This important innovation in orthodontics helps clinicians to better control unwanted orthodontic forces and shortens treatment time (Figure 29-21).



FIGURE 29-20 NeoLucent clear brackets: 0.014 composite clear archwire, lower teeth straightened with this extremely esthetic appliance.



FIGURE 29-21 Twelve-year-old girl with gummy smile, and deep overbite. Two incisal temporary anchorage devices (TADs) intrude the upper central incisors, reduce the gummy smile, and correct the deep overbite.

SUMMARY

Clinicians must be willing to diagnose and either treat or refer children with narrow upper and lower arches, retrognathic maxillae and mandibles, and overclosed vertical problems. These

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children can easily be treated with functional appliances before the permanent teeth have erupted, to reduce the need for extractions and orthognathic surgery.

As mentioned previously, one of the keys to preventing TMD, snoring, and sleep apnea is to treat younger patients with functional appliances before the eruption of the permanent teeth. It is far better for the children and parents to prevent orthognathic surgery, extractions, TMD, snoring, and sleep apnea by treating early with a functional philosophy.

As healthcare professionals, dentists and orthodontists must look beyond the teeth and treat the patient's whole body. Because a patent airway and jaw position are vital to the patient's overall health, it is imperative that practitioners learn to diagnose and treat patients who have orthodontic, orthopedic (skeletal), TMD, snoring, and sleep apnea problems. It has been estimated that 70% of children have some form of malocclusion, so the need is certainly there for general dentists, pediatric dentists, and orthodontists to develop their skills with functional appliances so they can help these children.

In the author's opinion, orthodontics (straightening teeth) and cosmetic dentistry (crowns, bridges, implants, and veneers) are finishing techniques. These final procedures should be done to give the patient a proper esthetic result. The orthopedic considerations, the shape of the maxilla and mandible, and the position of the maxilla in relationship to the mandible are critical problems that must be treated first. This is the foundation for the house, figuratively speaking, whereas the roof would be the orthodontic braces, crowns, or veneers. Clinicians must diagnose and treat the orthopedic (bone) problem first to achieve the best esthetic results. Correction of skeletal problems and jaw stabilization must be the first priority procedures, using functional appliances or splint therapy before orthodontic or cosmetic dentistry. To finish an orthodontic case with straight teeth while TMD remains is practicing below the standard of care. To finish a cosmetic case with new porcelain crowns or veneers and TMD is certainly not acceptable. Although one of our various treatment objectives is to achieve excellent dental and facial esthetics for our patients, we must also strive to achieve optimum health.

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Orthodontics as a Basis for Esthetics

Ingrid R. Castellanos

RELEVANCE OF ORTHODONTICS TO ESTHETIC DENTISTRY

Orthodontics creates the foundation for which esthetic procedures, and esthetic dentists can create perfect smile results. The orthodontist can align the patient's dentition to provide a sound and more exact foundation for the dentist. When the adult patient has crowded or misaligned teeth or diastemas, the orthodontist can align the teeth, close the diastemas, or make the spaces even so that the restorative dentist can correctly place veneers and bridges. The orthodontist can also influence the end result of the soft and hard tissue structures of the oral cavity. In cases of gingival misalignment, the orthodontist can extrude or intrude the teeth to correct crown-length discrepancies between the maxillary and lateral incisors and canines. When there are periodontal asymmetries in different areas of the mouth, orthodontists can help to stabilize both the hard and soft tissue levels. Orthodontists can also move bone to create more support for overlying esthetic restorations. In areas of missing teeth, the orthodontist can slowly move the teeth into the space to create new bone. This bone can be used to place an implant; this is in the anterior area.

If there are spacing issues in the anterior region, where some of the teeth have very large spaces between them and others have small spaces or none, orthodontic treatment can be used to equalize these spaces. This makes restorative dentistry procedures easier and more predictable.

In cases with peg laterals, orthodontists can move the canines distally to create space for normal-size lateral incisors. When teeth have erupted in misalignment, they are not generally suitable support for bridges or esthetic restorations. Orthodontic treatment can be used to move them into better arch alignment such that they provide the needed support for multiple abutment bridge situations.

Orthodontists can place teeth in the proper position. They communicate with the restorative dentist, who determines where the tooth needs to be for placement of the restoration; if necessary, the orthodontist also communicates with the periodontist. Among them, they will determine the best treatment plan for the patient. For example, they can upright a second molar when a lower first molar is missing so that the dentist can place a three-unit bridge. Generally the relevance of orthodontics to esthetic dentistry is that orthodontists can re-position natural existing teeth to be more suitable for restorative procedures.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF ORTHO-ESTHETICS

In previous years, it was thought that orthodontics only addressed malocclusions. Now that more adult patients are seeking treatment, other problems have presented. Patients have old and failing restorations, edentulous spaces, abraded teeth, periodontal bone defects, gingival level discrepancies, and various other restorative and periodontal problems that can compromise the orthodontic result. For these patients it is important to establish realistic, not idealistic, treatment goals. In these cases, the team (orthodontist, periodontist, oral maxillofacial surgeon, and restorative dentist) must work together to make prudent treatment decisions for the patient. Together they analyze the profile of the patient, how it changes as the teenaged patient grows, and other factors involved in the smile.

As a team the orthodontist and esthetic dentist work together to provide better results for the patient, with periodontists also a part of the team for adult patients. This multifunctional team does their best to achieve the best clinical result for the patient. The leader of the team is the general dentist. The general dentist acts as the central repository for the sequence of treatment and its timing. The others share ideas about how to proceed, and the general dentist coordinates the treatment. He or she usually sees the patient first and then consults with the orthodontist and/or the periodontist. Sometimes the patient needs periodontal treatment first. Preventive periodontal work is completed before orthodontic therapy. The orthodontist sends the patient back to the general dentist during the course of treatment for progress checks. In the meantime, the patient goes through all the maintenance and cleanings with the general dentist. Once the orthodontics are finished, the patient returns

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for the general dentist to place whatever restorations are needed. Throughout the process, the orthodontist is responsible for keeping the general dentist and the other specialists on the team informed.

RELATING FUNCTION AND ESTHETICS

As mentioned previously, orthodontics provides a better platform for the esthetic dentist. The orthodontist can proportion and place the teeth in the correct location so the general dentist can sequence the treatment of fabricating bridges, crowns, or veneers to achieve better stability. In the adult patient, orthodontists must address the dental history: occlusal habits, temporomandibular joint (TMJ) disorders, wear facets, abraded incisors, or other signs that would suggest that the treatment plan should include altering the existing occlusion. In some cases it is not necessary to correct posterior crossbite in adults who have no occlusal interferences and no shift of the mandible and whose dentition can be restored adequately despite their posterior crossbite relationship.

When a patient is missing a lot of teeth, it is important to establish treatment objectives that are occlusally realistic for the specific patient and not necessarily to establish idealistic Class I posterior occlusion. For instance, the restorative dentist may suggest altering the Class I occlusion to facilitate restoration of the teeth. It is important for the orthodontist to be aware of these proposed restorations before bracket placement in order to achieve an occlusally realistic relationship for the restorative patient. It is possible to predetermine the final occlusal and restorative outcomes by preparing a diagnostic wax-up. This is highly recommended for patients who are missing multiple permanent teeth or where implants will later be used to anchor restorative abutments. The wax-up will help to position the implants properly before the beginning of orthodontic treatment. Working as a team, the restorative dentist and the orthodontist harmonize orthodontic objectives.

A common problem in the adult orthodontic patient is wear or abrasion of the maxillary incisors, with uneven gingival levels and unequal crown length of adjacent central incisors. The treatment for this problem consists of periodontal crown lengthening to level the gingival margins, orthodontic intrusion of the longer central incisor, or extrusion of the shorter tooth. To diagnose this problem, one first needs to evaluate the labial sulcular depth of the maxillary incisors. If the secular depths are uniformly 1 mm, then the discrepancy is a result of uneven wear or trauma of the incisal edges. In these cases, the gingival margins are used as a guide to position the brackets and not the incisal edges. Also, mandibular incisal edge abrasion is common. When this occurs, the mandibular incisor typically erupts to maintain contact. In these cases the orthodontist intrudes the mandibular incisors to create space for the restorative dentist. If this is not done, the other option requires periodontal crown lengthening with bone removal, and apical positioning of the gingival margin.

CLINICAL CONSIDERATIONS

Indications

When the patient has large diastemas or severe crowding, severe overbite or overjet, crossbite, missing teeth, or simply wants to have a bridge (when the molar is at the wrong angulation or in the wrong position), orthodontic treatment may be required before esthetic work begins. Patients with TMJ problems may require help with occlusion. Essentially orthodontists try to solve minor to moderate problems of displacement, positioning, angulation, and spacing to make the restorative job easier. Orthodontic procedures are particularly useful for severe crowding.

Contraindications

Patients with poor oral hygiene, minor crowding, or a small diastema can be managed with direct bonding. Some patients prefer not to have orthodontic treatment. For patients with severe bony dysplasia (condition in which one arch is much larger than or malpositioned with respect to the other) a combination of orthodontic therapy and orthognathic surgery may be required. Esthetic procedures are possible after the orthognathic surgery. The orthodontic therapy must be done first, though, because the teeth must be aligned for the surgeon.

Other circumstances where orthodontic treatment before esthetic treatment is contraindicated include severe caries and poor oral hygiene.

TECHNIQUE OPTIONS

Advantages

Both fixed and removable orthodontic appliances are available. The advantage of the removable appliances is that the patient can put them on and take them off as needed. An example is Invisalign braces (Align Technology, Inc., Santa Clara, California), which are a good option for people who do not have severe problems. The Invisalign system consists of computer-fabricated aligners that are relatively transparent and easier to clean than traditional braces. They do not irritate the gingiva as much as traditional braces. The aligners are numbered and worn for 2 weeks each in sequence; treatment time is well established. The system includes a computer simulation showing how the patient's teeth will move during treatment. This allows the patient to see the projected final outcome. This system works, but the movement is slow and the orthodontist must depend on the patient's compliance. The trays are most appropriate for small, anterior diastemas. Tooth rotations present a challenge. A Hawley retainer with an anterior spring aligner corrects upper or lower interior incisors exhibiting minor rotations, but as mentioned, the results depend on patient compliance, and some patients lose the aligners—even adult patients.

The other option is the fixed appliance, which is the author's preference because the orthodontist is in control and the results are faster. Fixed appliances are metal or ceramic. There are two options for the bracket placement: facial or buccal/lingual.

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Lingual braces are metal and placed behind the teeth, which makes them virtually invisible. Orthodontists need special training to be able to treat patients with lingual brackets, therefore not every orthodontist provides them. Lingual braces tend to irritate the tongue, make it difficult to speak at first, treatment can take months longer than with traditional braces, and in some cases regular brackets have to be placed to finish the orthodontic treatment.

Metal brackets can be silver or gold, are very strong and can withstand most treatment forces. Most traditional metal braces require an elastic O-shaped rubber band called a *ligature* to hold the arch wire onto the bracket. One of the big advantages of these brackets is that they are strong and rarely break. The ceramic brackets are made of ceramic or composite materials. They are very strong as well and generally do not stain. Adults usually choose ceramic because they "blend in" with the teeth and are less noticeable than metal. The ligatures that hold the arch wire onto the ceramic brackets are white or clear. This looks great at first, but the ligatures can stain. Some patients feel that ceramic braces are more comfortable than metal and irritate the soft tissues less.

Self-ligating brackets do not need ligatures or metal tie wires to hold the arch wire onto the bracket. These brackets allow the wire to slide back and forth with less friction, requiring fewer adjustments and fewer appointments. A passive "trapdoor" or "sliding door" secures the arch wire to the bracket. These self-ligating brackets are smaller than traditional metal appliances, and less food is trapped during mastication. Additional advantages include a reduction in plaque build-up, additional comfort due to smooth, molded edges, and less chance of periodontal problems as there is no rubber ligature to harbor bacteria. Also being twin technology, these brackets provide four solid walls which enables effective torque expression and rotation control for meticulous finishing.

When using self-ligating brackets, the dentist begins with special lower-tension wires and moves up. Appointments are made every 6 to 8 weeks. The first wire in phase I is a .014 nitinol. Cosmetic wires are also available for a totally esthetic look. The author is currently treating her daughter who had crowding. In 3 months, all her anterior teeth were straightened. She went from Class II to a Class I simply by undergoing alignment and leveling, elimination of the rotations, and beginning arch form development.

Disadvantages

The disadvantages of Invisalign braces are that they cost as much (possibly more) as traditional braces; treatment can take as long as treatment with traditional braces; and in some cases the patient may still need traditional braces for a few months after Invisalign treatment to correct specific problems.

Ceramic brackets look good but the clear or white ligatures can stain, which defeats the esthetics. They can be changed at the monthly adjustment appointments, however. From a purely esthetic point of view, ceramic brackets are a bit larger than metal brackets.

The early self-ligating brackets had a clip-like door, and the hinge was very weak. With time, the clips would break or the patient would bite on the clip, requiring frequent change of wires. Self-ligating brackets tend to be more expensive than regular brackets. Special instruments are needed to open and close the brackets.

OTHER CONSIDERATIONS

The patient's compliance is essential. If rubber bands are used, the dentist relies completely on patient cooperation and good oral hygiene. Patients may not miss any of their appointments.

Cosmetic patients are picky. As the orthodontist is performing the treatment, he or she sends the patient back to the esthetic or restorative dentist to assess if the movement is occurring as planned. The restorative dentist may change the treatment plan, or other clinical considerations may present. At the beginning of the treatment, the esthetic or restorative dentist may have had one result in mind (ideal), but may modify the treatment plan because things appear differently (more realistic). The treatment plan can also be altered if the patient changes his or her mind after seeing the new appearance. For example, if the patient originally chose porcelain veneers and the orthodontist aligned the teeth for the restorative dentist, the patient may be satisfied with his or her smile and simply elect to have the teeth whitened.

If the patient has active caries, ortho-esthetics is not indicated because it is unlikely that the patient will alter habits and begin controlling the caries. Similarly, a patient who seems to have fairly significant periodontal problems would be referred to a periodontist first to be sure everything is under control. Once the periodontist stabilizes the situation, treatment can begin. However, the patient still must undergo follow-up cleanings every 3 or 4 months. For these visits the wires are removed by the orthodontist so the hygienist has better access. The author also does not put bands on the molars, using bond tubes instead, minimizing worry about pockets. Some orthodontists continue to use molar bands.

INNOVATIVE ELEMENTS

Scientific Elements

In planning the biomechanical aspects of orthodontic treatment for a specific patient, it is imperative that the orthodontist consider not only the forces required for the necessary tooth movement to achieve the patient's objectives, but also the undesired tooth movement that may occur in response to these forces. In the past, orthodontists searched for the perfect anchorage to minimize these undesired tooth movements, investigating headgear, elastics, adjacent teeth, and more. However, the main drawback was that they all relied on patient compliance in order to be successful. Mini-implant anchorage was created to assist the orthodontist in controlling tooth movement. The primary advantage over the previously mentioned forms of anchorage is that implants provide skeletal anchorage, which is undoubtedly more predictable and stable than methods requiring patient compliance.

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Recently, mini-screw implants have become very common for implant anchorage, based primarily on their ease of placement and retrieval. Once placed, the mini-screw is available for immediate load placement in conjunction with the specified treatment plan. Because mini-screws are retained in the interdental and interradicular alveolar crest, osseointegration is not required. However, because osseointegration is not required, the possibility exists that minor movement of the mini-screws (loss of anchorage) may occur. A final important consideration in the placement of mini-screws is the precise placement between the roots of adjacent teeth and the risks that may be associated with such a technique.

Sometimes the periodontist sees these patients, but usually the orthodontist performs this procedure. The treatment is a relatively minor procedure. Once orthodontics is finished, the implants are simply removed.

Technologic Advancements

The most significant technologic advancement is the self-ligating bracket. Most brackets have a slot for the arch wire, and small O-shaped rubber bands (ligatures) or metal tie wires to hold the arch wire into the bracket. Several companies have developed techniques for holding the arch wire in place without ligatures. Orthodontist Dwight Damon uses a "sliding door" technique in conjunction with the Damon Bracket (Ormco Corporation, Orange, California) and low-force wires. By using self-ligation technology, the brackets allow the wire to slide back and forth. This allows for fewer adjustments and appointments. These brackets *do not* need ligatures to hold the arch wire in place. They use a "trap door" to secure the arch wire to the bracket. They are smaller than traditional metal brackets, and less food is trapped around them when the patient eats. The new brackets have a small hook; the orthodontist just presses the wire on it and pushes it, and the clip closes. As a result, the wire moves freely around the slot; there is nothing holding it. 3M Unitek (St Paul, Minnesota) also came out with a self-ligating passive bracket called SmartClips. Unlike other self-ligating systems, SmartClips brackets do not have a "sliding door" or separate clip. The arch wire is held in place with a specially designed clip built into the bracket. With the traditional style bracket, there is more pressure and more friction. The friction is reciprocal to the root and can create root resorption when the pressure is severe, more so with a heavy wire. With the self-ligating bracket, movement is faster and less dangerous to the remaining tooth structure.

Ceramic brackets are as retentive on the tooth as metal brackets. The earliest versions had problems with fractures, but the ceramic brackets used currently have overcome that problem. It is possible to bond them to any surface.

TREATMENT PLANNING

For the new patient, the orthodontist does a full examination, prepares study models, and takes photographs and radiographs. Then the dentist, orthodontist, and periodontist, if needed, come together as a team to explore options. With some patients the process can be complicated, so it may be appropriate to offer options A, B, and C, corresponding to basic, intermediate, and ideal approaches. The patient is offered all three treatment options and allowed to choose. For example, a patient may be interested in only correcting lower anterior crowding, but the orthodontic work-up notes not just the lower crowding but also a deep bite, a severe C-curve, or an overjet. The team offers option A, to treat the lower anterior crowding; option B, to open the bite; and option C, to address the entire smile. In the last, the ideal option, the team would open the bite a bit, treat the lower anterior, and create a full smile by managing the collapsed upper arch, or cross bite. The team points out the smile. The patient can then consider the options. It may be possible to use an imaging system to visually present the options.

The dentist and orthodontist show the patient the perfect smile—which treats the jaw and the bite—even when the patient may not have reported problems in these areas. Often patients have thought about such problems but do not realize that they can be addressed until the team points out the possible solutions.

Part of the presentation is to tell the patient how long each treatment option will take and what the cost will be. An advantage of orthodontics is the longer term of the treatment phase. The patient can make a down payment and then be given time to complete payments over the course of treatment. Some patients may choose post-orthodontic veneers; others may choose bleaching. The team must ensure that the patient sees the benefits and drawbacks of each option. The patient can see how the braces and bleaching can inter-relate. This sequence of treatment was utilized in Figure 29-22.

TREATMENT CONSIDERATIONS

Preparation

Prior to treatment, the orthodontist considers the soft tissues and caries status to ensure the tasks of the general dentist, periodontist, and/or endodontist has been accomplished. No brackets are placed if caries are present.

Once the oral state is satisfactory, the orthodontic work commences, using the indirect technique. Preliminary Panorex images are taken. In the indirect technique, impressions are obtained and sent to the lab, with specific instructions to correct any tooth rotations, severe curve of Spee is corrected, lower incisors are intruded, and so on. Everything is measured and planned so the placement of the brackets facilitates the treatment. When the patient comes for bracket placement, the brackets are placed one by one using a special lab-provided instrument.

The orthodontist places all the brackets on a tray. The author typically bonds brackets to the first or the second molar (adults whose bites are being opened). All the brackets can be placed within 1 hour. Generally, the posterior is done first, and then the anterior segments.

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FIGURE 29-22 **A to F, Patient with a class II malocclusion with a posterior crossbite, collapse of the upper arch, and crowding of the lower incisors. The treatment plan is first to expand the upper arch with a Schwarz appliance, then to place self-ligating brackets, and finally to finish the case with a non-vital bleach for the maxillary left central and power bleaching for the entire dentition to overcome the patient's concern about the color of her teeth.**

Continued

When treatment is complete, the author removes the brackets and excess resin without using burs. She recommends first using a Sof-Lex Extra Thin XT coarse disk (3M ESPE, St. Paul, Minnesota) to remove the bulk of the resin followed by an Enhance disk (DENTSPLY Caulk, Milford, Delaware) to ensure the finish. This method removes none of the enamel while other methods can scratch the enamel, leaving it more susceptible to demineralization, plaque accumulation, and decay. The author recommends using magnification loupes to better see the difference between enamel and resin along with completing this process dry so that it is easier to see where the enamel and the resin are. After removing the resin and ensuring the finish, the author applies rubber polish to make sure everything is clean.

After orthodontic treatment is complete and the brackets and resin removed, an Essix retainer (0.35 thickness) is placed. This is a clear or transparent retainer, similar to a night guard, which extends molar to molar.

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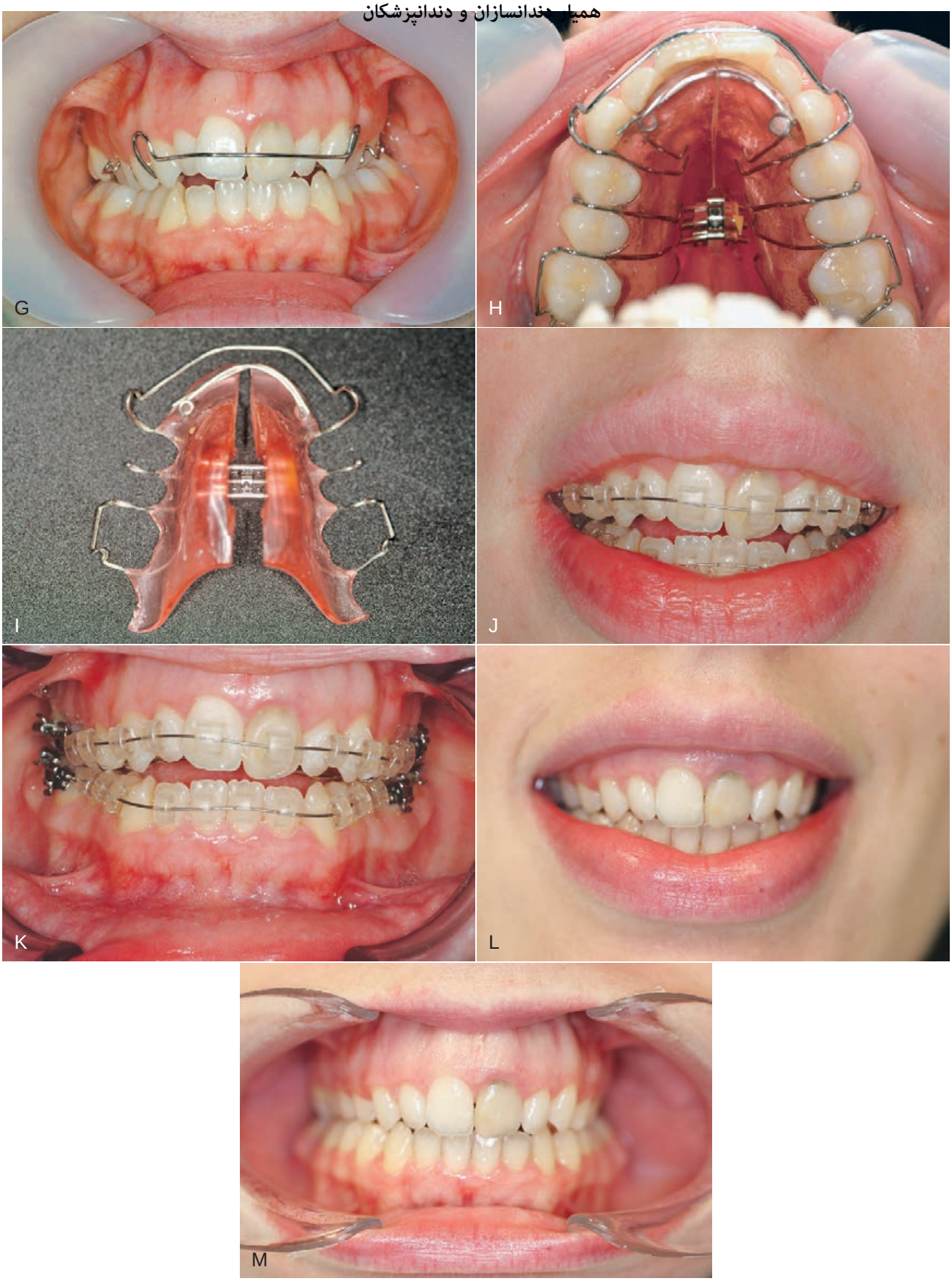


FIGURE 29-22, cont'd **G to I,** Palatal expansion with Schwarz appliance. **J and K,** First appointment with self-ligating brackets. **L and M,** Results after orthodontic treatment. The patient was in treatment for 18 months.

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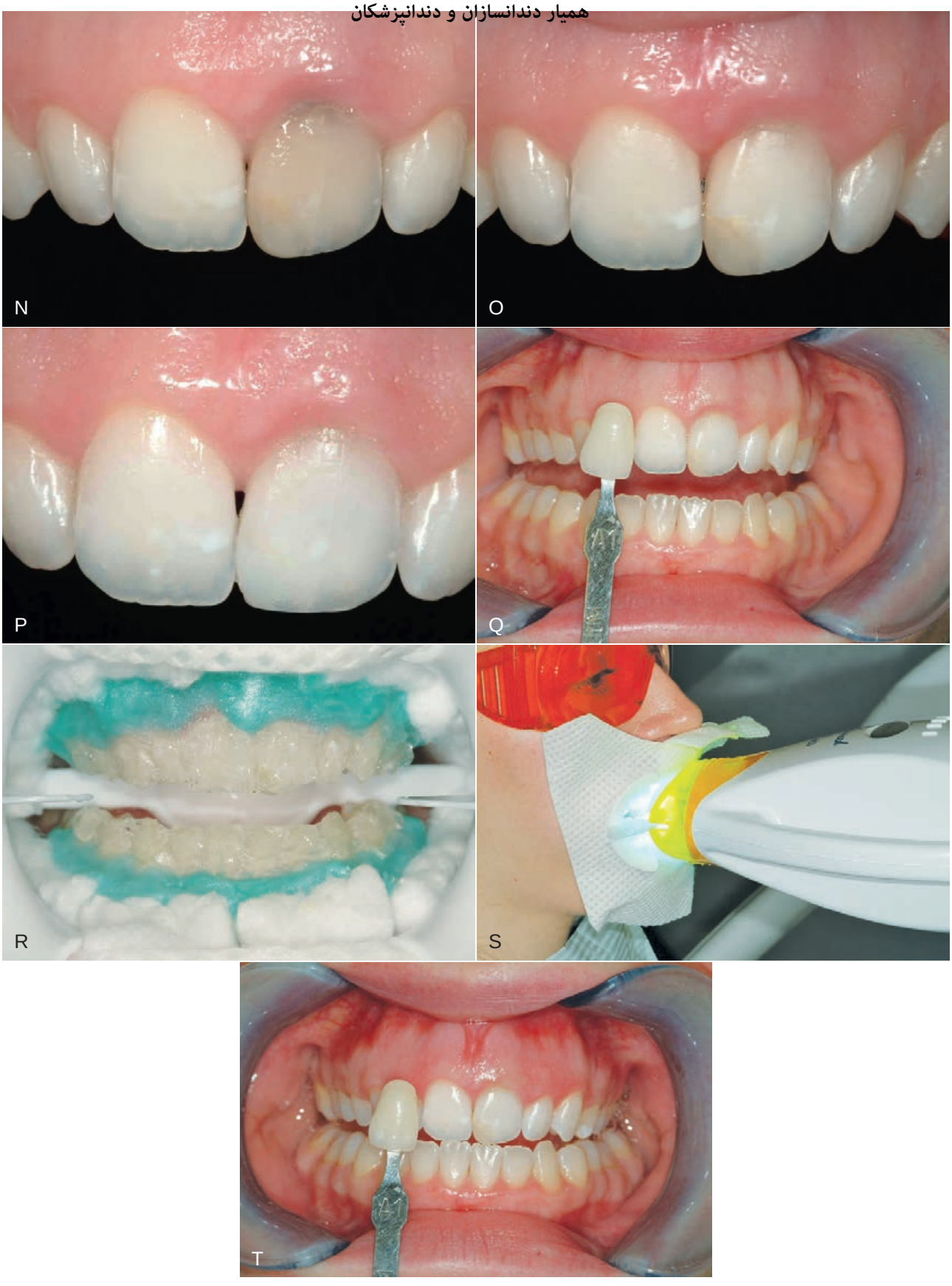


FIGURE 29-22, cont'd **N to P, Before (N) and after non-vital bleaching of tooth No. 9 (O). The mesial Class IV restoration was replaced 1 month after the bleaching was completed (P). Q to T, After the non-vital bleaching, the teeth were power bleached using the Zoom! Whitening System (Discus Dental, Culver City, California) to finish the case.**

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EVIDENCE-BASED PRINCIPLES

Treatment basically follows the principle of minimal destruction of healthy structure along with maximal preservation of healthy enamel and dentin. The repositioning of the teeth into more suitable, load-bearing areas and good occlusion make the forces on them more readily tolerated by the bone and soft tissue infrastructure. Therefore it is likely not only that the restorations will last longer but that the teeth themselves will be healthier.

CLINICAL CONSERVATION CONCEPTS

Orthodontic repositioning treatment is preferable to the tooth destructive procedures of crown or veneer preparation. Orthodontic treatment is less invasive, moving the entire tooth. When preparing for a crown, it is possible to move the tooth into the right position. A severely inclined tooth may require endodontic treatment and a post before crown placement is possible. Orthodontic repositioning places the tooth in a more parallel situation with the other abutments. In addition, the occlusal and lateral pressures on an abutment will be better supported if the pressures and the forces are angulated along the long axis of the tooth rather than at a severe angle. Orthodontic treatment ensures that the tooth is in the best position, where the forces that act on it are optimally distributed.

MAINTENANCE

The patient must keep the teeth clean, both by performing maintenance at home and by making regular appointments with the dentist. Patients also must attend regular orthodontic follow-up appointments. The teeth can move incorrectly, so the patient must see the orthodontist every 3 to 4 weeks with the older systems or every 4 or 5 weeks with the new wires. If the wires are not correctly adjusted, the tooth may move in the wrong direction and cause periodontal problems. Maintenance includes brushing, use of a Water Pik, use of Proxy brush or Piksters, and follow-up with the regular dentist and hygienist as well as the orthodontist.

The typically accepted recall pattern is every 6 months. When the patient is wearing fixed orthodontic appliances and wires, he or she should be seen more often. Before appointments with the hygienist the orthodontist should temporarily remove the patient's wires so the hygienist can clean the teeth more easily, after which the wires are replaced. Some caries-prone adult patients require oral hygiene care every 3 or 4 months.

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Pediatric Dental Procedures

Jenn-Yih (Simon) Lin, Joel H. Berg

RELEVANCE TO ESTHETIC DENTISTRY

Parents are more concerned about esthetics than ever before. In the past, parents accepted whatever restoration the dentist used, whether it was dental amalgam or stainless steel crowns. Those are still used in pediatric dentistry, but parents are asking more and more that the dentist incorporate an esthetically desirable approach into the restorative dentistry or other procedures. It may be an extension of the phenomenon in society that everything is about esthetics, perhaps as a result of the consumer marketing world or the professional world of dentistry. In pediatric dentistry, parents are typically young and often have had whitening or veneers. The difference between adult dentistry and pediatric dentistry with regard to esthetics is that pediatric patients are rarely brought in specifically for esthetic purposes. Esthetics is an added part of restoration fairly exclusively, whereas in adult dentistry esthetics is often the primary objective.

Effect of Esthetically Undesirable Teeth on Child's Self-Image, Growth, and Development

If a child loses the primary maxillary incisors prematurely, that is, before the permanent successors are erupted, he or she can have 2 or 3 years during which there is a space. The child might be made fun of in school or other social situations. Many studies show that children with crowded teeth may have low self-esteem.[1,2] A main cause of crowding in the permanent dentition is space lost in the primary dentition because orthodontic treatment was not performed. If the skeletal causes of orthodontic problems are excluded, crowding in the permanent dentition most often results from the early loss of primary teeth through decay or infections. Space may also be lost without loss of the tooth when an interproximal caries lesion remains untreated. Clearly the primary dentition can have an effect on the permanent dentition and can potentially damage the child's self-esteem.

BRIEF HISTORY OF CLINICAL DEVELOPMENT AND EVOLUTION OF PROCEDURES

Esthetically desirable procedures for children have undergone a continuous development process. Twenty or 30 years ago there were few choices of procedures or materials. Before command-cure resin composites were available, using a self-cured composite in a moving, young child was very challenging. Light-cured composites have been extremely important in pediatric dentistry. Stainless steel crowns have been a mainstay and still are used for primary molars when the decay extends beyond ideal size for a composite restoration. Amalgams have not stood the test of time well, whereas stainless steel crowns have. The convergence of the primary molar toward the occlusal surface anatomically makes it more challenging to perform an intracoronal restoration. The permanent counterparts, stainless steel crowns, have been around and are still used, but, as noted, parents are asking for esthetically desirable alternatives. The clinicians have responded by trying to create window facings on stainless steel crowns or to place composite resin (strip) crowns. Other substitutes for stainless steel crowns are more esthetically desirable prefabricated veneered stainless steel crowns.

CLINICAL CONSIDERATIONS

Primary Anterior Teeth

The greatest area of challenge in primary anterior teeth is the degree of surface decay present. Typically, interproximal and lingual decay sites are found in early childhood caries, formerly termed *nursing bottle decay.* Restoring these teeth esthetically with composite is a significant challenge for pediatric dentists because these lesions are mostly close to the pulp and may extend subgingivally. It is necessary to determine the pulp's status before the tooth is restored. If the pulp is involved in the preparation, with or without disease, pulpectomy should be included in the treatment plan. The diameter of the crown mesio-distally is greater than the length cervico-incisally, which makes the tooth appear wider. The retention of the restoration is compromised by the short crown length.

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Diagnostic Techniques

First, a radiograph is obtained to find out if the decay is close to the pulp. Second, the history is carefully reviewed with the parents. The diagnosis is based on the information obtained from the history, the dental radiographs, and the soft tissue examination. The visual and tactile examinations are very important. The dentist may not be able to see a sinus tract, but careful palpation can sometimes reveal small craters on the labial side, indicating that the pulp is involved.

Pulp Considerations

If pinpoint bleeding develops, direct pulp capping or pulpotomy on primary anterior teeth is contraindicated. A pulpectomy is required.

Treatment of Choice

Resin Composite (Strip) Crowns Resin composite crowns are the most esthetically desirable anterior restorations for primary anterior teeth but are also among the most technique-sensitive procedures. With crowding of the anterior teeth, it is quite challenging to perform a direct composite restoration. Also, primary teeth are whiter than permanent teeth. Most of the time, shade A1 or Extra White must be used. If in doubt, a tab of composite can be placed on the tooth and light cured to account for the shade changes occurring during polymerization. Once the proper shade has been selected, the process continues using that composite. Figure 30-1 presents an example of adhesively bonded resin composite (strip) crowns.

Preparation Design Preparation design for primary anterior teeth is different from what is needed for permanent anterior teeth because the teeth are small and more amenable to good esthetically desirable results. There should be sufficient incisal reduction (about 1.5 mm) to avoid incisal fracture. In the preferred design, more reduction on the labial surface is required. A small undercut on the facial surface in the gingival third of the tooth is recommended to serve as a mechanical lock. On the lingual surface there is often minimal reduction (about 0.5 mm) and a feather-edged gingival margin.

Isolation Technique Because placing composite is so technique sensitive, it is necessary to use rubber dam isolation to achieve a good result. Many isolation techniques have been used by clinicians. Traditionally the most popular techniques are the use of ligature ties with dental floss to retract the gingival tissue or gingivectomy with electrosurgery. A simplified technique using orthodontic elastomers was recently proposed and shown to be both efficient and effective.[3]

Stainless Steel Crowns with Window Facings Placement of stainless steel crowns with window facings is the most time-consuming of the anterior esthetically desirable procedures. A two-step procedure is required to place a stainless steel crown with a window facing. The preparation is almost identical to that for a strip crown except that no facial undercut is needed. Contouring and crimping of the stainless steel crown can provide adequate retention and a good marginal fit. Esthetically, these crowns are not as pleasing as the strip crowns because there is usually some metal showing. They are indicated for severely decayed teeth or children with evident severe bruxism.

Veneered Stainless Steel Crowns Many manufactures sell pre-veneered stainless steel crowns. A few studies have addressed their success in primary anterior teeth. More tooth structure reduction is required for veneered stainless steel crowns to accommodate their thickness. The advantages of these crowns are that they are (1) relatively less technique sensitive and (2) less time-consuming than resin composite crowns and stainless steel crowns with window facings. However, crimping of facial margins cannot be performed, and retention relies mainly on the lingual surfaces. In cases of anterior crowding, they can become very difficult to fit.

Summary—Primary Anterior Teeth

Esthetically, resin composite crowns are the best option among the other substitutes. In terms of gingival health, properly finished resin composite crowns are also better than either stainless steel crowns with window facings or veneered stainless steel crowns. However, adequate remaining tooth structure and controllable gingival hemorrhage are crucial for their success. Studies have reported high parental satisfaction with veneered stainless steel crowns.[4,5] The failure of the resin facings can be problematic, and these crowns cannot be repaired easily, as opposed to resin composite crowns. The stainless steel crowns with window facings are very retentive and can be used for teeth with minimal remaining structure. The facings may be dislodged as with veneered stainless steel crowns. Owing to their time-consuming and compromised esthetics compared with other options, stainless steel crowns are not very promising for a future in which alternative and easier solutions may be available.

Primary Molars

The typical restoration for primary molars with decay involving multiple surfaces is the stainless steel crown. Alternatives to these crowns are also used. In a situation with intracoronal decay, both composite, glass ionomer, and amalgam have been used for many years. The typical choice will be a direct composite for small or single-surface lesions. Other esthetically desirable alternatives are direct composite buildup, resin-modified glass ionomer, and veneered stainless steel crowns.

Treatment of Choice

Direct Composite Figure 30-2 illustrates a case involving a direct composite buildup.

Resin-Modified Glass Ionomer Figure 30-3 presents a case involving a resin-modified glass ionomer.

Veneered Stainless Steel Crowns A study showed that all veneered stainless steel crowns demonstrated chipping of facings after four years.[6] No difference was found for marginal extension, occlusion, crown adequacy, or periodontal health between stainless steel crowns and the "esthetic" crowns. Veneered

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FIGURE 30-1 Resin composite (strip) crowns. **A,** Clinical photograph shows extensive caries lesions and white spot lesions on all four incisors. Left untreated, these lesions will develop into larger lesions and possibly affect the adjacent teeth and the underlying permanent successors. **B,** Palatal view. Caries lesions are found in all the interproximal areas of the incisors. Wear facets are seen on the lingual aspect close to the gingival line. These wear facets result from the grinding of teeth, which is very common in primary teeth. **C,** Rubber dam isolation technique. Dental floss is used to secure the elastic rings. The procedure is performed using general anesthesia. Decayed areas are removed and the area restored. In this case, the lingual surface was prepared and tooth reduction was performed mainly on the facial and interproximal surfaces. The pulp was not exposed in these four incisors after complete removal of decay. **D,** Immediate post-treatment photograph shows gingival bleeding from the sulcus. **E,** Post-treatment photograph shows a slightly open bite. In restoring the case, the bite was intentionally opened slightly to eliminate the wear on the lingual facets of the maxillary anterior teeth.

stainless steel crowns would be appropriate for primary molars with decay involving multiple surfaces and when the parents request a more esthetically desirable substitute than stainless steel crowns. Parents need to be aware of the high failure rate of the esthetically desirable facings in order to make an informed decision on whether to use these esthetically desirable crowns versus traditional stainless steel crowns.

Summary—Primary Molars

The choice for the restoration of primary molars should depend on the size and location of the decay, as well as the patient's caries risk. With a high-caries-risk patient, the traditional stainless steel crown without veneer is the best option. For a moderate-caries-risk patient, resin-modified glass ionomer or a direct composite would be adequate. The main problem with veneered

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FIGURE 30-2 Direct composite. A, Clinical photograph showing extensive occlusal and buccal decay. Based on the radiographic examination, mesial and distal surfaces were intact. The parents requested no metal restorations in the mouth because of the child's history of allergies to metal. B, Rubber dam isolation. The technique shown is a slit technique. There are no individual holes. The second primary molar, first primary molar, and canine were isolated. C, The caries lesion removed, revealing involvement of the pulp. D, A pulpotomy was performed. The coronal pulp tissue was amputated and the bleeding was well controlled with wet cotton pallets. E, The radicular pulp was capped with zinc-oxide–eugenol and then a layer of glass ionomer cement owing to the possibility that the eugenol might interfere with the polymerization of the composite. F, Post-treatment photograph after direct composite application. The entire procedure took 15 to 20 minutes.

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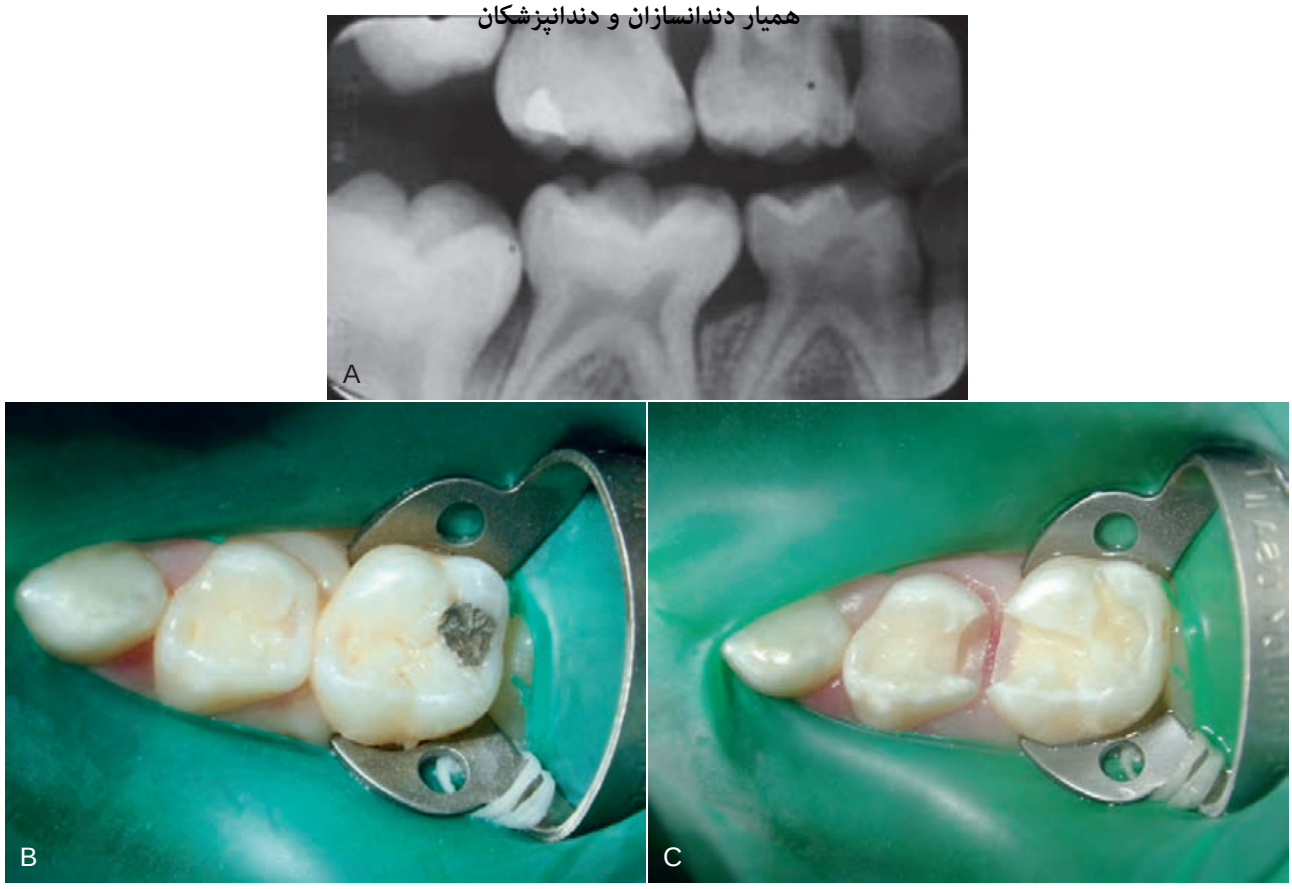


FIGURE 30-3 **Resin-modified glass ionomer. A, Pre-treatment bitewing radiograph shows interproximal decay on the mesial surface of the maxillary right first primary molar and second primary molar and on the distal surface of the primary first molar in the maxillary right quadrant. Note the emerging permanent teeth. The primary pulp chamber is relatively larger than that of the permanent teeth. The enamel is also thinner than on the permanent teeth, so the progression of caries lesion is more aggressive. If no restoration is undertaken, the pulp may become infected and develop into an abscess. Untreated interproximal decay can also cause a loss in space. B, Rubber dam isolation (slit) technique. C, Cavity preparation. Existing amalgam was removed owing to a marginal defect.**

Continued

stainless steel crowns is that the veneer chips away over time and is hard to repair. The advantages of the direct composite are its esthetics and that less tooth preparation is required. Direct composite restorations are also poor choices for high-caries-risk patients. Full-coverage crowns although possible to place, are extremely technique sensitive, particularly with young and potentially uncooperative patients.

Young Permanent Anterior Teeth

Discolored Anterior Teeth

Differential Diagnosis The causes of discoloration of the anterior teeth include trauma; intrinsic staining as a result of the use of tetracycline, which is not common today because most pediatricians are aware of the adverse effects of tetracycline; and extrinsic staining from tobacco use, soft drink, coffee, or tea drinking, or other dietary exposures. Thorough history taking and clinical and radiographic examinations are essential to recognize the cause in order to best manage the discoloration.

Management

Bleaching Figure 30-4 demonstrates the use of bleaching in a 15-year-old female patient who had experienced trauma.

Micro-Abrasion Micro-abrasion is a conservative and controlled technique for removing a thin layer of enamel to improve discolorations limited to the outer enamel layer. It involves an abrasive polishing powder to remove the very thin layer of enamel. Micro-abrasion is appropriate when the discoloration is limited to the outer layer of the enamel. Often, white spot lesions are too severe to be improved by this approach.

Control of White Spot Lesions Figure 30-5 demonstrates the use of a light-cured glass ionomer material (Vanish XT, 3M ESPE, St Paul, Minnesota) to control the progress of decalcification on the white spot lesions. The patient, a 15- year-old girl, had received orthodontic treatment a year previously. After that treatment was completed, the patient's main complaint was the white spot lesions on all facial surfaces of her anterior teeth. A patient who has undergone good orthodontic treatment and

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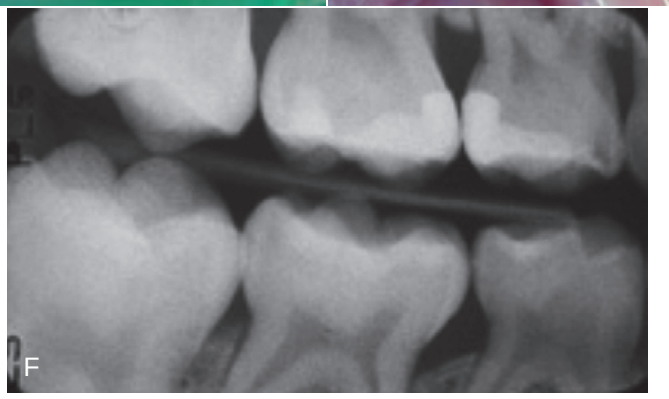


FIGURE 30-3, cont'd **D, Contoured matrix band placement. The most commonly used matrix band is the T band, but because the primary molars have more prominent curvatures, a regular T band will not be able to achieve the ideal contour. In this case, a contoured matrix band was used. For separation of the two teeth, a ring that comes with the matrix band was used. The normal etching, bonding, and restorative procedures were then performed. E, Final restoration. The final occlusion was checked carefully to avoid any occlusal overloading spots. F, Post-treatment bitewing radiograph. Note ideal contour of the posterior restorations, which matches the original contour.**

follows good homecare practices while wearing braces should not develop this kind of decalcification.

Direct Composite or Veneers For moderate discoloration cases in mixed dentitions or young permanent dentitions, direct composite or veneers might be considered. The young permanent tooth has a relatively large pulp chamber. Over-reduction of tooth structure may cause damage to the pulp tissue. The main concern regarding veneers is that the margins will gradually become visible as the anterior teeth continue to erupt. The margin can be easily discolored, consequently compromising the esthetics.

Chipped or Broken Teeth

Diagnosis and Treatment Planning The treatment plan depends on the severity of the trauma and how much of the structure was lost. An esthetic analysis should be done to determine whether a tooth can be restored to its original shape and position. If there are any orthodontic concerns, such as an open bite, crossbite, or crowding issues, the goal would be to improve on the original function or reshape the teeth to achieve an acceptable, esthetically desirable result. The clinician should also evaluate the periodontal tissue in cases with crown or root fractures. Periodontal surgery may be needed to achieve the esthetically desirable result and long-term success.

Management

Direct Composite Figure 30-6 shows a 15-year-old boy who sustained trauma in a sports-related accident that caused fracture of the crown of the maxillary right central incisor and maxillary right lateral incisor. The patient was not in pain but complained of sensitivity with various exposures.

Full Ceramic Crowns Severe trauma involving the pulp requires endodontic treatment. When this is completed, if the patient requires no further orthodontic treatment to align the teeth, full ceramic crowns are an option.

Young Permanent Posterior Teeth

Diagnosis and Treatment Planning Young permanent molars are more susceptible to pulpal damage caused by deep caries lesions owing to their relatively large pulps. Indirect pulp capping often is required for managing deep caries lesions. If the

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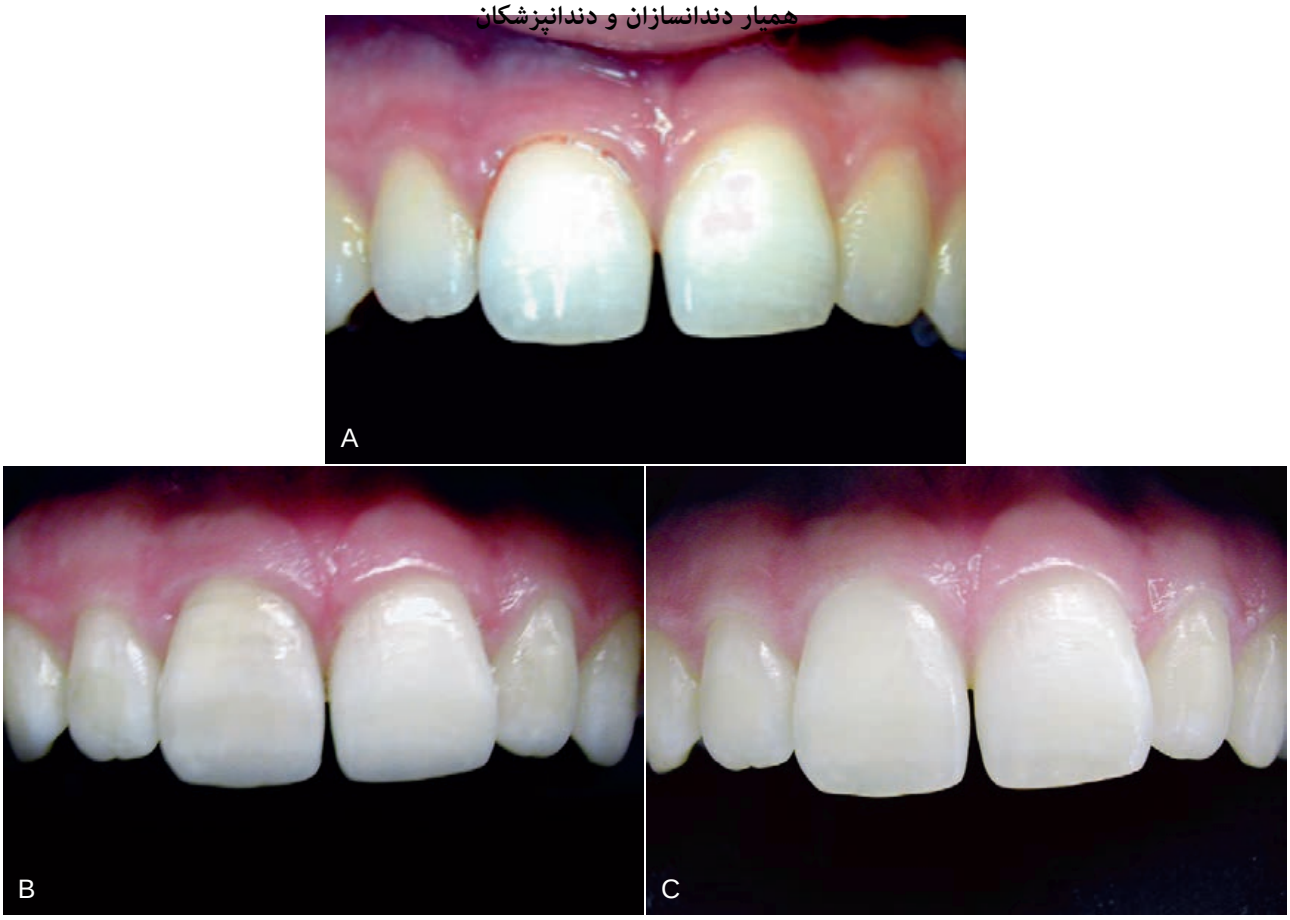


FIGURE 30-4 **Bleaching. A, Gingival bleeding was present around tooth No. 8, but tooth mobility was within normal limits. No treatment was performed. B, At the 6-month recall, the patient's chief complaint was discoloration of No. 8, but no pain, swelling, or discomfort was present. Soft tissue and tooth mobility were within normal limits. Tooth No. 8 was non-vital based on repeated vitality tests. Pulp necrosis was confirmed at access opening. After completion of the root canal treatment, glass ionomer (Fuji IX, GC America, Alsip, Illinois) was used to seal the canal orifice before bleaching was begun. An internal bleach was performed using 35% carbamide peroxide for 15 minutes. C, Clinical photograph showing the results immediately after a single bleaching appointment with 35% carbamide peroxide. The tooth was rinsed and the access to the canal restored with a direct composite. The composite was placed directly on top of the glass ionomer.**

patient has a need for orthodontic treatment, it is generally preferred to defer the permanent restorations until after the orthodontic treatment.

Management

Direct Composite Figure 30-7 shows a 15-year-old female patient with pit and fissure decay on the mandibular right first permanent molar.

Indirect Restorations Indirect restorations are indicated when the decay involves multiple surfaces and ideal contouring is difficult to achieve by matrices. An impression must be taken after tooth preparation and sent to the laboratory for fabrication. This procedure requires a minimum of two appointments rather than one. Material choices include composite and ceramic. Placement of ceramic restorations to restore caries lesions in posterior teeth requires careful attention. The excessive wear of opposing teeth may result in changes of occlusal planes in the long term. Strategic placement of ceramic inlays or onlays can be performed in teeth that are not subject to heavy occlusal loading and will result in more predictable long-term success.

Computer-Aided Design and Manufacturing Milled Restorations Chairside computed-aided design and manufacturing (CAD-CAM) milled restorations can be accomplished in one appointment. This is the main advantage over laboratory-fabricated restorations, especially for young patients. The need for a temporary restoration or a second injection of local anesthetic at delivery can be eliminated. Both ceramic and composite materials are available for milling. These restorations are proven color stable and wear at a clinically acceptable rate. The phenomenon of submargination is consistently observed owing to wear of the luting composite on occlusal surfaces. However,

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FIGURE 30-5 Control of white spot lesions. **A,** Clinical photograph showing obvious white spots on the canine and lateral incisor. **B,** After the teeth were cleaned, only the decalcified areas were acid etched for 15 seconds. **C,** A resin-modified glass ionomer (Vanish XT Extended Contact Varnish' 3M ESPE, St Paul, Minnesota), from which fluoride leaches, was applied. It helps to prevent decalcification of the enamel. Once the tooth had undergone light curing, it presented a smooth surface. **D,** The completed Vanish XT Extended Contact Varnish. **E,** The 3-month recall clinical photograph. The decalcifications have become much smaller and much less apparent. Whether treatment will be repeated depends on the patient's choice. In this case, the treatment was not continued because the patient was satisfied with the result at this point.

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FIGURE 30-6 Direct composite. **A,** Fifteen-year-old boy was involved in a traumatic sports-related accident that resulted in the fracture of the maxillary right central incisor crown and the maxillary right lateral incisor. The patient was not in pain but complained of sensitivity with various exposures. **B,** Occlusal view shows the dentin exposed on the maxillary right central and lateral incisors. This explained the patient's sensitivity. **C,** Frontal view of the traumatized central and lateral teeth before restoration. **D,** Silicone guide or template to facilitate the composite buildup. After the initial examination, a study model was obtained and then a wax-up was done on the study model. A silicone impression was taken on the model and cut off the labial part of the silicone. **E,** A veneer preparation was done on the labial surface, and a light chamfer was done on the palatal surface.

Continued

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FIGURE 30-6, cont'd **F,** Finished preparation from the occlusal aspect. **G,** After shade selection, a flowable composite is used to achieve better marginal adaptation. A composite buildup is used to replace the dentin and to mimic the mamelons on the young permanent incisors. The color used is slightly more yellow than the final restoration to replicate the actual dentinal color. The next step is to build up the enamel. A different shade is used to match the enamel. In this case, a bit of opaque was used to replicate the details of contralateral incisors. **H,** Frontal view of the final restoration. **I,** Occusal view of the final restoration. Note the perfect mesio-lingual and disto-lingual line angles achieved with this technique. The arch contour has been maintained on both the buccal and the lingual aspects. Those teeth fit in naturally with the existing dentition. After the treatment was performed a mouth guard was made to act as a protective device and for sports participation. It is anticipated that the patient will need further treatment at some point in the future, and possibly full ceramic crowns, after definitive orthodontic treatment.

consequences of this type of wear leading to restoration failure have rarely been reported[7] (Figures 30-8 and 30-9).

SUMMARY—YOUNG PERMANENT TEETH

The choice of treatment depends on the size and location of caries lesions and the caries risk of the patient. If the lesion involves only a single surface, direct composite will be ideal because it is cost-effective and less time-consuming. If the lesion involves multiple surfaces, indirect restoration such as laboratory made or chairside CAD-CAM milled restorations are the better options. CAD-CAM dentistry has improved tremendously in the past decades and appears to be very promising for the future. However, it requires investing in expensive equipment, and additional training is needed for dentists and their staff.

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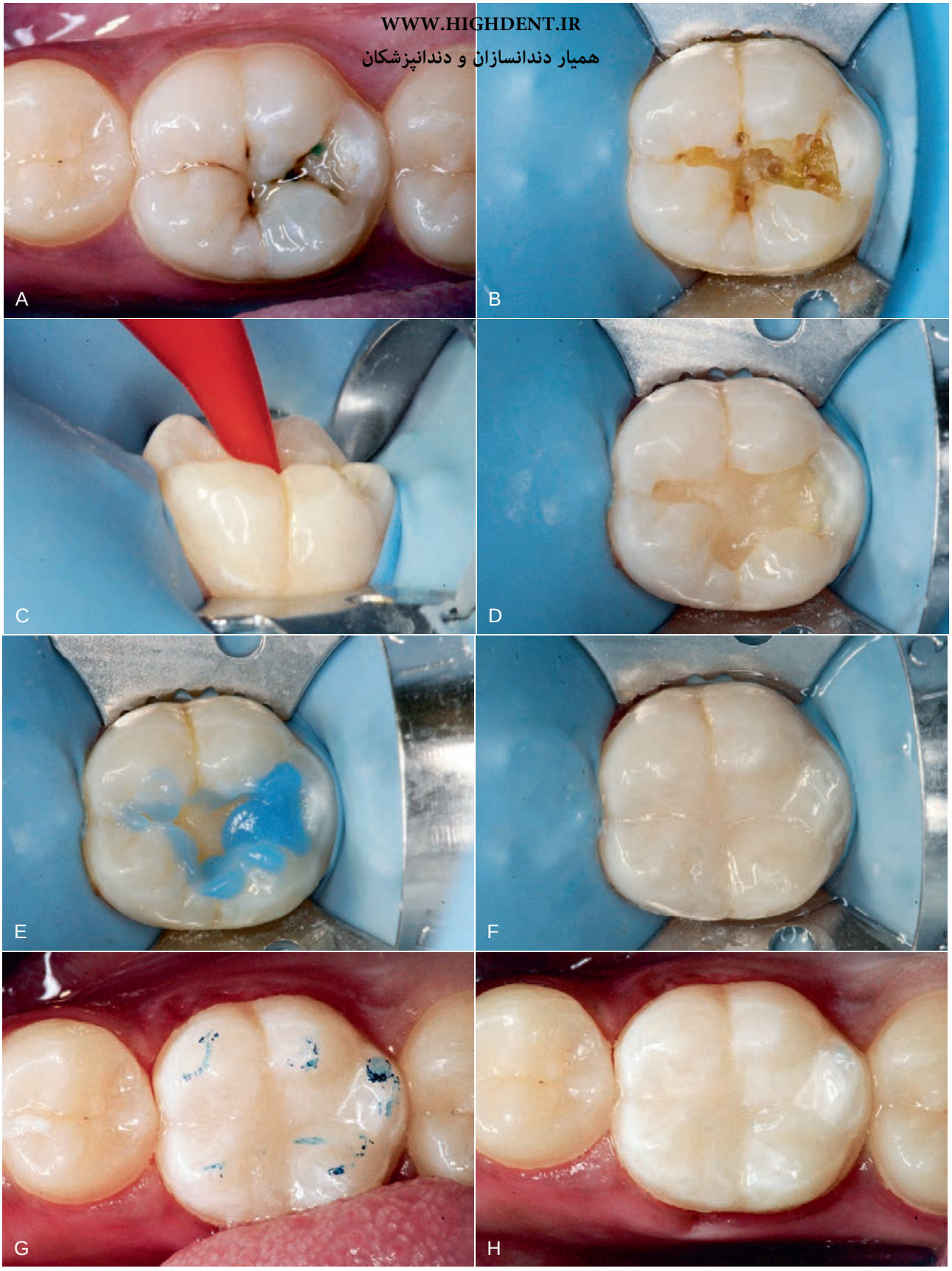


FIGURE 30-7 Direct composite. **A,** 15-year-old girl with pit and fissure caries on the mandibular right first permanent molar on clinical examination. The patient had no previous fillings placed on this tooth. Isolation was done under a rubber dam. A local anesthetic was used. **B,** After the pit and fissures were opened, more extensive decay involving the dentin was uncovered. That often happens when the enamel has been hardened by fluoride. As soon as the decay goes into the dentin, it balloons out. **C,** After the cavity perforation, glass ionomer is used to replace the dentin. **D,** Glass ionomer base. **E,** Enamel is acid etched for 15 seconds and rinsed with water. The bonding agent used was Adper Easy Bond (3M ESPE, St Paul, Minnesota). **F,** Direct composite placed. **G,** The occlusion is checked after removal of the rubber dam and the clamp. It is carefully inspected to be sure the restoration does not have any heavy contact points on the restoration. **H,** Final restoration.

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FIGURE 30-8 Eleven-year-old girl with an amalgam restoration with recurrent caries. **A,** Rubber dam placement with a slit technique. **B,** Clinical photograph showing the complete removal of the amalgam and decay. A resin-modified glass ionomer is placed as a base to protect the pulp and provide a flat surface. **C,** Powdering the preparation for an optical impression for a computer-aided design and manufacturing (CAD-CAM) restoration. Once the optical impression is taken, the software will convert the data so that a three-dimensional (3D) model of the preparation is generated. Software will facilitate the design of the restoration. Once that is completed, the 3D restoration data are sent to the milling machine. When the restoration comes out of the milling machine, it is ready to be tried in. If it fits, it can be cemented. **D,** Final restoration was cemented with a composite cement. The final product is polished to the margins, yielding a very esthetically desirable, functional, and strong restoration.

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FIGURE 30-9 Twelve-year-old girl with severe decay on the maxillary right permanent molar. The clinical examination shows extensive distal decay plus secondary decay around the occlusal amalgam. Occlusal (A) and buccal (B) views of amalgam and caries lesion. Note the shadow on the mesial of the occlusal surface. The lesion was confirmed on a bitewing radiograph. Local anesthesia with infiltration was used. C, Final cavity preparation. D, Occlusal view of the try-in of the restoration. E, Buccal view of the restoration before cementation. All the margins were examined carefully with the explorer. F, The restoration was cemented with the composite cement. It was polished, and the occlusion was adjusted.

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NEAR-FUTURE DEVELOPMENTS IN PEDIATRIC DENTISTRY

More esthetically desirable products will be on the market soon. Many manufacturers are trying to improve existing esthetically desirable crowns for severely decayed primary anterior and posterior teeth. No products actually achieve long-term success at this point. For smaller areas of decay involving one or two surfaces, tooth-colored materials will prevail. Dentists treating children will appreciate the continuing improvement of esthetically desirable, easy-to-handle materials with good physical properties and fluoride release. With CAD-CAM dentistry booming, it is easy to foresee more applications for young permanent dentition.

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Sleep and Snoring

Wayne Halstrom

RELEVANCE OF OBSTRUCTIVE SLEEP APNEA TO ESTHETIC DENTISTRY

"Esthetic" dentistry implies a move to a more pleasing countenance by enhancing the smile and inspiring confidence with an assured appearance. Sleep-disordered breathing, ranging from snoring to medically significant sleep apnea, demonstrates a very clear, direct, and dramatic connection to tooth grinding and clenching. Bruxism is very frequently present in the snoring and obstructive sleep apnea (OSA) patient. The most powerful reflex action possessed by the mammal is to protect the airway. There is clear evidence that the act of clenching of the teeth will result in some increase in the size of the airway. For many generations of dentists the root causes of bruxism have been issues of debate. Dentistry has considered stress and habit to be among the causes of this phenomenon. A shutdown of the airway may be the beginning of a long trail of clenching and grinding in the sleep apnea patient. Bruxing patients will tear apart the beautiful dentistry achieved through the many esthetic procedures available to dentists in the twenty-first century. It is common within a practice to be able to recount experiences in which cases with great similarities in dental requirements have resulted in a wide variation of time of service of the restorations. Often the patient who tears apart the dental work is a sleep-disordered–breathing patient whose condition went undiagnosed. The dentist, being unaware of the threat to the dental health, will have gone ahead in good faith to restore and protect the dentition, only to find that the restoration may break down as a result of an undiagnosed and untreated OSA condition.

No group of health professionals is more ideally placed to screen for people with sleep-disordered breathing than the dental team. Patients see their dentists on a regular and ongoing basis. Only on rare occasions is the dental service accompanied by pain, suffering, and general health disease. Compared with a medical practice, in which patient appointments are most commonly associated with some form of medical concern, dental appointments are much more benign. Dental patients who come in for regular recall visits can and should be screened for other issues related to their dental concerns. A mother sitting in the waiting room while her child is having a recall appointment is the ideal target for information on the snoring of her husband. There is nothing esthetic about the appearance of a snoring patient with the usual dropped jaw accompanied by ugly noises.

The snoring population has been the subject of much derision for generations. Often the target of cartoonists and humorists, the snorer has long been the butt of jokes. The development of sophisticated technology to define the medical importance of oxygen deficiency during sleep was the starting point for redefining of the relationship between snoring and sleep apnea. The term *sleep apnea* was not used in general medical practice as late as the 1970s. With the availability of the defining technology, medical researchers moved to seek treatment for nocturnally oxygen-deprived patients. Although there are distinct differences among some classifications of sleep apnea, the focus of this chapter is OSA.

In response to the need for therapy for this condition, a home ventilator device was developed. The device delivers *continuous positive airway pressure* (CPAP). The CPAP machine is a life-saving device for people with the more severe form of sleep apnea. The downfall of CPAP therapy is that it is generally overprescribed, in the sense that general medical practice has been to prescribe CPAP whenever any form of sleep apnea is present. The management of the device is difficult. There are difficulties with finding a mask that fits. The device requires that during sleep the wearer must be attached to a "blower" by a hose, which limits the ability to turn over. In general, a CPAP device is invasive to the sleep posture and comfort. If one's life is in danger every time the eyes are closed, which is unquestionably the case for the severely apneic patient, the patient will usually accommodate to anything. It is the milder levels of sleep apnea that, although medically significant, do not necessarily catch the attention of the patient. In the mild sleep apnea patient, the use of the CPAP machine is limited by the inconvenience and discomfort for the patient as well as the noise and disruption to the sleep of the sleep partner.

The use of oral appliances to treat sleep-disordered breathing became common after the late 1980s. The first recorded use of manipulation of the tongue position to alleviate OSA occurred in 1934. The technique lay dormant for the next 50 years until patient compliance with the use of CPAP therapy was identified as being problematic and other solutions were required. Since 1990 an enormous amount of research has been done, which

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eventually led to the release of the American Academy of Sleep Medicine position paper on the use of oral appliances in the treatment of sleep apnea and snoring. Until the release of this paper, which was 10 years in the making, one significant barrier to the use of oral appliances was the position taken by the insurance community identifying the therapy as being "experimental" and therefore not a covered service. Since the release of this position paper the landscape has dramatically changed, with most insurers, including some governmental agencies, now covering the service.

RELATING FUNCTION AND ESTHETICS

In considering oral sleep appliances, it is necessary to relate function and esthetics. Appliances used to treat sleep disorders offer protection for the teeth against damage resulting from destructive oral habits and jaw muscle responses related to sleep apnea.

Protection is important whether one has a natural dentition or a restored dentition. One important distinction is that the dentist treating the sleep disorder and the restorative dentist are not necessarily the same person. Appliance selection and the transmission of knowledge about the sleep disorder treatment to the general or specialist dentist are of paramount importance. There may be repercussions from wearing a jaw advancement device during the night. The five most feared words in the vocabulary of the sleep dentist is "Doctor, my bite has changed." Although a change in bite may be inevitable in some patients, ensuring that the patient is aware of and understands this possibility is only one part of the equation. Ensuring that other members of the patient's dental team are aware is critical to avoiding unnecessary inconvenience and perhaps medico-legal complications.

Research at the University of Montreal has shown that for patients who have OSA, the use of a single-arch maxillary night guard can make that patient's condition worse by a factor of 50% in half of the cases. This puts an entirely new light on the mass use of night guards to protect teeth from nighttime threats. If a patient exhibits the need for night guard therapy, the dentist should investigate the possibility of an OSA problem. It is important to remember that snoring and OSA are a part of a continuum. Snoring is the first and most obvious sign of a compromised airway. From there patients proceed along the spectrum of sleep-disordered breathing. The airway that is obstructed but not occluded presents a condition known as *upper airway resistance syndrome.* These patients are struggling to breath. The body response is hypertension leading to elevated blood pressure. In the dental realm is the natural body response of bruxism to alleviate a compromised airway.

One very common aspect of sleep-disordered breathing is that the signs and symptoms of the condition do not necessarily fall in line with the empirical numbers established by sleep studies. Many patients with a mild diagnosis will exhibit aggressive symptoms, and the converse is also true. Some of the more severely affected patients disavow the daytime sleepiness symptoms associated with OSA, whereas many diagnosed with mild OSA have significant and life-altering or life-threatening symptoms. OSA is divided into mild, moderate, and severe categories. Oral appliance therapy, as outlined by the American Academy of Sleep Medicine, is best suited but not necessarily limited to the treatment of OSA in the mild and moderate categories.

CLINICAL CONSIDERATIONS

Sleep apnea appliances are useful for people who snore. The dental office should develop a screening program that starts with three basic questions:

1. Do you snore?
2. Are you sleepy during the day?
3. Does your sleep partner report that you stop breathing at night?

If the answer to any of these questions is "yes," a more comprehensive screening is suggested. There are a number of validated questionnaires available. If the results indicate a high probability for OSA, the patient should be referred for a medical assessment and diagnosis. By virtue of training, experience, and licensure, dentists are not legally able to differentially diagnose patients who snore and do or do not have OSA. The opportunity to treat snoring patients exists. Proceeding with treatment without confirmation of the patient's medical assessment engenders risk. The medical condition of OSA may be negatively affected by the use of oral appliances in some cases. Medical backup is not only advisable but essential.

CLINICAL OPTIONS

A number of approaches are available for treating people with sleep-disordered breathing. The number one cause of this disorder is a genetic predisposition to the condition. Patients inherit a set of craniofacial characteristics that predispose to having a nighttime breathing problem. Typical Class II malocclusion patients are prime candidates because the tongue is jammed back owing to the mandibular positioning. Patients with a small air passage or a soft palate and uvula positioned low behind the tongue are at greater risk. The second of the "evil trio" is ageing. As one ages, every set of tissues in the body loses tone. This means that the collapsible tube called the *velopharynx,* which is 2½ inches long and is positioned right behind the tongue, will grow lax. The tube becomes progressively more collapsible over time. The third of the prime causes is being overweight.

When considering treatment alternatives, lifestyle changes are a first line of treatment. Treatment of a patient who is 40 pounds overweight will be a much greater challenge than if a loss of 20 pounds could be achieved. Lifestyle changes are the most cost-effective but may also be the most challenging.

Surgical approaches are a possibility. In appropriate anatomical situations, surgery may offer the only other "cure" for the problem. The surgical approach ranges from the most

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extreme—tracheostomy—to laser-assisted uvulopalatoplasty. Alteration of the throat anatomy by resecting the uvula and soft palate has been shown to be effective. One technique that has come available in the last few years is the Pillar Procedure. This intervention involves the placement of two or more rods in the soft palate to stiffen the tissue and thus relieve the snoring. However, no matter how the procedure is done, surgery is invasive. Conventional wisdom is to pursue the non-invasive options before going to the surgical alternative.

CPAP has been the most highly regarded therapy, as previously discussed. With compliance issues has come the impetus to consider alternatives. The use of oral appliances to reposition the mandible during sleep has presented a welcome alternative. Consensus exists that the tongue is the biggest of the players in sleep-disordered breathing problems. The most restorative and rejuvenating sleep is rapid eye movement (REM) sleep. During REM sleep there are only two sets of muscles active: the orbital muscles of the eyes and the cardiovascular system. As all other muscle groups and tissues become relaxed; the weight of the teeth, jaw, jowls, tongue, and lower half of the face become a dead weight to the jaw joint. The collapsing of the tongue into the airway then causes the airway to become obstructed.

There are two functional aspects to the use of oral appliances. The first is stabilization of the lower jaw. Dramatic evidence of the collapse of the lower jaw is best publicly demonstrated by looking at the sleeping passengers on an airplane—not particularly esthetic.

The second attribute of the oral appliance is the repositioning of the lower jaw in a forward position during sleep. As the jaw is repositioned forward, the tongue, attached as it is to the inferior aspect of the mandible, will be pulled forward and out of the airway.

Oral appliances exhibit significant advantages over other treatment modalities. The surgical approaches are invasive. CPAP is not only invasive at the human level but also an inconvenience when traveling. The shirt pocket placement of an oral appliance makes its use while traveling very attractive.

CURRENT BEST APPROACHES

The U.S. Food and Drug Administration (FDA) has now approved over 30 different oral appliances. Some appliances are very simple thermoplastic devices that can be used as screening tools to identify patients who may respond well to oral appliance therapy. Others are complex custom-made devices that are designed to offer significant adjustment features that engender comfort as well as performance. Differing materials offer other challenges. The thermoplastic materials may invite tooth positioning changes. The author prefers the use of a hard acrylic overlay to provide strength to the appliance but also to inhibit tooth movement. The hard acrylic is brought to just beyond the height of contour of the teeth, offering small "cups" of hard acrylic to stabilize the teeth. The body material of the appliance is an injected high-impact permanently elastic material the offers retention and comfort. The average length of service of this type of appliance has been shown to be 5 years. The longest-used appliance of this type was in continuous service for 16 years. Durability and other characteristics vary with the type of appliance chosen.



FIGURE 31-1 Silencer appliance. *(Courtesy Silencer Products International Ltd., Vancouver, British Columbia.)*

The process for finishing the device is the same as for all dental devices. Appliances should be sleek and smooth, with no appendages that will break and result in either ingestion of pieces or injury to soft tissue. Springs, clasps, and wires are not welcome additions. The author prefers relying on the interproximal areas to secure retention rather than using things that the patient might ingest or aspirate to create a medical emergency.

OTHER CONSIDERATIONS

Clinicians all develop biases based on knowledge and experience. The author's bias is toward the use of implant-grade titanium precision attachments to deliver the best results both in durability and function. The Silencer appliance (Figure 31-1) uses precision attachments to enable adjustments in both the anteroposterior positioning and the vertical positioning of the mandible.

The author believes that the use of the vertical adjustments in treatment of OSA patients is important. Bite change is a common companion to mandibular advancement therapy. There is a lack of consensus as to the reasons for this phenomenon. Experience involving a case load in excess of 3000 patients over a period of 20 years has convinced the author that in patients with a steep condylar pathway the increase of vertical dimension not only enhances the comfort of the wearer but also avoids stretching of the mandibular ligaments, which can invite a posterior open bite. Identifying the slope of the condylar pathway is possible using computed tomography (CT) scanning technology; however, further complicating the costs of therapy may be unwelcome. Very careful titration of the appliance in both dimensions will offer the best protection against unwelcome occlusal changes.

INNOVATIVE ELEMENTS

The earliest devices used to treat OSA were monobloc-style appliances that simply repositioned the jaw forward. No lateral movement was possible, and there were no adjustment features beyond segmenting the blocks of acrylic and rejoining them in a more forward position.

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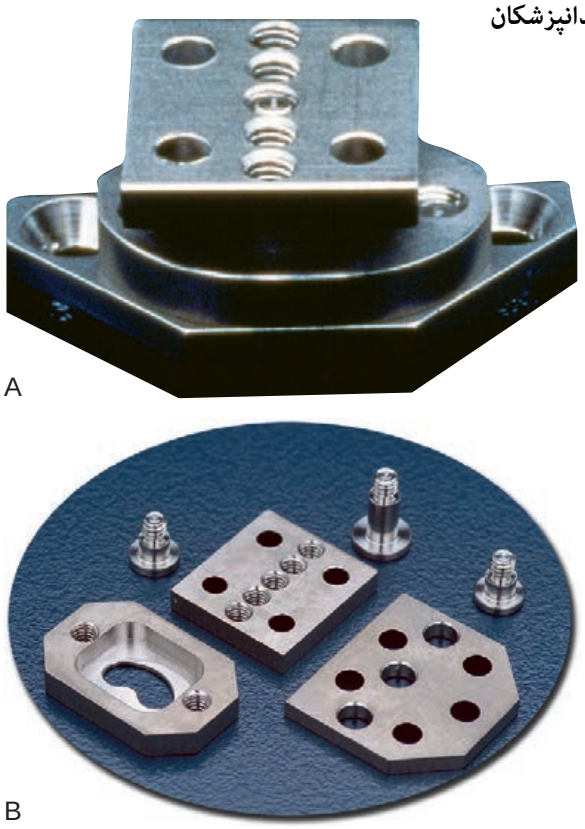


FIGURE 31-2 A, Halstrom Hinge. B, Disassembled Halstrom Hinge. *(Courtesy Silencer Products International Ltd., Vancouver, British Columbia.)*

In the early 1990s, research at the University of British Columbia identified the use of the Halstrom Hinge (Figure 31-2) in the management of jaw position. The Silencer appliance, using the Halstrom Hinge, permits incremental forward adjustment of the jaw as well as lateral movement. The lateral movement is critical to both patient comfort and relief of the impact of bruxism.

Modern appliances offer sensitivity to specific nuances. Consider, for instance, the class II patient. Cluttering the mouth with apparatus will further crowd the tongue space. Differently designed appliances can alleviate this problem. The severe bruxer must also be considered. The design of the appliance must allow for the jaw of the bruxing patient to move not only laterally but also elliptically. One variation of the Halstrom Hinge allows the mandible to accomplish the elliptical movement through a redesign of the apparatus to prevent the mandible from falling backward while permitting the patient to thrust the mandible forward to the maximum extension and permitting the elliptical movement so common to the bruxing patient.

ARTISTIC ELEMENTS

The artistic area involves the design of the appliances being used. Some patients, even though they know they will be asleep, worry about what the appliance will look like. They wonder whether it will have something that sticks out of the mouth during sleep or if it is sleek and will disappear into the oral cavity. The size of the device and blending of the device into the configuration of the lips and the oral cavity are important artistic considerations. It is important to recognize that for many patients the motivation for seeking therapy is driven by the sleep partner.

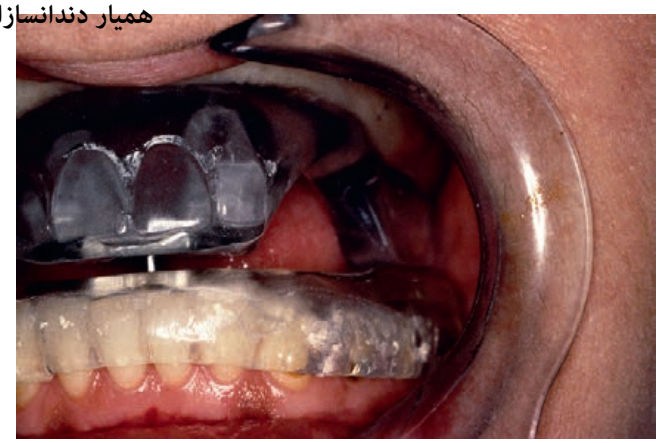


FIGURE 31-3 Upper denture patient with appliance in place. *(Courtesy Silencer Products International Ltd., Vancouver, British Columbia.)*

TREATMENT PLANNING

Once the patient has been diagnosed, it is necessary to make a "choice of weapons." Should the dentist use a press-fit type of appliance as a test to demonstrate to the patient the possible advantages of therapy? The author cautions that in using these devices a dentist should prepare the patient for the fact that this is not what it is like to wear a custom-made appliance. If the patient is nervous about the claustrophobic element or about the size of the appliance in the mouth, the author would choose not to go forward with a temporary device, as this may affect the treatment acceptance. Patient selection is particularly important to the successful oral appliance practice. Study models are an important part of the pre-treatment process. The best confirmation about whether oral appliance methods work is found in the research.

A question arises as to the possibility of treating edentulous patients with oral appliances. It is possible to successfully use an oral appliance in edentulous individuals. There has been considerable success with the maxillary edentulous; however, fully edentulous patients should undergo other treatment alternatives. In the author's experience, patients without upper teeth can be treated by using the maxillary component of the Halstrom Hinge precision attachment in a duplicate maxillary denture (Figure 31-3). This can be effective as long as there are sufficient lower teeth present to retain the appliance. One can expect sufficient retention from a well-fitted maxillary denture to manage the mandibular advancement necessary to have successful therapy.

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TREATMENT CONSIDERATIONS

The first issue to consider is whether or not the patient is a candidate for oral appliance therapy. Four anatomical considerations that might be barriers to treatment success are assessed. Dental issues that are important include the condition of the teeth required to support an appliance. The presence of evidence of bruxism will influence the decision as to the type of appliance to be used. The mandibular range of motion is important. The average range of motion from centric relation to maximum protrusion is 14 mm. If the range of motion is restricted to less than 7 mm, expectations of success from mandibular advancement must be reduced. The success gained from support to the lower jaw is unaltered, but the tension to be placed on the musculature around the airway will be reduced.

The second barrier to success may be the size of the tongue. The critically obese patient is more likely to have a tongue that will be difficult to manage. The more crowded the intra-oral space, the more difficult it will be for the patient to become accustomed to the appliance.

The third consideration is the positioning of the soft palate and uvula. A classification is used to guide practitioners in this respect. The Mallampati scale (Figure 31-4) rates patients from I through IV.

A class I patient will most likely not have an airway problem, as the arches of the soft palate are clearly visible without depressing the tongue. Conversely, the class IV patient's tongue must be significantly depressed in order for the uvula and the arches to be seen. The class IV patient is the least desirable oral appliance candidate. In such cases a referral to an otolaryngologist or ear, nose, and throat (ENT) surgeon for further evaluation is in order. In some cases a surgical procedure may be of assistance in reducing the tissue bulk and rendering the patient an oral appliance candidate.

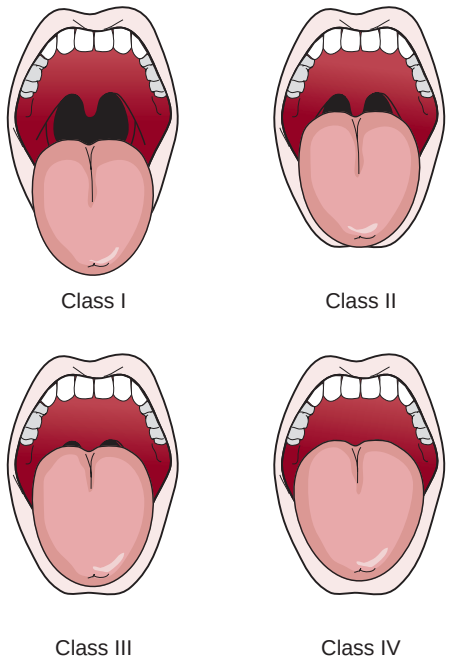


FIGURE 31-4 Mallampati classification. *(From Phillips N:* Berry and Kohn's operating room technique, *ed 11, St Louis, 2007, Mosby.)*

The fourth consideration is the depth of the posterior lingual space. Even though a patient may have a class II or III Mallampati configuration, if the posterior lingual space is sufficiently large, successful treatment may be attained.

For custom-made appliances, the dental procedures begin with an evaluation of the patient from the standpoint of dental qualification to wear an oral appliance. The presence of sufficient teeth to provide retention of the device is paramount. Some appliances require more tooth support than others.

It is important to identify any issues that will present problems for the use of the appliance. The configuration of the dentition must be compatible with the fitting of an appliance. Having qualified the patient, the dentist will go through the usual format for appliance creation. Impressions and bite registration begin the process. Once the appliance has been fabricated, the dentist will fit the appliance, ensuring proper retention and comfort. Successful therapy is a marriage between comfort and function. Without comfort there can be no function. With the patient sufficiently informed and prepared, the titration process begins. A start point will be taken during the bite registration at approximately 50% of the range of motion. From this point the airway response of the patient to the support of the lower jaw and the anterior positioning must be assessed. This may be accomplished only over time. The patient must become accustomed to wearing the device before an effective assessment of the function of the appliance may be accomplished. Once the patient can report success in wearing the appliance every night, the process of assessment of the proper positioning may begin. There will be a "sweet spot" in the positioning of the lower jaw that will deliver the best result. Determining this position will be a work in progress. It is always a good idea to make sure the patient understands this process will involve some trial and error. When the patient can report that there is some progress in the reduction of the symptoms that drove him or her to seek therapy, it is time to do a follow-up sleep test. There are alternatives from which to choose in this regard. These alternatives will range from the most simple—pulse oximetry—to fully monitored polysomnographic overnight studies. The choice will be made by the practitioner based on the advice and council of the medical advisors involved with the dental practitioner. The first and most obvious sign of a compromised airway is snoring. Elimination or relief in this symptom is the first sign that treatment is on the right track. Different settings may be chosen by the titration team, which may consist of the dentist, a respiratory therapist, and a registered nurse and/or a physician. When the appliance is functioning at the best position possible, a decision must be made as to the effectiveness of the treatment. This is a decision for the patient's physician. Communication between the titration team and the physician is essential so that the titration accomplishes the desired results. Some patients cannot be successfully treated by either CPAP or oral appliance therapy. When a patient with

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severe apnea cannot wear the CPAP device owing to the pressure required to maintain the airway, an oral appliance may be required to support the jaw and gain as much mechanical opening of the airway as possible. This form of combination therapy can be highly successful.

Successful therapy is assessed by a combination of resolution of clinical symptoms supported by hard data obtained via follow-up testing. Once the patient response is determined to be successful, the patient will be placed on long-term recall so that the dentist can check the appliance on a regular basis. The time chosen for recall will be dependent on individual clinical considerations.

A question that very frequently comes up is the relationship between temporomandibular joint (TMJ) issues and oral appliance therapy. Because the purpose of oral appliance therapy is to advance the mandible, most TMJ issues will be mitigated rather than made worse. It is prudent to treat patients with a history of TMJ issues in the most conservative fashion in relation to the amount and timing of the mandibular advancement, which can be delayed until the effects of a minimal amount of mandibular advancement have registered as beneficial to the TMJ symptoms.

In this regard it is pertinent to consider the issue of bite registration. The author prefers the use of a gothic arch tracing (Figure 31-5) as the mechanism to determine the starting point for the therapy. The advantage of using a tracing is that the clinician is able to measure the range of motion accurately. In addition, the use of the gothic arch tracing enables a level of TMJ diagnostics. Patients who have closed locks or other TMJ malfunctions can be identified by the variations in the pattern of the mandibular movement. If TMJ issues can be identified at the outset, problems may be either predicted or mitigated. Saving the tracing as a part of the permanent health record can be of inestimable value in cases in which there have been bite changes resulting from the wearing of a mandibular advancement device. The actual tracing apparatus is retained with the study models. It is possible to recreate the patient's bite relationship at any time, thereby permitting a defense against claims that there have been negative bite relationship changes when in fact the bite may not have been perfect in the beginning.

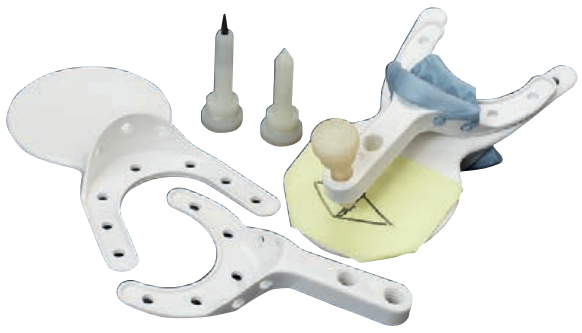


FIGURE 31-5 Gothic arch tracer (GAT). *(Courtesy Silencer Products International Ltd., Vancouver, British Columbia.)*

EVIDENCE-BASED PRINCIPLES

The amount of research on sleep-disordered breathing is extensive. It has been said that the sheer quantity of sleep-related research now rivals the amount of cardiovascular research. A great deal of current research has dealt with the efficacy and advantages of oral appliance therapy, with a number of projects involved with comparison studies between the modalities of CPAP and oral appliances. Over the last 15 years, a body of evidence has accumulated that is irrefutably in support of oral appliances. The latest element of interest has been the impact of bruxism. Bruxism was previously classified by the American Academy of Sleep Medicine as a "parasomnia." Bruxism has now been reclassified to stand on its own as a sleep-related movement disorder. This reclassification opens up the opportunity for more research on bruxism as a sleep disorder.

CONTROVERSIES

There is an ongoing debate as to the relevance of vertical adjustment capability in oral appliances. In the author's opinion, it is not only important but critical to success in cases in which minute adjustments can mean the difference between success and failure. Adjustments to the vertical can also be important to patient comfort. Some patients are more comfortable in a more closed position, and in others the reverse is true.

There remains debate as to the effectiveness of magnetic resonance imaging or acoustic resonance as a mechanism to predict airway response. Further research will help clarify this issue.

Another ongoing controversy is the treatment of bruxism, which requires extensive research to fully understand the underlying issues and their resolution.

NEAR-FUTURE DEVELOPMENTS

Precision attachments will become available that will enable dentists to further customize appliances to fit unusual cases.

The use of oral appliances in support of other therapies will become more common as the medical community affords the necessary respect to the value of oral appliance therapy.

The issues third-party payment will become resolved as the medical acceptance of oral appliance therapy moves forward. Most insurers leave the question of validation of procedures to a medical board. The respect gained within the medical community will carry this issue. Maintaining the dentist-physician relationship is essential to building the respect that oral appliance therapy deserves. Failure to recognize this issue pits the physician and the medical team against the dental team and will frustrate the potential of oral appliances as a recognized treatment modality.

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It is important that the dentist look at the relevance of other medical conditions that are core liabilities associated with sleep-disordered breathing. OSA invites diabetes, as oxygen deficiency inhibits the production of insulin. Reduced production of testosterone that results from depressed blood oxygen may limit sexual performance in men. Patients may be compromised through stroke and cardiovascular disease. Patients with significant apnea have a 2.5-times-higher risk of heart disease and a 2.8-times-higher risk of stroke than individuals without apnea.

Sleep disorders are a factor in obesity. They have negative effects including the accumulation of fatty deposits as a result of changes in hormones that affect the appetite as well as the metabolic process of burning of the fuel (calories) taken in. Reversal of blood oxygen deficits may enable the overweight population to have more success with weight loss programs.

SUMMARY

By following a strict protocol, the sleep dentist may engender respect within his or her medical community as well as providing a highly needed service that will affect and perhaps save the lives of patients.

SUGGESTED READINGS

The American Academy of Dental Sleep Medicine (www.aadsm.org) offers a reading list that is both extensive and complete. The author advises all dentists interested in this field to peruse this list and consider joining the Academy, an ongoing source of information and support.

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32 CHAPTER

Sterilization and Disinfection

A SECTION

Sterilization

George Freedman

RELEVANCE OF STERILIZATION TO ESTHETIC DENTISTRY

It is well established in the medical profession that antiseptic procedures involves more than just washing hands and by extension cleansing instruments. Sterilization of instruments is one of the cornerstones of modern dentistry. It is accepted without question that the process of cleansing instruments and other equipment between patients is a fundamental requirement of any dental procedure. In the process of delivering esthetic treatment to patients, it is extremely important not to risk the transmission of any disease. All materials that are inserted into a patient's mouth must be free of bacteria as well. The esthetic procedure must be performed under conditions that offer low risk to the patient, the dentist, and any auxiliary personnel. The sterilization procedures explained here are standard in the dental profession. No special precaution or procedure is required for esthetic procedures.

BRIEF HISTORY OF STERILIZATION

At one time merely wiping down dental instruments with an antiseptic solution was considered adequate to prevent the transmission of disease from one patient to another (Figure 32-1). In time, techniques progressed to cleansing instruments in solutions that were designed to eliminate most, if not all, bacteria and possibly viruses as well. It was then recognized that sterilization was the only effective means of ensuring that bacterial transmission did not occur (Figure 32-2). Coincidentally, the use of personal barriers such as gloves, masks, and protective eyewear also became common during this period (Figure 32-3).

Dental materials and instruments were categorized into two subsets:

- Sterilizable—typically metal and heavy-duty plastic items (Figure 32-4, *A*)
- Disposable—cotton, paper, or lightweight plastic recyclable items (Figure 32-4, *B*)

Eventually it became apparent that dental instruments were of two major types with respect to sterilization:

- Instruments that are solid, whose external surfaces must be sterilized (Figure 32-5, *A*)
- Hollow instruments, such as handpieces, that have internal lumens that can harbor bacteria and viruses and require flushing out during the sterilization process (Figure 32-5, *B*)

Today, effective sterilization systems are available that can be utilized for every type of dental instrument, whether solid or hollow, and regardless of shape or size. It is important to recognize that sterilizer verification is an absolute necessity. Not only must the sterilizer be working, but it must be regularly and continuously proven to be working effectively. Sterilizer verification can be done in house (Figure 32-6), at the dentist's office with kits that are commercially available, or by outside agencies that provide the service for a fee.

Different jurisdictions have different requirements for sterilization, and each practitioner must follow the rules in his or her local area. No matter what the rules are, the practitioner has an obligation to the patient and staff to maintain a healthy, clean practice environment.

The process of sterilization can be effectively accomplished using two separate components: (1) **pre-sterilization** (removing the debris) and (2) **sterilization** (eliminating the pathogens that can transmit and transfer disease). Both of these steps must be accomplished effectively and efficiently. *If the sterilization procedure takes too long, it can encourage individuals to take shortcuts*

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FIGURE 32-1 An instrument being wiped off with a piece of cloth.

that are detrimental to all concerned. Longer sterilization procedures also require more instruments sets, creating a financial liability for the practice. Sterilization must be predictable, effective, and efficient.

EFFECTIVE PRE-STERILIZATION

There are various approaches to in-office autoclaving, but a common thread of these procedures is that pre-sterilization (or washing) of the instruments is an indispensable step. Guidelines from the Centers for Disease Control and Prevention (CDC), the British Dental Association, and the Robert Koch Institute indicate a preference for automated washing over manual washing (Box 32-1). These guidelines and standards should be considered when establishing dental office protocols.



FIGURE 32-2 An autoclave "flash" sterilizer used for sterilization of instruments and handpieces *(Statim 5000s, Courtesy SciCan, Toronto, Ontario).*



FIGURE 32-3 Gloves, mask, and protective eyewear.

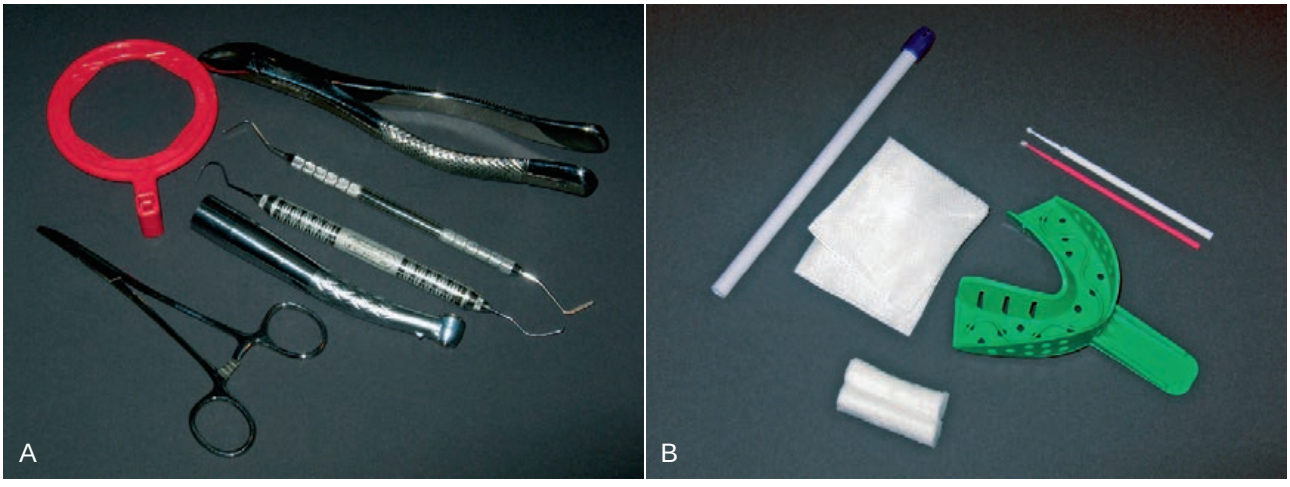


FIGURE 32-4 Metal and plastic instruments that can be sterilized (A), and cotton, paper, and lightweight plastic instruments that should be disposed of and not sterilized (B).

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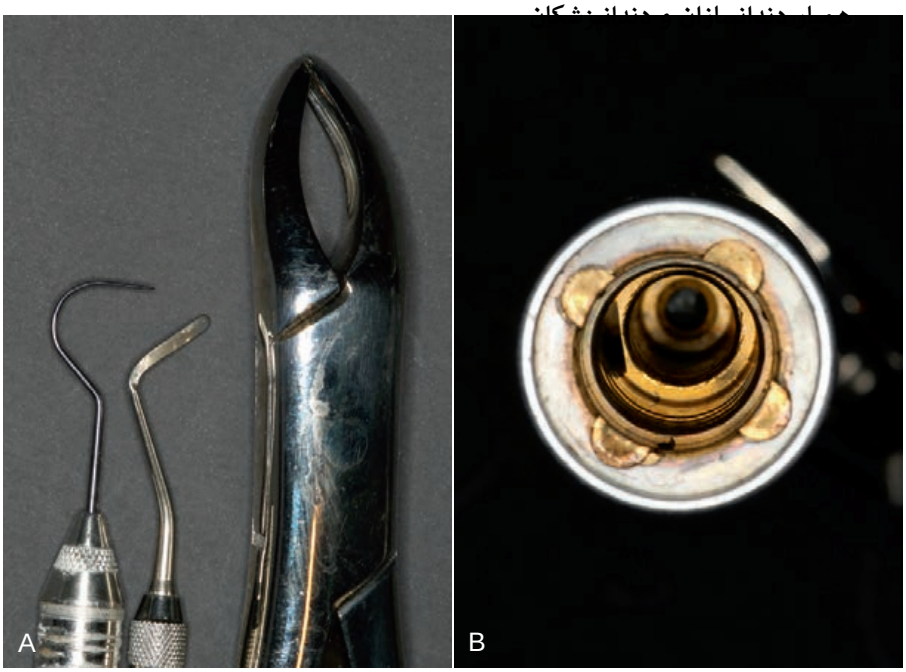


FIGURE 32-5 **A, Instruments with solid external surfaces. B, Hollow instrument.**



FIGURE 32-6 In-office systems used to monitor the effectiveness of sterilizers. A, SporeCheck. B, Bioview Incubator. *(A courtesy Hu-Friedy Mfg. Co., LLC, Chicago, Illinois; **B** courtesy North Bay BioScience, Traverse City, Michigan).*

The clinical success of pre-sterilization is directly related to two main factors:

- Effectiveness of the procedure
- Efficiency of the process

Pre-sterilization consists of three separate actions, each of which must be successfully completed to prepare for effective autoclaving. These are: (1) debris removal and washing, (2) rinsing, and (3) drying. All too often, some or all of these essential steps are overlooked or missed.

Debris Removal

The removal of organic and inorganic debris and protein is typically the most labor-intensive, most time-consuming, least effective, and most dangerous of the three actions. The most common technique for debris removal is hand scrubbing the instruments (Figure 32-7). The effectiveness of manual decontamination is highly suspect. No brushing instruments or scrubbing techniques can effectively eliminate 100% of all the debris on every single dirty instrument. Even if this could be accomplished, questions arise concerning how long the cleansing takes and how to verify its effectiveness. The evaluation of debris removal by scrubbing should be microscopic, but in the bustle of an active practice, often only a quick visual glance is practical. The inherent risks of manual scrubbing are serious ones:

1. Glove and/or skin punctures risk the dental auxiliary's health and well-being (Figure 32-8).
2. Incomplete debris removal risks cross-infection among patients (Figure 32-9).
3. The scrubbing action aerosolizes fluid droplets that can strike the auxiliary's unprotected arms, face, eyes, or mouth, risking the auxiliary's health (Figure 32-10).

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BOX 32.1 Organizations That Handle Infection Control

Centers for Disease Control and Prevention (CDC), Atlanta, Georgia

Overview

The CDC is one of the major operating components of the Department of Health and Human Services. They made their first set of complete recommendations directed specifically toward dentistry in 1986, with updates in 1993 and 2003. Most infection control procedures today are based on the 2003 recommendations.

Website

www.cdc.gov/oralhealth/infectioncontrol/guidelines/index.htm

British Dental Association (BDA), London, England

Overview

The BDA is the professional association and trade union for dentists in the United Kingdom. The BDA advice sheet, *Infection Control in Dentistry,* was developed in 2003 with the Department of Health in England and is consistent with current infection control policies in the National Health Service. Its production and distribution to dentists in the United Kingdom has been financed by the English Department of Health.

Website

www.bda.org

The Robert Koch Institute (RKI), Berlin, Germany

Overview

The tasks of the RKI include the monitoring of emerging diseases and risk factors in the general population as well as the provision of scientific research. These tasks make the RKI the central institution and the coordination center for the Federal Ministry for Health for applied and basic research in the following areas:

- Infectious diseases, including infection epidemiology
- Epidemiology of non-transmissible diseases

The RKI takes part in the preparation of guidelines, recommendations, and expert opinions for the federal government, the parliament, and the scientific sector and engages in other health-related political issues.

Website

www.rki.de/cln_169/nn_216268/EN/Home/homepage__node.html?__nnn=true

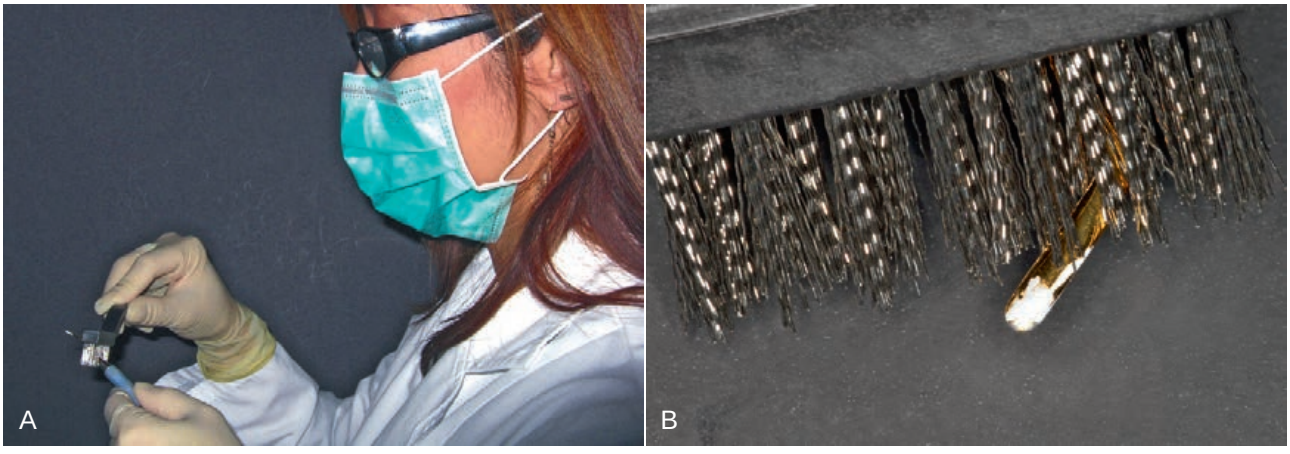


FIGURE 32-7 A, Dental auxiliary hand scrubbing an instrument. B, Close-up of the brush being used to scrub the instrument.

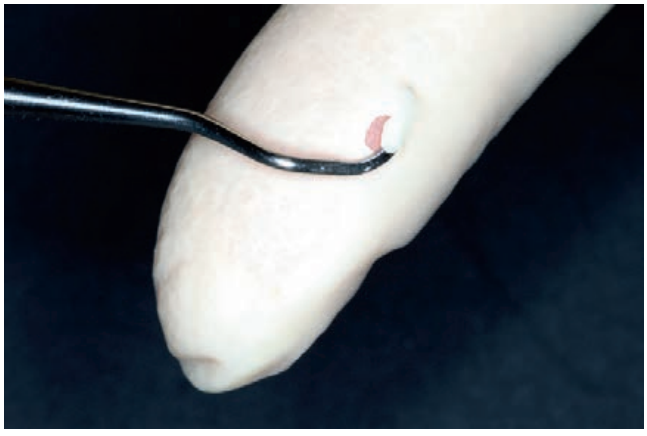


FIGURE 32-8 Glove punctured by an instrument.



FIGURE 32-9 Debris left on an instrument.

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FIGURE 32-10 Fluid droplets on mask and skin of the dental auxiliary caused by the scrubbing action.



FIGURE 32-11 Instruments sitting in an ultrasonic bath.

Ultrasonic baths and solutions (Figure 32-11) have been used to remove debris for many years. They apply high-frequency sound waves to separate debris from the instruments. The two major concerns with this approach are that ultrasonic baths may not have enough power to remove all of the debris (requiring an additional hand scrubbing session) and the ultrasonic process can destroy the sharpness of dental instruments. Ultrasonic solutions are not disinfecting and have no antimicrobial properties, yet they are often used for more than one patient over a day or longer. Hence instruments may be cross-contaminated prior to sterilization.

Automated debris removal with instrument washers (such as the HYDRIM C51w and HYDRIM L110w [SciCan, Ltd., Toronto, ON, Canada]) (Figure 32-12) is far less technique sensitive and much more predictable. These units are professional-grade, hospital-grade washers. They are loaded with instruments after the chairside removal of any residual dental materials, such as cements and composites, which are insoluble in water. Effective in removing over 99.9% of all protein from instruments, the washer provides uniform results in pre-sterilization instrument processing. The automated washing, rinsing, and drying procedure is hands-free, eliminating puncture and aerosolized microbe risks for the auxiliary.

Not all cleaning solutions are equally compatible with all instruments, and this is clearly indicated on packaging. Dentists, however, must deal with various metals and coatings, including stainless steel, carbon steel, and aluminum. It makes sense to use advanced chemistry cleaning solutions that have the best compatibility profile, such as HIP (HYDRIM Instrument Protection [SciCan Ltd.]) (Figure 32-13). HYDRIM washers automatically dispense small, optimal amounts of HIP solution to the pre-wash, wash, and rinse cycles for maximum effectiveness, providing benefits not only for dental instruments but also for the environment.

Rinsing

Instruments that have been manually scrubbed or placed in an ultrasonic bath are rinsed with cold or warm water at normal pressures to remove loosened debris. It is unlikely that even detached debris can be effectively rinsed out of the nooks and crannies of dental instruments (Figure 32-14).

Automated washers use elevated water temperatures and concentrated spray pressure to effectively rinse loosened debris from the instruments, leaving them ready for uncompromised sterilization. This is done hands-free as part of an automated cycle. Fresh water and cleaning solutions are used in the HYDRIM unit for each cycle, eliminating concerns about cross-contamination.

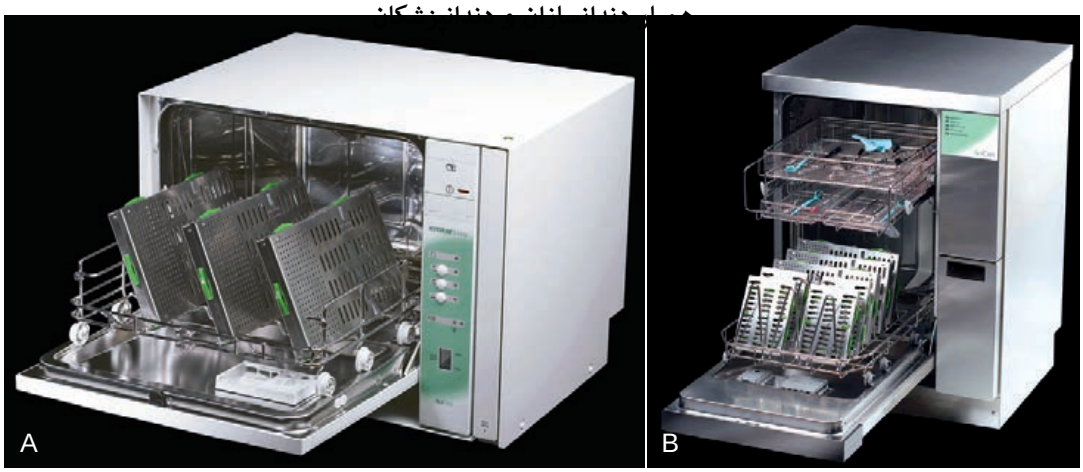


FIGURE 32-12 The HYDRIM C51w (A) and HYDRIM L110w (B) instrument washers. *(Courtesy SciCan, Ltd., Toronto, Ontario.)*



FIGURE 32-13 HYDRIM Instrument Protection (HIP) cleaning solution. *(Courtesy SciCan, Ltd., Toronto, Ontario.)*



FIGURE 32-14 Instruments being rinsed.

Drying

The two overriding concerns surrounding the drying procedure during pre-sterilization are the effectiveness and length of time for the desiccation process. If instruments are to be wrapped or bagged during the sterilization process, they must be thoroughly dried before being placed in the sterilizer.

Passive drying can often take an hour or longer (Figure 32-15, *A*). During this time the instruments are out of active clinical circulation. Patient treatment is an ongoing and continuous process, and each individual requires a freshly sterilized set of instruments. The longer the combined pre-sterilization and sterilization procedures take, the longer a set of instruments is out of active clinical use, requiring the practice to have more instrument sets. Because the typical instrument setup (including handpieces) can cost $2000 to $3000 or more, the number of instrument kits not in active clinical use at any given time has a major bearing on practice overhead.

Manual scrubbing and ultrasonic cleaning are usually followed by manual drying (patting dry) (Figure 32-15, *B*). However, manual drying does not completely eliminate wetness, risking instrument corrosion and compromising the sterilization process when instruments are wrapped or bagged. Manual drying risks puncture contamination for the auxiliary, and the process is also very time-consuming whether done properly or not. Automated drying in the HYDRIM is accomplished hands-free and is totally technique insensitive. Because the instruments are already warm from the thermal rinse, they take only 10 minutes or less to dry. Thus, instrument kits are efficiently cycled for rapid, efficient sterilization, reducing overall practice overhead. HYDRIM baskets are designed to fit precisely into a Statim sterilizer, allowing for their direct transfer from one unit to the other, further increasing efficiency.

The automated pre-sterilization technique is very simple and straightforward:

1. The instruments are loaded into the washer in cassettes and/or baskets (Figure 32-16, *A*).
2. The appropriate washing cycle is selected (Figure 32-16, *B*).

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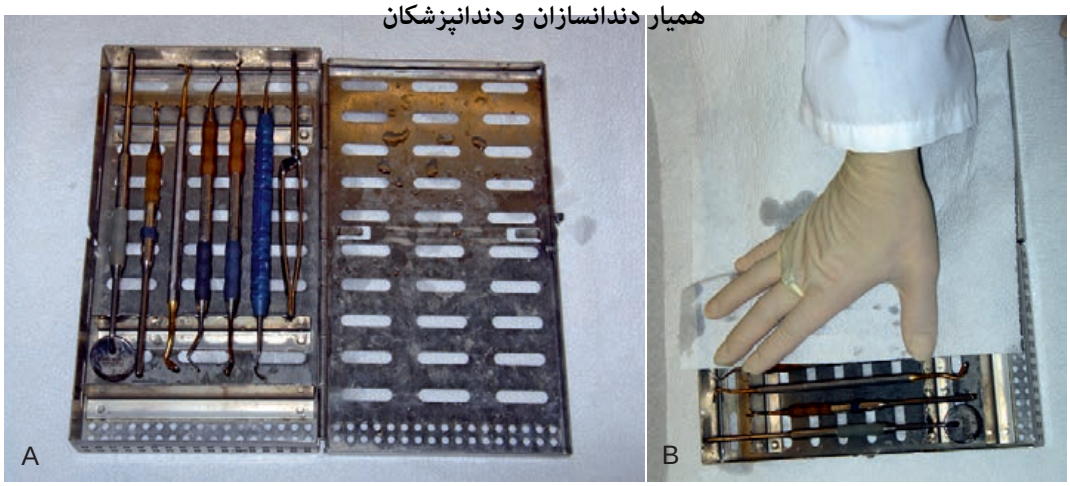


FIGURE 32-15 A, Passive drying of instruments. B, Manual drying of instruments (patting dry).



FIGURE 32-16 A, Instruments loaded into the washer in cassette and baskets. B, Washing cycle selected. C, Cassettes and instruments in baskets being unloaded.

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TABLE 32-1 Definitions in Sterilization and Disinfection

TERM	DEFINITION
Cleaning	Technique of removing visible contamination from a dental instrument or surface through physical scrubbing (manual decontamination), an energy-chemical process (ultrasonic cleaning), or automated washing to ensure it is thoroughly cleaned, free of debris, and ready for effective sterilization. Automated washing eliminates the need to pre-soak or scrub instruments. Process is used only as a preamble to sterilization and is unacceptable as a solitary cleaning procedure for dental instruments.
Disinfection	Destruction of microorganisms, pathogenic or otherwise, by physical or chemical means. Destroys most known pathogens but may not affect bacterial spores; in dental practice, the concept of "most but not all" pathogens can result in cross-infection.
Sterilization	Destruction of all viable microorganisms, including many resistant bacterial spores, by a physical (including heat) or chemical process. Process covers broad range of pathogens found in the oral cavity and is the only clinically acceptable means for dealing with reusable instruments between patients.

3. On completion of step 2, the cassettes and instruments are unloaded directly into the autoclave (Figure 32-16, *C*).

The technique is easily taught and easily learned, even by those with the least experience in dentistry. The debris removal result will be the same regardless of who performs the task.

Automated Pre-Sterilization

Automated, active pre-sterilization offers many benefits. The first and foremost is to fulfill the requirements of the pre-sterilization process: effectively remove debris; accomplish comprehensive washing, rinsing, and disinfecting; and effectively and efficiently dry the instruments. Because the only time that instruments are actually handled is during the loading phase (typically using cassettes), there is virtually no danger of puncture or aerosol contamination to the auxiliary. This reduces a very real risk for these dental team members. Effective automated pre-sterilization also eliminates the risk of cross-contamination for patients.

Automation of the various steps creates improved overall clinical simplicity, reduces technique sensitivity that can adversely affect sterilization, and thereby ensures the success of the entire procedure. The greater efficiency of automated pre-sterilization reduces the effort required, freeing up time and energy for other tasks. The reduced time required for HYDRIM pre-sterilization improves the turnover rate for instrument kits. This shorter cycle time allows more frequent use of each instrument kit, which in turn translates to fewer kits needed in the practice. In most dental offices, having fewer handpieces, hand instruments, cassettes, and so on will significantly lower the investment in these products. Hence the investment in an automated washer can be financially beneficial as well as reducing the risks of cross-contamination in the dental practice.

STERILIZATION AND DECONTAMINATION PROCEDURES

Over the past two decades there has been a quantum leap in the understanding of the microbial threats in the dental practice. Many new diseases and potentially dangerous organisms have also been identified. Fortunately, these threatening trends have been accompanied by significant advances in the science and technology of in-office sterilization and disinfection.

Sterilization can be a complicated subject, but dental professionals must have an adequate basic knowledge in this area of dentistry to protect patients' and staff members' health and lives. The dentist's health and that of his or her family, as well as the ability to continue to practice as a dental professional, are predicated on the ability to apply the best current science and technology to sterilization and disinfection in the dental office.

Much of the confusion surrounding decontamination can be traced to the lack of simplified, straightforward information and conflicting advertising claims in three categories:

- Basic definitions of sterilization and disinfection (Table 32-1)
- Autoclave cycle classification (Table 32-2)
- Validation (standardized techniques and outcome evaluations) (Figure 32-17)

Classification of Autoclave Cycles

(See Table 32-2)

The various types of autoclave cycles are differentiated by what they will or will not sterilize and how long they take to complete the process. The two most important parameters are whether the instruments are solid or hollow and whether they can be wrapped or must be left unwrapped. The concept of "porous load" also plays a major role in cycle definition. A sterilizing agent has more

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TABLE 32-2 Classification of Autoclave Cycles

	Small Sterilizers		
CYCLE TYPE	**N-CYCLE**	**B-CYCLE**	**S-CYCLE (STATIM)**
Materials that can be sterilized	Solid only Non-wrapped only	Solid and hollow Multi-wrapped and non-wrapped Porous	Solid and hollow Wrapped and non-wrapped
Air removal	Gravity displacement	Forced	Pressure pulsed
Standard minimum cycle time (16 L standard)	25 minutes	45 minutes	6-9 minutes



FIGURE 32-17 Biological indicator vial. *(Courtesy Hu-Friedy Mfg. Co., LLC, Chicago, Illinois.)*



FIGURE 32-18 N-cycle sterilizer, classified as passive system (also known as *gravity, non-vacuum,* or *downward displacement system*). *(From Robinson DS, Bird DL:* Essentials of dental assisting, *ed 4, St Louis, 2007, Saunders Elsevier.)*

difficulty *penetrating* and sterilizing a hollow object such as a handpiece than *surface-contacting* a solid object such as a dental mirror. The chemical or physical agent can be simply passed over a solid surface, whereas it must be forced or sucked into internal spaces that have restricted access. Many dental instruments are hollow in that they have lumina or difficult-to-access areas. The key problem is that the air and liquids trapped inside these hollow areas cannot be easily removed to allow the sterilizing agent to contact the instrument surface.

The sterilizing agent also takes longer to penetrate to instruments through wrapping (unwrapped instruments require no penetration). The wrapping effectively envelops the instruments in a hollow into which the agent must be forced or sucked. On the other hand, the convenience and organization of wrapping instrument kits together can greatly increase practice efficiency and success. Another advantage of wrapping is that the instruments maintain their sterility during storage after autoclaving. The ideal sterilization cycle for the dental practice is one that can handle both hollow and solid instruments, wrapped or unwrapped.

The least noticed phase of sterilization is the drying time. Instruments or wrapped packs should be allowed to dry inside the sterilizing chamber before removal and handling. If they are handled while they are moist and hot, the packing can act as a wick, absorbing moisture and bacteria from the outside and transporting them to the instruments inside.

The **N-cycle** is suitable for sterilizing unwrapped, solid instruments. N-cycle sterilizers are the most popular bench-top autoclaves and are classified as passive systems (also known as *gravity, non-vacuum,* or *downward displacement systems*) (Figure 32-18). Typically, as steam is admitted into the sterilization chamber, it forces unsaturated and saturated air out through a vent. The major concern with the N-cycle sterilizers is the non-removal of trapped air (especially air pockets in hollow instrument lumina and difficult-to-access areas of the load) during gravity displacement. Errors in packaging or overloading the sterilizer chamber can result in cool air pockets where items are not sterilized.

The **B-cycle** is used to sterilize solid, hollow, and porous instruments, wrapped or unwrapped (Figure 32-19). These pre-vacuum sterilizers are usually fitted with a pump that creates a vacuum to remove air from the sterilizing chamber before the

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chamber is pressurized with steam. This technique allows faster and more effective steam penetration throughout the entire instrument load compared with the gravity displacement technique used in sterilizers with N-cycles. Any air not removed from the chamber interferes with steam-instrument contact and may compromise sterilization. B-cycle sterilizers must be tested periodically for adequate air removal.

The **S-cycle** is indicated for unwrapped solid products; porous, hollow, single-wrapped products; or multi-layer wrapped products. Thus all dental instruments can be sterilized with this cycle. The S-cycle uses forced air removal created by vacuum or steam pulsing. The positive-pressure pulse system removes air from the sterilization chamber without a vacuum pump. Pressurized steam is injected into the chamber, gradually forcing the air out through a valve. Once the chamber is pressurized, the chamber is vented to near-atmospheric conditions. This process is repeated multiple times until effective air removal has been achieved. S-cycle autoclaves such as the Statim 2000s, 5000s (see Figure 32-2), and 7000s (Figure 32-20) (SciCan) use positive-pressure pulsed air displacement to offer a sterilization cycle specifically designed for clinical convenience so they can sterilize products effectively (with validation) with reduced cycle times.



FIGURE 32-19 **B-cycle sterilizer; pre-vacuum sterilizer that uses a pump to create a vacuum to remove air from the sterilizing chamber before the chamber is pressurized with steam.** *(Dri-Tec^{V}, courtesy SciCan, Ltd., Toronto, Ontario.)*

The length of the cycle time is the other important issue in selecting a sterilizer. The longer the cycle time, the more instrument sets and handpieces a busy practice requires. The time required for a sterilization cycle depends on several factors. The type of cassette and the size of the sterilization chamber are both critical. Light, thin cassette walls promote rapid heating and cooling. Smaller chambers, assuming they are large enough for the typical instrument load, remove air more quickly so steam and pressure can be introduced. Expelling the excess steam at the end of the cycle speeds up the drying stage and shortens the cycle time.

Because the limitations of N-cycle sterilization make it impractical for use in the dental office, the clinical choices should be limited to B- and S-cycle autoclaves. The B-cycle sterilizer takes a minimum of 47 minutes to complete versus the 6 to 9 minutes of a pressure-pulsed S-cycle (without drying). With regard to time management, pressure-pulsed autoclave systems make the most sense. Furthermore, because the S-cycled instruments (particularly expensive and delicate handpieces) spend less time in the corrosive environment of hot air and moisture, this technology offers not only a quicker but also a gentler sterilization for the dental practice.

Validation

Manufacturers should be able to provide autoclave users with microbiological validation confirming that their autoclaves are effective in sterilizing the instruments for which they are indicated, under the conditions listed in the instructions. Furthermore, each autoclave must be monitored on a regular basis to ensure the equipment can attain the physical parameters required to achieve effective sterilization. Chemical, biological, and temperature monitoring test kits can be used. These tests can be cumbersome, however, and are easily forgotten.

Statim autoclaves are microprocessor controlled, and all the important parameters are constantly monitored internally. The necessary information is presented on a user-friendly screen display, including prompts for continued operation as well as error messages. Because Statim automatically aborts the sterilization cycle in the case of malfunction, every completed cycle



FIGURE 32-20 **S-cycle sterilizer; uses forced air removal created by vacuum or steam pulsing.** *(Statim 7000, courtesy SciCan, Ltd., Toronto, Ontario.)*

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TABLE 32-3 Quick Guide to Sterilization and Disinfection Options

	Method		
PROCESS	MANUAL SCRUBBING	ULTRASONIC DEBRIS REMOVAL	AUTOMATED WASHING (HYDRIM)
Debris Removal			
Time (minutes)	20	15	10
Drawbacks	Puncture	Not disinfectant	None
Risks	Contamination Aerosolization	Enough power? Dulls instruments	None
Washing			
Time (minutes)	10	10	9
Drawbacks	Not effective	Re-uses solutions	None
Risks	How many times? Debris remains Puncture	Cross-contamination	None
Drying	Pat dry	Pat or drip dry	Automated active dry (hands-free)
Time (minutes)	60+	60+	10
Drawbacks	Inefficient	How effective?	None
Risks	Puncture Contamination	Inefficient Puncture Contamination	
Re-Use Solution	No	Yes	No
Risks		Cross-contamination	None
Total pre-sterilization time (minutes)	90+	85+	29

guarantees successful sterilization of the contents. However, load control and monitoring (chemical and biological indicators) are essential parts of the effective sterilization process.

STERILIZATION OVERVIEW

In-office sterilization of instruments between patients need not be a difficult or complicated process. A simplified description of the sterilization and disinfection options available quickly guides practitioners to the one that is most suitable for their dental offices (Table 32-3). A quick overview of the different sterilization cycles, their benefits and limitations, and their utility and operating times further guides decision making. Finally, the validation process provides confidence regarding sterilization to the dental professional and assurance to the dental staff and patients.

The guiding principles in sterilization, as in other dental areas, should be proven and demonstrable effectiveness in destroying pathogens, ease of use in a daily clinical setting, and practical efficiency.

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SECTION B

Disinfection

Peter Chiu Shun Tsang, Lakshman P. Samaranayake

RELEVANCE OF DISINFECTION TO ESTHETIC DENTISTRY

Infection control is of great importance for dental practitioners and patients. Every dentist should practice good infection control. Esthetic dentistry should not be the exception. It is the duty of the dentist to ensure that all staff members in the dental office practice good infection control. There should be little to no risk of infection to the patient or the dental staff during dental procedures.

As esthetic dentistry is becoming more popular, some dental procedures are being done outside of dental practice sites. If an esthetic procedure is being carried out without a dentist, such as whitening done in a bleaching center that is operated by non-dentists, there may be a greater risk. The dentist makes sure that infection-control procedures are properly carried out. Without that oversight, there is a greater danger that the knowledge of infection control will be lacking or that lack of infection control will cause problems for the patient.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF INFECTION CONTROL

About 115 years ago it was recognized that dental instruments could transmit infection from one patient to another. In the earliest days, washing instruments or wiping them with alcohol and similar materials was the only infection-control technique. In hospitals or in larger clinics the boiling of the instruments was considered a better practice and did remove most of the then-known bacteria that could be transferred. As more has become known about the infectious process and about the pathogens that cause disease, there has been more pressure on the dental and medical fields to create a comprehensive process of infection control. Today dentistry and medicine require a number of infection-control processes. They usually include vacuum or chemical autoclaving treatment cycles that involve high pressure, high temperature, or both. Most recently it has become important not only to go through the process of disinfection and sterilization but also to monitor and verify that these procedures are being done successfully and predictably.

The verification process documents the effectiveness of the sterilization. Spore testing and testing loads either every week or every day ensure that the process is being performed as it should. Also, the autoclave tape indicator shows the effectiveness of the sterilization or the drying process.

Previously only patients known to have an infectious disease were treated with infection-control procedures. Usually dental staff did not wear face masks or gloves. The introduction of universal precautions led to every patient being treated as infectious. With the introduction of standard precautions, infection control has been upgraded to consider saliva or any liquid secretion as infectious, which is a better standard (Box 32-2).

TRANSMISSION-BASED PRECAUTIONS

Transmission-based precautions are required in patients known or suspected to be infected with highly transmissible or epidemiologically important pathogens, in which standard precautions may be insufficient to prevent transmission. The three types of transmission-based precautions are as follows:

- *Airborne transmission precautions*—These apply to situations in which pathogens can be transmitted by the airborne route, that is, by small droplets of 5 µm or smaller (e.g., the organisms that cause tuberculosis, measles, and chickenpox and *Aspergillus*).
- *Droplet transmission precautions*—These apply to situations in which pathogens can be transmitted by large particle droplets, greater than 5 µm (e.g., the organisms that cause mumps, rubella, and influenza).
- *Contact transmission precautions*—These apply to situations in which pathogens can be transmitted by direct or indirect contact (e.g., methicillin-resistant *Staphylococcus aureus* [MRSA], herpes simplex virus, and hepatitis A virus).

Using the concept of standard precautions, everyone who comes into the clinic should undergo the same protocols, unless more serious infectious such as tuberculosis are involved, in

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BOX 32.2 Concept of Standard Precautions

In 1996 the Centers for Disease Control and Prevention introduced the concept of standard precautions, which integrate and expand the elements of universal precautions to protect both healthcare practitioners and patients from pathogens that can be spread by blood or any other body fluid, excretion, or secretion. Standard precautions apply to contact with (1) blood; (2) all body fluids, secretions, and excretions (except sweat), regardless of whether they contain blood; (3) nonintact skin; and (4) mucous membranes.

which case special protocols are employed. Standard precautions apply to contact with blood, body fluids, secretions, or excretions, except sweat. These precautions are used regardless of whether the fluids contain blood; they involve both nonintact skin and mucous membranes. No specific or special considerations are followed for patients with hepatitis. They should be treated in the same manner as other patients. There are other infectious diseases, such as airborne diseases, that are treated differently and with more precautions.

In general practice it is important for each dental clinic to have infection-control protocols in place so that each staff member knows his or her role and performs infection control effectively. It is the duty of the dentist to determine protocols and ensure that the staff follows those protocols. Each clinic should have its own protocols, but some generalizations are possible. The dentist's role is to make sure that the staff members follow the instructions. The dental assistant's role is to properly perform cleansing and ensure that the instruments are adequately cleaned. The dental hygienist also makes sure that standard precautions are carried out in a proper way. The cleaning of the area is done mainly by dental assistants.

CLINICAL CONSIDERATIONS

Patient Evaluation

When the patient first comes in, it is important to obtain a detailed medical history. Along with standard questions, it is important to know the travel history of the patient, especially in light of the H1N1 influenza pandemic and other pandemic diseases. It is also important to know if there is any systemic disease, because that may make the patient more prone to infection. The dentist should also check the medical history of the patient to see if there are any current infections indicating special precautions. Some immunosuppressed patients may be at greater risk of spreading infection, and extra precautions are necessary.

The medical questionnaire can also indicate if the patient has been ill with any antibiotic-resistant strains of bacteria that would make him or her possibly more difficult to treat. However, that depends heavily on whether the patient knows about his or her personal medical history. Patients may not know what medicines they are taking and may not be sure about their medical history. In these cases the dentist must contact the patient's physician to obtain missing information.

If the patient indicates he or she is taking certain medications, these may be flags that more information is needed. Dentists should discreetly ask patients about any issues that could be of concern. There are really no questions that are improper to ask. Any medical conditions, past medical history, or medication use that could put the patient at risk or put members of the dental team at risk should be investigated.

Personal Protection

There are issues for the patient, the assistant or other staff member, and the dentist with respect to personal protection.

Patient

To protect patients from getting infected, first of all the dental team should have proper vaccinations. They should be properly immunized so that they will not become infected and the patient will not become infected through the dental team. The dental office should be properly disinfected and the instruments sterilized to protect the patient. The dental staff should also be properly attired to keep the patient properly protected from becoming infected from the dental staff.

It is not possible to control what immunizations the patient has had. If a patient is coughing or is obviously sick with an unknown condition and this is not an emergency or urgent dental treatment for a condition that is causing the patient pain, the dental practice should defer treatment and reschedule after the symptoms decline. If the patient has an oral or general infection, the performance of nonurgent dental treatment depends on the nature of the infection—specifically, whether it can be transmitted during the dental procedure. If not, it is acceptable to perform the treatment. If there is a risk of transmission through dental treatment, the appointment should be deferred.

When patients come for treatment, they are in their street clothes and street shoes, not having necessarily washed their hands or even rinsed their mouth. There is a slight risk of infection when the patient's clothes are not clean, but it is minimal. It has been suggested that patients rinse with antibacterial mouthrinse before dental treatment.

Dental Team Members

It has already been stated that dental team members should be immunized. Depending on the nature of the infection, a dental team member with a current infection may or may not be allowed to work in the dental practice. If there is no risk of transmitting the infection to the patient, the dental team member should be able to work in the clinic.

The typical attire of team members to minimize the likelihood of the transmission of infection should include masks, head caps, protective eyewear, gloves, and gowns.

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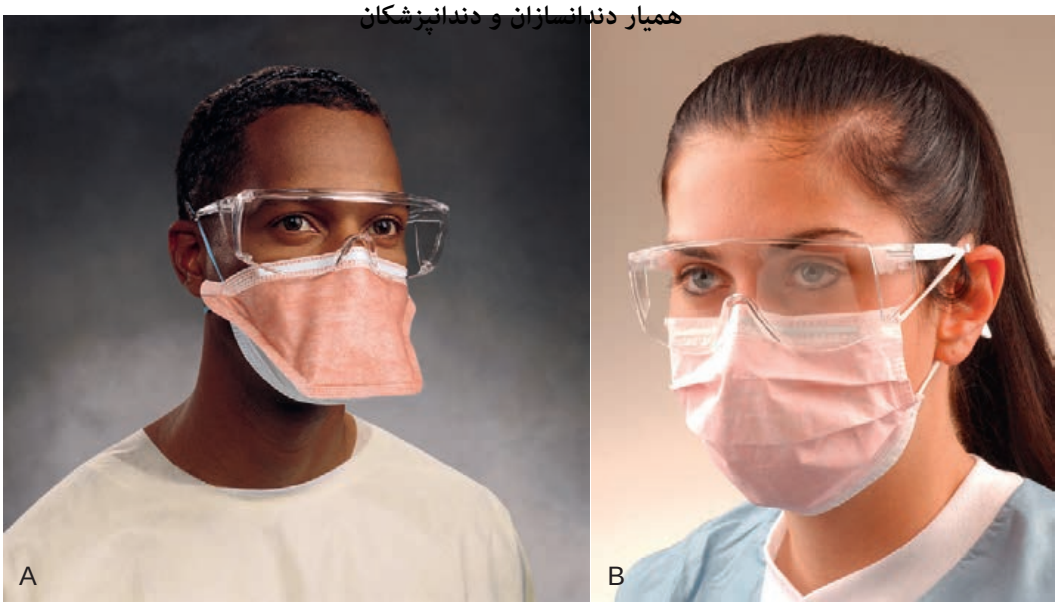


FIGURE 32-21 A, Example of an N95 respirator mask. B, Standard surgical masks (and safety glasses). *(A courtesy Kimberly-Clark Worldwide, Inc., Neenah, Wisconsin. B courtesy Crosstex, Hauppauge, New York)*



FIGURE 32-22 A, Latex examination gloves. B, Latex-free nitrile gloves. *(A courtesy Crosstex, Dallas, Texas. B courtesy DASH Medical Gloves, Inc., Franklin, Wisconsin.)*

Dentist

Dental practitioners should also have all appropriate immunizations. They also will wear protective masks, headgear, eyewear, gloves, and gowns.

Equipment

In terms of personal protective equipment, there are standards to be observed. There are respirator surgical masks (or N95 masks; Figure 32-21, *A*), but for routine patient treatment, surgical masks should be sufficient (Figure 32-21, *B*). If there is a known history of the patient having influenza, such as H1N1, the dentist may have to wear an N95 face mask. The gowns that the dentist and the team wear should be waterproof so that the water droplets cannot reach the underlying garments. Usually disposable gowns are preferred.

In terms of hand hygiene, before putting on and after removing gloves the dental team members should properly wash the hands. The most popular hand-washing agent is chlorhexidine hand scrub. When face masks and surgical gowns or head caps are worn, the hands also should be properly washed. Studies have shown that double gloving reduces the risk of perforating the innermost gloves and thus is recommended for high-risk surgical procedures. The worldwide standard for infection control in terms of hand protection is latex or nitrile gloves (Figure 32-22). A non-allergenic vinyl or neoprene glove can also be used if the patient or staff member is allergic to latex.

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MATERIAL OPTIONS IN STERILIZATION AND DISINFECTION

The dentist should choose materials that work quickly, are not irritating to the patient or staff, are safe to use, and have a long shelf life. For general disinfection of the clinical area, clinic soap or sodium hypochlorite is the common agent used. The advantages are that these options are inexpensive and easy to clean up. The disadvantages are the possible erosion of the metal, an unpleasant flavor, and eye irritation during the preparations. These agents also have a short shelf life and after preparation should be used within 1 day. Other materials include alcohol, which is easy to use but has the problem of flammability and cannot be stored in the clinic where an open flame may be used.

TriGene is a halogenated tertiary amine that both disinfects and cleans. Compared with sodium hypochlorite, it is not as corrosive to metal, does not have an irritative smell, and has a long shelf life. In addition, it does not cause discoloration of surfaces.

PROCEDURES

Sterilization

Sterilization can be achieved by one of three methods: moist heat, which is steam under pressure; dry heat; or gaseous or chemical cleansing. Moist heat sterilization is a very effective way to sterilize. The steam liberates latent heat when it condenses to form water and thus potentiates microbicidal activity. Moreover, the steam contracts in volume during condensation, thus reinforcing penetration.

Dry heat penetrates less well, and sterilization is less effective than with moist heat. Therefore both higher temperatures and longer times are required for dry heat sterilization.

A number of chemicals can be used for sterilization, including a combination of formaldehyde, alcohol, acetones, ketones, and steam under pressure. They achieve highly effective surface sterilization. Chemiclaves are faster than dry heat sterilizations and do not cost as much or corrode metal or burs. The problem is that adequate ventilation must be provided. Moreover, chemiclaves are not popular owing to the environmental contamination and related issues associated with them.

For sterilization the autoclave has a short cycle, usually just 3 to 30 minutes. The duration of the chemiclave's cycle is between those of a hot-air oven and an autoclave—about 30 to 45 minutes. Sterilization with dry hot air takes longer—more than 60 minutes. Hot air often does not leave any residual moisture, but the autoclave and chemiclave create residual moisture and can cause corrosion. The long-term effect on instruments that are autoclaved is corrosion. The chemiclave has a minimally corrosive effect on instruments. Hot air may affect the effectiveness of instruments' sharp edges. Chemiclaving may cause chemical hazards. A hot air oven may also have problems with spontaneous combustion of paper.

Cleaning, Decontamination, and Pre-Sterilization

There should be designated clinical areas for cleaning so that clean and dirty instruments are washed at different designated sites. The purpose of the cleaning is to remove residual dirt using water, soap, and detergent with a brush or cloth. Dental assistants should wear heavy-duty clothes to do this before the instruments are placed into the autoclave or dry heat oven. If there are any deposits on the surface, they may reduce the efficiency of the sterilization process. It is important that they be thoroughly clean before disinfection or sterilization. When ultrasonic cleaners, washers, or disinfectors are available, they should be used for pre-sterilization cleaning (Figure 32-23). The use of mechanical cleaning equipment can minimize the risk of sharps injury and decrease exposure to blood and body fluids. Use of washer-disinfectors is currently popular, as they serve a dual purpose. These are glorified dishwashers with a chemical disinfectant added to the washing cycle.

Disinfection of the Dental Units and Clinical Areas

At the beginning of each session, the dental unit and work surfaces should be disinfected with a liquid surface disinfecting agent and left to dry. Equipment and surfaces in the clinic area should then be covered with clear plastic wrap to limit contamination. The plastic cover must be removed from each surface after completion of a patient's treatment to avoid contamination. It should then be replaced if another patient is to be seen.



FIGURE 32-23 Example of an ultrasonic cleaning unit. *(Courtesy Midmark Corporation, Versailles, Ohio.)*

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Clinic floors should be washed daily using 1:49 sodium hypochlorite solution. Additional procedures for extra cleaning and scrubbing should be introduced according to need.

Disinfection of Laboratory Work

For hydrocolloids, plaster, and polyether impressions, rinse the impression under running water first and shake off the surface water. The impression is then dipped in 0.5% sodium hypochlorite solution and removed in 1 to 2 seconds. It is then rinsed under running water, and any surface water is shaken off. It is then placed again in sodium hypochlorite for 1 to 2 seconds. The impression is covered with gauze dampened with the sodium hypochlorite solution and left for 10 minutes. After that the impression is rinsed well under running water and the surface water shaken off. Hydrocolloid impressions should be covered with gauze and placed in a **polythene bag**, then sent to the laboratory.

Other impressions or items of laboratory work are rinsed under running water, and then the surface water is shaken off before immersion in sodium hypochlorite solution for 3 minutes. The item is then rinsed again under running water. A label is applied to indicate to the technician that the appliance or impression was disinfected before being sent to the laboratory.

WASTE DISPOSAL

General Handling of Waste

Careful attention must be paid to the safe disposal of waste, as this is potentially infectious material. Staff members who handle waste must wear gloves.

Needles and other sharp objects, including broken glass, must be discarded into puncture-proof containers. The containers must then be securely sealed.

Clinical Waste

Clinical waste categories that require special disposal include the following:

- Group 1—Used or contaminated sharps
- Group 2—Laboratory waste
- Group 3—Human and animal waste
- Group 4—Infectious materials
- Group 5—Dressings (dressings or swabs and all other waste dripping with blood, caked with blood, or containing free-flowing blood)
- Group 6—Other waste items that are likely to be contaminated with infectious material (other than those referred to in Group 4) or any clinical waste belonging to Group 1, 2, 3, or 5 that may pose a significant health risk

Extracted Teeth

The U.S. Occupational Safety and Health Administration considers extracted teeth to be potentially infectious. Extracted teeth are disposed of as regulated medical waste unless returned to the patient.

Sharps

All sharps should be handled with great care. Used sharps are placed in a puncture-resistant sharps container that is clearly labeled for such disposal (Figure 32-24). Sharps containers should be located at the workplace to enable immediate disposal after use. These containers are to be sealed and discarded when they have been filled to the designated *Fill* line on the container.



FIGURE 32-24 Sharps container. *(From Malamed SF:* Handbook of local anesthesia, *ed 5, St Louis, 2004, Mosby Elsevier.)*



FIGURE 32-25 Universal biohazard symbol. *(From Bird DL, Robinson DS:* Torres and Ehrlich modern dental assisting, *ed 10, St Louis, 2012, Saunders Elsevier.)*

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Personal Protective Equipment, Drapes, and Bibs

Dental healthcare personnel should fold or roll up soiled personal protective equipment, drapes, and bibs into the center. The soiled portion remains contained in the center of the bundle.

Packaging

Waste bags should be securely fastened when three-fourths full. Clinical waste requiring special disposal must be disposed of in **red plastic bags** conspicuously marked with the **biohazard** symbol (Figure 32-25). This clinical waste bag should be tied up using the "swan-neck" method of sealing. The clinical waste bag will be picked up by licensed clinical waste contractors.

Nonclinical Waste

All hospital waste other than that listed in categories of clinical waste that requires special disposal can be treated as domestic waste and disposed of in black plastic bags.

SUGGESTED READINGS

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Communication

Patient Communication

Howard S. Glazer

RELEVANCE TO ESTHETIC DENTISTRY

Unless the dental professional adequately and accurately communicates with the patient, it will be impossible to discuss his or her treatment needs. Patients come to the dental office with *wants,* and dentists have an obligation to review what their *needs* are. If the dentist cannot communicate accurately and adequately with the patient, it will not be possible to convert those *wants* into *needs.*

Communication is probably more relevant to esthetic dentistry than other areas in that patients are now more aware of what can be done esthetically for their smile. They come to the dental office and say, "I want this smile," often showing photographs from magazines. The dental professional then must translate that into a determination of how to satisfy the patient's want in a way that will mesh with the patient's actual needs. One of the most attractive things about a person is his or her smile; the ultimate fashion accessory is an attractive smile (Figure 33-1). Communication is essential so that the dentist understands what the patient wants and the patient understands what he or she needs and what the dentist can do.

BRIEF HISTORY OF PATIENT COMMUNICATION WITH RESPECT TO ESTHETICS

Patient communication has changed with the increased demand for esthetic procedures. Typically patients used to come to the dentist for either routine continuing care or for procedures that were urgently needed and/or reparative in nature. Today, they come for elective procedures. Dentists' communication must be fine-tuned to be able to address the specific needs relevant to esthetic demands.

KEY TERMS TO USE IN VERBAL AND WRITTEN COMMUNICATIONS

Several words can be used in verbal and written communications that will encourage patients to seek esthetic dental procedures (Box 33-1). For example, when talking with a patient about whitening, it is easy to use many of these words to help the patient better understand about the procedure, as follows:

> "Mr Smith, we have a *new* and *easy* way to whiten and brighten your teeth. The *advantage* of this process is that *you* will have a beautiful smile and the *results* will be wonderful for *you.* The *benefit* is that *you* will have a more youthful appearance and a healthier smile. We can do this for *you* in a *safe* and *proven* way."

VERBAL COMMUNICATIONS

Telephone Communications

The telephone is often the first chance that the dental office has to interact with the patient. The telephone can be considered the first line of offense. Patients typically call the office first rather than walk in. When the patient calls, the dental office has about 20 to 40 seconds to make the individual feel warm, welcome, and comfortable and to sense that this is the best possible office to satisfy his or her needs.

How one **answers the telephone** creates the initial impression for the patient or prospective patient. The person answering the telephone should maintain a very upbeat voice that indicates

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FIGURE 33-1 Examples of attractive smiles.

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BOX 33.1 KEY WORDS FOR PATIENT COMMUNICATIONS

Easy	New	Advantage
You	Safe or safety	Results
Positive	Guarantee	Proven
Save	Progress	Discovery
Help	Now	Money
Security	Benefit	Love



FIGURE 33-2 A voice that is upbeat and sounds happy makes the person calling feel comfortable and gives him or her the sense that this is the best possible office to satisfy his or her needs. *(From Finkbeiner BL, Finkbeiner CA:* Practice management for the dental team, *ed 7, St Louis, 2011, Mosby Elsevier.)*

that the person is smiling and happy to have received this call (Figure 33-2). An appropriate beginning is to say:

"Hi, thank you for calling us. This is Dr _____'s office. How may I help you?"

This conveys to the patient a warm, sincere welcome and indicates this is the right office.

Once the initial introduction or salutation has been made, an **information-gathering process** begins. One of the first pieces of information to collect from a caller is the person's name. Once the telephone respondent has the caller's name, he or she should begin to use that name in the rest of the conversation with that individual. The exchange may be as follows:

"Thanks for calling. May I have your name?"

"It's John Smith."

"Thank you, Mr Smith, for calling our office. How may I be of service to you?"

The key thing is to personalize one's communication by using the caller's name.

The rule of thumb is typically that if the caller is perceived to be older than the respondent, always use "Mr," "Mrs," "Ms," Dr," or whatever the formal title of that person is. If the caller is perceived to be younger, it is probably acceptable to use the caller's first name. When the respondent is not sure, the first thing to ask after ascertaining the caller's name is "May I call you [caller's first name]?"

Once the respondent has identified the caller and used his or her name, it is necessary to try to find out why the caller has contacted the office. Often when a patient or prospective patient calls the office, he or she will volunteer the reason for the call up front. If the caller says, "I broke a crown," the next obligation is to gather information from him or her relative to what the immediate need is. The first and foremost question to ask is "Are you in pain?" As healthcare providers who truly care about patients, dental professionals need to ascertain whether or not the patient is in pain and how quickly the patient can come into the office to address that problem. The caller may also report that a tooth is sensitive when something hot or cold is eaten. Regardless of the symptoms reported, the dental office respondent encapsulates the caller's reason in a response and assures the caller that the situation should not be a problem and that the office can make him or her very comfortable. The call should end with a reassurance, such as "We look forward to seeing you in our office so that we can help you."

If the patient is not in pain, a series of questions can be asked to gather more information. This includes asking when it was that the individual last saw the dentist. A new patient will never have seen the dentist but often will have been referred by a current patient. People tend to refer people similar to themselves. Type A patients are referred by type As, type Bs by type Bs, and so on. If the referring patient has always been a good patient and someone who has received esthetic treatment, the respondent may have a sense of why this prospective patient has elected to call this office. Another way to find out that someone has chosen this office through a referral is to ask, "Who may we thank for referring you to our office?" This helps build a relationship with the prospective patient and sends the message that (1) this office likes referrals and (2) it thanks those who refer others.

The initial conversation should also include a request for the caller's phone number. This ensures that should the call be dropped the respondent can immediately call back.

When the caller says he or she is in pain, the easiest way to determine whether the situation is an emergency is to ask the caller, "How soon can you be here?" If the caller cannot come until after work is finished for the day, it may not be an emergency. If the caller can come in right away, this is likely an emergency and every effort should be made to accommodate the caller and relieve the pain. After that, a more formal appointment can be made during which a more complete treatment can be developed.

Once it has been determined that the caller will be coming to the office, the respondent should ask whether the patient has ever been told to take medication before seeing the dentist. This does not mean taking a full medical history, but an affirmative answer to the simple question alerts the dental office that premedication is required.

Other information to discuss includes transportation information, parking availability, and directions. All of this

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information helps the dental office to better handle potential or established patients who call in.

The attitude of the person answering the phone is essential to good telephone communication. If the caller perceives that the person on the other end of the phone line is not paying attention, is not receptive to what the caller is saying, or sounds grumpy or bothered by the call, he or she forms a negative opinion of the rest of the office. It is important to greet each caller with a positive attitude in a very upbeat voice that conveys a sincere desire to help the caller and make a connection. The caller then knows this is the best possible office to help resolve his or her dental problem.

The person answering the telephone should be able to engage the caller in conversation relative to the caller's desires. For example, the prospective patient might be concerned about the color of his or her teeth, and the dental team member answering the phone should be well versed and comfortable in discussing the treatments available to whiten and brighten teeth. If the patient is concerned about cracked or chipped teeth, the respondent should be able to discuss in broad terms treatment options such as porcelain veneers or crowns. Keep in mind, though, that a diagnosis cannot and should not be made over the phone. The person answering the phone should be clear that he or she is speaking in generalities and it is only the doctor who can fully assess the patient's needs when he or she visits. The patient will then be informed of possible treatments before any services are performed.

Follow-up to the First Call

Following up with the patient after making the initial appointment is a second important step. If the situation is not of an urgent nature, the follow-up call would probably be made the day before the appointment. A typical call would be as follows:

"Mr Smith, it was great talking with you the other day. If you recall, we have an appointment time set aside for you tomorrow at 2:00. We look forward to having you here with us. Is there anything I can help you with to make your visit a little easier? Do you need directions to our office? May I tell you, if you're coming by car, where parking is available? You indicated that you need to take medications before the appointment; please remember to do that."

The follow-up call is made only if time permits before the patient's appointment.

Key Words and Phrases for the First Telephone Call

Some specific phrases to use are as follows:

"Are you in any discomfort?"

"We will be happy to take care of your problems."

"We look forward to seeing you."

The message is couched in positive terms. Although no single sentence will guarantee a successful outcome for the call, making sure that the call ends on a positive note is vital.

Patient Communications at the First Visit

The first visit with the dentist and staff is critical in establishing a relationship. It has been said that it takes 5 minutes for the patient to know whether he or she will be in the dental office for the next 15 years, and 15 years to figure out if he or she has been in the right office. If a new patient, Mr Smith, is coming in, the person at the front desk should be prepared to stand up and greet Mr Smith when he walks through the door. An appropriate greeting would be:

"Mr Smith, it's so nice to meet you. My name is Jane, and we are so glad that you are able to join us in the office today."

In addition, when the morning staff meeting is held, everyone should be made aware of who the new patient is and how many new patients are coming in that day. Then everyone should try to greet each new patient by name and welcome him or her to the office. That first contact is critical in securing a positive relationship with the patient.

Establishing Rapport

In establishing rapport with the patient, the acronym *FORM* is useful. This stands for *f*amily, *o*ccupation, *r*ecreation, and *m*otivation. Using that acronym provides points of conversation that will help you build a relationship with the patient.

Most people like to talk about their **family**, making this topic an easy way to begin a conversation, as follows:

"Mrs Smith, I see you have a picture of your grandchild on your necklace. How many grandchildren do you have?"

"I know you were referred here by Jane Roberts because your children are in the same playgroup. How many children do you have?"

Another subject is **occupation or work**. This should be evident on the initial questionnaire from the patient. Noting the patient's occupation, a conversation could begin as follows:

"I see you're an administrative assistant to the vice president. What do you do in that capacity? You probably have a lot of responsibilities."

People generally like to talk about what they do, so this subject may be a good conversation starter.

People also enjoy talking about their **recreation**, or what they like to do for fun. The dental assistant could ask the patient what he or she likes to do in their spare time. It is important to be able to discuss subjects like this with the patient.

The last question to typically ask a patient deals with **motivation**, in particular the motivation pertaining to the dental visit. A sample would be:

"I understand from Sally that when she made the appointment you were having trouble with a tooth on the lower right side. Can you tell me a little bit about the specific problem you are having?"

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With this approach, the dentist has indicated that although the office staff members know why the patient is here, they are seeking further information about what the patient would like to accomplish in this visit.

What to Expect in the Dental Visit

Typically the patient is told what to expect either on the phone, depending on the length of the conversation, or at the initial visit. First, it is important to meet with the patient, whether this is done by the dentist or the staff. With a new patient, the current procedure is to take full face and intra-oral photographs (Figure 33-3, *A* to *C*). Also, study impressions and models of the teeth may be made (Figure 33-3, *D*), and there may be a need for radiographs (Figure 33-3, *E* to *I*). Depending on how the staff and office are set up, a complete diagnostic work-up may be performed. Some of these tasks are handled by the dentist; some fall to the dental hygienist or auxiliary staff. The patient is fully informed of everything that will be done before the initial visit.



FIGURE 33-3 Information that may be obtained when a new patient comes to the office. **A**, Facial photograph. **B** and **C**, Intra-oral photographs. **D**, Study model.

Continued

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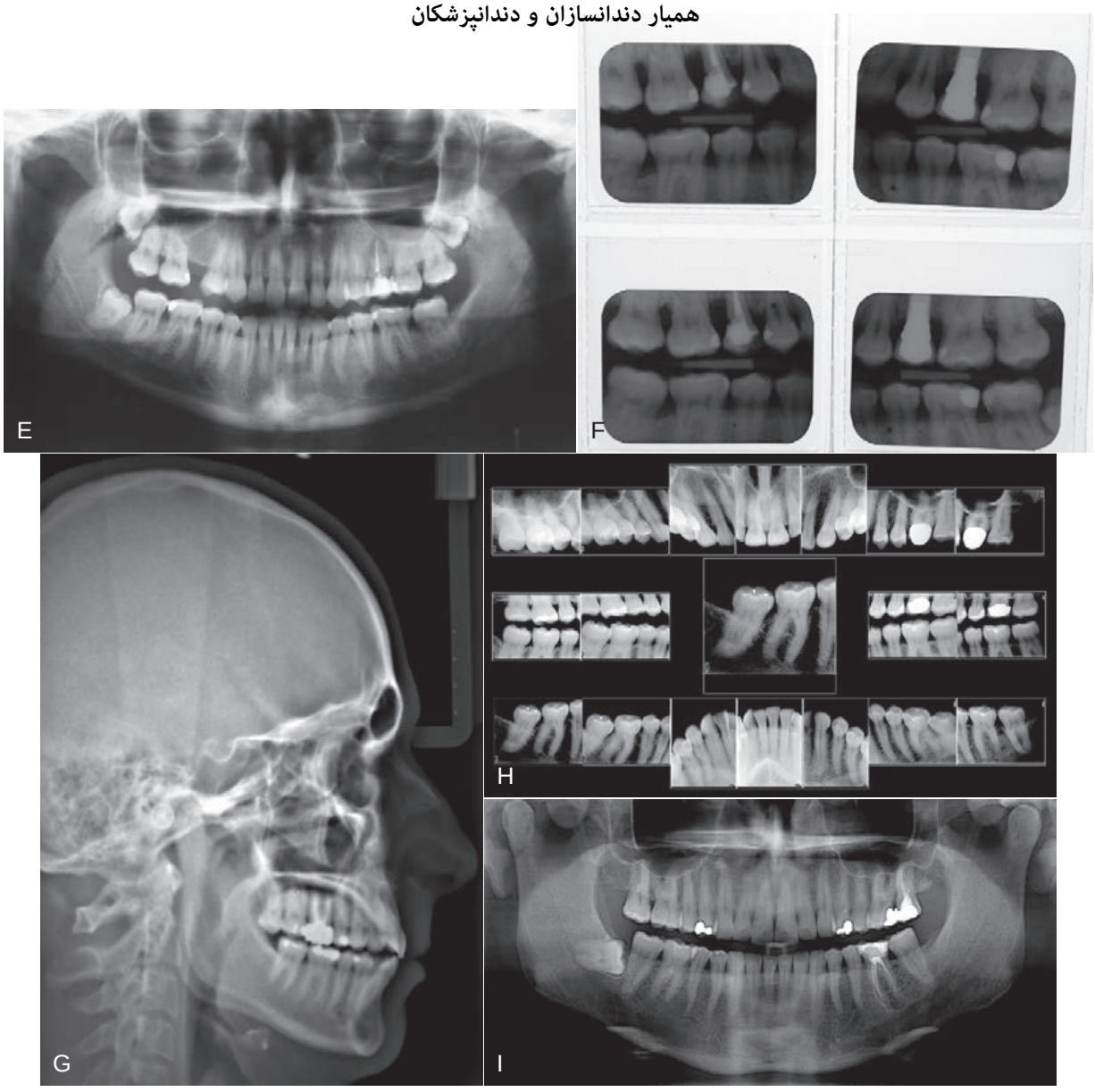


FIGURE 33-3, cont'd **E and F, Analog radiographs. G to I, Digital radiographs.**

WRITTEN COMMUNICATIONS

Depending on the time available from the initial phone call to the appointment time, it is a nice touch to send the prospective patient a note, preferably handwritten. This initial packet should also contain directions to the office, where parking is available for the office, and what bus, train, or subway station is closest to the office, as appropriate. The note could say:

> Dear Mrs Smith,
>
> It was great talking to you on the phone and I really look forward to seeing you at your appointment next Tuesday at 2 PM. I've enclosed an appointment reminder card as well as directions to our office. I've included a health history form that you can fill out in advance, as well as one of our recent newsletters.

Sending a health history form (Figure 33-4) to the patient in advance does two things: (1) it allows the patient to fill the form out at home with access to all his or her medications so they can be recorded accurately, and (2) it gives the patient the opportunity to read the form through completely and slowly. This is preferable to having the patient, while feeling nervous about the first appointment or perhaps being late getting there, going through a sheaf of papers covering the health history, Health Insurance Portability and Accountability Act (HIPAA) forms, and financial forms. All of that can be overwhelming at the first appointment, so sending these materials ahead of time, allowing patients to be prepared with them when they come into the office, will make the procedure go more smoothly and ensure the patient feels relaxed and welcome.

Dental offices often have a formalized policy that deals with subjects such as appointment scheduling, financial

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Welcome

About You

Name: Mr Mrs Ms Dr

Birth date: (day/mth/yr) Male Female

Home Address

City Province Postal Code

Home # Work # ext

Cell #

Email

Employer

Other family members seen by us

Whom may we thank for referring you?

In Case of Emergency, We Should Notify

Name: Relationship:

Daytime # Cell #

Insurance Information

Primary Insurance

Insured's Name: Insured's birth date day mth yr

Insured's Employer: Insurance company:

Group/Plan# Identification #/Certificate #

Secondary Insurance

Insured's Name: Insured's birth date day mth yr

Insured's Employer: Insurance company:

Group/Plan# Identification #/Certificate #

Dental History

Why have you come to the dentist today?

Are you currently in pain? Yes No

Do you require antibiotics before dental treatment? Yes No Unsure

Your current dental health is Good Fair Poor

Do you floss daily? Yes No Do your gums ever bleed? Yes No

Have you ever had periodontal disease? Yes No Are your teeth sensitive to Heat Cold Other

Approximate date of your last dental visit

Are you happy with the way your smile looks? Yes No

If not, what would you change?

Would you like a whiter smile?

FIGURE 33-4 Health history form.

arrangements, or cancelling appointments. It is important that if the office has a specific policy, it is explained to the patient in a written form. If this written policy is available and there is time, the form should be sent to the patient in advance of the first appointment.

There are several reasons for there to be written policies in place. First, written policies can be used to train new employees as they join the team. Second, they can be used to cross-train team members so that everyone becomes familiar with all office policies. The policies should be initially developed by the dentist and then discussed with the staff for comment and input. In the end, policies are the dentist's decision because it is his or her office.

Examples include the following:

Appointment scheduling: The policy should include a statement of how far in advance a patient must notify the office if he or she cannot make an appointment, for example, 24 or 48 hours. Notice should be given to the patient that a charge will be assessed for any appointment not cancelled within that timeframe as well as for any broken or missed appointments.

Financial policy: The policy should discuss forms of payment accepted, such as cash, check, or credit card. If the practice will be accepting credit cards, which cards will be accepted? The policy should also indicate if budgeted financial arrangements are possible.

CONSULTATION

Pre-Treatment Consultation

Before having a pre-treatment consultation with the patient, the dentist should interview the patient and collect records as needed, including radiographs, study models, and photographs. These are reviewed and a treatment plan is developed before the consultation. The purpose of the consultation is to present the treatment plan to the patient. The dentist should have all the exhibit materials readily available and be prepared to discuss at length what the problem is, what the major treatment approaches are, what the best option is for this case, and if there are additional options. The dentist must also present the negative and positive aspects of the various options and be prepared to alter the treatment plan based on the patient's input.

The consultation can be accomplished in the treatment room, in the dentist's private office, or in a separate consultation room. If the needed treatment plan is direct and short, it is generally acceptable to sit and explain it to the patient right in the operatory or treatment room. If the plan includes a smile makeover or full-mouth rehabilitation, more time will be needed to explain it all to the patient. In those cases it might be best to set aside a quiet area in which to have the discussion, with all the demonstrative aids readily available. If there is no private consultation area, the discussion can be carried out in the treatment room as long as it is quiet and distractions from other areas in the office are not present.

Regardless of where the discussion takes place, the key is preparedness. The dentist must have carefully reviewed the case, and all relevant information must be available at the discussion. The dentist should clearly and succinctly express what is needed to the patient in a form that is easily understood. The dentist must remember that the patient is a layperson and will require careful explanations of procedures. If demonstrative models, pamphlets, or short videos are available, these may prove useful in explaining the treatment plan and options.

Various staff members can take part in the consultation, depending on what the patient's specific needs are. Often the initial consultation begins when a hygienist or dental assistant comments on the patient's appearance or dental status. For example:

"I've noticed that you're missing your lower right first molar. I'm sure Dr _____ will want to talk to you about how to replace that."

This plants the seed for the consultation. The dentist should be the one responsible for the detailed consultation with the patient because he or she is the ultimate treatment provider. The dentist should have a relationship established with the patient, be able to carry out the treatment plan, and be available to answer questions relative to it.

Handling Future Appointments and Financial Arrangements

Future appointments and financial arrangements are handled in various ways. The front desk person can handle both scheduling and the explanation and review of financial arrangements with patients. The person who makes the financial arrangements is responsible for collecting on those financial arrangements because that person has established the appropriate relationship with the patient. If the patient understands that this staff person

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is responsible for collecting money, the patient will know who to contact for financial concerns.

Telephone Rounds

Dentists usually have the luxury of making rounds of patients by telephone from home or the office after hours. An exception might be the oral surgeon. The average practitioner or general dentist has the ability and responsibility to follow up with patients after treatment. For example, after a root canal treatment or extraction, the dentist can call the patient after hours to see how well he or she is doing. This is a key phrase. Rather than calling to ask *how* the patient is doing, the dentist should ask *how well* the patient is doing. This plants the seed of positive well-being. Calling to ask "how the patient is doing" may suggest that the dentist expects that the person will not necessarily be doing well. The call almost becomes an apologetic effort rather than a positive contact. If the patient has any particular problems, they can be raised at the follow-up call.

If the dentist cannot make telephone rounds at the end of the day, the next best person to do that is the treatment assistant because he or she was in the room during the procedure. This individual knows exactly what transpired and can easily make that call. If the patient mentions something that the treatment assistant is not comfortable addressing, the dentist should be available to come to the phone or call back immediately. Making the call to the patient reinforces the value of the decision to trust that particular dentist as the dental treatment provider.

Post-Treatment Consultation

After treatment has been rendered by the provider, it is important to have another consultation visit. First, the dentist expresses appreciation for the fact that the patient has valued the doctor-patient relationship and followed through on the care plan recommended. This is an opportunity to go back to the original diagnostic models and photographs, showing the patient where the case began and where it is now. The dentist can point out how well the dental care has addressed the patient's needs. This is also an opportunity to ask for referrals. A sample exchange might include the following:

> "Mr Smith, we are really glad that you accepted our treatment plan. You have been a delightful patient for us to be able to help and treat. Perhaps you know others in your family or your circle of friends who might want to avail themselves of our care. We would be delighted to see those individuals. Please take a couple of these cards and pass them to your friends and family."



FIGURE 33-5 **It is important to take postoperative photographs so they can be compared with the pre-treatment photographs. A and B, Pre-treatment photographs. C and D, Post-treatment photographs.**

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If the dentist is not comfortable handling the referral requests, the staff can handle this. The staff should have their own business cards and be able to refer and market the practice to potential patients.

Postoperative Photographs during the Post-Treatment Consultation

During the post-treatment visit, it is important to take postoperative photographs (Figure 33-5). Both patients and doctors can forget where the process started. These photographs can be compared with pre-treatment photographs in the consultation room. This gives doctor and patient a record of where the case began and how it has finished. The dentist can give the patient a copy of the pre-operative photographs; patients are their own postoperative photographs. It is wise to stamp the back of these pre-operative photographs with the dentist's name, address, and phone number. A staff member in the room then gives the patient a business card as well.

If the staff members believe that they are working for the best dentist in the city, they should feel comfortable marketing that practice. Staff members may have different social contacts than the dentist. They can be trained to look at individuals as potential patients. When the opportunity arises, they can say:

> "I work for a great dentist. I enjoy what I do and I know we could help you. So, here's our business card."

Having the staff ask for referrals and give out business cards also can be seen as job security. If the dentist has fewer patients, the need for staff also falls. The dentist and staff are in the dentistry business as a TEAM—an acronym for *T*ogether *E*veryone *A*chieves *M*ore.

CONCLUSION

Dentists must understand that patients are not an interruption of work; they *are* the work, and the reason the practice exists. In talking to patients and practicing dentistry—in fact, when going through life—the three keys to being successful are doing everything sincerely, doing everything confidently, and doing everything with enthusiasm. Dentists must communicate well and take every opportunity to market both themselves and their practices. They must also remember to do this sincerely, confidently, and with enthusiasm.

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B SECTION

Patient Management

Louis Malcmacher

RELEVANCE TO ESTHETIC DENTISTRY

The key relevant topics for esthetic dentistry are financial management, which is needed to finish any kind of esthetic dentistry case, and patient communication. Managing the patient's expectations in esthetic dentistry requires managing how the dentist relates to the patient personally and how he or she deals with clinical and financial issues. Patients look to the dentist, especially in esthetic dentistry, almost for a lifestyle change—not just a change in the teeth or the smile. Usually they want to change something in their lives, perhaps to overcome low self-esteem because of poor esthetics, to manage the effects of a recent divorce, or to address the effects of another major life event. Dealing with the teeth is only a small part of the equation. Dentists must consider the overall facial esthetics of the patient, including psychological aspects, and be aware of where the patient is, where he or she wants to go, and how he or she thinks an attractive smile will help accomplish that. With the rise of Botox and dermal fillers in dentistry, it is imperative that dentists learn how to administer these procedures because a dental esthetic case is not complete without esthetically treating the surrounding soft tissues of the mouth to complete the patient's smile. It is now mandatory that dentists are trained in these procedures as this has totally transformed dental esthetics into a more comprehensive approach that patients expect.

Some patients see an advertisement for an esthetic dental or facial product, such as teeth whitening, Botox, dermal fillers, or veneers, and are already "sold" on the concept. They then begin working through issues such as whether it is right for them, exactly what they are looking for, and whether they want a tooth makeover or an entire smile makeover. At this point the bond with the dentist comes into play. As a leader and teacher, the dentist helps the patient determine what he or she wants and whether that is appropriate. Often the dentist and patient must work through what it is that the patient *really* wants, and many times patients have no clue. Usually they want straight, white teeth, but they want the dentist to lead them along the path to get there. Occasionally patients ask for a specific esthetic dental product; those can be the easiest cases. The only question is whether the patient is an appropriate candidate for that product.

PRESENTING TREATMENT

Involved esthetic cases differ significantly from the typical case involving individual restorative dentistry. Addressing this difference is a major challenge for most dentists. When a patient comes in with a broken tooth, the need for a root canal, a crown, or both is clear. Generally the fee in the United States is a few thousand dollars, and insurance pays half. This type of simple treatment presentation is seen every day. Dentists develop a mindset in which they are trapped into considering just these small cases. A complex esthetic dental case may involve other dental treatments including orthodontic procedures, periodontic procedures such as crown lengthening and gingivectomy, endodontic therapy, implants, whitening, and finally prosthodontic restorations such as esthetic crowns or porcelain veneers. The complex esthetic case involves a totally different dynamic in the way treatment is presented, how the patient will accept it, and how it will be paid for. These larger cases cost $3500 to $5000. The process through which the patient determines whether or not to go ahead is not the same as for a small case. Dentists often have the frustrating experience of sitting down with the patient and talking for 10 minutes to an hour about the tooth case presentation, then having the patient say, "You know what, Doctor? I'll get back to you," and the patient is never seen again. To avoid this type of experience requires establishing the proper buying mentality. Patients must go through a process, a cycle of decision making, and dentists must patiently guide them through that process.

PRACTICE MANAGEMENT CONSIDERATIONS

Practice management considerations for esthetic dentistry differ markedly from those for any other kind of dentistry. The first consideration is recognizing that the patient wants to have a great-looking smile when the treatment is finished. To convey great results, the dentist's and team members' own teeth must look esthetically pleasing. If the patient is asking about tooth whitening and bleaching and the assistant who is presenting the procedure to the patient has yellow ordinary teeth that are crooked or malpositioned, the patient is unlikely to choose that

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office for whitening and bleaching. Patients will ask themselves, "If the dentist and staff don't invest in these procedures, why should I go ahead and do it?" Patients are affected by what the team members look like in terms of their own smiles and how they present themselves. The staff can be role models for patients. For example, if the patient wants bleaching, it is effective to call over a team member who has had bleaching. Team members keep their pre-operative pictures in their pockets; their post-operative "picture" is actually in their mouth. Patients see the dental team members' beautiful teeth and quickly understand that the office really believes in esthetics and achieves excellent results. The message is that just as it was successful for the team member, it will be successful for the patient.

The dental team is extremely important in patient acceptance of esthetic procedures. They are the primary motivators and educators and must be knowledgeable enough to answer questions about all esthetic options. The dental team must be part and parcel of the office philosophy regarding esthetic dentistry. Pictures of successful esthetic cases and testimonials from other patients and the team members themselves are powerful tools that the team can provide to patients to begin the discussion of esthetic dentistry's benefits. Often overlooked is the team's role and relationship with the patient—indeed, more often than not the patient will trust the dental team before he or she accepts the treatment recommendations.

Second, the dental practice must have an esthetic-looking office and website. The office must be up to date, look sleek, and have an esthetic presentation. The website should be attractive and user friendly. The appearance of the practice conveys the priority placed on esthetics by the practitioners there. The office and website that reflect that esthetic procedures are a main consideration directly affect patients' choice with regard to these procedures (Figure 33-6).

Third, a wide variety of communication tools are available to help bring the patient to an understanding and an acceptance of the esthetic dentistry procedure that is required (Figure 33-7). Pictures speak thousands or millions of words. In esthetic dentistry, pictures can tell the entire story. Most esthetic dental companies will send educational materials with before-and-after shots to show to patients or put up in the office. The Aurum Group (Calgary, Canada), which has been highly successful in providing esthetic smiles for patients, makes beautiful practice management aids for motivating patients to go ahead with the esthetic dentistry (Figure 33-8). Dentists should take down some of the beautiful paintings that are supposed to calm patients and make the office a nicer looking place. Instead they should put up beautiful pictures of before-and-after smiles, whitening pictures, or veneers to show patients the difference (Figure 33-8). These large pictures of what can happen, or books that show before-and-after pictures, can be quite effective. Ideally, a patient will come into the office, sit down in the chair, point to a poster on the wall of the before-and-after whitening case or before-and-after veneer case, and ask to have his or her teeth look like that. When patients ask questions about treatment, they are very close to being ready to accept treatment.



FIGURE 33-6 **Esthetically pleasing dental office.**



FIGURE 33-7 **Types of communication tools. Pictured is the InStyle Smile Starter Kit.** *(Courtesy Trident Dental Laboratories, Hawthorne, California.)*



FIGURE 33-8 **Poster provided by dental lab.** *(Poster courtesy Aurum Ceramic Dental Laboratories, Co., Calgary, Canada. Dentistry courtesy Ted Hadgis, DDS.)*

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FIGURE 33-9 Before (A) and after (B) treatment photos.

They are engaged. If the dentist tries to sell a procedure through a long discussion with lots of pictures, the patient may or may not be interested by the time it is done. If patients ask questions about what they have seen, they are much closer to being ready. From a practice management perspective in esthetic dentistry, the key is getting the patient to be ready. If a patient is ready to go ahead and commit financially, it is much easier to proceed.

It is critical that the before-and-after photographs be full-face shots and that the "after" views show happy people who have had treatments done (Figure 33-9). Dentists love the retracted views that get in close to the mouth structures; professionals want to make sure that all the dental angles, emergence profiles, and restorative margins are proper. But for talking to patients or showing them before-and-after pictures, full-face images are best. Patients cannot understand the significance of seeing white teeth until they see the full-face pictures and how a white smile fits into the overall facial esthetics. Teeth are not isolated from the rest of the face. A full-face photograph of a beautiful esthetic dental case shows the patient how beautiful teeth transform into a beautiful smile, which is what the patient wants. Seeing the differences in the patient's entire face is what makes the most impact.

MOTIVATING PATIENTS TO ACCEPT TREATMENT

Clinical Considerations

To help the patient decide to have esthetic dentistry, the dentist can take an impression and send it to the laboratory for a **diagnostic wax-up** (Figure 33-10). This is popular with dentists.



FIGURE 33-10 Diagnostic wax-up.

However, **diagnostic imaging** is very popular with patients because they can see a corrected smile right on their face and take home a photograph of what they will look like. Dentists may be nervous with this approach because there is no guarantee that this is exactly the way the smile will look. However, when dealing with a full-face photograph, most diagnostic imaging programs get very close to the actual outcome. Some dental companies make diagnostic imaging fairly easy. Many esthetic dental laboratories and companies make diagnostic imaging easy for dentists to provide in their office. The provider sets up a system in the office so the dentist can take as many pictures as wanted during the day. These are emailed directly to the laboratory while the patient is still in the chair. Within 20 minutes,

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FIGURE 33-11 **A, Patient with slightly misaligned teeth. B, Composite mock-up on maxillary teeth. C, Esthetic mock-up smile shown to patient.**

an image of the patient with the new smile comes through. That is a very strong message; the patient can be sent home to show family and friends what he or she would look like with the new smile.

There are simple digital imaging processes available online. A patient can select a smile, then upload a self-image to get a general idea of what he or she would look like with that smile. Both digital imaging and diagnostic imaging are very successful in motivating patients to go ahead with treatment.

Another approach to motivating patients is to give them an in-the-mouth and intra-oral demonstration. If a patient comes in for an oral examination or 6-month recall visit, and the prophylaxis is being done, it is possible to set the patient up and create a composite mock-up in the mouth. This works best for patients who have space between the two front teeth or a very dark front tooth (Figure 33-11, *A*). Composite resin in a light shade is used to cover the site, closing the diastema or replacing the dark tooth with the mock-up (Figure 33-11, *B*). This can be shown to the patient in the mirror so he or she can see what the finished smile would look like (Figure 33-11, *C*). While the patient is watching, the dentist can take the mock-up off; this gives a before-and-after effect (Figure 33-12). Once patients see what they might look like after cosmetic dentistry, they can become motivated to pursue this option.

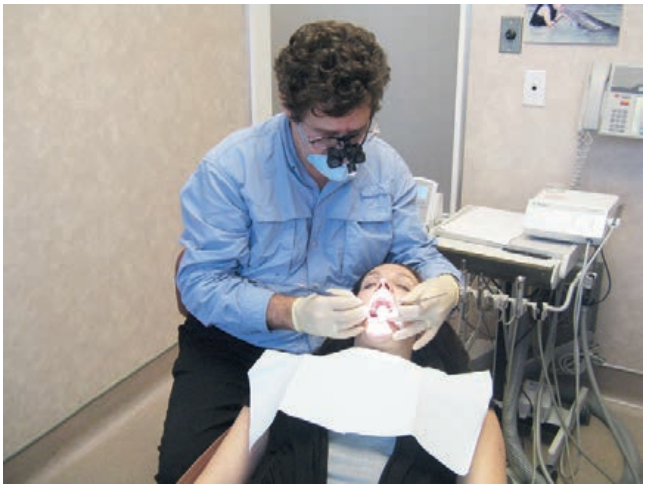


FIGURE 33-12 **Dentist working with patient.**

Financial Considerations

The best person to talk to the patient about payment depends on the individual office. In most cases, it is best to separate the dentist from the financial discussion, as most dentists are not comfortable dealing with these issues. In addition, the dentist should be focusing on providing dental treatment and

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should delegate this part of the process to trained office personnel. Front office managers are best able to work with the patients in discussing the various options available, segmenting the dental treatment with the payment schedule, and arranging financing if necessary. The key is to make the esthetic dental treatment comfortable for the patient in terms of schedule and lifestyle.

The other major motivating factor involves making cosmetic procedures affordable for patients. Many patients want the treatment but want to know how they will be able to afford it before proceeding. With the higher cost of esthetic dentistry, patients go through a different kind of decision-making process, and affordability is a major part of that process. When a person buys a house, a car, or anything else major, they will obtain financing for it. This same process is used when patients seek to purchase esthetic dentistry services. The best way to make these procedures affordable is through financing. Patients can put the fees on a credit card and take almost as long as they like to pay off the balance. Alternatively, and probably the most popular way of financing dentistry, the CareCredit program (CareCredit LLC, Costa Mesa, California) provides a way to manage esthetic dentistry costs with 0% or low-interest payment plans for up to 24 months. This approach has been a huge boon to getting people to accept esthetic dentistry.

INNOVATIVE ELEMENTS

Patients may not agree to esthetic procedures on their first visit. It is possible that they are not convinced yet, they do not have the money yet, they do not see a need for esthetic procedures yet, or they have not yet experienced a major life event that convinces them of the value of esthetic dentistry. It is critical that the dental office keep communicating with the patient. Most dentists believe that they recommend treatment for the patient and the patient chooses to go with it or not, and that ends the interaction. With esthetic dentistry cases, the dentist needs to get patients to be ready. One way to do that is to be in constant communication, be it by email, text messaging, newsletters, or other services (Figure 33-13). For example, Patient Activator at 1-800-DENTIST (Los Angeles, California) is a technologic way to keep in touch with patients. This service develops beautiful esthetic materials that are communicated to patients on a regular basis. These materials will stimulate patients' acceptance because the idea is kept in front of them. In marketing and advertising, this is called being "top of mind" and means that when patients are finally ready for esthetic dentistry, they will already know where they can go. Dentistry is a very competitive business. Patients are inundated with advertisements from various dental practices. Patients may want a small makeover and may have talked it over with their dentist. Then they see an ad that another dentist offers a new twist such as the Aurum Group's minimally invasive Cristal veneers, and the patient ends up going to that dentist. Constant reminders are very important for patients so that they remember what they expressed an interest in and that their dentist is the one who can provide it.



FIGURE 33-13 Patient communications tools: reminder postcards, appointment cards, and others.

COMMUNICATION DURING TREATMENT PLANNING

Patients often request minimal dental treatment, for example, "I only want two veneers on these front teeth." The dentist must determine what the patient really wants. Today patients want white teeth, but simply putting two white veneers on the front teeth will make the rest of the teeth look dark, and the patient will not be happy. In fact, research shows that each unhappy patient will tell 20 friends about being unhappy. Instead of limiting treatment to the patient's request, the dentist should give the patient a mirror and say, "Mr. Jones, what you're really looking for is a great smile. Let's count the number of teeth that make up that smile." The patient quickly realizes that it is usually at least six teeth, often eight, and many times the smile extends back to the second bicuspid and the tenth tooth on the upper arch, including some teeth on the lower arch. In this way the dentist leads the patient out of "tooth mode" and substitutes "smile mode"—because what is really wanted is a great smile. Once patients understand this—that the smile they want involves six, eight, or 10 teeth—then they must choose what comes next. The dentist can offer choices in terms of treatment planning and how the smile can be accomplished. Part of the process is dealing with financial realities. At about $1000 per tooth for 10 front teeth, that's $10,000 (in the United States). Often the patient cannot afford that. The way to accomplish these cases, then, is to segment them.

The minimum number of teeth recommended for a segmented case is four, although in the best case scenario it would be six teeth, extending from cuspid to cuspid. The changes that result are quite dramatic. If the patient chooses to do only four, it is recommend that the lateral and central incisors be treated. In such cases the practice should obtain a strong informed consent from the patient as well. The dentist may agree to start

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with the four but must warn the patient that the color will be radically different from that of the rest of the teeth. At that point, patients often choose to do four immediately, then save up for the next treatment. Once patients see how beautiful the results look, they usually choose to complete the rest of the recommended treatment.

This approach gives a good start on what the patient is looking to accomplish. Patients must be reminded that the dentist is creating a beautiful smile, not just beautiful teeth. Dentists should be cautioned not to compromise to please patients by agreeing to do only one or two teeth. This makes patients look minimally better but seldom satisfies them. On the other hand, the dentist must also be cautioned about the other extreme. If procedures on 10 teeth are recommended, the dentist should not insist that the patient do all 10 teeth or nothing. The best cases in esthetic dentistry are segmented, taking into account the patient's desires and what the patient can afford. To have a successful case requires taking the long-term view rather than the short-term view.

Difficult patients or patients with impossible esthetic expectations are best dealt with preventatively. In other words, you need to diagnose these difficult patients before you begin any kind of treatment on them. If patients have been to many other dentists and have not been satisfied, there is little chance that you will be the hero they are seeking. If their expectations of white teeth are unrealistic, then it is best to refer these patients elsewhere.

Dissatisfied patients are hard to deal with for every dental office. This is why the discussion of what the patient wants to achieve and whether the dentist can achieve it is important to have before treatment is begun. An informed consent is mandatory for esthetic dental cases; this document must spell out clearly what the benefits and risks of treatment are as well as the challenges the individual case presents that may prevent the dentist from achieving the patient's desired goals.

CONSERVATION CONCEPTS

Patient communication is critical. First, dentists must make sure that the patient has realistic expectations. Patients have visions of coming out of the dental office looking like a Hollywood star, with 28 gleaming, white, perfect teeth immediately. They also want them simply, without braces or complex treatment. These are unrealistic expectations. To be successful in esthetic dentistry, dentists must have the verbal communication skills to moderate their patients' expectations.

Second, it is better to under-promise and over-deliver than over-promise and under-deliver. If the dentist over-promises and under-delivers, the patient will almost never be happy. All conversations with the patient beforehand must be based on the dentist's skills and knowledge of where he or she thinks this patient can go in terms of esthetic dentistry. Whether that involves making the teeth perfectly straight and perfectly white or accomplishing more difficult tasks, the dentist must be clear that the goal will not be accomplished without some time and that it will involve specific treatment. Ideally, most dentists want patients to go through some type of orthodontic treatment, then move to esthetics to finish the case. Unfortunately, few patients agree to do that. The dentist should also share what he or she feels the case will develop into, including the complications that might arise. It is important to note some of the compromises that must be made because of the patient's existing oral status. Most of the time when patients say they want white teeth, they are not interested in the shape or the position of the teeth. In every case, though, it is important to let patients know what they are asking for and what is possible. This includes covering individual topics such as highly chromatized teeth and incisal translucence and whether the patient wants them.

Looking at the beautiful smiles on celebuties, patients see natural white teeth and think that is what they want. The dentist needs to communicate with the patient that what he or she thinks is a perfect natural tooth may be different from what a dentist thinks of as a perfect natural tooth. Dental practitioners think of the nonchromatic or translucent perfect teeth from dental school—not usually what patients want. Many patients do not want incisal translucence or polychromatic teeth. To clarify these issues, dentists should show pictures to patients of what these things are and discuss what the patients have. If the patient has polychromatic teeth, this should be pointed out, and he or she should be asked if this is desired in the esthetic dentistry plan. The same process is used for incisal translucence. If patients have no incisal translucence, they probably will not want it in their revised smile either. It is important to have a clear conversation about exactly what the patient desires in these areas. If the dentist does not know what the patient desires, there is no way to know what is appropriate for the case. These conversations will direct treatment, reveal whether or not the patient has unrealistic expectations, and help determine the color really wanted for the teeth. Dentists can glean a lot of information by discussing the technical aspects that dental professionals take for granted. People can be very particular about the look they want, so dentists must identify potential problem areas ahead of time.

Patient management of the esthetic dental case is very possibly more important than the clinical aspects of the case. Every dentist can do the dentistry the patient needs. As training is needed to achieve proficiency in the clinical techniques, training in being able to adequately communicate with patients and stimulate them to accept treatment is also essential for office personnel. Patient management takes as much skill and as much care in completing a successful esthetic dental case.

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Practice Management

Establishing an Esthetic Dental Practice

Roger P. Levin

HOW PRACTICE MANAGEMENT MATTERS IN ESTHETIC DENTISTRY

Establishing a cosmetic practice differs dramatically from building an "everyday" or traditional dental practice. Traditional dentistry typically focuses on need-based dental care and deals with broken teeth, decayed teeth, malocclusion, and so on. Cosmetic dentistry is an elective area wherein patients make a buying decision as to whether they want to spend discretionary dollars to improve their appearance.

In talking about building a cosmetic practice, it is necessary to first explore how practices grow. Cosmetic dentistry has provided a powerful engine for practices to experience a growth rate that is much more rapid than usual. Typical practices, when the economy is stable, will grow about 5% to 7% annually. Even in a depressed economy, practices can still grow. Cosmetic dentistry cases have a higher production level and higher profit margin but require less time and less overhead, not including possibly increased laboratory costs. Cosmetic dentistry typically has a higher comprehensive fee because most cases involve more than one tooth. Also, many cases involve smile design in both the maxillary and the mandibular arches. Thus we see higher average production rates per patient for esthetic dentistry cases, along with a higher profit margin. For these reasons cosmetic dentistry is very alluring to practices as an added service that most trained dentists can readily accomplish.

Dentists themselves often find cosmetic dentistry to be enjoyable and satisfying. Dentists may feel limited by managing one tooth at a time. Adding cosmetic dentistry is a gratifying choice because patient satisfaction is evident immediately after the case is completed. This positive feedback energizes both the dentist and the dental team.

In terms of patient demand, patients are becoming savvier about cosmetic procedures. The primary reason is **Internet education**, which has made the entire world much more aware of cosmetic opportunities. Second, there is increasing **social pressure** to look good. People want to look nice and to appear young at every age, even at 90 years old. When deciding who might be interested in cosmetic procedures, do not discount older people.

Another reason for the increased demand in cosmetic dentistry is the improved **convenience** of these procedures. Patient satisfaction surveys over the years reveal that the number one complaint concerning cosmetic dentistry was the lack of convenient access. This included obtaining appointments and scheduling completion of the procedures required. Today cosmetic dentistry is widely available worldwide. Not only are appointments easier to schedule, but also the procedures themselves require considerably less time than previously. We can literally change a mouth in a few days to a week if the patient is properly prepared and the case well designed.

Additionally, cosmetic practices have also benefitted from the extremely **high success rate**. In the 1980s and early 1990s, cosmetic materials were inferior to those available today. Cosmetic dentistry is now much easier and quicker to perform. When easier and faster are combined, the result is a service that breaks down several of the barriers identified by patients in years past. Most patients will invest 3 days to a week to complete a case, or 2 to 3 weeks or longer if implants are involved.

In the United States, patient **financing** is available for cosmetic procedures, which is yet another reason cosmetic dentistry has grown in popularity. This option enables patients to access a separate loan or line of credit. About 65% of patients are approved for these procedures, and 85% receive the entire amount requested.

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Levin Group recommends that practices establish a system for superior customer service that provides patients with an exceptional experience so that they expresses appreciation for the doctor and staff and become an active referral source. By delivering exceptional customer service, dental practice team members begin to realize that the sole focus is no longer on treating teeth but also providing an experience for the patient throughout the entire process.

Although cosmetic dentistry decreased slightly during the recent recession, it is coming back again and offers a tremendous opportunity for practice growth. Cosmetic dentistry services should be a part of the service mix in every general practice. The minimum target proposed for elective dentistry is 22% of the practice production.

THE BUSINESS OF ELECTIVE VERSUS TRADITIONAL DENTISTRY

Maslow's Hierarchy of Needs

Abraham Maslow created a pyramid referred to as *Maslow's Hierarchy of Needs* (Figure 34-1). As Figure 34-1 shows, for people at the physiologic level, lacking shelter or food, improving their life beyond meeting these physiologic basic needs is not an issue. Moving up the pyramid, people become interested in meeting other needs, such as safety or love and relationships. Once basic needs are satisfied, people become interested in addressing more complex needs, such as relationships. At the higher level, esteem, people may be seeking cosmetic dentistry.

As this hierarchy demonstrates, the *"want business"* differs from the *"need business."* Dentists are trained to meet needs, and many do not fully comprehend the difference between a need and a want. A *need* is something one has to have, often immediately. People find ways to obtain what is needed, such as food, clothing, or shelter. A *want* is something that is not necessary but is desirable. In dentistry, a *want* is considered elective. In the elective zone, patients are willing to start thinking about elective dentistry, cosmetic dentistry, and discretionary expenditures. Often, wants are related to an individual's age or social situation.

Establishing a Practice within a Practice

Adding cosmetic dentistry to an existing traditional dental practice means having essentially two distinct practices under one roof. In many cases cosmetic dentistry is not being considered as a different kind of business with different systems, which creates problems. Five factors must be considered (Box 34-1):

1. **Dentists trained in traditional dentistry have received education that usually merely touches on cosmetic procedures and implants.** Dental schools have so much to cover that they really have no time to give the full array of information or to challenge students by doing many cases in this area. This approach stays with most dentists well into their career.
2. **Clinical excellence does not create clinical success.** Most dentists spend considerable time on continuing education but do not realize that clinical excellence is not a guarantee of either practice performance or practice success.

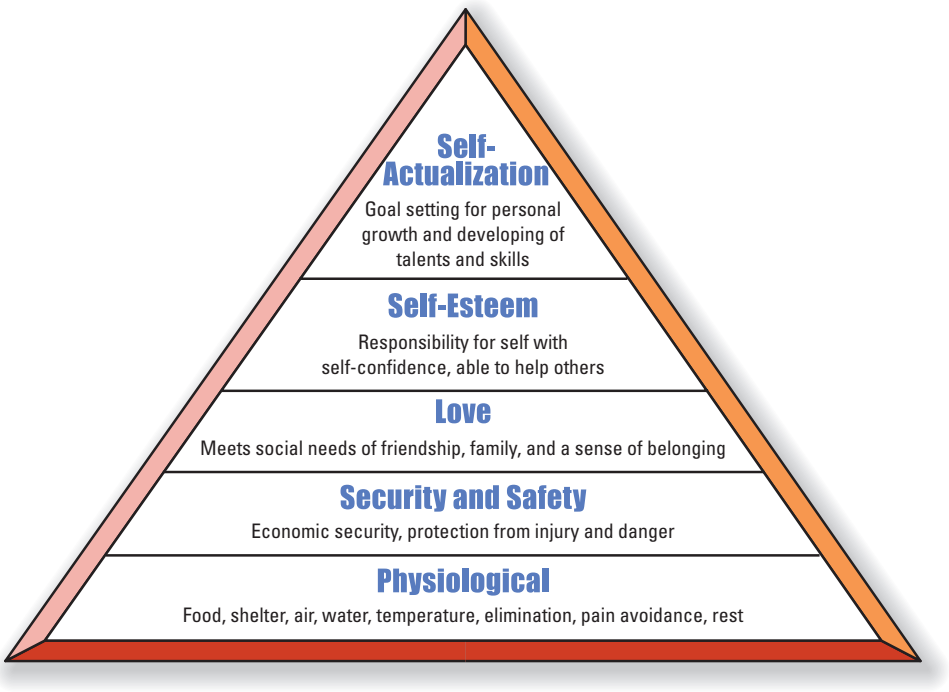


FIGURE 34-1 Maslow's hierarchy of needs. *(From Gerdin J: Health careers today, ed 5, St. Louis, Mosby, 2012.)*

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BOX 34.1 A Practice within a Practice

Reason One—Dental Schools Teach Traditional Dentistry

- Curricula are mostly traditional dentistry—not cosmetics or implants.
- Cosmetics and implants are learned haphazardly through continuing education.
- There are gaps in cosmetic and implant education.

Reason Two—Clinical Excellence Does Not Create Success

- Clinical excellence is essential, but it is one of the least important factors in building a successful practice.
- Clinical skill alone will not build a cosmetic and implant practice.

Reason Three—Traditional Dentistry Is Self-Evident

- When something hurts, breaks, or fails, people know they need to fix it!
- When something seems desirable to buy, people think about value.

Reason Four—Cosmetics Are Always Elective

- Cosmetic dentistry is not about need.
- There are multiple factors in cosmetic decision making.
- Cosmetic dentistry is always based on discretionary income.

Reason Five—Elective Choices Are Emotional

- Need decisions are based on logic.
- Cosmetic dentistry is not a need.
- Cosmetic patients want motivation and excitement.

BOX 34.2 Cosmetic Dentistry Growth Plan

Phase One

1. Value creation
2. First phone call—add value
3. All new cosmetic and implant patients scheduled within 7 to 10 days
4. Scripting—benefit statements
5. Rule of 10

Phase Two

1. Office to "scream" cosmetics
2. Every patient should have cosmetic education
3. During new patient calls, mention cosmetics
4. Show before-and-after photos

Phase Three

1. List of top three benefits per service
2. Ask for feedback
3. Develop a relationship
4. Five key questions
   - What is it?
   - What will it do for me?
   - How long will it take?
   - How much does it hurt?
   - How much does it cost?

Phase Four

1. Train *all* staff to discuss and promote cosmetics
2. Do not give technical information
3. All should have an outstanding attitude
4. Have a beautiful environment

3. **Traditional dentistry is self-evident.** When something hurts or breaks or fails, we know it and we know it must be fixed. Our only consideration is which option we will choose. When something is not necessary but is desirable, we tend to think more about value. We may or may not choose to act, and we evaluate the choices very differently.
4. **Cosmetic dentistry is always elective; it is never about need.** People can live a long life without cosmetic dentistry. No one ever dies from having an unattractive smile. Cosmetic dentistry is based on discretionary income and the choice often comes down to money and whether or not the patient feels the procedure is worthwhile personally.
5. **Elective choices are basically emotional.** When you have a need, you make a logical decision after evaluating the options. With cosmetic dentistry, there is no need, so patients make decisions based more on motivation, excitement, or external investment. These are all more emotional than logical ways to make a decision.

COSMETIC DENTISTRY GROWTH PLAN

Four phases can be used to enhance growth in the percentage of cosmetic dentistry done in the practice (Box 34-2).

Phase 1

The first phase has five parts.

Value creation. Dentists need to increase or replace the current systems serving the practice. These current systems are geared toward need-based dentistry, and adding cosmetic dentistry requires systems geared toward want-based dentistry along with the need-based side. **Scripting** is a critical component of the changes because in a cosmetic practice, the language must motivate and excite the patient plus create a sense of value and desirable return on investment. The basic script, which has proved functional with traditional approaches, must be augmented with text that conveys value. It can convey such value

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by helping people become knowledgeable and enthusiastic about cosmetic dentistry.

1. The *initial phone call*. In the first phone call about 20 steps and 18 scripts are available that can take just a few minutes to use. The approach is more than just getting the patients scheduled and their basic information. The patient also learns a little bit about the dentist and is exposed to some of the cosmetic procedure choices. The receptionist or front desk staff person who handles telephone communications actually spends time building a relationship with the patient. This is critical because the patient should always finish the phone call having the sense that this is the right office and placing a higher value on that office than before the call was made.
2. All new cosmetic and implant patients should be *scheduled within 7 to 10 days*. The reason is that the longer it takes to schedule the patient, the more the patient's motivation wanes. The patient may cancel the appointment or something else may arise that raises a barrier to the cosmetic procedure. The scheduling system should be flexible enough to permit time for a certain number of patients to be seen and treated within a 7- to 10-day cycle. Focus on adding value by using **benefit statements**. Patients start wanting to know more about why the procedure will benefit them and how it actually will work.
3. The **Golden 10**, which means we learn 10 personal things about each patient before we ever touch him or her. By learning these 10 things, we move from a professional-only relationship to a professional and a personal relationship.

Phase 2

After training the office staff in how to implement the five parts of phase 1, we move to phase 2, which has four steps.

1. The office should "scream" cosmetics, from the office's décor to patient education, it must be clear that the practice offers cosmetic dentistry. Many practices have focused on looking beautiful but have ignored marketing their cosmetic services. It is important to create a complete cosmetic feel that includes the physical beauty of the facility but goes further to specifically focus on cosmetic opportunities.
2. All patients in a practice should know about cosmetic dental options, whether they need them or not and whether they have rejected them in the past or not. Patients should be educated about what is available, from whitening to the newest crown and bridge, to posterior white restoration of the ceramic, porcelain, or composite. The goal is to create an understanding that cosmetic dentistry is available, real, in the mainstream, and worth considering.
3. In the new patient phone call, cosmetic opportunities should be mentioned even if the prospective patient did not call about cosmetics. This can simply be informing the patient that the office offers a complete array of cosmetic dental services and the dentist will be delighted to discuss procedures at the visit if the patient is interested. When you combine this introduction with the office "screaming" cosmetics, you are beginning to influence and open the patient's mind.
4. Use before and after photography. Psychologists show that people learn by comparison. Often they do not know they have a less-than-attractive smile until they get a sense of what a beautiful smile could look like.

Phase 3

Phase 3 of the Cosmetic Dentistry Growth Plan also has four steps.

1. Identify the top three benefits of every service a practice offers and tell the patient these benefits for the desired service. You can offer at least 10 or 20 benefits, but when you give adults three, they respond best. Everyone in the office should know the top three benefits of each cosmetic procedure. Most patients, after a treatment consultation, will go to the front desk and ask a quick clinical or clarifying question. The answer they receive must give the same information as what was obtained from the dentist, hygienist, or treatment coordinator.
2. Request feedback. In about 10 to 12 seconds, the patient is asked what he or she is thinking. This is important information so that a customized presentation can be developed to help the patient understand the procedure and be comfortable that it is something that he or she wants. The patient will then become motivated to accept treatment. Use of several feedback loops is suggested, stopping to ask questions along the way.
3. In part three of phase 3, one tries to develop a key relationship with the patient. This relationship was begun in phase 1, but now it is advanced to cover more about why the patient would want cosmetic dentistry, what the individual thinks it will accomplish in his or her life, and what area he or she would specifically like to improve.
4. Focus on the key questions a patient is likely to ask during the presentation of cosmetic dentistry, specifically (1) What is it? (2) What will it do for me? (3) How long will it take? (4) How much does it hurt? (5) How much will it cost? Most of the time is spent on question 2 because the answer focuses on benefits.

Phase 4

In phase 4 of the Cosmetic Dentistry Growth Plan, four things are recommended.

1. All of the staff members are trained to discuss and promote cosmetic procedures. The hygienist, assistants, and front desk attendants should all be comfortable discussing cosmetic procedures and motivating patients in an educational manner.
2. Do not overstate technical information. Most patients do not care about the details of the clinical procedure. When they are interested, they will ask for more information. In most cases they want to understand benefits, not technical information.
3. Address the entire attitude of the office. Everyone on the team in a cosmetic office must be an upbeat, energized individual whose presence is enjoyable and who comes to work every day excited and enthusiastic about cosmetic dentistry.

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BOX 34.3 Cosmetic Dentistry Growth Plan: Features versus Benefits

Features
- Features are commodities.
- Features are boring.
- Features do not sell procedures.

Benefits
- Benefits motivate, excite, and energize.
- Benefits create desire.
- Benefits sell procedures.

4. The office must create a beautiful environment. No one will buy or believe he or she can buy excellent cosmetic dentistry in an office that does not represent a superior cosmetic facility appearance or design.

FEATURES AND BENEFITS

Features are about commodities and making comparisons, which are boring and typically do not create the excitement needed to sell the case. Benefits motivate, excite, and energize the patient. Benefits answer the question "What will it do for me?"—which is where the bulk of the time in treatment presentation is spent. Benefits create desire and sell the case (Box 34-3).

LOGIC VERSUS EMOTION

As already mentioned, logical thinking is how need-based dentistry should be approached (Box 34-4). Patients know when something is necessary and know they must select an option. So they evaluate their options, but the final decision is generally dictated by money. They do not always make the best choice, but they will do what they can afford. In cosmetic dentistry, emotional thinking takes precedence. For example, emotional thinking is "I got divorced, I need to look better to be more attractive" or "I look older and this is not enjoyable." For an emotional decision, one may choose to not make a decision because there is no deadline or hurry. The emotional thinker evaluates options and makes decisions based on money, desire, motivation, excitement, impulse, and belief. To influence patients to accept cosmetic dentistry, one must find what motivates the patient, create excitement, and then energize the patient (meaning the patient actually gains more energy as he or she learns more). As a result, the patient is led to trust the dentist to provide what is being offered and to ensure that it is all that has been promised.

Patients who consider cosmetic dentistry ask themselves if they want it or not. The answer will depend on their own self-perception, self-esteem, monetary situation, and social situation. This is why the dental office's presentations must be individualized.

BOX 34.4 Logical versus Emotion

Logical Thinking
- Need-based dentistry is a *logical* decision.
  "I broke my tooth, I need a crown."
  - Evaluates options.
  - The decision is only about money.

Emotional Thinking
- Cosmetic dentistry is an *emotional* decision.
  "I got divorced, I need to look better."
  "I look older—this sucks."
  - May make no decisions.
  - Evaluates options.
  - The decision is about money and desire, motivation, excitement, impulse, and belief.

The Dentist Must
- Motivate
- Excite
- Energize
- Create trust

Need Versus Want
- The need question—"Do I need this or not?"
- The want question—"Do I want it or not?"
- Want is affected by:
  - Self-perception
  - Self-esteem
  - Monetary situation
  - Social situation

Life Factors to Evaluate Emotion
- Comfort
- Convenience
- Age
- Appearance
- Life change

Life Factors to Evaluate
- Effect of advertising
- Effect of beauty magazines
- Comparison with others
- Income
- Upcoming life events

Patients will make decisions about cosmetic dentistry based on the following factors:

1. *Comfort.* If patients are comfortable with their smile, they may never do anything unless the dentist can demonstrate, through a comparison, how a more beautiful smile can be achieved and the benefits of doing so.
2. *Convenience.* Some patients would love to have cosmetic dentistry but they find the appointment times or the office inconvenient or they do not want to go through it at this point in life, so they choose not to do it.
3. *Age.* People at age 30 years have very different perceptions than people at age 50 or 70 years.

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4. *Appearance.* If patients are unhappy with their smile, they may ask for cosmetic dentistry. If the person is happy with the appearance or does not value the smile, he or she may not be interested.
5. *Life change.* Often treatment is accepted based on a life change—a milestone event such as an engagement, a wedding, a job change, a divorce, or a significant birthday (e.g., age 40 or 50).
6. *Advertising*. Many people never consider cosmetic dentistry until they see advertising for these procedures. Then they began to think about whether or not they should do it. The effect of advertising can be a powerful factor for choosing cosmetic services.
7. *Beauty magazines.* The world is populated by movie stars, celebrities, athletes, and politicians who have beautiful smiles. Patients can relate to these attractive people and want the same look for themselves.
8. *Comparison with others.* Neighbors, brothers or sisters, and others may have had their smiles redone and may look much better than before, so the patient decides to have it done too. Comparison is a powerful motivator.
9. *Income.* Individuals in higher income groups will pay for cosmetic dentistry much more readily than those in lower income groups. Cosmetic dentistry is chosen as an accepted practice in proportion to the income of the individual.
10. *Upcoming life event.* This may be a special party, a reunion, a visit to see family for the first time in 30 years, and so on. The occasion is important enough that patients want to look their best.

MARKETING COSMETIC DENTISTRY

Internal Marketing

Internal marketing (Box 34-5) is an approach using the existing patient base as the target market for cosmetic services. Ways to reach patients include sending quarterly emails, promoting patient referrals, offering cosmetic brochures and implant brochures, and using specific messaging. In the **theory of three**, patients hear about cosmetic dentistry in three different subtle ways each time they come to the practice. This requires motivational scripting, but it can also rely on staff members who have used the cosmetic services. They can talk about themselves, which is quite motivating. If patients do not accept cosmetic dentistry when it is first presented, the topic should be re-visited when they are seen at the 6- or 12-month recall visit. Other sources are website educational presentations from the practice and posters placed throughout the office. The results of internal marketing are highly predictable: It will create cosmetic cases when done properly.

External Marketing

External marketing (see Box 34-5) can be quite expensive and has an erratic success rate. It involves advertising in magazines, in direct mail pieces, in newspaper, on radio, on TV, or on websites that do not belong to the practice. The problem is that it does not contain a call to action. Most dental advertising is really branding. When you do enough high-quality external marketing, you begin to influence the local community, but there are no guarantees that you will personally regain your initial investment. Some practices do extremely well with external marketing, but others do not. Taking this step requires care and thought about what you are getting into and what external marketing will do to your costs.

BOX 34.5 Elective Marketing

Internal
- Patient quarterly emails
- Promotion of patient referrals
- Cosmetic and implant brochures
- Specific messaging—the theory of three
- Motivational scripting
- Revisiting of conversations
- Website education
- Posters
- Social media

External
- Magazines
- Direct mail
- Newspaper
- Radio
- TV
- Web
- Search engine optimization

NINETY PERCENT OF CASES ACCEPTED

If everything that has been discussed is implemented, 90% of the potential cosmetic cases are accepted (Box 34-6). Practice management is all about systems, so the first step is to put appropriate systems in place. The preliminary steps of case acceptance are as follows:

1. Educate every patient about cosmetic and implant dentistry. Any patient who does not know about cosmetics is a potential loss for the practice.
2. Teach the three benefits of each service to all the staff. If the staff does not know the benefits, they cannot talk about it, they will not be excited, and they will gradually forget about cosmetic dentistry.
3. Assume patients will want cosmetic dentistry or an implant. Do not assume they will not want it because that attitude will destroy the level of cases accepted.
4. Consider having no-cost consultations for people who were referred and for new cosmetic patients. Eliminating the fee is a small gesture that can eliminate one hurdle so people will

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BOX 34.6 NINETY PERCENT CASE ACCEPTANCE

Preliminary Steps of Case Acceptance

1. Educate every patient about cosmetic and implant dentistry.
2. Teach three benefits of every service to all staff.
3. Assume patients will want cosmetics or implants.
4. Offer no-cost consultations for referrals and new patients.
5. Have flexible financial options.
6. Offer convenient 7- to 10-day scheduling.

The Consultation—Five Amazing Questions

1. What is it? (10%)
2. What will it do for me? (60%)
3. How long will it last? (10%)
4. How much will it hurt? (10%)
5. How much will it cost? (10%)

Follow-Up

1. Two or three consultations
2. The key decision maker
3. Evening follow-up
4. The law of motivation—1-week follow-up

come in, and it encourages people to feel more comfortable referring other people.

5. Have different payment options that work for the practice. It is not possible to have everybody pay the whole fee up-front because many patients do not have the needed cash available. Offer the option of credit cards and outside financing. No matter what methods are chosen, ensure the patients that the payment options and financing plans are safe.
6. See interested patients within 7 to 10 days because the longer they wait, the greater the chance they will lose interest in moving forward.

During the case presentation, about 10% of the time should be spent answering the question "What is it?" The answer focuses on the technical factors of cosmetic procedures. About 60% of the time should answer the question "What would it do for me?" This answer refers to benefits. Ten percent of the time is to be spent explaining how long the treatment will last. Ten percent should review how much it will hurt, and 10% how much it will cost. Practitioners must cover all of these areas so that patients will not create their own obstacles or negative feelings. Remember, cosmetic dentistry is an emotional decision.

If the cases are presented and the patient does not accept treatment right away, consider offering a second or third consultation, or invite the spouse or a relative to accompany the patient and help make the decision. Accommodating the key decision maker is a factor for many people who do not want to spend money without talking to a spouse or someone else. You may want to arrange for an evening telephone consultation so everyone can review the presentation. We have found this to be a powerful technique that creates high levels of case acceptance. The Law of Motivation states that if the patient has been in, either the case should be started in 7 to 10 days or the office should follow up within 7 to 10 days with a second consultation or a phone call. More than a week should not go by without some specific contact or notation so the patient does not lose motivation.

SUGGESTED READINGS

Levin Group Inc. (website): www.levingroup.com. Accessed September 2, 2011.

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Managing an Esthetic Dental Practice

Debra Engelhardt-Nash

RELEVANCE OF PRACTICE MANAGEMENT PRINCIPLES TO ESTHETIC DENTISTRY

It is important for the dental team to understand the components of esthetic dentistry and what esthetic dentistry means. Sometimes there is confusion. Those who represent the practice, from the person answering the telephone to the treatment coordinator or concierge, to the hygienist and the dental assistant, the team must have considerable understanding of esthetic dentistry and what it means. Typically they are the first people who will articulate the nature of the practice to the patient. The practice is introduced through whatever external marketing has drawn patients to the office. When the patient calls in for a first contact, the message must be congruent with these external messages. What patients hear when they call, what they see when they walk in, and how they are being treated as a patient must line up with the image presented in the advertising.

Esthetic dentistry must also feel different and sound different from regular dentistry. Esthetic dentistry is necessary or elective dentistry done with cosmetic materials. Whether or not it is necessary to address decay, disease, or function, the dentist is asking the patient to make a personal choice to invest in his or her own dental care and personal dental appearance. For many consumers that involves discretionary spending and time. It is necessary to appeal to patients' discretionary sense of why they would choose to make this investment with this specific practice. This is not an insurance-driven type of practice in which the patient is asking, "What is my maximum allowance per year going to pay for?" This is another tier of dentistry and requires the individuals in the practice to be different, to be exceptional, and to be noticed by the patient from the first contact. From correspondence that has welcomed the patient or brochures that have been sent out, the message must be consistent and exceptional. If we are talking about appearance-oriented dentistry, we also must talk about the sort of appearance being provided to the patient in the practice literature, the facility, and the appearance of the dental team. This does not necessarily mean that they all must look as though they have come from a supermodel magazine. They must, however, be professional. Questions to ask include the following:

- Are we "walking the walk"?
- Do we have the type of dentistry in our own mouths that we are suggesting our patient wants?
- Are we living models of our work?
- Do we have an enthusiasm that is palpable to patients when they come in?

These are all important components. Of course, if we do not manage the patient account appropriately or the system of treating the patient well, that will be a chink in the armor that can lead to a potentially decisive moment when the patient says, "Ouch! That didn't feel good. I don't like the way they handled my scheduling protocol. I don't like the way I had to wait in the reception room too long—that doesn't feel good. I need to feel important, and they didn't give me that feeling."

It is important to look at the office systems to be certain that the management of the patient on paper is done in a way that is congruent with the quality of care being provided. A dental office can claim to offer beautiful dentistry and show examples of the work, but if the presentation is not consistent at every step of the way—how we speak to patients, how we write to them, how we look to them, how we interact with them—if that is not congruent, the patient may question the quality of the care. Most experts say that the patient's decision to accept dentistry actually happens within the first 10 minutes of entering the practice. If that is the case, the patient has not even met the dentist yet. Typically he or she has met only dental team members.

Most patients do not choose a dentist based on the quality of care or the clinical abilities of the dentist. They do not usually know what those clinical abilities are and whether they are superb, average, or below average until that is demonstrated and unless the patient is educated. The last person to educate the patient about the quality of dentistry typically is the dentist. The team members should introduce the outstanding abilities and clinical aptitude of the person for whom they work. Most dentists do not walk into an operatory and say, "I'm really good and you're lucky to be here." They typically have a humility regarding themselves. There are very few dentists who walk into an operatory aggrandizing themselves; such a huge clinical ego could offend or put off a patient. It is important for the team members to understand that they

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are the frontrunners, the liaison to the patient, and have the responsibility of explaining, demonstrating, and using visual aids to help the patient understand the clinical expertise and abilities of the practitioner. That is a part of training and practice management.

With respect to clinical considerations, it is important for the dentist to demonstrate his or her clinical aptitude to everyone on the team. The financial coordinator who is talking to patients about their dental investment must understand the skill, artistry, and intensity required to achieve the specific level of dental care. To be superb, to provide a fine product to the patient, and to achieve a fantastic end result requires that everyone on the team understand and appreciate the dentist's passion and commitment to providing the highest level of care to the patient. The passion and commitment of the dentist then are transferred to the team members, who transmit them to the patient. The patient must be able to sense from the team the genuine and authentic commitment to an excellent level of care. Above all else, that is a winning point.

BRIEF HISTORY OF THE DEVELOPMENT OF PRACTICE MANAGEMENT

In dentistry in the late 1970s there was one practice management company, which had started as a vendor of dental forms. In response to questions they received from their clients, they started doing some practice management and eventually consultation. Among the pioneers in practice management are Jennifer de St. Georges and Linda Miles. They worked in offices that were successful, so other people asked them questions and tried to model their own behaviors on what was working for those practices. That is how it all started—with a very seasoned, very experienced, very mature, enthusiastic, passionate person in dentistry who started talking about what worked. In the history of practice management, if a staff member told a dentist that he or she wanted to attend a practice management program, the dentist's first question was, "How will that help me clinically?" It does not help clinically, but before the dentist clinically treats the patient, the office must behave in a way that moves the patient to the dental chair. More and more people have realized that this is something that happens only once—that patient gets in the chair for the first time. The challenge is how to get patients there, how to treat them, and how to motivate them to pay their bills and understand the system.

More and more systematic practice management companies formed. In the 1980s the author was with a company that started with dental office design and building for practitioners. Dentists started coming back to the designer and asking, "I have this beautiful facility; now what do I do? I've got the external part of it—what do I do with the inside, the guts of the practice?" A successful dentist from California, Dr Philip D. Whitener, DDS, began applying business principles to dental practice management and team management. Dr Whitener was another pioneer of practice management, along with the Roadys. The Roadys' practice management sprang from their dental supply company.

Practice management was a bit of an afterthought until the 1990s, when it became more accepted. There were times when dentists did not want their colleagues to know that they had hired a practice management consultant, implying they could not figure out how to do things on their own. Eventually dentists came to realize that they did not go to dental school to learn to run a business, be a personnel director, or act as a human resources director. They also realized that their education and skills training were in the technical aspects of a dental practice, and they now had to address other components, such as personnel, hiring, overhead, basic accounting, and all the systems and training. These are as important as the clinical aspects of dentistry. The two must marry well.

Practice management started with a few people who had great experience and a lot of charisma. They began doing a smattering of lectures, and the process grew. After Jennifer de St Georges and Linda Miles, Practicon Dental (Greenville, North Carolina) and some of the other companies developed. It began as a cottage-type industry and has become big business.

Current Status

Consulting companies work hand in hand with practitioners. It is a more accepted protocol to have a consultant or coach today. More and more people talk about having a life coach or dental coach who helps not only with managing the practice but also with managing life. More and more practice management consultants have now received coaching training and are becoming life coaches for their clients. This trend is continuing to grow and reflects a critical component of practice management.

Often the dentist who needs the consultant most is the dentist who can afford it least. Sometimes they say, "My wife is going to manage my practice and my wife is going to work in the office with me." The question a practice consultant should ask is, "What kind of experience has your wife had in a dental office or managing people?" Usually she has not had any. She may have a degree in accounting, which would be helpful, but she will still need the help of a specialist, a consultant in the healthcare field. Consulting has grown considerably and continues to grow.

Clinical Excellence and Practice Management

Clinical excellence must always come before practice development. It also comes before marketing—there must be something to market. It has been said that "Before you cook a gourmet meal, you have to clean up the kitchen." Clinical excellence is more than even what happens at the dental chair. It is a demonstration to everyone of the dentist's level of commitment to the patient and to his or her work. Dentists, whether they want to be or not, are role models for their teams. To develop a

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practice the dentist must be able to demonstrate to the team members and to the world that what he or she does is excellent and worthy of their trust. Clinical excellence must come first.

Team members may come to the practice consultant and indicate concern about the dentist's level of commitment at the chair. Some dentists might say it is not the team members' or the staff's responsibility or their right to judge the dentist's clinical ability. Whether it is their right or not, team members may sense what is happening at the chair or may experience something that concerns them. It is very difficult for team members who do not believe in the dentist's clinical abilities to sanction the practice. They may stay, but they view it as just a job—it is not their profession or their career, and they have no further interest; it just pays the bills. This attitude makes a huge difference. A lack of clinical excellence affects the way the team behaves.

It is important that the staff be able to be authentic and genuine in their marketing endeavors—what patients are being told, what is being written to them, and what the community is being told. If the marketing person is writing about a commitment to quality or excellence or superb clinical skills and it is not ringing true, patients will sense that the team is not on board with the written word or what has been advertised.

INNOVATIVE ELEMENTS

The cycles of any dental practice are predictable. The first stage of a dental practice is fairly generic. Patients expect certain behaviors when they walk into the dental office. Someone should greet them, give them an appointment card, notify them when they are scheduled to come back again, handle financial arrangements, and so on.

The next cycle is called *augmented behavior.* Here, the expected behavior is "kicked up a notch" to make things more readily accepted by the patient and more pleasant. For example, formerly when patients walked into a dental practice they expected a reception room with magazines to read while waiting. Now they expect a flat-screen television in the reception room. Taking it one step further, the dental office may include an Internet section so patients can access the Web or check their email while waiting for their appointment. Another augmentation may be having a videogame system so they can play golf or do yoga while they wait.

In the third cycle, called *potential behavior,* things can be done in the office to make people take notice—things that make the office so different that people tell others about it. Patients typically do not tell their friends, "I had the best periodontal charting today! You must go see Dr. Smedley because he does a phenomenal perio chart!" or "You will not believe how beautifully they filled out my insurance form!" or even "Look at the tertiary anatomy on my crown. Isn't that margin fabulous?" They *might* go to their friends and say, "I just left my dental office and at the end of my visit I received a Sonicare toothbrush and a beautiful spa kit with bath salts and a loofa" or "I received a gift certificate to go have a makeover at the local spa" or "My dentist gave me a free photo shoot." Especially for esthetic practice management, one must consider what can be done to make patients notice the practice.

Considering the work environment and practice management, one innovative element is to encourage a sense of enjoyment or serenity. Certain steps will make sure that when patients enter the office, they will "feel good" while they are there. One thing dental practices can do is ensure this sense of feeling good. Consumers buy from people they like and frequent places where they feel comfortable or at ease. The office can have rules, protocols, and manuals. All of those are important internal elements and form the foundation of a solid dental business. Innovators go a step beyond, seeking what can be done in the practice that gets noticed by patients. This is behavior that would not be expected in most dental offices.

> Yesterday I asked a gentleman who admittedly had been looking at some other dental practices for his cosmetic dentistry, "What made you choose us?" He said, "I had been to a few other dental offices and I received treatment plans and fee information but I was not choosing the office based on the fee. I wanted to go to somebody who had the right experience and the expertise I would need, so I did some research. I found your website and read about the dentist's credentials. Then I called the office and was impressed by the way that I was treated. Your office shared information with me that no one else shared. Typically when I called a dental office they asked my name, asked about my insurance, and asked other perfunctory questions, but they didn't really talk to me about what I was looking for. They were more concerned about getting my information than they were about asking what I wanted. Also, when I walked in, I was impressed by how graciously I was treated here, how much information was shared with me, and how much time was spent with me during my appointment. I just knew I was in the right place."

When talking about innovations, we must consider what kind of information is put on the website and in other external promotional material. All of those things are part of a system that is designed to make the patient want to come to the practice. It is not happenstance but a systematic approach to putting an attractive face on the practice.

Innovations also apply to how patients are handled and how protocols are set up in the office. The goal is to have the patient say, "Wow!" The dilemma is that the more one does these types of things, the more likely they are to become a trend. Then it is necessary to think of the next step. A patient in the author's practice mentioned another office he had visited; many of the things that office did were the same as in the author's practice. The dentist spoke to the patient, saying, "I really appreciate the fact that they like what we do so much that they copy us. I suppose I should consider it a compliment." Once one office starts doing something and it becomes a trend, then the dental team must think about how to stay on the forefront.

Once an office has established its protocols, plans, marketing, and so on, it must tell itself that it is ever evolving. Just as the art and science of dentistry continue to evolve, so does the art

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of practice management. It must continue to be innovative. Things that are recommended now may not have been recommended 5 or 10 years ago.

Something that many offices do not do before they embark on an external or internal marketing plan is a psychographic or demographic study of their practice. They do not study their location and what suits the consumers they are trying to reach. Certain questions should be asked, such as the following:

- What is the target?
- Will the office be a general practice or an esthetic practice?
- To whom is the practice trying to appeal?
- Whom does the practice want to attract?
- Within what mile radius does the practice want to reach customers?
- Should the practice become a destination practice or a local practice?

An innovation for many offices is to actually step back and scrutinize: Who are we? Where are we? To whom do we appeal? What is our market? To actually have a plan is innovative for some offices.

Sometimes the dentist and/or other team members attend a seminar and hear a great idea. They decide to go back to the office and use it. It may not be appropriate for their practice or their location. Then they will say, "That did not work for us." It may not have worked because of geography or some other factor that differs from the situation presented at the seminar. Before innovation comes study. Great resources, often inexpensive, are available so that offices can do research, including psychographic or demographic studies. Perhaps the community has changed over the last 2 to 5 years; maybe it has become more transient. Maybe the median age of the residents has changed. Maybe the dental office needs to change how it is addressing that population relative to age, employer, or socioeconomic factors. To be innovative requires doing some homework, analysis, and planning.

ARTISTIC ELEMENTS

There are several components related to artistic elements. First, can the art and science of dentistry, the artistic abilities of the dentist, be taught? The answer is that they can, but some dentists have more innate abilities than others. In practice management it is necessary to look at the clinical artistic abilities of the dentist. Both artistic ability and professional image are critical. Second, in marketing there are external and internal aspects. Dentists, even esthetic dentists, need to have a specialist on the team—whether a graphic artist or an advertising director—who has the savvy, the experience, the networking abilities, and the know-how to create the right image for the practice. The author recalls a dental office in a small town where she received a business card that had been designed by a team member. It depicted a stick figure holding a tooth, with a football goal on it and a football helmet on the figure. The dentist had been a local football hero in his high school years. Although this was fun, it was not drawn professionally but looked like a child's drawing. For business cards and such, the dentist must ask if this is the image he or she really wants to have in the community. Although a few patients might be attracted to the stick figure card, many more would not. They would view it as amateurish.

There must be someone who understands the artistic nature of images, from logo, to website, to stationary and card design, to brochure design—all must be done very carefully. Some excellent companies have generic and in-stock brochures, literature, and patient forms; these can be used, but one must consider again the cycles of a dental practice. Such forms are what is expected, they are generic, and they are not artistic for the most part. An excellent graphic designer can design a logo and put it on all of the elements of the practice, including website advertising pieces. That person will ask the right questions, and from the answers he or she will create an image that truly reflects the passion, the vision, and the personality of the dentist. If the dentist claims that he or she does beautiful, precise, meticulous dentistry but then gives out a patient form that is a crookedly reproduced fourth-generation photocopy, that does not convey "meticulous attention to detail."

Often this is an area requiring a referral. The author personally charges no referral fee.

The clinical artistic abilities of the dentist must also be demonstrated by meticulous attention to the artistic details in the image of the office. The facility does not have to be grandiose or expensive, but it should convey the right message. If the first thing the patient sees when he or she walks into the clinical area is a torn and frayed operatory chair with the foam coming out of the top of the dentist's stool, the facility is not conveying a concern for appearance or details. It is critical to reflect the artistry of what the esthetic dentist does in what is shown to the patient.

TREATMENT PLANNING

Dental Team Involvement

The dental team is not involved in the diagnosis, but in terms of introducing possibilities to the patient, showing the patient what is available, and finding out what the patient's interests are, the team is definitely part of treatment planning. Having a dental team member involved in the initial conversation may prompt the patient to reveal more about what he or she is looking for than when the initial conversation is with only the dentist. Certain patients feel more comfortable having a heart-to-heart chat with a team member. They may share information, expectations, and desires more openly with team members than with the dentist. This may reflect differences between the way the team practices and how the dentist approaches the patient. The dentist may be more clinical and not as relationship based as the team member. Every interaction with the patient should be based on a relationship, not limited to the clinical area.

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Treatment planning involves asking the right questions and making the patient aware of what treatment possibilities are available. Displaying examples of the kind of work that the office can provide is a wonderful way of transitioning the patient into the clinical meeting with the dentist. This can lead to discussing patient expectations, talking about dental history, and noting concerns or objections. It is also a great introduction to the dentist. The team member can talk about the dentist's clinical virtues and artistic abilities during the initial treatment planning process.

The other area where the team member is involved in treatment planning is being present during the process. The dentist should never walk into an operatory by himself or herself. There should always be a team member present with the patient when the dentist enters the operatory. The team member then stays during the examination and diagnosis. Team members may act as the dentist's scribe in documenting the treatment plan and the clinical findings, so they are quite involved during the examination, diagnosis consultation, and documentation process. They are critical to that and often also explain the treatment, clinical findings, and recommendations to the patient. Some dentists do this well and some do not. The latter can defer to someone on the team who is a more effective communicator. Everyone on the team should be trained and professional enough to be able to articulate a treatment plan to the patient, whether he or she has acted as a treatment coordinator or as a dental assistant. It is good sometimes to designate one person to be a treatment coordinator. This is the only person who has the training and possibly the personality to present treatment plans effectively to the patient. That can be an obstacle, however, because if for some reason that person is no longer available or is not available at the time and no one else can function in that capacity, then it cripples that office.

It is critical for the team to be very involved in the treatment plan. Should the team members offer opinions? Probably not—that could confuse the patient. They need to make sure that treatment recommendations and diagnosis are left to the dentist, but defining, explaining, and further educating the patient about the treatment plan are absolutely appropriate. One must be careful, however. Overly aggressive team members can become too involved and start diagnosing the patient. That is taking a strength and making it a weakness.

CLINICAL CONSERVATION CONCEPTS

It is important in practice management for the team members to understand the dentist's treatment philosophy because they are responsible for articulating it to the patient. The philosophy is expressed in all forms: the website, printed matter, advertising pieces, welcome letters, and so on. Some offices have a written treatment philosophy that is posted in the reception room. *None of the previously described things can replace having a conversation with a patient about the dentist's treatment philosophy.*

The dentist's treatment philosophy to conserve as much natural tooth as possible may extend to the point of being radically conservative—perhaps not even doing tooth whitening because "I believe you should live with the color that God gave you." Team members need to find a way of positively articulating that life philosophy, which has transcended into a treatment philosophy. For example, one could present this treatment philosophy as so conservative that the dentist will do a beautiful job of blending restorations in with the natural color of the teeth. This is an extreme example, but the patient must understand that there are several ways to approach esthetic dentistry. Explanations are given without denigrating other approaches. The team members need to focus on their employers' approach and be committed to it entirely. When patients call the practice and ask about a particular procedure or product, it is possible to say, "I can understand why you would ask about that particular procedure [or product] because it's been advertised widely. For some patients that is a viable solution. Let me explain that particular procedure [or product] and what it is best for." The practice may not perform that procedure or use the product in a restoration, but it can be discussed noncritically and educationally. Relaying the dentist's philosophy is critical, but one does not have to build oneself up by tearing others down.

SUGGESTED READINGS

JdSG International Inc. (website): www.jdsg.com. Accessed September 1, 2011.

Miles Global (website): www.milesglobal.net. Accessed September 1, 2011.

Practicon Dental: Practice Management (website): www.practicon.com/help-detail.aspx?oid=121.

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Evaluating Esthetic Materials

Michael Miller

RELEVANCE OF EVALUATING MATERIALS AND TECHNIQUES TO ESTHETIC DENTISTRY

Important Terminology

AccuVol: Volumetric shrinkage of restorative composites is determined using this specialized scanning device designed by Bisco.

Bond strength: Bond strength tests are done with operators and assistants working together to simulate the clinical procedure.

Digitized microleakage: Microleakage at the margins of class V restorations is measured using an imaging algorithm reading from sectioned specimens viewed through a stereo microscope.

Fluorescence: Fluorescence of materials is tested intraorally in a live subject in a custom-made black light cabinet. It is not possible to test fluorescence using extracted teeth or discs.

Hardness: Depth of cure of composites and curing time as it relates to hardness are tested in a digital hardness tester.

Modified molar for depth of cure: Modified class II preparation is used to determine depth of cure and gingival wall hardness instead of the much more common but clinically irrelevant metal cylinder technique.

Porosity: Trans-illuminating and digitizing disks of composite quantify porosity in composites. Materials with high levels of porosity can cause problems during the finishing and polishing phase of a restoration.

Specimen preparation: Specimens for bond strength testing are prepared on a dual-wheel model trimmer.

Thermocycler: A thermocycler is used to simulate the temperature extremes that a restoration would experience intraorally.

Translucency and opacity: Spectrophotometry determines the translucency and opacity of materials to allow more specific selection. These properties are important in choosing materials to replace enamel and dentin and to simulate incisal effects.

Unless there is some science behind the materials or methods used in dental trials, there is no way a clinician can know whether a product works as advertised. Experience in evaluating dental materials, including esthetic materials, devices, and equipment, reveals that many claims made by manufacturers are shaky or even untrue.

Numerous evaluations are available, so it is important to assess the *source* of the evaluation. The people doing the evaluation must be totally unbiased. If there is any commercial overtone in an evaluator's profile, that tends to negate many of the findings. For example, the evaluator may be working under a grant from a manufacturer, suggesting bias. It is well known that those who pay the bills are more favorably treated, so it is very important to know who is doing the evaluation, what is behind it, and who is paying for it.

The methods by which evaluations are done are also important. For example, a facility tests a new nanocomposite restorative material and finds that the product does not light cure well at the bottom of a proximal box. If a clinician is using this in a class II situation and places it on a gingival wall and cures it for the manufacturer's recommended time, most likely the material will be undercured. The manufacturer may not have ever performed a test under those conditions. *Many products on the market have undergone testing but nothing that subjects the product to all the uses for which it is recommended.* The issue of validation for the clinical dentist is one of confidence in use. To be confident that the material will function in a certain manner, the dentist must have an independent non-manufacturer, non-distributor evaluation that indicates the uses of the material and the results expected.

Many materials are good materials made by ethical, well-meaning manufacturers. As noted, the way the products are used is not always investigated by the manufacturer. Even when the manufacturer has a recommended technique, that technique may not be appropriate or may not optimize the material's performance. In these cases, dentists using these products according to the manufacturer's directions come up with less-than-optimal results. Often a manufacturer's directions are based on outdated tests designed by the International Organization for Standardization (ISO), the American Dental Association (ADA), or other regulatory bodies. These tests may have been applicable years ago but no longer apply to modern materials. Tests must be adjusted frequently so they

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reflect how a product is being used clinically. The way to optimize the product's use is not necessarily in the instruction manual that comes in the box. Most instruction manuals or, as manufacturers call them, the DFUs (directions for use), are poorly written, presented in extremely small type, and printed on paper that is not amenable to disinfection procedures. If the dentist picks up the instructions while using the material and his or her gloves are contaminated, the instructions can blur and become contaminated. The instructions may also be ambiguous. Probably the most egregious example is adhesives, because many adhesives today demand that the dentist use certain types of moisture substrates. Moist states range from the tooth glistening with moisture to being completely dry. The manufacturer's description of what the dentist should achieve in the substrate condition is typically so ambiguous that it is virtually impossible to achieve.

BRIEF HISTORY OF THE CLINICAL DEVELOPMENT AND EVOLUTION OF EVALUATING ESTHETIC MATERIALS

The ADA and ISO have testing programs and regulations in place for materials presumably before they can go on the market. Because these quasi-governmental bodies are somewhat slow in responding to changes, many products are not tested properly or involve old materials. In the 1970s, Clinical Research Associates (CRA) started a private testing program. Although its testing program is acceptable, there are flaws in it because dentists do not conduct the tests, so they are not always clinically relevant.

In the early 1980s the Dental Advisor offered a testing program along the same lines as those used by CRA or universities. The main researcher behind that program was not a dentist. REALITY Publishing Company (www.realityesthetics.com) came on the scene in 1986. The goal of REALITY is to test products in a more clinically relevant manner, as used by normal dentists in normal practices.

REALITY follows a three-pronged attack method. First, the products are tested in the REALITY research lab, which is staffed primarily by research dentists plus some auxiliaries who handle non-dental activity. The products are tested in a controlled manner using techniques that match clinical techniques as closely as possible. *There is always a gap between laboratory and clinical views, but the techniques are designed to simulate the clinical situation as closely as possible.* Second, 38 clinical evaluators throughout the world, with various types of experience and academic credentials, are used to obtain a good geographic balance between clinical and academic, scientific and practical assessments. This yields a variety of opinions on these materials, products, and equipment. Third, the scientific literature is reviewed even though much of it has little relevance to clinical practice.

RELATING FUNCTION AND ESTHETICS

When a material or product is used during a clinical procedure, it is important to understand its function as well as its esthetics. REALITY grades materials every year, and the clinical evaluation team fills out a new online comprehensive survey form. A product might initially work quite well. The evaluator may place a composite, for example, finish it, polish it, and see that it looks great. However, a year later the evaluation rating process is repeated, and if the restoration does not appear as good, the evaluator will downgrade the original rating. Esthetics and function obviously go hand in hand. In the laboratory, products are tested from a property standpoint, a handling standpoint, and a clinical standpoint. When these products approach their expiration date, they may be retested. The goal is to make sure that the expiration dates offered by the manufacturers are accurate.

CLINICAL CONSIDERATIONS

Indications

What drives product use is most often the product's advantages over previous products in that category. For example, resin cements were originally modified lower viscosity composites. It was still necessary to etch teeth, place some kind of adhesive, and then use the resin cement either in a light-cure situation or mixed by hand and used in a self-cure situation. Resin cement has morphed to include self-etching primers and eliminate the etchant. Going from using an etchant to primer to the cement is three steps. Now the driving force is the ability to use only two steps, which is easier, faster, and less complicated. Those are factors that always play a part. The latest rendition in resin cement would be the self-adhesive versions, in which not only the etchant but also the primer is eliminated. At least some resin cements are just as easy to use as a more conventional or traditional cement in which the tooth is simply cleansed before the restoration is cemented. Driving product use are (1) ease of use, (2) how fast it can be used, (3) the complications involved, and (4) the clinical results. If the product performs well, is simpler, is easier to use, and meets or exceeds the advantages of a previous-generation product, it will be used.

Contraindications

Unfortunately these same factors also drive the contraindications. Often in dentistry when steps are cut out, the efficacy of the product is diminished. Sometimes the decreased efficacy is not clinically apparent and is not a big deal. Continuing with the example of a resin cement, use of etchant, primer, and cement may have been "overkill." Although it was not necessarily hurting anything, it made the process too complex, increasing the risk of complications and the chance that something would go wrong. Through simplification of the process, fewer things could go wrong. However, if the simplification process makes the product perform below a threshold level of clinical

همیار دندانسازان و دندانپزشکان

acceptance, problems may develop. For instance, using the example of self-adhesive resin cements, several have already been taken off the market because of poor performance. Other complaints have been made about products that remain on the market. Simplification can drive product development but may have a downside to it, so it is a double-edged sword.

MATERIAL OPTIONS

Both clinical and laboratory evaluations can bring out differences in materials that appear on the surface to be very similar. For example, continuing with the example of cements, one cement may have a longer working time than another cement. That longer working time will be revealed both in the laboratory evaluation and in the clinical evaluation. When the dentist typically seats only one or two restorations at a time, that long working time for cement is probably not important. However, if the dentist seats multiple restorations at one time, requiring a longer working time, these evaluations will distinguish between materials. In seating multiple restorations, if the cement starts to set during the procedure, it is a major issue to clean it out of the restoration, especially if some of these restorations are already being seated on preparations—they do not go all the way down. Just considering this one parameter, *the clinical evaluations combined with the laboratory testing can significantly influence the choice between what seem to be similar materials.*

Today in dentistry many products are made by one manufacturer but placed on the market under different names. This is the "clones phenomenon." It is not dissimilar from what is done for products in supermarkets when a particular item is made by a well-known branded manufacturer but offered under both that brand name and a store brand. The products are exactly the same, but one is cheaper than the other. The problem in dentistry is that if the clone is used, the dentist does not know who makes the product. That becomes a problem if an untoward effect occurs. It becomes much more difficult to trace it.

Regarding clones, or very similar products, it is preferable to have dentists use branded merchandise made by the manufacturer listed on the box for critical procedures. This includes cement and composite, among other products. Off-brand or clone-type merchandise is acceptable when it comes to things like paper products or anesthetics. It is clear immediately after an anesthetic is used whether the patient is numb or not, so that is generally not an issue. When the dentist's reputation is linked to a specific product and it fails, the result is bad for both dentist and patient. For critical procedures, clones are not indicated.

With regard to the evaluation process, dentists can assess anything in their own offices. If they choose they can purchase two or three similar products, such as headlamps or magnification loupes, to test because most of these manufacturers actually allow dentists to use their products for up to 30 days. If the dentist does not like the product, it can be returned. When it comes to restorative products, most cannot be easily changed out without risk and patient displeasure. With these, if the dentist chooses incorrectly, both dentist and patient will be inconvenienced and the dentist will be out significant production time, which will cost money and goodwill with the patient. In selecting products for more or less definitive restorations, *most dentists are better off relying on an evaluation service such as REALITY.*

INNOVATIVE ELEMENTS

One of the weaknesses of composite materials is their shrinkage. Over the last 20 years or so there has been a concerted effort by manufacturers to produce composite materials with lower shrinkage, which presumably will reduce stress at the margins, leading to lower leakage levels, less opportunity for recurrent caries, and less sensitivity potential. Some evidence shows that composite shrinkage can actually fracture enamel margins, producing untoward effects. Many new composites advertise low shrinkage or low stress. Shrinkage is one issue, but if a product shrinks less but the stress at the margin is not reduced, the shrinkage is probably of little or no import.

With low shrinkage, typically something else is sacrificed. Some low-shrinkage materials have other undesirable effects. For example, one of the lowest-shrinkage materials currently on the market shrinks about 1%, whereas most conventional composite materials shrink about 3% or 4%. A 1% shrinkage is a fairly significant advance over the old material, but there are also problems with this particular material. First, it requires a special adhesive. Because it has a new monomer system, conventional adhesive does not work, limiting use by type of adhesive. Second, the material does not cure well. It is quite opaque and requires extended light curing. This particular material is marketed for posterior use, and it does not cure well at the bottom of the proximal box. Third, this particular product has a high exotherm, so heat is produced during curing not by the curing light but through the exothermic reaction itself. Those three factors alone raise eyebrows as to whether having low shrinkage really offers sufficient advantages. The product may be adding disadvantages on one end even though it offers an advantage on the other end. Whenever there are technical leaps into new territory, it is wise to be aware of the downsides that accompany these advances.

From a scientific perspective, low shrinkage seems good in all regards. The less a material shrinks, the better the results compared with materials that shrink more. On the other hand, from a clinical perspective, there may be no advantages. The practicing dentist may not realize any benefits. Many newer materials shrink 2%. Going from 2% down to 1% could be said to halve the shrinkage. However, it must be determined whether that 1% will really pay off from a clinical perspective. Materials that shrink 2% are still a major advance over materials that shrink 4%, for example. Even clinical studies showing the benefits of low-shrinkage materials are quite difficult to conduct, difficult to track, and hard to analyze properly. It is necessary to look at them over a period of perhaps 5 years, but no manufacturer does a 5-year study because it is too expensive and competition is too stiff. Many materials are brought onto the market based on short-term studies, maybe 6 months or a year, and they may not be compared—meaning no control material was included in the

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study. About the only thing such studies do is place a 1% shrinkage material in 50 teeth and recheck at the end of 6 months or a year. If the teeth are still doing well, researchers state that the material performs well with little marginal leakage or few gaps detected at the margins and note whether the material met other criteria. In essence, the material is compared with older materials, so advances are much more difficult to analyze.

ARTISTIC ELEMENTS

Polishing is easy to test. Tests of translucency and opacity of materials show clearly which materials have a dentin-like opacity and which have an enamel-like opacity. For an incisal edge it is possible to look at the translucency of incisal-type material. Those types of aspects are easily determined with a great deal of precision. However, it is not possible to test the elusive chameleon effect that many composites claim to have. Those types of tests must be done in a clinical situation. It is difficult to even try to do them on extracted teeth because extracted teeth do not exhibit the same type of optical properties as vital teeth in patients. The same thing applies to fluorescence. Fluorescence of material is an artistic or physical property area that is highly relevant to certain categories of individuals who are in the performing arts, in broadcasting, and so on. Fluorescence testing done by manufacturers has used a black light on disks. If the material glowed, it was classified as fluorescent. The problem with such tests is that it is possible to have a material that fluoresces too much or not enough. Fluorescence of material is now tested in live models. Non-vital teeth fluoresce differently than vital teeth. Overall, some artistic elements can be tested very precisely whereas others are more difficult and elusive to test.

TREATMENT PLANNING

Knowing the true parameters of various dental materials can help in treatment planning. *If treatment planning is being done for an individual who is in the public eye, the treatment plan for a restorative process will differ from a plan for somebody who is not in the public eye or who has priorities that are much different.* The latter types of individuals may be more inclined to think of the teeth as something to eat with, without having much concern about how the teeth look. For such individuals the plan would focus on a stronger and perhaps less esthetic material without worrying about fluorescence, and so on.

Sequence

Knowing the parameters of materials helps with the sequence for use as opposed to instructions stated in the manufacturer's manual. There are procedures that must be followed. When the sequencing is disrupted, whether because of the manufacturer's directions, the clinician's habit, or another reason, the dentist can get into trouble. In the testing process a method is established by which the use of these products is optimized so dentists do not get into trouble.

TREATMENT CONSIDERATIONS

Knowledge of the materials and their usage and result parameters makes a difference in treatment—for example, when choosing for patients with a high caries rate. A variety of restorative materials must be assessed. Included would be an ionomer, a compomer, a giomer, and a nanohybrid, microhybrid, or microfill. *The needs of each patient must be considered. Choice of material is based on what will help that specific patient.*

For example, the author's daughter had a disto-buccal lesion on her lower left first molar. Her mother, who is an orthodontist, was preparing to place a bracket on the tooth and put her into orthodontic treatment. The author chose to use an ionomer because of the fluoride release and because the patient was a 10-year-old with braces who might not be as conscientious about cleaning as would be ideal. The differential diagnosis led the author to choose the ionomer material with its fluoride release despite its esthetic and surface finish liabilities, which really did not come into play in that particular instance anyway.

EVIDENCE-BASED PRINCIPLES

Both evidence-based principles and experience-based knowledge have a place in the selection of materials and techniques. Problems with experientially based decision making are that it is impossible to do side-by-side comparisons and that everyone is subject to personal biases. Dentists will look at work that they have done differently than if someone else did it. For example, the dentist may look at a restoration that he or she placed, perhaps an anterior restoration, and believe it looks beautiful. Then the dentist takes a picture and looks at it later on the computer screen or as a blow-up through a projector and sees that it is not perfect. The camera does not lie. *Looking at something from a clinical perspective is always important, but first it is necessary to know that something will work from an evidence-based standpoint.* Some laboratory-based values, as alluded to earlier, allow one to assess performance—for example, the ability of a composite on the gingival wall of a proximal box to cure clinically. Even down the road it may be difficult for dentists to look interproximally and determine whether the material was cured properly. The curing can be measured specifically as part of the laboratory testing. Ultimately both experiential and evidence-based data are necessary. The laboratory testing is done first, then the experientially based testing can be done, but it is important to have both.

CLINICAL CONSERVATION CONCEPTS

There has been a general trend toward conservation. Evaluating materials can help in selecting those that will conserve more healthy tooth structure and generally keep more natural tooth structure intact in the mouth. A dentist "owns" the carious

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material, but the patient owns the enamel. This means leaving unsupported enamel when preparing posterior teeth using such techniques as tunnel preps and other preparation configurations such as slot preparations. Another advantage of these preparations is not opening up contacts. A remineralization product recently came on the market that uses resin-based infiltration of caries-invaded enamel. The technique involved is cumbersome, but conservation of tooth structure is an appropriate goal. Some conservative techniques are difficult to actually assess in the laboratory. This is one area in which clinical testing probably is much more applicable than doing laboratory tests. For example, testing how strong a marginal ridge is over a tunnel preparation is difficult in the lab owing to the many variables such as the integrity of the remaining marginal ridges. *Clinical conservation of tooth structures is a trend all dentists should be aware of and should practice.*

MAINTENANCE

Years ago the author was an editor for a publication called *Maintaining Esthetic Restorations* (Reality Publishing, 1989). This book outlined various ways that auxiliary personnel such as expanded duty assistants and hygienists can help maintain restorations in the office. There were also hints for patients, telling them what they could be doing. The unfortunate fact is that very little of this was evidence based; there has been little information on whether, for instance, proper polishing technique will create a longer-lasting restoration. It certainly looks better and feels better to the patient and probably is retained better. There has not been much information offered nor testing done in this area. Mouthwashes and other products that contain alcohol have been tested and have been shown to potentially affect the surface integrity of various restorative materials. Even so, most of those studies were done in the laboratory and were not clinically based or even conducted using clinically relevant techniques. Maintaining restorations in the mouth either by the dental office or by the patient is still an area that needs work.

CONTROVERSIES IN EVALUATING ESTHETIC MATERIALS

The most important controversy involves how materials are evaluated and whether the laboratory testing of materials is relevant. *Some may say the clinical test is the final test and laboratory testing cannot be definitive. However, it is not possible to take a product and put it on the market based on clinical use because clinical use does not show everything that could happen.* In addition, many tests have been done by agencies whose methods and criteria have not been updated over the years, so the results probably do not really tell clinicians whether products in common use are better than less common products or whether new products are better than products that have been around for a while.

When one looks at testing from different areas and different testing centers, there may be vastly different results. However, the ranking of products in any given category is usually quite similar across the board. The difference in testing methods is responsible for the different values. Tests can be done in ways that are radically different. For example, analysis of depth of cure by most institutions and manufacturers uses the ISO method, which is a brass ring that is filled up with composite and cured from one side. It is actually a split mold. The tester opens it up, scrapes off the uncured material, measures the resultant cylinder, and then takes 50% of that height to determine the depth of cure of the composite material. However, this has no bearing on what dentists do in the mouth. A new, nondestructive test was designed using a real tooth in a modified Class II preparation that measures true hardness using a computerized and calibrated hardness machine. Testers measure the difference between the hardness of the composite at the top and at various depths. What is actually being measured is the depth of cure in a real tooth the way the dentist would actually restore it in the office. The results, however, are radically different. *The literature and some manufacturers may point out that composites can cure to 4, 5, 6, or even 8 mm deep in as little as 10 seconds. Results in real-life situations are not even close to that—the maximum is usually 2 to 3 mm.* The ranking of products may go from very deep curing to moderately deep to shallow. The ranking using other measurements may be in a similar sequence, even though the information the clinician obtains is radically different. Some calibrated tests may give the clinician a distorted view of how deeply a composite can cure.

Some manufacturers think of evaluators as thorns in their sides. However, legitimate, well-meaning manufacturers look at evaluators as a way to improve their products. Most manufacturers, even though they may not always like what evaluators say, see the value of independent evaluations. Manufacturers often convene focus groups, which are really a kind of evaluation, although not to the depth that one might like to see. Manufacturers also spend considerable time on research and development. When they are ready to introduce a product, if they receive negative comments through testing and evaluations, either clinical or laboratory, they lose valuable time. They must answer to their stockholders and consider financial aspects. Many manufacturers appreciate the information and use test results to improve their products.

There should be a cooperative effort in product testing. Product evaluation should improve the quality of materials for the benefit of the practitioner and the patient. If the evaluation shows the product to be everything the manufacturer says, then the manufacturer has more credibility and reaps a benefit. *The evaluation process can be a positive force that benefits all parties involved.*

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همیار دندانسازان و دندانپزشکان

Index

A
A Enamel composite system, 426
Abbot, C, 341-342, 342f, 343b
Abel, MG, 307-308
Abfraction, dental bonding in, 210, 210f-213f
Abrasive disks/strips, 268-269, 278, 279f, 289, 291f-292f
Abrasive particles, 269, 269f, 278-279, 288-289, 288f-291f
Abrasives, loose/paste, 270-271, 270f
Abutments, implant, 681
AccuDose NeedleTubes, 542-543
Acetic acid mouthrinse, 628, 632-633
Acid etching in dental bonding, 204
Acrylic in dentures, 562-563
Actinobacillus actinomycetemcomitans, 596, 601, 604
A-dec tooth dryer, 506
Adenosine triphosphate (ATP) levels
  in caries risk assessment, 6, 8
  low-level laser therapy and, 606
Adhesive (resin-based) cements, 547, 548b. *See also* Cements, dental
Adhesive techniques/technologies
  clinical considerations for
    caries detection and, 170-172, 171f-173f
    caries management and, 13, 13f, 25, 27-28
  conservation dentistry and, 84, 85f, 171f, 187-188
  controversies in, 188
  esthetic dentistry and, 168, 190, 191f
  for esthetic try-in, 117
  evidence-based principles for, 187
  future developments in, 188
  history/evolution of
    in 1-7th generations, 168-170, 169b, 172-177, 175f-176f
    in 4-7th generations, 190-195, 191f-199f
    in conservative dentistry, 170, 171f
  innovative elements in, 178-179
  maintenance in, 188
  selecting, 177-178, 177f-178f
  treatment planning for
    overview of, 179-180, 179f-180f
    finishing/curing in, 185-187
    at intertubular level, 185, 186f-187f
    moist/wet bonding in, 181-182, 181f
    preparation in, 182-185, 182f-184f
    surface contamination and, 185
  See also Bonding; Cements, dental
Adper Easy Bond, 256, 729f
Adper Scotchbond SE, 196f-197f
Advertisements, 770
Aesthetic pre-evaluation temporary (APT), 460-461
Age
  oral screening and, 631-632
  response to tooth whitening and, 387-388, 387f-388f
  sleep apnea and, 734
  See also Pediatric dental procedures
Aged appearance
  dental restorations for, 132-134, 133f-134f
  tooth discoloration due to, 347, 393
Air abrasion, 252, 591f, 593, 594f
Air dispersal of water, 204, 205f-206f
Airway obstruction, 705, 705f-706f, 734
Airway resistance syndrome, upper, 734
Alcohol in mouthrinses, 30-31
Alignment of anterior teeth, 216f
Alkaptonuria, 345
All-Bond 2, 169b
Allergic reaction to metals, 510
AlloDerm, 664
Aluminum-oxide paste/particles, 228, 231f, 278-279
Amalgam cores, 485, 485b
Amalgams
  advantages/disadvantages of, 413
  to composites, 191f, 255
  versus composites, 256
  inlays/onlays to replace, 472f
  limitations of, 81
  retreatment for old, 250-251, 250f, 253-255, 253f-255f
  tooth discoloration due to, 393
  use of, 469
Amelogenesis imperfecta, 345, 345f
American Academy of Cosmetic Dentistry (AACD) examination, 55, 55f-58f
American Academy of Pediatrics, 706
American Academy of Periodontology, 604, 607-608
American Academy of Sleep Medicine, 733-734, 738
American Dental Association (ADA)
  caries criteria by, 17
  caries risk assessment form by, 5-6
  dental cement classification by, 538
  dental materials tests by, 785-786
  research unit of, 33, 34f
Amorphous calcium phosphate (ACP), 394
Anderson, John, 560
Angle, Edward, 698
Anterior direct composites
  beveling/contouring/finishing, 227-228, 227f-230f
  class IV restorations for, 232-236, 236f-243f
  color/shade of, 226-228, 226f
  considerations for
    clinical, 219-220, 219f-222f, 233
    treatment, 220-224, 235
  controversies in, 235
  future developments in, 231, 235
  handling properties of, 226
  histological approach to layering, 423-435, 431f-435f
  history/evolution of, 214
  maintenance regimen for, 228-231, 231f, 235
  material options for, 215-216
  minimally-invasive and esthetic, 214, 215f-216f, 224
  morphology (artistic elements) of, 224, 225f
  opaquing system for, 216-218, 217f
  in smile design, 224-226, 226f
  tints and, 218-219, 218f
  treatment planning for, 220-224, 223f-224f, 234-235
Anterior Sagittal Appliance, 694f-695f, 697-698
Anterior teeth
  alignment of, 216f
  primary, 719-720, 721f
  young permanent, 719, 725f-728f
Antimicrobial therapy
  in caries treatment, 3, 5, 8-9
  in periodontal therapy, 663-664, 666, 684
Apically repositioned flap, 671, 672f-673f
Apnea, obstructive sleep
  functional appliances for, 703-704, 703f-704f, 706-707
  oral appliance therapy for, 733-739, 735f-738f
Apnea defined, 706
Apnea-hypopnea index (AHI), 706, 706t
Appliances, functional
  after restorations, 31
  caries risk and, 24
  clinical considerations for
    crossbite in, 692-693, 694f-695f
    lower posterior teeth upright in, 693, 696f
    maxilla positioned correctly in, 687, 689f-690f
    maxilla/mandible relationship in, 689-690, 691f-692f
    maxillary incisors inclination in, 690-692, 693f
    maxillary width in, 686, 687f-688f
    vertical dimension in, 693-695, 697f-698f

Page numbers with "t" denote tables; "f" denote figures; and "b" denote boxes.

WWW.HIGHDENT.IR
همیار دندانسازان و دندانپزشکان

Appliances, functional *(Continued)*
esthetics and
facial, 707-708
improving, 704-706, 705f
relating, 686
history of, 685-686
innovations in orthodontics and, 708-709, 708f-709f
orthodontic treatment for
planning, 706-707, 706f, 706t
using, 695-699, 695t
treatment considerations for
Class II skeletal malocclusions in, 699-703, 700f-702f
philosophies of orthodontic, 699
sleep apnea/ADHD in, 703-704, 703f-704f
See also Oral appliance therapy
Arch. *See* Maxillary arch, developing.
Arestin. *See* Minocycline-impregnated microspheres.
Arm and Hammer Baking Soda products, 5
Artglass indirect resin restoration, 497
Articulator in smile design, 103, 108-109
Artiste composites, 425
Artistic elements, 788
Aschmann, F, 272-273
Aseptim Plus
about, 582-583, 585f, 593
for photoactivated disinfection, 619, 621f, 623f
techniques for using, 623-624, 624f
Asmussen, Erik, 190
Astropol polishing tip, 269, 506
Astroquartz, 323
Atopobium, 1-2
Atridox. *See* Doxycycline-impregnated spheres.
Attachments, precision/semi-precision, 575-581, 576f-579f
Attention-deficient/hyperactivity disorder (ADHD), 703-704
Aurum Group (Alberta), 767-768, 770
Authentic pressable all-ceramic porcelain, 498
Auto-fluorescence, tissue. *See* Fluorescence visualization technology.
A-Z cements, 550

B

Bacteria
culture of, in caries risk assessment, 6
dental plaque and, 14, 14f
salivary secretion and, 24
See also Biofilm, dental
Bacterial infection, cariogenic
diagnosing, 26-27, 26f-27f
diode laser for, 601, 603f, 604, 612, 612f
evolution of strategies for, 1-2, 582-583, 585f
innovative strategies for, 9
minimally-invasive treatment of, 595-598, 596f
photoactivated disinfection for. *See* Photoactivated disinfection (PAD)
restorative dentistry and treating, 1, 26-28, 246-247
Baking soda, restorations and, 514
Bands, circumferential matrix, 262
B-cycle sterilizer, 748-749, 749f
Beam theory, 305-306, 305f
BeautiBond, 85f, 169b, 198f-199f, 209-210
BEAUTIFIL Flow, 117f, 211f-212f, 583f-584f
BEAUTIFIL II, 210, 213f
Beauty therapists/spas for bleaching, 392, 399
Behavioral changes
of biofilm, 9
of habits, after restorations, 31
as modifiable risk factor, 5, 25
as treatment strategy, 2
See also Patient involvement/expectations
belleGlass composite, 424
belleGlass indirect resin restoration, 497
Belvedere, PC, 304, 307-309
Beresin, VE, 561, 563
Bertollotti, Raymond, 169
Beveling anterior restorations, 227-228, 227f
Beverages. *See* Foods/beverages, chromogenic.
Biclear Matrix Systems, 247
Biofilm, dental
CAMBRA and, 8-9, 26
caries as disease of, 1-2
dental plaque and, 15
dentures and, 564
risk factors and controlling, 5-6
Biohazard symbol, 755f, 756
Bioluminescence technology, 6
BioMers colorless wires, 709
Biopsy, brush, 629-630
Biozonix water ozone system, 583f-584f, 594f
Bis-acrylic composites
in layering direct composites, 427
for provisional restorations, 102-104, 103b, 104f, 109
BisCem (cement), 542-543
BisCover resin, 506
Bisphenol A glycidyl methacrylate (BIS-GMA) resins, 110
Bite change, 734-735
Bite patterns, porcelain laminates and, 436
Bite registration
for esthetic try-in, 120-124, 120f-121f, 130f
for oral appliance therapy, 738, 738f
for smile design, 107
Biting, after restorations, 31
Black, GV
about, 1-2, 12, 27-28
composite preparation style of, 252-253, 253f
"Black diamonds", 670
Blades, 680
Bleaching bar kiosks/spas, 392
Bleaching lights, 362-363, 363f-364f
Bleaching of teeth
artistic elements of, 388, 388f, 395
case presentations of, 400-401, 400f-401f
clinical considerations for, 343-348
differentiating stains in, 344-348, 344b, 393-394
existing restorations in, 387-388
existing tooth sensitivity in, 388-389, 397-399
indications/contraindications in, 344-348, 385, 393-394, 394b
conservation concepts in, 378-379, 390, 399
controversies in, 379-381, 390-391, 399
esthetics/function of, 343, 384-385, 392-393
evidence-based principles for, 374-378, 375f-378f, 390, 399
future developments in, 381-382, 381f-382f, 391, 399
history/evolution of, 132, 341-343, 342f-343f, 343b, 384, 392
at-home considerations for, 352-360
innovative elements in, 354-358, 355f
long-term stability in, 353-354, 354f
safety and, 352-353, 353f
at-home material options for, 348-352
custom-fabricated tray as, 342f, 348f-351f, 349-351, 355-358, 356f-357f
over-the-counter kits for, 362, 385f, 386, 386t, 392
pre-fabricated double tray system as, 349f, 351-352, 351f
tray-less strip system, 349f, 352, 352f, 358, 359f, 384
Bleaching of teeth *(Continued)*
at-home treatment planning for, 358-360
categories of, 397
professionally dispensed, 386, 386t
self-directed, 362, 386, 386t, 392
side effects of, 397
innovative elements in, 362, 387-388, 387f-388f, 395
maintenance regimen for, 379, 380f, 390, 399
in-office material options for, 360
advantages/disadvantages of, 360-361, 394
bleaching lights as, 362-363, 363f-364f
carbamide peroxide concentrations in, 394-395
complications with, 361
current best approach using, 361-362, 394
in-office techniques for
advantages/disadvantages of, 385-386, 388
classifications of, 395, 395b
dry, with light, 368-370, 369f
with lasers, 364-366, 367f
power, with heat/light, 364-366, 365f-366f, 397, 398b
professionally administered, 362, 385, 386t
to remove mottling/white spots, 371-374, 372f, 386-387
sequence of, 389
wet, with light, 370-371, 370f
in-office treatment planning for, 389-390, 389f, 395-397
patient behavior and. *See* Patient involvement/expectations
in pediatrics, 723-724, 725f
Bleaching pens/rods (paint-on), 382, 382f
"Bleachorexia", 399
Blood thinner medications, periodontal therapy and, 664, 677
Bohr, Niels, 611
Bond 1, 169b
Bond Force, 169b, 209-210
Bonding
dentin
in abfracted lesions, 210, 210f-213f
of ceramic/resin veneers, 210
chemistry of agents for, 178
clinical effect of acid on, 209, 209f
esthetic dentistry and, 190
generation 4-7 agents compared for, 190-197, 194f-199f
history/evolution of, 190-197
need for moist/wet, 181-182, 181f
sensitivity after, 206-209, 207f-208f
total-etch/self-etch agents for, 197-201, 200f, 256, 502-503
total-etch/self-etch procedures for, 201, 202f-203f
dentures and, 563
direct composite
about, 405-410, 410f
histological approach to layering, 423-435, 431f-435f
See also Anterior direct composites; Posterior direct composites
transitional
controversies in, 421
esthetics/function of, 411-412, 412f
evidence-based/conservation principles of, 421
financial considerations for, 414
future developments in, 421-422
history/evolution of, 411
indications/contraindications for, 412-413

Bonding *(Continued)*
transitional *(Continued)*
innovative elements in, 414
maintenance regimen for, 421
material options for, 413-414
treatment considerations for, 415-421, 419f-420f
treatment planning for, 414-415, 416f-417f
See also Adhesive techniques/technologies
Bone grafts
innovative materials for, 679-680, 684
types of, 666, 671, 678
Bone loss/resorption
dentures and, 562, 643
tooth extraction without, 681, 682f-683f
Bone morphogenetic protein (BMP), 677, 679-680
Bone regeneration, 677-678, 684
Boucher, Carl, 560
Bowen, Rafel, 33, 34f
Bowen, Ray, 320
Bowles, WH, 361
Braces
clear, 709, 709f, 712-713
lingual, 712-713
Brackets
ceramic, 713-714
ligature, 713
self-ligating, 713-714, 715f-717f
Brånemark, Per-Ingvar, 680
Breakage of prosthesis, 562
Bridges, fiber-reinforced
anterior, technique for, 309-314, 310f-313f
conservation concepts in, 308-309
fabrication of, 309
indirect/direct, 307-308
mechanisms of failure of, 306
posterior, technique for, 314-315, 315f-316f
provisional, technique for, 315-316, 317f-318f
British Columbia Cancer Institute, 618
British Dental Association, 741, 743b
Brundo, GD, 107-108
Brushing after restorations, 30
Bruxism
after restorations, 31, 503, 509
dentures and, 562, 564
sleep apnea and, 733-734, 736-738
TMJ and, 693
BruxZir restoration, 503
Buonocore, Michael G, 190, 191f, 214, 309, 320, 582
Burlew Wheel, 206
Burns, skin, bleaching and, 361
Burs. *See* Fissurotomy burs.
Burstone, CJ, 304
Butler rubber tip, 507

C

Calamia, John R, 459
Calcific metamorphosis (CM), 393
"Calla lily" Class I preparation, 254-255, 255f
Cameras
body/lens of, 53, 63-64, 64f
brands of, for dentists, 54, 62, 62f, 71
color to black & white feature of, 65, 65f
entry-level digital SLR, 52, 52f, 62, 62f
flash/focus of, 53-54, 53f, 62-65, 63f-65f, 71
light metering of, 54
multiple, in office, 53
Camphorated paramonochlorophenol (CMCP), 597
Canary System for caries detection, The, 20, 21f, 596f
Cancer, screening for oral, 629-632, 631b, 632f
Candida albicans, 2
Captek, 511, 511f, 516
Carbamide peroxide
concentrations of, 394-395
evidence-based principles of, 374-377, 376f-378f, 395
mint-flavored gel, 354-357, 355f
mouthrinses, 354
in-office use of, 360
safety of, for home use, 352-353
Carbide bur, 288-289, 289f-290f, 298f
Carbohydrates, control of, 26. *See also* Sugar intake
CareCredit program, 770
Caridex chemical dissolution system (not available), 252
Caries management by risk assessment (CAMBRA)
case examples of, 9f-10f
clinical conservation concepts in, 8-9, 21f
controversies in, 9
evidence-based principles in, 8
future developments in, 9
maintenance and, 9
restorative dentistry and, 26-27, 26f
Caries risk assessment
in dental restorative patients, 23-25, 24f
evolution of, 1-2
form for, 5-6, 7f
indications for, 2
innovative strategies for, 6
orthodontic treatment and, 713
patient-specific information in, 6
restorative dentistry and
esthetic outcome of, 6-8
outcome of, 5
relevance of, 1-2
treatment plan based on
controversies in, 9
evidence-based principles for, 8, 14-16, 24
future-developments in, 9
maintenance in, 9
modifiable/non-modifiable factors in, 6
options/sequence in, 8, 9f-10f
using conservation concepts, 8-9
CarieScan PRO, 22-23, 23f, 596f
Caries/carious lesions, dental
ADA criteria for, 17
as bacterial infection, 1-2, 26-28
detection of
adhesive techniques and, 170-172, 171f-173f
auto-fluorescence technology for, 611-612, 612f
ICDAS for, 3, 4f
traditional versus contemporary, 3, 16, 16f
diagnostic tools for, 17-23
etiology of, 14, 14f
larger, inlays/onlays for, 469
management of
evolution of procedures for, 1-2, 12-13
technology and. *See* Minimally-invasive dentistry.
traditional versus contemporary, 13-16
medical model of
changing to, 26
incorporating, 27
innovative elements in, 6
versus surgical model, 1-3
posterior direct composites and, 246-247, 250f, 252
preparation tools for, 590-593, 591f-592f
preparing single-surface occlusal, 585f-586f, 592f
risk factors for
explained, 23-25
identifying, 25
modifiable/non-modifiable, 6
time and formation of, 15
treatment options for, 2-5, 252. *See also* Ozone technology; Photoactivated disinfection (PAD)
CariFree products, 5
CariFree Treatment Rinse, 3
CariScreen meter, 27, 27f
CariScreen score, 6, 7f, 8, 9f-10f
Case acceptance. *See* Consultation.
Case presentations/studies
bleaching
fluorosis stains, 401, 401f
at-home single-tooth, 400, 400f
caries risk (high/low), 9-10, 9f-10f
class IV anterior restorations, 236, 236f-243f
denture fabrication, 565-573, 565f-573f
direct veneers
composite bonding of, 410, 441f
histological approach to layering, 430, 431f-435f, 433
facelift, nonsurgical, 133-134, 134f
fiber reinforcement
using GlasSpan natural tooth bridge, 323-326, 324f-327f
using GlasSpan reinforcement with tissue replacement, 331-334, 332f-335f
using GlasSpan Trauma Kit, 328, 329f-330f
fractured incisor, 667, 667f
gingivectomy to enhance perioesthetics, 668-669, 668f-669f
implant-supported denture, 648-662, 649f-662f
inlays/onlays, esthetic, 475, 475f-480f, 478, 480
porcelain veneers (indirect)
inserting using Griptab system, 456-458, 456f-457f
laminate, 464, 464f-468f
technique for, 441-448, 441f-442f, 444f-448f
posts/cores, esthetic, 492, 493f-495f
smile design, 107-108
Cavitron THINsert tips, 665
Cementation
artistic elements of, 556
clinical considerations for, 551-552, 552f
of composites
about, 41, 42f
color change and, 143, 143f, 148-149, 153t
if posterior direct, 250-251
definitive versus permanent, 537
dual-cure resin
controversies in, 558-559
current best approach using, 554, 555f-556f
maintenance regimen for, 558
treatment planning for, 556-557, 558f
See also Curing systems
history/evolution of, 72, 73f, 496, 547-551, 548f-550f
retrievable, 550-551
strength/margins/color in
conservation concepts in, 558
esthetics/function of, 547, 548f, 551, 551f
evidence-based principles for, 557-558
Cemento-enamel junction (CEJ), 670, 671f, 674f, 680

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همیار دندانسازان و دندانپزشکان

Cements, dental
classification of
ADA/ISO categories of (3), 538-545
applications of each, 539t
brands listed in each, 540t
traditional categories of (2), 547, 548b
esthetics/function of, 537-538
material options based on properties of, 538, 538b
oil-based, 538
resin-based (adhesive)
about, 547, 548b
advantages/disadvantages of, 552-553, 553f
clinical considerations for, 551-552
compomers as, 255, 486, 486b
composite (light-/self-/dual-cure) types of, 538, 542, 550, 550f, 552f, 554
composite (one-step) type of, 550, 550f, 554, 558-559
etch-and-rinse adhesive as, 542, 543f-544f
recommendations for, 543-545
self-etch self-adhesive as, 41-42, 42f, 502, 542-543, 545f
translucent (dual-cure) type of, 82-83, 83f, 85, 86f, 554
water-based (luting)
about, 538, 547, 548b
glass ionomer type of, 486, 502, 540-541, 549-551, 549f
resin-modified glass ionomer type of, 73f, 486, 541, 541f, 549-550, 549f
zinc phosphate type of, 72, 73f, 486, 547-551, 548f, 558-559
zinc polycarboxylate type of, 549-551, 549f
See also Adhesive techniques/technologies; Bonding
Centers for Disease Control and Prevention
on HPV and oral cancer, 630-631
on infection control, 741, 743b
CeraGlaze porcelain polisher, 506-507
Ceramic crown
in pediatrics, 724
posts/cores and, 483
Ceramic systems, commercial, 471t
Ceramics, dental
bonded, 82-84, 82f
compared to other materials, 81, 81f, 413
in esthetic try-in, 110
future developments in, 98
history/evolution of, 72, 73f
materials for polishing, 279-280, 284f
pressed, 437-438, 440
for single-tooth restorations, 497-503
See also Porcelain restorations; Porcelain-fused-to-metal (PFM) restorations
Ceramists. *See* Lab technician/dental labs.
Cercon restoration, 502
CEREC crowns/overlays, 705
CEREC inLab restoration, 502
CEREC milling machine, 474, 516-517, 519
CERECi milling machine, 508
Cerestore single-unit crown, 496
Cermets, 485
C-factor (configuration factor), 246, 247f-250f
Chairside bleaching defined, 360
Chairside Oral Scanner C.O.S., 503-504
Chairside restoration technology. *See* Computer-aided design/manufacturing (CAD-CAM) technologies.
Change Your Smile (Goldstein), 12
Chapple, 341, 343b
Charting, dental
periodontal, in smile design, 107
photography for, 51
See also Documentation, clinical
Chayes, HES, 73, 378f
Chemotherapeutic agents in periodontal therapy, 684. *See also* Chlorhexidine
Chemotherapy and tooth bleaching, 394
Cherchève, Rafael, 680
Chewing
after restorations, 29-30
and dentures, 562-563
Chewing simulator. *See* Articulator.
"Chiclets look", 90, 91f, 419
Child. *See* Pediatric dental procedures.
Chlorhexidine
for caries treatment, 3, 5
for periodontal treatment, 684
in restorative dentistry, 27
Chlorhexidine gluconate, 30-31
Chlorhexidine varnish, 30-31
Chlorhexidine-impregnated collagen strips, 666
Chlorine dioxide, 399
Circulatory insult
restorative dentistry and, 247
tissue regeneration and, 684
Clark, William, 701
Clark Class II restoration
posterior direct composites and, 245f, 250f, 252, 253f
preparation for, 584f
Cleaning, teeth, 17, 30, 98
Clearfil SE Bond, 209-210
Clinical case presentations. *See* Case presentations/studies.
Clinical evidence. *See* Evidence-based principles.
Clinical excellence, 781-782
Clinical Research Association (CRA), 786
Cohen, G, 280-281
CoJet silica coating, 503
Collagen membranes, 675-676
Color and shade of teeth
anterior direct composites and, 216f, 222f, 226-228, 226f
artistic elements of, 148-149, 149f
cements and esthetics of, 547, 548f, 551, 551f
clinical considerations for matching
additive system in, 140, 140f
color perception and, 139, 142-143, 142f-143f, 143t, 149, 149f-150f, 153t, 154-155, 154f-155f
importance of, 137-138
metamerism in, 142f, 143-145, 144f-145f
subtractive system in, 140-141, 140f-142f, 141t
traditional/digital techniques and, 138-140, 138f-140f
communicating, 532-533
devices for selecting
digital shade-matching, 139-140, 140f
digital shade-scanning, 137f, 145-148, 145f-148f
in esthetic dentistry (overview), 135
future developments matching, 153-154
history/evolution of using, 135-137, 136f-138f, 144f
selecting
evidence-based principles for, 139f, 152
overall technique for, 137f, 150, 150f-151f
preparation/documentation and, 150-152
troubleshooting problems with, 152-153, 153t
single-tooth restorations and, 504
in smile design, 102, 102f
Color and shade of teeth *(Continued)*
systems available for taking
overview of, 154-155
VITA Easyshade Compact, 146, 146f, 154, 158-159, 159f-160f
VITAPAN 3D-Master Shade, 139f, 154, 156-158, 157f-158f
VITAPAN Classic Shade Guide, 139f, 154-156, 155f-156f
tooth whitening and, 358
using, to create restorations
clinical technique for, 164-167, 164f-167f
considerations for, 162
indications for, 161
material options for, 161-162
relevance/history of, 161
treatment planning for, 162-164
See also Lab technician/dental labs
Color blindness, 142-143, 143t
Color "check" at routine checkups, 354, 354f
Color map, tooth, 138, 138f, 150, 151f, 153t. *See also* Shade tabs/guides
Color of gingival tissue
after tissue grafting, 671, 675f-676f
for health and symmetry, 670, 671f, 674-675
tissue regeneration and, 678
Color wheels/organization, 135, 136f
Colorimeter, 139-140
Communication, dentist-lab technician. *See* Lab technician/dental labs.
Communication, patient
conservation concepts in, 771
esthetic dentistry and, 757, 758f
in esthetic try-in, 113f, 118-119
key terms used in, 757, 759b
photography for, 51, 60, 61f, 62, 64-65
in smile design, 101-103, 107
in tissue screening, 629
tools for, 767-768, 767f, 770, 770f
tooth whitening and, 360, 395
during treatment planning. *See* Consultation.
verbal
establishing rapport in (FORM acronym), 760-761
telephone and, 757-760, 759f, 764
video for, 532
written, 762-763
Compomers, 255, 486, 486b, 539t-540t
Composhine, 269
Composite cements. *See* Cements, dental.
Composite cores, 485, 486b
Composite stains. *See* Stains, composite/porcelain.
Composites, direct/indirect
advantages/disadvantages of
versus amalgams, 191f
for transitional bonding, 413-414
in ultraconservative dentistry, 81-82, 81f-82f
adverse health effects of (possible), 256
anterior. *See* Anterior direct composites.
components of, 34-36, 35f-36f
in dentures, 562-563
fiber-reinforced. *See* Fiber reinforcement.
filler particles in (classes of), 39-40
if hybrid, 39, 39f
if macrofilled, 39, 39f
if microfilled, 39, 39f
if nanofilled, 39, 40f
levels of, by volume, 39-40
finishing/polishing. *See* Finishing and polishing.
flowable, 427
fluoride-releasing, 43, 43f
future developments in, 44-45
history of, 33-34

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همیار دندانسازان و دندانپزشکان

Composites, direct/indirect *(Continued)*
laminate, 304
luting and cementing, 41, 42f
in pediatrics, 720-721, 722f, 724-725, 727f-729f
physical properties of, 36-39
elastic modulus in, 36-37, 37f
expansion in, 37-38, 38f
shrinkage in, 38-39, 38f, 44
strength in, 36f-37f
toughness in, 37, 38f
posterior. *See* Posterior direct composites
resin. *See* Resin composites
retreatment for failed, 250f, 253-255, 253f-255f
self-adhesive, 44
smart type of, development of, 44-45
specialized formulations of, 41, 41f
strength-resistance compromise of
if flowable, 40, 40f
if packable, 40-41, 41f
strength-resistance compromises in, 40-41
Comprepol, 269
CompuMaster, 269
Computed tomography (CT)
denture fabrication and, 564
implant-supported denture and, 646, 648-649, 649f-654f, 662f
mandibular advancement therapy and, 735
Computer software, esthetic try-in and, 130
Computer-aided design/manufacturing (CAD-CAM) technologies
for inlays/overlays, 474
for pediatric dental procedures, 725-728, 730f, 732
for porcelain-fused-to-metal restorations, 515-519
for single-tooth restorations, 497, 500, 502-503, 508
in transitional bonding, 421
in ultraconservative dentistry, 98
Computerized shade-matching system, 136-137, 137f-138f, 140f
Condylar pathway, slope of, 735
Connect fiber reinforcement, 322
Consent, patient
for dental/facial photography, 54
for tooth whitening, 396
during treatment planning, 770-771
Consepsis syringe, 585f
Conservation dentistry
50% rule in, 518
CAMBRA and, 8-9, 21f
communicating, 771
concepts in, 788-789
defined, 28
minimally-invasive dentistry as, 8-9
See also Ultraconservative dentistry
Consultation
case acceptance in, 778-779, 779b
post-treatment, 764-765
screening
patient medical history in, 752
in pre-treatment consultation, 763-765
in smile design, 107, 439
treatment planning in, 766, 770-771
See also Referrals, patient
Contact problems with composites, 247
Contamination during restoration, 185, 246-247
Contouring anterior direct composites, 225f, 228, 228f
Controversies on materials, 789
Cosmetic dentistry defined, 439
Costs
all-ceramic restorations and, 497
attachments and, 577
cementation of restoration and, 537
digital versus film photography and, 52, 60
direct composite bonding and, 407
esthetic try-in and, 116-117
financial arrangements for, 763-764, 766, 769-770, 773
of gingival allografts, 664
of implant-supported dentures, 645
of instrumentation, 745
laboratory-fabricated composites and, 81
of laser technology, 600-601
obtaining estimates of, 534
oral appliance therapy and, 735, 738
shade-matching systems and, 137, 139
in smile design, 108
tooth bleaching and, 352, 365, 388, 390
transitional bonding and, 414
types of metals used and, 510, 519
Coupling agents in esthetic try-in, 110
CPAP (continuous positive airway pressure) machine, 733, 735, 737-738
C-POST fiber reinforcement, 322
CPP-ACP (casein phosphopeptide-amorphous calcium phosphate), 2
Cracked tooth. *See* Fracture of tooth.
Crest 3D Whitestrips, 348-349, 349f, 352, 352f, 358, 381, 381f
Cristobal indirect resin restoration, 497
Crossbite, correction of, 689f-690f, 692-693, 694f-695f, 715f-717f
Crown lengthening, 671
Crowns. *See* Porcelain-fused-to-metal (PFM) restorations; Posts/cores, esthetic; Single-tooth all-ceramic restorations; Stainless steel crowns; *specific type or brand*.
Culy, G, 308
Curing
adhesive techniques and, 185-187
heated composites and, 255
polymerization shrinkage and, 246, 248f-250f, 265
Curing lights, 34, 34f
Curing systems
chemical/self cured material as, 43, 43f
comparison of, 43-44
dual-cure, 44, 44f
photoinitiator, 43-44, 44f
Curtain procedure, 670
Cynovad ShadeScan, 147, 147f, 151f, 532
Cytology, liquid, 629-630

D

Damon, Dwight, 714
Damon bracket, 714
Danville Materials matrix system, 263
de Chauliac, Guy, 341
de St. Georges, Jennifer, 781
Débridement therapy. *See* Pocket débridement laser therapy (PDLT); Scaling and root planing (SRP), laser-assisted.
Decalcification, anterior direct composites for, 215f
Demographic factors, caries risk and, 16
Den-Mat, 342-343
Dental materials. *See* Materials, restorative.
Dental practice. *See* Practice management.
Dental visit, first, 761, 761f-762f
DenTASTIC UNO, 194f-195f, 211f-212f
DenTASTIC UNO-DUO, 175, 176f, 489, 490f-492f
Dentin, tooth
hypercalcification of, 393
remineralization of teeth and, 15
Dentin-enamel junction (DEJ), adhesive techniques and, 171, 172f
Dentinogenesis imperfecta, 345, 345f
Dentist
color sensitivity of, 142-143, 143t
communicating to dental lab. *See* Lab technician/dental labs
office of. *See* Practice management.
as photographer, 54
role of
in esthetic dentistry, 99, 110-111
in smile design, 101-102, 105, 107-109
in ultraconservative dentistry, 85-86
Dentistry, types of
combining, 774-775, 775b
defined, 439
Dentition
history of rehabilitation of, 72, 73f-74f
leaving mixed, untreated, 706-707
mission of dentistry versus dentures for, 561
reinforcing, using physical properties of materials, 109-110
self-image/quality of life and, 246b
showing wear. *See* Tooth wear
supervised neglect of, 683-684, 706-707
See also Tooth/teeth
DentLight DOE System, 641
DentLight Nano Loupe Light, 589f
DENTSPLY Caulk, 257
Denture adhesive for esthetic try-in, 117, 118f
Dentures
complete, 560-574, 565f-573f
implant-supported, 643. *See also* Implants, tooth
partial, 575, 576f
DeOx, 474
Diabetes, sleep apnea and, 698-699
Diaglaze, 409
DIAGNOdent, 3
Diagnostic software development, 641
Diagnostic wax-up
patient motivation and, 768f
in smile design, 101f, 102-103, 103f, 108
Diamond-containing polishing devices, 269, 278-279, 288-289
Diastema
before/after closure of, 301f-303f
anterior direct composites for, 220f
orthodontic treatment and, 712
Dicor single-unit crown, 496
Dietary habits
caries risk and, 15, 24
caries treatment and, 5-6, 26
dental plaque and, 14
Dietschi, Didier, 429
Diffusion of low-viscosity bonding agent, 204, 205f-206f
Digital fiberoptic transillumination (DIFOTI), 19
Digital impression systems, 503-504, 508, 519
Digital photography. *See* Photography, dental.
Digital shade-matching devices. *See* Shade-matching devices, digital.
Digital transitional bonding system, 421-422
Diode lasers
about, 604
affordability of, 600-601
ease of use of, 600
efficacy/safety of, 604-605
future developments in, 618
indications for, 601, 602f-603f, 612, 612f-613f

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همیار دندانسازان و دندانپزشکان

Diode lasers *(Continued)*
for periodontal treatment, 601, 603f, 604, 606-609, 607f
protocol for use of, 605-606, 605f, 608f, 609
science of, 600, 601f
Discoloration of teeth. *See* Stains, tooth.
Disease management. *See* Caries management by risk assessment (CAMBRA); Medical model of caries.
Disinfection
defined, 747t
esthetic dentistry and, 751-756, 752b, 753f-755f. *See also* Infection control; Sterilization
options for, 750t
Disputes, patient, photography for, 51, 60, 64
Documentation, clinical
to accompany photography, 532, 534
check list for, in smile design, 108
photography for, 51-52, 54, 60, 61f, 62, 430, 535, 536f
of shade-matching, 152, 533
of tooth whitening, 358, 396
using multimedia, 532
Doxycycline-impregnated spheres, 664, 666
Drawing
occlusal sketch versus photographing, 52
over preoperative photos, 102-103, 103f
Drinking after restorations, 30
Dubbe, JW, 272-273
Dyer, SR, 305
Dysplasias, screening for oral, 631

E
E4D milling machine, 474, 508, 516-517, 519
Eakle, WS, 210
Easy Bond, 251-252
Eating after restorations, 29-30
Edentulous patients
caries risk assessment and, 2
dentures and, 560-561, 563
oral appliance therapy and, 736
Education, patient/practitioner
center for laser, 603-604
photography to increase, 51
in ultraconservative dentistry, 86, 94-95
Elden, LM, 704
Electric handpieces to remove old dental work in smile design, 108
Electrical caries monitor (ECM), 596, 596f
Electrical conductance, caries detection and, 19
Electrochemical impedance spectroscopy (EIS), caries detection and, 22-23, 23f
E-mail communication, 770
e.max restorations. *See* IPS e.max restorations; IPS e.max Press restorations.
Embletta X100 home sleep study, 703
Embrace Dual Cure Cement, 82-83, 83f, 256
Empress restorations. *See* IPS Empress. restorations; IPS Empress II restorations.
Endodontic treatment in minimally-invasive dentistry, 597
Endodontics, restorative dentistry and, 28, 29f-31f
Endosseous implants, 680-681
Enhance points, 269, 517-518, 715
EP Esthetic Polishing System, 269
Epic, 5
ERA Attachment System, 644-649, 644f-645f, 651f-654f, 656f-659f
Erythroblastosis fetalis, 346
Essential oils/ethyl alcohol for caries treatment, 3
Essix retainer, 715
Esthetic dentistry defined, 439
Esthetic Inlay/Onlay bur kit, 473
Esthetic inlays/onlays. *See* Inlays/onlays, esthetic.
Esthetic restorations
after caries assessment, 5-8
chairside, future developments in, 98
evolution of, 132, 191f
histological approach in, 423-435, 431f-435f
posterior direct composites and, 244, 245f-246f, 252
self-image and, 246b
See also Restorations, dental
Esthetic try-in (ETI)
esthetic dentistry and, 110-111, 111f-113f
evidence-based/conservation principles of, 124-130, 130f-131f
future computerized developments in, 130
indications for, 116-117, 120
innovative tooth guide for, 119, 119f
material options for, 117-118, 117f-118f
previewing/assessing
esthetic sense via, 111-116, 113f-115f
occlusal relationships via, 115, 115f-116f
size and shape via, 115-116, 116f-117f
treatment planning for, 120-124
analyzing facial shape/size in, 121f-129f
artistic/scientific approach to, 119-120, 130
communication with lab in, 118-119, 119f, 130f
equipment for, 120f-121f
sequence of, 120
using composite mock-up, 769, 769f
Esthetics
evolution of, 132
rules of
artistic/scientific approach to, 105-107, 105f-107f, 106b
history of, 99-100, 100f
Esthet-X HD composite system, 424-426
ET Carbide Finishing Kits, 228f
Etch and rinse cements. *See* Cements, dental.
Etch-Rite, 194f-195f, 582, 583f-584f
Ethnic populations, incidence of malocclusions in, 699
Ethyl alcohol, caries treatment and, 3
Ethylene glycol dimethacrylate (EGDMA), 427
Eugenol, 538, 539t
Evaluation of esthetic materials, 785-789, 785b
Evidence, photography as, 58-59
Evidence-based principles
of esthetic materials, 788
indicating surgical intervention, 3
of medical model of caries, 26
of minimally-invasive approach, 3
of treatment by risk assessment, 8-9
Examination, visual
clinical tactile method of, 17
described, 17
efficacy of, 3
illumination for, 589, 589f, 593
isolating working field for, 589-590, 590f, 593
magnification loupes for, 587-593, 587f-588f
meticulous clinical method of, 17
with temporary tooth separation
alone, 17
and impression of the approximal lesion, 17
ExciTE F bond, 169b, 175-176
Exhaustive technique for denture fitting, 563
Expectoration. *See* Spitting and dentures.
Explorer tip. *See* Probing instrument.
Extreme Smile Makeover Kit, 767f
Eyck, Jan van, 136, 137f
E-Z Temp Inlay/Onlay, 474
ezlase 940, 601, 607f, 609

F
Face lift, dental restorations as non-surgical, 132-134, 133f-134f
Faceplate. *See* Tooth guide/indicator and faceplate for esthetic try-in.
Facial esthetics
ortho-esthetics and, 685, 707-708
proportions in, 408, 643
Facial expressions and dentures, 563
Failed composites, retreatment for, 250f, 253-255, 253f-255f
Feinman, RA, 342
Feldspathic porcelain restorations, 84, 85f, 497
Ferguson, GC, 538
Fiber reinforcement
case examples of
using GlasSpan natural tooth bridge, 323-326, 324f-327f
using GlasSpan reinforcement with tissue replacement, 331-334, 332f-335f
using GlasSpan Trauma Kit, 328, 329f-330f
clinical techniques for, 309-316
anterior bridge in, 310f-313f
posterior bridge in, 315f-316f
provisional bridge in, 317f-318f
conservation concepts in, 308-309, 323
considerations for
clinical, 305-306, 305f, 321
treatment/technical, 307-308
controversies in, 323
esthetics/function of, 320-321
evidence-based principles for, 323
future developments in, 323
history/evolution of, 304-305, 320, 321b
maintenance regimen for, 323
material options for, 306-307, 321-323
Fiberoptic transillumination (FOTI), caries detection and, 19
Fiber-Post fiber reinforcement, 322
Fiber-Splint reinforcement, 322
Fibreflex reinforcement, 322
FibreKor fiber reinforcement, 322
Fibrin clot, visualization of, 633-634, 637f
Field-of-view screening, 628
Filtek Low Shrink Posterior Restorative System, 256-257, 427
Filtek Supreme, 252
Filtek Supreme Ultra restorative, 425-426
Financial arrangements, 763-764, 766, 769-770, 773. *See also* Costs
Finesse All-Ceramic, 498
Finishing and polishing
artistic elements of, 271, 281, 291, 292f, 295f
clinical considerations for, 268, 268f, 271, 278, 286, 289, 294f
clinical techniques for, 273-275, 274f-275f, 289f, 291f, 301-302, 301f-303f
controversies in, 272, 285, 301
defined, 277
esthetics/function of, 277, 278f, 286, 287f, 292-293
evidence-based/conservation principles of, 271-272, 282-283, 299
future developments in
abrasive-impregnated brushes as, 272-273, 272f
challenges of, 285
rotary devices as, 273, 273f
single versus progressive polisher in, 301

WWW.HIGHDENT.IR
همیار دندانسازان و دندانپزشکان

Finishing and polishing *(Continued)*
glazing versus, 299
heating during, 280-281
history/evolution of, 267, 277, 286
innovative elements in, 271, 290-291, 294f
maintenance regimen for, 272, 283-285, 441
material options for
table of (listed), 287t-288t
abrasive disks/strips as, 268-269, 289, 291f-292f
abrasive particles on instruments as, 278-279, 278f-279f
abrasive particles via instruments as, 288-289, 288f-291f
abrasive pastes/loose abrasives as, 32, 270-271, 270f
advantages/disadvantages of, 271
current best approach using, 271, 279-281, 288-289, 288f-293f
rubber wheels/cups/points as, 269f, 271, 289, 293f
in minimally-invasive dentistry, 597, 597f
need/rationale for, 32, 267-268
restorations
anterior direct composite, 228, 228f-230f
ceramic-based, 279-280, 284f
class V, 296f, 299
esthetic try-in (temporary), 118, 118f
posterior direct composite, 256, 257f
resin composite, 279, 280f-283f
zirconia and, 280
treatment planning for, 271, 281-282, 291f, 296-299, 296f-300f
Fissurotomy burs
adhesive techniques and, 172, 173f
in minimally-invasive dentistry, 582, 583f-584f, 586f, 590, 592f, 593-595, 595f
Flashbuster, 273
Flavin adenine dinucleotide (FAD), 633-634
Fletcher, Paul, 680, 684
FlexiBuff/FlexiStrip/FlexiDiscs, 228, 229f-231f, 269
FlexiCups, 269, 273
Flossing
after restorations, 30
anterior direct composites and, 228
attachments and, 580
caries detection after, 17
Fluorapatite-containing restoration, 497
Fluorescence defined, 408
Fluorescence visualization technology
laser technology for, 611-612, 612f, 618
for tissue screening, 628-629, 633-634, 637b, 637f
Fluoride
after restorations, 31
in bleaching agents, 394
CAMBRA and, 8
caries risk and use of, 15-16, 24
for caries treatment, 2, 5
pre- versus post-eruptive use of, 15
rinses after attachments, 577, 580
sugar consumption and, 15
Fluoride varnish
after restorations, 24
for initial caries treatment, 5-8
Fluoride-releasing composites, 43, 43f, 45
Fluoride-releasing glass ionomers, 6-8
Fluorosis stains, bleaching, 345-346, 346f, 386-387, 401, 401f
Flur-Opal Varnish, 374
Fogel, 353
Food entrapment, 562
Foods, hard/crunchy, 409, 441
Foods/beverages, chromogenic
direct veneers and, 429
tooth discoloration due to, 344b, 348, 353, 379, 394, 399. *See also* Stains, tooth
FORM acronym to communicate, 760-761
4-Seasons composite system, 426
Fracture mechanics, fiber reinforcement and, 306
Fracture of prosthesis, 566
Fracture of restoration
direct veneers for, 411, 413
esthetic posts in, 486, 488
fiber reinforcement for, 315-316
inlays/onlays for, 474
porcelain veneers for, 441
porcelain-fused-to-metal restorations for, 509, 513, 518, 527, 528f-530f
single-tooth all-ceramic restorations for, 497-498, 502, 507
Fracture of tooth
adhesive techniques and, 206, 207f
anterior
class IV restorations for, 232-236, 236f-243f
direct composites for, 216-218, 217f, 219f
direct veneers for, 406, 411
in children, 724, 727f-728f
clinical case presentation on (incisor), 667, 667f
esthetic posts and root, 485, 487, 488f
inlays/onlays for, 478, 478f-480f, 480
in porcelain-fused-to-metal restorations, 510, 510f
posterior, composites for, 244-246, 245f, 249, 250f
Fracture toughness
of direct veneers, 414, 421
of esthetic posts, 482, 485
fiber reinforcement and, 304-305, 309
of inlays/onlays, 471
of single-tooth all-ceramic restorations, 498, 500, 502
Freedman, G, 392
Frenectomy, laser, 601, 603f
Fuji IX glass ionomer, 725f
Fuji IX GP EXTRA, 210, 213f
FujiCEM, 502
Fusayama, A, 169
Fusio Liquid Dentin, 427

G

Gag reflex and dentures, 561
Garretson, 343b
Garrison ring matrix device, 262-263
Gastro-esophageal reflux disease (GERD)
restorations and, 425-426
sleep apnea and, 698-699
tooth discoloration/bleaching and, 394
G-CEM (cement), 542-543
G-Coat Plus resin, 296-297, 506
Gelb appliance in non-surgical face lift, 133-134
Gene sequence in caries risk assessment, 6
Gene therapy, caries treatment and, 9
Genes, bone regeneration and, 684
Gingiva
color and symmetry of
after tissue regeneration, 678
in healthy tissue, 671f, 674-675
enhancement of keratinized, 663-669, 667f-669f. *See also* Margin, restorative
Gingival curettage, 604, 607-608
Gingival health, restorative dentistry and, 247, 663, 667, 667f
Gingival hyperplasia
laser re-contouring of, 601, 603f
medications and, 665, 675, 676f
Gingival levels
color pigmentation at, 670, 671f
recession of tooth and, 675-677, 677f
in smile design, 107, 107f
See also Margin, restorative
Gingival troughing, 601, 602f, 612, 612f
Gingival ulcerations/blanching, bleaching and, 361
Gingivectomy
to enhance perioesthetics, 668-669, 668f-669f
laser, 601, 602f
See also Periodontal plastic surgery
Glass ceramics, pressable, 496, 498-500, 500f-501f. *See also* Leucite-reinforced glass ceramics (LRGCs)
Glass ionomer cements. *See* Cements, dental.
Glass ionomer cores, 485, 485b
Glass ionomers restoratives
about, 337-340, 338t, 339f
advantages/disadvantages of, 81, 255, 413
finishing/polishing, 296, 297f
if previous posterior restoration, 250-251
for initial caries treatment, 6-8
in pediatrics, 720, 723f-724f
resin-modified, 255
Glass-infiltrated alumina crowns, 496, 502
Glass-infiltrated ceramics, 500-502
Glass-infiltrated magnesium alumina crowns, 496
GlasSpan fiber reinforcement
ceramic fibers in, 321
clinical considerations for, 321
history/evolution of, 320
in natural tooth bridge, 323-326, 324f-327f
with tissue replacement, 331-334, 332f-335f
GlasSpan Trauma Kit, 328, 329f-330f
Glazing, 299
Gluma Comfort Bond, 169b
Gluma Desensitizer, 207-208, 208f
Gluma Solid Bond, 192f-193f, 211f-212f
Glutaraldehyde sealer, 538
Gold crown for single-tooth restorations, 496-497
Gold inlay/onlay, cast, 469-470
Gold posts, 483
"Gold standard" of full-coverage restoration, 514
Goldberg, AJ, 304-305
Goldman, Leon, 611
Goldstein, Ronald, 12
Goldstep, Fay, 187
Golub-Evans, Jeff, 320, 321b
Gothic arch tracing device, 563, 738, 738f
Gradia composite system, 424-425
Grafts. *See* Bone grafts; Tissue grafts.
Great White bur. *See* SS White Burs.
Grinding teeth. *See* Bruxism.
Griptab system, 449-458, 450f-451f, 453f-457f
Grupe, 670
GUIDOR Bioreabsorbable Matrix Barrier, 675-676
Gum chewing
restorative dentistry and, 27
tooth-whitening, 379, 380f
Gygax, M, 13

H

HA Nano Gel, 2
Hagger, Oskar, 190
Halo Metal Porcelain, vintage, 85f
Halstrom Hinge, 736, 736f
Harlan, 341, 343b
Harvard University, 618
Hashimoto, M, 178, 213
Hawley retainer, 712
Haywood, VB, 392, 513

WWW.HIGHDENT.IR
همیار دندانسازان و دندانپزشکان

HealOzone system, 582, 585f, 590, 592f, 593, 594f
Heart attacks, sleep apnea and, 698-699
Heat generation when polishing, 280-281
Heating to enhance bleaching, 364, 365f
Hemaseal and Cide Desensitizer, 206
Hemostasis, lasers for, 601, 602f, 604
Hepatitis, 755
Herbst appliance, 701-703, 702f
Hering, Ewald, 135
Heymann, HO, 392, 513
Histological layers, restorations based on, 423-435, 431f-435f
Histological micrograph of oral lesion, 629-630, 630f
"Hollywood crowns", 132
Home care after restorations
  future developments in, 98
  instructions for, 29-31
Horn, Harold, 459
HPV infections, oral cancer and, 630-631, 633
Hy-Bond polycarboxylate cement, 549f
Hy-Bond zinc phosphate cement, 548f
Hybridization process in adhesion, 169, 180-182, 181f, 185, 186f, 194f-195f, 201-206, 205f-206f
HYDRIM C51w/L110w sterilizers, 744, 745f
HYDRIM Instrument Protection (HIP) solution, 744, 745f
Hydrogen peroxide
  activating rods, 381f, 382
  developments in use of, 392
  evidence-based principles of, 395
  in-office use of, 360-362
  safety of, for home use, 352, 353f
  tetrasodium pyrophosphate and, 362
Hydroxyapatite
  for caries treatment, 2
  on implants, 681
  radiographs and, 684
Hygienist, dental
  color sensitivity of, 142-143, 143t
  maintenance regimen after restorations by, 31-32
  as photographer, 54
  role of
    in smile design, 107
    in tooth bleaching, 362
Hypertension, sleep apnea and, 698-699, 734
Hypoplasia, anterior direct composites for, 215f
Hypopnea, 706, 706t
Hyrax appliance, 693

I

Icon technique for caries removal, 252
Identoflex Polishers, 269
Ikam shade analysis system (METALOR), 148
Illumination of working field, 589, 589f, 593, 628
Imaging for motivation, 768-769, 769f
Immediate dentin sealing (IDS), 474
Implacare tips, 665
Implants, tooth
  attachments to, 575
  versus dentures, 562
  enhancing gingiva around, 663, 666, 684
  history/evolution of, 671
  innovative elements in, 680-681
  to support dentures
    artistic elements of, 646
    case study on, 648-662, 649f-662f
    controversies in, 647-648
    esthetics/function of, 643-644
Implants, tooth *(Continued)*
  to support dentures *(Continued)*
    evidence-based principles for, 647
    expense of, 645
    future developments in, 648
    history/development of, 643-644, 644f
    indications/contraindications for, 644-645
    innovative elements in, 645-646, 645f
    material options for, 644f-645f, 645
    treatment planning/considerations for, 646-647
Impression systems
  controversies in, 50
  for custom-tray bleaching, 349-351, 350f
  digital, 503-504, 508, 519
  esthetic dentistry and, 46, 47f
  for esthetic try-in, 119f-120f, 120-124
  future developments in, 49t, 50
  gingival toughing prior to using, 601, 602f
  history/evolution of, 46, 47f-48f
  indications/contraindications for, 46-47
  innovative elements in, 48, 49f
  material options for, 47
  for smile design, 102
  treatment plan/considerations for using, 48-50
In-Ceram restorations, 500, 507
Incisors
  anterior direct composites for peg/missing, 221f
  correcting inclination of maxillary, 690-692, 693f
India, smile design in, 101, 101f
Infection. *See* Bacterial infection.
Infection control, 740, 741f, 751-756, 752b, 753f-755f. *See also* Disinfection; Sterilization
Inflammation, mucogingival
  aqueous ozone treatment for, 597
  periodontal therapy to reduce, 663-669
Influenza, 751-752
Infuse Bone Graft, 679-680
Injury, traumatic tooth, tooth discoloration due to, 348, 393
Inlays/onlays, esthetic
  about, 469-481, 471t, 472f-473f
  case presentations of, 475, 475f-480f, 478, 480
Innovative elements, 787-788
In-office bleaching defined, 360
Inspektor Biluminator, 20, 22, 22f
Instrumentation
  for amalgams versus composite, 262
  to be sterilized, 740, 741f-742f
  for finishing/polishing. *See* Finishing and polishing.
  removing debris from, 741f, 742-744, 743f-744f
  titanium-coated, 224, 225f
  washers for, 741, 744, 745f
Insurance
  financial arrangements and, 766
  oral appliance therapy and, 738
Integrity provisional restoration, 505
International Caries Detection and Assessment System (ICDAS), 3, 4f
International Center for Laser Education, 603-604
International Organization for Standardization (ISO), 538, 785-786
Internet and awareness, 773
Invisalign braces, 709, 709f, 712-713
IPS e.max restorations, 497-498, 503
IPS e.max Press restorations, 500
IPS Empress restorations, 496-498, 503, 507
IPS Empress II restorations, 497-498
IPS Eris restoration, 497-498
Iron tablets and tooth discoloration, 394
Isolation of working field, 589-590, 590f
Isolite System, 589-590, 590f
iTero digital impression system, 503-504, 519

J

Jaw, forces placed on, implant-supported denture and, 643
Jaw orthopedic appliances. *See* Appliances, functional.
Jazz Ceramic and Composite polisher, 118
Jazz P35 Porcelain and Metal 3-step Polishing System, 91f, 558f
Jazz Supreme Composite 1-Step Polishing System, 256, 257f, 558f, 597, 597f
Jenkins, CBG, 309
Jenson, L, 3
Jiffy Polishing Brush, 273
Jiffy Tubes, 542-543
Johns Hopkins on oral cancer, 630-631
Joint vibration analysis, 691f
Jones, 364
Jordan, RE, 309
Jowl problem, dental restorations for, 133-134

K

Kalore monomer composite, 429
Kane, 341-342, 343b
Karbhari, VM, 306
KaVo DIAGNOdent, 20, 20f
Kennedy class partial denture, 575-577
Kleer-Veneer Light Cure Cement, 42f, 82-83, 83f
Klusmeier, William, 392
Kois Dento-Facial Analyzer System, 428
Kool-Dam, 343, 343f

L

Lab technician/dental labs
  communicating to, 535f
    check list for, 532b
    for esthetic try-in, 118-119, 119f, 124
    photography for, 531-536, 533f-536f
    for porcelain-fused-to-metal restorations, 512, 512f
    for shade-matching, 148, 152-153, 153t
    for single-tooth restorations, 503
    in smile design, 102-103, 102f-103f, 108-109
  role of
    versus dentist control, 533
    in direct composites, 214
    in esthetic dentistry, 99, 110
    in esthetic try-in, 130f
    in porcelain-fused-to-metal restorations, 517
    in single-tooth restorations, 503
    in smile design, 105
    in ultraconservative dentistry, 85-86
Lactobacillus
  antimicrobial therapy and, 3
  caries formation and, 1-2, 24
  culturing, 6
  dental plaque and, 14, 14f
  salivary tests for, 26-27
  treatment strategy and, 26
Ladder (image tool), 533
Laminate composites, 304. *See also* Porcelain laminate veneers
Land, Charles H, 496
Laser ablation, 252
Laser bleaching, 360, 364-366, 367f
Laser caries detection technology, 3
Laser education, 603-604

Laser fluorescence, caries detection and, 3, 20-22, 20f-22f
Laser-assisted periodontal therapy (LAPT)
as adjunct to scaling/root planing, 601, 603f, 606, 608f, 609
compared to other laser therapies, 604
protocol for, 605-606, 605f, 609
Lasers/laser technology
for hard/soft tissue management, 611-618, 612f-615f, 617f, 664-665
types of, in dental applications, 364, 604, 611
See also Diode lasers
Lava zirconia-core restoration, 497, 502
Law, Isaiah, 680
Layering. *See* Histological layers, restorations based on.
Lee, WC, 210
Legal issues
photography and, 51, 60, 64
photography for, 58-59, 64
snoring/apnea treatment and, 734
Leucite-based ceramics
bonded, 83-84, 87-88
finishing/polishing, 279-280, 284f
Leucite-reinforced glass ceramics (LRGCs), 496-498
Light
caries detection and, 17
to enhance bleaching, 363f-364f, 364, 366f
See also Curing lights
Light metering in photography, 54
Light-based technology, 618. *See also* Lasers/laser technology
Light-cure cements, 540t, 542, 552, 552f, 554
Light-emitting diode (LED)
for illumination, 589, 589f
to kill microorganisms, 582-583, 585f, 619
Lingual space and sleep apnea, 737
Linkow, Leonard, 680
Listening skills. *See* Communication, patient.
Lithium disilicate, 437-438, 497
Lithium disilicate glass ceramics (LDGCs), 497-500, 500f-501f
LOCATOR attachments, 578f
Low-level laser therapy (LLLT), 604-606, 608, 618
Lucirin TPO, 424
Lussi, A, 13
Luting (water-based) cements, 547, 548b. *See also* Cements, dental
Luting composites, 41, 42f
LuxaFlow resin, 506
LuxaGlaze resin, 506
Luxatemp provisional restoration, 505

M

MacBoyle retainer, 308
Magill, 353
Magne, Pascal, 474
Magnification handpiece, 589, 589f
Magnification loupes
about, 587-593, 587f
with illumination, 589, 589f, 593
improved visualization using, 587-589, 587f-588f
isolating working field, 589-590, 590f, 593
Maiman, Theodore, 611
Maintaining Esthetic Restorations, 789
Maintenance regimens
after restorative dentistry, 28-32, 789
in CAMBRA, 9
in caries management, 12
need for, 13, 13f
Mallampati scale of airway obstruction, 737f
Malocclusion, skeletal
orthodontics for, 693f, 699-703, 700f-702f, 708f, 715f-717f
sleep apnea and, 734
Mandible
improving relationship between maxilla and, 689-690, 691f-692f
measuring range of motion of, 563, 738, 738f
Mandibular advancement therapy, 735
Mandibular Anterior Repositioning Appliance (MARA), 689-690, 692f, 701-703, 702f, 705
Manhattan Bridge for reinforcement, 321b
Manhold, 353
Margeas, Robert, 462
Margin, restorative
anterior direct composites and, 222f
cements and esthetics of, 547, 548f, 551, 551f, 556-557
in direct composite bonding, 409
evidence-based principles for, 92-93, 95f
maintenance regimen for, 95-96
materials and defining location of, 73f, 83-84, 83f-84f
microscopic exam of, 535-536, 587-588, 588f
posterior direct composites and, 247, 250f
posts/cores and, 483
See also Gingiva, enhancement of keratinized
Marketing, 770, 778, 778b
Marsh, Philip, 1-2
Maryland bridges, 309, 449
Maslow's Hierarchy of Needs, 774, 774f
Mastication. *See* Chewing.
Materials, restorative
application of specific composites in, 40-44
curing systems compared in, 43f-44f
fluoride-releasing composites in, 43f
luting and cementing in, 42f
pit/fissure sealants in, 43f
self-adhesive resin cements in, 42f
specialized formulations in, 41f
strength-resistance compromise in, 40f-41f
temporary restorations in, 42f
classes of, 39f-40f
components of, 35f-36f
descriptions of basic, 34-40
evaluating, 785-789
future developments in, 44-45
historical perspective of, 33-34, 34f
physical properties of, 36f-38f
terminology in, 785b
tooth discoloration due to, 348
in ultraconservative dentistry
for defining the restorative margin, 83-84, 83f-84f
history/evolution of, 72, 73f-74f
versus restorative dentistry, 81-84, 81f-83f
See also Impression systems; *specific restoration type*
Matrix systems for posterior composites, 262-266, 264f-265f
MaxCem Elite, 502
Maxilla
correcting position of, 687, 689f-690f
improving relationship between mandible and, 689-690, 691f-692f
Maxillary Anterior Sagittal fixed appliance, 691-692
Maxillary arch, developing, 685-686, 708, 708f, 715f-717f
Maxillary width, developing correct, 686, 687f-688f
McCloskey, R, 341-342
McIntyre, FM, 309
McNamara, James A, Jr., 706-707
MD Anderson Cancer Center (TX), 618
MDM (master diagnostic model), 533, 534f, 536
Medical history of patient
caries risk and, 25
health history form for, 762-763, 763f
infectious diseases in, 752
Medical model of caries
changing to, 26
incorporating, 27
innovative elements in, 6
versus surgical model, 1-2
Medications
gingival hyperplasia and, 665, 675, 676f
periodontal therapy and, 664, 677
tooth stains/bleaching and, 344b, 347, 347f, 382, 382f, 393-394
Mercury issue with amalgams, 469
Metal coping, 511
Metals as restorative materials
advantages/disadvantages of, 81
for inlays/onlays, 469-470
for porcelain-fused-to-metal restorations, 510, 510f, 516, 519
for posts/cores, 483-485, 484b-485b
tooth discoloration due to, 347, 348f
Metamerism, 142f, 143-145, 144f-145f
Methicillin-resistant *Staphylococcus aureus* (MRSA), 751
Methyl methacrylate dentures, 562
MHT color system, 358
MI Paste, 2
Microabrasion, 723
Microbrush, 205f-206f, 507
Midwest Caries I.D., 20
Miles, Linda, 781
Minimally-invasive dentistry
as conservation dentistry, 8-9
medical model of caries as, 26
patient demand for, 111
restoration strategies for, 3, 4f
technology and
controversies in, 598
esthetics/function of, 582-583, 583f-584f, 586f
evidence-based principles for, 597-598
future developments in, 598
history/development of, 582-583, 585f
illumination in, 589, 589f
indications/contraindications for, 583-586, 586f
innovative elements in, 593-595, 594f-595f
isolating working field in, 589-590, 590f
magnification loupes in, 587-593, 587f
positioning patient for, 586, 587f
preparation tools for, 584f-586f, 590-593, 591f-592f
treatment planning/considerations for, 2, 595-597, 596f-597f
visualization in, 587-589, 587f-588f
tools for, 20
See also Ultraconservative dentistry
Minocycline. *See* Tetracycline-discolored teeth.
Minocycline-impregnated microspheres, 666
Mirror, caries detection and dental, 17
Mixtures, rule of, 306
Mock-up, composite, 769, 769f
Models, study, in smile design, 107
Molars
all-ceramic restorations and, 507
inlays/onlays and second, 470
posterior direct composites and, 249, 252
primary, 720-723, 722f-724f
Montreal, University of, 734
Moore silicon carbide disks, 269
Moore-Flex polishing system, 269

WWW.HIGHDENT.IR
همیار دندانسازان و دندانپزشکان

Mottling of teeth, 371-374, 372f
Mouth Cancer Foundation (UK), 631
Mouthrinses
  acetic acid, for tissue screening, 628, 632-633
  after restorations, 30-31
  for attachments, 577
  attachments and, 580
  carbamide peroxide (whitening), 354
  denture wearing and, 564
  fluoride, after restorations, 24, 27
  studies on, 789
Mucogingival junction, 670, 671f. *See also* Gingival levels
Mucogingival surgery. *See* Periodontal plastic surgery.
Multilink Automix bonding agent, 502-503
Multimedia communication/documentation, 532
Munksgaard, EC, 177
Munro, 343b, 354
Munsell, Henry, 135, 136f
Murphy, Neil, 708
Mutans streptococci. *See Streptococcus mutans*.
Myers, Terry, 611

N
Nabers, Claude, 670-671
Nakabayashi, N, 169, 213
Nasal cavity obstruction, 705, 705f
National Institute of Standards and Technology (NIST), 33
N-cycle sterilizer, 748, 748f
Neglect, supervised, 683-684, 706-707
Neurological deficiencies and dentures, 562
Newsletter communication, 770
Newton, Isaac, 135
Nickel-titanium coil springs, nickel-, 708, 708f
Night guard
  after restorations, 31, 441, 503
  vital bleaching using, 392
Nixon, Robert, 462
NovaMin, 2, 368, 369f, 370
Nursing bottle decay, 719
Nutting, EB, 342, 343b, 392
Nuva-Fil, 214
Nyman, Sture, 684
Nyvad, B, 1-2, 9

O
Obesity, sleep apnea and, 734, 739
Occlubrush, 273
Occlusal sketch, photography for, 52
Occlusal surface esthetics, 245f-246f, 246b
Occlusal vertical dimension. *See* Vertical dimension occlusion (VDO).
Occlusion
  anterior restorations and, 224f, 233
  cuspid-guided, 101
  See also Skeletal malocclusions
Ochronosis, 345
OCT Dental Imaging System, 22, 23f
Odontoblastic process, 206-207, 207f
Odyssey Mini # Watt LED, 589f
Oil-based cements, 538, 539t
Olsenella, 1-2
Omnii 3M, 5
One Step bond, 169b
One Step Plus bonding system, 175, 176f
One-step composite resin cement. *See* Cements, dental.
Opacity defined, 408
OpalCup, 373
Opalescence Trèswhite Supreme, 348-349, 349f, 358, 359f, 381
Opalustre bleaching, 372f, 373-374
Opaquers, direct composites and, 216-218, 217f
Operative dentistry, 28, 29f
Operculectomy, laser, 601
OptiBond Solo Plus, 542
Optical coherence tomography (OCT), 22, 23f, 618, 641
OptiClean, 273
OptiDisc, 269
Optimal Pressable Ceramic (OPC), 498
OptraStick, 506-507
Oral appliance therapy, 733-739, 735f-738f. *See also* Appliances, functional
Oral environment, maintaining healthy, 12-16, 24f. *See also* Caries management by risk assessment (CAMBRA); Caries/carious lesions, dental; pH environment, oral
Oral hygiene
  orthodontic treatment and, 712
  periodontal therapy and, 664, 666, 677, 683
  tooth whitening and, 362, 379
Oral hygiene instructions
  for attachments, 577, 581
  for caries treatment, 2, 5-6, 25
Orthodontic movement in smile design, 109
Orthodontics
  advantages/disadvantages of, 712-713
  for class II skeletal malocclusions, 699-703, 700f-702f
  esthetics/function in, 686, 711-712
  evidence-based/conservation principles of, 718
  functional appliances used by. *See* Appliances, functional
  history/evolution of esthetic, 685-686, 711-712
  indications/contraindications for, 712
  innovations in
    arch expansion as, 708, 708f
    clear braces as, 709, 709f
    colorless wires as, 709
    mini-implant anchorage as, 713-714
    self-ligating bracket as, 714
    temporary anchorage devices as, 709, 709f
  maintenance regimen for, 718
  patient behavior and, 713
  treatment philosophies in, 699
  treatment planning/considerations for, 714-715, 715f-717f
  two-phase treatment in, 695t
    orthodontic phase (ages 12-14), 696-699
    orthopedic phase (ages 6-11), 695-696
Orthopedic appliances, jaw. *See* Appliances, functional.
Oxiranes, 427
Oxygen deficits, effects of, 739
Ozone technology
  for caries preparation, 590-593, 592f, 595, 595f
  controversies in, 598
  for endodontic treatment, 597
  esthetics/function of, 582, 583f-584f
  evidence-based principles for, 597-598
  HealOzone system in, 582, 585f, 593, 594f
  history/development of, 582-583
  indications for, 585-586
  for periodontal treatment, 596
  in restorative dentistry, 596
  water systems in, 593, 595f, 597
Ozone therapy, 399
Ozonix ozone generator, 592f

P
Paffenbarger, G, 33, 34f
Paffenbarger Research Center (PRC), 33, 34f
Pain, facial, 101
Palate, soft, and sleep apnea, 737, 737f
Palodent matrix system, 262
PANAVIA F bonding agent, 502-503
Pancherez, H, 702-703
Parasomnia, 738
"Particle plucking", 424-425
Pashley, DH, 206
Patient Activator, 770
Patient involvement/expectations
  diagnostic wax-up for, 768-769, 768f
  establishing rapport in (FORM acronym), 760-761
  esthetic dentistry and, 99, 111, 405, 439
  first visit and, 761, 761f-762f, 782
  history/evolution of, 72
  Internet and, 773
  motivation tools in, 768-770, 768f-769f, 774, 774f
  orthodontics and, 713
  tooth whitening and, 360, 362, 387, 394-395
  in ultraconservative dentistry, 85-86, 91-92
  See also Behavioral changes
Patient management. *See* Communication, patient; Consent, patient; Consultation; Disputes, patient; Education, patient/practitioner; Referrals, patient.
Paul, SJ, 474
Pearl Drops paste, 507
Pearson, H, 342, 343b
Pediatric dental procedures
  child development and, 706-707, 706f, 706t, 708f, 719
  clinical considerations for
    permanent anterior teeth, 719, 725f-728f
    permanent posterior teeth, 724-728, 729f-731f
    primary anterior teeth, 719-720, 721f
    primary molars, 720-723, 722f-724f
  esthetic dentistry and, 719
  functional appliances in, 686
  future developments in, 732
  history/evolution of, 719
  orthodontic phases of, 695-699, 695t
  tooth bleaching in, 385
Peening, 368, 369f
Pellicle, 344
Perhydrol urea. *See* Carbamide peroxide.
Peridex, 3
PeriGuard, 3
PerioChip. *See* Chlorhexidine-impregnated collagen strips.
Periodontal plastic surgery
  about, 663-669, 667f-669f
  laser-assisted. *See* Laser-assisted periodontal therapy (LAPT)
  in minimally-invasive dentistry, 596
  orthodontic treatment and, 713
  TMJ assessment before, 685
  See also Gingivectomy; Pocket débridement laser therapy (PDLT); Scaling and root planing (SRP), laser-assisted
Periodontal pocket, 606-608, 607f, 611-612
Periodontal therapy. *See* Periodontal plastic surgery.
Perioesthetics
  artistic elements of, 680-682, 682f-683f
  controversies in, 683-684
  evidence-based/conservation principles of, 682-683
  function and, 671
  future developments in, 684
  history/evolution of, 670-671, 671f-676f
  indications/contraindications for, 671f, 674-677, 676f-677f
  innovative elements in, 679-680
  maintenance regimen for, 683
  material options for, 677-678
  restorative dentistry and, 670
  treatment considerations for, 678-679

WWW.HIGHDENT.IR
همیار دندانسازان و دندانپزشکان

Permagen, 169b
PermaSeal, 296-297
pH environment, oral
  caries and, 1-2
  dental plaque and, 14-15
  developments in improving, 6, 9
  dietary habits and, 15
  fluoride and, 15
  fungal infections and, 2
  remineralization of teeth and, 15
  salivary secretion and, 16
  treatment strategies to improve, 2, 5-6, 8
  See also Oral environment, maintaining healthy
Phenylketonuria, 345
Phenyl-propanedione (PPD), 424
pHluorigel HA, 2
Phobia of objects in oral cavity, 561
Photoactivated disinfection (PAD)
  for caries preparation, 591-593, 592f, 595
  for caries treatment, 619, 620f-621f
  history/development of, 582-583, 585f
  in minimally-invasive dentistry, 596
  mode of action of, 619-622, 622f
  for periodontal treatment, 585-586, 619
  techniques for, 623-624, 623f-625f
Photobiomodulation, 611-612, 615, 618
Photodynamic therapy (PDT), 618
Photography, dental
  artistic elements of, 54-55, 66f-71f, 71
  consent for, 54
  digital
    backup/storage of, 57-61
    cameras for, 52-54, 52f, 62, 62f
    current best approach to, 53-54, 53f, 62-65, 63f-64f
    digital negative format (RAW file) in, 58-59
    future developments in, 59, 71
    history/evolution from film to, 51-52, 60-61
    image manipulation in, 58, 60-61, 64
    innovative elements in, 54, 65, 65f
    in periodontal therapy, 664
    in porcelain-fused-to-metal restorations, 512
    preparation for, 57, 64-65
    in single-tooth restorations, 504
    theft of, 61
    for tissue screening, 627
    transportation of, 60-61
  in esthetic try-in, 111
  for first dental visit, 761, 761f-762f
  incidence of use of, 60
  for lab technician, 532-536, 533f-536f
  need for, 51-52, 60, 61f
  photographer for, 54
  for post-treatment consultation, 764-765, 764f
  risks of not using, 51, 64, 430
  in smile design, 102-103, 102f-103f, 107
  standard views (12) for, 55-57, 55f-58f
  in tooth bleaching, 397
  in waiting room, 767-768, 768f
Photoinitiator/photoactivator in bleaching, 360-362
Picasso diode laser, 600-601, 601f, 607f, 609
Pic-n-Stic, 506-507
Piezo tips, 665-666
Piezoelectric débridement therapy, 663, 665
Piksters, 718
Pillar Procedure, 734-735
"Pink esthetics"
  restorative dentistry and, 247
  in smile design, 107, 107f
Pin-Tweezers for posterior direct composites, 264
Pits and fissures, sealing, 172
Pitts, NB, 17
Plaque, dental
  caries and, 1-2
  onset/progression of, 14-15, 14f
  salivary secretion and, 16
Plaque control, caries risk and, 5, 24
Plasma spray, 681
Plaster cast in smile design, 108, 108f
Plastic surgeons and esthetics, 132
Pocket débridement laser therapy (PDLT), 606-608, 607f, 611-612, 619. *See also* Periodontal plastic surgery
Poe, GS, 342, 343b, 392
PoGo, 269
Point spectroscopy, 641
Polish, types of, 91f, 118, 441
Polishing restorations. *See* Finishing and polishing.
Polycrystalline ceramics, 497, 502-503
Polyglycolic membrane, 675-676
Polymerization shrinkage of cavity preparation
  inlays/onlays and, 469
  layering of anterior direct composites ands, 426-427
  posterior direct composites and, 246, 247f-250f, 265
Polysomnograms, 703
Porcelain, 438
Porcelain, stacked/layered, 437-438
Porcelain dentures, 562
Porcelain jacket crown (PJC), 496
Porcelain laminate veneers
  about, 459-468, 464f-468f
  extended (360°), 438
  versus porcelain veneers, 436
Porcelain restorations
  evolution of, 132
  feldspathic, 84, 85f, 497
  history/evolution of, 72
  maintenance regimen for, 109
  posterior direct composites and, 249, 252
  in smile design, 102f, 105, 109
  zirconium, 84, 85f
  See also Ceramics, dental; Veneers
Porcelain-fused-to-metal (PFM) restorations
  about, 509-514, 509f-514f
  advantages/disadvantages of, 81, 81f
  for porcelain veneers, 132
  posts/cores and, 483
  for single-tooth restorations, 496-497, 502, 507
  as zirconium crowns/bridges, 515-530
    for anterior tooth, 519f-520f
    for complete reconstruction, 525f-527f
    for posterior reconstruction, 528f-530f
    for posterior tooth (provisional), 521f-523f
    using two cord retraction, 524f
Porphyria, 346, 347f
Positioning head for dental care, 586, 587f
Posterior direct composites
  artistic elements of, 252
  bonding of, 209-210, 250-251
  case examples of, 257-261, 258f-261f
  considerations for
    clinical, 249-251, 263
    treatment, 253-255, 253f-255f, 264, 264f-265f
  controversies in, 256-257
  esthetics/function of, 244, 245f-246f, 246b, 252, 257f
  evidence-based/conservation principles of, 255-256, 256t, 265f, 266
  five Cs of, 244-247, 247f-250f
  future developments in, 257
  history/evolution of, 244
  innovative elements in, 245f, 252
  maintenance regimen for, 256, 257f
Posterior direct composites *(Continued)*
  material options for, 251-252
  matrix systems for contacts of, 262-266, 264f-265f
  treatment planning for, 252-253, 253f, 255f, 264
Posterior teeth
  correcting inclination of lower, 693, 696f
  young permanent, 724-728, 729f-731f
Posters in waiting room, 767-768, 767f
Posts/cores, esthetic
  case presentation of, 492, 493f-495f
  cements for, 486-487, 486b, 487f
  clinical techniques for, 489, 490f-492f
  considerations for
    clinical, 483
    time and convenience in, 487
  core materials for, 485, 485b
    amalgam, 485b
    cast metal, 485b
    composite, 486b
    glass ionomer, 485b
  esthetics/function of, 482-483
  evidence-based/conservation principles of, 489
  future developments in, 489
  history/evolution of, 482-483
  innovative elements in, 487, 488f
  post materials for, 483-485
    cast metal, 484b
    prefab metal, 484b
    resin fiber, 484b
  treatment planning for, 488-489
Posture of dentist, ergonomic, 587, 587f-588f
Potassium nitrate, 394
Povidone iodine for caries treatment, 3, 5
Power bleaching, 364-366
  defined, 360
  with heat, 365f
  with lasers, 367f
  with light, 366f
Practice management
  considerations for, 766-768, 767f, 769f-770f
  elective-versus-traditional-dentistry business of, 774
  establishing a practice within a practice, 774-775, 775b
  esthetic dentistry and, 773-774
  growth plan in, 775-777, 775b, 777b
  logic versus emotion in, 777-778, 777b
  marketing in, 770, 778, 778b
  relevance/history/elements of, 780-784
  See also Communication, patient
Practicon Dental, 781
Practitioners. *See* Dentist; Hygienist, dental; Lab technician.
Precautions, transmission-based, 751-752, 752b
Pregnancy, tooth bleaching and, 385
Prep Start H20, 590, 591f
Preparation, guided approach to. *See* Esthetic try-in (ETI).
Preparation guide/stent in smile design, 108, 108f
Prescriptions, written, 532, 536
Press-fits implants, 680-681
Prevotella intermedia, 596
Preza, D, 1-2
Prime & Bond NT, 169b, 542
Proactive Intervention Dentistry, 187
Probing instrument, caries detection and, 3, 17
Procera AllZirkon restoration, 502, 507
Procera polycrystalline ceramics, 497
Product evaluation, 785-789, 785b
Profin reciprocating handpiece, 91f
Prophy-Jet, 441

WWW.HIGHDENT.IR
همیار دندانسازان و دندانپزشکان

Prosthesis
fixed versus removable, 101
implant-retained, 562, 575-577, 577f, 643
removable. *See* Dentures
Prosthetics design, fiber-reinforced materials for, 307
Protocoling the case, 535
Provisional restorations
about, 5, 8, 10f
oil-based cements for, 538, 539t
for posterior teeth, 519, 521f-523f
in single-tooth restorations, 505
in smile design, 102f, 103-104, 103b, 104f
See also Esthetic try-in (ETI); Temporary restorations
Proxabrush tips, anterior composites and, 228
Proxyt polishing paste, 507
Pseudoramibacter, 1-2
Pulp necrosis, tooth discoloration and, 393
Pulpal recession, idiopathic, 348
Pulpal-dentin complex, restorative dentistry and, 28, 29f-31f
Pulp-capping composite development, 45
Pulp-capping liner development, self-adhesive, 44
Pulpdent UNO-DUO, 169b

Q
Quality of life and dentition, 246b
Quantitative light-induced fluorescence (QLF), 3, 20, 22, 22f
Quikee touch-up bleaching, 379, 380f

R
Radiographs
alloplastic materials and, 684
bitewing, caries detection and, 3, 17-18, 18f
computer-aided, 18-19, 19f
digital, caries detection and, 3, 18, 18f
for first dental visit, 761, 761f-762f
panoramic, in smile design, 107
tomographic, for functional appliance, 691f
Radiopaqueness of cement, 553, 553f
Rapid simplified veneer provisionals (RSVP), 462
Rapport, FORM acronym for patient, 760-761
R.A.P.T.O.R. burs, 288-289, 291f
REALITY Publishing Company, 786
Recaldrant, 2
Record keeping
for denture fabrication, 563
digital/paperless, 532, 536
length of storage in, 532
photography for, 51, 66f-71f, 71
Referrals, patient, photography for, 52, 60
Rehabilitation of dentition, 72, 73f-74f
Reinforcement treatment. *See* Fiber reinforcement.
RelyX Luting Plus Cement, 502
RelyX Unicem cement, 502, 542-543
RelyX Veneer Cement, 506
Remineralization of teeth, dental caries and, 15
Remineralization therapy for caries treatment, 2, 5, 8
Renamel Restorative System, 215f-220f, 216-218, 222f-224f, 226f-227f, 230f
Reservoir technique for bleaching teeth, 354-355, 355f
ResiCem cement, 550
Resiment, 496
Resin composites
fiber-reinforced. *See* Fiber reinforcement.
materials for polishing, 279-281, 280f-283f
for transitional bonding, 414
Resin desensitizer-sealer, 538
Resin fiber posts, 484-485, 484b
Resin ionomers, 413
Resin restoration, commercial indirect, 497
Resin systems, commercial indirect, 471t
Resin-based composite cements. *See* Cements, dental.
Resolute reabsorbable mesh, 675-676
Resorbable blasting media (RBM), 681
Restorations, dental
checklist for large, 532b
Clark Class II, for posterior composites, 245f, 250f, 252, 253f
class I, II, and IV, for posterior composites, 249-250, 262
class IV, for anterior composites, 232-236, 236f-243f
class V restorations, finishing, 293-296
fiber-reinforced. *See* Fiber reinforcement.
finishes of, 8
finishing/polishing. *See* Finishing and polishing.
fractures of. *See* Fracture of restoration.
handling/placement of, 449-458, 450f-451f, 453f-457f
material options for. *See* Materials, restorative
minimally-invasive, 2-3, 4f
provisional
about, 5, 8, 10f
oil-based cements for, 538, 539t
for posterior teeth, 519, 521f-523f
in single-tooth restorations, 505
in smile design, 102f, 103-104, 103b, 104f
See also Esthetic try-in (ETI)
removing for maintenance, 96-97, 96f
temporary
about, 42, 42f
maintenance regimen for, 109
as part of preparation, 101, 101f
without caries assessment
incidence of replacing, 2
as weak link in tooth interface, 13, 13f
See also Esthetic restorations
Restorative dentistry
caries management and
esthetic outcome of, 6-8
importance/relevance of, 1-2, 12, 13f
maintenance regimen for, 12, 28-32
outcome of, 5
restoration longevity in, 12, 13f
restoration–dental pulp complex in, 12, 28, 29f-31f
material options in, versus ultraconservative dentistry, 81-84, 81f-83f
operative considerations in, 595-596, 596f
periodontics and, 670
TMJ assessment before, 685
treatment strategy in
overview of, 25
criteria for, 25
diagnosing caries as infection, 26-28, 26f
timing of, 25-26
Retief, DH, 177
Retreatment for failed composites, 250f, 253-255, 253f-255f
Retrievable cements, 550-551
Retrievable implants, 681
Ribbond fiber reinforcement, 322
Ribbond wings, 449-451
Rick-A-Nator, 693, 697f-698f, 705
Ridge augmentations, esthetic, 680-681, 682f-683f
Risk assessment. *See* Caries risk assessment.
Roady, 781
Robert Koch Institute, 741, 743b
Rocatec silica coating, 503
Rochette bridge design, 309
RONDOflex, 590, 591f
Root canals, disinfection of, 597
Root forms, 680
Root planing. *See* Scaling and root planing (SRP), laser-assisted.
Rosensteil, SF, 361
Rosenthal, 341-342, 343b
Roswell Park Cancer Institute (NY), 618
Rubber wheels/cups/points for polishing, 269, 269f, 278, 279f, 289, 293f
Rudo, DN, 306
Ruf, S, 702-703

S
Safety of diode lasers, 605
Safety of tooth bleach/bleaching, 352-353, 353f, 361
Salivary diagnostics, 641
Salivary secretion
caries risk and, 16, 24
evaluation of, 598
surface contamination and, 185
See also Xerostomia
Salivary tests, 26-27, 26f
Scaler, ultrasonic, 441
Scaling, hand
anterior direct composites and, 228
for attachments, 580
outcome of, alone, 683-684
Scaling and root planing (SRP), laser-assisted
efficacy of, 601, 603f, 683-684
evidence for routine use of, 604-606, 609
periodontal pocket and, 607-608, 619
protocol for, 605-606, 605f, 608f, 609
safety of, 593
See also Periodontal plastic surgery
Schärer, P, 474
Scharf, J, 323
Schiesser, FJ, 561, 563
Schluger, Saul, 683-684
Schwarz appliance, 687f-688f, 693, 694f-696f, 715f-717f
Screening consultation. *See* Consultation; Referrals, patient.
Screw-fit implants, 680-681
Sculpture fiber reinforcement, 322
Scurria, MS, 513
S-cycle sterilizer, 741f, 749, 749f
Sealants, composite
after restorations, 32
pit and fissure, 43, 43f
Seal-n-Shine, 296-297
Selenomonas, 1-2
Self-etch adhesive cements. *See* Cements, dental.
Self-image and dentition, 246b
Sensitivity, tooth/gingival
dental bonding and, 206-209, 207f-208f, 538, 553
polishing-generated heating and, 280-281
restorative dentistry and, 247
tooth bleaching and, 357-358, 360-362, 365, 380-382, 385, 388-389, 394, 397-399
Sequence, 788
Shade. *See* Color and shade.
Shade tabs/guides, 138-139, 139f, 152, 155f. *See also* Color map, tooth
ShadeEye NCC (no longer available), 147-148, 147f
Shade-matching devices, digital, 137f, 139-140, 140f, 154-155
Shade-scanning devices, digital, 137f, 145-148, 145f-148f
Shape & Shine polisher, 256, 257f
Sharpey fibers, regeneration of, 678
Sharps container, 755, 755f
Shavell, Harold M, 515, 518
Shipman, 353
Sickle cell anemia, 346-347

Silanes, 110, 113f
Silencer appliance, 735-736, 735f
Silicate replacements, history of, 33, 34f
Silicon carbide particles for polishing, 278-279, 288-289
Silicone Points C type, 269
Silk-Wrap system of reinforcement, 321b
Simonsen, RJ, 309
Sinfony indirect resin restoration, 497
Single Bond, 169b
Single-tooth all-ceramic restorations
  artistic elements of, 504
  considerations for, 497, 503
  esthetics/function of, 496-497
  evidence-based/conservation principles of, 507
  future developments in, 508
  history/evolution of, 496-497
  innovative elements in, 503-504
  maintenance regimen for, 507-508
  material options for, 497-503, 498f-501f
  treatment planning/considerations for, 504-507
Sinus area regeneration, 679-680
Skeletal malocclusions
  orthodontics for, 693f, 699-703, 700f-702f, 708f, 715f-717f
  sleep apnea and, 734
Sleep apnea, obstructive
  functional appliances for, 703-704, 703f-704f, 706-707
  oral appliance therapy for, 733-739, 735f-738f
Sleep study, home, 703
Smart Bur II, 586f
SmartClips, 714
Smedley, 782
Smile Analysis Sheet for esthetics try-in, 125f-130f
Smile design
  anterior composites and, 224-226, 226f
  artistic versus scientific approach to
    golden proportions and, 106-107, 106f-107f
    rules/formulas and human variations in, 105, 105f-106f, 106b
  clinical principles for, 102, 102f
  diagnostic wax-up for, 102-103, 103f
  esthetic dentistry and, 99-100, 758f
  evidence-based/conservation principles of, 108-109
  function/esthetics of, 101-102, 101f
  history of procedures in, 100-101, 100f-101f
  maintenance regimen for, 109
  ortho-esthetics and, 685
  in periodontal therapy, 664, 680
  periodontics and, 670
  provisional restorations for, 103-104, 103b, 104f. *See also* Esthetic try-in (ETI)
  treatment planning/protocol in, 107-108, 108f
  ultraconservative dentistry and, 85
Smoking
  restorations and, 30, 429
  tooth discoloration due to, 379, 393
Snacking, frequent
  caries risk and, 1-2, 9f-10f
  oral pH and, 5, 15
  See also Dietary habits
Snoring, oral appliance therapy for, 733-739, 735f-738f
"Snow-capped" appearance of bleached tooth, 386-387, 394
Social factors, caries risk and, 16, 25
Social pressure, 773
Sodium hypochlorite (NaClO)
  for caries treatment, 3, 5
  versus ozone technology, 597
Sof-Lex Brush, 272-273
Sof-Lex disks, 271f
Sof-Lex Extra Thin XT coarse disk, 715
Sof-Lex Finishing/Polishing System, 269
SOPROLIFE, 20, 21f
Sorensen, JA, 305
Spasser, HF, 392
Speaking space and dentures, 563
Spectra laser device, 20, 22f
Spectrophotometer, 137f, 139-140, 140f, 150, 151f
Spectroscopy, 22-23, 23f
SpectroShade (MHT), 138f, 140f, 147, 147f, 151f
Spee, curve of, 693
Spee-Dee, 489
Spero Flex implant attachment, 577f
Spiro orthocarbonates (SOCs), 427
Spitting and dentures, 562
Splint-It fiber reinforcement, 322
Spry, 5
SS White Burs, 582, 583f-584f, 590, 592f, 593-595, 595f
STAINBUSTER bur, 290, 294f
Stainless steel crowns, 720-721
Stainless steel posts, 483
Stains, composite/porcelain
  problems with, 252
  removing, 32
Stains, tooth
  in children, 723-724, 725f
  de-staining. *See* Bleaching of teeth
  differentiating, 344, 393-394
  evidence-based principles of, 374, 375f-376f
  extrinsic, 344
  intrinsic, 344-348
    post-eruptive, 347-348, 348f
    pre-eruptive, 345-347, 345f-347f
  treating mottling as, 371-374, 372f, 723-724, 725f-726f
  See also Foods/beverages, chromogenic
Standard of care/materials
  ADA process on, 33
  CAMBRA and, 9
  risk assessment form for, 5-6
  surgical model not accepted, 1-2
Stem cell material, 679-680, 684
Sterilization
  decontamination procedures and, 741f, 747-750, 747t-748t, 748f-749f
  defined, 747t
  esthetic dentistry and, 740
  history of, 740-741, 741f-742f
  overview of options for, 750, 750t
  washing/rinsing/drying in, 741-747, 743b, 743f-746f
  See also Infection control
Sterilizer verification, 740, 742f, 748f, 749-750
Sterilizers, autoclave, 741f, 747-749, 748f-749f, 748t
Sterngold semi-precious attachment, 576f
"Stick bite", 428
Stick Tech fiber reinforcement, 322
Stim-U-Dent plaque removers, 228
Streptococcal bacteria (other than *mutans*), 1-2
Streptococcus mutans
  CAMBRA controlling, 9
  caries etiology and, 1-2
  caries risk and, 24
  culturing, 6
  dental plaque and, 14, 14f
  levels of
    salivary tests for, 26-27
    treatment strategy and, 26
  traditional caries treatment of, 3
  treatment of, in restorative dentistry, 27
Stroke, sleep apnea and, 698-699
Subperiosteals, 680
"Suck back", 250f
Sucking, dentures and, 561
Sucrose. *See* Sugar intake.
Sugar intake
  control of, 26
  dental caries and, 1-2, 5
  dental plaque and, 14
  fluoride and, 15
  See also Carbohydrates
Super Snap disks, 269, 409
Supersmile Professional Whitening Gum, 379, 380f
SureFil, 257
SureFil SDR flow, 427
Surface, composite/tooth
  contamination of, and bonding, 185, 247
  esthetics of lower posterior, 246f
  texture and color of, 135, 281f
Surgical model of caries
  disease management versus, 26
  indications for, 3
  not accepted standard, 1-2
Swimming and tooth discoloration, 394
Systemp Inlay/Onlay, 474
Systemp.link luting cement, 506

T
"Taco shell" laminate, 406
Taft, 341, 343b
Takahashi, N, 1-2, 9
Tandem Appliance, 687, 689f-690f, 697-698
Targis fiber reinforcement, 322
Targis/Vectris indirect resin restoration, 497
Tarnow, Dennis, 680, 684
Tay, FR, 206
TEAM acronym, 765
Technological communications, 770
Technology and esthetics. *See* Diode lasers; Minimally-invasive dentistry.
Telephone communications, 757-760, 759f
Telephone rounds by dentist, 764
Telio CS Link luting cement, 506
TempBond Clear luting cement, 506
Template, silicon putty, in smile design, 103, 103f
Temporary anchorage device (TAD), 709, 709f
Temporary restorations
  about, 42, 42f
  maintenance regimen for, 109
  as part of preparation, 101, 101f
  See also Provisional restorations
Temporomandibular joint (TMJ)
  appliances for dysfunction of. *See* Appliances, functional.
  assessment of
    in esthetic dentistry, 685
    in smile design, 101, 107
  keys to health of, 686
  sleep apnea appliance and, 738
  unfinished restorations and, 292-293
Tetracycline-discolored teeth, 347, 347f, 382, 382f, 393
Tetrasodium pyrophosphate, 362
Text messaging communication, 770
Thalassemia, 346-347
Theophrastus, 341
TherOzone, 583f-584f, 595f
Thompson, LR, 361
Three-layered trendy technique, 429
Time
  digital photography saving, 51-52
  tooth whitening in less, 365, 388

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Tints, direct composites and, 218-219, 218f. *See also* Color and shade
Tissue ablation, 611-612
Tissue grafts
  color of, 671, 675f-676f
  innovative elements in, 679, 681-682
  types of, 664-665, 678
Tissue management, hard/soft
  artistic elements of, 680-682, 682f-683f
  dental lasers for, 611-618, 612f-615f, 617f
Tissue protection, soft
  bleaching and, 360-361
  dentures and, 564
Tissue regeneration, 678, 684
Tissue regeneration (GTR), guided
  for recession of tooth, 675-677, 677f
  xenograft for, 678
Tissue removal, soft
  artistic elements of, 680
  laser-assisted, 601, 602f-603f, 604, 607-608
  in ultraconservative dentistry, 72, 96
Tissue screening, soft
  clinical considerations for, 630-633, 632f, 634f-636f
  esthetics/function of, 627, 630
  evidence-based/conservation principles of, 640-641
  future developments in, 641
  history/evolution of, 627-630, 628f-630f
  innovative elements in, 633-634, 637b, 637f
  material options for, 629f, 632-633
  procedural steps in oral, 629f, 637-640, 637f, 638b, 640f
  treatment planning and, 634-635, 637
Titanium nitride coatings, 578, 578f
Titanium on implants, 680-681
Titanium posts, 483
Tobacco stains, 344b
Tobacco usage and oral cancer, 630-631
Tofflemire matrix system, 263
Tokuso ceramic primer, 110, 113f
Tokuyama Bond, 85f
Tokuyama Bond Force, 198f-199f, 582
Toluidine blue (nuclear) stain, 627-628
Toluidine chloride photoactivator solution, 622, 622f, 625f
Tomography. *See* Optical coherence tomography (OCT).
Tongue movements and dentures, 562
Tongue size and sleep apnea, 737, 737f
Tooth extraction without resorption, 681, 682f-683f
Tooth guide/indicator and faceplate for esthetic try-in, 117f, 119-124, 119f, 121f-128f
Tooth needs, hierarchy of, 256, 256t
Tooth stains. *See* Stains, tooth.
Tooth structure, conserving
  in esthetic dentistry, 111, 111f, 113f
  in esthetic try-in, 110, 124-130, 130f-131f
  hierarchy of tooth needs and, 256, 256t
  in minimally-invasive dentistry, 583, 584f, 586f
  in post/core buildup, 482
  in smile design, 109
  in ultraconservative dentistry, 72, 96-97, 97f
  See also Conservation dentistry
Tooth wear
  anterior direct composites for, 215f, 223f
  dentures for, 561
  See also Fracture of tooth
Tooth whitening. *See* Bleaching of teeth.
Toothbrush
  after restorations, 30, 429
  anterior direct composites and, 228
  dentures and, 564
Toothpaste (patient use) after restorations
  fluoride-containing, 16, 30
  low-abrasive, 429, 514
  pumice-free, 283-285
  with whitening capabilities, 514
Toothpastes (office use), fine, 507. *See also* Abrasives, loose/paste
Toothpicks, anterior composites and, 228
Tooth/teeth
  correcting inclination of lower posterior, 693, 696f
  disposing of extracted, 755
  forces on healthy, 488f
  tissue recession of, 675-677, 677f
  See also Dentition
Transcription factors and aqueous ozone, 597
Transepithelial cytology collection, 629-630
Transformational toughening, 502
Transillumination before tooth whitening, 358-360. *See also* Digital fiberoptic transillumination (DIFOTI); Fiberoptic transillumination (FOTI)
Translucency
  artistic element of, 252, 408
  detection of, 150, 151f
  innovations in, for restorations, 503
  shine-through in, 216-218
Translucent cements, 82-83, 83f, 85, 86f, 554
Transmission precautions, 751-752, 752b
Tranzgraft collagen matrix, 675-676
Trauma. *See* Injury, traumatic.
Treatment planning/considerations, 788
Triad Provisional Material, 693
Tribochemical silica coating, 503
Tri-Clip matrix device, 262
Trident, 2
Triethylene glycol dimethacrylate (TEGDMA), 427
Triodent V3 Ring and Matrix, 262-264, 623
Triturator, 542-543
tRNA extraction in caries risk assessment, 6
Trubyte Bioform Mould Chart, 129f
Trubyte Tooth Indicator and faceplate, 119f, 120-124, 121f-122f, 124f-125f, 127f
Tuff-Temp provisional veneer, 87f
Twin Block appliance, 701-703, 701f, 705
Twin Block II appliance, 705
Two cord retraction technique, 519, 524f
Tyas, MJ, 308

U

Ultraconservative dentistry
  artistic elements in, 85-86
  controversies on preparation in, 73f, 97-98
  esthetic dentistry and, 72, 73f
  esthetic try-in as, 110, 112f, 130f
  evidence-based principles for, 92-93, 95f
  future developments in, 98
  history/evolution of, 72, 73f-74f
  indications for, 80, 80f
  innovative elements in, 84-85, 85f-86f
  maintenance regimen for, 94-97, 96f-97f
  material options in
    for defining the restorative margin, 83-84, 83f-84f
    versus restorative dentistry, 81-84, 81f-83f
  occlusal vertical dimension in, 74-77, 74f-77f
Ultraconservative dentistry *(Continued)*
  treatment
    patient decisions in, 91-92
    planning/sequence/followup in, 86-87, 87f
    tooth preparation in, 87-88, 87f-89f, 88b, 90-91, 92f-95f
    veneer placement/finishing in, 88-90, 89f-91f
  veneer preparation in, 77-80, 78f-79f
  See also Minimally-invasive dentistry
Ultrasonic cleaning unit, 754, 754f
Ultrasonic débridement therapy, 663, 665
Ultrasonic tips, 665-666
UltraVac Vacuum Former, 349-351, 350f
Ungwuneri, Z, 361
Uniformed Services University of the Health Sciences (MD), 618
Universal Posterior Bioclear Matrix, 258f-260f
Urea peroxide. *See* Carbamide peroxide.
Uvula and sleep apnea, 737, 737f
Uvulopalatoplasty, 734-735

V

V3 ring matrix for posterior composites, 262-266, 264f-265f
Vaccination, caries treatment and, 9
Vallittu, PK, 304-305
Valsalva maneuver, 561
Vanish XT Extended Contact Varnish, 726f
Variolink Veneer, 506
VELscope, 628-629, 628f, 633, 640-641
Veneer cements (brand names listed), 540t
Veneering teeth in ultraconservative dentistry. *See* Esthetic try-in (ETI); Ultraconservative dentistry.
Veneers
  ceramic, dental bonding in, 210
  composite resin
    dental bonding in, 210
    direct composite bonding of, 405-410, 410f
    histological approach to layering, 423-435, 431f-435f
    transitional bonding of. *See* Bonding.
  extended (360° laminate), 438
  porcelain (indirect)
    about, 436-448
    advantages/disadvantages of, 407
    case examples of, 441-448, 441f-442f, 444f-448f
    color and shade of, 135
    esthetic dentistry and, 73f
    esthetic-try-in for. *See* Esthetic try-in (ETI).
    evolution of, 132
    inserting, 449-458, 450f-451f, 453f-457f
    laminate, 436, 459-468, 464f-468f
    replacing aging, 124-130, 131f
    in smile design, 111f
Ventris fiber reinforcement, 322
Venturini, D, 273
Venus composite system, 424-426
Vertical dimension occlusion (VDO)
  in esthetic try-in, 115, 115f-116f
  functional appliances for proper, 693-695, 697f-698f
  implant-supported denture and, 643
  in smile design, 107
  transitional bonding for. *See* Bonding, transitional.
  in ultraconservative dentistry, 74-77, 74f-77f
Vertise Flow, 427
VICRYL woven mesh, 675-676
Video, dental, 532
Vig, RG, 107-108
Viguie, G, 305

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Virginia Commonwealth University study, 628
Visual examination. *See* Examination, visual.
VITA Classical Shade Guide, 423
VITA Easyshade Compact system, 146, 146f, 154, 158-159, 159f-160f, 222f, 358
VITA Easyshade system, 137f, 145-146, 145f, 532
VITA In-Ceram ALUMINA, 496, 502
VITA In-Ceram SPINELL, 496, 502
VITA In-Ceram ZIRCONIA, 496, 502
Vitalescence composite system, 426
VITAPAN 3D-Master Shade system, 139f, 152, 154, 156-158, 157f-158f
VITAPAN Classical Shade Guide, 139f, 152, 154-156, 155f-156f
ViziLite Plus, 632-633
Voids, composite, problems with, 252
Vomiting, restorations and, 425-426
V-ring matrix, for posterior composites, 262. *See also* V3 ring matrix for posterior composites

W
Warren, 670
Washington, George, 560
Waste disposal, 755-756, 755f
Water, air dispersal of, 204, 205f-206f
Water Pik, 718
Water-based cements. *See* Cements, dental.
Wave-Wedge for posterior composites, 263-266, 264f
White spots on tooth, 723-724, 725f-726f
Whitener, Philip D, 781
Whitening, tooth. *See* Bleaching of teeth.
Williams, 353
Williams, Leon, 1-2
Williams, Michael, 708
Wolf fiberoptic handpiece, 589f
Woodside, Donald G, 698, 706-707
Wound healing, diode laser for, 604

X
Xerostomia
  attachments and, 577
  in caries risk assessment, 2, 6
  dentures and, 561
X-Rite ShadeVision System, 148, 148f, 532
Xylitol
  CAMBRA and, 8
  for caries treatment, 5, 8
  oral pH and, 15
  restorative dentistry and, 27

Y
Yap, AUJ, 273
Yarborough, 343b, 365-366
Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) blanks, 497, 502

Z
Zach, L, 280-281
Zentler, Arthur, 670
Zidan, O, 538
Zinc oxide–eugenol/non–eugenol cements, 539t
Zinc phosphate cement, 72, 73f, 486, 539t-540t, 547-551, 548f, 558-559
Zinc polyacrylate cement, 539t-540t
Zinc polycarboxylate, 549
Zinc polycarboxylate cement, 549-551, 549f
Zirconia core single-tooth restorations, 497, 502
Zirconia/zirconium
  evolution dental products and, 132, 440
  for full-mouth splint, 519
  polishing restorations containing, 280
  for porcelain-fused-to-metal restorations, 516
  for single-tooth restorations, 496-497
  solid monolithic, restoration, 503
Zoom! Whitening System, 715f-717f
ZR zirconia porcelain, vintage, 85f