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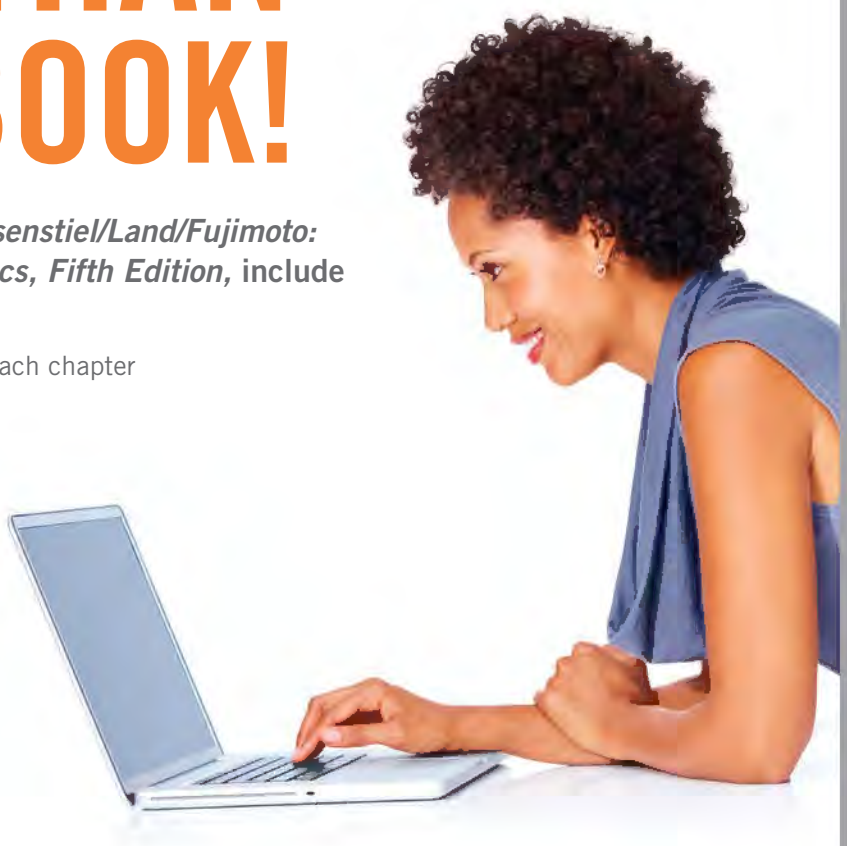

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CONTEMPORARY FIXED PROSTHODONTICS

FIFTH EDITION

Stephen F. Rosenstiel, BDS, MSD
Professor Emeritus, Restorative and Prosthetic Dentistry
College of Dentistry
The Ohio State University
Columbus, Ohio

Martin F. Land, DDS, MSD
Professor of Fixed Prosthodontics
School of Dental Medicine
Southern Illinois University, Edwardsville
Alton, Illinois

Junhei Fujimoto, DDS, MSD, DDSc
Part-Time Lecturer, Tokyo Medical and Dental University
Director, J.F. Occlusion and Prosthodontic Postgraduate Course;
Private Practice
Tokyo, Japan

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Contributors

Robert F. Baima, DDS
Clinical Associate Professor, Department of Periodontology and Restorative Dentistry, School of Dentistry, University of Detroit Mercy, Detroit, Michigan; Diplomate, American Board of Periodontology, Diplomate, American Board of Prosthodontics

Rick K. Biethman, DMD
Assistant Professor, Department of Restorative Dentistry, School of Dental Medicine, Southern Illinois University, Alton, Illinois

William A. Brantley, PhD
Professor and Director of the Graduate Program in Dental Materials Science, Division of Restorative and Prosthetic Dentistry, College of Dentistry, The Ohio State University, Columbus, Ohio

Isabelle L. Denry, DDS, MS, PhD
Professor, Department of Prosthodontics and Dows Institute for Dental Research, College of Dentistry, The University of Iowa, City, Iowa

R. Duane Douglas, DMD, MS
Associate Professor and Chair, Department of Restorative Dentistry, School of Dental Medicine, Southern Illinois University, Alton, Illinois

A. Jon Goldberg, PhD
Professor, Department of Reconstructive Sciences, Director, Center for Biomaterials, School of Dental Medicine, University of Connecticut, Farmington, Connecticut

Julie A. Holloway, DDS, MS
Professor and Head, Department of Prosthodontics, College of Dentistry, The University of Iowa, Iowa City, Iowa

Christa D. Hopp, DMD, BS
Associate Professor,
Section Head, Operative Dentistry, School of Dental Medicine, Southern Illinois University, Alton, Illinois

William M. Johnston, PhD
Professor Emeritus, Division of General Practice and Materials Science, College of Dentistry, The Ohio State University, Columbus, Ohio

Peter E. Larsen, DDS
The Larry J. Peterson Endowed Professor, and Chair of Oral and Maxillofacial Surgery, College of Dentistry, The Ohio State University, Columbus, Ohio

Edwin A. McGlumphy, DDS, MS
Professor, Department of Restorative and Prosthetic Dentistry, College of Dentistry, The Ohio State University, Columbus, Ohio

Jonathan C. Meiers, DMD, MS
Chief, Dental Service, VA Connecticut Healthcare System, 950 Campbell Ave. West Haven, Connecticut

Donald A. Miller, DDS, MS
Private Practice, Chicago and Naperville, Illinois, Clinical Associate Professor, University of Illinois at Chicago College of Dentistry; Diplomate, American Board of Endodontics

Van P. Thompson, DDS, PhD
Professor, Division of Tissue Engineering and Biophontics, King's College London Dental Institute, London, United Kingdom

Alvin G. Wee, DDS, MS, MPH
Associate Professor, Division of Oral Facial Prosthetics/Dental Oncology, Department of Otolaryngology—Head and Neck Surgery; Member, Cancer Prevention and Control Program, University of Nebraska Medical Center Eppley Cancer Center, Courtesy Associate Professor, College of Dentistry, University of Nebraska Medical Center, Omaha, Nebraska

Burak Yilmaz, DDS, PhD
Associate Professor, Division of Restorative Science and Prosthodontics, College of Dentistry, The Ohio State University, Columbus, Ohio

Preface

In the late summer of 1975, three young dentists from England, Holland, and Japan met for the very first time at the School of Dentistry in Indianapolis. They shared a common interest in "crown and bridge" prosthodontics. Little did they know that 40 years later they would take immense satisfaction in having completed the fifth edition of *Contemporary Fixed Prosthodontics*.

As the three of us embarked on mastering the art and science of fixed prosthodontics, we encountered the complete range of human emotions, ranging from insecurity to self-confidence, from frustration to fulfillment, and from anxiety to satisfaction and occasional pride. It is with much pride that we introduce this comprehensively updated and revised edition of one of the most widely used and translated texts in our field.

The task once again was overwhelming. Technology had developed far beyond our comfort zones of clinical sciences and dental materials. The technological advances in imaging and CAD/CAM tempted us to add a chapter (in an appropriate place in the text) summarizing new technological developments. Instead, we opted to integrate new technologies throughout the text, as we consistently tried to do in earlier editions. Early in the review process, we realized that describing some of the new systems would be impossible in a step-by-step format. Advances and improvements occur at such a pace that a chapter that was comprehensively rewritten would soon be out of date. As a result, we embarked on a process of breaking down the newer technologies into their underlying principles and then integrating this information—often gleaned from sources outside the conventional dental literature—into the text.

The fifth edition now includes cone-beam technology for diagnostic purposes and implant placement. Impression making was expanded with a section on optical imaging, and solid casts are contrasted with their virtual counterparts. Wax pattern fabrication is still presented in the classical manner but is augmented with specific information on computer-aided design followed by either printing or milling. Similarly, the section on the fabrication of metal ceramic substructures and all-ceramic restorations was revised to include the new CAD/CAM techniques.

Since the publication of the fourth edition, the dental laboratory industry has undergone revolutionary change. Smaller laboratories must compete with large corporations that can more easily invest in expensive new technologies. When we visited laboratories and manufacturers, we realized that the transition to CAD/CAM was not a seamless process.

A number of years ago, a highly skilled and seasoned ceramist at a major dental laboratory was put in charge of the digital production of all-ceramic restorations. He shared with us that the learning curve had been particularly steep in the beginning when he tried to teach the very best and brightest computer personnel he could find the necessary dental knowledge. A number of years into this process, he started to teach his most experienced certified dental technicians how to operate some of the newly developed CAD/CAM tools, and, as he told us, "In six months, we were up and running, and we have never looked back."

The foregoing experience reinforces the importance of establishing a solid foundation in the fundamental skill sets for fixed prosthodontics before successfully applying them to some of the new technologies. Any student of fixed prosthodontics must have a thorough knowledge of dental anatomy, tooth form and function before embarking on even the classical approaches to the fabrication of individual crowns or simple fixed dental prostheses. A thorough understanding of form and function is, in turn, prerequisite to achieving mastery of today's cutting-edge technologies. A sincere effort was made to include new illustrations of commonly incorporated techniques in undergraduate curricula throughout the United States and Canada. Popular techniques have been added to the previously recommended approaches, illustrations of instrumentation have been replaced to incorporate contemporary equipment, and other new materials have been incorporated throughout.

With this text, we hope to serve predoctoral students, postdoctoral fellows, practitioners, and researchers. The text is well indexed, and every effort has been made to ensure the rapid retrievability of evidence-based information for the busy practitioner or dental manufacturer.

Stephen F. Rosenstiel
Martin F. Land
Junhei Fujimoto

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In recognition of so many colleagues and friends …

Where to begin? After three decades, we are unlikely to achieve absolute accuracy in crediting all of those whose selfless contributions to the development of this text have helped it evolve. Whenever we asked, we met with a willingness to share concepts, new technology, illustrations, photographs, materials, and whatever else we requested. Permissions were routinely granted and, invariably, most kindly approved. We again have made every effort to accurately and precisely give credit to all of those to whom credit is due. Any errors and omissions are absolutely unintentional and the sole responsibility of the authors—we apologize if such should have occurred.

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Our contributors: Robert F. Baima, Rick K. Biethman, William A. Brantley, Isabelle L. Denry, R. Duane Douglas, Martin A. Freilich, A. Jon Goldberg, Julie A. Holloway, Christa D. Hopp, William M. Johnston, Peter E. Larsen, Leon W. Laub, Edwin A. McGlumphy, Jonathan C. Meiers, Donald A. Miller, M. H. Reisbick, James L. Sandrik, Van P. Thompson, Alvin G. Wee, and Burak Yilmaz.

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In each of the previous editions, we have written a special thank you to our spouses, Enid, Karen, and Yoshiko. Sadly Karen Tolbert Land died on January 4, 2014, and was not able to see this fifth edition through to completion. Her home in Alton, Illinois, always served as our base when we met with Elsevier in St. Louis. Working on this edition was not the same without her hospitality.

"Looking back over my career, I can tell you a lot of things about fixed prosthodontics. Most importantly, I can tell you very sincerely: I have never been bored" said the experienced teacher.

The fifth edition of *Contemporary Fixed Prosthodontics* is close to what we originally envisioned as we embarked on this original journey. We hope that it will help advance the art and science of what is beyond question the most challenging clinical dental specialty. We know that we do not have all the answers, but we hope that students and practitioners, researchers and manufacturers, and all who demonstrate the interest and commitment necessary to achieve mastery in a discipline we have come to love and respect, may find many, if not most, of the answers they seek.

Stephen F. Rosenstiel
Martin F. Land
Junhei Fujimoto

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PART I

PLANNING AND PREPARATION

CHAPTER 1

History Taking and Clinical Examination

Fixed prosthodontic treatment involves the replacement and restoration of teeth by artificial substitutes that are not readily removable from the mouth. Its focus is to restore function, esthetics, and comfort. Fixed prosthodontics can offer exceptional satisfaction for both patient and dentist. It can transform an unhealthy, unattractive dentition with poor function into a comfortable, healthy occlusion capable of years of further service while greatly enhancing esthetics (Fig. 1-1, *A* and *B*). Treatment can range from fairly straightforward measures—such as restoration of a single tooth with a cast crown (see Fig. 1-1, *C*), replacement of one or more missing teeth with a fixed dental prosthesis (see Fig. 1-1, *D*), or an implant-supported restoration (see Fig. 1-1, *E*)—to highly complex restorations involving all the teeth in an entire arch or the entire dentition (see Fig. 1-1, *F*).

To achieve predictable success in this technically and intellectually challenging field, meticulous attention to every detail is crucial: the initial patient interview and diagnosis, the active treatment phases, and a planned schedule of follow-up care. Otherwise, the result is likely to be unsatisfactory and frustrating for both dentist and patient, resulting in disappointment and loss of confidence in each other.

Problems encountered during or after treatment can often be traced to errors and omissions during history taking and initial examination. The inexperienced clinician may plunge into the treatment phase before collecting sufficient diagnostic information that helps predict likely pitfalls.

Making the correct diagnosis is prerequisite for formulating an appropriate treatment plan. All pertinent information must be obtained. A complete history includes a comprehensive assessment of the patient's general and dental health, individual needs, preferences, and personal circumstances. This chapter is a review of the fundamentals of history taking and clinical examination, with special emphasis on obtaining the necessary information to make appropriate decisions about fixed prosthodontic treatment.

HISTORY

A patient's history should include all pertinent information concerning the reasons for seeking treatment, along with any personal information, including relevant previous medical and dental experiences. The chief complaint should be recorded, preferably in the patient's own words. A screening questionnaire (Fig. 1-2) is useful for history taking; it should be reviewed in the patient's presence to correct any mistakes and to clarify inconclusive entries. If the patient is mentally impaired or a minor, the guardian or responsible parent must be present.

Chief Complaint

The accuracy and significance of the patient's primary reason or reasons for seeking treatment should be analyzed first. These may be just the obvious features, and careful examination often reveals problems and disease of which the patient is unaware; nevertheless, the patient perceives the chief complaint as the major or only important problem. Therefore, when a comprehensive treatment plan is proposed, special attention must be given to how the chief complaint can be resolved. The inexperienced clinician who tries to prescribe an "ideal" treatment plan can easily lose sight of the patient's wishes. The patient may then become frustrated because the dentist does not appear to understand or does not want to understand the patient's point of view.

Chief complaints usually belong to one of the following four categories:

- Comfort (pain, sensitivity, swelling)
- Function (difficulty in mastication or speech)
- Social (bad taste or odor)
- Appearance (fractured or unattractive teeth or restorations, discoloration)

Comfort

If pain is present, its location, character, severity, and frequency should be noted, as well as the first time it occurred, what factors precipitate it (e.g., pressure, hot, cold, or sweet things), any changes in its character, and whether it is localized or more diffuse in nature. It is often helpful for the patient to point at the area while the dentist pays close attention.

If swelling is present, the location, size, consistency, and color are noted, as well as how long it has been felt and whether it is increasing or decreasing.

Function

Difficulties in chewing may result from a local problem such as a fractured cusp or missing teeth; they may also indicate a more generalized malocclusion or neuromuscular dysfunction.

Social Aspects

A bad taste or smell often indicates compromised oral hygiene and periodontal disease. Social pressures prompt many affected patients to seek care.

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FIGURE 1-1 ■ **A,** Severely damaged maxillary dentition. **B,** Restoration with metal-ceramic fixed prostheses. **C,** Complete cast crown that restores mandibular molar. **D,** Three-unit fixed dental prosthesis that replaces missing mandibular premolar. **E,** Congenitally missing maxillary lateral incisors replaced with implant supported crowns. **F,** Extensive fixed prosthodontics involving restoration of multiple teeth. (**C,** Courtesy Dr. X. Lepe. **D,** Courtesy Dr. J. Nelson. **E,** Courtesy Dr. A. Hsieh.)

Appearance

Compromised appearance is a strong motivating factor for patients to seek advice as to whether improvement is possible (Fig. 1-3). Such patients may have missing or crowded teeth, or a tooth or restoration may be fractured. The teeth may be unattractively shaped, malpositioned, or discolored, or there may be a developmental defect. A single discolored tooth may indicate pulpal disease.

Personal Details

The patient's name, address, phone number, gender, occupation, work schedule, marital status, and budgetary flexibility are noted. Much can be learned in a 5-minute, casual conversation during the initial visit. In addition to establishing rapport and developing a basis on which the patient can trust the dentist, small and seemingly unimportant personal details often have considerable influence in establishing a correct diagnosis, prognosis, and treatment plan.

Medical History

An accurate and current general medical history should include any medications the patient is taking and all relevant medical conditions. If necessary, the patient's

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HEALTH QUESTIONNAIRE

REG. NO. _____

Name _____ Date _____ Age _____

Write Yes or No.

1. Have you been hospitalized or under the care of a physician within the last 2 years? _____
2. Has there been a change in your general health within the past 2 years? _____
3. Are you allergic to penicillin or any other drugs? _____
4. Indicate **Yes** or **No** to any of the conditions below for which you are being or have been treated:

Y / N	Heart attack	Y / N	Hives, skin rash	Y / N	Substance abuse
Y / N	Heart trouble	Y / N	Cancer treatment	Y / N	AIDS
Y / N	Heart surgery	Y / N	Radiation therapy	Y / N	HIV infection
Y / N	Angina (chest pain)	Y / N	Ulcers	Y / N	Diabetes
Y / N	High blood pressure	Y / N	Gastritis	Y / N	Hepatitis
Y / N	Prolapsed mitral valve	Y / N	Hiatus hernia	Y / N	Kidney trouble
Y / N	Heart murmur	Y / N	Easy bruising	Y / N	Psychiatric treatment
Y / N	Artificial heart valves	Y / N	Excessive bleeding	Y / N	Fainting spells
Y / N	Congenital heart lesions	Y / N	Artificial joint	Y / N	Seizures
Y / N	Cardiac pacemaker	Y / N	Arthritis	Y / N	Epilepsy
Y / N	Rheumatic fever	Y / N	Asthma	Y / N	Anemia
Y / N	Stroke	Y / N	Persistent cough		
Y / N	Allergies	Y / N	Emphysema		

Women only
Y / N Currently pregnant
Y / N Nursing
Y / N Female problems

Do you use tobacco? Y / N Type _____ How much? _____
Do you drink alcohol? Y / N Type _____ How much? _____

5. Have you had any serious illness, disease, or condition not listed above? _____
   If so, explain _____
6. Indicate date of your last physical examination _____
7. Name and address of your personal physician _____
8. List any medications you are currently taking _____
9. Have you had any problems or anxiety associated with previous dental care? _____
   If so, explain _____

DENTAL QUESTIONNAIRE

Indicate Yes or No to the following:

Y / N 10. Does it hurt when you chew?
Y / N 11. Is a tooth sensitive or tender?
Y / N 12. Do you have frequent toothaches or gum pain?
Y / N 13. Do your gums bleed a lot when you brush your teeth?
Y / N 14. Do you have occasional dryness or burning in your mouth?
Y / N 15. Do you have occasional pain in the jaws, neck, or temples?
Y / N 16. Does it hurt when you open wide or take a big bite?
Y / N 17. Does your jaw make "clicking or popping" sounds when you chew or move your jaw?
Y / N 18. Do you suffer from headaches?
Y / N 19. Do you have occasional ear pain or pain in front of the ears?
Y / N 20. Does your jaw "feel tired" after a meal?
Y / N 21. Do you ever have to search for a place to close your teeth?
Y / N 22. Does a tooth ever get in the way?

23. Is there anything you wish to tell us that has not been asked?
24. Were there any items you did not understand?

I will inform the Clinic of any changes in the above

Person completing form sign here: _____
self parent guardian

Circle relationship
If minor: parent or legal guardian signature

Date signed: _____

FIGURE 1-2 ■ Screening questionnaire.

physician or physicians can be contacted for clarification. The following classification may be helpful:

1. Conditions affecting the treatment methods (e.g., any disorders that necessitate the use of antibiotic premedication, any use of steroids or anticoagulants, and any previous allergic responses to medication or dental materials). Once such conditions are identified, treatment usually can be modified as part of the comprehensive treatment plan, although some conditions may severely limit available options.
2. Conditions affecting the treatment plan (e.g., previous radiation therapy, hemorrhagic disorders, extremes of age, and terminal illness). These can be expected to affect the patient's response to dental treatment and may influence the prognosis. For instance, patients who have previously received radiation treatment in the area of a planned extraction require special measures (hyperbaric oxygen) to prevent serious complications.
3. Systemic conditions with oral manifestations. For example, periodontitis may be exacerbated by diabetes, menopause, pregnancy, or the use of anticonvulsant drugs (Fig. 1-4); in cases of gastroesophageal reflux disease, bulimia, or anorexia nervosa, teeth may be eroded by regurgitated stomach acid[1,2] (Fig. 1-5); certain drugs may generate side effects that mimic temporomandibular disorders[3] or reduce salivary flow.[4,5]
4. Possible risks to the dentist and auxiliary personnel (e.g., patients who are suspected or confirmed carriers of hepatitis B, acquired immunodeficiency syndrome, or syphilis).

Dental offices practice "universal precautions" to ensure appropriate infection control. This means that full infection control is practiced for every patient; no additional measures are needed when dentists treat known disease carriers.[6]

Dental History

Clinicians should complete a thorough examination before establishing a diagnosis. With adequate experience, a clinician can often assess preliminary treatment needs during the initial appointment, but review and

FIGURE 1-3 ■ Poor appearance is a common reason for seeking restorative dental treatment.

FIGURE 1-4 ■ Severe gingival hyperplasia associated with anticonvulsant drug use. (Courtesy Dr. P.B. Robinson.)

FIGURE 1-5 ■ **A,** Extensive damage caused by self-induced acid regurgitation. Note that the lingual surfaces are bare of enamel except for a narrow band at the gingival margin. **B,** Teeth prepared for partial-coverage restorations. **C** and **D,** The completed restoration.

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analysis of additional diagnostic information are frequently necessary (see Chapter 2). Also, assessing the quality of a previously rendered treatment fairly can be difficult because the circumstances under which the treatment was rendered are seldom known. When such an assessment is requested for legal proceedings, the patient should be referred to a specialist familiar with the "usual and customary" standard of care.

Periodontal History

The patient's oral hygiene is assessed, and current plaque-control measures are discussed, as are previously received oral hygiene instructions. The frequency of any previous debridement should be recorded, and the dates and nature of any previous periodontal surgery should be noted.

Restorative History

The patient's restorative history may include only simple composite resin or dental amalgam fillings, or it may involve crowns and extensive fixed dental prostheses. The age of existing restorations can help establish the prognosis and probable longevity of any future fixed prostheses.

Endodontic History

Patients often forget which teeth have been endodontically treated. These can be readily identified with radiographs. The findings should be reviewed periodically so that periapical health can be monitored and any recurring lesions promptly detected (Fig. 1-6).

Orthodontic History

Occlusal analysis should be an integral part of the assessment of dentition after orthodontic treatment. If restorative treatment needs are anticipated, the restorative dentist should perform the occlusal evaluation. Occlusal adjustment (reshaping of the occlusal surfaces of the teeth) may be needed to promote long-term positional stability of the teeth and to reduce or eliminate parafunctional activity (see Chapter 6). On occasion, root resorption (detected on radiographs) (Fig. 1-7) may be attributable to previous orthodontic treatment. Because this may affect the crown-to-root ratio, future prosthodontic treatment and its prognosis may also be affected. Restorative treatment can often be simplified by minor tooth movement. In orthodontic treatment, considerable time can be saved if minor tooth movement (for restorative reasons) is incorporated from the start. Thus good communication between the restorative dentist and the orthodontist may prove very helpful.

Removable Prosthodontic History

The patient's experiences with removable prostheses must be carefully evaluated. For example, a partial removable dental prosthesis may not have been worn for a variety of reasons, and the patient may not even mention its existence. Careful questioning and examination usually elicits discussion concerning any such devices. Listening to the patient's comments about previously unsuccessful removable prostheses can be very helpful in assessing whether future treatment will be more successful.

Oral Surgical History

The clinician must obtain information about missing teeth and any complications that may have occurred during tooth removal. Special evaluation and data collection procedures are necessary for patients who require prosthodontic care after orthognathic surgery. Before any treatment is undertaken, the prosthodontic component of the proposed treatment must be fully coordinated with the surgical component.

Radiographic History

Previously made radiographs may prove helpful in judging the progress of dental disease. They should be obtained if possible. Dental practices usually forward radiographs or acceptable duplicates promptly on request.

FIGURE 1-6 ■ Defective endodontic treatment has led to recurrence of a periapical lesion. Re-treatment is required.

FIGURE 1-7 ■ Apical root resorption after orthodontic treatment.

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In most instances, however, a current diagnostic radiographic series is essential and should be obtained as part of the examination.

Myofascial Pain and Temporomandibular Joint Dysfunction History

Myofascial pain, clicking in the temporomandibular joints (TMJs), or neuromuscular symptoms, such as abnormal muscle tone or tenderness to palpation, should be treated and resolved before fixed prosthodontic treatment begins. A screening questionnaire efficiently identifies patients with these symptoms who may be at higher risk for complications. Such patients should be questioned regarding any previous treatment for joint dysfunction (e.g., occlusal devices, medications, biofeedback, or physical therapy exercises).

EXAMINATION

In an examination, the clinician uses sight, touch, and hearing to detect abnormal conditions. To avoid mistakes, it is critical to record what is actually observed rather than to make diagnostic comments about the condition. For example, "swelling," "redness," and "bleeding on probing of gingival tissue" should be recorded, rather than "gingival inflammation" (which implies a diagnosis).

Thorough examination and data collection are needed for prospective patients who desire fixed prosthodontic treatment, and more detailed protocols for this effort can be obtained from various textbooks of oral diagnosis.[7,8]

General Examination

The patient's general appearance, gait, and weight are assessed. Skin color is noted, and vital signs, such as respiration, pulse, temperature, and blood pressure, are measured and recorded. Middle-aged and older patients can be at higher risk for cardiovascular disease. Relatively inexpensive cardiac monitoring units are available for in-office use (Fig. 1-8). Patients whose vital sign measurements are outside normal ranges should be referred for a comprehensive medical evaluation before definitive prosthodontic treatment is initiated.

Extraoral Examination

Special attention is given to facial asymmetry because small deviations from normal may hint at serious underlying conditions. Cervical lymph nodes are palpated, as are the TMJs and the muscles of mastication.

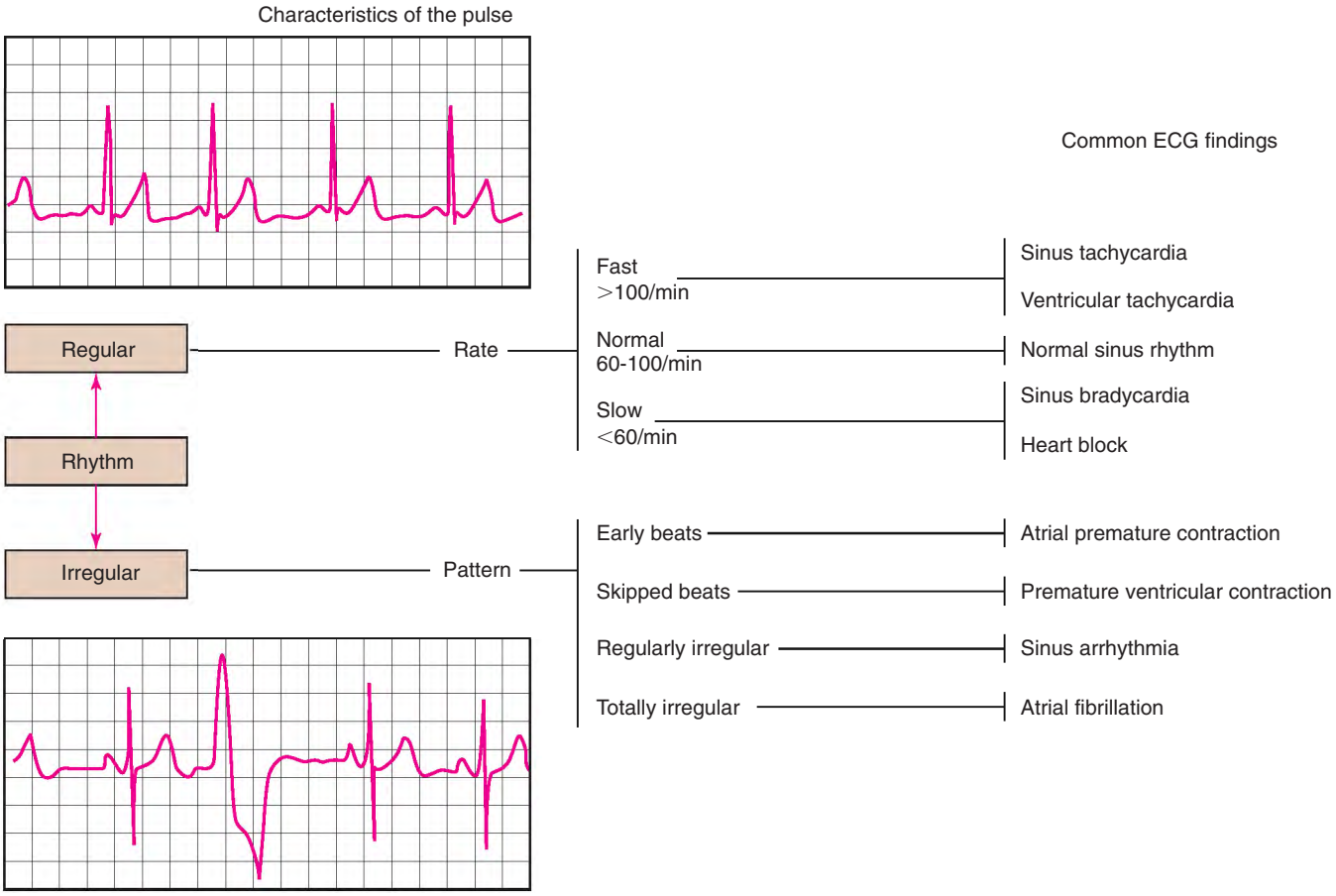

FIGURE 1-8 ■ Cardiac monitoring printout and representative ECG findings. (Courtesy Dr. T. Quilitz.)

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FIGURE 1-9 ■ Auricular palpation of the posterior aspects of the temporomandibular joints.

FIGURE 1-10 ■ Maximum opening of more than 50 mm **(A)** and lateral movement of approximately 12 mm **(B)** are normal.

Temporomandibular Joints

The clinician locates the TMJs by palpating bilaterally just anterior to the auricular tragi while the patient opens and closes the mouth. This enables a comparison between the relative timing of left and right condylar movements during the opening stroke. Asynchronous movement may indicate a disk displacement that prevents one of the condyles from making a normal translatory movement (see Chapter 4). Auricular palpation (Fig. 1-9) with light anterior pressure helps identify potential disorders in the posterior attachment of the disk. Tenderness or pain on movement is noted and can be indicative of inflammatory changes in the retrodiscal tissues, which are highly vascular and innervated. Clicking in the TMJ is often noticeable through auricular palpation but may be difficult to detect in palpation directly over the lateral pole of the condylar process because the overlying tissues can muffle the click. By placing the fingertips on the angles of the patient's mandible, the clinician can identify even a minimal click because very little soft tissue lies between the fingertips and the mandibular bone.

A maximum mandibular opening resulting in less than 35 mm of interincisal movement is considered restricted, because the average opening is greater than 50 mm.[9,10] Such restricted movement on opening can be indicative of intracapsular changes in the joints. Similarly, any midline deviation on opening or closing is recorded. The maximum lateral movements of the patient can be measured (normal is approximately 12 mm) (Fig. 1-10).

Muscles of Mastication

Next, the masseter and temporal muscles, as well as other relevant postural muscles, are palpated for signs of tenderness (Fig. 1-11). Palpation is best accomplished bilaterally and simultaneously. This allows the patient to compare and report any differences between the left and right sides. Light pressure should be used (the amount of pressure that can be tolerated without discomfort on one's closed eyelid is a good comparative measure), and if any difference is reported between the left and right sides, the patient is asked to classify the discomfort as mild, moderate, or severe. If there is evidence of significant asynchronous movement or TMJ dysfunction, the clinician should follow a systematic sequence for comprehensive muscle palpation as described by Solberg (1976)[9] and Krogh-Poulsen and Olsson (1966).[11] Each palpation site is scored numerically on the basis of the patient's response. If neuromuscular or TMJ treatment is initiated, the examiner can then repalpate the same sites periodically to assess the response to treatment (Fig. 1-12).

Lips

The patient is observed for tooth visibility during normal and exaggerated smiling. This can be critical in the planning of fixed prosthodontic treatment,[12] especially when the need to fabricate crowns or fixed dental prostheses is anticipated in the esthetic zone. Some patients show only their maxillary teeth during smiling. More than 25% do not show the gingival third of the maxillary central incisors during an exaggerated smile[13] (Fig. 1-13). The extent of the smile depends on the length and mobility of the upper lip and the length of the alveolar process. When the patient laughs, the jaws open slightly and a dark space is often visible between the maxillary and mandibular teeth (Fig. 1-14). This has been called the *negative space*.[14] Missing teeth, diastemas, and fractured or poorly restored teeth disrupt the harmony of the negative space and often must be corrected.[15] (See Chapter 23.)

Intraoral Examination

The intraoral examination can reveal considerable information concerning the condition of the soft tissues, teeth, and supporting structures. The tongue, floor of the mouth, vestibule, cheeks, and hard and soft palates are examined, and any abnormalities are noted. This information can be evaluated properly during treatment planning only if objective indices, rather than vague assessments, are used.

Periodontal Examination*

In a periodontal examination,[16] the clinician evaluates the status of bacterial accumulation, the response of the host

*This section is written by Robert F. Baima.

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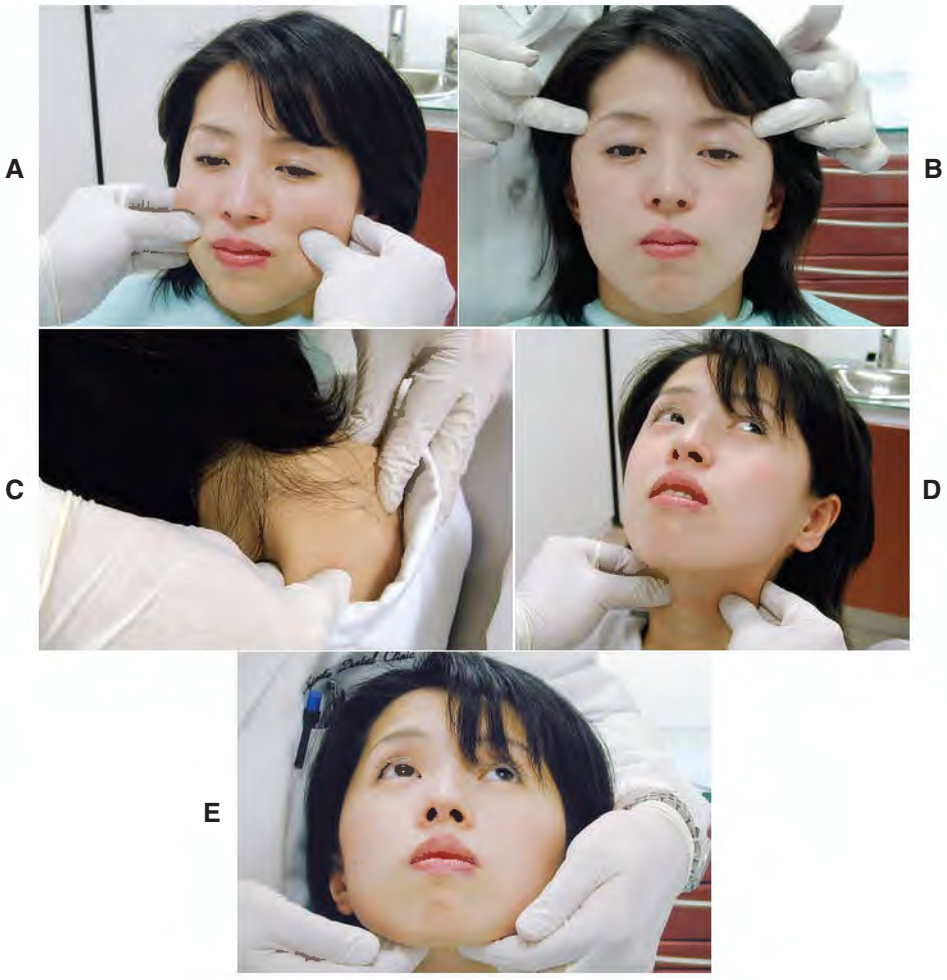

FIGURE 1-11 ■ Muscle palpation of the masseter **(A),** the temporal muscle **(B),** the trapezius muscle **(C),** the sternocleidomastoid muscle **(D),** and the floor of the mouth **(E).**

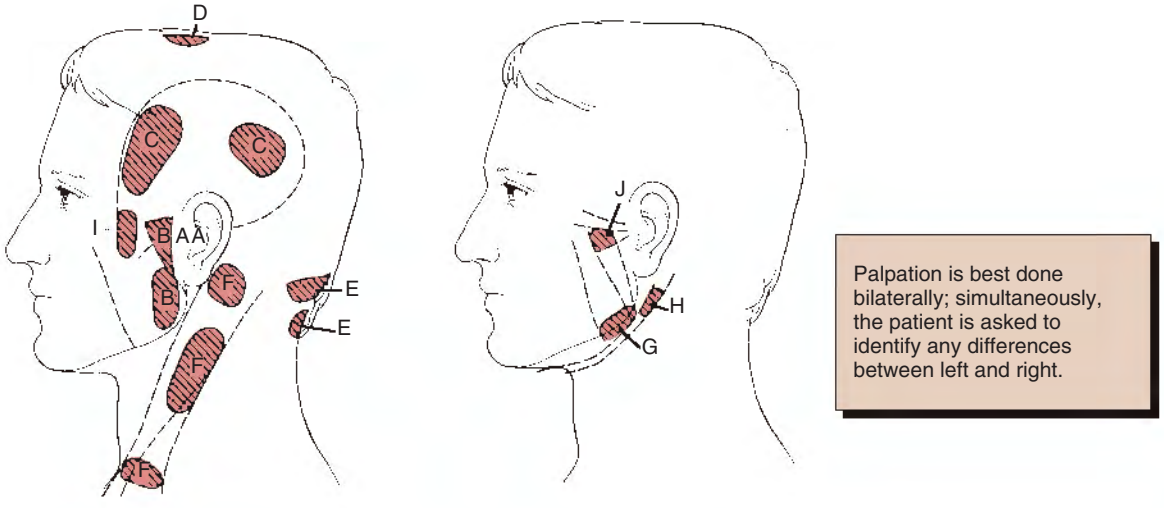

FIGURE 1-12 ■ Palpation sites for assessing muscle tenderness. **A,** Temporomandibular joint capsule: lateral and dorsal. **B,** Masseter: deep and superficial. **C,** Temporal muscle: anterior and posterior. **D,** Vertex. **E,** Neck: nape and base. **F,** Sternocleidomastoid muscle: insertion, body, and origin. **G,** Medial pterygoid muscle. **H,** Posterior digastric muscle. **I,** Temporal tendon. **J,** Lateral pterygoid muscle. (From Krogh-Poulsen WG, Olsson A: Occlusal disharmonies and dysfunction of the stomatognathic system. Dent Clin North Am 10:627, 1966.)

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FIGURE 1-13 ■ Smile analysis is an important part of the examination, particularly when anterior crowns or fixed dental prostheses are being considered. **A,** Some individuals show considerable gingival tissue during an exaggerated smile. **B,** Others may not show the gingival margins of even the central incisors. **C,** This individual shows little tooth when smiling.

FIGURE 1-14 ■ The "negative space" between the maxillary and mandibular teeth is assessed during the examination.

tissues, and the degree of reversible and irreversible damage. Long-term periodontal health is prerequisite for successful fixed prosthodontics (see Chapter 5). Existing periodontal disease must be corrected before any definitive prosthodontic treatment is undertaken.

Gingiva

The gingiva is dried for the examination so that moisture does not obscure subtle changes or detail. Color, texture, size, contour, consistency, and position are noted. The gingiva is carefully palpated to express any exudate present in the sulcular area.

Healthy gingiva (Fig. 1-15, *A*) is pink, stippled, and firmly bound to the underlying connective tissue. The free gingival margin is knife-edged, and sharply pointed papillae fill the interproximal spaces. Any deviation from these findings is noted. With the development of chronic marginal gingivitis (see Fig. 1-15, *B*), the gingiva becomes enlarged and bulbous, stippling is lost, the margins and papillae are blunted, and bleeding and exudate are observed.

To assess the width of the band of attached keratinized gingiva around each tooth, the clinician measures the width of the surface band of keratinized tissue in an apicocoronal dimension with a periodontal probe and subtracts the measurement of the sulcus depth. Alternatively, the marginal gingiva can be gently depressed with the side of a periodontal probe or explorer. At the mucogingival junction (MGJ), the effect of the instrument is seen to end abruptly, indicating the transition from tightly bound gingiva to more flexible mucosa. A third technique is to inject anesthetic solution into the nonkeratinized mucosa close to the MGJ to make the mucosa balloon slightly.

Periodontium

The periodontal probe (Fig. 1-16, *A*) provides a measurement (in millimeters) of the depth of periodontal pockets and healthy gingival sulci. The probe is inserted essentially parallel to the tooth and is "walked" circumferentially through the sulcus in firm but gentle steps; the examiner determines the measurement when the probe is in contact with the apical portion of the sulcus (see Fig. 1-16, *B*). Thus any sudden change in the attachment level can be detected. The probe may also be angled slightly (5 to 10 degrees) interproximally to reveal the topography of an existing lesion. Probing depths (usually six per tooth) are recorded on a periodontal chart (Fig. 1-17), which also contains other data such as tooth mobility or malposition, open proximal contact areas,

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FIGURE 1-15 ■ **A,** Healthy gingiva is pink, knife-edged, and firmly attached. **B,** In gingivitis, plaque and calculus cause marginal inflammation, with changes in color, contour, and consistency of the free gingival margin. In this case, inflammation extends into the keratinized attached gingiva.

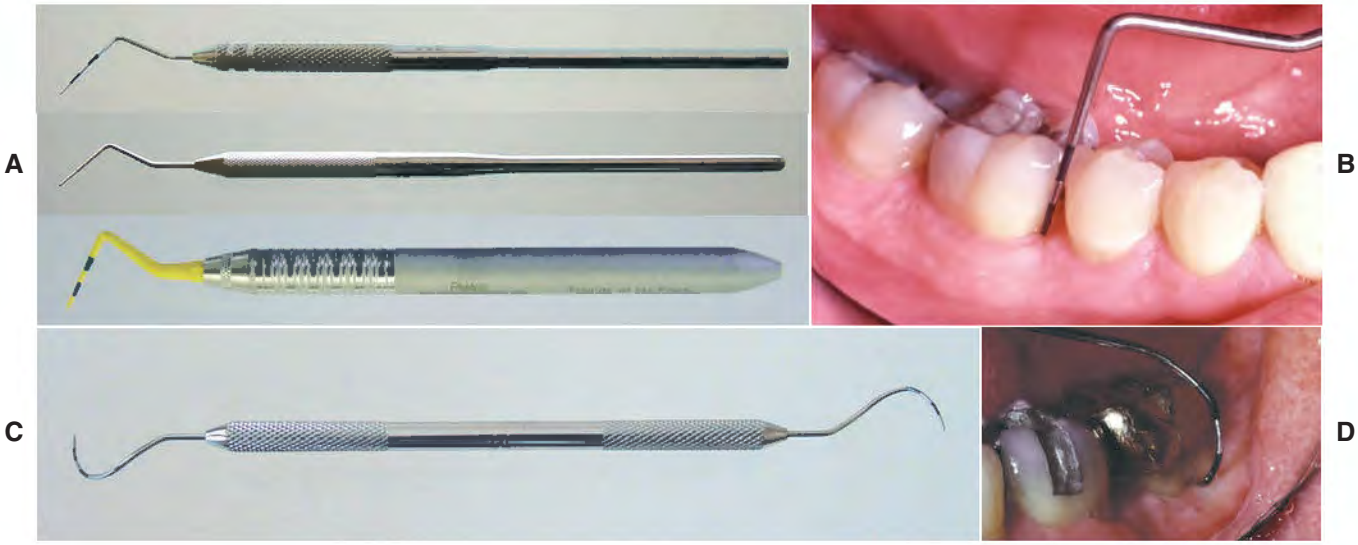


FIGURE 1-16 ■ **A,** Three types of sulcus/pocket-measuring probes. **B,** Correct position of a periodontal probe in the interproximal sulcular area, parallel to the root surface and in a vertical direction as far interproximally as possible. **C** and **D,** Graduated furcation probe. (**A** and **C**, From Boyd LB: Dental instruments, 5th ed. St. Louis, Saunders, 2015.)

inconsistent marginal ridge heights, missing or impacted teeth, areas of inadequate attached keratinized gingiva, gingival recession, furcation involvements, and malpositioned frenum attachments).

Clinical Attachment Level

Documenting the level of epithelial attachment helps the clinician quantify periodontal destruction and is essential for rendering a diagnosis of periodontitis (loss of connective tissue attachment).[17,18] This measurement also provides objective information regarding the prognosis of individual teeth. The clinical attachment level is determined by measuring the distance between the apical extent of the probing depth and a fixed reference point on the tooth, most commonly either the apical extent of a restoration or the cementoenamel junction (CEJ). This is recorded on modified periodontal charts (Fig. 1-18). When the free margin of the gingiva is located on the clinical crown and the level of the epithelial attachment is at the CEJ, there is no attachment loss, and recession is noted as a negative number. When the attachment level is on root structure and the free gingival margin is at the CEJ, attachment loss equals the probing depth, and the recession is scored 0. When increased periodontal destruction and recession are present, attachment loss equals the probing depth plus the measurement of recession[19] (see Fig. 1-18, *B* and *C*). Clinical attachment loss is a measure of periodontal destruction at a site, rather than of current disease activity; it may be considered the diagnostic "gold standard" for periodontitis[20] and should be documented in the initial periodontal examination.[21] It is an important consideration in the development of the overall diagnosis, treatment plan, and the prognosis of the dentition.

• • •

Dental Charting

An accurate charting of the state of the dentition reveals important information about the condition of the teeth and facilitates treatment planning. Adequate charting (Fig. 1-19) shows the presence or absence of teeth, dental caries, restorations, wear faceting and abrasions, fractures, malformations, and erosions. Tooth loss often affects the position of adjacent teeth (see Treatment of Tooth Loss section, Chapter 3). The presence of caries

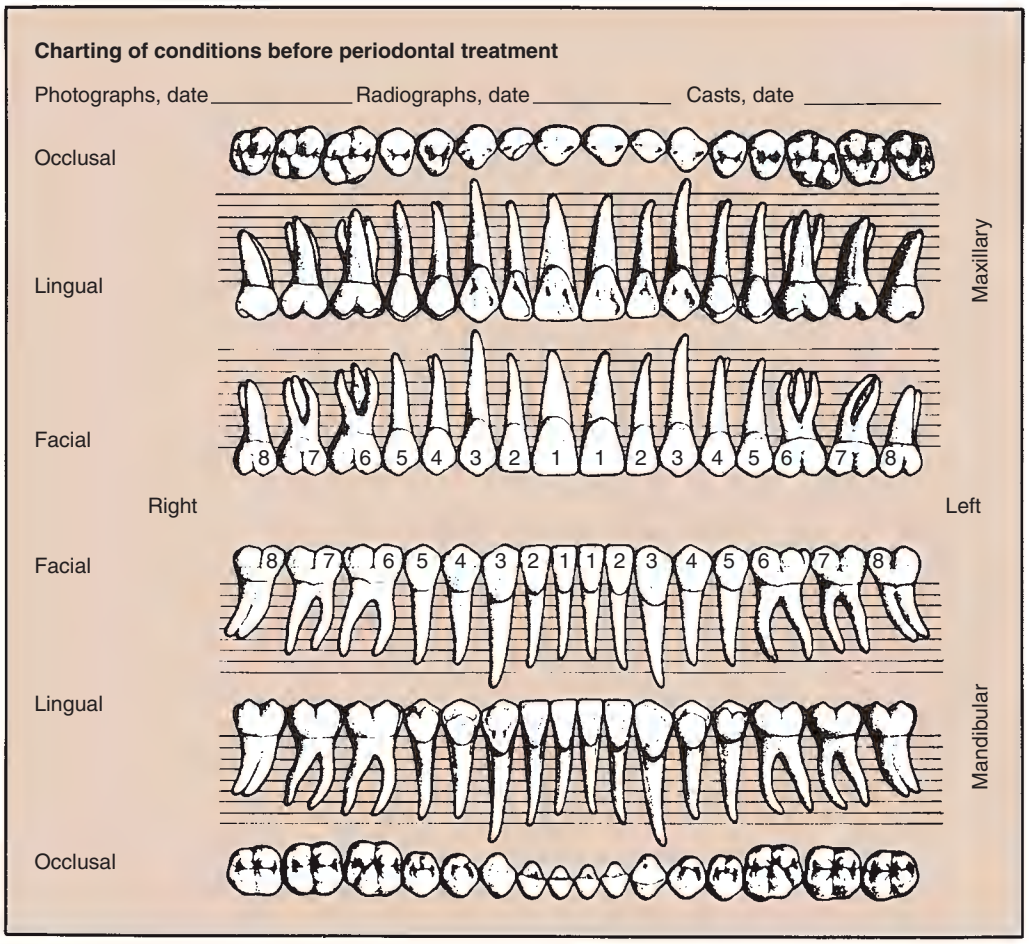


FIGURE 1-17 ■ Chart for recording pocket depths. The parallel lines are approximately 2 mm apart. The notations involved in using the chart are as follows: 1, Block out any missing teeth. 2, Draw a red × through the crown of any tooth that is to be extracted. 3, Record the gingival level with a continuous blue line. 4, Record pocket depths with a red line interrupted at the proximal surfaces of each tooth. 5, Shade the pocket form on each tooth with a red pencil (between the red and blue lines). 6, Indicate bifurcation or trifurcation involvements with a small red × at the involved area. 7, Record open contacts with vertical parallel lines (||) through the area. 8, Record improper contacts with a wavy red line through the area. 9, Record gingival overhang(s) with a red spur (∧) through the area. 10, Outline cavities and faulty restorations of periodontal significance in red. 11, Indicate rotated teeth by outlining in blue to show their actual position. (Modified from Goldman HM, Cohen DW: Periodontal Therapy, 5th ed. St. Louis, Mosby, 1973.)

on one interproximal surface should prompt the examiner to carefully inspect the adjacent proximal surface, even if caries is not apparent radiographically. The degree and extent of caries development over time can have a considerable effect on the eventual outcome of fixed prosthodontic treatment. The condition and type of the existing restorations are noted (e.g., amalgam, cast gold, composite resin, all-ceramic). Open contacts and areas where food impaction occurs must also be identified. The presence of wear facets is indicative of sliding contact sustained over time and thus may indicate parafunctional activity (see Chapter 4). Wear facets are often easier to see on diagnostic casts, however (see Chapter 2); during the clinical examination, the location of any observed facet is recorded. Fracture lines in teeth may necessitate fixed prosthodontic intervention, although minor hairline cracks in walls that are not subject to excessive loading can often go untreated and simply be observed at recall appointments (see Chapter 32). The location of fractures and any other abnormalities should be recorded.

Occlusal Examination

The clinician starts the occlusal examination by asking the patient to make a few simple opening and closing movements, which the clinician carefully observes. The objective is to determine to what extent the patient's occlusion differs from the ideal (see Chapter 4) and how well the patient has adapted to any difference that may exist. Special attention is given to initial contact, tooth alignment, eccentric occlusal contacts, and jaw maneuverability.

Initial Tooth Contact. The relationship of teeth in both centric relation (see Chapter 4) and the maximum intercuspation should be evaluated. If all teeth come together simultaneously at the end of terminal hinge closure, the centric relation (CR) position of the patient is said to coincide with the maximum intercuspation (MI) (see also Chapters 2 and 4). The patient is guided into a terminal hinge closure to detect where initial tooth contact occurs (see also the sections on bimanual manipulation and terminal hinge closure in Chapters 2 and 4).

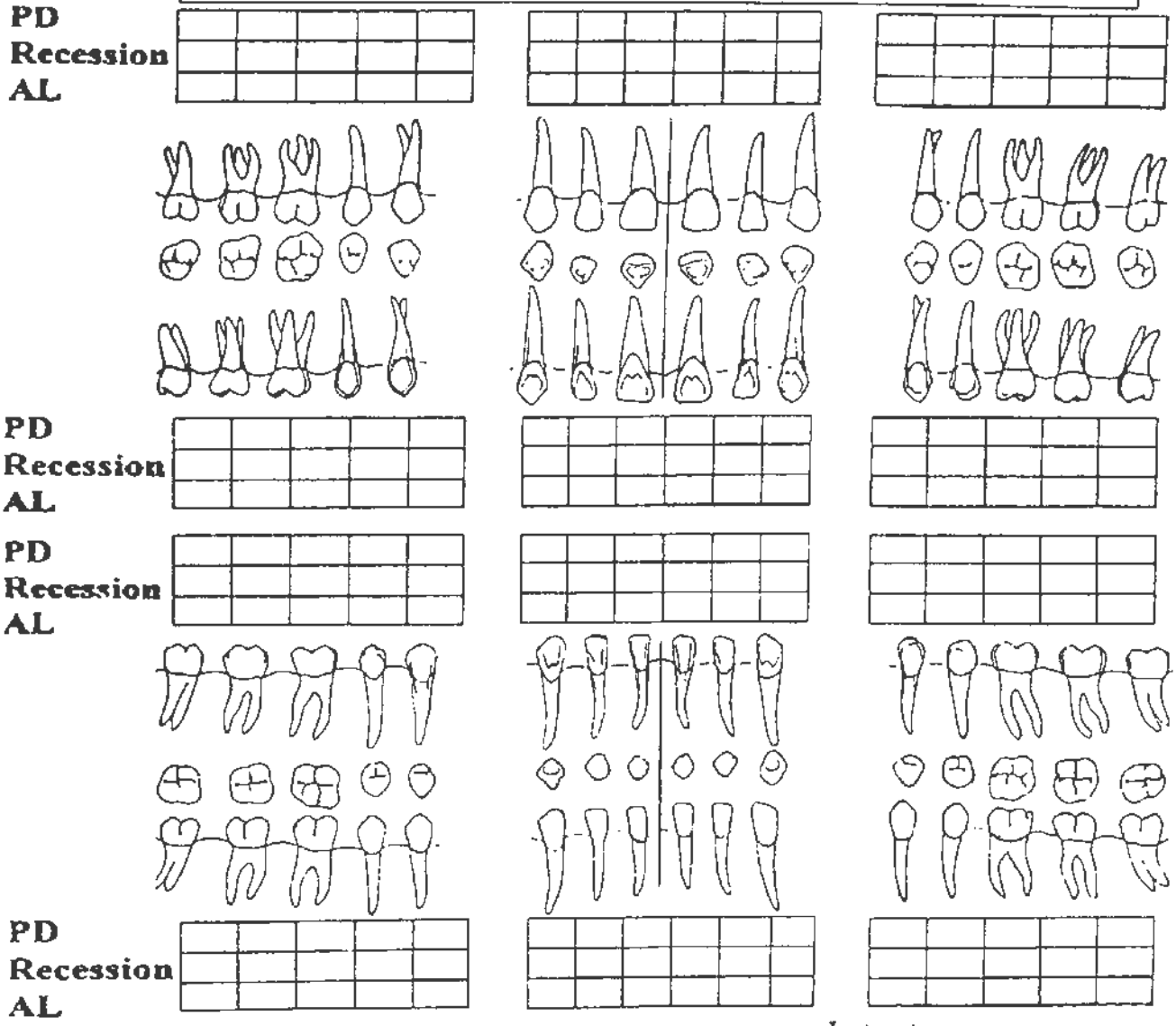
Date: _____

Patient name: _____

Student name: _____

Periodontal Chart:	Initial	Re-evaluation	SPT	POE
Pages of chart:	1-4	1 & 5	6 and/or 1-4	1-4

Medical Alert:



Instructor:
(Name & number)

Keys:
Furcation: V (I), ∇ (II), ▼ (III)
Missing tooth: (x)
Unerupted/Impacted tooth:
Crown:
Open contact: //
Root canal:
Overhang:
Rotation:
Drifting: D →
Mobility: I, II, III (written in space between occlusal and buccal surface)

A

FIGURE 1-18 ■ **A,** Modified periodontal chart.

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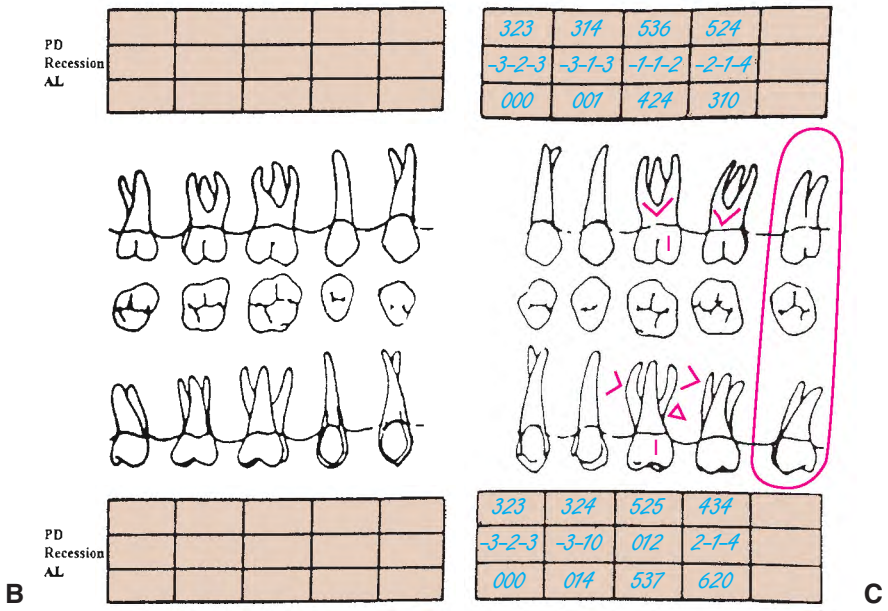

FIGURE 1-18, cont'd ■ **B,** Maxillary right sextant of modified periodontal chart with areas to record probing depths (PD), recession, and attachment loss (AL). **C,** Maxillary left sextant of modified periodontal chart exhibiting clinical documentation. (Courtesy University of Detroit Mercy School of Dentistry, Department of Periodontology and Dental Hygiene, Detroit.)

The clinician should ask the patient to "close feather-light" until any of the teeth touch and to have the patient help identify where that initial contact occurs by asking him or her to point at the location. If initial contact occurs between two posterior teeth (usually molars), the subsequent movement from the initial contact to the MI position is carefully observed and its direction noted. This is referred to as a *slide from CR to MI*. The presence, direction, and estimated length of the slide are recorded, and the teeth on which initial contact occurs are identified. Any such discrepancy between CR and MI should be evaluated in the context of other signs and symptoms that may be present: for example, abnormal muscle tone previously observed during the extraoral examination, mobility (noted during the periodontal evaluation) on the teeth where initial contact occurs, and any wear facets on the teeth contacting during the slide.

General Alignment. Any crowding, rotation, supra-eruption, spacing, malocclusion, and vertical and horizontal overlap (Fig. 1-20) are recorded. In many cases, teeth adjacent to edentulous spaces have shifted slightly. Even minor tooth movement can significantly affect fixed prosthodontic treatment. Tipped teeth affect tooth preparation design or may necessitate minor tooth movement before restorative treatment. Supra-erupted teeth are easily overlooked clinically but frequently complicate fixed dental prosthesis design and fabrication.

The relative relationship of adjacent teeth to planned fixed prostheses is important. A tooth may have drifted into the space previously occupied by the tooth in need of treatment because a large filling was lost for some time. Such changes in alignment can seriously complicate or preclude fabrication of a cast restoration for the damaged tooth and may even necessitate its extraction (see Fig. 1-20, *B*).

Lateral and Protrusive Contacts

The degree of vertical and horizontal overlap of the teeth is noted. When asked, most patients are capable of making an unguided protrusive movement. During this movement, the degree of posterior disclusion that results from the overlaps of the anterior teeth is observed. Excursive contacts on posterior teeth may be undesirable (see Chapter 4).

The patient is then guided into lateral excursive movements, and the presence or absence of contacts on the nonworking side and then the working side is noted. Such tooth contact in eccentric movements can be verified with a thin Mylar strip (shim stock). Any posterior cusps that hold the shim stock are evident (Fig. 1-21). Teeth subjected to excessive loading may develop varying degrees of mobility. Tooth movement (fremitus) should be confirmed by palpation (Fig. 1-22). If excessive occlusal contact is suspected, a finger placed against the buccal or labial surface while the patient lightly taps the teeth together helps locate fremitus in MI.

Jaw Maneuverability

The ease with which the patient moves the jaw and the way the mandible can be guided through hinge closure and excursive movements should be evaluated because this information is useful for assessing neuromuscular and masticatory function. If the patient has developed a pattern of protective reflexes, manipulating the jaw in a reproducible hinge movement can be difficult or impossible. Any restriction in maneuverability is recorded. A patient may move relatively freely in one lateral excursion but have difficulty moving to the contralateral side. Such limitation in maneuverability should be considered in the context of comprehensive

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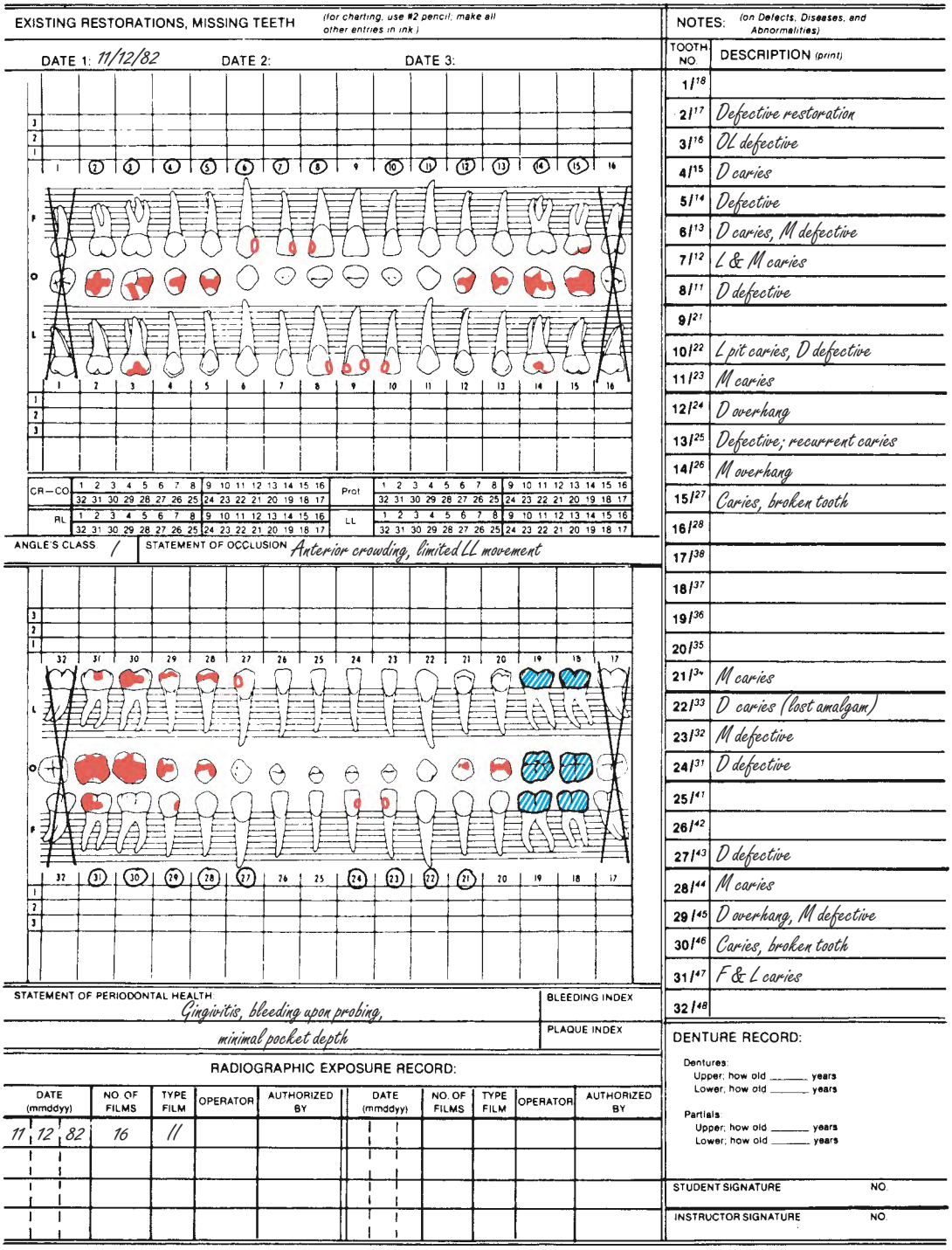

A

FIGURE 1-19 ■ An appropriate charting system **(A)** designates the location, type, and extent of existing restorations and the presence of any disease condition, all of which become part of the patient's permanent record. Radiographic findings obtained from a full-mouth series

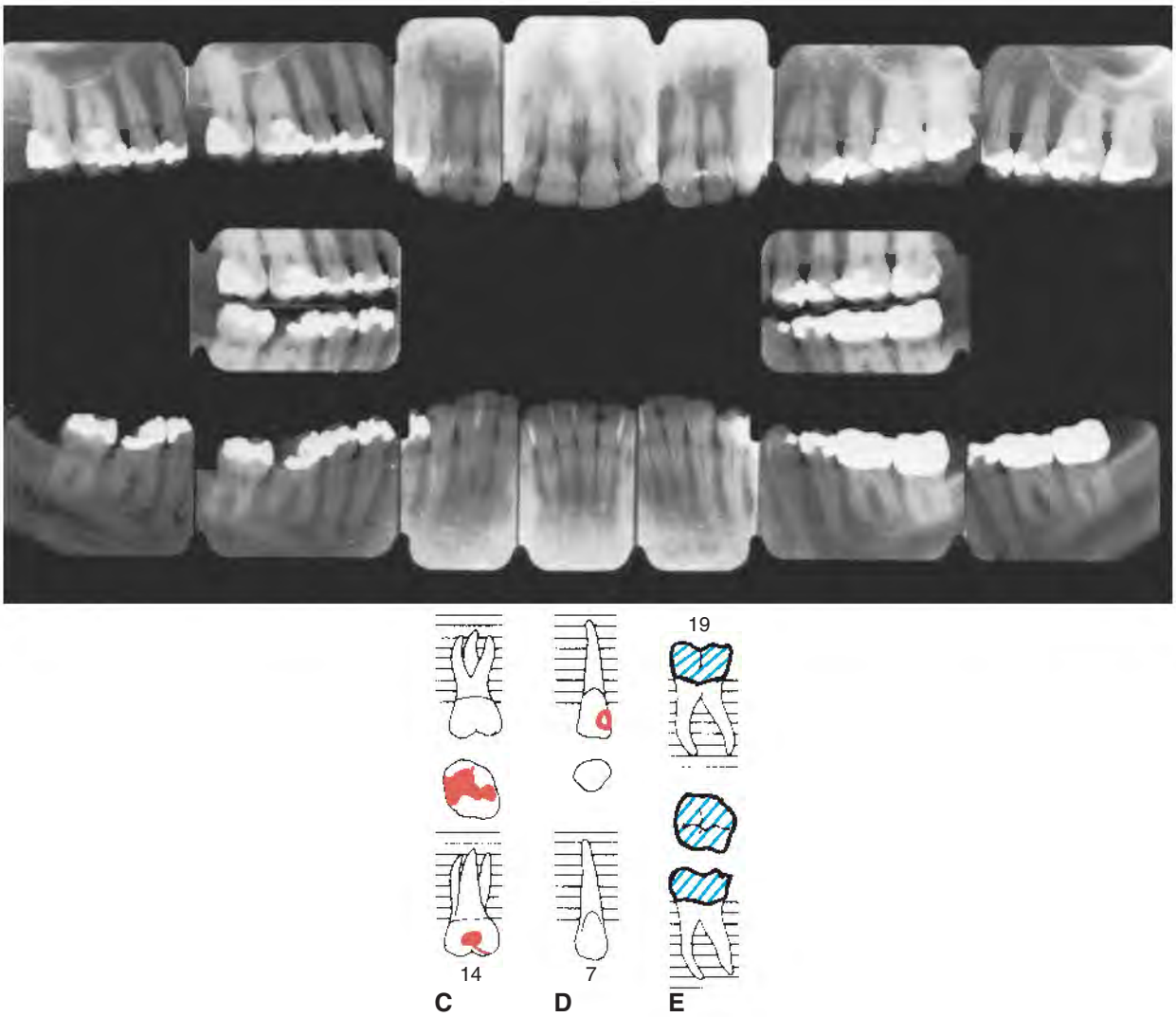

FIGURE 1-19, cont'd ■ **(B)** are compared with the clinical findings and noted in the record. Charting is performed to provide a quick reference to conditions in the mouth. The following may be useful: (1) Amalgam restorations **(C)** are depicted by an outline drawing blocked in solidly to show the size, shape, and location of the restoration. (2) Tooth-colored restorations **(D)** are depicted by an outline drawing of the size, shape, and location of the restoration. (3) Gold restorations **(E)** are depicted by an outline drawing inscribed with diagonal lines to show the size, shape, and location of the restoration. (4) Missing teeth are denoted by a large *X* on the facial, lingual, and occlusal diagrams of each tooth that is not visible clinically or on radiographs. (5) Caries is recorded by circling the tooth number at the apex of the involved tooth and noting the presence and location of the cavity in the description column corresponding to the tooth number on the right. (6) Defective restorations are recorded by circling the tooth number and noting the defect in the description column. (Modified from Roberson T, et al: The Art and Science of Operative Dentistry, 4th ed. St. Louis, Mosby, 2002.)

occlusal and neuromuscular analysis (see Chapters 4 and 6).

Radiographic Examination

Digital radiographs provide essential information to supplement the clinical examination. Detailed knowledge of the extent of bone support and the root structure of each standing tooth is critical for establishing a comprehensive fixed prosthodontic treatment plan. According to radiation exposure guidelines, the number of radiographs should be limited to only those that will result in potential changes in treatment decisions; however, a full periapical series (Fig. 1-23) is normally required for new patients so that a comprehensive fixed prosthodontic treatment plan can be developed.

Panoramic films (Fig. 1-24) provide useful information about the presence or absence of teeth. They are especially helpful in assessing third molars and impactions, evaluating the bone before implant placement (see Chapter 13), and screening edentulous arches for buried root tips. However, they do not provide a detailed view sufficient for assessing bone support, root structure, caries, or periapical disease.

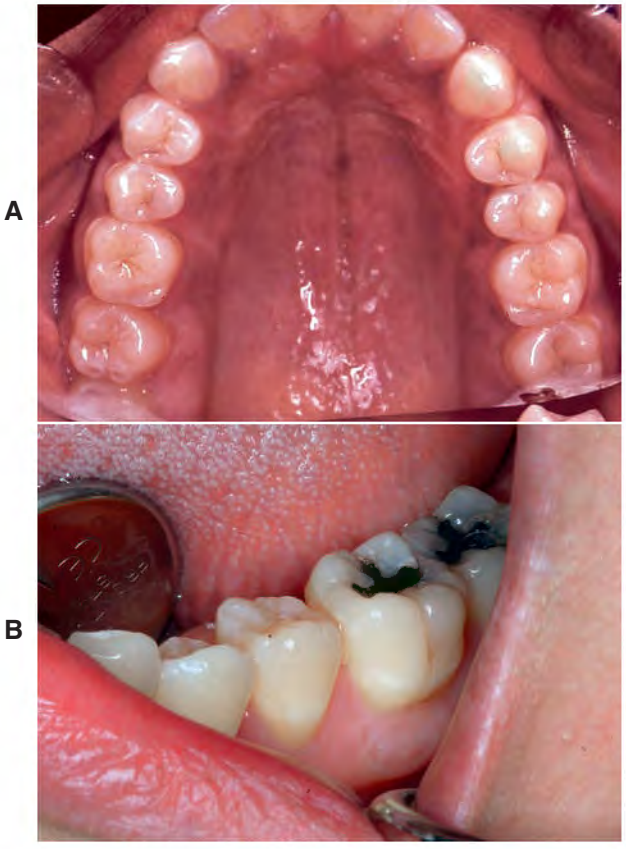

FIGURE 1-20 ■ Alignment of the dentition can be assessed intraorally, although diagnostic casts allow a more detailed assessment. **A,** This set of teeth is free of caries and in good alignment. **B,** Poor vertical alignment: the mandibular molar is supra-erupted, which has resulted in marginal ridge height discrepancy.

FIGURE 1-21 ■ Thin Mylar shim stock **(A)** can be used to test eccentric tooth contact **(B).**

FIGURE 1-22 ■ **A,** Fremitus (movement on palpation) indicates tooth contact during lateral excursions. **B,** Mobility is tested by exerting horizontal force on the tooth between the handles of two instruments.

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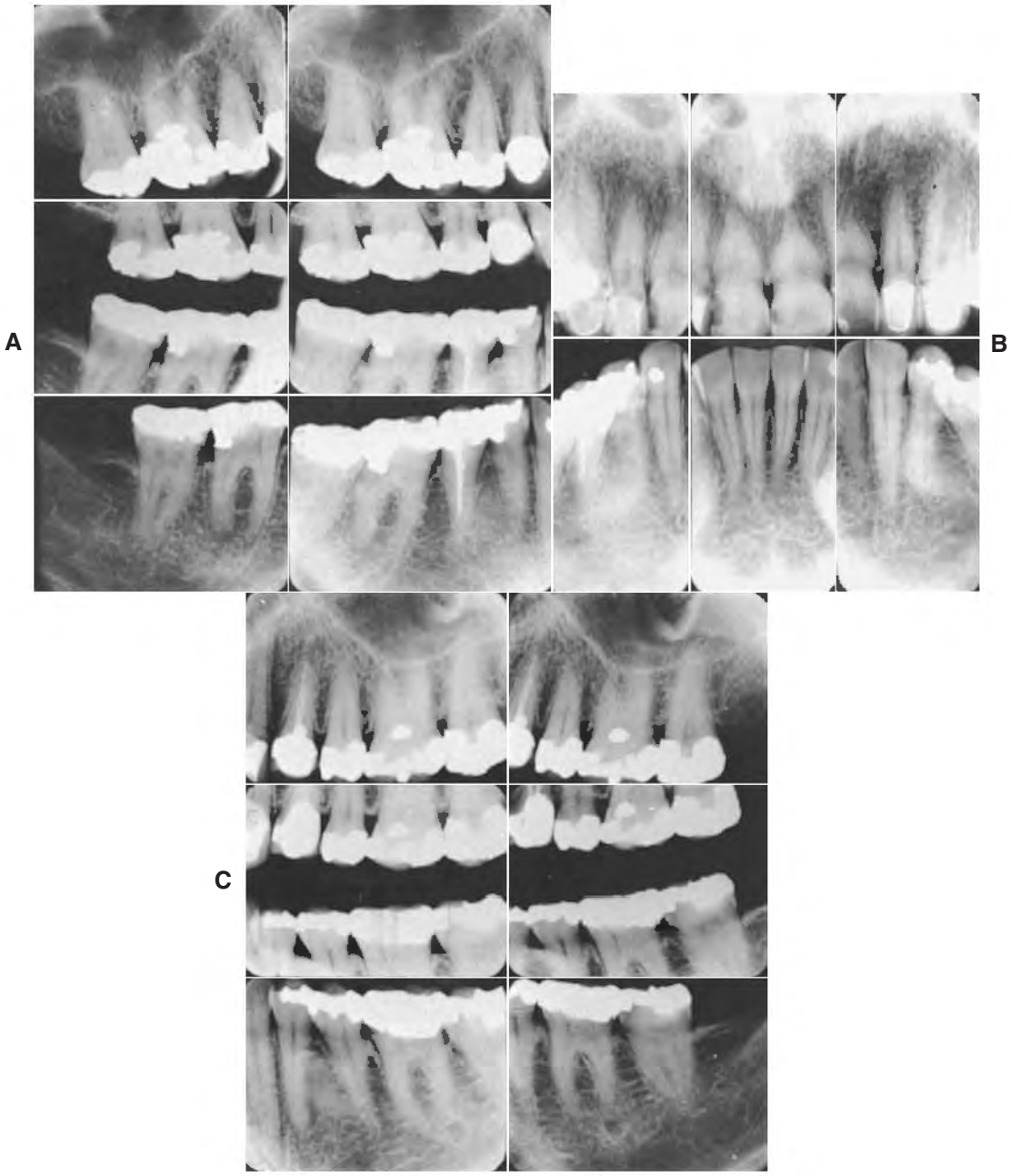

FIGURE 1-23 ■ **A** to **C,** A full-mouth radiographic survey should enable the dentist to make a detailed assessment of the structure of each tooth and its bone support.

FIGURE 1-24 ■ A panoramic film cannot be substituted for a full-mouth series because the image is distorted. Nevertheless, it is very useful for assessing unerupted teeth, screening edentulous areas for buried root tips, and evaluating the bone before implant placement.

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FIGURE 1-25 ■ A transcranial radiograph shows the lateral pole of the mandibular condyle *(arrow).*

Special radiographs may be needed for the assessment of TMJ disorders and a wide variety of pathologic conditions ranging from bone and mineral disorders to metabolic disorders, genetic abnormalities, and soft tissue calcifications, such as carotid artery calcification.[21] For assessment of the TMJs, a transcranial exposure (Fig. 1-25), with the help of a positioning device, reveals the lateral third of the mandibular condyle and can be used to detect some structural and positional changes. However, interpretation may be difficult,[22] and more information may be obtained from other images[23] (Fig. 1-26). Cone-beam imaging is considered prerequisite to most dental implant placements. In this form of imaging, osseous contours and bone volume are visualized, which improves decision making about the size of implant fixtures that realistically can be accommodated (Fig. 1-27).

Vitality Testing

Before any restorative treatment is begun, pulpal health must be confirmed, usually by assessing the response to thermal stimulation. In vitality tests, however, only the afferent nerve supply is assessed. Misdiagnosis can occur if the nerve supply is damaged but the blood supply is intact. Careful inspection of radiographs is therefore essential in the examination of such teeth.

DIAGNOSIS AND PROGNOSIS

Not all patients seeking fixed prosthodontic treatment have diagnostic problems. Nevertheless, diagnostic errors are possible, especially when a patient complains of pain or of symptoms of occlusal dysfunction. Treatment may be needed to eliminate obvious potential sources of the complaint, such as dental caries or a fractured tooth. A logical and systematic approach to diagnosis helps avoid mistakes.

Differential Diagnosis

When the history and examination are complete, a differential diagnosis is made. The most likely causes of the

FIGURE 1-26 ■ More sophisticated techniques enable the generation of computer-assisted images of clinician-determined cross-sections. **A,** A computed tomographic (CT) scan. **B,** A magnetic resonance image showing the soft tissue in greater detail. (Courtesy Dr. J. Petrie.)

observed conditions are identified and recorded in order of probability. A definitive diagnosis can usually be developed after such supporting evidence has been assembled.

A typical diagnosis condenses the information obtained during the clinical history taking and examination. For instance, a diagnosis could read as follows: "28-year-old male, no significant medical history; vital signs normal. Chief complaint: Mesiolingual cusp fracture on tooth #30. Teeth #1, #16, #17, #19, and #32 missing. Patient reports significant postoperative discomfort after previous molar extraction. High smile line. Caries: #6, mesial; #12, distal; #20, mesio-occlusal; and #30, mesio-occlusal–distal. Tooth #8 has received previous endodontic treatment. Generalized gingivitis in four posterior quadrants, with recession noted on teeth #23, #24, and #25; 5-mm pockets on teeth #18, #30, and #31. Radiographic evidence of periapical pathology in tooth #30. Tooth #30 tests nonvital."

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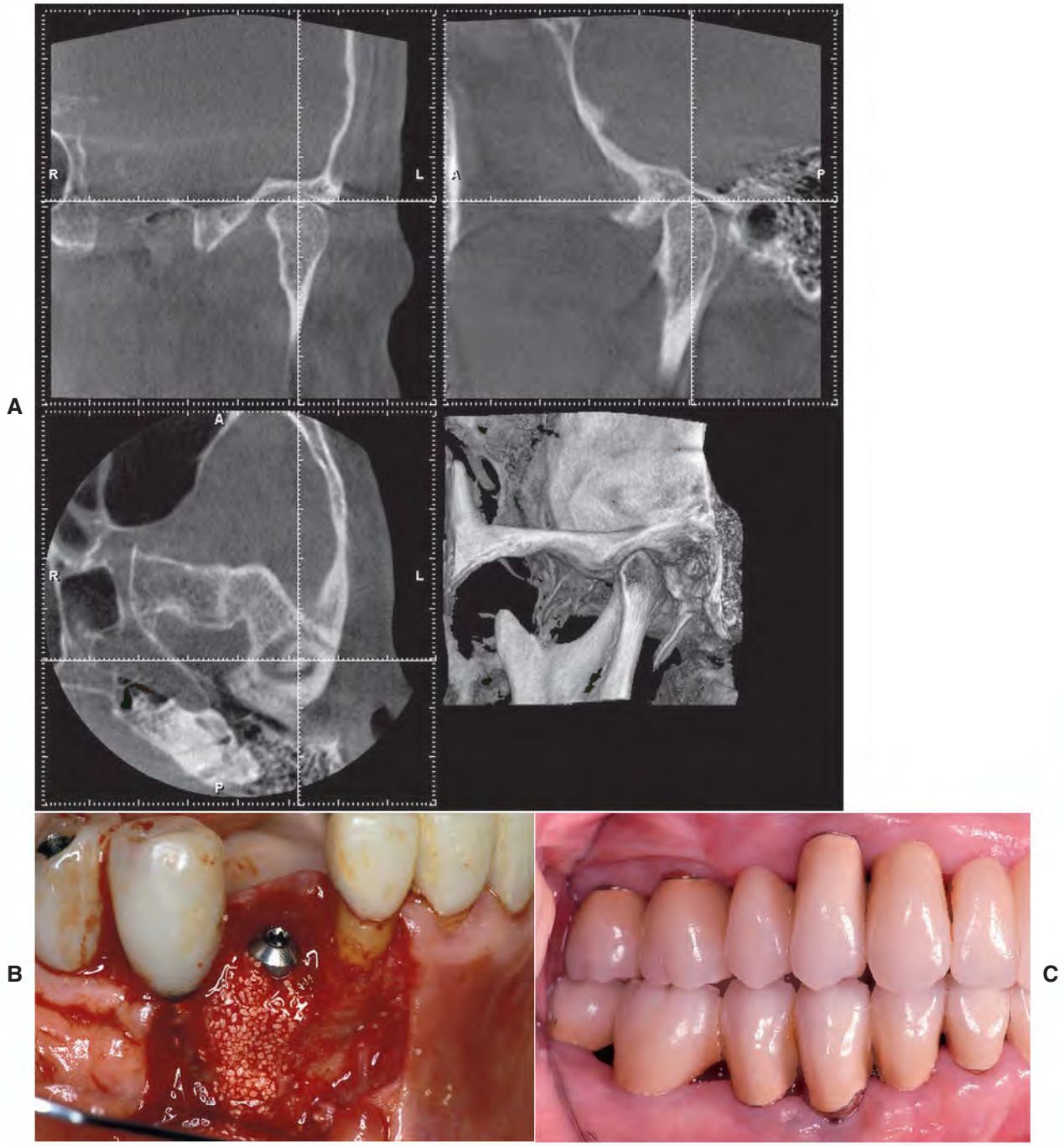

FIGURE 1-27 ■ **A,** Cone-beam technology is useful for definitive evaluation of pathologic conditions of the temporomandibular joint because it enables viewing of any desired cross section. **B,** Ridge augmentation surgery. **C,** Completed restoration.

This hypothetical scenario summarizes the patient's problems, allowing subsequent prioritization as a treatment plan is developed (see Chapter 3). In this case, the patient's chief complaint probably has existed longer than the symptoms that caused the patient to seek care.

Prognosis

The prognosis is an estimation of the likely course of a disease. It can be difficult to make, but its importance to patient management and successful treatment planning must nevertheless be recognized. The prognosis of dental disorders is influenced by general factors (age of the patient, lowered resistance of the oral environment) and local factors (forces applied to a given tooth, access for oral hygiene measures). For example, a young person with periodontal disease has a more guarded prognosis than does an older person with the same disease experience. In the younger person, the disease has followed a more virulent course because of the generally less developed systemic resistance; these facts should be reflected in treatment planning.

Fixed prostheses function in a hostile setting: In the moist oral environment, the teeth are subject to constant changes

in temperature and acidity and to considerable load fluctuation. A comprehensive clinical examination helps establish the likely prognosis. All facts and observations are first considered individually and then correlated appropriately.

General Factors

The overall caries rate of the patient's dentition indicates future risk to the patient if the condition is left untreated. Important variables include the patient's understanding and comprehension of plaque-control measures, as well as the physical ability to perform those tasks. Analysis of systemic problems in the context of the patient's age and overall health provides important information. For example, the incidence of periodontal disease is higher in diabetic patients than in the general population, and special precautionary measures may be indicated in those patients before treatment begins. Such conditions also affect the overall prognosis.

Some patients are capable of exerting an extremely high occlusal force (see Fig. 7-39), whereas others are not. If muscle tone of hypertrophied elevator muscles is identified as abnormal during the extraoral examination and multiple intraoral wear facets are observed, loading of the teeth is considerably higher than in the dentition of a frail 90-year-old patient who fatigues easily when asked to close. Other important factors in determining overall prognosis are the history and success of previous dental treatments. If a patient's previous dental care has been successful over a period of many years, a better prognosis can be anticipated than when apparently properly fabricated prostheses fail or become dislodged within a few years of initial placement.

Local Factors

The observed vertical overlap of the anterior teeth has a direct effect on the load distribution in the dentition and thus can have an effect on the prognosis. Minimal vertical overlap is generally less favorable because higher load on posterior teeth results (see Chapter 4). In the presence of favorable loading, minor tooth mobility is less of a concern than in the presence of unfavorably directed or high load. Impactions adjacent to a molar that will be crowned may pose a serious threat in a younger patient, in whom additional growth can be anticipated, but may be of lesser concern in an older patient.

Individual tooth mobility, root angulation, root structure, crown-to-root ratios, and many other variables all have an effect on the overall prognosis for fixed prosthodontic devices. They are addressed later in this book (see also Chapter 3).

Prosthodontic Diagnostic Index (PDI) for Partially Edentulous and Completely Dentate Patients

The American College of Prosthodontists (ACP) has developed diagnostic indices for partial edentulism[24] and for completely dentate patients[25] on the basis of diagnostic findings that are summarized here with the permission and support of the ACP. These guidelines are intended to help practitioners determine appropriate treatments for their patients. For each index, four categories, class I to class IV, are defined; class I represents an uncomplicated clinical situation and class IV represents a complex clinical situation. The indices are designed for use by dental professionals involved in the diagnosis and treatment of partially edentulous and completely dentate patients. Potential benefits of the system include (1) improved intraoperator consistency, (2) improved professional communication, (3) insurance reimbursement commensurate with complexity of care, (4) improved screening tool for dental school admission clinics, (5) standardized criteria for outcomes assessment and research, (6) enhanced diagnostic consistency, and (7) simplified decision to refer a patient.

Each class is differentiated by specific diagnostic criteria (ideal or minimal, moderately compromised, substantially compromised, or severely compromised) of the following (for partially edentulous patients):

1. Location and extent of the edentulous area or areas
2. Condition of the abutment teeth
3. Occlusal scheme
4. Residual ridge

For completely dentate patients, only tooth condition and occlusal scheme are evaluated.

Location and Extent of the Edentulous Areas

In the *ideal or minimally compromised edentulous area*, the edentulous span is confined to a single arch, and one of the following conditions is present:

- Any anterior maxillary span that does not exceed two missing incisors
- Any anterior mandibular span that does not exceed four missing incisors
- Any posterior maxillary or mandibular span that does not exceed two premolars or one premolar and one molar

In the *moderately compromised edentulous area*, the edentulous span is in both arches, and one of the following conditions exists:

- The span includes any anterior maxillary span that does not exceed two missing incisors.
- The span includes any anterior mandibular span that does not exceed four missing incisors.
- The span includes any posterior maxillary or mandibular span that does not exceed two premolars or one premolar and one molar.
- The maxillary or mandibular canine tooth is missing.

The *substantially compromised edentulous area* includes the following conditions:

- Any posterior maxillary or mandibular span that is greater than three missing teeth or two molars
- Any edentulous span, including anterior and posterior areas of three or more missing teeth

The *severely compromised edentulous area* includes the following condition:

- Any edentulous area or combination of edentulous areas whose care requires a high level of patient compliance

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Condition of the Abutment Teeth (Tooth Condition for Completely Dentate Patients)

In cases of ideal or minimally compromised abutment teeth,

- No preprosthetic therapy is indicated.

In cases of moderately compromised abutment teeth,

- Tooth structure is insufficient to retain or support intracoronal restorations, in one or two sextants.
- Localized adjunctive therapy (i.e., periodontal, endodontic, or orthodontic procedures, in one or two sextants) is required for abutments.

In cases of substantially compromised abutment teeth,

- Tooth structure is insufficient to retain or support intracoronal or extracoronal restorations, in four or more sextants.
- Extensive adjunctive therapy (i.e., periodontal, endodontic or orthodontic procedures, in four or more sextants) is required for abutments.

In cases of severely compromised abutment teeth,

- Abutments have a guarded prognosis.

Occlusal Scheme

Ideal or minimally compromised occlusal schemes are characterized by the following conditions:

- No preprosthetic therapy required
- Class I molar and jaw relationships

Moderately compromised occlusal schemes are characterized by the following conditions:

- Necessity for localized adjunctive therapy (e.g., enameloplasty on premature occlusal contacts)
- Class I molar and jaw relationships

Substantially compromised occlusal schemes are characterized by the following conditions:

- Necessity for reestablishment of entire occlusal scheme, but without any change in the occlusal vertical dimension
- Class II molar and jaw relationships

Severely compromised occlusal schemes are characterized by the following conditions:

- Necessity for reestablishment of entire occlusal scheme, with changes in the occlusal vertical dimension
- Class II, division 2, and class III molar and jaw relationships

Residual Ridge

The Classification System for Complete Edentulism[26] is used to categorize any edentulous span present in a partially edentulous patient.

Classification System

The four criteria and their subclassifications are organized into an overall classification system for partial edentulism; the two criteria provide the system for completely edentulous patients.

Class I

This class (Figs. 1-28 and 1-29) is characterized by ideal or minimal compromise in the location and extent of an edentulous area (which is confined to a single arch), abutment conditions, occlusal characteristics, and residual ridge conditions. All four of the diagnostic criteria are favorable.

1. The location and extent of the edentulous area are ideal or minimally compromised:
   - The edentulous area is confined to a single arch.
   - The edentulous area does not compromise the physiologic support of the abutments.
   - The edentulous area may include any anterior maxillary span that does not exceed two incisors, any anterior mandibular span that does not exceed four missing incisors, or any posterior span that does not exceed two premolars or one premolar and one molar.
2. The abutment condition is ideal or minimally compromised, with no need for preprosthetic therapy.
3. The occlusion is ideal or minimally compromised, with no need for preprosthetic therapy; maxillomandibular relationship consists of class I molar and jaw relationships.
4. Residual ridge structure conforms to the class I complete edentulism description.

Class II

This class (Figs. 1-30 and 1-31) is characterized by moderately compromised location and extent of edentulous areas in both arches, abutment conditions that necessitate localized adjunctive therapy, occlusal characteristics that necessitate localized adjunctive therapy, and residual ridge conditions.

1. The location and extent of the edentulous area are moderately compromised:
   - Edentulous areas may exist in one or both arches.
   - The edentulous areas do not compromise the physiologic support of the abutments.
   - Edentulous areas may include any anterior maxillary span that does not exceed two incisors, any anterior mandibular span that does not exceed four incisors, any posterior span (maxillary or mandibular) that does not exceed two premolars, or one premolar and one molar or any missing canine (maxillary or mandibular).
2. Condition of the abutments is moderately compromised:
   - Abutments in one or two sextants have insufficient tooth structure to retain or support intracoronal or extracoronal restorations.
   - Abutments in one or two sextants necessitate localized adjunctive therapy.
3. Occlusion is moderately compromised:
   - Occlusal correction necessitates localized adjunctive therapy.
   - Maxillomandibular relationship is characterized as class I molar and jaw relationships.
4. Residual ridge structure conforms to the class II description of complete edentulism.

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FIGURE 1-28 ■ Class I. This patient is categorized as class I because of an ideal or minimally compromised edentulous area, abutment condition, and occlusion. There is a single edentulous area in one sextant. The residual ridge is considered type A. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Frontal view, protrusive relationship. **G,** Right lateral view, right working movement. **H,** Left lateral view, left working movement. **I,** Full-mouth radiographic series. (From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)

FIGURE 1-29 ■ Class I. This patient is categorized as class I because an ideal or minimally compromising tooth condition and occlusal scheme are exhibited. A single large amalgam core restoration requires a complete coverage restoration in one sextant. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Panoramic radiograph. (From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)

FIGURE 1-30 ■ Class II. This patient is categorized as class II because edentulous areas are present in two sextants in different arches. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Frontal view, protrusive relationship. **G,** Right lateral view, right working movement. **H,** Left lateral view, left working movement. **I,** Full-mouth radiographic series. (From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)

FIGURE 1-31 ■ Class II. This patient is categorized as class II because one sextant exhibits three defective restorations with an esthetic component. Additional variables of gingival architecture and individual tooth proportions increase the complexity of diagnosis. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Panoramic radiograph. (From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)

Class III

This class (Figs. 1-32 and 1-33) is characterized by substantially compromised location and extent of edentulous areas in both arches, abutment condition that necessitates substantial localized adjunctive therapy, occlusal characteristics that necessitate reestablishment of the entire occlusion without a change in the occlusal vertical dimension, and residual ridge conditions.

1. The location and extent of the edentulous areas are substantially compromised:
   - Edentulous areas may be present in one or both arches.
   - Edentulous areas compromise the physiologic support of the abutments.
   - Edentulous areas may include any posterior maxillary or mandibular edentulous area greater than three teeth or two molars or anterior and posterior edentulous areas of three or more teeth.
2. The condition of the abutments is moderately compromised:
   - Abutments in three sextants have insufficient tooth structure to retain or support intracoronal or extracoronal restorations.
   - Abutments in three sextants necessitate more substantial localized adjunctive therapy (i.e., periodontal, endodontic, or orthodontic procedures).
   - Abutments have a fair prognosis.
3. Occlusion is substantially compromised:
   - The entire occlusal scheme must be reestablished without an accompanying change in the occlusal vertical dimension.
   - Maxillomandibular relationship is characterized as class II molar and jaw relationships.

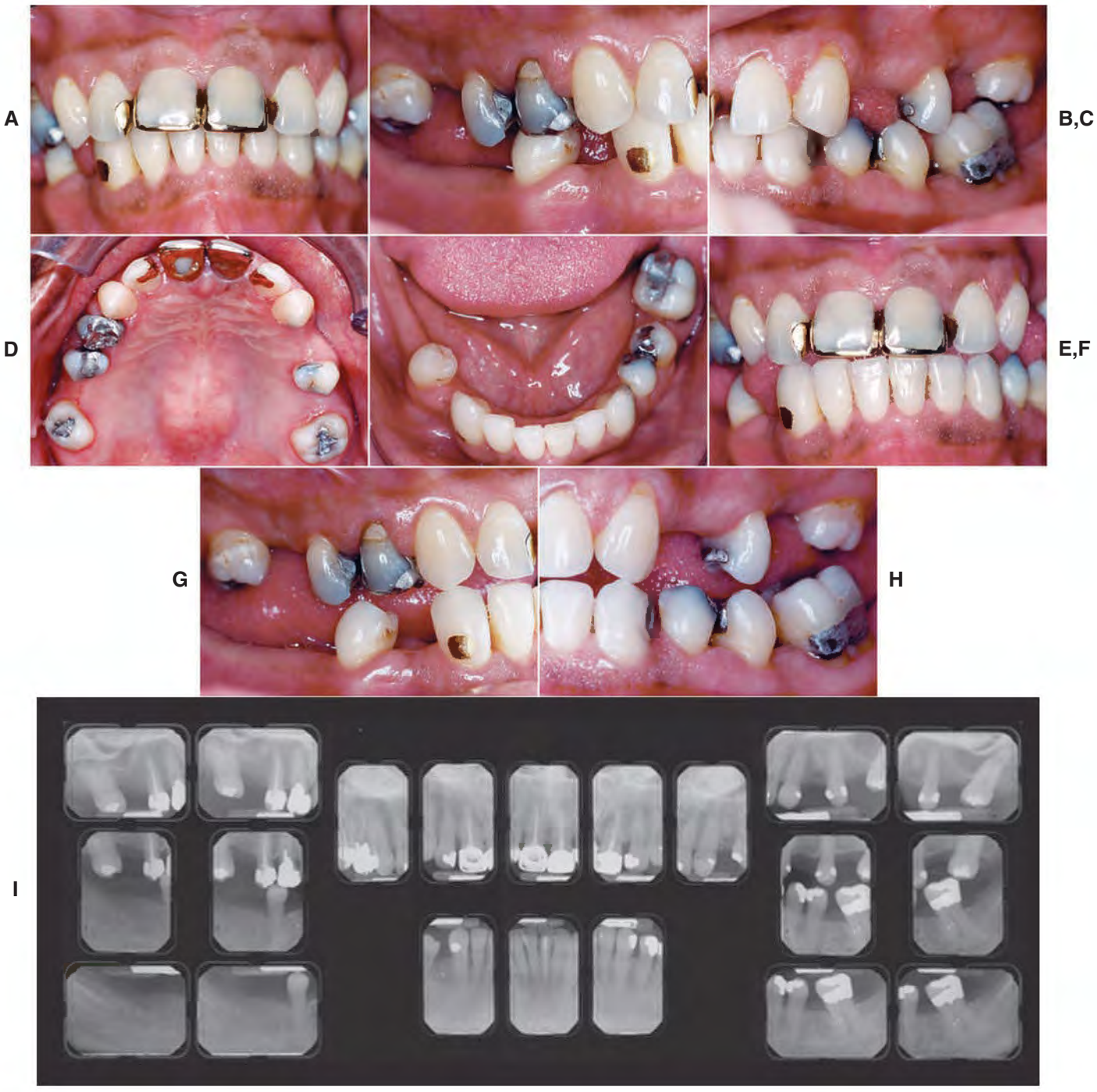

FIGURE 1-32 ■ Class III. This patient is categorized as class III because the edentulous areas are located in both arches and there are multiple such locations within each arch. The abutment condition is substantially compromised as a result of the need for extracoronal restorations. There are teeth that are extruded and malpositioned. The occlusion is substantially compromised because reestablishment of the occlusal scheme is required without a change in the occlusal vertical dimension. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Frontal view, protrusive relationship. **G,** Right lateral view, right working movement. **H,** Left lateral view, left working movement. **I,** Full-mouth radiographic series. (From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)

FIGURE 1-33 ■ Class III. This patient is categorized as class III because large defective amalgam and composite restorations are present in four sextants. The remaining tooth structure is substantially compromised in most posterior teeth. The occlusion is substantially compromised, which necessitates reestablishment of the occlusal scheme without a change in the occlusal vertical dimension. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Panoramic radiograph. (From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)

4. Residual ridge structure conforms to the class III complete edentulism description.

Class IV

This class (Figs. 1-34 and 1-35) is characterized by severely compromised location and extent of edentulous areas with guarded prognosis, abutment conditions that necessitate extensive therapy, occlusion characteristics that necessitate reestablishment of the occlusion with a change in the occlusal vertical dimension, and residual ridge conditions.

1. The location and extent of the edentulous areas result in severe occlusal compromise:
   - Edentulous areas may be extensive and may be present in both arches.
   - Edentulous areas compromise the physiologic support of the abutment teeth, and so the prognosis is guarded.
   - Edentulous areas include acquired or congenital maxillofacial defects.
   - At least one edentulous area has a guarded prognosis.
2. Abutments are severely compromised:
   - Abutments in four or more sextants have insufficient tooth structure to retain or support intracoronal or extracoronal restorations.
   - Abutment conditions in four or more sextants necessitate extensive localized adjunctive therapy.
   - Abutments have a guarded prognosis.

FIGURE 1-34 ■ Class IV. This patient is categorized as class IV because edentulous areas are found in both arches, and the physiologic abutment support is compromised. Abutment condition is severely compromised as a result of advanced attrition and failing restorations, which necessitates extracoronal restorations and adjunctive therapy. The occlusion is severely compromised, which necessitates reestablishment of occlusal vertical dimension and proper occlusal scheme. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Frontal view, protrusive relationship. **G,** Right lateral view, right working movement. **H,** Left lateral view, left working movement. **I, Full-mouth radiographic series.** (From McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.)

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FIGURE 1-35 ■ Class IV. This patient is categorized as class IV because advanced attrition of the occlusal surfaces is present in more than three sextants. The occlusion is severely compromised, which necessitates reestablishment of occlusal vertical dimension and a proper occlusal scheme. **A,** Frontal view, maximum intercuspation. **B,** Right lateral view, maximum intercuspation. **C,** Left lateral view, maximum intercuspation. **D,** Occlusal view, maxillary arch. **E,** Occlusal view, mandibular arch. **F,** Panoramic radiograph. (From McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.)

3. Occlusion is severely compromised:
   - Reestablishment of the entire occlusal scheme, including changes in the occlusal vertical dimension, is necessary.
   - Maxillomandibular relationship is characterized as class II, division 2, or class III molar and jaw relationships.
4. Residual ridge structure conforms to the class IV complete edentulism description.

Other characteristics include severe manifestations of local or systemic disease, including sequelae from oncologic treatment, maxillomandibular dyskinesia or ataxia, and refractoriness (a patient's presenting with chronic complaints after appropriate therapy).

Guidelines for the Use of PDI Classification System for Partial Edentulism and Complete Dentition

The analysis of diagnostic factors is facilitated with the use of a worksheet (Fig. 1-36 and Table 1-1). Each criterion is evaluated, and a checkmark is placed in the appropriate box. In instances in which a patient's diagnostic criteria overlap two or more classes, the more complex class is the selected diagnosis.

The following additional guidelines should be followed to ensure consistent application of the classification system:

1. Consideration of future treatment procedures must not influence the choice of diagnostic level.

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Description	Class I	Class II	Class III	Class IV
Location and Extent of Edentulous Areas				
Ideal or minimally compromised: single arch				
Moderately compromised: both arches				
Substantially compromised: more than three teeth				
Severely compromised: guarded prognosis				
Congenital or acquired maxillofacial defect				
Abutment Condition				
Ideal or minimally compromised				
Moderately compromised: one to two sextants				
Substantially compromised: three sextants				
Severely compromised: four or more sextants				
Occlusion				
Ideal or minimally compromised				
Moderately compromised: local adjunctive treatment				
Substantially compromised: occlusal scheme				
Severely compromised: change in occlusal vertical dimension				
Residual Ridge				
Class I edentulous				
Class II edentulous				
Class III edentulous				
Class IV edentulous				
Conditions Creating a Guarded Prognosis				
Severe oral manifestations of systemic disease				
Maxillomandibular dyskinesia and/or ataxia				
Refractory condition				

FIGURE 1-36 ■ Worksheet used to determine prosthodontic diagnostic index classification. Note: Individual diagnostic criteria are evaluated, and the appropriate box is checked. The most advanced finding determines the final classification. Guidelines for use of the worksheet: 1. Possession of any single criterion of a more complex class places the patient into the more complex class. 2. Consideration of future treatment procedures must not influence the diagnostic level. 3. Initial preprosthetic treatment and/or adjunctive therapy can change the initial classification level. 4. If there is an esthetic concern/challenge, the classification is increased in complexity by one level in class I and II patients. 5. In the presence of symptoms of temporomandibular disorder, the classification is increased in complexity by one or more levels in class I and II patients. 6. In the situation in which the patient presents with an edentulous mandible opposing a partially edentulous or dentate maxilla, the patient is categorized as class IV.

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TABLE 1-1 **Worksheet Used to Determine Prosthodontic Diagnostic Index Classification of Completely Dentate Patients**

Description	Class I	Class II	Class III	Class IV
Teeth Condition				
Ideal or minimally compromised: three or fewer teeth in one sextant	X			
Moderately compromised: one or more teeth in one to two sextants		X		
Substantially compromised: one or more teeth in three to five sextants			X	
Severely compromised: four or more teeth, all sextants				X
Occlusal Scheme				
Ideal or minimally compromised	X			
Moderately compromised: anterior guidance intact		X		
Substantially compromised: extensive rest/same OVD			X	
Severely compromised: extensive rest/new OVD				X
Conditions Creating a Guarded Prognosis				
Severe oral manifestations of systemic disease				X
Maxillomandibular dyskinesia or ataxia				X
Refractory condition				X

Note: Individual diagnostic criteria are evaluated, and the appropriate box is checked. The most advanced finding determines the final classification.

Guidelines for use of this worksheet:

1. Consideration of future treatment procedures must not influence the diagnostic level.
2. Initial preprosthetic treatment or adjunctive therapy can change the initial classification level.
3. If there is an esthetic concern/challenge, the classification is increased in complexity by one or more levels.
4. In the presence of temporomandibular joint symptoms, the classification is increased in complexity by one or more levels.
5. It is assumed that the patient will receive therapy designed to achieve and maintain optimal periodontal health.
6. Situations that fail to conform to the definition of completely dentate should be classified according to the classification system for partial edentulism.

OVD, Occlusal vertical dimension.

2. Initial preprosthetic treatment or adjunctive therapy can change the initial classification level. Classification may need to be reassessed after existing prostheses are removed.
3. Esthetic concerns or challenges raise the classification by one level in cases of class I and class II dentition.
4. The presence of symptoms of temporomandibular disorder raises the classification by one or more levels in patients with class I and class II dentition.
5. In a patient presenting with an edentulous maxilla opposing a partially edentulous mandible, each arch is diagnosed according to the appropriate classification system; that is, the maxilla is classified according to the complete edentulism classification system, and the mandible is classified according to the partial edentulism classification system. The sole exception to this rule is the case of an edentulous mandible opposed by a partially edentulous or dentate maxilla. This clinical situation entails significant complexity and potential long-term morbidity and, as such, should be categorized as class IV in either system.
6. Periodontal health is intimately related to the diagnosis and prognosis for partially edentulous patients. For the purpose of this system, it is assumed that patients receive therapy to achieve and maintain periodontal health so that appropriate prosthodontic care can be accomplished.

The classification system for partial edentulism is based on the most objective criteria available to facilitate uniform use of the system. Such standardization may help improve communications among dental professionals and third parties. This classification system serves to identify patients most likely to require treatment by a specialist or by a practitioner with additional training and experience in advanced techniques. This system should also be valuable to research protocols as different treatment procedures are evaluated. With the increasing complexity of treatment, this partial edentulism classification system, coupled with the complete edentulism classification system, helps dental school faculty assess entering patients for the most appropriate patient assignment for better care. On the basis of use and observations by practitioners, educators, and researchers, this system is modified as needed.

SUMMARY

A comprehensive history and a thorough clinical examination provide sufficient data for the practitioner to formulate a successful treatment plan. If they are too hastily accomplished, details may be missed, which can cause significant problems during treatment, when it may be difficult or impossible to make corrections. Also, the overall outcome and prognosis may be adversely affected. In particular, it is crucial to develop

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a thorough understanding of each patient's special concerns relating to previous care and his or her expectations about future treatment. Many problems encountered during fixed prosthodontic treatment are directly traceable to factors overlooked during the initial examination and data collection. A diagnosis is a summation of the observed problems and their underlying causes. The patient's overall prognosis is influenced by general and local factors.

REFERENCES

1. Moazzez R, et al: Dental erosion, gastro-oesophageal reflux disease and saliva: how are they related? J Dent 32:489, 2004.
2. Milosevic A: Eating disorders and the dentist. Br Dent J 186:109, 1999.
3. Cope MR: Metoclopramide-induced masticatory muscle spasm. Br Dent J 154:335, 1983.
4. Pajukoski H, et al: Salivary flow and composition in elderly patients referred to an acute care geriatric ward. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 84:265, 1997.
5. Hunter KD, Wilson WS: The effects of antidepressant drugs on salivary flow and content of sodium and potassium ions in human parotid saliva. Arch Oral Biol 40:983, 1995.
6. Infection control recommendations for the dental office and laboratory. J Am Dent Assoc (Suppl):1, 1992.
7. Epstein O, et al: Pocket Guide to Clinical Examination, 4th ed. St. Louis, Elsevier, 2009.
8. Little JW, et al: Little and Falace's Dental Management of the Medically Compromised Patient, 8th ed. St. Louis, Elsevier, 2012.
9. Solberg WK: Occlusion-related pathosis and its clinical evaluation. In Clark JW, ed: Clinical Dentistry, vol 2, chap 35. Hagerstown, Md, Harper & Row, 1976.
10. Pullinger AG, et al: Differences between sexes in maximum jaw opening when corrected to body size. J Oral Rehabil 14:291, 1987.
11. Krogh-Poulsen WG, Olsson A: Occlusal disharmonies and dysfunction of the stomatognathic system. Dent Clin North Am 10:627, 1966.
12. Moskowitz ME, Nayyar A: Determinants of dental esthetics: a rational for smile analysis and treatment. Compend Contin Educ Dent 16:1164, 1995.
13. Crispin BJ, Watson JF: Margin placement of esthetic veneer crowns. I. Anterior tooth visibility. J Prosthet Dent 45:278, 1981.
14. Lombardi RE: The principles of visual perception and their clinical application to denture esthetics. J Prosthet Dent 29:358, 1973.
15. Rosenstiel SF, Rashid RG: Public preferences for anterior tooth variations: a web-based study. J Esthet Restor Dent 14:97, 2002.
16. Parameter on comprehensive periodontal examination. American Academy of Periodontology. J Periodontol 71:847, 2000.
17. Guidelines for periodontal therapy. American Academy of Periodontology. J Periodontol 69:405, 1998.
18. Carranza FA Jr, Newman MG: Clinical Periodontology, 8th ed. Philadelphia, WB Saunders, 1996.
19. Goodson JM: Selection of suitable indicators of periodontitis. In Bader JD, ed: Risk Assessment in Dentistry. Chapel Hill, N.C., University of North Carolina Dental Ecology, 1989.
20. American Academy of Periodontology: Parameters of Care. Chicago, American Academy of Periodontology, 1998.
21. Carter L: Clinical indications as a basis for ordering extraoral imaging studies. Compend Contin Educ Dent 25:351, 2004.
22. Van Sickels JE, et al: Transcranial radiographs in the evaluation of craniomandibular (TMJ) disorders. J Prosthet Dent 49:244, 1983.
23. Brooks SL, et al: Imaging of the temporomandibular joint: a position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83:609, 1997.
24. McGarry TJ, et al: Classification system for partial edentulism. J Prosthodont 11:181, 2002.
25. McGarry TJ, et al: Classification system for the completely dentate patient. J Prosthodont 13:73, 2004.
26. McGarry TJ, et al: Classification system for complete edentulism. The American College of Prosthodontics. J Prosthodont 8:27, 1999.

STUDY QUESTIONS

1. Discuss the importance of the chief complaint and its management during examination and presentation of the treatment plan.

2. What is the classification of conditions observed as part of the medical history?

3. Describe the various areas included in the documentation of a comprehensive dental history.

4. What systemic conditions may cause oral manifestations that can affect a plan for fixed prosthodontic treatment?

5. What is included in a comprehensively conducted extraoral examination? Specify all structures included in palpation.

6. Discuss three critical observations that are part of a comprehensive periodontal examination. Why are they important in the evaluation for fixed prosthodontic treatment?

7. What would be recorded as part of an intraoral charting?

8. Discuss the various types of radiographs available for diagnostic purposes. What are the advantages and limitations of each technique?

9. Give examples of general and local factors that may influence the patient's prognosis.

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CHAPTER 2

Diagnostic Casts and Related Procedures

Accurate diagnostic casts transferred to a semiadjustable articulator (Fig. 2-1) are essential in planning fixed prosthodontic treatment. This enables examination of static and dynamic relationships of the teeth without interference from protective neuromuscular reflexes, and unencumbered views from all directions reveal aspects of the occlusion not always easily detectable intraorally (e.g., the relationship of the lingual cusps in the occluded position). If the maxillary cast has been transferred with a facebow, a centric relation (CR) interocclusal record has been used for articulation of the mandibular cast, and the condylar elements have been appropriately set (as with protrusive and excursive interocclusal records), reproducing the patient's movements with reasonable accuracy is possible. If the casts have been articulated in CR, both the CR and the maximum intercuspation (MI) position can be assessed because any slide can then be reproduced.

Other critical information not immediately apparent during the clinical examination includes the occlusocervical dimension of edentulous spaces. On an articulator, these are readily assessed in the occluded position and throughout the entire range of mandibular movement. Relative alignment and angulation of proposed abutment teeth are easier to evaluate on casts than intraorally, as are many other subtle changes in individual tooth position. Articulated diagnostic casts enable a detailed analysis of the occlusal plane and the occlusion, and diagnostic procedures can be performed for a better diagnosis and treatment plan; tooth preparations can be "rehearsed" on the casts, and diagnostic waxing procedures allow evaluation of the eventual outcome of proposed treatment.

IMPRESSION MAKING FOR DIAGNOSTIC CASTS

Accurate impressions of both dental arches are required. Flaws in the impressions result in inaccuracies in the casts that easily multiply. For instance, a small void in the impression caused by the trapping of an air bubble on one of the occlusal surfaces results in a nodule on the occlusal table. If it is not recognized and carefully removed, it leads to an inaccurate articulator mounting, and the diagnostic data are incorrect.

As long as the impression extends several millimeters beyond the cervical line of the teeth, the borders of diagnostic impressions are usually not of great concern for fixed prosthodontic purposes, unless a removable prosthesis is also to be fabricated. Properly manipulated irreversible hydrocolloid (alginate) is sufficiently accurate and offers adequate surface detail for planning purposes. However, the material does require pouring within 2 hours to avoid dimensional change[1] and does not reproduce sufficient surface detail for suitable definitive casts and dies on which actual fixed prostheses are fabricated (see Chapter 17). Materials with a composition similar to that of vinyl polysiloxane materials (see Chapter 17) have been marketed as an alternative to traditional irreversible hydrocolloids.[2] These materials should be considered if a delay in pouring is necessary.[3]

Irreversible Hydrocolloid

The irreversible hydrocolloids, or alginates, are essentially sodium or potassium salts of alginic acid and are therefore water soluble. They react chemically with calcium sulfate to produce insoluble calcium alginate. These materials contain other ingredients, chiefly diatomaceous earth (for strength and body), trisodium phosphate (Na_3PO_4), and similar compounds to control the setting rate as they react preferentially with calcium sulfate. When this reaction is complete and the retarder is consumed, gel formation begins. The clinician can control the reaction rate by varying the temperature of the mixing water. Because irreversible hydrocolloid is largely water, it readily absorbs (by imbibition) as well as gives off (by syneresis) liquid to the atmosphere, causing distortion of the impression. Alginate impressions must therefore be poured immediately.

Diagnostic Impression Technique

Armamentarium

- Impression trays
- Modeling compound
- Mixing bowl
- Mixing spatula
- Gauze squares
- Irreversible hydrocolloid
- American Dental Association (ADA) type IV or V stone
- Vacuum mixer
- Humidor
- Disinfectant

Tray Selection

All impression materials must be retained in the impression tray. This can be accomplished for irreversible hydrocolloid with an adhesive or by means of perforations or undercuts around the rim of the tray. All types of trays are capable of producing impressions with

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FIGURE 2-1 ■ Diagnostic casts mounted on a semi-adjustable articulator. (Courtesy Whip Mix Corporation, Louisville, Ky.)

FIGURE 2-2 ■ Stock impression trays can be readily modified with modeling compound to provide better support for the alginate. The posterior border typically needs extension. If the patient has a high palate, the alginate should be supported here, too, although the compound should not block out the retentive area of the tray.

clinically acceptable accuracy,[4] although casts may be produced more accurately by rigid plastic trays than by perforated metal trays.[5] For irreversible hydrocolloids, the largest tray that will fit comfortably in the patient's mouth should be selected. A greater bulk of material produces a more accurate impression (i.e., a bulky impression has a more favorable ratio of surface area to volume and is less susceptible to water loss or gain and therefore unwanted dimensional change). In contrast, elastomeric impression materials work well with a relatively tightly fitting custom impression tray in which a uniform thin layer of material is used. This produces the most accurate impression (see Chapter 14).

Distortion of irreversible hydrocolloid can occur if any part of the impression is unsupported by the tray or if there is movement of the tray during setting. For these reasons, the tray may need to be extended and its perimeter modified with modeling compound (Fig. 2-2).

Impression Making

For optimum results, the teeth should be cleaned and the mouth thoroughly rinsed. Some drying is necessary, but excessively dried tooth surfaces cause the irreversible hydrocolloid impression material to adhere. The material is mixed to a homogenous consistency and loaded into the tray, and its surface is smoothed with a moistened gloved finger.[6] Concurrently, a small amount of material is wiped into the crevices of the occlusal surfaces (Fig. 2-3, *A* and *B*) before the tray is seated (see Fig. 2-3, *C*). Also, a small amount can be applied by wiping it into the mucobuccal fold. As the tray is inserted into the patient's mouth and seated, the patient is instructed to "close gently" on the tray. If the patient continues to stretch the mouth wide open while the tray is being fully seated, impression material is often squeezed out of the mucobuccal fold or from underneath the upper lip.

A loss of tackiness of the material (gelation) implies initial set. The tray should be removed quickly 2 to 3 minutes after gelation. Teasing or wiggling the set impression from the mouth causes excessive distortion as a result of viscous flow. Also, certain irreversible hydrocolloid materials become distorted if held in the mouth more than 2 or 3 minutes after gelation.[7] After removal (see Fig. 2-3, *D*), the impression should be rinsed and disinfected, dried slightly with a gentle air stream, and poured immediately. For disinfection, spraying with a suitable glutaraldehyde and placement in a self-sealing plastic bag for approximately 10 minutes is recommended, after which it can be poured. Alternatively, the impression can be immersed in iodophor or glutaraldehyde disinfectant. The disinfection protocol is an essential precaution for preventing cross infection and protecting laboratory personnel (see Chapter 14); irreversible hydrocolloid impressions carry significantly higher numbers of bacteria than do elastomeric materials.[8] No significant loss of accuracy or surface detail is caused by the disinfection procedure.[9,10] To ensure accuracy, pouring should be completed within 15 minutes after the impression is removed from the mouth. Keeping an impression in a moist towel is no substitute for pouring within the specified time. Trimming off gross excess impression material before setting the tray down on the bench top is helpful. A vacuum-mixed ADA type IV or type V stone is recommended. The choice of the brand of stone is important because of the harmful surface interactions between specific irreversible hydrocolloid materials and gypsum products.[11]

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FIGURE 2-3 ■ Making an alginate impression for diagnostic casts. **A** and **B,** A small amount of alginate being wiped into the crevices of the occlusal surfaces. **C,** Seating of the tray. **D,** The completed impression.

After mixing, a small amount of stone is added in one location (e.g., the posterior aspect of one of the molars). Adding small amounts consistently in the same location helps minimize bubble formation (see the section on pouring stone dies in Chapter 17). If air is trapped, a small instrument (e.g., a periodontal probe or a wax spatula) can be used to poke the bubbles and eliminate them. While they are setting, the poured impressions must be stored tray side down, not inverted. Inverting freshly poured impressions results in a cast with a rough and grainy surface.[12] Stone is added to create a sufficient base that provides adequate retention for mounting on the articulator. To achieve maximum strength and surface detail, the poured impression should be covered with wet paper and stored in a humidor for 1 hour. This minimizes distortion of the irreversible hydrocolloid during the setting period. The setting gypsum cast should *never* be immersed in water. If this is done, setting expansion of plaster, stone, or die stone doubles or even triples through the phenomenon of hygroscopic expansion (see Chapter 22). For best results, the cast should be separated from the impression 1 hour after being poured.

Evaluation

Although it is apparently a simple procedure, diagnostic cast fabrication is often mishandled. Seemingly minor inaccuracies can lead to serious diagnostic errors. Questionable impressions and casts should be discarded and the process repeated (Fig. 2-4). Voids in the impression create nodules on the poured cast. These can prevent proper articulation and effectively render useless a subsequent occlusal analysis or other diagnostic procedure.

Articulator Selection

Handheld casts can provide information concerning alignment of the individual arches but do not enable analysis of functional relationships. For such analysis, the diagnostic casts need to be attached to an articulator, a mechanical device that simulates mandibular movement. Articulators can simulate the movement of the condyles in their corresponding fossae. They are classified according to how closely they can reproduce mandibular border movements. Because the movements are governed by the bones and ligaments of the temporomandibular joints, they are relatively constant and reproducible. With most

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FIGURE 2-4 ■ Diagnostic casts must be accurate if they are to articulate properly. **A,** Occlusal nodules may make proper occlusal analysis impossible. **B,** Proper technique ensures a satisfactory cast.

articulators, mechanically adjustable posterior controls are used to simulate these movements; in some, plastic premilled or customized fossa analogs are used. If an articulator closely reproduces the actual border movements of a given patient, chair time is significantly reduced because the dental laboratory can then design the prosthesis to be in functional harmony with the patient's movements. In addition, less time is needed for adjustments at delivery.

On some instruments, the upper and lower members are permanently attached to each other, whereas on others they can be readily separated. The latter instruments may have a latch or another clamplike feature that locks the two components together in the hinge position. Instrument selection depends on the type and complexity of treatment needs, the demands for procedural accuracy, and general expediency. For instance, when a fixed dental prosthesis is waxed, it is advantageous to be able to separate the instrument into two parts that are more easily handled. Use of the proper instrument for a given procedure can translate into significant time saving during subsequent stages of treatment.

Small Nonadjustable Articulators

Many cast restorations are made on small nonadjustable articulators (Fig. 2-5). Their use often leads to restorations with occlusal discrepancies because these instruments do not have the capacity to reproduce the full range of mandibular movement. Some discrepancies can be corrected intraorally, but this is often time consuming and leads to increased inaccuracy. If discrepancies are left uncorrected, occlusal interferences and associated neuromuscular disorders may result.

FIGURE 2-5 ■ A small nonadjustable articulator.

Of practical significance are differences between the hinge closure of a small articulator and that of the patient. The distance between the hinge and the tooth to be restored is significantly less on most nonadjustable articulators than in the patient; thus restorations may have premature tooth contacts because cusp position is affected. This type of arcing motion on the nonadjustable articulator results in steeper travel than occurs clinically, which subsequently results in premature contacts on fabricated restorations between the distal mandibular inclines and the mesial maxillary inclines of posterior teeth (Fig. 2-6).

Depending on the specific design of the articulator, ridge and groove direction may be affected in accordance with the same principle. This is important to note because resulting premature contacts are likely to occur on the nonworking side (see Chapters 1, 4, and 6).

Semiadjustable Articulators

For most routine fixed prostheses, the use of a semiadjustable articulator (Fig. 2-7) is a practical approach to obtaining the necessary diagnostic information while minimizing the need for clinical adjustment during treatment. The use of semiadjustable instruments does not require an inordinate amount of time or expertise. They are about the same size as the anatomic structures they represent. Therefore, the articulated casts can be positioned with sufficient accuracy so that arcing errors are minimal and usually of minimal clinical significance (i.e., minimal time should be required for chairside adjustments of fabricated prostheses).

There are two basic designs of the semiadjustable articulator: the arcon (for articulator and condyle) (Fig. 2-8, *A* and *C*) and the nonarcon (see Fig. 2-8, *B* and *D*). Nonarcon instruments gained considerable popularity in complete denture prosthodontics because the upper and lower members are rigidly attached, enabling easier control when artificial teeth are positioned. As a consequence of their design, however, certain inaccuracies occur in cast restorations, which led to the development of the arcon-type instrument.

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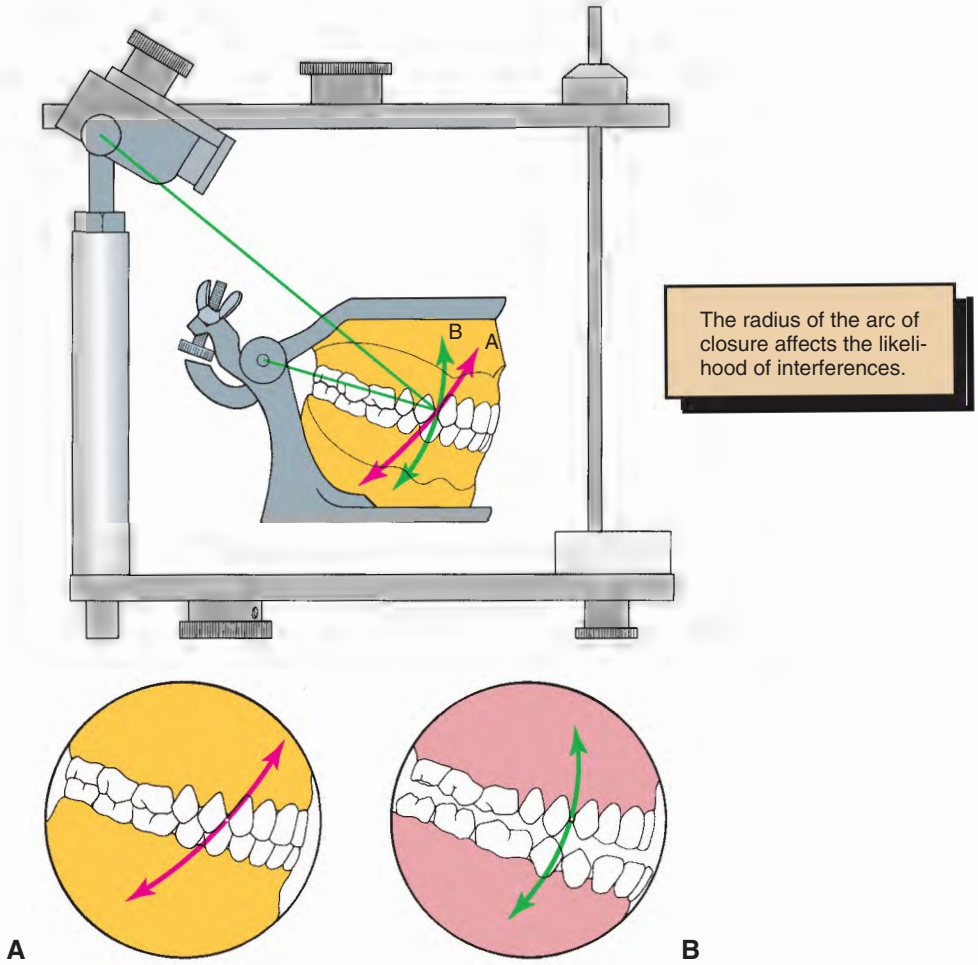

FIGURE 2-6 ■ Discrepancies in the path of closure when a small nonadjustable articulator is used can cause restorations to have premature occlusal contacts. **A,** An anatomically accurate articulator shows an accurate path of closure. **B,** With the small nonadjustable instrument, the radius of the path of closure is smaller, which results in premature contact at the clinical try-in between the premolars during hinge closure.

In an arcon articulator, the condylar spheres are attached to the lower component of the articulator, and the mechanical fossae are attached to the upper member of the instrument. Thus the arcon articulator is anatomically "correct," which makes understanding of mandibular movements easier, as opposed to the nonarcon articulator (whose movements are confusingly "backwards"). The angulation of the mechanical fossae of an arcon instrument is fixed in relation to the occlusal plane of the maxillary cast; in the nonarcon design, it is fixed in relation to the occlusal plane of the mandibular cast.

Most semiadjustable articulators allow adjustments to the condylar inclination and progressive or immediate side shift. Some have straight condylar inclined paths, although newer instruments have curved condylar housings, which are more anatomically correct.

The mechanical fossae on semiadjustable articulators can be adjusted to mimic the movements of the patient through the use of interocclusal records. These consist of several thicknesses of wax or another suitable material into which the patient has bitten. These records can be several millimeters thick, and so an error is introduced when nonarcon articulators are set with protrusive wax records because the condylar path is not fixed in relation to the maxillary occlusal plane. As the protrusive record used to adjust the instrument is removed from the arcon articulator, the maxillary occlusal plane and the condylar inclination become more parallel, which causes reduction in cuspal heights in subsequently fabricated prostheses (see Table 4-3).

Fully Adjustable Articulators

A fully (or highly) adjustable articulator (Fig. 2-9) has a wide range of positions and can be set to follow a patient's border movements. The accuracy of reproduction of movement depends on the care and skill of the operator, the errors inherent in the articulator and recording device, and any malalignments resulting from slight flexing of the mandible and the nonrigid nature of the temporomandibular joints.

Rather than relying on wax records to adjust the instrument, a series of special pantographic tracings are used to record the patient's border movements. The

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FIGURE 2-7 ■ Semiadjustable arcon articulators. **A,** The Denar Mark 330 articulator. **B,** The Whip Mix model 2240 articulator. **C,** The Hanau Wide-Vue articulator. (**A** to **C,** Courtesy Whip Mix Corporation, Louisville, Ky.)

armamentarium used to generate these tracings is then transferred to the articulator, and the instrument is adjusted so that the articulator replicates the tracings, essentially reproducing the border movements of the patient. The ability of fully adjustable instruments to track irregular pathways of movement throughout entire trajectories enables the fabrication of complex prostheses, which require minimal adjustment at the evaluation and delivery appointment.

Fully adjustable articulators are not often required in general practice. Using and adjusting them can be time consuming and require a high level of skill and understanding by the dentist and the technician. Once this skill has been acquired, however, the detailed information they convey can save considerable chairside time. They can be very useful as treatment complexity increases (e.g., when all four posterior quadrants are to be restored simultaneously or when it is necessary to restore a patient's entire dentition, especially in the presence of atypical mandibular movement).

FACEBOWS

Transverse Horizontal Axis

The mandibular hinging movement around the transverse horizontal axis is repeatable. Therefore, the

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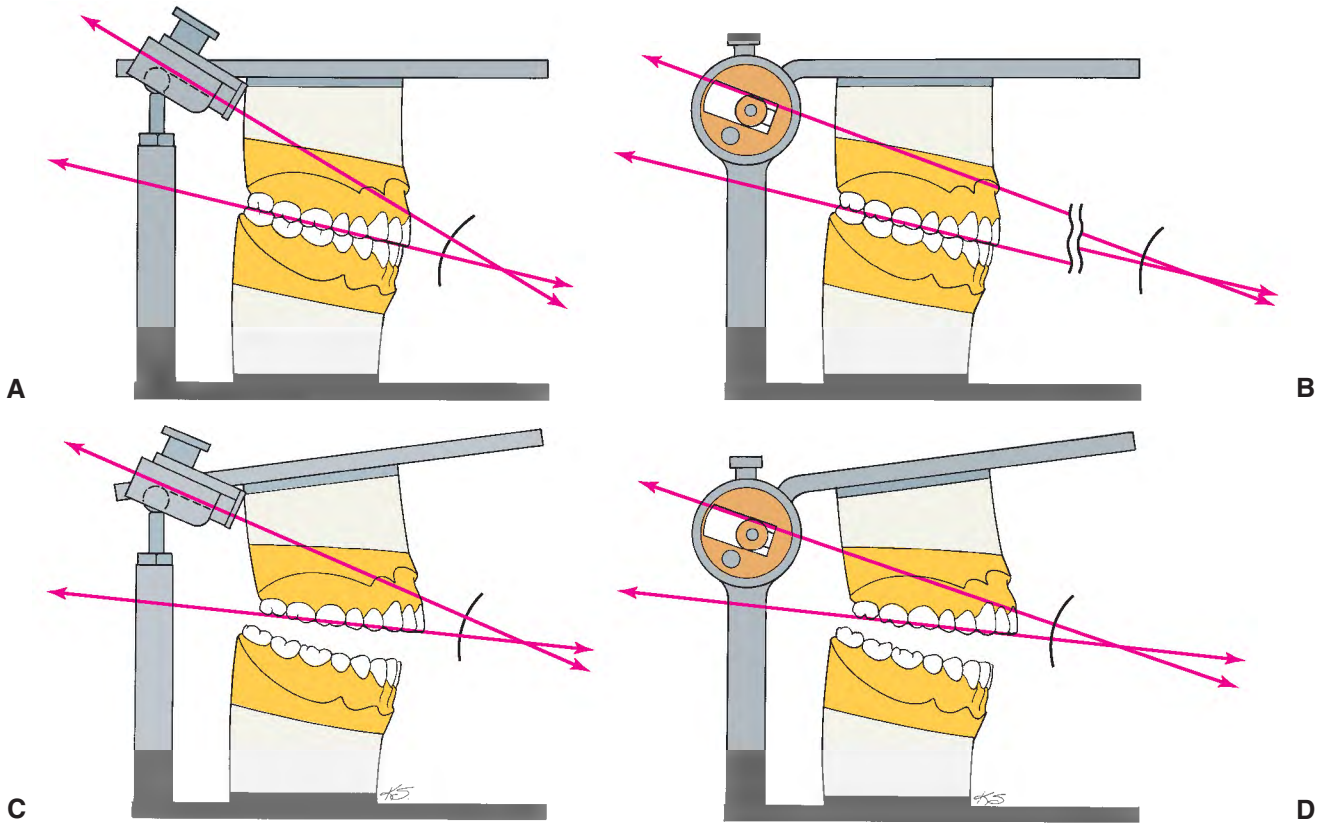

FIGURE 2-8 ■ Articulators. **A** and **C,** An arcon articulator; **B** and **D,** a nonarcon articulator. An advantage of the arcon design is that the condylar inclination of the mechanical fossae is at a fixed angle to the maxillary occlusal plane. With the nonarcon design, the angle changes as the articulator is opened, which can lead to errors when a protrusive record is being used to program the articulator. (Redrawn from Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 2nd ed. Chicago, Quintessence Publishing, 1981.)

imaginary hinge axis around which the mandible may rotate in the sagittal plane is of considerable importance when fixed prostheses are fabricated. Facebows are used to record the anteroposterior and mediolateral spatial position of the maxillary occlusal surfaces in relation to this transverse opening and closing axis of the patient's mandible. The facebow is then attached to the articulator to transfer the recorded relationship of the maxilla by ensuring that the corresponding cast is attached in the correct position in relation to the hinge axis of the instrument (Fig. 2-10). After the maxillary cast has been attached to the articulator with mounting stone or plaster, the mandibular cast is subsequently related to the maxillary cast with an interocclusal record. If the patient's casts are accurately transferred to an instrument, considerable time is saved in the fabrication and delivery of high-quality prostheses.

Most facebows are rigid, caliper-like devices that allow some adjustments. Two types of facebows are recognized: arbitrary and kinematic. Arbitrary facebows are less accurate than the kinematic type, but they suffice for most routine dental procedures. Kinematic facebows are indicated when it is crucial to precisely reproduce the exact opening and closing movements of the patient on the articulator. For instance, when a decision to alter the occlusal vertical dimension is to be made in the dental laboratory during the fabrication of fixed prostheses, the use of a kinematic facebow transfer in conjunction with an accurate CR interocclusal record is indicated.

Kinematic Hinge Axis Facebow

Hinge Axis Recording

The clinician can determine the hinge axis of the mandible to within 1 mm by observing the movement of kinematic facebow styli positioned immediately lateral to the temporomandibular joint, close to the skin. A clutch, which is essentially a segmented impression tray–like device, is attached to the mandibular teeth with a suitable rigid material such as polyvinyl siloxane putty or impression plaster. The kinematic facebow consists of three components: a transverse component and two adjustable side arms. The transverse rod is attached to the portion of the clutch that protrudes from the patient's mouth. The side arms are then attached to the transverse member and adjusted so that the styli are as close to the joint area as possible. The mandible is then manipulated to produce a terminal hinge movement, and the stylus locations are

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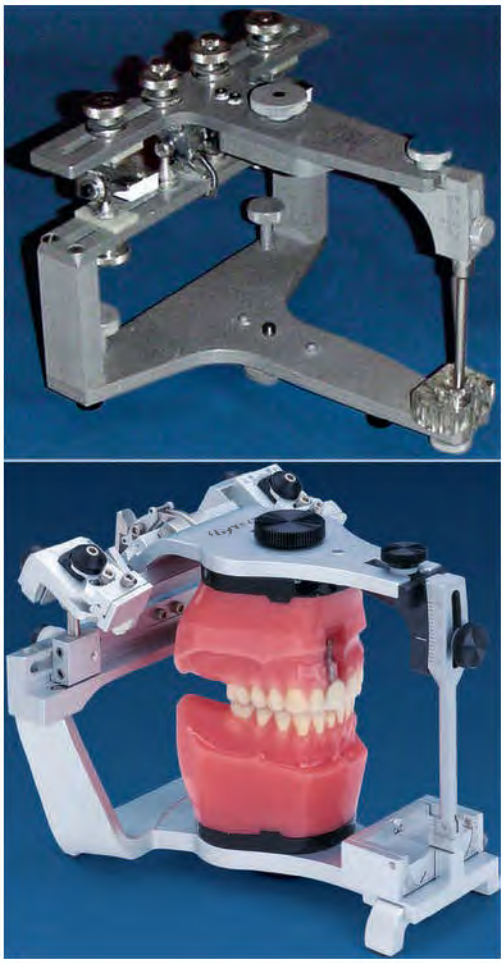

FIGURE 2-9 ■ Fully adjustable articulators. **A,** The Stuart articulator. **B,** The Denar D5A articulator. (Courtesy Whip Mix Corporation, Louisville, Ky.)

adjusted with thumbscrews (superiorly and inferiorly, anteriorly and posteriorly) until they make a purely rotational movement (Fig. 2-11). Because the entire assembly is rigidly attached to the mandible, a strictly rotational movement signifies that stylus position coincides with the hinge axis. When this purely rotational movement is verified, the position of the hinge axis is marked with a dot on the patient's skin, or it may be permanently tattooed if future use is anticipated or required.

Kinematic Facebow Transfer

An impression of the maxillary cusp tips is obtained in a suitable recording medium on a facebow fork (Fig. 2-12). The facebow is attached to the protruding arm of the fork. The side arms are adjusted until the styli are aligned with the hinge axis marks on the patient's skin. To prevent skin movement from introducing any inaccuracy, the patient must be in the same position that was used when the axis was marked. A pointer device is usually attached to the bow and adjusted to a repeatable reference point selected by the clinician. The reference point is used later for reproducibility. The kinematic facebow recording is then transferred to the articulator, and the maxillary cast is attached.

The kinematic facebow technique is time consuming, and so its use is generally limited to extensive prosthodontics, particularly when a change in the occlusal vertical dimension is to be made. A less precisely derived transfer would then lead to unacceptable errors and compromise the result.

Arbitrary Hinge Axis Facebow

Arbitrary hinge axis facebows (Fig. 2-13) approximate the horizontal transverse axis and rely on anatomic average values. Manufacturers design these facebows so that the relationship to the true axis falls within an acceptable degree of error. Typically, an easily identifiable landmark such as the external acoustic meatus is used to stabilize the bow, which is aligned with earpieces similar to those on a stethoscope. Such facebows can be used single-handedly because they are self-centering and assembly is not complicated. They depict a sufficiently accurate relationship for most diagnostic and restorative procedures. However, regardless of which arbitrary position is chosen, a minimum error of 5 mm from the axis can be expected,[13] as can errors in the steepness of the occlusal plane.[14] When coupled with the use of a thick interocclusal record made at an increased vertical dimension, this error can lead to considerable inaccuracy.

Anterior Reference Point

The use of an anterior reference point (Fig. 2-14) enables the clinician to duplicate the recorded position on the articulator at future appointments. This saves time because previously recorded articulator settings can be used again. An anterior reference point, such as the inner canthus of the eye or a freckle or mole on the skin, is selected. After this point has been marked, it is used, along with the two points of the hinge axis, to define the position of the maxillary cast in space. This procedure has the following advantages:

- After the posterior controls have been adjusted initially, subsequent casts can be mounted on the articulator without the need to repeat the facebow determinations and reset the posterior articulator controls.
- Because the maxillary arch is properly positioned in relation to the axis, average values for posterior articulator controls can be used without the need to readjust the instrument on the basis of eccentric records.
- When the articulator has been adjusted, the resulting numerical values for the settings can be compared with known average values to provide information about the patient's individual variations and the likelihood of encountering difficulties during restorative procedures.

Facebow Transfer

Armamentarium

- Arbitrary hinge axis facebow
- Modeling compound
- Cotton rolls

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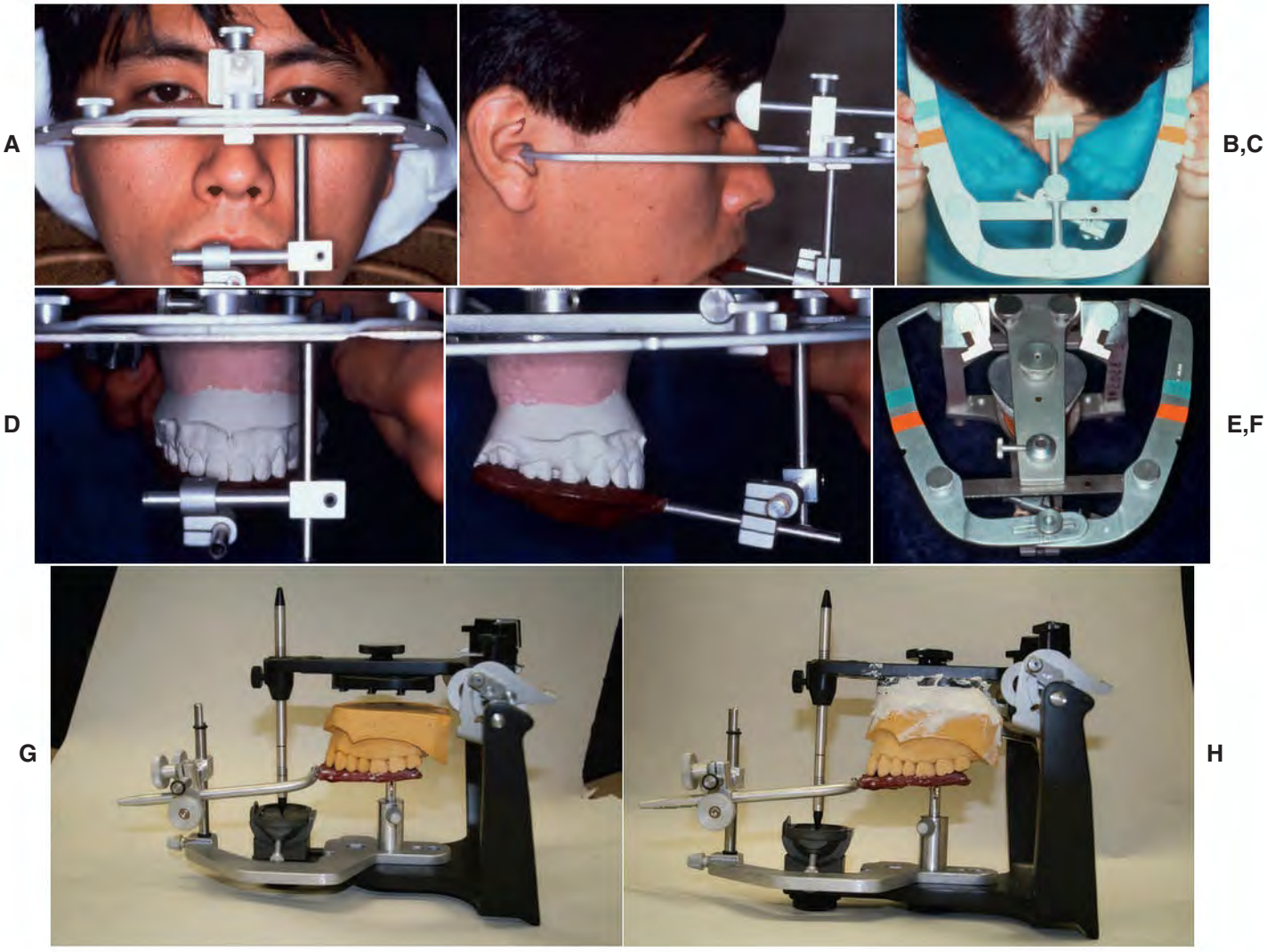

FIGURE 2-10 ■ Semi-adjustable facebow transfer orients the relationship of the maxillary cast to the hinge axis. **A,** Frontal view of facebow assembled on patient. **B,** Lateral view, in which the nasion is used as third reference point. **C,** Superior view. **D** to **F,** Same views demonstrating the relationship to the axis of the articulator. Alternatively, a special transfer jig may be used to transfer the relationship to the instrument (**G, H**).

Step-by-Step Procedure

1. Add modeling compound to the facebow fork (Fig. 2-15, *A*).
2. Temper in water and seat the fork, making indentations of the maxillary cusp tips. The facebow fork is positioned in the patient's mouth, and an impression is made of the maxillary cusp tips. The impression must be deep enough to allow accurate repositioning of the maxillary cast after the facebow fork has been removed from the mouth. Only the cusp tips should be recorded. It is not necessary to get an impression of every cusp, or even an entire cusp—just one that is sufficient to position the diagnostic cast accurately. If the impression is too deep, repositioning of the cast can become inaccurate because the diagnostic casts are not absolutely accurate reproductions of the teeth. In general, the tips are reproduced more accurately than the fossae.
3. Remove the fork from the mouth. Chill and reseat the fork, and check that no distortion has occurred (see Fig. 2-15, *B*). The inclusion of details of pits and fissures in the recording medium leads to inaccuracies in trying to seat the stone cast. Trim the recording medium as necessary before reseating. After reseating, check for stability.
4. Have the patient stabilize the facebow fork by biting on cotton rolls. As an alternative, wax can be added to the mandibular incisor region of the fork. The mandibular anterior teeth stabilize the fork as they engage the wax.
5. Slide the universal joint onto the fork, and position the caliper to align with the anterior reference mark (see Fig. 2-15, *C*).
6. Tighten the screws securely in the correct sequence to complete the transfer (see Fig. 2-15, *D*).

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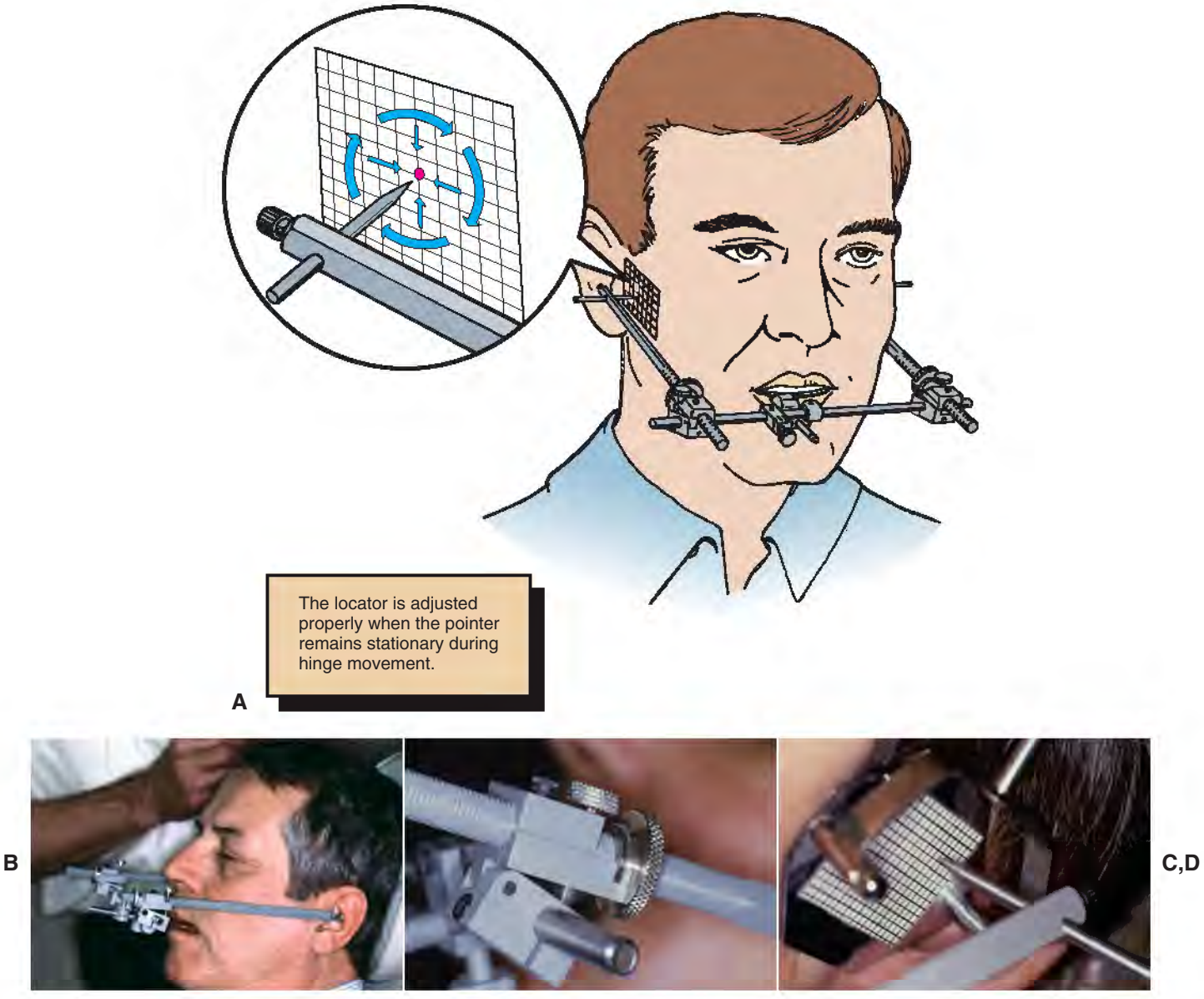

FIGURE 2-11 ■ Hinge axis recording. **A,** Left and right styli are attached via a facebow to a clutch affixed to the mandibular teeth. When the mandible makes a strictly rotational movement, the stylus remains stationary if aligned with the actual axis of rotation. If the stylus is positioned forward or backward, above or below the actual axis, it travels one of the arcs indicated by the *arrows* when the mandible makes a rotational movement. Thus the arc indicates in what direction an adjustment should be made to the stylus position. **B,** Hinge axis locator is positioned. **C,** Set screws allow side arm adjustment. **D,** Adjustment continues until no arcing of the pointer is seen.

7. If the articulator has an adjustable intercondylar width, record this measurement (see Fig. 2-15, *E*). Remove the facebow from the mouth.

The technique is slightly different with other arbitrary facebows (see Fig. 2-15, *F* to *K*).

Centric Relation Record

A CR record (Fig. 2-16) provides the orientation of mandibular to maxillary teeth in CR in the terminal hinge position, in which opening and closing are purely rotational movements. *Centric relation* is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks, with the condyle-disk complex in the anterosuperior position against the articular eminences. This position is independent of tooth contact.

MI may or may not be coincident with the CR position. The CR record is transferred to the maxillary cast on the articulator and is used to relate the mandibular cast to the maxillary cast. Once the mandibular cast is attached to the articulator with mounting stone, the record is removed. The casts then occlude in precisely the CR position as long as the maxillary cast is correctly related to the hinge axis with a facebow (see Fig. 2-15). When the articulator controls are set properly, through

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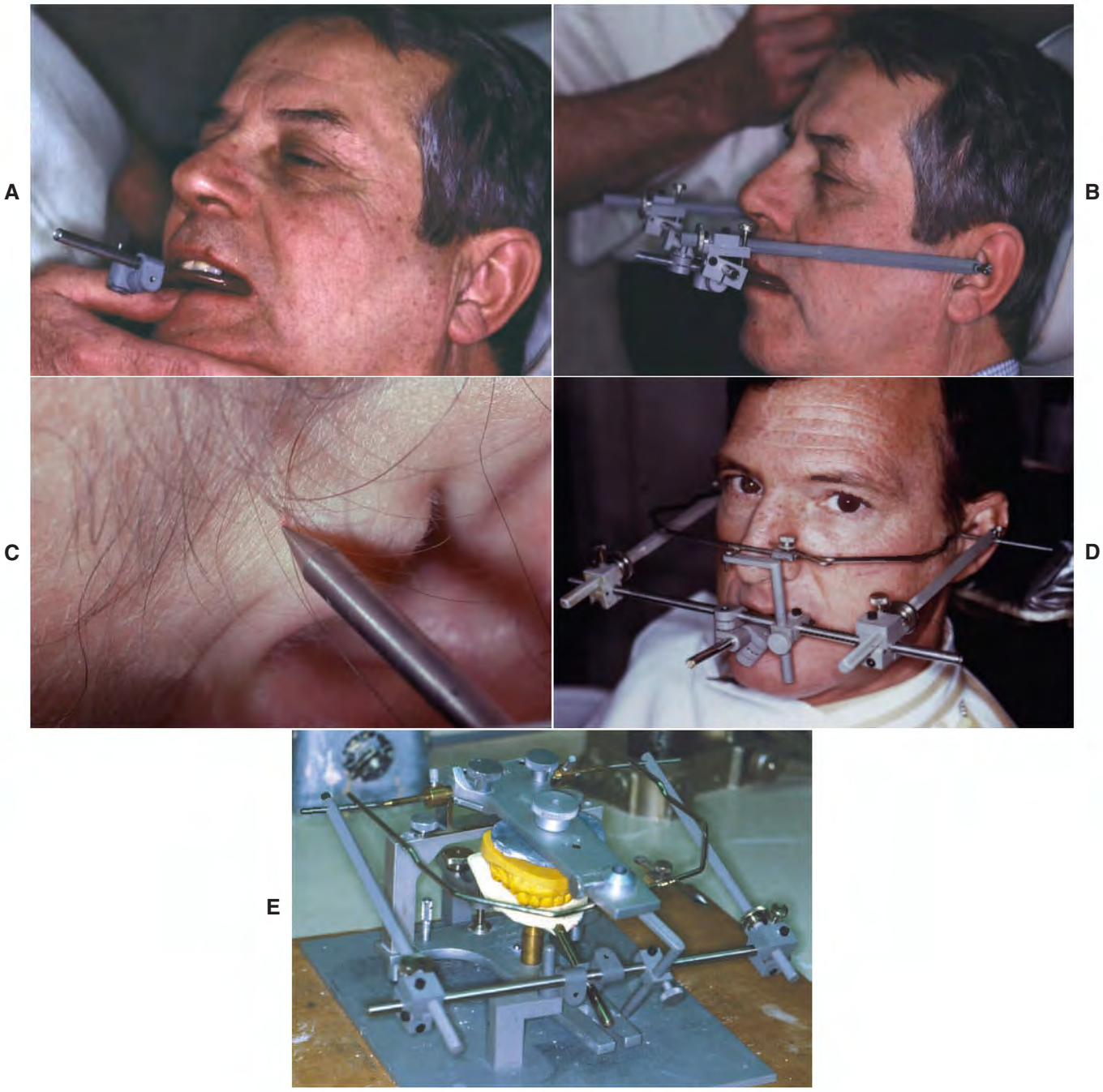

FIGURE 2-12 ■ Kinematic hinge axis facebow. **A,** Clutch seated on the mandibular teeth. To separate the clutch for removal into two components, the screws on left and right sides are loosened. **B,** Kinematic hinge axis facebow assembly positioned. **C,** Pointers aligned with the previously marked hinge axis location. **D,** Assembled kinematic hinge axis facebow. **E,** Kinematic hinge axis facebow aligned on the articulator.

the use of appropriate excursive records, translated mandibular positions can be reproduced from CR. A CR/MI slide is readily reproducible on casts that have been articulated in CR. Thus, premature tooth contacts (deflective contacts) can be observed, and the clinician can determine whether an occlusal correction is necessary or appropriate before fixed prosthodontic treatment. Casts articulated in the MI position do not enable the evaluation of CR and retruded contact relationships. Therefore, the articulation of diagnostic casts in CR is of greater diagnostic value.

In theory, when a kinematic facebow is used, the thickness of a terminal hinge record is unimportant; a thicker record merely increases the amount of rotation. When an arbitrary facebow is used, any arcing movement results in some degree of inaccuracy. The use of either type of facebow is subject to small errors, which can be minimized by keeping the record thin.[15,16] However, it is

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FIGURE 2-13 ■ Arbitrary hinge axis facebows. **A,** The Denar Slidematic facebow. **B,** The Whip Mix QuickMount facebow. Note the nasion relator as the anterior reference point. (Courtesy Whip Mix Corporation, Louisville, Ky.)

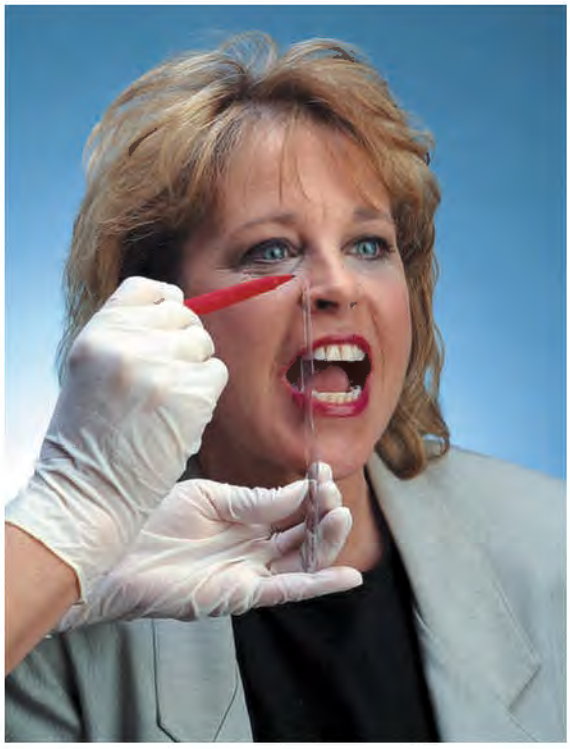

FIGURE 2-14 ■ Anterior reference point. With the Denar Slidematic facebow, a mark 43 mm superior to the incisal edge of the maxillary central incisor serves as an anterior reference point. With other systems, the infraorbital foramen or nasion is used to determine the anterior reference point. The mark serves as a reference to average anatomic values. It also allows subsequent casts to be mounted without repeated recording. (Courtesy Whip Mix Corporation, Louisville, Ky.)

essential that the teeth not perforate the record. Any tooth contact during record fabrication can cause mandibular translation (because of neuromuscular protective reflexes governed by mechanoreceptors in the periodontium) and thereby render the resulting articulation useless.

Jaw Manipulation

Accurate mounting of casts depends on the dentist's precise manipulation of the patient's mandible. The condyles should remain in the same place throughout the opening-closing arc. Trying to force the mandible backwards leads to downward translation of the condyles, and restorations made to such a mandibular position are in supraclusion at the evaluation stage (Fig. 2-17).

The load-bearing surfaces of the condylar processes, which face anteriorly, should be manipulated into apposition with the mandibular fossae of the temporal bones; the disk should be properly interposed. The ease with which this can be accomplished depends on the degree of the patient's neuromuscular relaxation and on sound technique. The latter, in turn, depends on the patient's permitting the dentist to control the mandible. Attempts to force or shake the mandible lead to a protective muscle response by the patient.

The bimanual manipulation technique described by Dawson (1973)[17] is recommended as a reproducible technique[18] that can be reliably learned.[19] In this technique, the dental chair is reclined, and the patient's head is cradled by the dentist. With both thumbs on the patient's chin and the fingers resting firmly on the inferior border of the patient's mandible (Fig. 2-18, *A*), the dentist exerts gentle downward pressure on the thumbs and upward pressure on the fingers, manipulating the condyle-disk assemblies into their fully seated positions in the mandibular fossae. Next, the mandible is carefully hinged along the arc of terminal hinge closure. In the single-handed approach (see Fig. 2-18, *B*), the fingers exert upward pressure. In this way, it is more difficult to ensure that the condyles are properly located, although this technique does allow the other hand to hold the record.

Anterior Programming Device

In some patients in whom CR does not coincide with MI, resistance may be encountered when the mandible is hinged. Because of well-established protective reflexes

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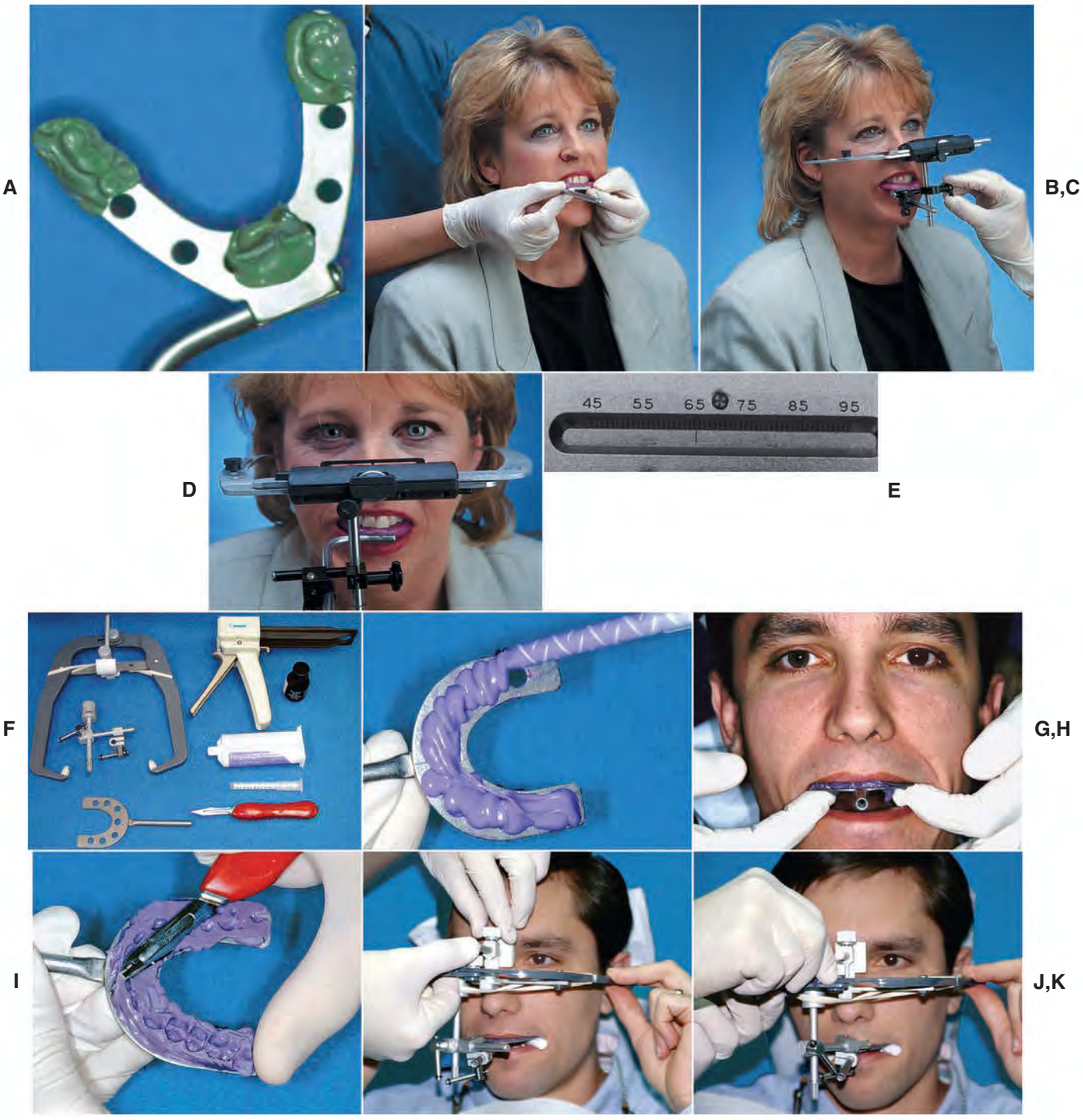

FIGURE 2-15 ■ Facebow technique. **A** to **E,** Denar Slidematic facebow technique: **A,** Indentations are obtained in compound. **B,** Facebow fork is positioned. **C,** Facebow is attached to facebow fork, and toggles are tightened. **D,** Transfer is complete. **E,** Width measurement is read from the top of the facebow. **F** to **K,** Whip Mix QuickMount facebow technique: **F,** Armamentarium. **G,** Automixed elastomer is applied to the transfer fork. **H,** The facebow fork is adapted to the maxillary teeth. **I,** The obtained record is trimmed with a sharp blade to facilitate seating. **J,** The nasion relator is positioned. **K,** Knobs and toggles are tightened. (Courtesy Whip Mix Corporation, Louisville, Ky.)

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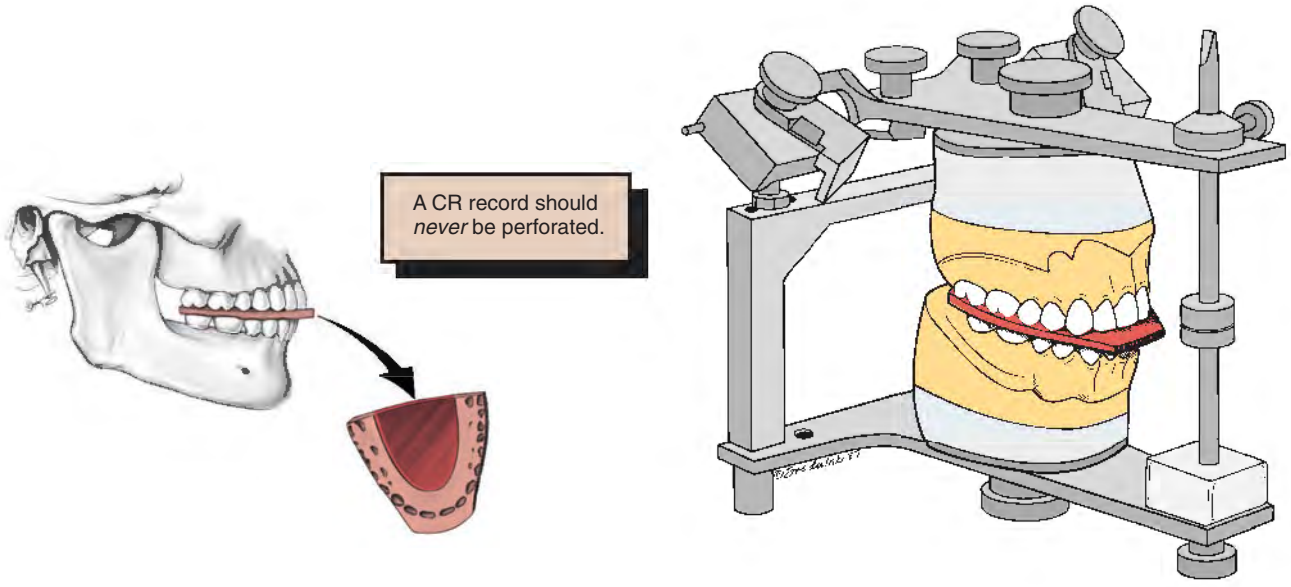

FIGURE 2-16 ■ A centric relation (CR) record transfers the tooth relationships at CR from the patient to the articulator.

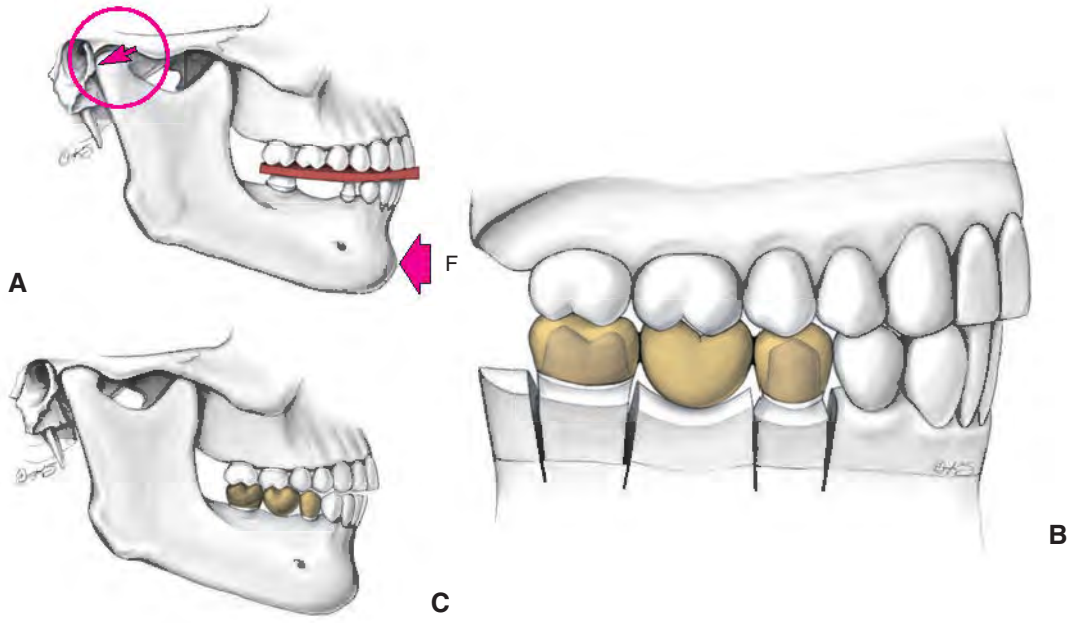

FIGURE 2-17 ■ Incorrect centric relation (CR) recording. **A,** If the mandible is forced backward *(F),* the condyles are not in their most superior position but are moved backward and downward *(small arrow).* **B,** Any restorations made on casts related with this CR record are in supraclusion when tried in the mouth. **C,** Note the relationship of the anterior teeth.

that are reinforced every time the teeth come together, such patients do not allow their mandibles to be manipulated and hinged easily. If tooth contact can be prevented, these reflexes disappear, and manipulation becomes easier. The teeth can be kept apart with cotton rolls, a plastic leaf gauge (Fig. 2-19), or a small anterior programming device made of autopolymerizing acrylic resin (also known as a *Lucia jig*).[20]

If the mandible cannot be manipulated satisfactorily after an anterior programming device has been in place for 30 minutes, the patient is likely to have marked neuromuscular dysfunction. Normally, this is relieved by an occlusal device (whose fabrication and adjustment are described in Chapter 4).

Centric Relation Recording Technique

Different techniques can be used to make a CR record. The choice of recording medium is, to some degree, a function of the casts to be articulated. For instance, very accurate casts made from elastomeric impression materials can be articulated with a high-accuracy interocclusal record material such as polyvinyl siloxane. However, less accurate diagnostic casts poured from irreversible

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hydrocolloid are better articulated with the use of a more malleable material, such as interocclusal wax, provided the record is properly reinforced. Most studies have shown considerable variability among various registration materials and techniques,[21] and so particular care is needed with this procedure.

Reinforced Aluwax Record

Reinforced Aluwax is a malleable material for recording the CR position (Fig. 2-20, *A*). This type of record, originally described by Wirth (1971)[22] and Wirth and Aplin (1971),[23] is reliable and the technique has provided consistent results.[24,25]

Armamentarium

- Heat-retaining wax sheet (i.e., Aluwax; see Appendix A)
- Soft metal sheet (No. 7 Ash's soft metal; see Appendix A)
- Hard pink wax
- Sticky wax
- Scissors
- Ice water

Step-by-Step Procedure

1. Soften half a sheet of occlusal wax in warm water, and adapt it to the maxillary cusp tips (see Fig. 2-20, *B*). Allow the patient to close lightly, and make cuspal indentations of the mandibular teeth. These indentations form no part of the record, but they thin the wax slightly and indicate the approximate positions of the mandibular teeth for later reference.
2. Add hard pink baseplate wax to the mandibular anterior region of the record (see Fig. 2-20, *C*), add soft metal sheet to reinforce the palatal area, and seal along the periphery with sticky wax (see Fig. 2-20, *D*).
3. Readapt the record to the maxillary teeth, resoftening if necessary. Guide the patient's mouth into centric closure, making shallow indentations in the wax. Verify that no posterior tooth contact occurs.

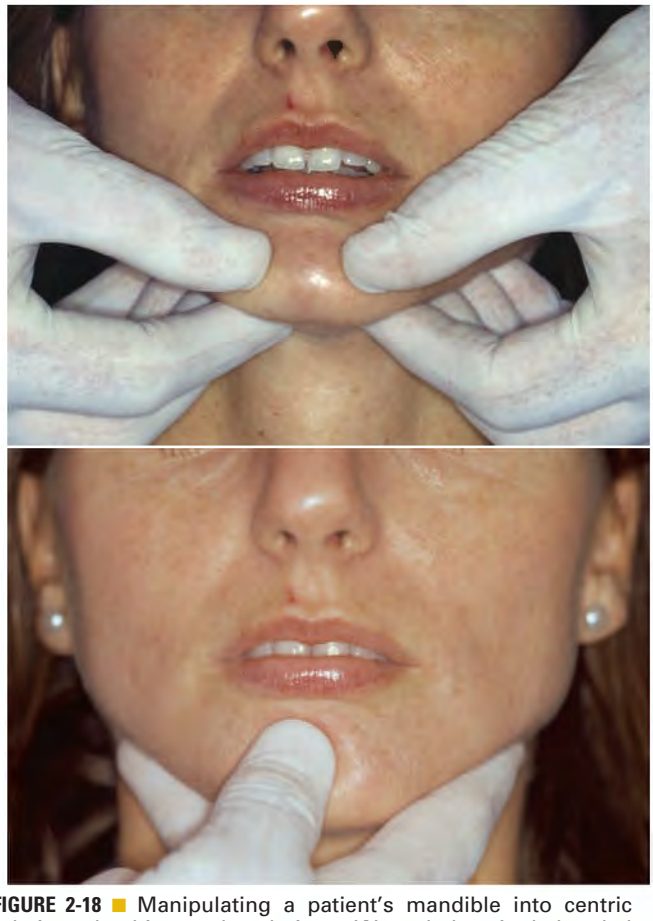

FIGURE 2-18 ■ Manipulating a patient's mandible into centric relation: the bimanual technique **(A)** and the single-handed technique **(B)**. Note the position of the dentist's thumbs and fingers on the mandibular border.

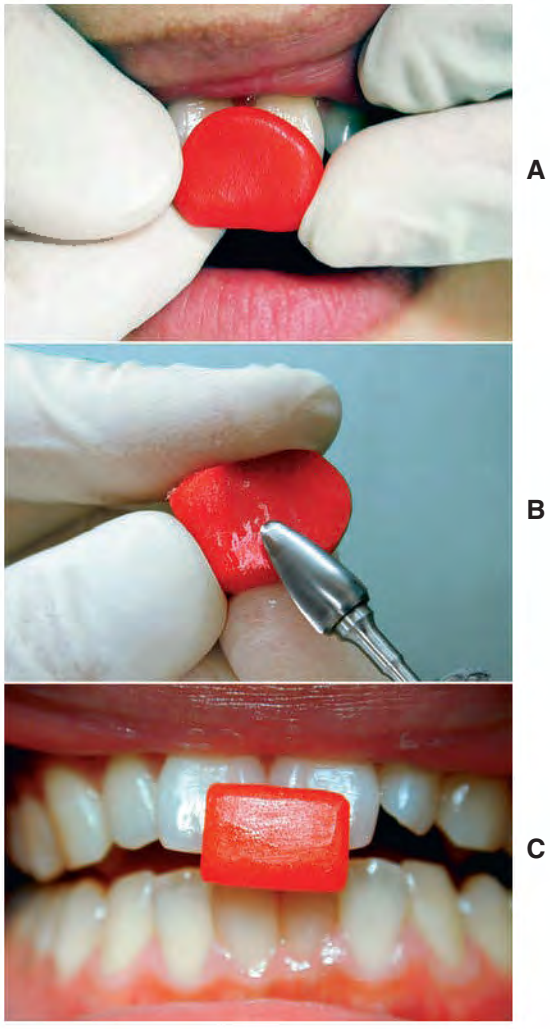

FIGURE 2-19 ■ An anterior programming device is used to facilitate centric relation recording. **A,** Autopolymerizing resin is mixed and adapted to the maxillary central incisors. The patient's mouth is guided into closure and stopped when the posterior teeth are about 1 mm apart. **B,** The indentations are used as a guide during trimming of the device. **C,** The completed device should allow the patient to make smooth lateral and protrusive movements. An inclined contact area must be avoided, because it will tend to cause the mandible to retrude excessively.

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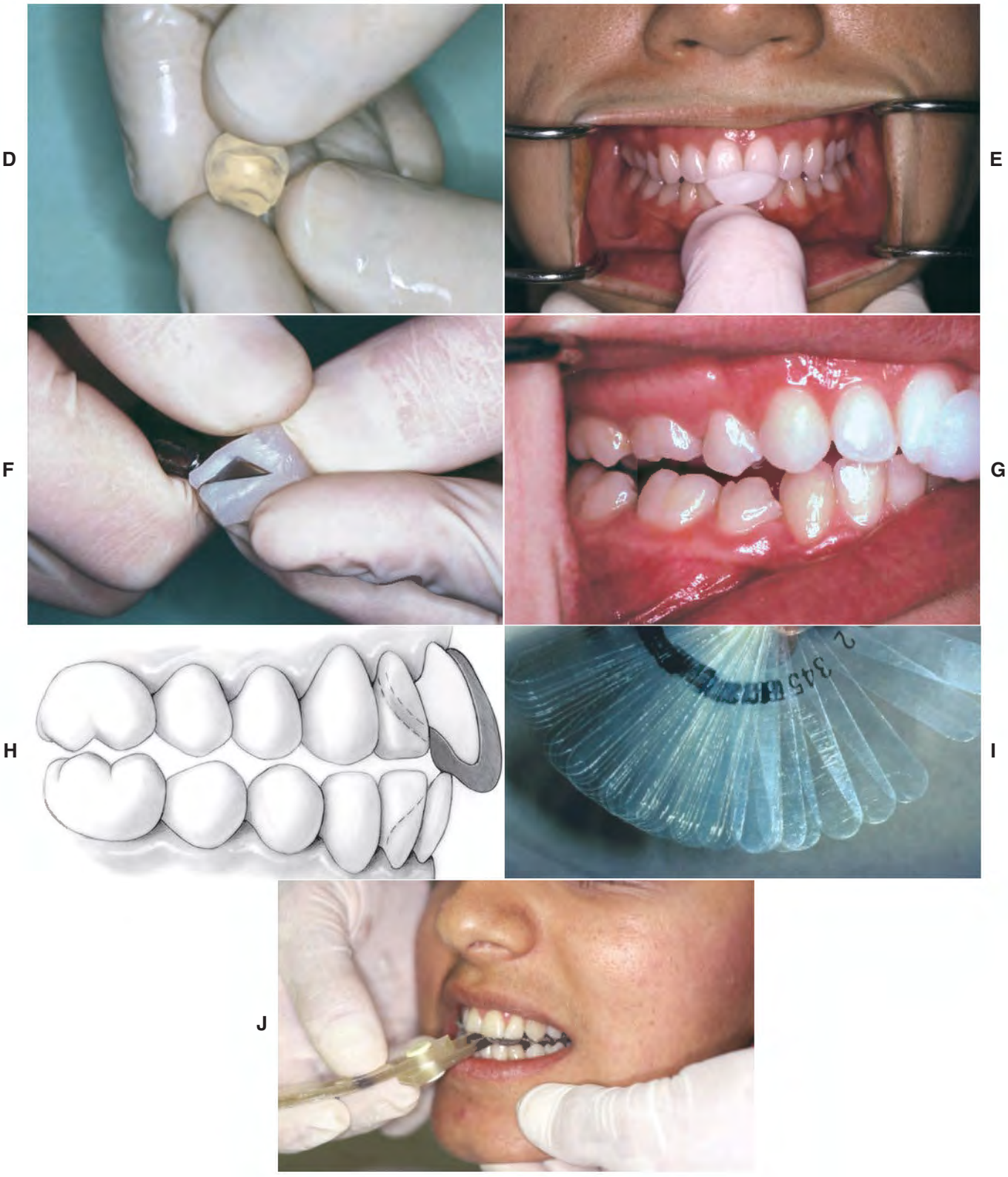

FIGURE 2-19, cont'd ■ **D,** Alternatively, a thermoplastic material can be used. **E,** After softening and positioning, the mandible is guided into centric relation closure. **F,** The device is trimmed with a scalpel. **G,** Again, posterior disclusion is verified. **H,** Cross section view through the device is illustrated. **I** and **J,** A plastic leaf gauge may be used to prevent habitual closure into maximal intercuspation.

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FIGURE 2-20 ■ Centric relation (CR) recording technique. The reproducibility of the CR position is verified because CR has to be reproduced several times while the record is made. **A,** Armamentarium. **B,** A sheet of soft Aluwax is adapted to the maxillary arch. **C,** A piece of hard pink wax is added to the lower anterior portion of the wafer. **D,** Some No. 7 Ash's soft metal is folded around the posterior border and luted to the wafer with sticky wax to increase rigidity. **E,** The reinforced sheet is repositioned, and the mandible is guided into CR until the pink wax provides a stop for vertical closure. **F,** Note that the maxillary indentations capture only the cusp tips. Some Aluwax is added to the lower incisor indentations. The record is repositioned, and the CR closure repeated. **G,** The incisor indentations are reproduced in the Aluwax. **H,** Additional wax is added to the area of the first molars. **I,** Hinge closure is repeated. **J,** The molar indentations are clearly visible. The incisor indentations should have been reproduced. Any "double" indentation indicates inaccuracy. **K,** The CR closure is repeated one more time after additional Aluwax is added to the premolar regions. **L,** The CR record is completed. (Courtesy Dr. J.N. Nelson.)

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If it does, add another layer of baseplate wax (see Fig. 2-20, *E* and *F*).
4. Remove the record carefully, and verify that no distortion has occurred. Then chill it thoroughly in ice water.
5. Reseat the record on the maxillary teeth, and evaluate it for stability. If the maxillary cast is available, evaluate the fit of this as well.
6. Add heat-retaining wax in the mandibular incisor region only, and manipulate the mandible as previously described. Having the patient in a supine position for this manipulation allows better control.
7. Make indentations of the mandibular incisor tips in the wax (see Fig. 2-20, *G*), repeating several times to ensure reproducibility. Remove the wax record, and rechill it in ice water until the anterior indentations are hard.
8. Add a small amount of heat-retaining wax in the mandibular posterior region (see Fig. 2-20, *H*) and reseat the record (see Fig. 2-20, *I*). Remember that when new wax is added, the record should be dried; otherwise, the wax does not adhere and may become detached. Then guide the mandibular teeth into the anterior indentations and have the patient close lightly. The baseplate wax prevents excessive closure. Excessive force may distort the record or flex the mandible.[26] The elevator muscles of the mandible ensure that the most superior position of the condylar processes is recorded.
9. Remove the record and chill it.

The advantage of this sequential technique is that the CR position is reproduced multiple times as the record is generated. The heat-retaining Aluwax is soft and becomes distorted easily. Therefore, if the patient's mouth is not guided into exactly the same position, this problem becomes readily apparent (see Fig. 2-20, *J*). Once the completed record has been obtained with adequate but fairly shallow indentations for all cusps (see Fig. 2-20, *K* and *L*), the same arcing motion has been reproduced four times, confirming that the CR position has been accurately captured.

CR records can be generated with different techniques and materials. Hard pink baseplate wax and preformed blue wax wafers with a slight taper from front to back are especially popular choices for these records (Figs. 2-21 and 2-22).

Anterior Programming Device with Elastomeric or Zinc Oxide–Eugenol Record

Armamentarium
- Self-curing resin
- Petroleum jelly
- Elastomeric material
- Syringe
- Scalpel blade

Step-by-Step Procedure
1. Fabricate an anterior programming device from self-curing resin. The resin should be mixed to the consistency of putty and, after lubrication of the central incisors with petroleum jelly, adapted to the teeth. The lingual aspect of the anterior programming device should follow the lingual contours of the teeth. After trimming, it should result in separation of the posterior teeth (see Fig. 2-19, *H*). When the patient closes on the anterior programming device, no translation should occur.
2. Verify that no posterior contact remains and that the only occlusal contact is on the anterior programming device. The device should be stable and remain in position. If necessary, some petroleum jelly can be applied to its internal surface.
3. Rehearse the closing of the mandible with the patient until a reproducible CR position is obtained.
4. Verify that the syringe tip is large enough to allow free flow of the elastomeric material. Enlarge the opening of the syringe tip if necessary by trimming it with a scalpel blade.
5. Dispense and mix the elastomeric material according to the manufacturer's instructions (Fig. 2-23, *A*). (The Automix materials are convenient.)
6. Dry the occlusal surfaces of the teeth with an air compressor, and, using a syringe, apply the material onto the occlusal surface of the mandibular arch (see Fig. 2-23, *B*).
7. Guide the patient's mandible into hinge movement until the mandible comes to rest on the anterior programming device. Have the patient maintain this position until the material has set.
8. Remove the record from the mouth (see Fig. 2-23, *C*) and trim with the scalpel blade, following the buccal cusps.
9. Verify that the mandibular and maxillary casts seat fully in the record.

As an alternative to the use of elastomeric material, a gauze mesh with zinc oxide–eugenol (ZOE) occlusal registration paste can be used (Fig. 2-24). The step-by-step procedure is the same as that for the elastomeric material, but rather than using a syringe to apply the material onto the mandibular arch, the practitioner should coat the interocclusal cloth forms outside the mouth and interpose them, after which the patient's mouth can be guided into CR. Care must be taken, however, to position the frame that holds the cloth form so that it does not interfere with the closure movement.

Alternative materials for the recording medium include impression plaster or autopolymerizing resin. With all these materials, accuracy depends on complete seating of the casts into the recording medium. Seating is often prevented by better detail reproduction in the record than in the casts, especially around the fossa. This additional detail needs to be carefully trimmed until the cast is completely seated in the record.

Recording Jaw Relationships in Partially Edentulous Dentitions

When there are insufficient teeth to provide bilateral stability, obtaining a CR record as described may not be possible. As a result, acrylic resin record bases must be fabricated (Fig. 2-25). To avoid errors caused by soft tissue displacement, which prevents accurate transfer of rigid materials from one set of casts to another, these bases should be made on the casts

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FIGURE 2-21 ■ Centric relation (CR) recording technique with hard pink baseplate wax. **A,** Armamentarium. **B,** After being softened and folded into a double layer, the record is trimmed to the appropriate shape. **C,** Hinge movement is practiced with the patient. **D,** The record is adapted to the maxillary arch. **E,** The adaptation ensures shallow indents of the cusp tips from the canine posteriorly. **F,** The record is trimmed through the buccal cusp tips of the premolars and molars. **G,** The trimmed record has this appearance. **H,** The wax is bent over the facial aspect of the canine teeth. The patient stabilizes the record while the hinge movement is reproduced. **I,** The frontal view of the completed record has this appearance. **J,** Note the shallow indentations, which allow accurate seating of the cast.

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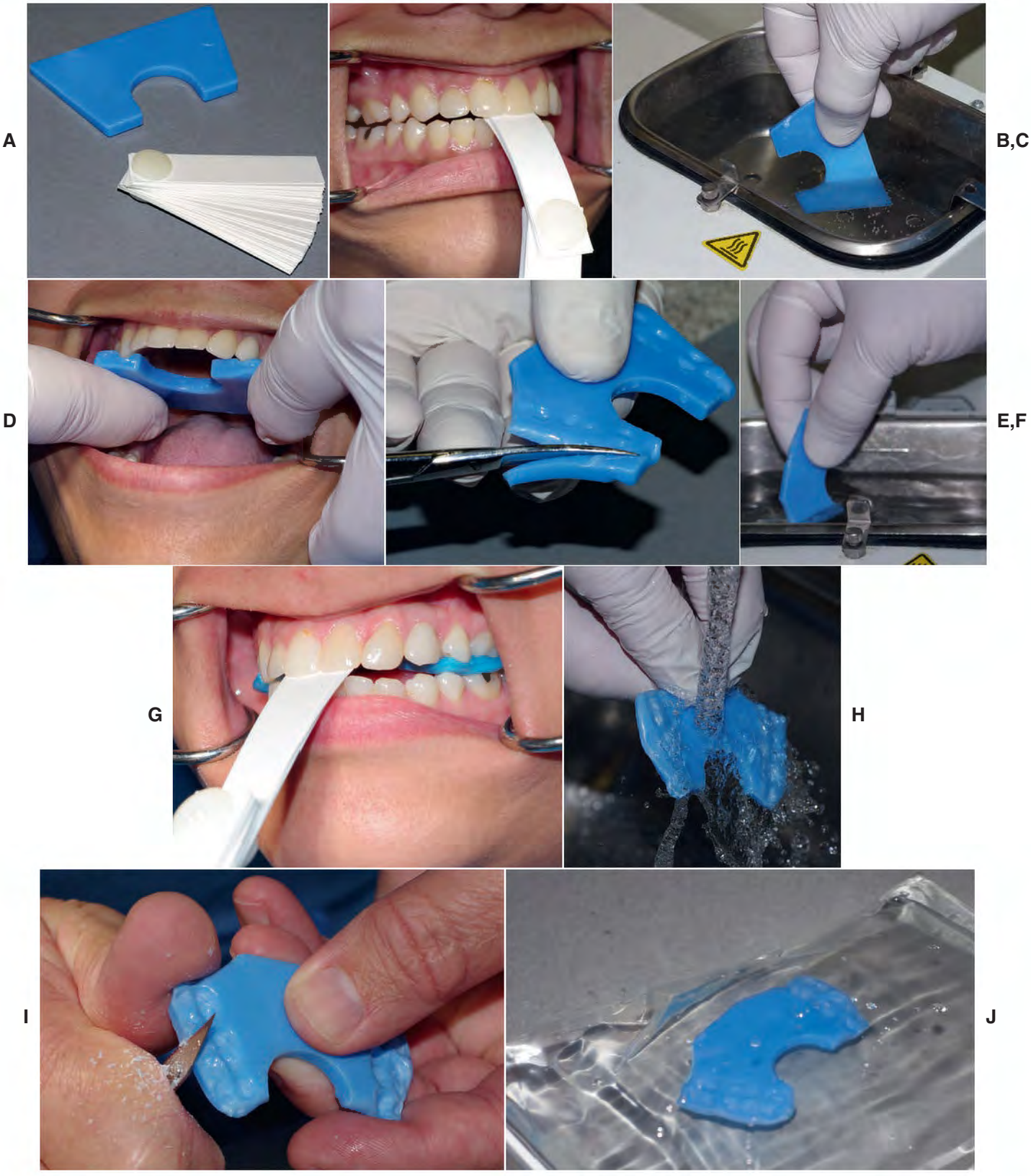

FIGURE 2-22 ■ Centric relation (CR) recording technique with preformed wax wafer and leaf gauge. **A,** Preformed wax and a leaf gauge are used for occlusal registration. **B,** The leaf gauge is positioned to achieve separation of the posterior teeth. **C,** Lateral aspects of the wax are softened in a water bath. **D,** The wax record is adapted to the maxillary teeth. **E,** The record is trimmed through the buccal cusp tips. **F,** The wax is resoftened. **G,** The patient's mandible is guided into centric relation, and indents of the mandibular cusp tips are obtained. **H,** The record is chilled with cold water. **I,** Excess wax can be removed with a sharp blade until only indents of the cusp tips remain. **J,** After clinical verification, the record is stored in cold water for subsequent use in the laboratory.

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FIGURE 2-23 ■ Centric relation (CR) recording. **A,** Elastomeric material is used for CR recording. **B,** Once mandibular quadrants are coated, the dentist uses an anterior resin jig (see Fig. 2-10) to ensure that a reproducible recording position is obtained. The patient remains occluded until the material has set. **C,** This is the appearance of the record before trimming. (**A,** Courtesy Parkell, Inc., Edgewood, N.Y.)

FIGURE 2-24 ■ Gauze mesh cloth forms with plastic holders, and zinc oxide–eugenol (ZOE) paste can be used instead of elastomeric paste.

that are to be articulated. If breakage of the casts is a concern, it may be advisable to make record bases on an accurate duplicate cast made with reversible agar hydrocolloid impression material in a flask designed for that purpose.

Articulating the Diagnostic Casts

Maxillary Cast. The maxillary cast (Fig. 2-26) is seated in the indentations on the facebow fork after the facebow is attached to the articulator. Wedges or specially designed braces can be used to support the weight of the cast and to prevent the fork from flexing or moving. After it has been scored and wetted, the cast is attached to the mounting ring of the articulator with a low-expansion, fast-setting mounting stone or plaster.

Mandibular Cast. To relate the mandibular cast properly to the maxillary cast, the incisal guide pin should be lowered sufficiently to compensate for the thickness of the CR record. The articulator is inverted, and the record is seated on the maxillary cast. The mandibular cast (Fig. 2-27) is then carefully seated in the record, and each cast is checked for stability. The maxillary and mandibular casts can be luted together with sticky wax and either metal rods or pieces of wooden tongue blade. The mandibular member of the articulator is closed into mounting stone; the condylar balls should be fully seated in the corresponding fossae. If the articulator has a centric latch, this step is simplified. Otherwise, the articulator should be held until the stone has reached its initial set. No attempt should be made to smooth the stone until it has fully set.

Evaluation. Accuracy is crucial in both CR and MI. Before the articulator controls are adjusted, the dentist must confirm the accuracy of CR by comparing the tooth

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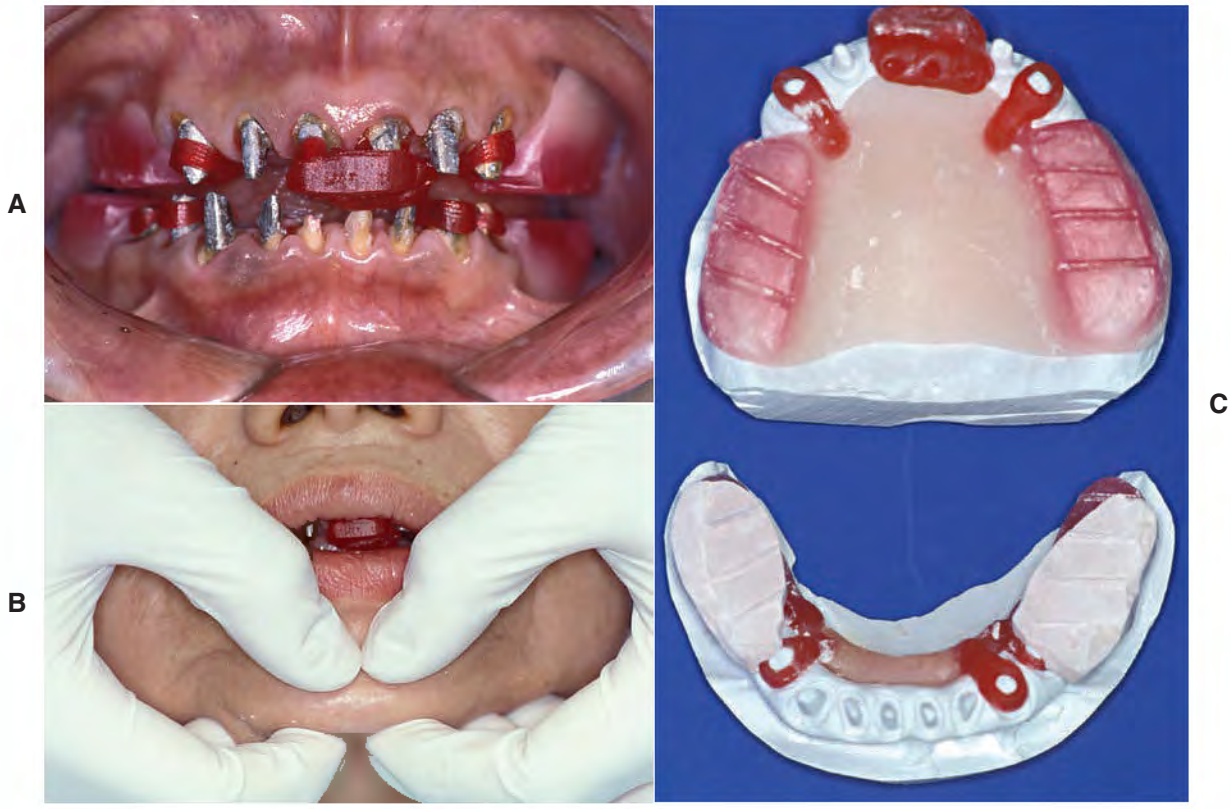

FIGURE 2-25 ■ **A** to **C,** Acrylic resin record bases used to mount partially edentulous casts.

contacts on the casts with those in the patient's mouth (Fig. 2-28). During the clinical examination, the position of tooth contacts in CR can be marked with thin articulating film. Normally, the markings are on the mesial inclines of maxillary cusps and the distal inclines of mandibular cusps. To transfer their exact location, the patient should close through thin occlusal indicator wax. The articulated casts are closed, and the retruded tooth contacts marked with articulating film. When the indicator wax is transferred to the casts, the perforations should correspond exactly to these marks.

For additional verification, MI of the articulated casts should be examined. MI is usually a translated mandibular position that may not be reproducible with absolute accuracy on a semiadjustable articulator. However, any substantive discrepancy invariably indicates an incorrect mounting. If further confirmation of mounting accuracy is required (as may be the case when definitive casts are being articulated), additional CR records can be made and compared with a split-cast mounting system or a measuring device such as the Denar Centri-Check marking system (Whip Mix Corporation, Louisville, Ky.) (Fig. 2-29).

Posterior Articulator Controls. The advantages and disadvantages of the different articulators are summarized in Table 2-1. The more sophisticated (fully adjustable) articulators have a large range of adjustments that can be programmed to follow the condylar paths precisely. Their posterior controls are designed to enable simulation of movement of the condylar processes, duplicating protrusive and lateral tooth contacts. The semiadjustable instruments can be adjusted to a lesser extent. Their posterior controls are designed to replicate the most clinically significant features of mandibular movement (e.g., condylar inclination and mandibular side shift). These instruments can be programmed from eccentric interocclusal records or a simplified pantograph. An alternative technique is to use average values for the control settings. It is important to note that no method used to program an articulator to reproduce eccentric jaw movements is without error.[27]

Arbitrary Values. On the basis of clinical investigations, certain generally applicable average anatomic values have evolved for condylar inclination, both immediate and progressive side shift. These values have been described in relation to the Frankfort horizontal plane and the midsagittal plane. For instance, an average value of 1.0 mm has been reported[28] for immediate side shift.

When arbitrary values are used to adjust posterior articulator controls, the actual instrument settings vary from one manufacturer to another. However, depending on the degree of adjustability of the articulator, the use of arbitrary values does not necessarily lead to less accuracy than do alternative techniques (e.g., eccentric interocclusal records to program a semiadjustable articulator, particularly when the instrument can execute only a straight protrusive path).

Eccentric Interocclusal Recordings. Eccentric interocclusal records (check bites) have been recommended[29]

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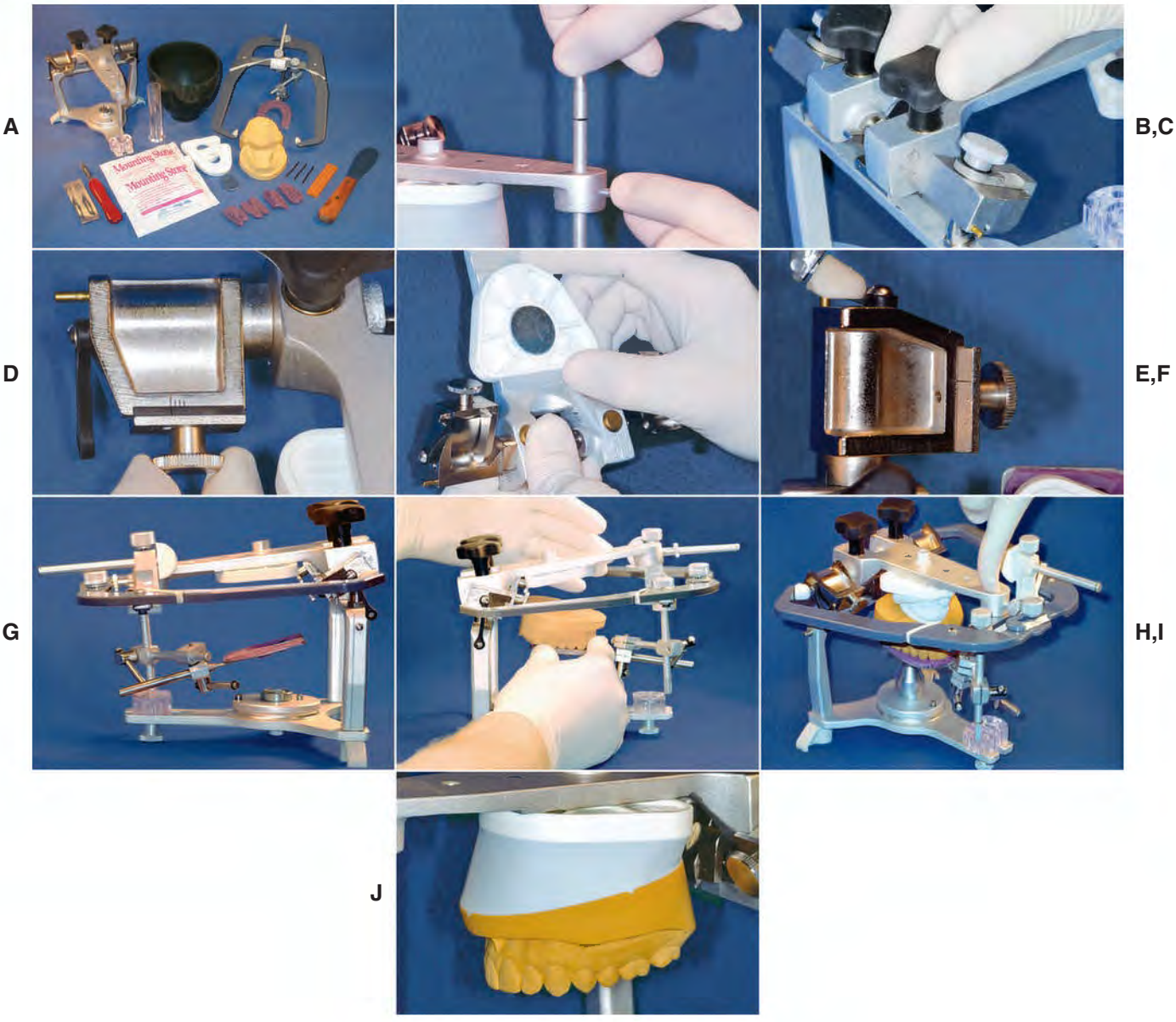

FIGURE 2-26 ■ Mounting the maxillary cast on a Whip Mix articulator. **A,** Armamentarium. **B,** The incisal pin is removed. **C,** The condylar inclination is adjusted to the facebow setting. **D,** The side shift is set to zero. **E,** A mounting plate is attached. **F,** The facebow earpieces are attached to the condylar elements. **G,** The facebow is attached to the articulator. **H,** The scored maxillary cast is positioned on the facebow fork, and the cast is prewetted. **I,** The mounting stone is applied to the cast and the mounting plate. The upper member of the articulator is closed until it contacts the crossbar of the facebow. **J,** Additional stone is added as needed. (Courtesy Whip Mix Corporation, Louisville, Ky.)

for setting the posterior controls of a semiadjustable articulator. These consist of wax or another recording material interposed between the maxillary and mandibular arches; they record the position of the condyles in eccentric mandibular positions. Static positional records are made in translated jaw positions: a protrusive record and two lateral records. The protrusive record can be used to adjust both condylar inclinations on the articulator, and the lateral records are used to adjust the side shift on semiadjustable articulators.

An articulator set by an eccentric record is accurate in only two positions: at CR and at the position recorded by the record (Fig. 2-30). This occurs because the path taken between these may differ significantly on the articulator from what is actually performed by the mandible. A semiadjustable instrument may have a protrusive path and a side shift path that are straight lines, whereas the true paths are invariably curved. In an attempt to minimize errors, many contemporary semiadjustable articulators come with curved fossae.

Armamentarium

- Interocclusal wax record material

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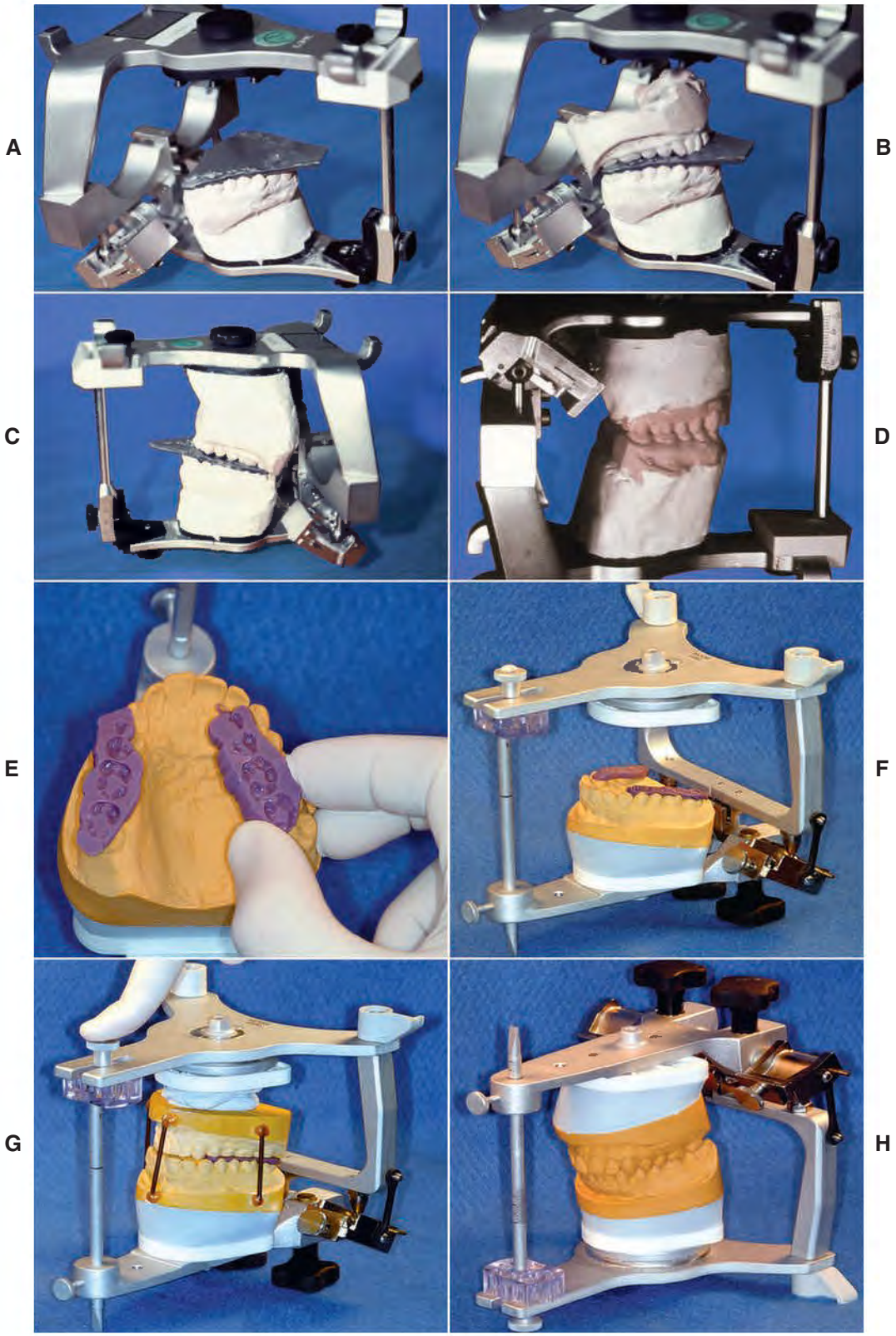

FIGURE 2-27 ■ Mounting the mandibular cast. **A** to **D,** Denar articulator: **A,** The centric relation (CR) record is positioned on the inverted maxillary cast. **B,** The incisal guide pin is adjusted, and the mandibular cast is oriented in the record. **C,** The cast is attached with mounting stone. **D,** When the pin is raised, the casts contact in CR closure. **E** to **H,** Whip Mix articulator: **E,** Elastomeric CR records are trimmed. **F,** CR records are positioned on the inverted articulator. **G,** The incisal guide pin is adjusted, the cast is stabilized, and plaster is applied to the prewetted cast and the mandibular mounting plate before the articulator is closed. **H,** Mounting is completed. (**E** to **H,** Courtesy Whip Mix Corporation, Louisville, Ky.)

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Step-by-Step Technique

1. Practice the three excursive positions until they can be reproduced. The patient's mandible can be guided into an anterior end-to-end position and into left and right lateral positions in which the canines are end to end when viewed from the front. The author and colleagues have found guiding the patient helpful in obtaining the records easily, although unguided records have been equally accurate.[30]
2. Adapt a wax record to the maxillary arch (Fig. 2-31, *A*) and guide the patient's mouth into a protrusive position. Have the patient close to form indentations in the recording medium (see Fig. 2-31, *B*). Verify that the midline remains properly aligned and that, when viewed from the side, the maxillary and mandibular incisors are end to end.
3. For the lateral records, add additional wax to one posterior quadrant of a wax record to compensate for the additional space on the patient's nonworking side.
4. Adapt this to the patient's maxillary arch and guide the patient's mandible into an excursive position, again verifying that the canines are end to end (see Fig. 2-31, *C* and *D*).

FIGURE 2-28 ■ Verifying mounting accuracy. **A,** Occlusal indicator wax is adapted to the maxillary teeth, and the patient's mouth is guided into centric relation closure. **B,** The cast contacts are marked with thin articulating film. **C,** If the mounting is accurate, the markings correspond to perforations in the wax.

FIGURE 2-29 ■ The Denar Centri-Check marking system. The casts are positioned in the same relationship as on the articulator, but the condylar elements are replaced by styli. Each stylus marks graph paper attached to the maxillary half of the articulator. By examining these marks, the dentist can compare successive centric relation records. (Courtesy Whip Mix Corporation, Louisville, Ky.)

TABLE 2-1 **Articulator Selection for Fixed Prosthodontics**

Fully Adjustable	Semiadjustable		Nonadjustable		Unmounted Casts	
DENAR D5-A	ARCON	NONARCON	LARGE	SMALL	ARCH	QUADRANT
Stuart	Denar Mark II	Hanau 96H20				
TMJ	Whip Mix	Dentatus				
	Hanau 183-2					
More ←	Diagnostic information provided				→ Less	
More ←	Occlusal information conveyed to laboratory				→ Less	
More ←	Time and skill needed at initial appointment				→ Less	
Less →	Chair time needed before cementation				→ More	
Multiple opposing restorations No anterior guidance Extensive occlusal pathology	Diagnostic assessment and treatment of most patients requiring fixed prosthodontics		Larger articulators for single restorations; some adjustment necessary Small hinge articulator only when occlusal influence minimal		Only when occlusal influence minimal	

Modified from Rosenstiel SF: Occlusal relationships, registration, and articulation. In Rayne J, ed: General Dental Treatment. London, Kluwer, 1983.
TMJ, Temporomandibular joint.

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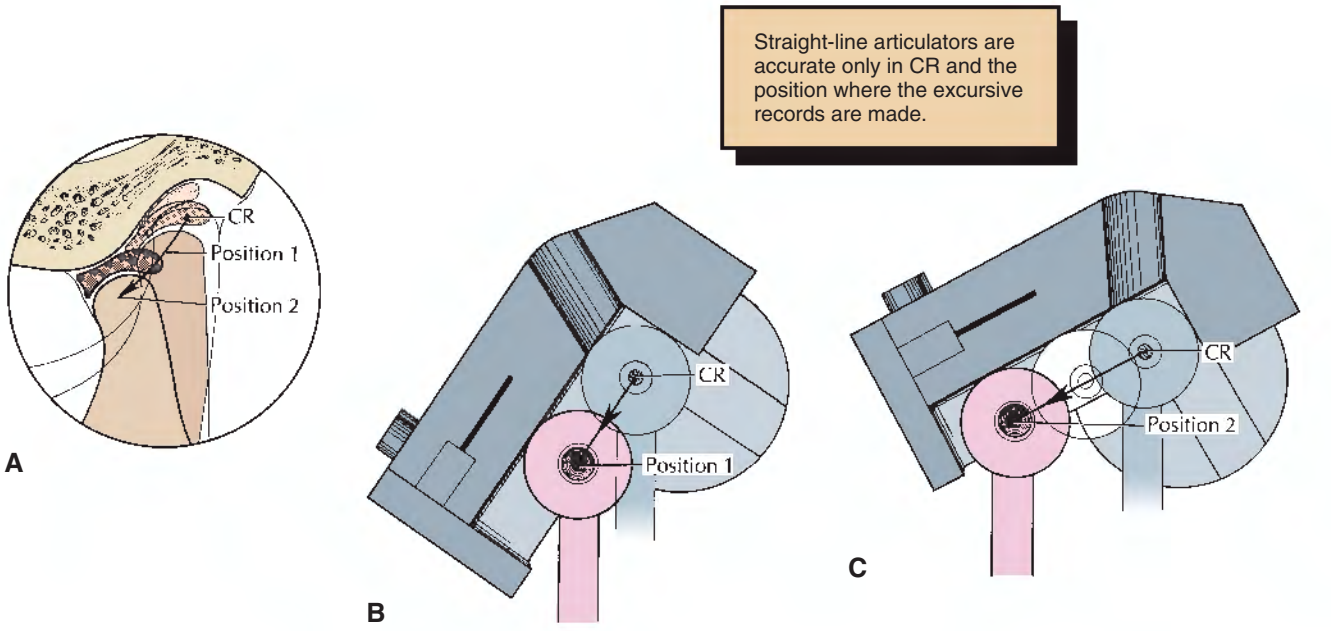

FIGURE 2-30 ■ **A,** The typical condylar path is curved, with its steepest inclination near centric relation (CR). If a semiadjustable articulator with a straight condylar path is programmed from an eccentric record, very different values will be obtained (depending on where the record is made) from what is actually performed by the mandible. **B,** Record made at position 1. **C,** Record made at position 2.

FIGURE 2-31 ■ Eccentric interocclusal records. **A,** Adaptation of wax to the maxillary arch. **B,** Protrusive record. **C** and **D,** Guiding the patient's mandible into left and right lateral excursive movements. Records are made in the left and right canine edge-to-edge positions. **E,** The completed records.

5. Repeat this step for the other lateral excursion.
6. Mark each record to facilitate its identification when it is used to adjust the posterior articulator controls (see Fig. 2-31, *E*).

Simplified Pantographs. A simplified pantograph (Fig. 2-32) measures only certain components of mandibular movement thought to be of greatest clinical significance: usually the condylar inclinations and mandibular side shift. This device can be assembled quickly. Numerical values are measured directly from the recording and are used to set a semiadjustable articulator to provide useful diagnostic information.

Simplified pantographs may reveal an excessively shallow condylar inclination or an exaggerated mandibular side shift. If either of these conditions is identified, restoration of the posterior teeth is likely to be complex, and the use of a fully adjustable articulator is recommended. Some manufacturers offer inserts of standard "fossae" of varying configuration, whose selection depends on the measurements obtained with a simplified pantograph (Fig. 2-33).

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FIGURE 2-32 ■ **A,** The Panadent Axi-Path Recorder. **B** and **C,** An axis stylus traces the condylar path and measures the amount of Bennett movement (B″ and B′) while the patient's mouth is guided into an eccentric border movement. (**A** to **C,** Courtesy Panadent Corporation, Colton, Calif.)

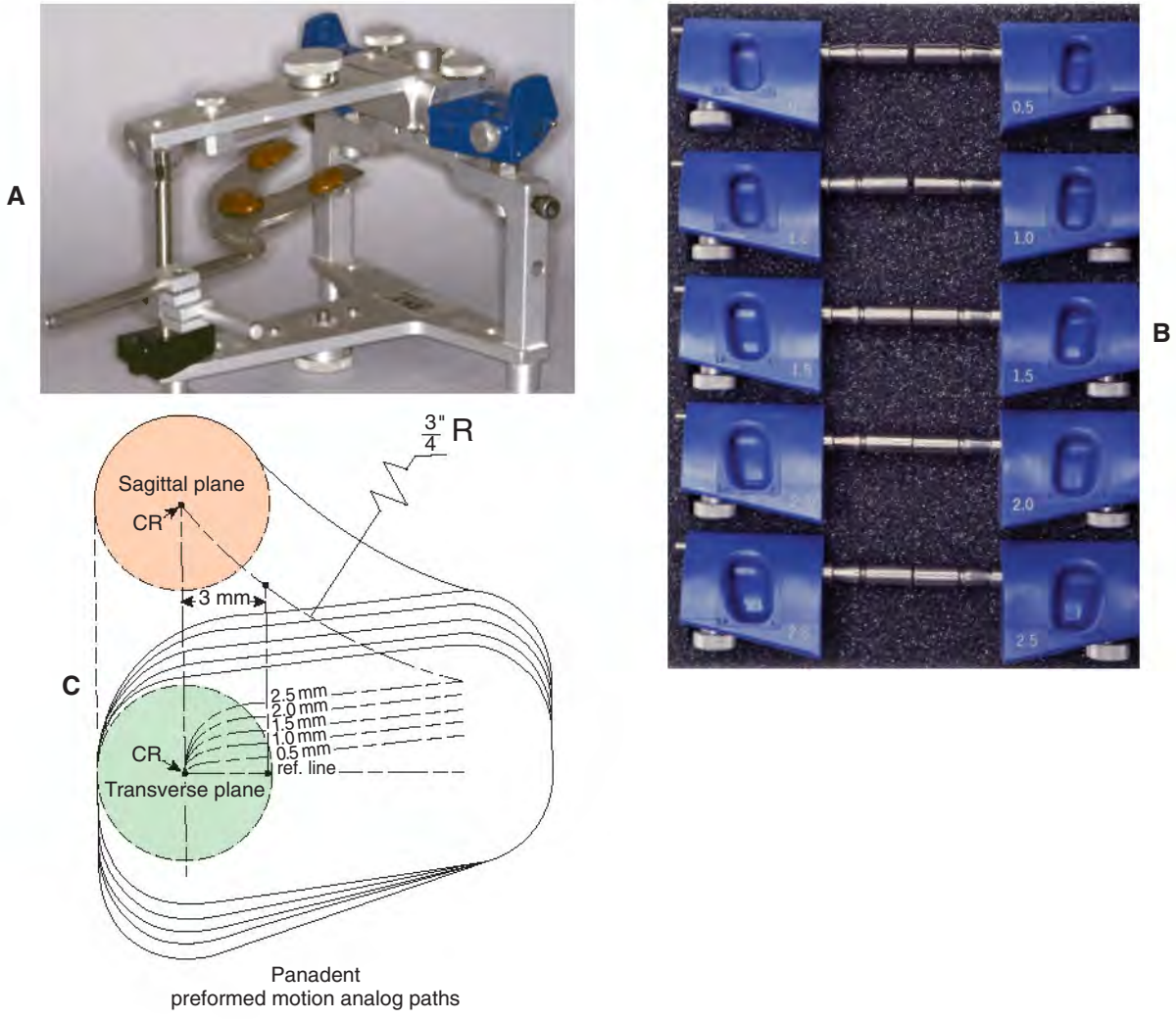

FIGURE 2-33 ■ **A,** The Panadent PCH Articulator with support legs. **B,** Fossa blocks (motion analogs) with different amounts of Bennett movement are selected from the simplified recorder or lateral interocclusal records. The blocks are rotated to the correct condylar inclination. **C,** Schematic showing the sagittal and transverse planes of the available motion analog blocks. *CR,* centric relation; *¾″ R,* ¾-inch radius of fossa curvature. (**A** to **C,** Courtesy Panadent Corporation, Colton, Calif.)

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Pantographic Recordings. Fully adjustable articulators are usually programmed on the basis of a pantographic recording (Fig. 2-34). Jaw movements are registered by directional tracings on recording plates. The plates are rigidly attached to one jaw, and the recording styli are attached to the other. A total of six plates are needed to achieve a precise movement record of the mandible. Left and right lateral border and protrusive tracings are made on each plate. The pantograph is then attached to the articulator, and the controls are adjusted and modified until the instrument can faithfully reproduce the movements of the styli on the tracings (Fig. 2-35). A simpler, although less accurate, procedure is to measure the tracings directly and adjust the condylar controls without transferring the recordings.

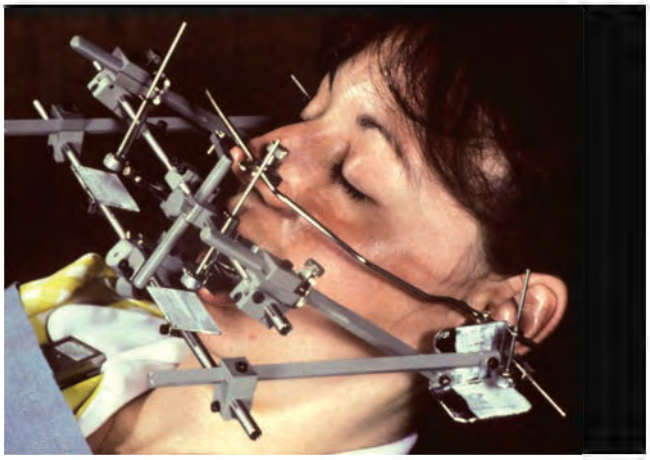

FIGURE 2-34 ■ The Stuart instrument, used to make pantographic recordings. (Courtesy Drs. R. Giering and J. Petrie.)

Electronic Pantograph. The electronic pantograph (the Cadiax Compact 2 System) is designed to record and measure functional and border movements (Fig. 2-36). It consists of upper and lower bows that record and measure mandibular movements and has been shown to provide valid and reliable measures of condylar determinants.[31]

Stereograms. Another approach to reproducing posterior condylar controls is to cut or mold a three-dimensional recording of the jaw movements. This "stereogram" is then used to form custom-shaped fossae for the condylar heads.

Anterior Guidance. Border movements of the mandible are governed by tooth contacts and by the shape of the left and right temporomandibular joints. In patients with normal jaw relationships, the vertical and horizontal overlap of anterior teeth and the lingual concavities of the maxillary incisors are highly significant during protrusive movements. In lateral excursions, the tooth

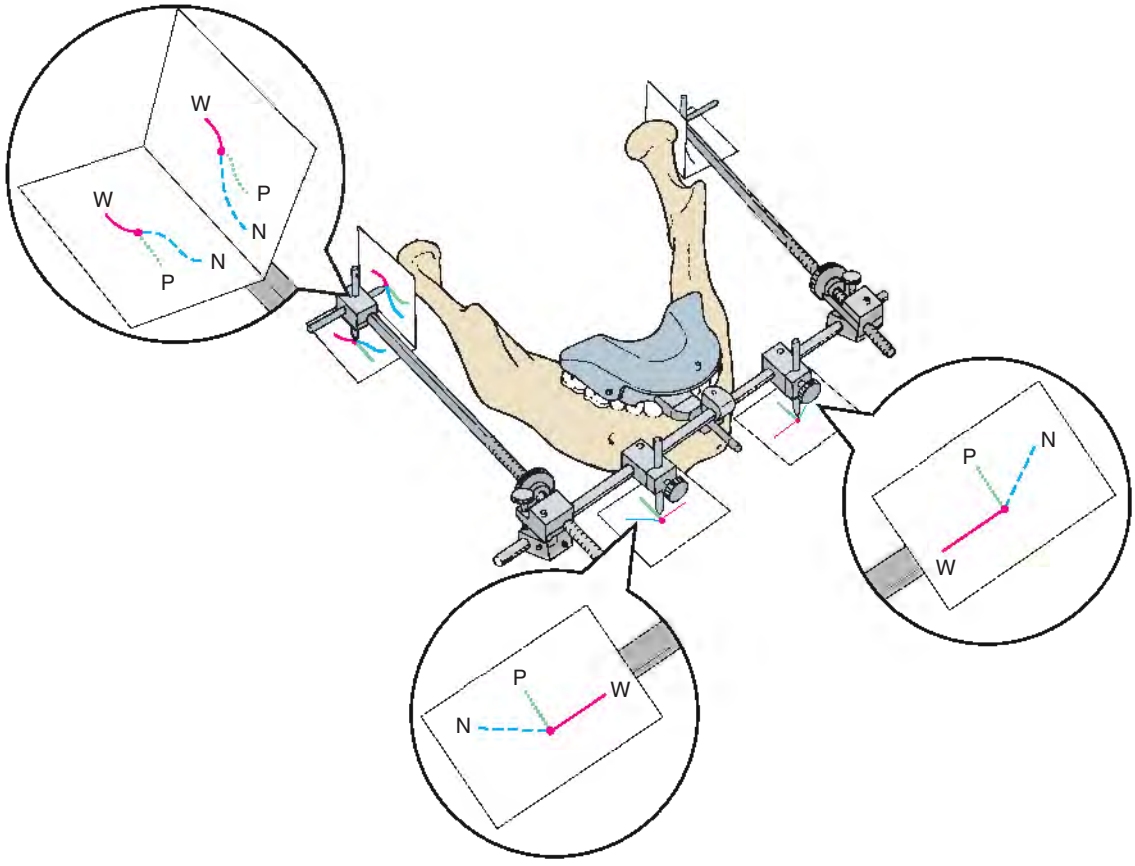

FIGURE 2-35 ■ Pantographic tracings represent information that could be obtained only with an infinite number of excursive records. This simplified schematic shows the relative orientation of six recording plates (attached to the maxillary bow, omitted for clarity) to the scribing styli, attached to the mandibular bow. *N,* nonworking or balancing movement; *P,* protrusive movement; *W,* working movement. The centric relation position is represented by the intersection of the paths marked by the dot.

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FIGURE 2-36 ■ **A** and **B,** Electronic jaw recording system. The Cadiax Compact 2 System is an electronic recording system that automatically calculates articulator adjustment. (Courtesy Whip Mix Corporation, Louisville, Ky.)

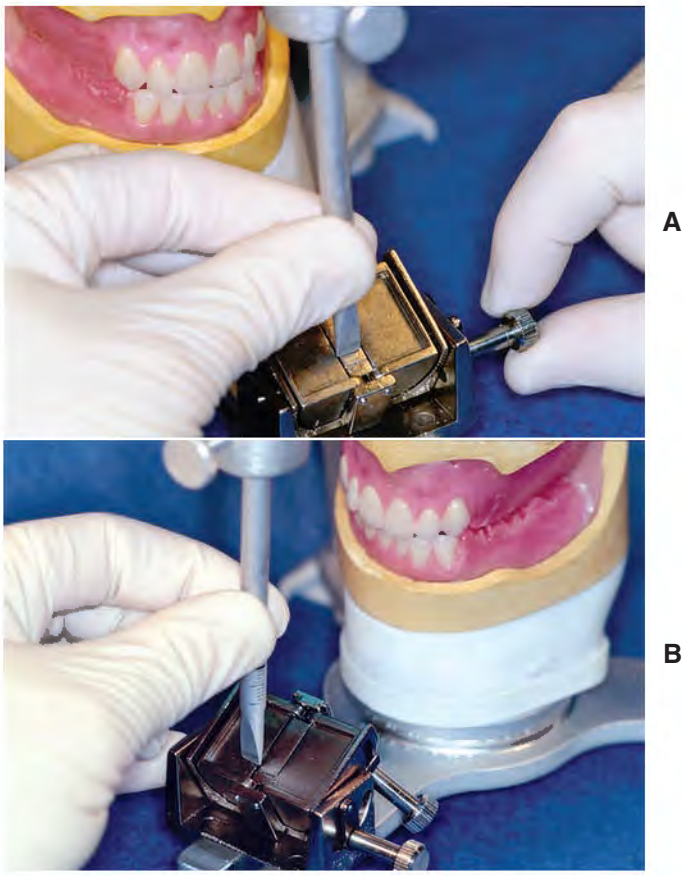

FIGURE 2-37 ■ Mechanical anterior guide table. **A,** The protrusive path has been adjusted. The side screw adjusts the lateral flange. **B,** Lateral flange adjusted to the right working movement.

contacts normally existing between the canines are usually dominant, although the posterior teeth may also be involved (see Chapter 4). Restorative procedures that change the shape of the anterior teeth can have a profound effect on excursive tooth contacts. For this reason, when preparation of anterior teeth is contemplated, the exact nature of the anterior contacts should be transferred to the articulator, where it can be studied and stored before these teeth are prepared.

Mechanical Anterior Guide Table. Most articulator manufacturers supply a mechanical anterior guide (incisal guidance) table (Fig. 2-37). Such tables can be pivoted anteriorly and posteriorly to simulate protrusive guidance, and they have lateral wings that can be adjusted to approximate lateral guidance. However, the sensitivity of these adjustments is insufficient for successfully transferring the existing lingual contours of natural teeth to newly fabricated restorations. Therefore, the principal use for these mechanical tables is in the fabrication of complete dentures and occlusal devices (see Chapter 4).

Custom Acrylic Anterior Guide Table. This simple device is used for accurately transferring to an articulator the contacts of anterior teeth when the dentist is determining their influence on border movements of the mandible. Acrylic resin is used to record and preserve this information, even after the natural lingual contours of the teeth have been altered during preparation for complete coverage restorations (Fig. 2-38, *A*). The technique is similar to that for stereographic recording used in setting the posterior controls of some articulators.

Custom Guide Table Fabrication

Armamentarium

- Plastic incisal table
- Tray and fossa acrylic resin
- Petrolatum

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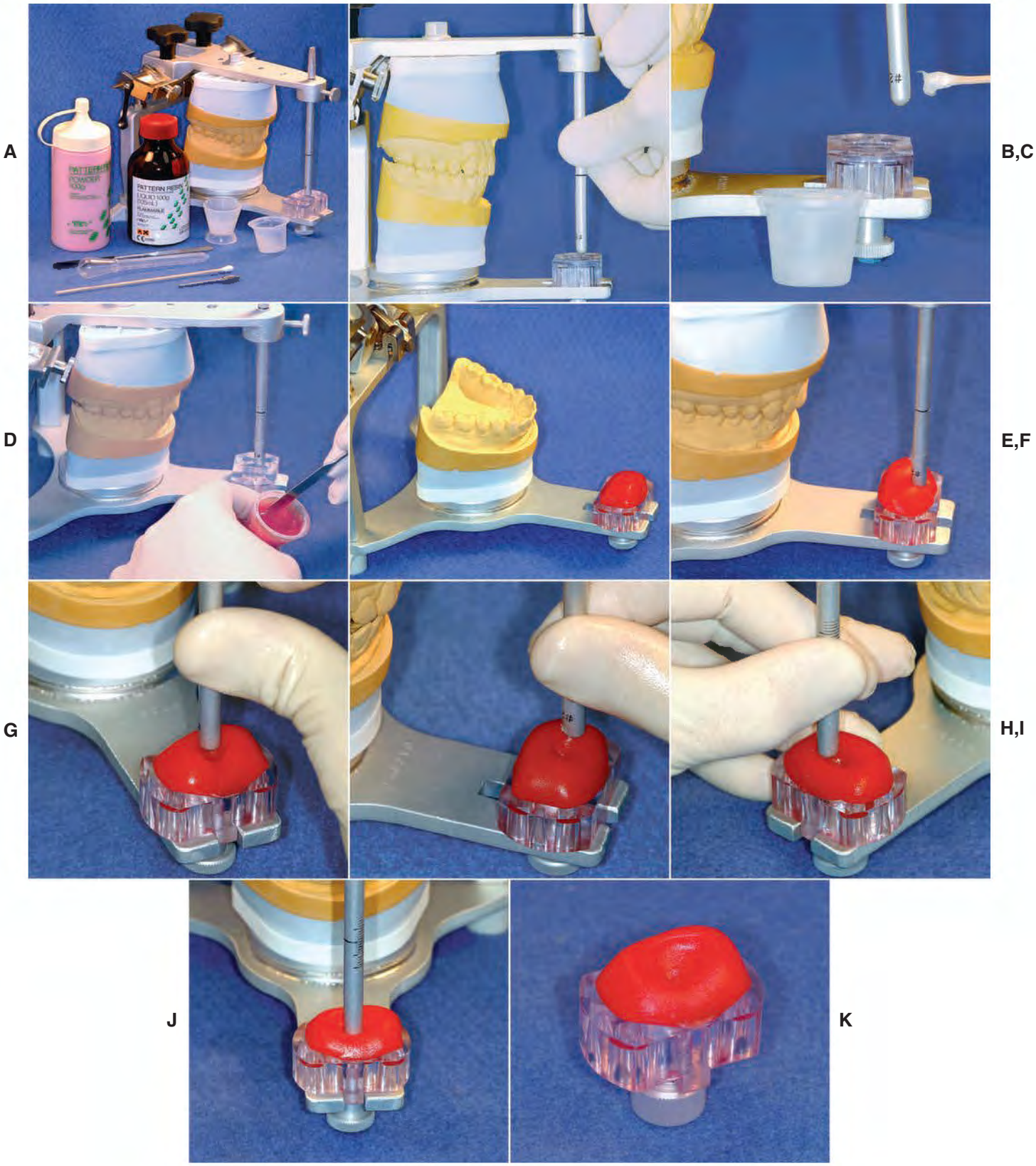

FIGURE 2-38 ■ Fabrication of a custom anterior guide table. **A,** Armamentarium. **B,** Incisal pin is raised 1 or 2 mm. **C,** The tip of the pin is lubricated. **D,** Resin is dispensed and mixed. **E,** Resin is applied to acrylic table. **F,** Pin is inserted when resin is at the doughy stage. **G,** The protrusive path is tracked. **H,** Right working movement and all intermediate laterotrusive paths. **I,** Left working movement and all intermediate laterotrusive paths. **J,** Resin is allowed to set. **K,** Excess resin still needs to be removed. (Courtesy Whip Mix Corporation, Louisville, Ky.)

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Step-by-Step Procedure

1. After the pin is raised and lubricated, moisten the plastic incisal table with acrylic resin monomer to ensure a good bond (see Fig. 2-38, *B* to *D*).
2. Mix a small quantity of resin and mold it to the table (see Fig. 2-38, *E*).
3. Raise the incisal pin about 2 mm from the table, cover its tip with petrolatum, and close it into the soft resin (see Fig. 2-38, *F* and *G*).
4. Manipulate the articulator in hinge, lateral, and protrusive movements while the resin is in the doughy stage of polymerization (see Fig. 2-38, *H* to *I*). As the pin moves through these excursions, its tip pushes into and molds the doughy acrylic resin lying in its path, ultimately creating an accurate and rigid three-dimensional record of the mandibular movements and their lateral and protrusive limits through the functional range (see Fig. 2-38, *J* and *K*).
5. Continue these closures until the resin is no longer plastic, being careful not to abrade or damage the casts during the process. A thin film of plastic foil placed between the casts will help minimize abrasion without significantly affecting the accuracy of the guide table.

Evaluation. When the custom anterior guide table has been completed, the incisal pin should contact the table in all excursive movements. This can be checked with thin shim stock (Mylar strips). If contact is deficient, a small mix of new resin is added and the process repeated. If too much resin has been used, the table may interfere with the hinge opening-closing arc of the articulator (Fig. 2-39). Excess can be easily trimmed away.

Diagnostic Cast Modification. One advantage of having accurately articulated diagnostic casts is that proposed treatment procedures can be rehearsed on the stone cast before any irreversible changes are made in the patient's mouth. These diagnostic procedures are essential when the dentist attempts to solve complicated problems. The most experienced clinician may have difficulty deciding between different treatment plans. Even in apparently simple situations, time that the practitioner spends rehearsing diagnostic procedures on the casts is usually well rewarded.

Diagnostic cast modifications include the following:

1. Changing the arch relationship preparatory to orthognathic procedures when skeletal jaw discrepancy is to be corrected surgically.
2. Changing the tooth position before orthodontic procedures (Fig. 2-40).
3. Modifying the occlusal scheme before any selective occlusal adjustment is attempted.

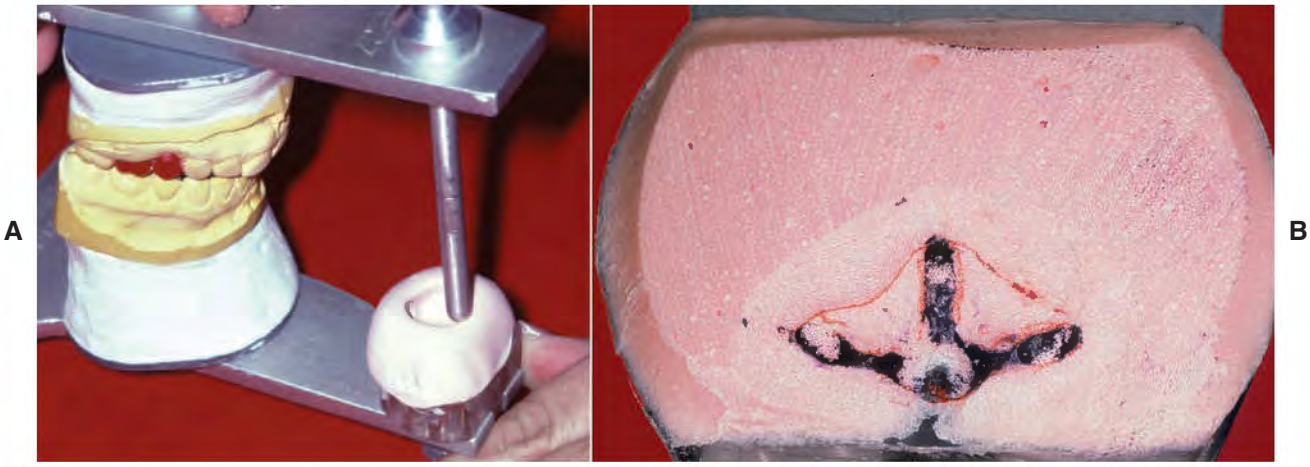

FIGURE 2-39 ■ **A,** A custom anterior guidance table made with excess resin. This must be trimmed if it interferes with the path of closure of the incisal pin. **B,** The completed table with excess resin ground away. Note the lateral and protrusive paths.

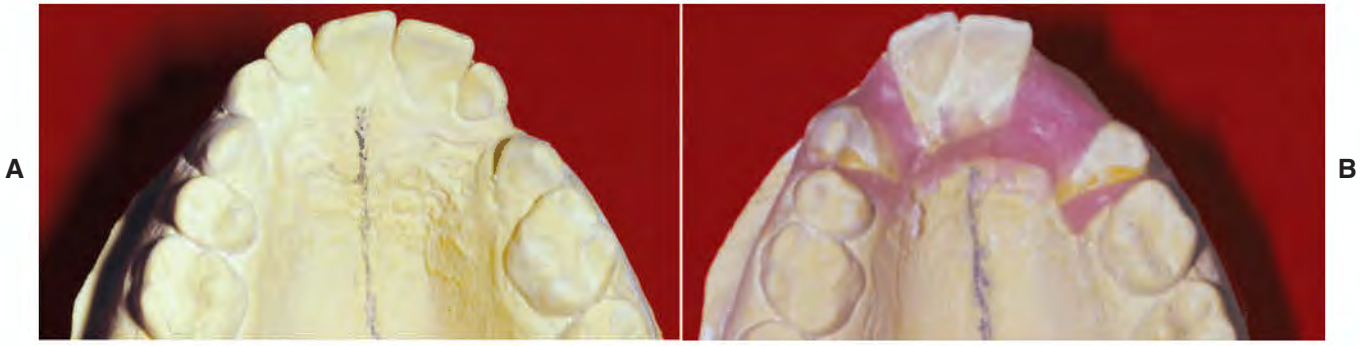

FIGURE 2-40 ■ **A, B,** Diagnostic cast modifications in advance of orthodontic treatment.

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FIGURE 2-41 ■ Diagnostic waxing procedure. Diagnostic tooth preparation and waxing help simplify complex prosthodontic treatment planning for predictable results. **A** and **B,** Cross-mounted diagnostic casts. A record base is used to articulate the partially edentulous mandibular cast. **C** and **D,** Diagnostic tooth preparations determine the correct reduction for esthetics and function. **E** to **H,** Diagnostic waxing, performed in conjunction with diagnostic denture tooth arrangement. (Courtesy Dr. J. Bailey.)

4. Trial tooth preparation and waxing (Fig. 2-41) before fixed restorative procedures. (This is one of the most useful diagnostic techniques for patients seeking fixed prosthodontics. It enables the practitioner to rehearse a proposed restorative plan and to test it on a stone cast, providing considerable information in advance of the actual treatment and helping explain the intended procedure to the patient.)

On many occasions, it is necessary to combine two or more of these options. In fact, dentists can simplify most treatment planning decisions (e.g., preparation design, choice of abutment teeth, selection of an optimum path of placement of a fixed dental prosthesis, or deciding to treat a patient with a fixed or removable dental prosthesis) by adhering to these diagnostic techniques.

Virtual Articulators

With the advances in computer-aided design and computer-aided manufacturing (CAD/CAM), optical scanning of entire arches has become a fairly straightforward procedure (see also the section Optical Impressions, Chapter 14). Recent software developments include virtual articulators.[32] Virtual casts derived from an optical scan can be positioned within the framework of the virtual articulator, and several of these have some degree of adjustability of condylar controls. Positioning the virtual cast in its proper orientation in relation to the hinge axis requires the digital equivalent of a facebow. Instead, current casts are typically positioned in an arbitrary position on the basis of average values (Fig. 2-42). One system (Fig. 2-43) has the ability to position the virtual cast in its correct orientation. It entails the use of scans made from hard (analog) stone casts that have been articulated in the conventional manner with a facebow and centric relation record, previously described in this chapter. First, the individual complete arch casts are scanned. Once virtual complete arch casts have thus been obtained, special extra-thick mounting plates are used to reduce the height of the stone casts and mounting stone sufficiently to allow them to be positioned in a laboratory scanner on a special reference platform with the bite registration interposed. This enables scanning the relative relationship of the maxillary and mandibular casts and enables their proper orientation in relation to the arbitrary axis of the virtual articulator. The virtual condylar (posterior) controls can be adjusted on the basis of the settings initially obtained on the analog stone articulation.

In its current version, the software does not capture an anterior guidance component that is truly interactive with those adjusted posterior controls, and the manufacturer reports that straight-line average values are used to govern the excursive movements of the casts in the virtual

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FIGURE 2-42 ■ Two examples of virtual articulators. **A,** The Wieland system positions occluded virtual quadrant casts arbitrarily within the three-dimensional rendering of the articulator. **B,** The Cerec virtual articulator also positions the virtual casts arbitrarily on the basis of average values that can be modified.

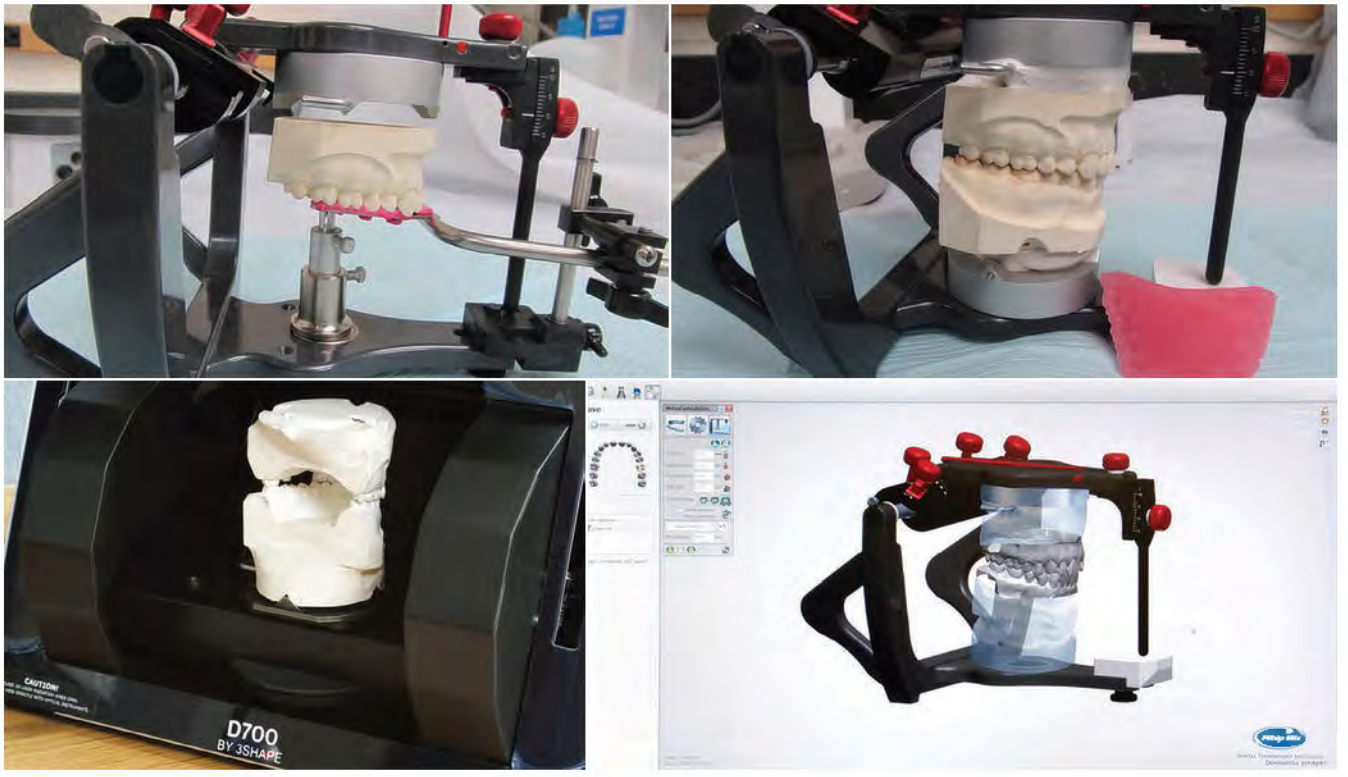

FIGURE 2-43 ■ Virtual reproduction of mandibular movement. **A,** The Denar Mark 330 articulator can be used with special mounting plates that permit repositioning of casts in the laboratory scanner. **B,** Excursive records are used to adjust the posterior controls. **C,** TEH scanner contains a platform that corresponds with the geometry of the special mounting plates, resulting in precise orientation of the virtual cast after scanning relative to the hinge axis of the virtual articulator (**D**). (Courtesy Whip Mix Corporation, Louisville, Ky.)

articulator. Development of a means to capture a desired anterior guidance (from either the original diagnostic casts, a diagnostic waxing, or from a cast made from interim restorations that have been clinically tested) seems to be one of the next logical steps in the development of this technology.

SUMMARY

Diagnostic casts provide valuable preliminary information and a comprehensive overview of the patient's needs that are often not apparent during the clinical examination. They are obtained from accurate irreversible hydrocolloid impressions and should be transferred to a semiadjustable articulator with the use of a facebow transfer and interocclusal record. For most routine fixed prosthodontic diagnostic purposes, the use of an arbitrary hinge axis facebow is sufficient. If special concerns apply, such as a change in vertical dimension, a kinematic facebow transfer is needed. Two types of articulators are recognized: arcon and nonarcon. For highly complex treatment needs, a fully adjustable articulator may be indicated. Such articulators are adjusted by means of a pantographic tracing.

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Diagnostic casts should be articulated in CR to enable observation of deflective tooth contact and to assess any slide that may be present from CR to MI. *Centric relation* is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterosuperior position against the shapes of the articular eminences. This position is independent of tooth contact. To record it, the dentist uses a suitable medium interposed between the maxillary and mandibular teeth and guides the patient into the CR position. This can be accomplished through bimanual manipulation. If many teeth are absent, record bases with wax rims may need to be fabricated to obtain a CR record.

If it is difficult to manipulate a patient's mandible into a reproducible hinge movement, a deprogramming device is helpful. This can be used to help minimize "muscle memory," which would result in easier replication of the rotational hinge movement of the mandible.

Posterior articulator controls can be adjusted on the basis of arbitrary values according to anatomic averages by means of eccentric records, simplified pantographs, pantographs, or stereographs.

Anterior guidance can be approximated on articulators with a mechanical guide table. As an alternative, a custom acrylic guide table can be generated from the diagnostic casts. The latter is useful when anterior teeth are to be restored.

The development of virtual articulators is exciting. In its current form, the software used for such virtual instrumentation is not quite capable of rendering the simulation of mandibular movements that can be observed on stone casts.

Diagnostic procedures such as diagnostic waxing, tooth preparation, and diagnostic cast modification can greatly enhance diagnosis and treatment planning.

REFERENCES

1. Erbe C, et al: Dimensional stability of contemporary irreversible hydrocolloids: humidor versus wet tissue storage. J Prosthet Dent 108:114, 2012.
2. Patel RD, et al: An in vitro investigation into the physical properties of irreversible hydrocolloid alternatives. J Prosthet Dent 104:325, 2010.
3. Nassar U, et al: Dimensional stability of irreversible hydrocolloid impression materials as a function of pouring time: a systematic review. J Prosthet Dent 106:126, 2011.
4. Mendez AJ: The influence of impression trays on the accuracy of stone casts poured from irreversible hydrocolloid impressions. J Prosthet Dent 54:383, 1985.
5. Damodara EK, et al: A randomized clinical trial to compare diagnostic casts made using plastic and metal trays. J Prosthet Dent 104:364, 2010.
6. Lim PF, et al: Adaptation of finger-smoothed irreversible hydrocolloid to impression surfaces. Int J Prosthodont 8:117, 1995.
7. Khaknegar B, Ettinger RL: Removal time: a factor in the accuracy of irreversible hydrocolloid impressions. J Oral Rehabil 4:369, 1977.
8. al-Omari WM, et al: A microbiological investigation following the disinfection of alginate and addition cured silicone rubber impression materials. Eur J Prosthodont Restor Dent 6:97, 1998.
9. Hall BD, et al: Effects of a chemical disinfectant on the physical properties of dental stones. Int J Prosthodont 17:65, 2004.
10. Johnson GH, et al: Dimensional stability and detail reproduction of irreversible hydrocolloid and elastomeric impressions disinfected by immersion. J Prosthet Dent 79:446, 1998.
11. Reisbick MH, et al: Irreversible hydrocolloid and gypsum interactions. Int J Prosthodont 10:7, 1997.
12. Young JM: Surface characteristics of dental stone: impression orientation. J Prosthet Dent 33:336, 1975.
13. Palik JF, et al: Accuracy of an earpiece face-bow. J Prosthet Dent 53:800, 1985.
14. O'Malley AM, Milosevic A: Comparison of three facebow/semi-adjustable articulator systems for planning orthognathic surgery. Br J Oral Maxillofac Surg 38:185, 2000.
15. Piehslinger E, et al: Computer simulation of occlusal discrepancies resulting from different mounting techniques. J Prosthet Dent 74:279, 1995.
16. Adrien P, Schouver J: Methods for minimizing the errors in mandibular model mounting on an articulator. J Oral Rehabil 24:929, 1997.
17. Dawson PE: Temporomandibular joint pain-dysfunction problems can be solved. J Prosthet Dent 29:100, 1973.
18. Tarantola GJ, et al: The reproducibility of centric relation: a clinical approach. J Am Dent Assoc 128:1245, 1997.
19. McKee JR: Comparing condylar position repeatability for standardized versus nonstandardized methods of achieving centric relation. J Prosthet Dent 77:280, 1997.
20. Lucia VO: A technique for recording centric relation. J Prosthet Dent 14:492, 1964.
21. Gross M, et al: The effect of three different recording materials on the reproducibility of condylar guidance registrations in three semi-adjustable articulators. J Oral Rehabil 25:204, 1998.
22. Wirth CG: Interocclusal centric relation records for articulator mounted casts. Dent Clin North Am 15:627, 1971.
23. Wirth CG, Aplin AW: An improved interocclusal record of centric relation. J Prosthet Dent 25:279, 1971.
24. Lundeen HC: Centric relation records: the effect of muscle action. J Prosthet Dent 31:244, 1974.
25. Kepron D: Variations in condylar position relative to central mandibular recordings. In Lefkowitz W, ed: Proceedings of the Second International Prosthodontic Congress, p 210. St. Louis, Mosby, 1979.
26. Teo CS, Wise MD: Comparison of retruded axis articular mountings with and without applied muscular force. J Oral Rehabil 8:363, 1981.
27. Tamaki K, et al: Reproduction of excursive tooth contact in an articulator with computerized axiography data. J Prosthet Dent 78:373, 1997.
28. Lundeen HC, Wirth CG: Condylar movement patterns engraved in plastic blocks. J Prosthet Dent 30:866, 1973.
29. Bell LJ, Matich JA: A study of the acceptability of lateral records by the Whip-Mix articulator. J Prosthet Dent 38:22, 1977.
30. Celar AG, et al: Guided versus unguided mandibular movement for duplicating intraoral eccentric tooth contacts in the articulator. J Prosthet Dent 81:14, 1999.
31. Chang WSW, et al: An in vitro evaluation of the reliability and validity of an electronic pantograph by testing with five different articulators. J Prosthet Dent 92:83, 2004.
32. Solaberrieta E, et al: Direct transfer of the position of digitized casts to a virtual articulator. J Prosthet Dent 109:411, 2013.

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STUDY QUESTIONS

1. Discuss the uses and limitations of irreversible hydrocolloid, and include an overview of its material properties.

2. Why are diagnostic casts articulated in centric relation? Why are they not articulated in maximum intercuspation?

3. List five items that are determined more easily on diagnostic casts than intraorally.

4. What is accomplished with a facebow transfer? How do arbitrary facebows differ from kinematic facebows? When would one be selected over the other?

5. Describe the differences between arcon and nonarcon articulators. When would use of a simple hinge instrument be acceptable, and when would it be contraindicated? Why?

6. What is the role of excursive records in adjusting the articulator?

7. What does a simplified pantograph record? What does a pantograph record? When would either be indicated?

8. For what purpose is a custom acrylic guide table fabricated, and when is its use necessary?

9. Give two examples of situations in which a diagnostic waxing procedure is indicated.

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CHAPTER 3

Treatment Planning

Treatment planning consists of developing a logical sequence of treatment designed to restore the patient's dentition to good health, optimal function, and optimal appearance. The plan should be presented in writing and discussed in detail with the patient. Good communication with the patient is critical as the plan is formulated. Most dental problems can be solved in a number of different ways; the patient's preferences and concerns are paramount in establishing an appropriate treatment plan. In appropriate proper planning, the patient is informed about the current conditions and problems, the extent of dental treatment that is proposed, the time and cost of treatment, and the level of home care and professional follow-up necessary for success. Also, before any irreversible procedures are initiated, the patient should understand that some of the planned procedures may need to be changed as treatment progresses and new information becomes available.

This chapter outlines the necessary decisions in planning fixed prosthodontic treatment. Foremost among these is the identification of patients' needs and their preferences, which must be correlated with the range of treatments available. For long-term success, when a fixed dental prosthesis (FDP) is being considered, the abutment teeth must be carefully evaluated. Finally, the treatment plan must be properly sequenced as part of an ongoing program of comprehensive dental care.

IDENTIFICATION OF PATIENT NEEDS

Successful treatment planning is based on proper identification of the patient's needs. If the dentist attempts to make the patient conform to the "ideal" treatment plan rather than make the treatment plan conform to the patient's needs, success is unlikely. In many cases, several plans are presented and discussed, each with advantages and disadvantages. Indeed, failing to explain and present available options may be considered legally negligent.

Treatment is necessary to accomplish one or several of the following objectives: correcting an existing disease, preventing future disease, restoring function, and improving appearance.

Correction of Existing Disease

Existing disease is revealed during the clinical examination (see Chapter 1). Active disease can usually be halted by identification and reduction of the initiating factors, identification and improvement of the resistive factors, or both (Fig. 3-1). For example, oral hygiene instruction helps reduce the amount of residual plaque, an initiating factor, and thus helps reduce the likelihood of further dental caries. Such instruction also helps improve gingival health, and the resulting healthy tissue is more resistant to disease. In such patients with extensive caries, additional preventive measures are necessary (e.g., mouth rinses, high-fluoride toothpastes, dietary analysis). Restorative treatment replaces damaged or missing tooth structure, but additional treatment is crucial to control the underlying causes.

Prevention of Future Disease

The likelihood of future disease can be predicted from the patient's disease experience and from the prevalence of the disease in the general population. Treatment should be proposed if future disease seems likely in the absence of such intervention.

One of the first phases of treatment is to stabilize active disease, which often includes replacement of defective restorations and treatment of carious lesions. If a patient presents initially with poor oral hygiene, the dentist should monitor if improvement in plaque control results during the stabilization phase. If such does not occur, renewed emphasis on proper oral hygiene measures is indicated. Subsequently identified limitations in the patient's oral hygiene may justifiably affect the final treatment plan.

Restoration of Function

Although objective measurement can be difficult, the level of function is assessed during the examination. Treatment may be proposed to correct impaired function (e.g., mastication or speech). Prerequisite treatment may include mandibular repositioning through occlusal reshaping before fixed prosthodontic treatment (see Chapters 4 and 6) and orthodontically repositioning teeth in more favorable locations before missing teeth are replaced.

Improvement of Appearance

Patients often seek dental treatment because they are dissatisfied with their appearance. However, it is difficult to assess dental esthetics objectively (see Chapter 23). The dentist should develop expertise in this area and should be prepared to appraise the appearance of the patient's dentition and listen carefully to the patient's views. If the existing appearance is far outside socially accepted values, the feasibility (and limitations) of corrective procedures should be brought to the patient's attention. Long-term dental health should not be

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FIGURE 3-1 ■ Poor plaque control with dental caries and tooth wear.

compromised by unwise attempts to improve appearance. Patients should always be made aware of the possible adverse consequences of treatment.

AVAILABLE MATERIALS AND TECHNIQUES

All existing restorative materials and techniques have limitations, and none exactly match the properties of natural tooth structure. Clinicians must understand these limitations before they can select the appropriate procedure. This helps prevent an experimental approach to treatment.

Plastic Materials

Plastic materials (e.g., silver amalgam or composite resin) are the most commonly used dental restoratives. They allow simple and conservative restoration of damaged teeth. However, their mechanical properties are inferior to those of cast metal or metal-ceramic restorations. Their longevity depends on the strength and integrity of the remaining tooth structure. When the tooth structure needs reinforcement, a cast metal restoration should be fabricated, often with amalgam or composite resin as the foundation or core (see Chapter 6).

Large amalgam restorations (Fig. 3-2, *A*) are shaped or carved directly in the mouth. Because of the great degree of difficulty with this direct approach, defective contours and poor occlusion often result. The indirect procedure, used in making crowns (see Fig. 3-2, *B* and *C*), facilitates the fabrication of more accurately shaped restorations.

Cast Metal

Cast metal crowns (see Fig. 3-2, *B*) are fabricated in the dental laboratory and are cemented with a luting agent. They fit over a prepared tooth, somewhat like a thimble's fitting on a finger. To minimize exposure of the luting agent to oral fluids, a long-lasting crown must fit the tooth well. Precise technique enables the routine fabrication of metal crowns with excellent marginal fit and precisely shaped axial and occlusal surfaces. Replication of optimal anatomic form in crowns helps maintain periodontal health and good occlusal function. The internal dimensions of a crown must allow it to seat without binding against the vertical preparation walls while remaining stable and not becoming displaced during function. Thus crowns must be fabricated to precise tolerances. Preparation design for cast metal restorations is critical and is discussed in detail in Chapters 7 through 10 (Fig. 3-3).

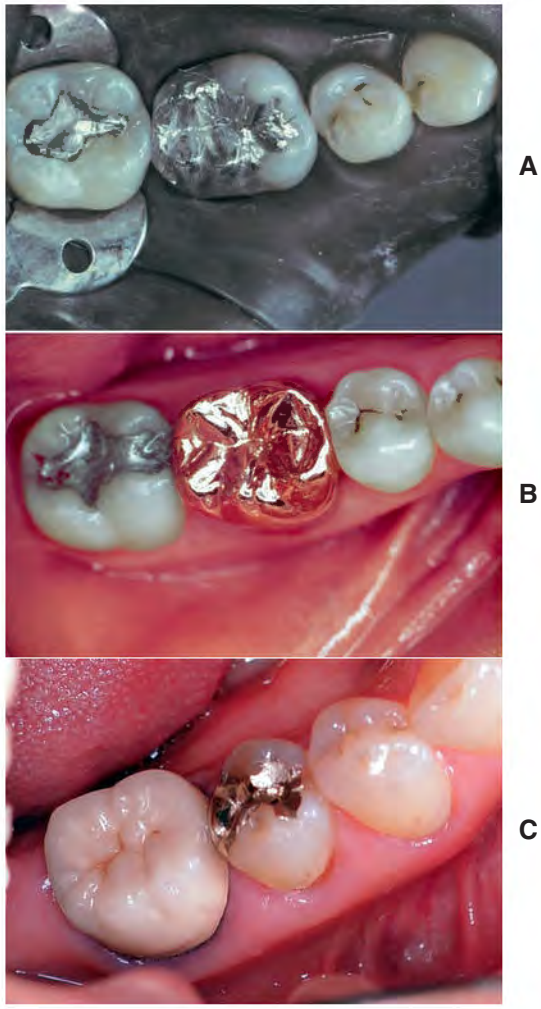

FIGURE 3-2 ■ **A,** The large amalgam restoration is hard to condense and contour accurately. **B,** The complete cast metal crown is stronger and can be shaped by an indirect procedure in the dental laboratory. **C,** Although an esthetic crown is weaker than cast metal, it was used to restore this first molar.

Intracoronal Restorations

An intracoronal cast metal restoration (Fig. 3-4), or inlay, relies on the strength of the remaining tooth structure for support and retention, just as a plastic restoration does. However, greater tooth bulk is needed to resist any wedging effect on the preparation walls (see Fig. 7-28). Therefore, this restoration is contraindicated in a significantly weakened tooth (see Fig. 3-2, *A*). When fabricated correctly, intracoronal inlays are extremely durable because of the strength and corrosion resistance of the gold casting alloy; however, in a tooth with a minimal proximal carious lesion, an inlay usually necessitates greater removal of tooth structure than does an amalgam preparation.

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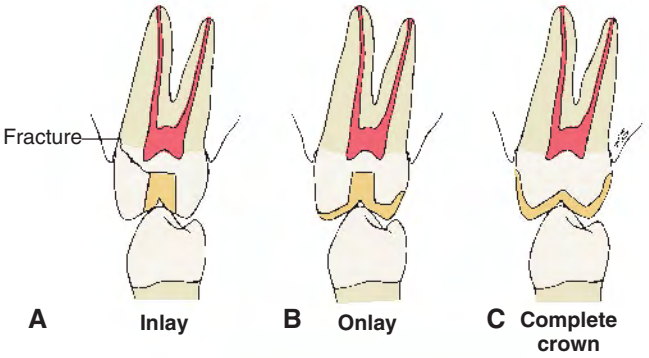

Cuspal protection becomes more important as the structural durability of the cusps is compromised.

FIGURE 3-3 ■ **A,** An intracoronal cast restoration (inlay) can act as a wedge during cementation or function. If the cusps are weakened, fracture will occur. **B,** A cuspal-coverage onlay provides better protection but often lacks retention. **C,** A complete crown provides the best protection against fracture. It also has the best retention, but it can be associated with periodontal disease and poor esthetics. (Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment. London, Kluwer Publishing, 1983.)

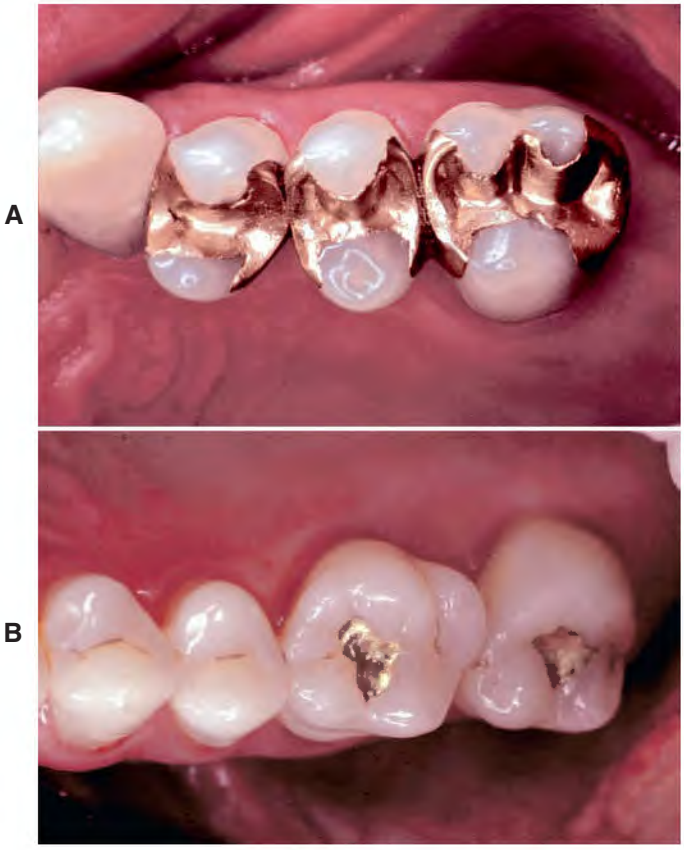

FIGURE 3-4 ■ **A,** The mesio-occlusal-distal (MOD) inlay is generally contraindicated because of the risk of tooth fracture. However, it can be a very long-lasting restoration. These, placed in 1948, were still satisfactory when the patient died in 2012. **B,** These small gold foil restorations were placed in 1943.

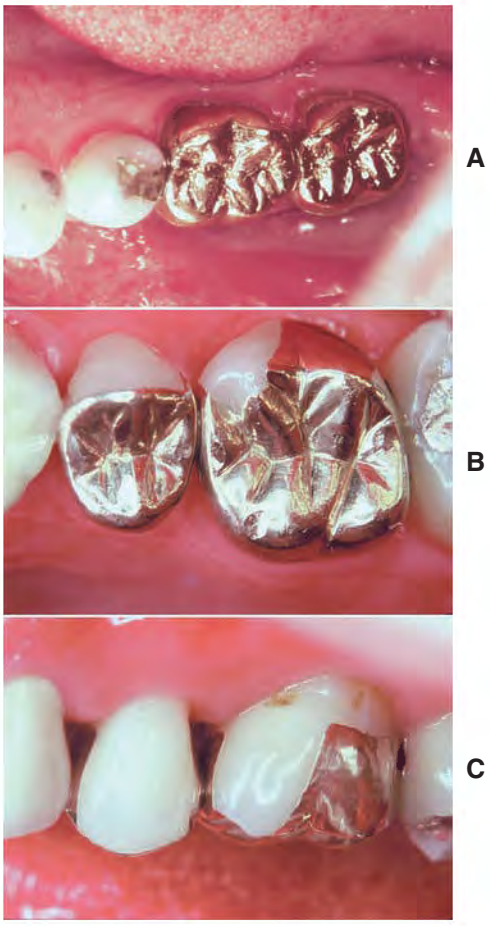

FIGURE 3-5 ■ **A,** Complete cast metal crowns restore the molars. Occlusal **(B)** and buccal **(C)** views of two partial veneer crowns. With partial veneer crowns, more tooth structure is conserved.

Extracoronal Restorations

An extracoronal cast metal restoration (Fig. 3-5), or crown, encircles all or part of the remaining tooth structure and the occlusal surface. Crowns strengthen and protect teeth weakened by caries or trauma. To provide the necessary bulk of material for strength, considerably more tooth structure must be removed than for an intracoronal restoration. The margins of an extracoronal restoration often must be near or below the crest of the free gingiva, which can make maintenance of tissue health difficult. Tooth preparation for an extracoronal restoration may be combined with intracoronal features (e.g., grooves and pinholes) to obtain retention mechanical advantage (see the Retention and Resistance section, Chapter 7).

Metal-Ceramic Material

Metal-ceramic crowns (Fig. 3-6) consist of a tooth-colored layer of porcelain bonded to a cast metal substructure. They are used when a complete crown is needed to restore appearance and function. Tooth structure must be reduced sufficiently to provide space for the bulk of porcelain needed for a natural appearance. Thus the preparation design for a metal-ceramic crown is

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FIGURE 3-6 ■ **A** and **B,** Metal-ceramic restorations used to restore the maxillary anterior teeth.

FIGURE 3-7 ■ Fiber-reinforced fixed dental prosthesis.

among the least conservative, although tooth structure can be conserved if only the most visible part of the restoration is veneered.

The labial margins of a metal-ceramic restoration are often discernible and may detract from its appearance. They can be hidden by subgingival placement, although they then have the potential for increasing gingival inflammation; this should be avoided when possible.[1] Appearance can be improved by omitting the metal shoulder and making the labial margin in porcelain. As discussed in Chapter 24, this is a more challenging laboratory procedure.

Fiber-Reinforced Resin

Advances in composite resin technology, especially the introduction of glass and polyethylene fibers,[2-4] have prompted the use of indirect composite resin restorations for inlays, crowns, and FDPs.[5] Excellent marginal adaptation and esthetic results are achievable (Fig. 3-7), but they do not withstand functional loads well over time. Therefore, they are very useful as long-term interim restorations. (See the Fiber-Reinforced Interim Restorations section, Chapter 15).

FIGURE 3-8 ■ Complete ceramic restoration.

Complete Ceramic

Crowns, inlays, and laminate veneers made entirely of dental porcelain are among the most esthetically pleasing of all fixed restorations (Fig. 3-8). Drawbacks include a comparative lack of strength and—depending on the fabrication method used—the difficulty in achieving an acceptable internal and marginal fit. Some all-ceramic restorations are fabricated in the dental office, whereas others must be fabricated in the dental laboratory. In general, the internal fit of some of the laboratory fabricated restorations is superior to that of those fabricated by milling in the dental office. The advantage of the latter is that the esthetic restoration can be placed in a single appointment without the need for an interim restoration. The current focus in improving the strength of esthetic restorations is on either veneering a high-strength alumina, zirconia, spinel, or lithium disilicate core[6-8] with a more translucent porcelain or using a leucite-reinforced translucent material[9-12] (see Chapter 25). Monolithic esthetic restorations are among the strongest ceramic restorations, and colored monolithic zirconia crowns have very acceptable esthetics for posterior teeth.[13] Complete ceramic restorations are fabricated by an indirect technique, and etchable ceramic crowns are generally retained with composite resin. The acid etching of the internal crown surface is used to provide retention "keys."

Fixed Dental Prostheses

An FDP (Fig. 3-9) is often indicated when one or more teeth must be removed or are missing. Such teeth are replaced by *pontics* that are designed to fulfill the functional and often the esthetic requirements of the missing teeth (see Chapter 20). Pontics are attached with *connectors* to the FDP *retainers*, which are the restorations on prepared abutment teeth.

All the components of an FDP are fabricated and assembled in the laboratory before cementation in the mouth. This requires precise alignment of tooth preparations. Because unseating forces on individual retainers can be considerable, retentive restorations are essential.

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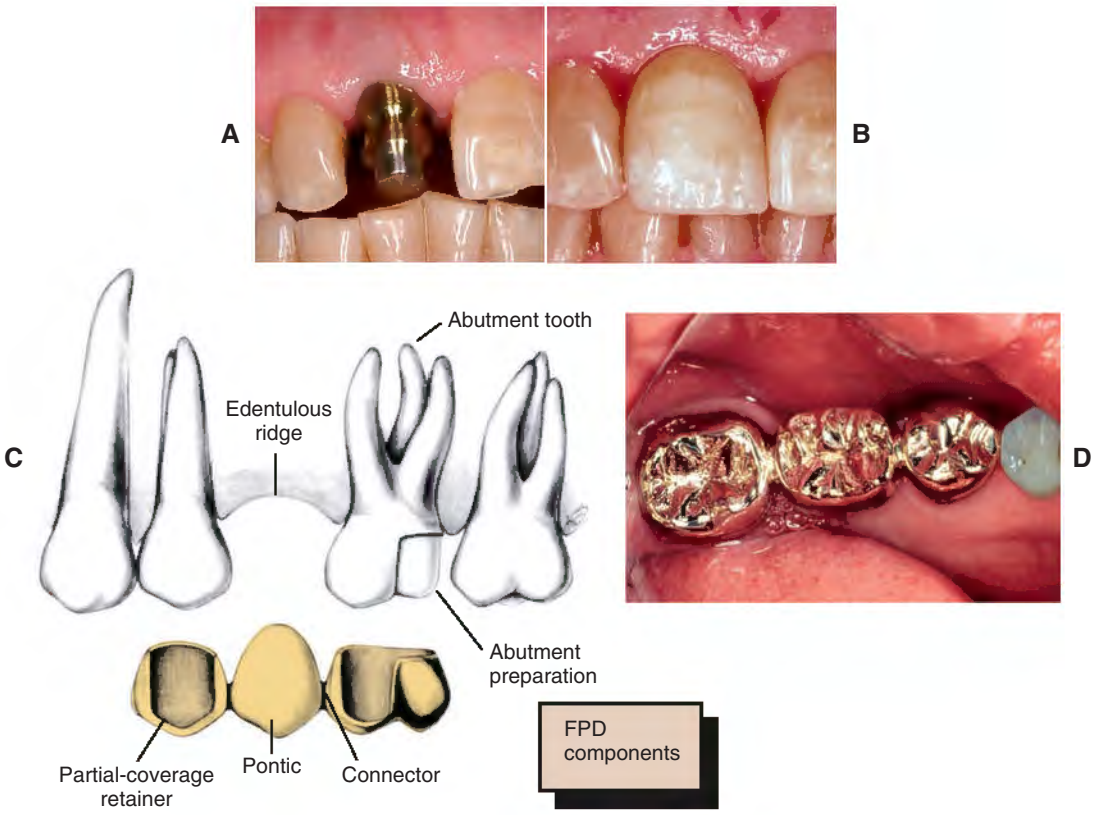

FIGURE 3-9 ■ **A,** A maxillary right central incisor that will be replaced by a single-unit implant-supported prosthesis. The impression post is tightened into the implant. **B,** All-ceramic restoration. **C,** Illustration of a three-unit fixed dental prosthesis, showing the main components. **D,** The pontic rigidly attached to crowns on the abutment teeth. The connectors should occupy the normal interproximal contact area and be large enough for strength but not so large as to impede plaque control.

FDPs have been demonstrated to have exceptional long-term success,[14] which is ensured by controlling the magnitude and direction of loading and by making sure the patient practices appropriate oral hygiene measures.

Implant-Supported Prostheses

Single or multiple missing teeth can be replaced with an implant-supported prosthesis (Fig. 3-10). For the successful "osseointegrated" technique, the bone is atraumatically drilled to receive precisely fitting titanium cylinders.[15] These are either left in place without loading for several months until they are osseointegrated or restored immediately with an interim restoration. Then function and esthetics are restored with a prosthesis (see Chapter 13).

Partial Removable Dental Prosthesis

A partial removable dental prosthesis (RDP) (Fig. 3-11) is designed to replace missing teeth and their supporting structures. Forces applied to a well-designed partial RDP are distributed to the remaining teeth and the residual alveolar ridges. These forces are most accurately controlled if the abutment teeth can be reshaped with fixed cast restorations that have carefully contoured guide planes and rest seats (see Chapter 21). Specific design requirements of the partial RDP can affect tooth preparation design for such *survey crowns*.

FIGURE 3-10 ■ **A,** Single tooth implant with healing abutment in place. **B,** Implant supported crown replacing maxillary lateral incisor.

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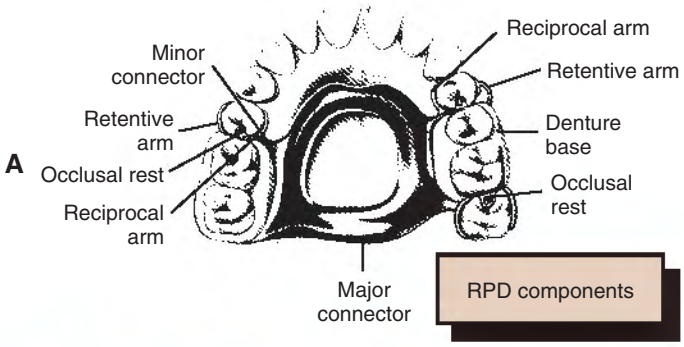

FIGURE 3-11 ■ The component parts of a partial removable dental prosthesis (RDP) **(A)**. Missing posterior teeth are replaced with a partial RDP supported by surveyed metal-ceramic crowns on the premolars and gold crowns on the molars **(B)**.

Complete Dentures

Common difficulties encountered with *complete dentures* relate to the lack of denture stability and gradual loss of supporting bone over time. Denture stability is enhanced if the denture has a carefully designed occlusion. Problems with maxillary denture stability can be especially severe when the mandibular incisors are the only teeth retained, with ensuing damage to the opposing premaxilla,[16] although any treatment plan that involves a complete denture opposing fixed restorations requires careful planning of the occlusion (Fig. 3-12). For selected patients, providing an overdenture that rests on endodontically treated roots may help preserve the residual ridge and enhance the stability of the complete denture[17] (see Fig. 21-39).

TREATMENT FOR TOOTH LOSS

A treatment plan involving fixed prostheses often includes the replacement of missing teeth. In most cases, the loss of teeth is a result of dental caries or periodontal disease. In rare cases, they may be congenitally absent or lost as a result of trauma or neoplastic disease.

Decision to Remove a Tooth

The decision to remove a tooth is made after the advantages and disadvantages of its retention are weighed. Sometimes it is possible to retain a tooth with an

FIGURE 3-12 ■ Special planning is required when a combination of a complete maxillary denture is to be provided opposing a fixed mandibular prosthesis (FDP), which in turn offers support to a partial removable dental prosthesis. In general, a trial maxillary denture is indicated so that the FDP can be fabricated to a well-aligned occlusal plane. **A,** Preoperative appearance. **B,** Metal-ceramic crowns support a bar. **C,** Mandibular partial dental prosthesis. **D, E,** Completed restoration. (Courtesy Dr. J.A. Holloway.)

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apparently hopeless prognosis through highly specialized and complex techniques. In those circumstances, the patient must thoroughly understand the risks and benefits of the treatment decision. In other cases, removing the tooth is the treatment of choice (Fig. 3-13). A decision if and how a missing tooth will be replaced is best made at the time its removal is recommended, rather than months or years after the fact.

FIGURE 3-13 ■ Poor treatment planning. The displaced premolar should never have been restored under these circumstances. (Courtesy Dr. P.B. Robinson.)

Consequences of Removal without Replacement

The decision to replace or not replace missing teeth requires a careful analysis of the costs and benefits of the action. As a result of the loss of posterior support in association with posterior tooth loss, excessive forces may be exerted on the remaining dentition, causing damage and poor function. However, studies have demonstrated that adequate function is possible with reduced posterior occlusion,[18] although replacing a missing second molar with an implant-supported crown has been shown to improve both objective masticatory ability and subjective satisfaction.[19] Not replacing a tooth may lead to a situation in which normal tooth alignment cannot be maintained. The balance of forces previously exerted on that tooth by the adjacent and opposing teeth and supporting tissues and by the soft tissues of the cheeks, lips, and tongue is upset (Fig. 3-14). Consequences may be

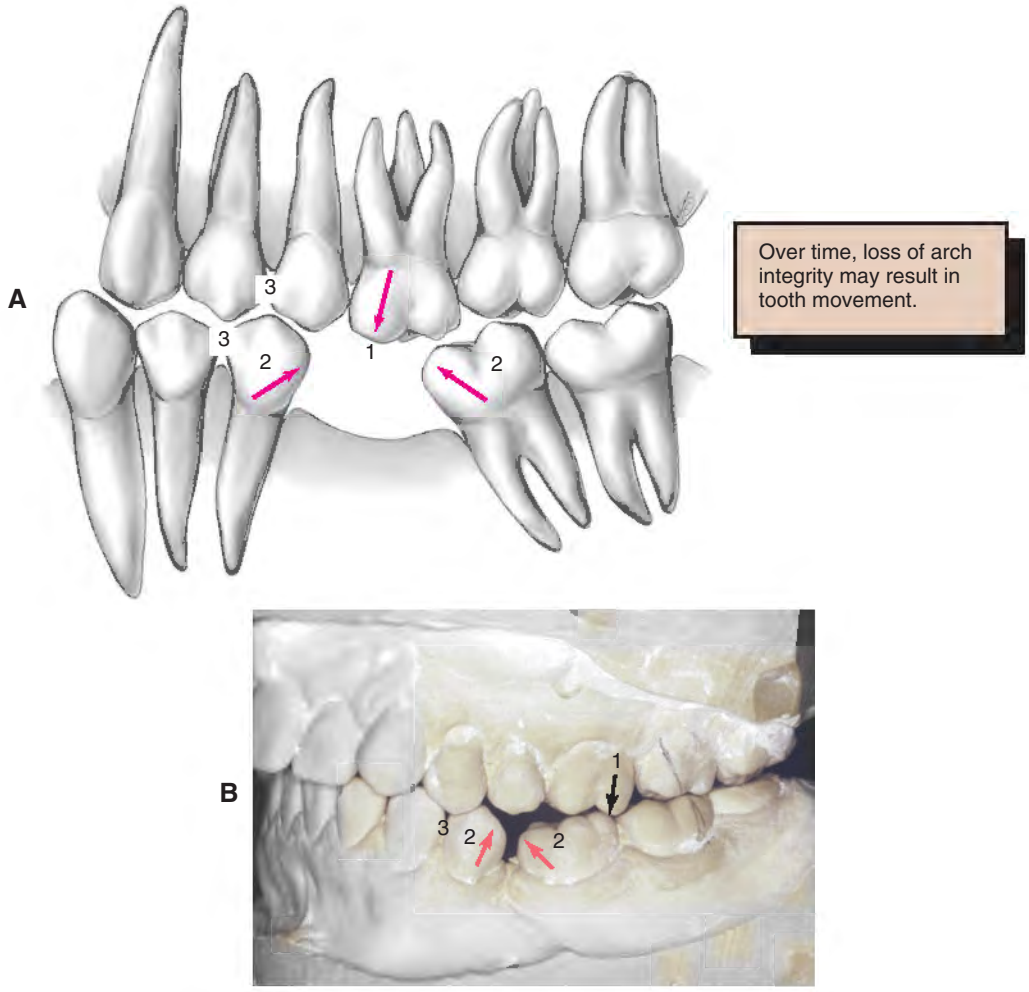

FIGURE 3-14 ■ Loss of a mandibular first molar not replaced with a fixed dental prosthesis: illustration **(A)** and diagnostic cast **(B).** The typical consequences are supraclusion of opposing teeth *(1),* tilting of adjacent teeth *(2),* and loss of proximal contacts *(3).* (**A,** Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment. London, Kluwer Publishing, 1983.)

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FIGURE 3-15 ■ **A** to **C,** Congenitally missing lateral incisors were replaced with two simple three-unit fixed dental prostheses. **D** to **F,** Another patient had a missing canine tooth, as well as two congenitally missing lateral incisors. This presented a much greater restorative challenge than the situation in part **A,** necessitating an eight-unit prosthesis.

supraocclusion of the opposing tooth or teeth, tipping of the adjacent teeth into the new edentulous space, and loss of proximal contact of the tooth that tips away from the neighboring tooth. In turn, these consequences may result in disturbances in the health of the supporting structures and the occlusion. However, the teeth adjacent to an edentulous space have not been shown to be at greater risk of damage,[20] and the rate of positional change of teeth adjacent to an edentulous space is usually slow.[21]

However, if significant movement of adjacent teeth has occurred, simple replacement of the missing tooth at this late stage may prevent further disruption, although it may be insufficient to allow the dentition to return to full health. Extended treatment plans, including orthodontic repositioning and additional cast restorations (to correct the disturbed occlusal plane), may be needed to compensate for the lack of timely treatment at the time of tooth removal.

SELECTION OF ABUTMENT TEETH

Whenever possible, FDPs should be designed as simply as possible, with a single well-anchored retainer fixed rigidly at each end of the pontic. The use of multiple splinted abutment teeth, nonrigid connectors, or intermediate abutments makes the procedure much more difficult, and in many cases, the result compromises the long-term prognosis (Fig. 3-15).

Replacement of a Single Missing Tooth

Unless bone support has been weakened by advanced periodontal disease, a single missing tooth can almost always be replaced by a three-unit FDP that includes one mesial and one distal abutment tooth. An exception is when the FDP is replacing a maxillary or mandibular canine tooth. Under these circumstances, the small lateral incisor needs to be splinted to the central incisor

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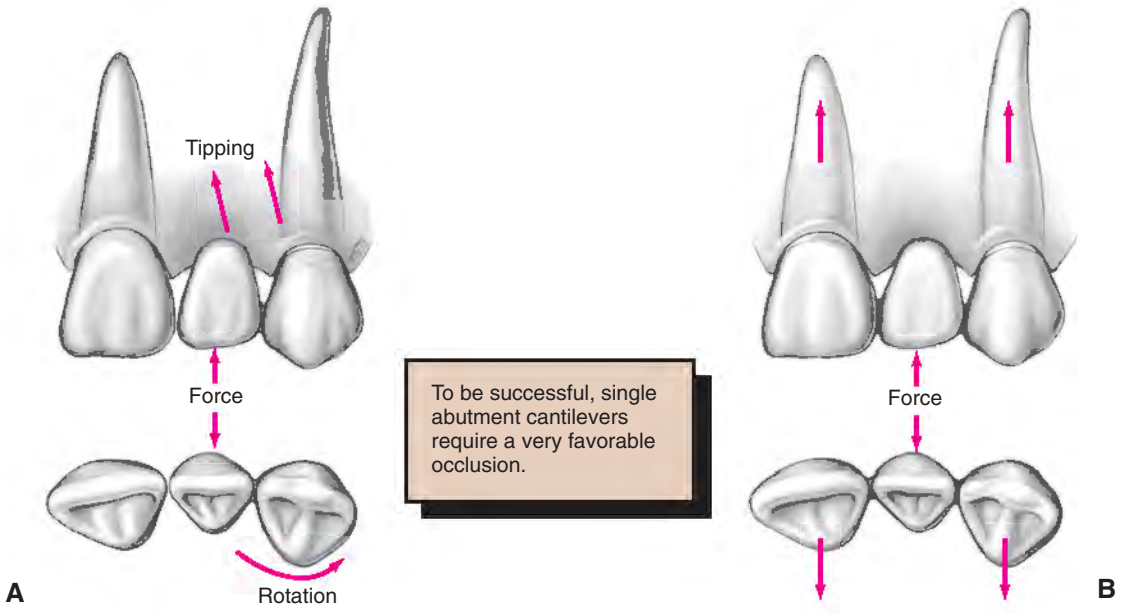

FIGURE 3-16 ■ **A,** Forces applied to a cantilever fixed dental prosthesis are resisted on only one side, which leads to imbalance. Vertical forces can cause tipping, and horizontal forces can cause rotation, of abutment teeth. **B,** By including both adjacent teeth in the prosthesis, it is possible to resist forces much better because the teeth have to be moved bodily rather than merely rotated or tipped. (Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment. London, Kluwer Publishing, 1983.)

to prevent lateral drift of the FDP. This use of two abutment teeth on the anterior aspect is referred to as *double-abutting*.

Cantilever Fixed Dental Prostheses

FDPs in which only one side of the pontic is attached to a retainer are referred to as *cantilevered*. An example would be a lateral incisor pontic attached only to an extracoronal metal-ceramic retainer on a canine tooth. Cantilevered FDPs remain popular because some of the difficulties encountered in making a three-unit FDP are lessened. Also, many clinicians are reluctant to prepare an intact central incisor, preferring instead to use a cantilever.

However, the long-term prognosis of the single-abutment cantilever is poor.[22] Forces are best tolerated by the periodontal supporting structures when directed along the long axes of the teeth.[23] This is the case when a simple three-unit FDP is used. A cantilever induces lateral forces on the supporting tissues, which may be harmful and lead to tipping, rotation, or drifting of the abutment (Fig. 3-16). Laboratory analysis[24,25] has confirmed the potential harmful nature of such FDPs. However, clinical experience with resin-retained FDPs has suggested that cantilever designs may be preferred, especially because repeated adhesion after failure is greatly facilitated[26] (see Chapter 26).

When multiple missing teeth are replaced, cantilever FDPs can have considerable application (see Fig. 3-20). The harmful tipping forces are resisted by multiple abutment teeth with sound periodontal support, and movement of the abutments is unlikely. Cantilevers are also successfully used with implant-supported prostheses (see Chapter 13).

Evaluation of Abutment Teeth

The dentist can save considerable time and expense, and can reinforce a patient's confidence, by thoroughly investigating each abutment tooth before proceeding with tooth preparation. Radiographs are made, and the dentist assesses pulpal health by evaluating the response to thermal or electrical stimulation, or both. Existing restorations, cavity liners, and residual caries are removed[27] (preferably under a rubber dam), and a careful check is made for possible pulpal exposure. Teeth in which pulpal health is doubtful should be treated endodontically before fixed prosthodontic treatment is initiated. Although a direct pulp cap may be an acceptable risk under a simple amalgam or composite resin, conventional endodontic treatment is normally preferred when crowns are planned. Fixed prosthodontic treatment is time consuming and costly; when endodontic treatment is needed after a complex prosthesis has been fabricated, access must be established through the occlusal surface of the newly fabricated prosthesis, which jeopardizes its long-term prognosis and the overall success of treatment.

Endodontically Treated Abutments

If a tooth is properly treated endodontically, it can serve well as an abutment with a post and core foundation for retention and strength (see Chapter 12). Failures occur, however, particularly on teeth with short roots or little remaining coronal tooth structure. Care is needed to obtain maximum retention for the post and core. Sometimes it is better to remove a badly damaged tooth than to attempt endodontic treatment.

The type of restoration that is anticipated after endodontic treatment can help the dentist make the best

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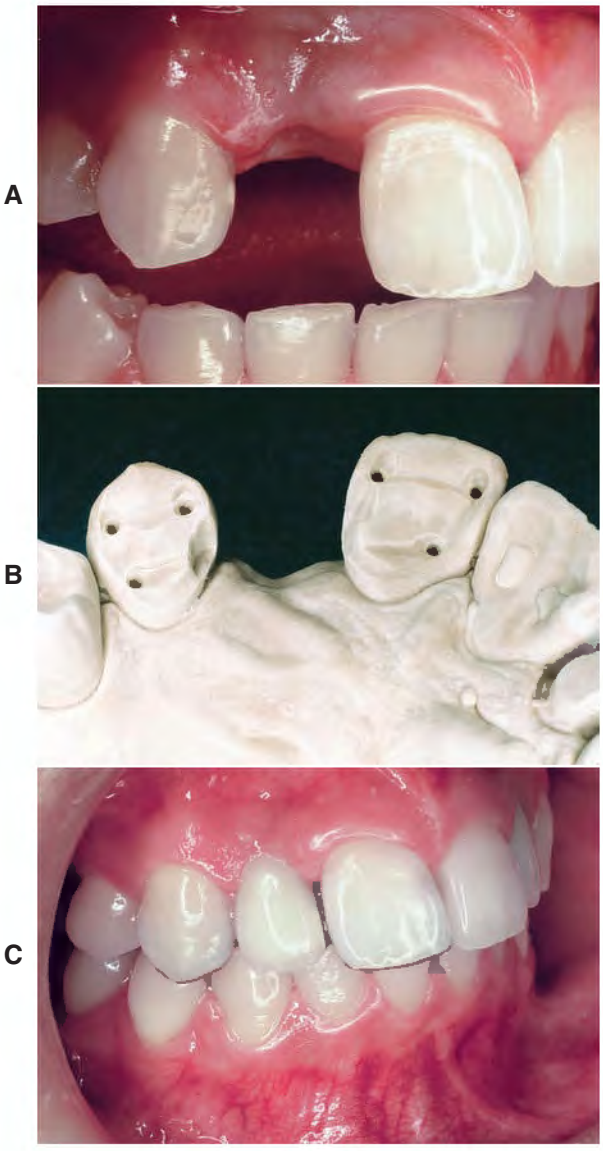

FIGURE 3-17 ■ **A** and **B,** Unrestored abutment teeth can be prepared for conservative retainers. **C,** An esthetic fixed dental prosthesis is used to replace a maxillary incisor.

decision. For instance, a maxillary premolar that requires a crown is typically restored with either an all-ceramic or metal-ceramic crown; if endodontic treatment is performed, a patient presenting with a maxillary buccal cusp fracture has a better prognosis than does a patient presenting with a lingual cusp fracture. The esthetic crown requires a wide buccal shoulder preparation, which will significantly weaken the remaining buccal cusp, whereas the remaining lingual cusp can be prepared more conservatively, with retention of additional tooth structure and, consequently, a better prognosis (see Chapters 7, 9, and 12).

Unrestored Abutments

An unrestored, caries-free tooth is an ideal abutment. It can be prepared conservatively for a strong retentive restoration with optimum esthetics (Fig. 3-17). The retainer margin can be placed without the modifications often needed to accommodate existing restorations or caries. In an adult patient, an unrestored tooth can be safely prepared without jeopardizing the pulp as long as preparation design and technique are wisely chosen. Some patients are reluctant to have a perfectly sound tooth cut down to support an FDP. In these cases, the overall dental health of the patient, rather than the condition of each individual tooth, should be emphasized.

Mesially Tilted Second Molar

Loss of a permanent mandibular first molar to caries early in life is still relatively common (Fig. 3-18). If the resulting space is ignored, the second molar may drift mesially, especially with eruption of the third molar. It then becomes difficult or even impossible to make a satisfactory FDP because the positional relationship no longer allows for parallel paths of placement without interference from the adjacent teeth.

In such circumstances, an FDP is sometimes made with modified preparation designs or with a nonrigid connector; as an alternative, a straightforward solution[28] may be considered: uprighting the tilted abutment orthodontically with a simple fixed appliance. However, the problem can be avoided altogether if a space-maintaining appliance (Fig. 3-19) is fabricated when the first molar is removed. This device may be as simple as a square section of orthodontic wire bent to follow the edentulous ridge and anchored with small restorations in the adjacent teeth.

Replacement of Several Missing Teeth

Fixed prosthodontic treatment becomes more difficult when several teeth must be replaced. Problems are encountered in restoring a single long, uninterrupted edentulous area or multiple edentulous areas with intermediate abutment teeth (Fig. 3-20), especially when anterior and posterior teeth are to be replaced with a single FDP. Underestimation of the problems involved in extensive prosthodontic treatment can lead to failure. One key to ensuring a successful result is to plan the prostheses by diagnostically waxing the intended restorations on articulated diagnostic casts. This is essential for complex fixed prosthodontic treatments, particularly when an irregular occlusal plane is to be corrected, the occlusal vertical dimension is to be altered, an implant-supported prosthesis is recommended, or a combination of FDPs and partial RDPs is to be used. The precise end point of such complicated treatments can be far from evident, even to an experienced prosthodontist (see Fig. 2-41).

Overloading of Abutment Teeth

The ability of the abutment teeth to accept applied forces without drifting or becoming mobile must be estimated and has a direct influence on the prosthodontic treatment plan. These forces can be particularly severe during parafunctional grinding and clenching (see Chapter 4), and the need to eliminate them becomes obvious during

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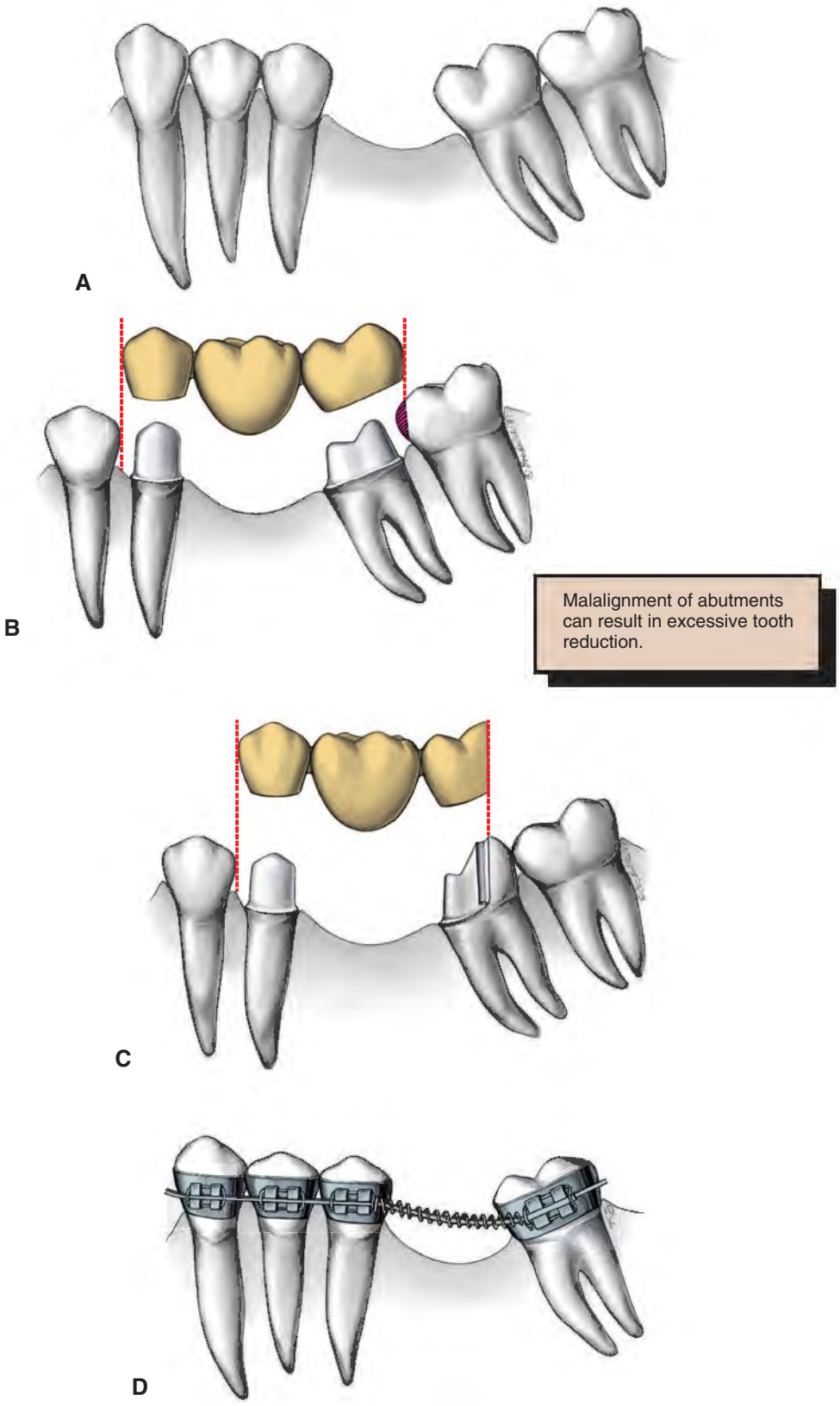

FIGURE 3-18 ■ **A,** Illustration of mesial tilting and drifting of the second and third molars as a result of early loss of a mandibular first molar. **B,** A conventional three-unit fixed dental prosthesis will fail because its seating is prevented by the third molar. **C,** A modified preparation design can be used on the distal abutment. **D,** A better treatment plan would be to remove the third molar and upright the second molar orthodontically before a fixed dental prosthesis is fabricated. (Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment. London, Kluwer Publishing, 1983.)

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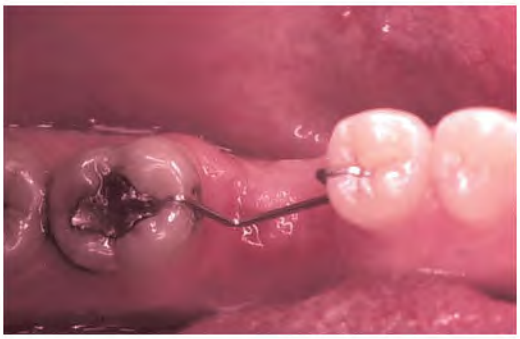

FIGURE 3-19 ■ Square section orthodontic wire can be used as a simple stabilizing device to prevent drifting of abutment teeth after exodontia. The wire is retained by the placement of small restorations. As an alternative, orthodontic bands can be used as the retainer. Note that these simple stabilizers do not prevent supraeruption of opposing teeth; in areas where this is anticipated, a provisional fixed dental prosthesis is needed.

the restoration of such damaged dentition. Although it is hoped that a well-reconstructed occlusion will reduce the duration and strength of any parafunctional activity, there is little scientific evidence to support this. It is unwise to initiate treatment on the assumption that new restorations will reduce parafunctional activity, unless this has been demonstrated with occlusal device treatment over a significant period.[29]

Direction of Forces. Whereas the magnitude of any applied force is difficult to regulate, a well-fabricated FDP can distribute these forces in the most favorable way: namely, directing them along the long axes of the abutment teeth. Potentially damaging lateral forces can be confined to the anterior teeth, where their effect is reduced by the greater distance from the fulcrum in the temporomandibular joints (i.e., the longer lever arm; see Chapter 4).

Root Surface Area. The root surface area of potential abutment teeth must be evaluated when fixed prosthodontic treatment is planned. Ante[30] suggested in 1926 that it was unwise to provide an FDP when the root surface area of the abutments was less than the root surface area of the teeth being replaced; this suggestion has been adopted and reinforced by other authors[31-33] as *Ante's law*. Average values for the root surface area of permanent teeth are given in Table 3-1.[34] As an example of Ante's law, consider the patient who has lost a first molar and a second premolar (Fig. 3-21). In this situation, a four-unit FDP is an acceptable risk, as long as there has been no bone loss from periodontal disease, because the second molar and first premolar abutments have root surface areas approximately equal to those of the missing teeth. If the first molar and both premolars are missing, however, an FDP is not considered a good risk because the total root surface area of the teeth being replaced is greater than that of the potential abutments.

Nyman and Ericsson,[35] however, cast doubt on the validity of Ante's law by demonstrating that teeth with considerably reduced bone support can be successfully used as FDP abutments. In the majority of the treatments that they discussed, the abutment root surface area was less than half that of the replaced teeth, and there was no loss of attachment after 8 to 11 years. Nyman and Ericsson attributed this success to meticulous root planing during the active phase of treatment, proper plaque control during the observed period, and meticulous occlusal design of the prostheses. Other authors have confirmed that abutment teeth with limited periodontal bone can successfully support FDPs (see Fig. 31-45, *G* and *H*).[36,37]

Root Shape and Angulation

When periodontal support is compromised, the root shape and angulation must be considered. A molar with divergent roots provides better support than does a molar with conical roots and little or no interradicular bone. A single-rooted tooth with an elliptic cross section offers better support than does a tooth with similar root surface area but with a circular cross section. Similarly, a well-aligned tooth provides better support than a tilted one. Poor alignment can be improved with orthodontic uprighting (Fig. 3-22).

Periodontal Disease. After horizontal bone loss from periodontal disease, the periodontal ligament–supported root surface area can be dramatically reduced.[38] Because of the conical shape of most roots (Fig. 3-23), when one third of the root length has been exposed, half the supporting area is lost. In addition, the forces applied to the supporting bone are magnified because of the greater leverage associated with the lengthened clinical crown. Thus, potential abutment teeth need very careful assessment when significant bone loss has occurred.

In general, successful FDPs can be fabricated on teeth with severely reduced periodontal support if the periodontal tissues have been returned to excellent health and long-term maintenance has been ensured[39,40] (Fig. 3-24). When extensive prosthetic rehabilitation is attempted without complete control over the health of the periodontal tissues, the results can be disastrous.

Healthy periodontal tissues are a prerequisite for all fixed restorations. If the abutment teeth have normal bone support, an occasional lapse in plaque removal by the patient is unlikely to affect the long-term prognosis. However, when teeth with severe bone loss resulting from periodontal disease are used as abutments, there is very little tolerance. It then becomes imperative that excellent plaque-removal technique be implemented and maintained at all times.

Span Length. Excessive flexing under occlusal loads may cause failure of a long-span FDP. It can lead to fracture of a porcelain veneer, breakage of a connector, loosening of a retainer, or an unfavorable soft tissue response and thus render a prosthesis useless. All FDPs flex slightly when subjected to a load; the longer the span, the greater the flexing. The relationship between deflection and length of span is not simply linear but varies with the cube of the length of the span. Thus, other factors being equal, if a span of a single pontic is deflected a certain amount, a span of two similar pontics will move

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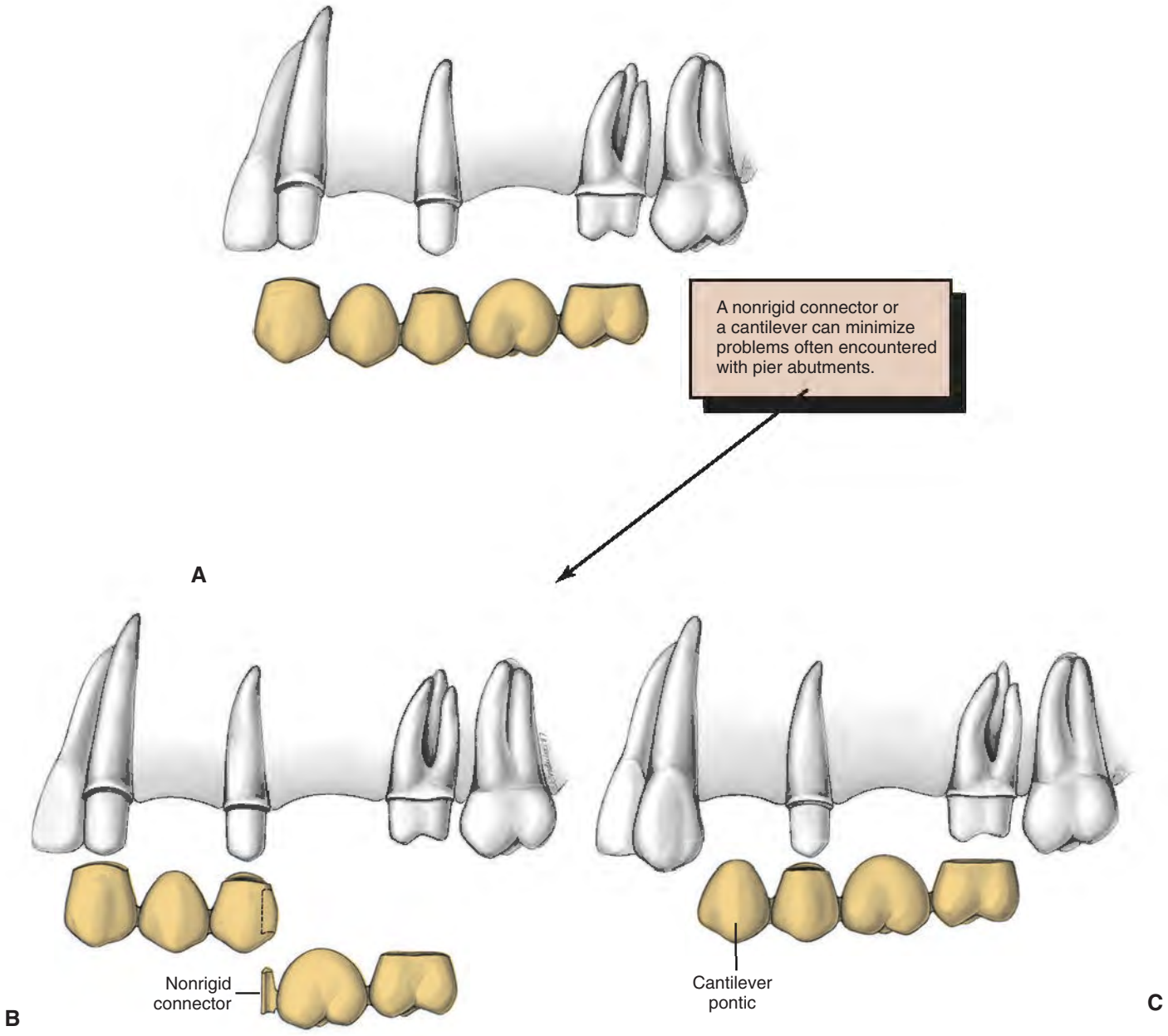

FIGURE 3-20 ■ **A,** A five-unit fixed dental prosthesis (FDP) is replacing the maxillary first molar and first premolar. The middle abutment can act as a fulcrum during function, with possible unseating of one of the other retainers. To be successful, this type of FDP needs extremely retentive retainers. **B,** An alternative approach is a nonrigid dovetail connector between the molar pontic and the second premolar. **C,** Where periodontal support is adequate, a much simpler approach would be to cantilever the first premolar pontic. (Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment. London, Kluwer Publishing, 1983.)

eight times as much, and a span of three will move 27 times as much[41] (Fig. 3-25).

Replacing three posterior teeth with an FDP rarely has a favorable prognosis, especially in the mandibular arch.[42] Under such circumstances, an implant-supported prosthesis or a partial RDP often has a better long-term prognosis.

If, nevertheless, a long-span FDP is fabricated, pontics and connectors cross sectionally should be made as bulky as possible to ensure optimum rigidity without jeopardizing gingival health. In addition, the prosthesis should be made of a material that has high strength and rigidity (see the Metal Selection section, Chapter 19).

Replacing Multiple Anterior Teeth

When anterior teeth are replaced, special considerations include problems with appearance and the need to resist tipping forces not directed parallel to the long axes of the teeth.

The four mandibular incisors can usually be replaced by a simple FDP with retainers on each canine tooth. It is not usually necessary to include the first premolars. If a lone incisor remains, it should be removed because its retention unnecessarily complicates the FDP design and fabrication and can jeopardize the long-term prognosis. Mandibular incisors, because of their small size, generally

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TABLE 3-1 Root Surface Area of Abutment

Area in Quadrant	Root Surface Area (nm^2)	Percentage of Root Surface
Maxillary		
Central incisor	204	10
Lateral incisor	179	9
Canine tooth	273	14
First premolar	234	12
Second premolar	220	11
First molar	433	22
Second molar	431	22
Mandibular		
Central incisor	154	8
Lateral incisor	168	9
Canine tooth	268	15
First premolar	180	10
Second premolar	207	11
First molar	431	24
Second molar	426	23

Data from Jepsen A: Root surface measurement and a method for x-ray determination of root surface area. Acta Odontol Scand 21:35, 1963.

Ante's law is useful for determining the prognosis of fixed dental prostheses.

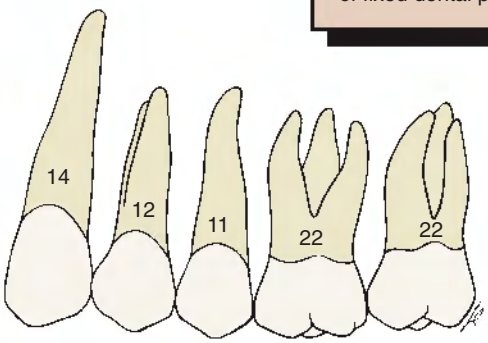

FIGURE 3-21 ■ To assess the support of a fixed dental prosthesis (FDP), Ante's law proposes a relationship between the root surface areas of the missing teeth and those of the potential abutment teeth. (The numbers represent root surface area percentages.) If the first molar (22%) and second premolar (11%) are missing, the abutments for a four-unit FDP have a slightly greater total root surface area (34%) than do the teeth being replaced. In that case, in the absence of other detrimental factors, an FDP's prognosis is favorable. However, if the first premolar (12%) is also missing, the lost root surface area of potential abutment teeth is 45%, whereas the remaining abutments have only 36% of root surface area, which is much less favorable.

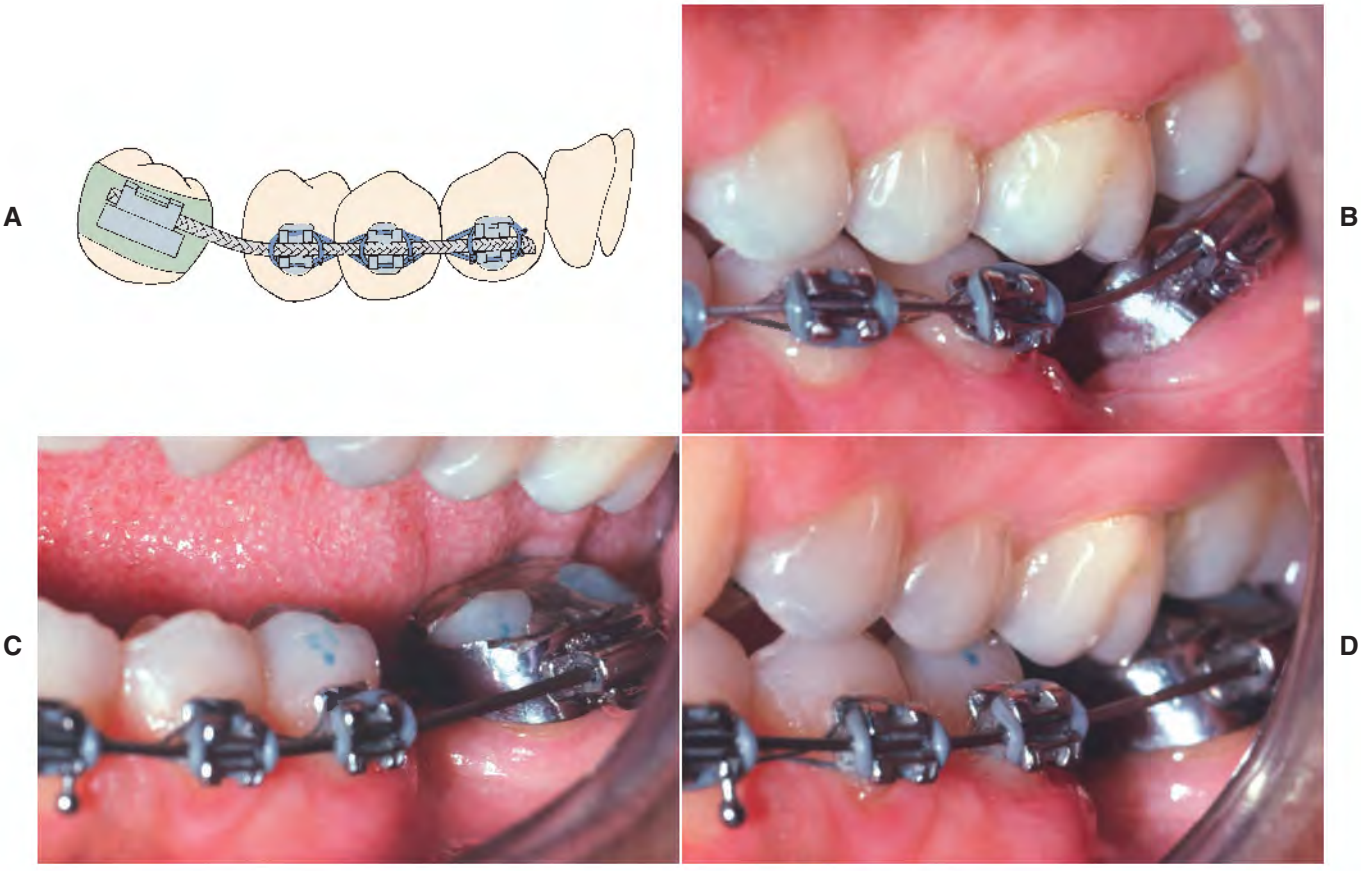

FIGURE 3-22 ■ **A,** A misaligned abutment tooth may be difficult or impossible to prepare for a fixed dental prosthesis abutment and provides poor support. **B,** The tilted mandibular molar was uprighted with a continuous flexible wire. **C,** Progress after 1 month. **D,** Uprighting essentially completed 2 months later. (From Proffit WR, Fields HW, Sarver DM: Contemporary Orthodontics, 5th ed. St. Louis, Mosby, 2013.)

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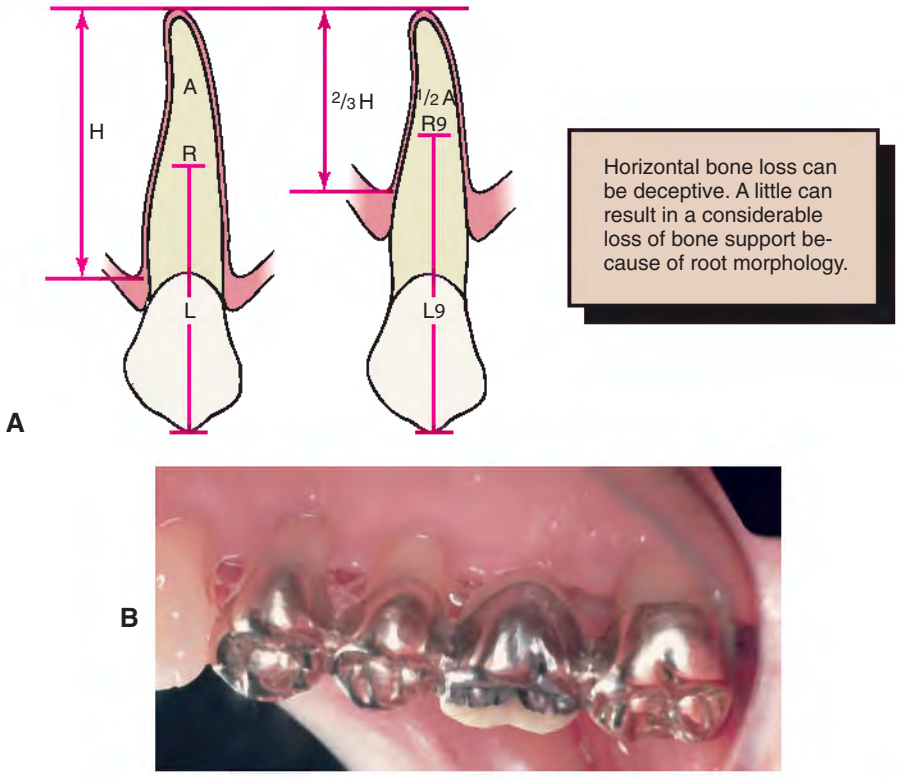

FIGURE 3-23 ■ **A,** Because of the conical shape of most roots, the actual area of support *(A)* diminishes more than might be expected from the height of the bone *(H)*. In addition, the center of rotation *(R)* moves apically *(R′)* and the lever arm *(L′)* increases, magnifying the forces on the supportive structure. **B,** A fixed dental prosthesis (FDP) replacing a maxillary first molar. The first premolar is an abutment providing additional stabilization for this FDP on abutment teeth with compromised bone support. (**A,** Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General dental treatment. London, Kluwer Publishing, 1983.)

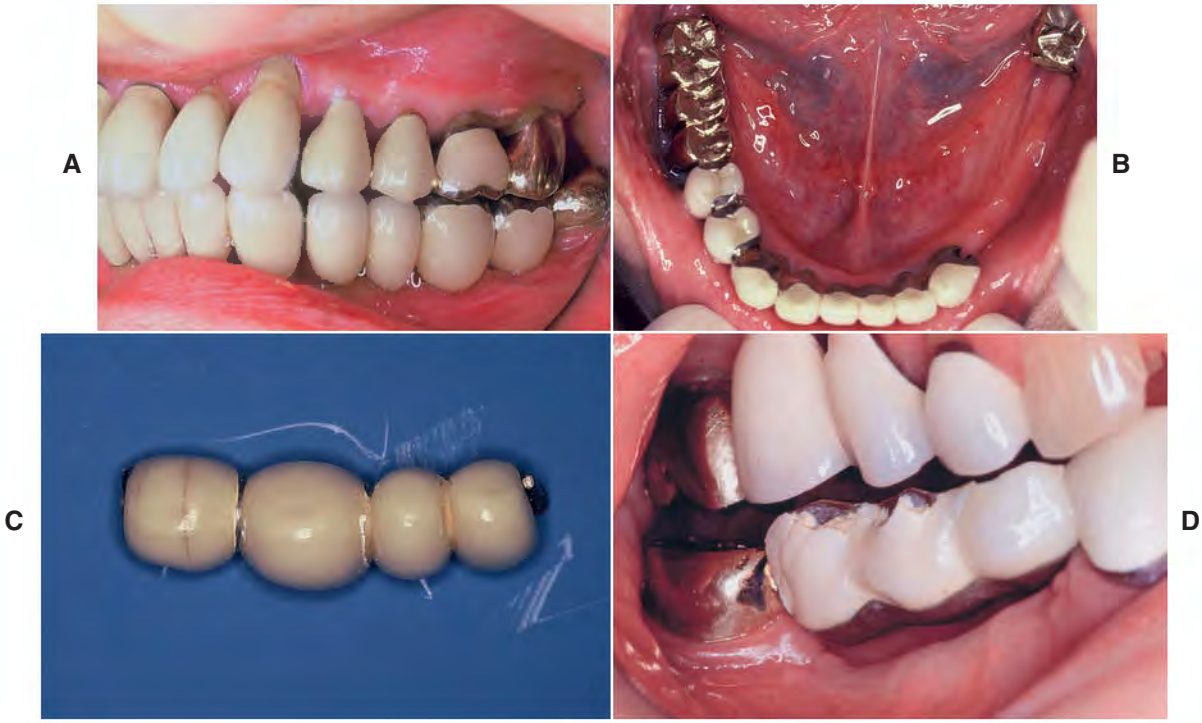

FIGURE 3-24 ■ **A,** Although this unusually long fixed dental prosthesis (FDP) provided 9 years of service, the connector between the distal pontic and the retainer eventually failed **(B). C,** Note the buccolingual crack through the ceramic as a result of flexure. **D,** Failure of a long-span FDP.

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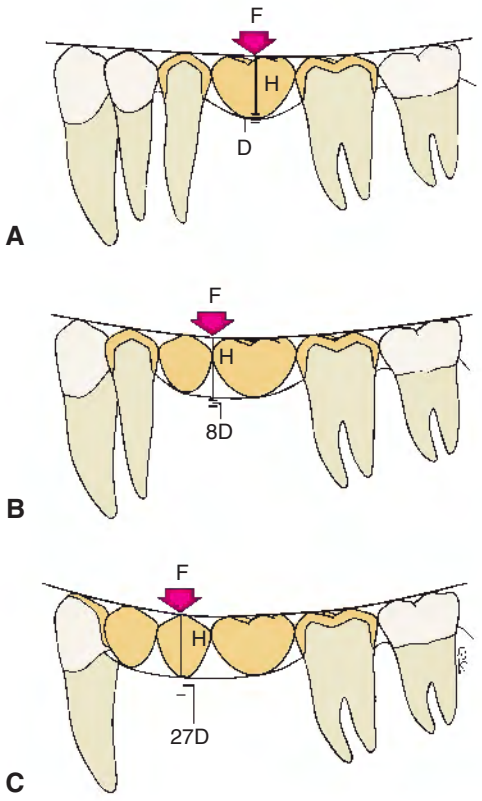

Excessive span length is a common contraindication for fixed dental prostheses.

FIGURE 3-25 ■ The deflection of a fixed dental prosthesis is proportional to the cube of the length of its span. **A,** A single pontic deflects a small amount *(D)* when subjected to a certain force *(F).* **B,** Two pontics deflect 2^3 times as much (8*D*) to the same force. **C,** Three pontics deflect 3^3 times as much (27*D*).

are poor abutment teeth. It is particularly important not to have overcontoured restorations on these teeth because plaque control may become nearly impossible. Thus, the clinician may have to make a choice among (1) compromised esthetics from too thin a ceramic veneer, (2) pulpal exposure during tooth preparation, and (3) selective tooth removal.

Restoration of appearance and providing support after the loss of several maxillary incisors presents a much greater challenge. Because of the curvature of the dental arch, forces directed against a maxillary incisor pontic tend to tip the abutment teeth outward. Unlike the mandibular incisors, the maxillary incisors are not positioned in a straight line (particularly in patients with narrow or pointed dental arches). These tipping forces must be resisted by means of additional abutment teeth at each end of a long-span anterior FDP. Thus in general, when the four maxillary incisors are replaced, the canine teeth and first premolars should be used as abutment teeth.[43]

There may be considerable difficulty in achieving a good appearance when several maxillary incisors are replaced with an FDP. Obtaining optimal tooth contours and position for appearance and phonetics can be a challenge. A diagnostic waxing procedure is extremely helpful to evaluate specific esthetic problems. As treatment progresses, an interim restoration is provided (see Chapter 15). This is used to test appearance, lip support, and phonetics. It may also be readily shaped and modified until the patient is satisfied with its appearance, after which the final restoration can be made to copy it, thereby avoiding any embarrassing misunderstandings when the finished FDP is delivered.

FIGURE 3-26 ■ Two incisors were lost in an accident. Considerable alveolar bone has also been lost. An esthetic fixed dental prosthesis would be very difficult or impossible to fabricate without surgical ridge augmentation. (Courtesy Dr. N. Archambo.)

If anterior bone loss has been severe, as can happen when teeth are lost as a result of trauma or periodontal disease, there may be a ridge defect (Fig. 3-26). In an affected patient, a partial RDP should be considered, especially when the patient has a high smile line, because an FDP generally replaces only the missing tooth structure, not the supporting tissues. Again, an interim restoration may help the patient and dentist jointly determine the most appropriate treatment. A surgical ridge augmentation procedure[44] may also be an option, although the surgical results can be somewhat unpredictable.

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FIGURE 3-27 ■ A partial removable dental prosthesis replacing the mandibular right first and second molars. (Courtesy Dr. J.A. Holloway.)

FIGURE 3-28 ■ Where there has been considerable bone loss, a partial removable dental prosthesis has a more natural appearance than a fixed dental prosthesis.

Indications for Partial Removable Dental Prostheses

Whenever possible, it is preferable to restore edentulous spaces with FDPs rather than partial RDPs. A well-fabricated FDP improves health and has better function than does a partial RDP[45] and is preferred by most patients. Under the following circumstances, however, a partial RDP is indicated:

1. Where vertical support from the edentulous ridge is needed; for example, in the absence of a distal abutment tooth (Fig. 3-27)
2. Where resistance to lateral movement is needed from contralateral teeth and soft tissues; for example, to ensure stability with a long edentulous space
3. When there is considerable bone loss in the visible anterior region and an FDP would have an unacceptable appearance (Fig. 3-28)

Multiple edentulous spaces often are best restored with a combination of FDPs and partial RDPs (Fig. 3-29). The objective is to use FDPs to reduce the number of modification spaces in the RPD, to eliminate lone-standing pier abutments, and especially to eliminate anterior modification spaces to retain an intact smile even when the patient is not wearing the partial RDP. The latter can be of significant psychological benefit to the patient.

TREATMENT SEQUENCE

When a patient's needs have been identified and the appropriate corrective measures have been determined, a logical sequence of steps must be decided on, including the treatment of symptoms, stabilization of deteriorating conditions, definitive therapy, and a program of follow-up care. The importance of proper sequencing is emphasized because mistakes can lead to compromised effort or unnecessary and expensive remakes.

Treatment of Symptoms

The relief of discomfort accompanying an acute condition is a priority in planning treatment (Fig. 3-30). Discomfort can result from one or more of the following: a fractured tooth or teeth, acute pulpitis, acute exacerbation of chronic pulpitis, a dental abscess, acute pericoronitis or gingivitis, and myofascial pain dysfunction.

The clinician needs only sufficient diagnostic information to ascertain the nature of a particular condition and to form a diagnosis; treatment is instituted without delay. A full examination is neither desirable nor generally possible until the symptoms of such an acute condition have been addressed.

Urgent Treatment of Nonacute Problems

Fortunately, most potential candidates for fixed prosthodontic treatment do not seek treatment for acute conditions; however, they may have a specific problem that warrants immediate attention, such as a lost anterior crown, a cracked or broken porcelain veneer, or a fractured partial RDP (Fig. 3-31).

Stabilization of Deteriorating Conditions

The second treatment phase involves stabilizing deteriorating conditions such as dental caries or periodontal disease by removing the etiologic factors, increasing the patient's resistance, or doing both.

Dental Caries

Treatment of carious lesions is approached in a conventional manner, and the teeth are restored with properly contoured plastic materials. These may serve as a foundation for FDPs during a subsequent phase of treatment (see Chapter 6). However, definitive crowns are best avoided in a patient with active caries because the results of such extensive treatment will be jeopardized by disease recurrence. This risk can be addressed through a combination of dietary advice, oral hygiene measures, and fluoride treatment and regular follow-up appointments to monitor the patient's progress.

Periodontal Disease

Chronic periodontitis with continuing irreversible bone loss should be treated as early as possible by effective daily plaque control. The proper removal of plaque

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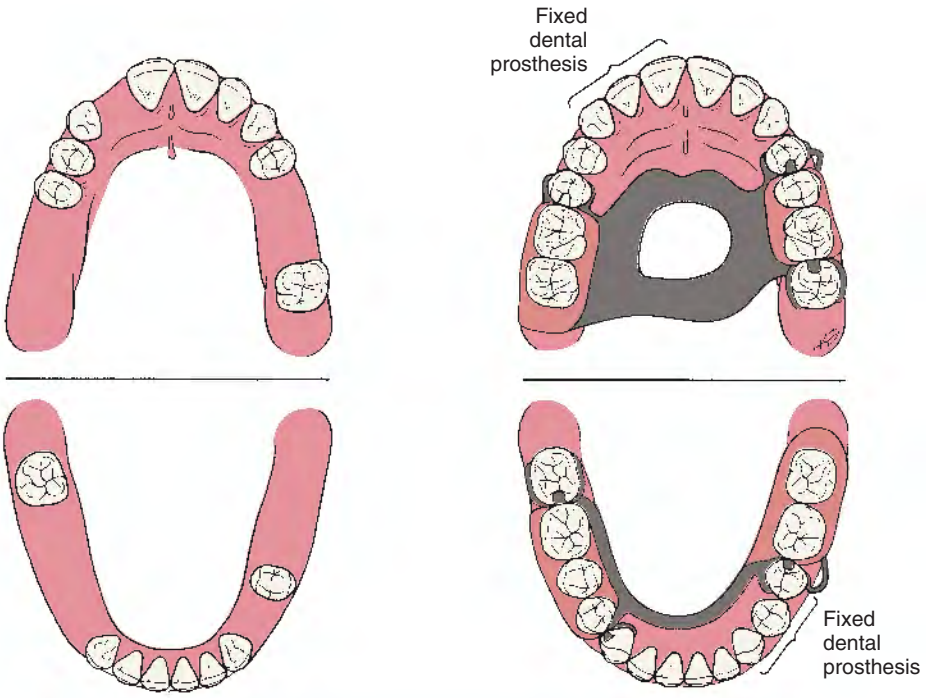

Minimizing the number of modification spaces in a removable partial dental prosthesis is often helpful.

FIGURE 3-29 ■ Treatment planning for multiple edentulous spaces. A combination of fixed dental prostheses (FDPs) and partial removable dental prostheses (RDPs) may provide the best replacement when several teeth are missing. In the maxillary arch, the missing lateral incisor has been restored with a simple three-unit FDP, which is more easily cleaned than is a partial RDP. In the mandibular arch, the single remaining premolar is splinted to the canine tooth with a three-unit FDP. A partial RDP that fits around a lone-standing premolar usually does not have a good prognosis. (Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General Dental Treatment. London, Kluwer Publishing, 1983.)

FIGURE 3-30 ■ Swelling from an acute periapical abscess. (Courtesy Dr. P.B. Robinson.)

is possible only if the teeth are smooth and their contours allow unimpeded access to the gingival sulci. Therefore, the following procedures are essential (Fig. 3-32):

- Replacement of defective restorations
- Removal of carious lesions
- Recontouring of overcontoured crowns (especially near furcation areas)
- Proper oral hygiene instruction and adequate implementation at home

FIGURE 3-31 ■ For both appearance and comfort, fractured porcelain often necessitates urgent treatment.

Definitive Therapy

When the stabilization phase has been completed, successful elective long-term treatment aimed at promoting dental health, restoring function, and improving appearance can begin. On occasion, this takes considerable time. Several therapeutic proposals may be applicable to a single patient and may range in complexity from minimum restorative treatment with regular maintenance to full-mouth prosthodontic rehabilitation preceded by orthognathic surgery and orthodontic treatment. The advantages and disadvantages of all presented options should be thoroughly explained to the patient. Diagnostic casts and waxings are highly effective communication tools. When

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FIGURE 3-32 ■ Overhangs and defective restorations impede proper plaque control and should be corrected as part of the stabilization phase.

the dentist develops a definitive treatment plan, he or she should strive to reduce the risk of having to repeat earlier treatment if problems later occur. Usually oral surgical procedures are scheduled first, followed by periodontics, endodontics, orthodontics, fixed prosthodontics, and finally, removable prosthodontics.

Oral Surgery

The treatment plan should allow time for healing and ridge remodeling. Therefore, teeth with a hopeless prognosis, unerupted teeth, and residual roots and root tips should be removed early. Similarly, all preprosthetic surgical procedures (e.g., ridge contouring) should be undertaken during the early phase of treatment.

Periodontics

Most periodontal procedures should (or will) have been accomplished as part of the stabilization phase of treatment. Any surgery, pocket elimination, mucogingival procedure, guided tissue regeneration, or root resection is performed at this time (see Chapter 5).

Endodontics

Some endodontic treatment may have been accomplished as part of the relief of discomfort and stabilization of conditions. Elective endodontic treatment may be needed to provide adequate space for a cast restoration or to provide retention for a badly damaged or worn tooth.

If a tooth with doubtful pulpal health is to be used as an abutment for an FDP, it should be endodontically treated prophylactically, despite the consideration that periodic recall might have been a more appropriate treatment if a single restoration were planned.

Orthodontics

Minor orthodontic tooth movement is a common adjunct to fixed prosthodontic treatment, and the benefit of moving teeth into their optimal locations to accommodate subsequent prosthodontic treatment cannot be overemphasized Too often an effort is made in the dental laboratory to "correct" anatomic form while the supporting abutment is malpositioned. Such efforts invariably affect the prognosis adversely. Teeth can be uprighted, rotated, moved laterally, intruded, or extruded to improve their relationship before fixed prosthodontic treatment is initiated. Orthodontic treatment should always be considered when a treatment plan is proposed, especially if tooth loss has been neglected and drifting has occurred.

Fixed Prosthodontics

Fixed prosthodontic treatment is not initiated until the preparatory procedures have been completed. This permits modification of the original plan if unforeseen difficulties surface during treatment. For example, a tooth scheduled for endodontic treatment might prove to be untreatable, resulting in its loss, and necessitating considerable modification of the initial fixed prosthodontic treatment plan.

Occlusal Reshaping. Occlusal reshaping is often necessary before fixed prosthodontic treatment is started. Its rationale is twofold: Either occlusal reshaping may help reduce neuromuscular pathology (see Chapters 4 and 6), or occlusal reshaping assists in achieving orthopedic stability prerequisite to comprehensive fixed prosthodontic rehabilitation. When extensive fixed prosthodontic treatment is to be provided, an accurate and well-tolerated occlusal relationship may be obtainable only if a slide between maximal intercuspation and centric relation is eliminated first (see Chapter 4). When less extensive treatment is planned, it may be acceptable to modify the FDP to conform to the existing occlusion, provided the patient is functioning satisfactorily. However, any supraeruption or drifting should be corrected rather than be allowed to compromise the patient's occlusal scheme.

Anterior Restorations. If both anterior and posterior teeth are to be restored, the anterior teeth are usually restored first because they influence the border movements of the mandible and thus affect the shape of the occlusal surfaces of the posterior teeth (see Chapters 4 and 18). If the posterior teeth are restored first, a subsequent change in the lingual contour of the anterior teeth could necessitate considerable adjustment of the posterior restorations.

Posterior Restorations. Restoring opposing posterior segments at the same time is often advantageous. This allows the development of an efficient occlusal scheme through the application of an additive wax technique (see Chapter 18). If at all feasible, treatment of one side of the mouth should be completed before the other side is treated; restoring all four posterior segments at the same time can readily lead to considerably more complications for the patient and dentist, including fracture or breaking of interim restorations, discomfort with bilateral local anesthesia, and difficulties in confirming the accuracy of jaw relationship recordings.

Complex Prosthodontics. Carefully planned treatment sequencing is critically important in the planning of complex prosthodontic treatments involving alteration of the vertical dimension or a combination of FDPs and partial RDPs. One recommended approach is the use of cross-mounted diagnostic casts, illustrated in Figure 3-33.

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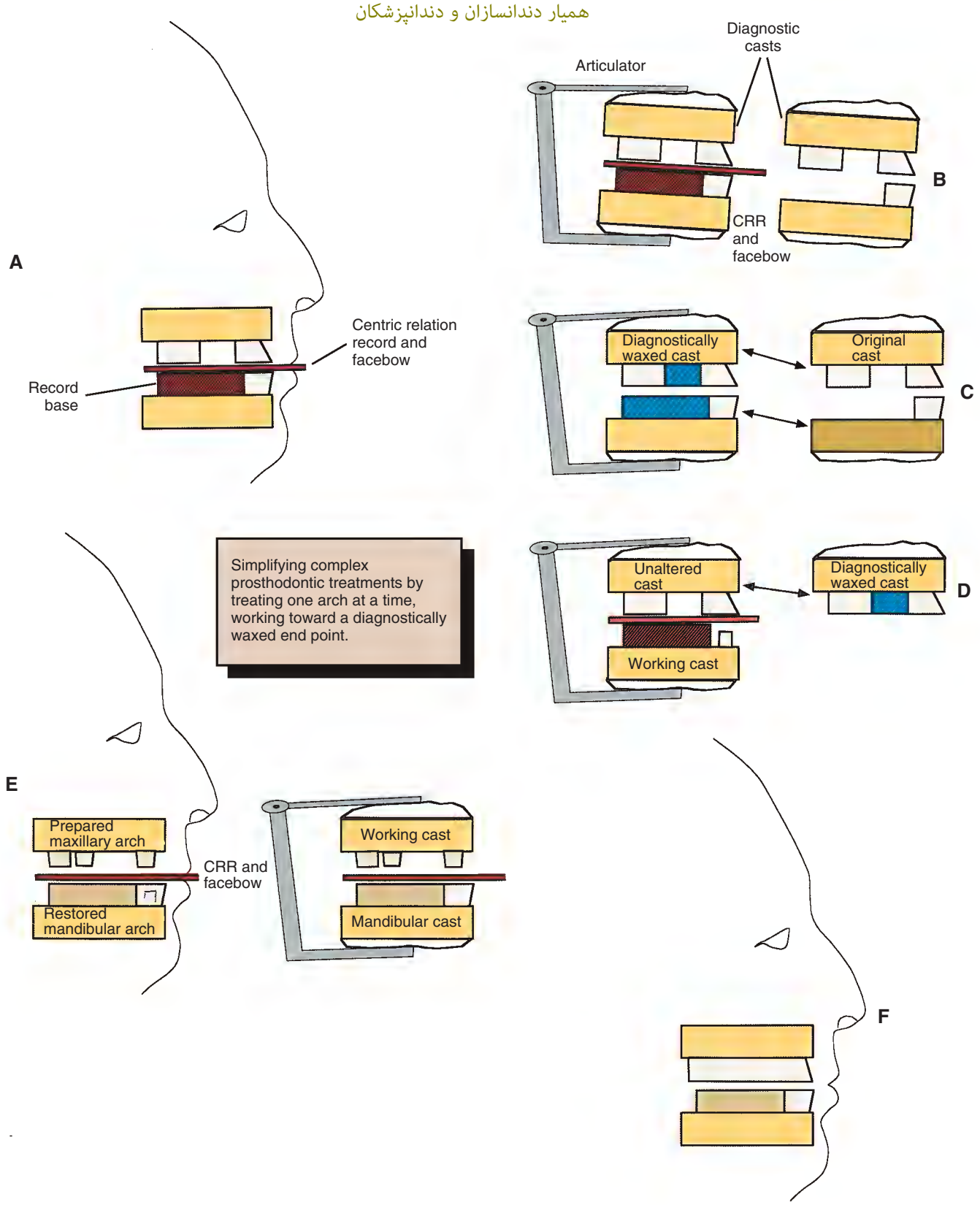

FIGURE 3-33 ■ Complex prosthodontic treatment sequence with the use of cross-mounted diagnostic casts. **A,** Diagnostic impressions, facebow, and centric relation records *(CRRs)* are made for a patient requiring complex prosthodontic treatment. In this schematic, a record base is needed for mounting the mandibular cast. **B,** The diagnostic casts are duplicated, and each set is mounted in the identical orientation of an articulator through the use of the facebow and CRR. **C,** One pair of diagnostic casts is waxed to the proposed end point of treatment. If a partial removable dental prosthesis is planned, denture teeth are set for this step. The other pair of casts is left unaltered. **D,** One arch is treated at a time. In this example, the mandibular arch has been prepared for crowns. The definitive cast is mounted on the articulator with a CRR made against the (unaltered) maxillary teeth. This record is used to mount the definitive cast against the (unaltered) maxillary cast. Then the maxillary cast is removed and replaced with the cross-mounted diagnostically waxed cast. The mandibular restorations are fabricated against this cast to ensure an optimal occlusal plane. **E,** Once the mandibular arch has been restored, the maxillary teeth are prepared and mounted against a cast of the newly restored mandibular arch. **F,** The completed restoration conforms to the diagnostic waxing.

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Two sets of diagnostic casts are accurately mounted so they can be precisely interchanged on the articulator. One set is prepared and waxed to the intended end point of treatment, with denture teeth inserted where partial RDPs are to be used. The waxing is carefully evaluated on the articulator in relation to occlusion and appearance. When anterior teeth are to be replaced, they can be assessed for appearance and phonetics directly in the mouth if they are mounted on a removable record base. Definitive tooth preparation starts in one arch only, so that the occlusal surfaces of the opposing arch are preserved to act as an essential reference for mounting the definitive cast. The definitive restorations are waxed against the diagnostically waxed cast, which establishes optimal occlusion. When one arch has been completed, the opposing cast can be restored and the predicted result thus achieved.

FOLLOW-UP

A specific program of follow-up care and regular recall is an essential part of the treatment plan. Its aim is to monitor dental health, to identify newly developed signs of disease early, and to initiate corrective measures promptly as needed (see Chapter 32). Restorations do not last forever; they are subject to wear and may need replacement. Adequate follow-up care will help maintain long-term dental health.

SUMMARY

The basis of logical treatment planning consists of identifying the patient's needs, eliciting his or her expectations and wishes, and comparing these with the available and feasible corrective materials and techniques. Planning also involves evaluating whether a technique will yield a good prognosis. Then a rational sequence of treatment may be initiated for symptomatic relief, stabilization, definitive therapy, and follow-up care. The extent of treatment is modified throughout and is dictated by the patient's attitude and ability to cooperate and by the defined goals and objectives for the specific individual.

REFERENCES

1. Palomo F, Peden J: Periodontal considerations of restorative procedures. J Prosthet Dent 36:387, 1976.
2. Karmaker AC, et al: Continuous fiber reinforced composite materials as alternatives for metal alloys used for dental appliances. J Biomater Appl 11:318, 1997.
3. Rosenthal L, et al: A new system for posterior restorations: a combination of ceramic optimized polymer and fiber-reinforced composite. Pract Periodontics Aesthet Dent 9(5 suppl):6, 1997.
4. Zanghellini G: Fiber-reinforced framework and Ceromer restorations: a technical review. Signature 4(1):1, 1997.
5. Frese C, et al: Fiber-reinforced composite fixed dental prostheses in the anterior area: A 4.5-year follow-up. J Prosthet Dent 112(2):143, 2014.
6. Claus H: Vita In-Ceram, a new procedure for preparation of oxide-ceramic crown and bridge framework. Quintessenz Zahntech 16:35, 1990.
7. Magne P, Belser U: Esthetic improvements and in vitro testing of In-Ceram Alumina and Spinell ceramic. Int J Prosthodont 10:459, 1997.
8. Zimmer D, et al: Survival rate of IPS-Empress 2 all-ceramic crowns and bridges: three years' results. Schweiz Monatsschr Zahnmed 114:115, 2004.
9. Denry IL: Recent advances in ceramics for dentistry. Crit Rev Oral Biol Med 7:134, 1996.
10. Sorensen JA, et al: IPS Empress crown system: three-year clinical trial results. J Calif Dent Assoc 26:130, 1998.
11. Denry IL, et al: Effect of cubic leucite stabilization on the flexural strength of feldspathic dental porcelain. J Dent Res 75:1928, 1996.
12. Fabbri G, et al: Clinical evaluation of 860 anterior and posterior lithium disilicate restorations: retrospective study with a mean follow-up of 3 years and a maximum observational period of 6 years. Int J Periodontics Restorative Dent 34:165, 2014.
13. Dhima M, et al: Practice-based clinical evaluation of ceramic single crowns after at least five years. J Prosthet Dent 111:124, 2014.
14. Walton TR: An up to 15-year longitudinal study of 515 metal-ceramic FPDs: Part 1. Outcome. Int J Prosthodont 15:439, 2002.
15. Adell R, et al: A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 10:387, 1981.
16. Saunders TR, et al: The maxillary complete denture opposing the mandibular bilateral distal-extension partial denture: treatment considerations. J Prosthet Dent 41:124, 1979.
17. Brewer AA, Morrow RM: Overdentures, 2nd ed. St. Louis, Mosby, 1980.
18. Sarita PTN, et al: Chewing ability of subjects with shortened dental arches. Community Dent Oral Epidemiol 31:328, 2003.
19. Nam DH, et al: Change in masticatory ability with the implant restoration of second molars. J Prosthet Dent 111:286, 2014.
20. Shugars DA, et al: Survival rates of teeth adjacent to treated and untreated posterior bounded edentulous spaces. J Am Dent Assoc 129:1089, 1998.
21. Gragg KL, et al: Movement of teeth adjacent to posterior bounded edentulous spaces. J Dent Res 80:2021, 2001.
22. Cheung GS, et al: A clinical evaluation of conventional bridgework. J Oral Rehabil 17:131, 1990.
23. Glickman I, et al: Photoelastic analysis of internal stresses in the periodontium created by occlusal forces. J Periodontol 41:30, 1970.
24. Wright KWJ, Yettram AL: Reactive force distributions for teeth when loaded singly and when used as fixed partial denture abutments. J Prosthet Dent 42:411, 1979.
25. Yang HS, et al: Stress analysis of a cantilevered fixed partial denture with normal and reduced bone support. J Prosthet Dent 76:424, 1996.
26. Briggs P, et al: The single unit, single retainer, cantilever resin-bonded bridge. Br Dent J 181:373, 1996.
27. Christensen GJ: When to use fillers, build-ups or posts and cores. J Am Dent Assoc 127:1397, 1996.
28. Miller TE: Orthodontic therapy for the restorative patient. I. The biomechanic aspects. J Prosthet Dent 61:268, 1989.
29. Holmgren K, et al: The effects of an occlusal splint on the electromyographic activities of the temporal and masseter muscles during maximal clenching in patients with a habit of nocturnal bruxism and signs and symptoms of craniomandibular disorders. J Oral Rehabil 17:447, 1990.
30. Ante IH: The fundamental principles of abutments. Mich State Dent Soc Bull 8:14, 1926.
31. Dykema RW, et al, eds: Johnston's Modern Practice in Fixed Prosthodontics, 4th ed, p 4. Philadelphia, WB Saunders, 1986.
32. Tylman SD, Malone WFP: Tylman's Theory and Practice of Fixed Prosthodontics, 7th ed, p 15. St Louis, Mosby, 1978.
33. Shillingburg HT, et al: Fundamentals of Fixed Prosthodontics, 2nd ed, p 20. Chicago, Quintessence Publishing, 1981.
34. Jepsen A: Root surface measurement and a method for x-ray determination of root surface area. Acta Odontol Scand 21:35, 1963.
35. Nyman S, Ericsson I: The capacity of reduced periodontal tissues to support fixed bridgework. J Clin Periodontol 9:409, 1982.
36. Freilich MA, et al: Fixed partial dentures supported by periodontally compromised teeth. J Prosthet Dent 65:607, 1991.
37. Decock V, et al: 18-Year longitudinal study of cantilevered fixed restorations. Int J Prosthodont 9:331, 1996.
38. Penny RE, Kraal JH: Crown-to-root ratio: its significance in restorative dentistry. J Prosthet Dent 42:34, 1979.
39. Nyman S, et al: The role of occlusion for the stability of fixed bridges in patients with reduced periodontal tissue support. J Clin Periodontol 2(2):53, 1975.

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40. Laurell L, et al: Long-term prognosis of extensive polyunit cantilevered fixed partial dentures. J Prosthet Dent 66:545, 1991.
41. Smyd ES: Dental engineering. J Dent Res 27:649, 1948.
42. Napankangas R, et al: Longevity of fixed metal ceramic bridge prostheses: a clinical follow-up study. J Oral Rehabil 29:140, 2002.
43. Dykema RW: Fixed partial prosthodontics. J Tenn Dent Assoc 42:309, 1962.
44. Olin PS, et al: Improved pontic/tissue relationships using porous coralline hydroxyapatite block. J Prosthet Dent 66:234, 1991.
45. Aquilino SA, et al: Ten-year survival rates of teeth adjacent to treated and untreated posterior bounded edentulous spaces. J Prosthet Dent 85:455, 2001.

STUDY QUESTIONS

1. Discuss 12 considerations that affect the design of a fixed dental prosthesis (FDP) and their general effect on the design of such prostheses.

2. Discuss at least four different indications for a partial removable dental prosthesis, as opposed to a fixed dental prosthesis.

3. When would a nonrigid connector be indicated in a fixed dental prosthesis? When would it be contraindicated?

4. If a patient has a multitude of needs involving all clinical dental disciplines, in what typical sequence would treatment be conducted? Why? How are the various stages of occlusal therapy sequenced? Why?

5. Contrast the replacement of all the maxillary incisors by an FDP with the replacement of all the mandibular incisors by an FDP. How would you treat each situation?

6. Which occlusal forces are of least concern? Why? Which forces/loading should be avoided? Why?

7. How do span length and design of the FDP influence flexure? When is rigidity essential? Why?

8. List the steps in treating a patient with extensive restorative needs, using the cross-mounted cast method of treating complex prosthodontic problems. Explain briefly the importance of treatment sequence.

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CHAPTER 4

Principles of Occlusion

Most restorative procedures affect the shape of the occlusal surfaces. Proper dental care ensures that functional occlusal contact relationships are restored in harmony with both dynamic and static conditions. Maxillary and mandibular teeth should contact uniformly on closing to allow optimal function, minimize trauma to the supporting structures, and allow for uniform load distribution throughout the dentition. Positional stability of well-aligned teeth is crucial if arch integrity and proper function are to be maintained over time.

Most dentitions deviate from optimal alignment and occlusion. Many patients adapt well to less than optimal occlusion, but malocclusion may be associated with undesirable changes to the teeth, the musculature, the temporomandibular joints (TMJs), or the periodontium. As an aid to the diagnosis of occlusal dysfunction, it is helpful to evaluate the condition of specific anatomic features and functional aspects of a patient's occlusion with reference to a concept of "optimum" or "ideal" occlusion. Deviation from this concept can then be measured objectively and may prove to be a useful guide during treatment planning and active treatment phases.

Over time, many concepts of "ideal" occlusion have been proposed. In the literature, the concepts of what is "ideal," "acceptable," and "harmful" continue to evolve.

This chapter reviews the anatomic structures important to the study of occlusion and includes a discussion of mandibular (lower jaw) movement. The concept of ideal versus pathologic occlusion is introduced, as is the history of occlusal theory. The chapter concludes with general guidelines for the initial phase of occlusal treatment.

ANATOMY

Temporomandibular Joints

The major components of the TMJs are the cranial base, the mandible, and the muscles of mastication with their innervation and vascular supply. The TMJs are ginglymoarthrodial, meaning that they are capable of both a hinging and a gliding articulation. An articular disk separates the mandibular fossa and the articular tubercle of the temporal bone from the condylar process of the mandible.

The articulating surfaces of the condylar processes and fossae are covered with avascular fibrous tissue (in contrast to most other joints, which have hyaline cartilage). The articular disk consists of dense connective tissue; it also is avascular and devoid of nerves in the area where articulation normally occurs. Posteriorly, it is attached to loose highly vascularized and innervated connective tissue: the retrodiscal pad or bilaminar zone (called *bilaminar* because it consists of two layers: an elastic superior layer and a collagenous inelastic inferior layer). The retrodiscal pad connects to the posterior wall of the articular capsule surrounding the joint (Fig. 4-1). Medially and laterally, the articular disk is attached firmly to the poles of the condylar process. Anteriorly, it fuses with the capsule and with the superior lateral pterygoid muscle. Superior and inferior to the articular disk are two spaces: the superior and inferior synovial cavities. These are bordered peripherally by the capsule and the synovial membranes and are filled with synovial fluid. Because of its firm attachment to the poles of each condylar process, the articular disk follows condylar movement during both hinging and translation, which is made possible by the loose attachment of the posterior connective tissues.

Ligaments

The body of the mandible is attached to the base of the skull by muscles and three paired ligaments: the temporomandibular (also called the *lateral*), the sphenomandibular, and the stylomandibular ligaments (Table 4-1). Ligaments cannot be stretched significantly, and thus joint movement is limited. The temporomandibular ligaments restrict rotation of the mandible, limit border movements, and protect the structures of the joint.[1] The sphenomandibular and stylomandibular ligaments (Fig. 4-2) limit separation between the condylar process and the articular disk; the stylomandibular ligaments also limit forward *(protrusive)* movement of the mandible.

Musculature

Several muscles are responsible for mandibular movements. These can be grouped as the muscles of mastication and the suprahyoid muscles (Fig. 4-3). The former include the temporal, masseter, and medial and lateral pterygoid muscles; the latter are the geniohyoid, mylohyoid, and digastric muscles. Their respective origins, insertions, innervation, and vascular supply are summarized in Table 4-2.

Muscular Function

The functions of the mandibular muscles are well coordinated and complex. Three paired muscles of mastication provide elevation and lateral movement of the mandible: the temporal, masseter, and medial pterygoid muscles. The lateral pterygoid muscles each have two bellies that function as two separate muscles, which

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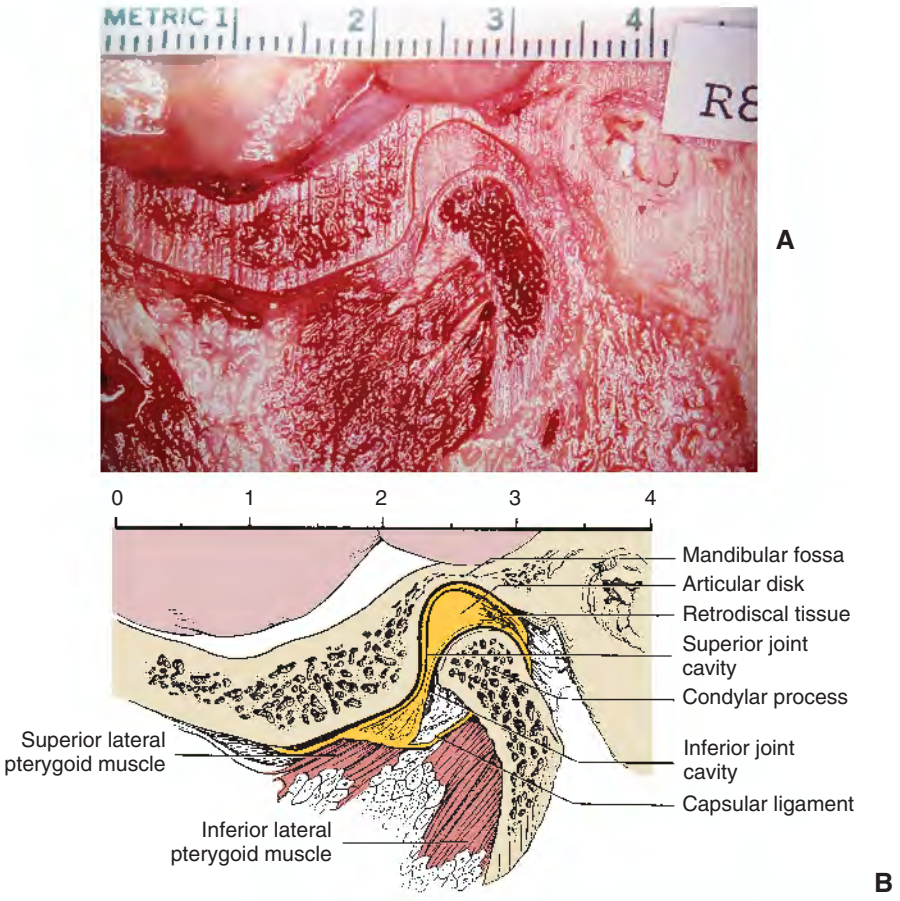

FIGURE 4-1 ■ Temporomandibular joint (lateral section). The mandible is open. (**A,** Courtesy Dr. K.A. Laurell.)

TABLE 4-1 **Mandibular Ligaments**

Ligament	Origin	Insertion	Function
Temporomandibular			
Superficial	Outer surface of articular eminence	Posterior aspect of neck of condylar process	Limits mandibular rotation on opening
Medial	Crest of articular eminence	Lateral aspect of neck of condylar process	Limits posterior movement
Sphenomandibular	Spine of sphenoid	Inferior to lingula	Accessory to temporomandibular articulation; influence on mandibular movement disputed
Stylomandibular	Styloid process	Mandibular angle and fascia of medial pterygoid muscle	Limits extreme protrusion of the mandible; influence on mandibular movement disputed

contract in the horizontal plane during opening and closing; the inferior belly (inferior lateral pterygoid muscle) is active during protrusion, depression, and lateral movement of the mandible; the superior belly (superior lateral pterygoid muscle) is active during closure. Because the superior belly has been shown to attach to the articular disk and the neck of the condyle, it is thought to assist in maintaining the integrity of the condyle–articular disk assembly by pulling the condylar process firmly against the articular disk.

The suprahyoid muscles have a dual function: They can elevate the hyoid bone or depress the mandible. The movement that results when they contract depends on the state of contraction of the other muscles of the neck and mandibular region. When the muscles of mastication are in a state of contraction, the suprahyoid muscles elevate the hyoid bone. However, if the infrahyoid muscles (which anchor the hyoid bone to the sternum and clavicle) are contracted, the suprahyoid muscles depress and retract the mandible. The geniohyoid and mylohyoid muscles initiate the opening movements, and the anterior belly of the digastric muscle completes mandibular depression. Although the stylohyoid muscle (which also belongs to the suprahyoid group) may contribute indirectly to mandibular movement through fixation of the hyoid bone, it does not play a significant role in mandibular movement.

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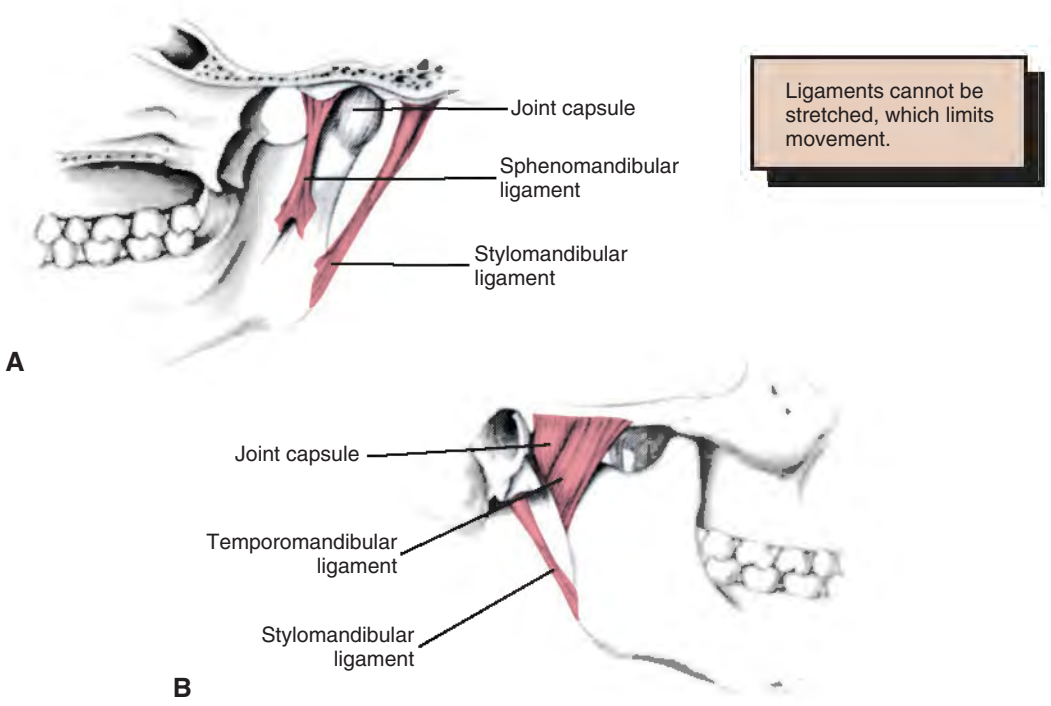

FIGURE 4-2 ■ Ligaments of the temporomandibular joint. **A,** Medial view. **B,** Lateral view.

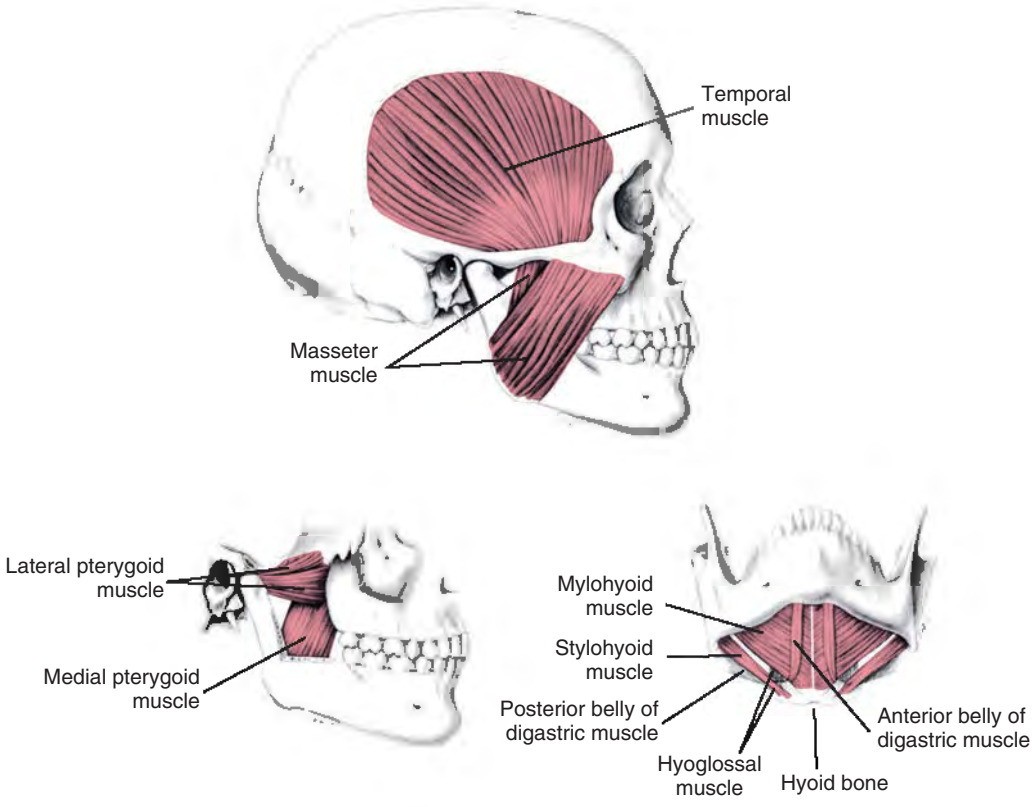

FIGURE 4-3 ■ The muscles of mastication and the suprahyoid muscles.

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TABLE 4-2 **Muscles of Mastication**

Muscle	Origin	Insertion	Innervation	Vascular Supply	Function
Temporal	Lateral surface of skull	Coronoid process and anterior border of ramus	Temporal nerve (branch of mandibular nerve)	Middle and deep temporal arteries (branches of superficial temporal and maxillary arteries)	Elevates and retracts mandible, assists in rotation; active in clenching
Masseter	Zygomatic arch	Angle of mandible	Masseteric nerve (division of trigeminal nerve)	Masseteric artery (branch of maxillary artery)	Elevates and protracts mandible, assists in lateral movement; active in clenching
Medial pterygoid	Pterygoid fossa and medial surface of lateral pterygoid plate	Medial surface of angle of mandible	Medial pterygoid nerve (division of trigeminal nerve)	Branch of maxillary artery	Elevates mandible, enables lateral movement and protrusion
Superior lateral pterygoid	Infratemporal surface of greater wing of sphenoid	Articular capsule and disk, neck of condyle	Branch of masseteric or buccal nerve	Branch of maxillary artery	Positions articular disk in closing
Inferior lateral pterygoid	Lateral surface of lateral pterygoid plate	Neck of condyle	Branch of masseteric or buccal nerve	Branch of maxillary artery	Protrudes and depresses mandible, enables lateral movement
Mylohyoid	Inner surface of mandible	Hyoid and mylohyoid raphae	Branches of mylohyoid nerve (division of trigeminal nerve)	Submental artery	Elevates and stabilizes hyoid bone
Geniohyoid	Genial tubercle	Hyoid bone	First cervical nerve via hypoglossal nerve	Branch of lingual artery	Elevates and draws hyoid bone forward
Anterior belly of digastric nerve	Tendon linked to hyoid bone by fascia	Digastric fossa (lower border of mandible)	Branch of mylohyoid nerve (division of trigeminal nerve)	Branch of facial artery	Elevates hyoid bone, depresses mandible

Dentition

The relative positions of the maxillary and mandibular teeth influence mandibular movement. Many "ideal" occlusions have been described.[2] In most of these, the maxillary and mandibular teeth contact simultaneously when the condylar processes are fully seated in the mandibular fossae, and the teeth do not interfere with harmonious movement of the mandible during function. Ideally, in the fully bilateral seated position of the condyle–articular disk assemblies, the maxillary and mandibular teeth exhibit maximum intercuspation. This means that the maxillary lingual and mandibular buccal cusps of the posterior teeth are evenly distributed and in stable contact with the opposing occlusal fossae. These functional cusps can then act as stops for vertical closure without excessively loading any one tooth, while left and right TMJs concurrently are in an unstrained position.

However, in many patients, maximal intercuspal contact occurs with the condyles in a slightly translated position. This position is referred to as *maximum intercuspation*, which is defined as the complete intercuspation of the opposing teeth, independent of condylar position; this is sometimes considered the best fit of the teeth regardless of condylar position.

If the mesiobuccal cusp of the maxillary first molar is aligned with the buccal groove of the mandibular first molar, the orthodontic relationship is considered Angle class I (Fig. 4-4); this is considered normal occlusion. In such a relationship, the anterior teeth overlap both horizontally and vertically. This position is defined as the dental relationship in which the anteroposterior relationship of the jaws is normal, as indicated by correct intercuspation of maxillary and mandibular molars, Orthodontic textbooks[3] have traditionally described an arbitrary 2-mm horizontal overlap and 2-mm vertical overlap as being ideal. For most patients, however, greater vertical overlap of the anterior teeth is desirable for preventing undesirable posterior tooth contact. Mandibular flexing during mastication also may contribute to such undesirable contact. Empirically, dentitions with greater vertical overlap of the anterior teeth appear to have a

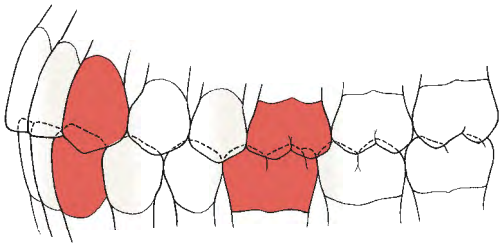

FIGURE 4-4 ■ The Angle class I occlusal relationship.

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better long-term prognosis than do dentitions with minimal vertical overlap.

CENTRIC RELATION

Centric relation is defined as the maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective articular disks with the complex in the anterosuperior position against the shapes of the articular eminences. This position is independent of tooth contact. It is also clinically discernible when the mandible is directed superior and anterior and is restricted to a purely rotary movement about the transverse horizontal axis.

Centric relation is considered a reliable and reproducible reference (and treatment) position. If maximum intercuspation coincides with the centric relation position, restorative treatment is often straightforward. When maximum intercuspation does not coincide with centric relation, it is necessary to determine whether corrective occlusal therapy is needed before restorative treatment is initiated.

MANDIBULAR MOVEMENT

As any other movement in space, complex three-dimensional mandibular movement can be divided into two basic components: *translation*, in which all points within a body have identical motion, and *rotation*, in which the body is turning about an axis (Fig. 4-5). Every possible three-dimensional movement can be described in terms of these two components. It is easier to understand mandibular movement when the components are described as projections in three perpendicular planes: sagittal, horizontal, and frontal (Fig. 4-6).

Reference Planes

Sagittal Plane

In the sagittal plane (Fig. 4-7), the mandible is capable of a purely rotational movement, as well as translation. Rotation occurs around the terminal hinge axis, an imaginary horizontal line through the rotational centers of the left and right condylar processes. The rotational movement is limited to about 12 mm of incisor separation before the temporomandibular ligaments and structures anterior to the mastoid process force the mandible to translate. The initial rotation or hinging motion occurs between the condylar process and the articular disk. During translation, the inferior lateral pterygoid muscle contracts and moves the condyle–articular disk assembly forward along the posterior incline of the tubercle. Condylar movement is similar during protrusive mandibular movement.

Horizontal Plane

In the horizontal plane, the mandible is capable of rotation around several vertical axes. For example, lateral

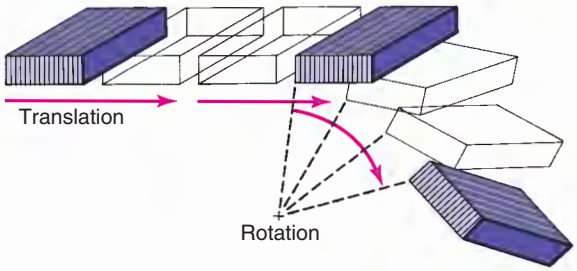

FIGURE 4-5 ■ Three-dimensional movement of a body can be defined by a combination of translation (all points within the body having identical movement) and rotation (all points turning around an axis).

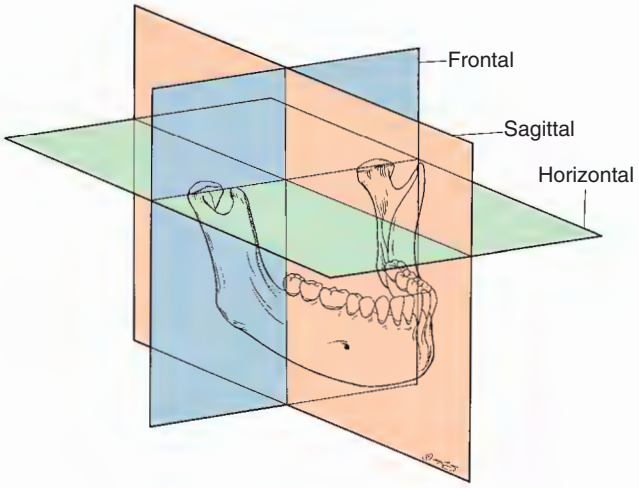

FIGURE 4-6 ■ Reference planes.

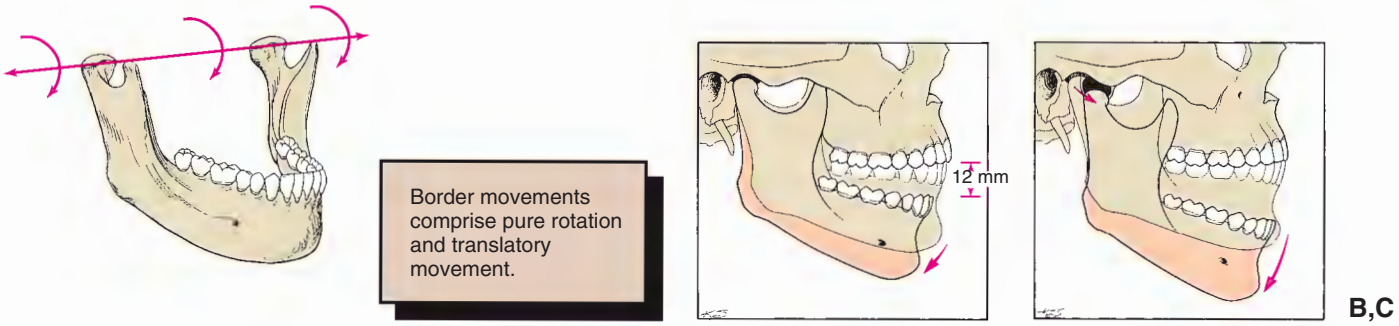

FIGURE 4-7 ■ **A,** In a sagittal plane, the mandible can rotate around the terminal hinge axis. **B,** After about 12 mm of incisal opening, the mandible is forced to translate. **C,** Maximum opening; the condyles have translated forward.

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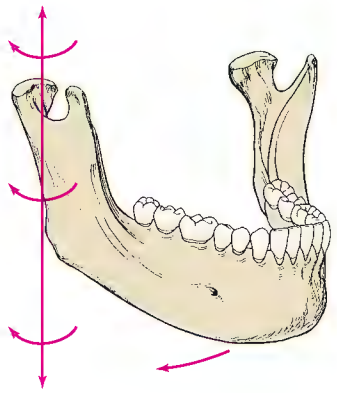

FIGURE 4-8 ■ Rotation in the horizontal plane occurs during lateral movement of the mandible. (The vertical axis is situated in the condylar process.) Normally, there is relatively little translation (side shift).

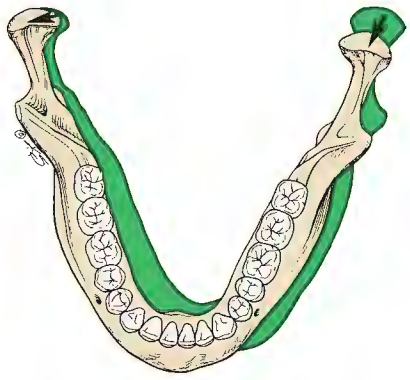

FIGURE 4-9 ■ Right lateral mandibular movement in the horizontal plane.

movement consists of rotation around an axis situated in the working *(laterotrusive)* condylar process (Fig. 4-8) with relatively little concurrent translation. A slight lateral translation of the condyle on the working side in the horizontal plane—known as *laterotrusion*, Bennett movement,[4] or mandibular side shift (Fig. 4-9)—is frequently present. This may be in a slightly forward direction *(lateroprotrusion)* or slightly backward direction *(lateroretrusion)*. The orbiting (nonworking) condyle travels forward and medially as limited by the medial aspect of the mandibular fossa and the temporomandibular ligament. In addition, the mandible can make a straight protrusive (anterior) movement (Fig. 4-10).

Frontal Plane

In a lateral movement in the frontal plane, the nonworking *(mediotrusive)* condyle moves down and medially, whereas the working *(laterotrusive)* condyle rotates around the sagittal axis perpendicular to this plane (Fig. 4-11). Again, as determined by the anatomy of the medial wall of the mandibular fossa on the mediotrusive side, transtrusion may be observed; as determined by the anatomy of the mandibular fossa on the laterotrusive side, this movement may be lateral and upward *(laterosurtrusion)* or lateral and downward *(laterodetrusion)*. A straight

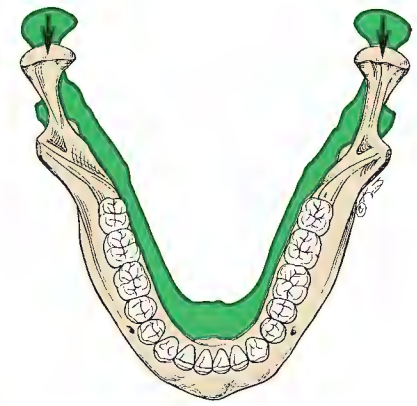

FIGURE 4-10 ■ Protrusive mandibular movement in the horizontal plane.

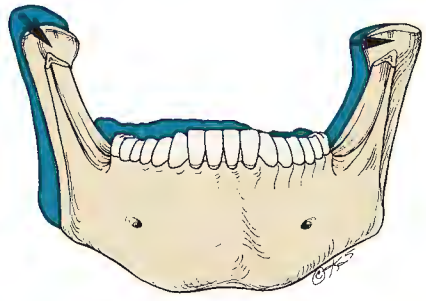

FIGURE 4-11 ■ Lateral movement in the frontal plane.

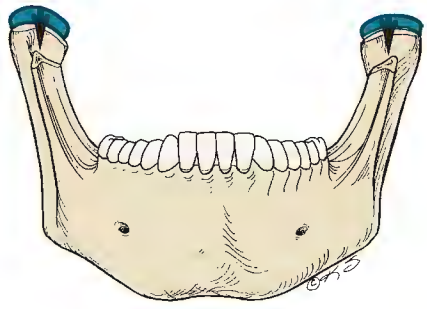

FIGURE 4-12 ■ Protrusive movement in the frontal plane.

protrusive movement observed in the frontal plane, with both condylar processes moving downward as they slide along the tubercular eminences, is shown in Figure 4-12.

Border Movements

Mandibular movements are limited by the TMJs and ligaments, the neuromuscular system, and the teeth. Posselt[5] was the first to describe mandibular movement at the limits dictated by anatomic structures, as viewed in a given plane, which he called *border movements* (Fig. 4-13). His classic work is well worth reviewing to help understand how the determinants control the extent to which movement can occur.

Posselt used a three-dimensional representation of the extreme movements of which the mandible is capable (see Fig. 4-13, *B*). All possible mandibular movements occur within its boundaries. At the top of both illustrations, a

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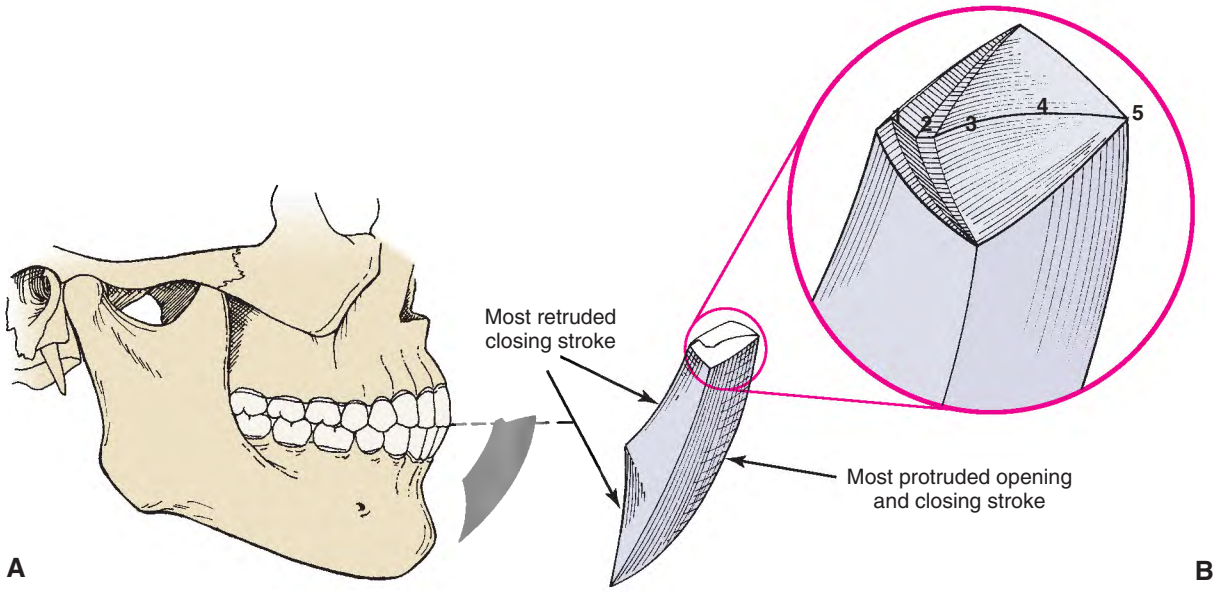

FIGURE 4-13 ■ **A,** Mandibular border movement in the sagittal plane. **B,** Posselt's three-dimensional representation of the total envelope of mandibular movement. *1,* Mandibular incisors track along the lingual concavity of the maxillary anterior teeth. *2,* Edge-to-edge position. *3,* Incisors move superiorly until posterior tooth contact recurs. *4,* Protrusive path. *5,* Most protrusive mandibular position.

horizontal tracing represents the protrusive movement of the incisal edge of the mandibular incisors (solid numbered line in Fig. 4-13, *B*).

Starting from the maximum intercuspation position, in the protrusive pathway, the lower incisors are initially guided by the lingual concavity of the maxillary anterior teeth. As a result, posterior tooth contact is gradually lost as the incisors reach the edge-to-edge position. This is represented in Posselt's diagram by the initial downward slope. As the mandible moves farther protrusively, the incisors slide over a horizontal trajectory that represents the edge-to-edge position (the flat portion in the diagram), after which the lower incisors move upward until new posterior tooth contact occurs. Further protrusive movement of the mandible typically takes place without significant tooth contact.

The border farthest to the right of Posselt's solid in Figure 4-13, *B*, represents the most protruded opening and closing stroke. The maximal open position of the mandible is represented by the lowest point in the diagram. The left border of the diagram represents the most retruded closing stroke. This movement occurs in two phases: The lower portion consists of a combined rotation and translation, until the condylar processes return to the fossae. The second portion of the most retruded closing stroke is represented by the top portion of the border that is farthest to the left in Posselt's diagram. It is strictly rotational.

Posterior and Anterior Determinants of Mandibular Movement

These determinants (Table 4-3) are the anatomic structures that dictate or limit the movements of the mandible. The *anterior determinant* of mandibular movement is the articulation of the teeth. The posterior determinants of mandibular movement are the temporomandibular controls and their associated structures The *posterior determinants* (Fig. 4-14)—shape of the articular eminences, anatomy of the medial walls of the mandibular fossae, configuration of the mandibular condylar processes—cannot be altered by the dentist, and the neuromuscular responses of the patient can be influenced only indirectly (e.g., through changes in the shape of the contacting teeth or with an occlusal device). If a patient has steeply sloped eminences, the large downward component of condylar movement during lateral and protrusive excursions results in early separation of the posterior teeth. Similarly, variations in the anatomy of the medial wall of each fossa, which normally allows the condyle to move slightly medially as it travels forward (mandibular side shift, or *transtrusion*), affect the extent of medial movement. The side shift becomes greater as the extent of medial movement increases. The anatomy of the joint dictates the actual path and timing of condylar movement. Laterotrusive movement of the working condylar process is influenced predominantly by the anatomy of the lateral wall of the mandibular fossa. The amount of the side shift is a function of the mediotrusive condyle; on the working side, however, the anatomy of the lateral aspect of the fossa is what guides the working condyle straight out or upward and downward. The amount of side shift does not appear to increase as the result of a loss of occlusion.[6]

The *anterior determinants* (Fig. 4-15) are the vertical and horizontal overlaps of the anterior teeth and the form of the lingual concavities of the maxillary anterior teeth. These can sometimes be altered by restorative and orthodontic treatment. More vertical overlap causes increased downward mandibular incisor movement during the early phase of protrusive movement and a more vertical pathway at the end of the chewing stroke. Increased

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TABLE 4-3 **Effect of Selected Variables on Occlusal Form of Restorations**

Determinants	Variation	Effect on Restoration
Posterior		
Inclination of articular eminence	Steeper	Posterior cusps may be taller
	Flatter	Posterior cusps must be shorter
Medial wall of glenoid fossa	Allows more lateral translation	Posterior cusps must be shorter
	Allows minimal lateral translation	Posterior cusps may be taller
Intercondylar distance	Greater	Smaller angle between laterotrusive and mediotrusive movement
	Lesser	Increased angle between laterotrusive and mediotrusive movement
Anterior		
Horizontal overlap of anterior teeth	Increased	Posterior cusps must be shorter
	Reduced	Posterior cusps may be taller
Vertical overlap of anterior teeth	Increased	Posterior cusps may be taller
	Reduced	Posterior cusps must be shorter
Other		
Occlusal plane	More parallel to condylar guidance	Posterior cusps must be shorter
	Less parallel to condylar guidance	Posterior cusps may be longer
Anteroposterior curve	More convex (shorter radius)	The most posterior cusps must be shorter
	Less convex (larger radius)	The most posterior cusps may be longer

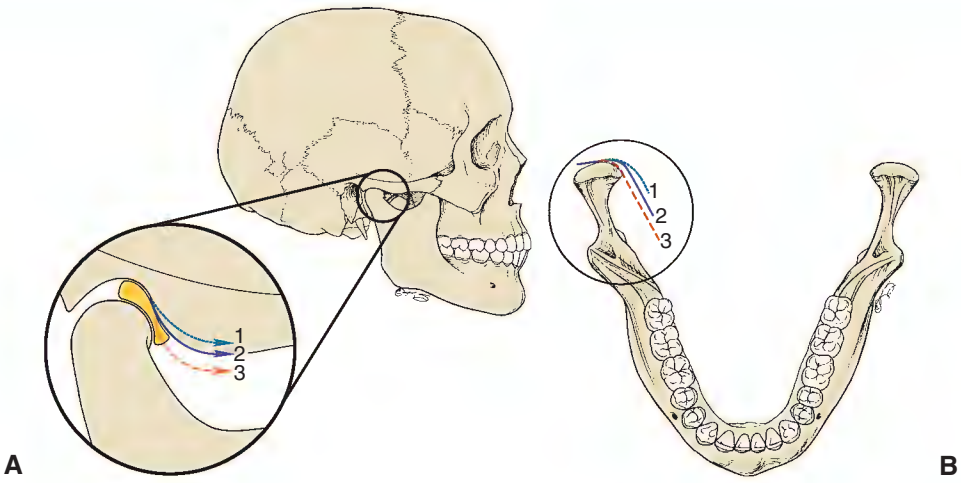

FIGURE 4-14 ■ Posterior determinants of occlusion. **A,** Angle of the articular eminence (condylar guidance angle). *1,* Flat; *2,* average; *3,* steep. **B,** Anatomy of the medial walls of the mandibular fossae. *1,* Greater than average; *2,* average; *3,* minimal side shift.

horizontal overlap allows a more horizontal mandibular movement.

Although the posterior and anterior determinants combine to affect mandibular movement, no correlation has been established[7]; that is, patients with a steep anterior guidance angle do not necessarily have a steep posterior disclusion, and those with a steep posterior disclusion do not necessarily have a steep guidance angle.

Functional Movements

Functional mandibular movement is defined as all normal, proper, or characteristic movements of the mandible made during speech, mastication, yawning, swallowing, and other associated activities. Most functional movement of the mandible (as occurs during mastication and speech) takes place inside the physiologic limits established by the teeth, the TMJs, and the muscles and ligaments of mastication; therefore, these movements are rarely coincident with border movements.

Chewing

Mastication is a learned process. At birth, no occlusal plane exists, and only after the first teeth have erupted far enough to contact each other is a message sent from the receptors to the cerebral cortex, which controls the stimuli to the masticatory musculature. Stimuli from the tongue and cheeks, and perhaps from the musculature itself and from the periodontium, may influence this feedback pattern.

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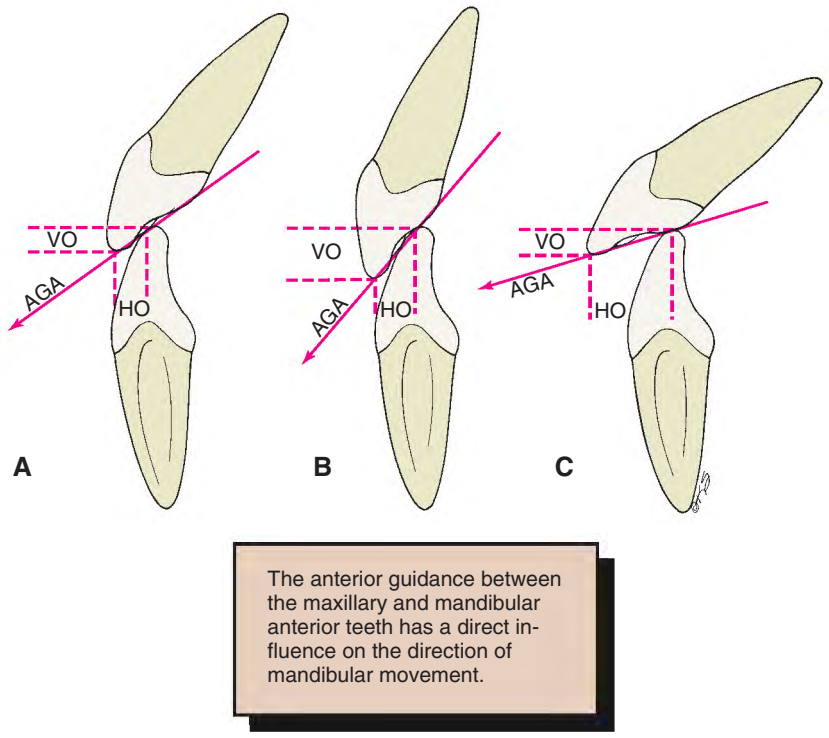

FIGURE 4-15 ■ Anterior determinants of occlusion. Different incisor relationships with differing horizontal overlap *(HO)* and vertical overlap *(VO)* produce different anterior guidance angles *(AGA).* **A,** Angle class I. **B,** Angle class II, division 2 (increased VO; steep AGA). **C,** Angle class II, division 1 (increased HO; flat AGA).

When incising food, adults open their mouths a comfortable distance and move the mandible forward until they incise, with the anterior teeth meeting approximately edge to edge. The food bolus is then transported to the center of the mouth as the mandible returns to its starting position, with the incisal edges of the mandibular anterior teeth tracking along the lingual concavities of the maxillary anterior teeth (Fig. 4-16). The mouth then opens slightly, the tongue pushes the food onto the occlusal table, and, after moving sideways, the mandible closes into the food until the guiding teeth (typically the canines) contact.[8] The cycle is completed as the mandible returns to its starting position.[9] This pattern repeats itself until the food bolus has been reduced to particles that are small enough to be swallowed, at which point the process can start over. The direction of the mandibular path of closure is influenced by the inclination of the occlusal plane with the teeth apart and by the occlusal guidance as the mandible approaches maximum intercuspation.[10]

The chewing pattern observed in children differs from that found in adults. Until about age 10, children begin the chewing stroke with a lateral movement. After the age of 10, they start to chew increasingly like adults, with a more vertical stroke[11] (Fig. 4-17). Stimuli from the pressoreceptors play an important role in the development of functional chewing cycles.[12]

Speaking

The teeth, tongue, lips, floor of the mouth, and soft palate form the resonance chamber that affects pronunciation. During speech, the teeth are generally not in contact, although the anterior teeth may come very close together during soft "c," "ch," "s," and "z" sounds, forming the "speaking space: the space that occurs between the incisal and/or occlusal surfaces of the maxillary and mandibular teeth during speech."[13] When a person pronounces the fricative "f," the inner vermilion border of the lower lip traps air against the incisal edges of the maxillary incisors. Phonetics is a useful diagnostic guide for correcting vertical dimension and tooth position during fixed and removable prosthodontic treatment.[14-17]

Parafunctional Movements

Parafunctional movements of the mandible may be described as sustained activities that occur beyond the normal functions of mastication, swallowing, and speech. There are many forms of parafunctional activities, including bruxism, clenching, nail biting, and pencil chewing. Parafunction is typically manifested by long periods of increased muscle contraction and hyperactivity. Concurrently, excessive occlusal pressure and prolonged tooth contact occur, which is inconsistent with the normal chewing cycle. Over a protracted period, parafunction can result in excessive wear; widening of the periodontal ligament; and mobility, migration, or fracture of the teeth. Muscle dysfunction such as elevated muscle tone, myospasm, myositis, myalgia, and referred pain (headaches) from trigger point tenderness may occur as well. The degree of symptoms varies considerably among individuals. The two most common forms of parafunctional activities are bruxism and clenching. Radiographic bone density

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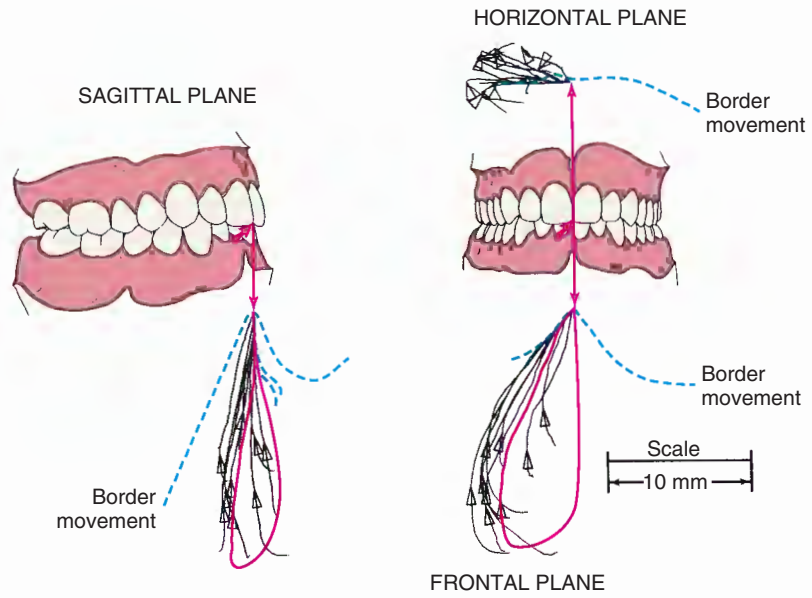

FIGURE 4-16 ■ Comparison of border and chewing movements for soft food at the central incisor: sagittal, frontal, and horizontal views in an orthographic projection. (From Gibbs CH, et al: Chewing movements in relation to border movements at the first molar. J Prosthet Dent 46:308, 1981.)

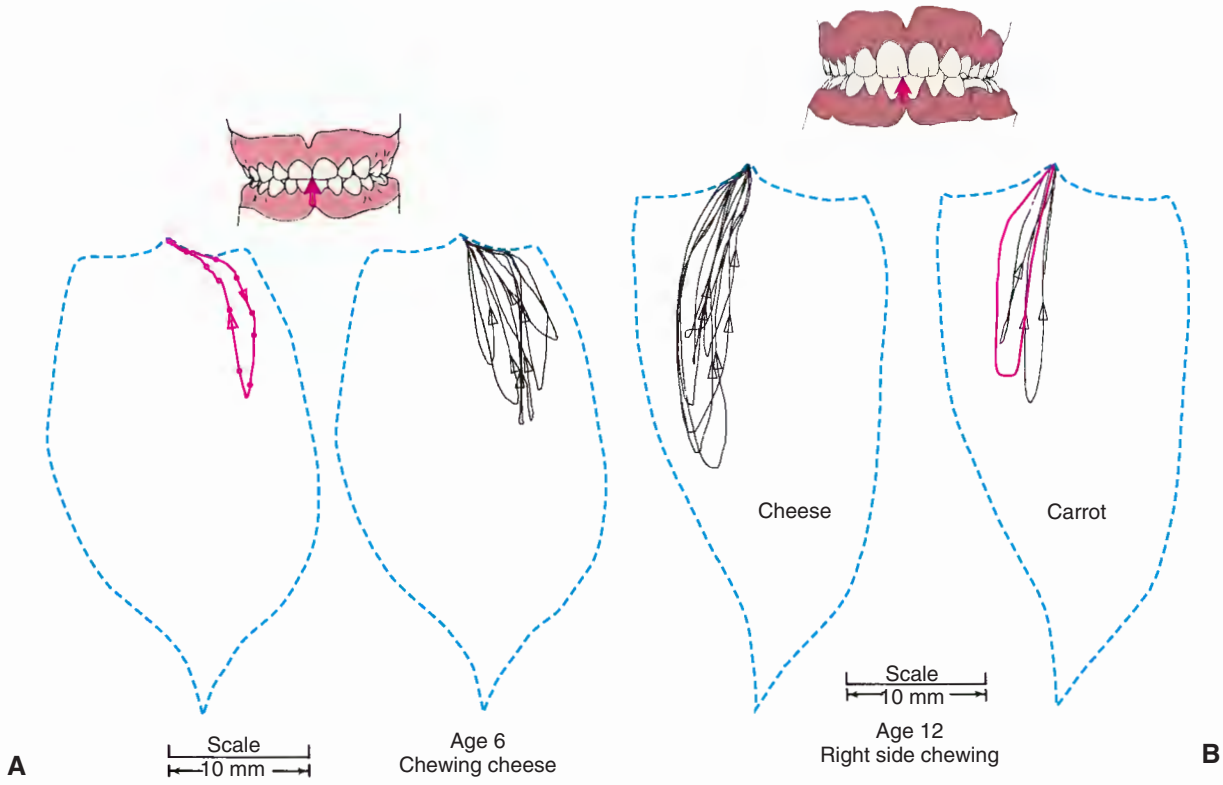

FIGURE 4-17 ■ Frontal views of chewing. The *dashed lines* represent border movements. **A,** Chewing in a young person, characterized by a wide lateral movement on opening and decreased lateral movement on closing. **B,** In an older child, the chewing pattern resembles that of an adult. (From Wickwire NA, et al: Chewing patterns in normal children. Angle Orthod 51:48, 1981.)

of the alveolar process is often increased in patients with a history of sustained parafunctional activity.

Bruxism

Involuntary rhythmic or spasmodic nonfunctional gnashing, grinding, or clenching of teeth, in other than chewing movements of the mandible, may lead to occlusal trauma; such oral habits are collectively known as *bruxism* (Fig. 4-18). This activity may be diurnal, nocturnal, or both. Although bruxism is initiated on a subconscious level, nocturnal bruxism is potentially more harmful because the patient is not aware of it during sleep. Therefore, it can be difficult to detect, but it should be suspected

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FIGURE 4-18 ■ Extensive abrasion (tooth wear) that resulted from parafunctional grinding. (Courtesy Dr. M. Padilla.)

in any patient exhibiting abnormal tooth wear or pain. The prevalence of bruxism is about 10% and is less common with age.[18] The causes of bruxism are often unclear. Some theories relate bruxism to malocclusion, neuromuscular disturbances, responses to emotional distress, or a combination of these factors.[19] A study on cohort twins has demonstrated substantial genetic effects[20]; the condition has been related to sleep disturbance[21]; and the symptoms of bruxism are three times more common in people who smoke.[22] Altered mastication has been observed in subjects with bruxism[23,24] and may result from an attempt to avoid premature occlusal contacts (occlusal interferences). There may also be a neuromuscular attempt to "rub out" an interfering cusp. The fulcrum effect of rubbing on posterior interferences creates a protrusive or laterotrusive movement that can cause overloading of the anterior teeth, with resultant excessive anterior wear. It is common for wear on anterior teeth to progress from initial faceting on the canines to the central and lateral incisors. Once vertical overlap diminishes as the result of wear, posterior wear facets are commonly observed. However, the chewing patterns of normal people can be quite varied, and the relationship, if any, between altered mastication and occlusal dysfunction is not clear.[25]

According to one theory,[26] bruxism is performed on a subconscious reflex-controlled level in relation to emotional responses and occlusal interferences. In certain malocclusions, the neuromuscular system exerts fine control during chewing to avoid particular occlusal interferences. As the degree of muscle activity necessary to avoid the interferences becomes greater, muscle tone may increase, with subsequent pain in the hyperactive musculature, which in turn can lead to restricted movement. The relationship, if any, between bruxism and temporomandibular disorders is still unclear.[27]

FIGURE 4-19 ■ Prominent masseter muscles at the angle of the mandible.

Patients with bruxism can exert considerable forces on their teeth, and much of this may have a lateral component. Posterior teeth do not tolerate lateral forces as well as vertical forces in their long axes. Buccolingual forces, in particular, appear to cause rapid widening of the periodontal ligament space and increased mobility.

Clenching

Clenching is defined as the pressing and clamping of the jaws and teeth together frequently in association with acute nervous tension or physical effort. The pressure thus created can be maintained over a considerable time with short periods of relaxation in between. The causes can be associated with stress, anger, physical exertion, or intense concentration on a given task, rather than an occlusal disorder. In contrast to bruxism, clenching does not necessarily result in damage to the teeth because the concentration of pressure is directed more or less through the long axes of the posterior teeth without the involvement of detrimental lateral forces. Abfractions—cervical defects at the cementoenamel junction—may result from sustained clenching.[28,29] Also, the increased load may result in damage to the periodontium, TMJs, and muscles of mastication. Typically, the elevator muscles become overdeveloped; affected patients may have noticeably prominent masseter muscles at the angle of the mandible (Fig. 4-19). Muscle splinting, myospasm, and myositis may progress, causing the patient to seek treatment. As with bruxism, clenching can be difficult to diagnose and difficult, if not impossible, for the patient to control voluntarily.

HISTORY OF OCCLUSAL STUDIES

Historically, the study of occlusion and articulation has undergone an evolution of concepts. These can be

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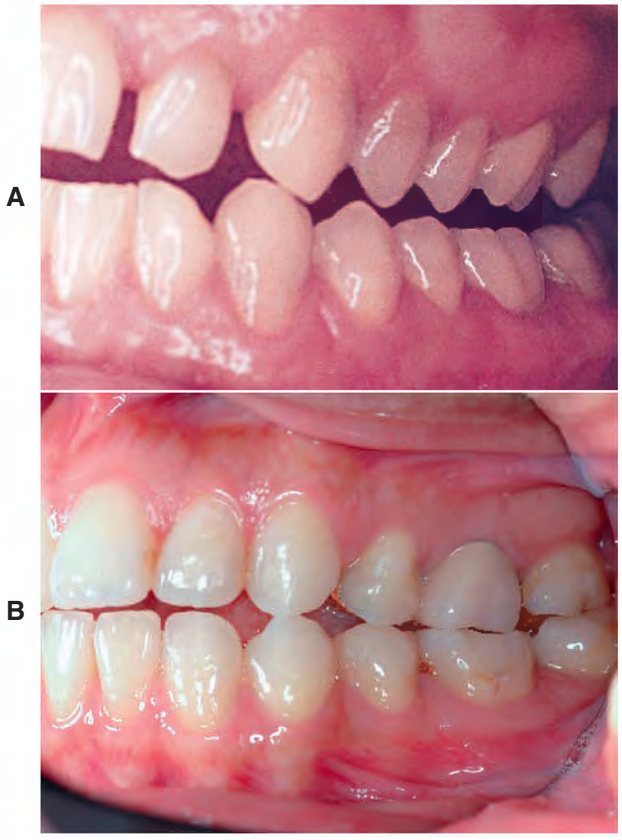

FIGURE 4-20 ■ **A,** Mutually protected (canine-guided) articulation. During lateral excursions, there are no contacts on the mediotrusive (nonworking side) teeth; all contacts are between the laterotrusive (working side) canines. **B,** Unilaterally balanced (group function) occlusion. During lateral excursions, there are no contacts between teeth on the mediotrusive (nonworking) side, but there are uniform excursive contacts on the laterotrusive (working) side.

broadly categorized as concepts of bilaterally balanced,[30] unilaterally balanced, and mutually protected articulation. Current emphasis in teaching fixed prosthodontics and restorative dentistry has been on the concept of mutual protection (Fig. 4-20). However, because restorative treatment requirements vary, the clinician should understand possible combinations of occlusal schemes and their advantages, disadvantages, and indications.

In most patients, maximum tooth contact occurs anterior to the centric relation position of the mandible. Often, this maximum intercuspation position anterior to centric relation is referred to as *centric occlusion*, although this term is also used to refer to occlusal contact in centric relation. To avoid confusion, *maximum intercuspation* and *centric relation* are the terms used in this text.

Bilaterally Balanced Articulation

Early work in removable prosthodontics centered on the concept of a bilaterally balanced articulation. This requires having a maximum number of teeth in contact in maximum intercuspation and all excursive positions. In complete denture fabrication, this tooth arrangement helps maintain denture stability because the nonworking

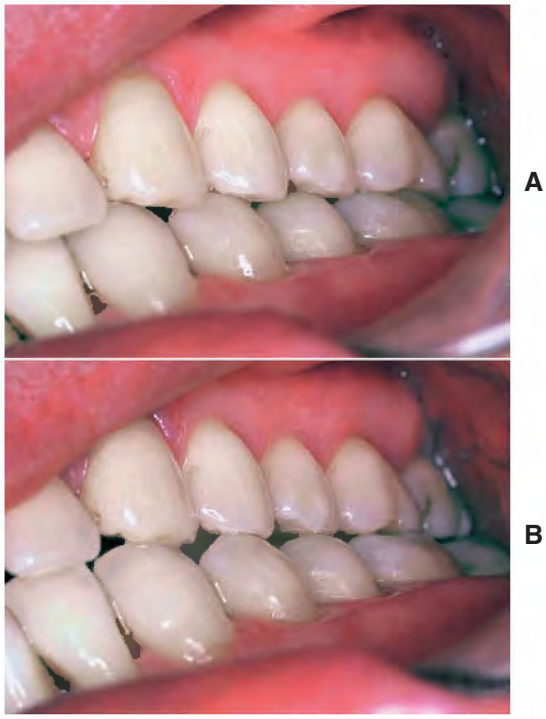

FIGURE 4-21 ■ Unilaterally balanced (group function) occlusion. During lateral excursions, there are no contacts between teeth on the mediotrusive (nonworking) side **(A),** but even excursive contacts occur on the laterotrusive (working) side **(B).**

contact prevents the denture from being dislodged. However, as the principles of bilateral balance were applied to the natural dentition and in fixed prosthodontics, it proved to be extremely difficult to accomplish, even with great attention to detail and with the use of sophisticated articulators. In addition, rates of failure were high. The rate of occlusal wear was increased, periodontal breakdown was increased or accelerated, and neuromuscular disturbances occurred. The last were often relieved when posterior contacts on the mediotrusive side were eliminated in an attempt to eliminate unfavorable loading. Thus the concept of a unilaterally balanced occlusion (group function) evolved[31] (Fig. 4-21).

Unilaterally Balanced Articulation (Group Function)

In a unilaterally balanced articulation, excursive contact occurs between all opposing posterior teeth on only the laterotrusive side. This occlusal arrangement is also referred to as *group function*. On the mediotrusive side, no contact occurs until the mandible has reached centric relation. Thus the load is distributed among the periodontal support of all posterior teeth on the working side. This can be advantageous if, for instance, the periodontal support of the canine is compromised. On the working side, the occlusal load during functional movement is then distributed over the periodontal surface area of all teeth in the quadrant while the posterior teeth on the nonworking side do not contact. In the protrusive movement, no posterior tooth contact occurs.

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Long Centric

As the concept of unilateral balance evolved, it was suggested that allowing some freedom of movement in an anteroposterior direction is advantageous. This concept is known as *long centric*. Schuyler[32] was one of the first to advocate such an occlusal arrangement. He thought that it was important for the posterior teeth to be in harmonious gliding contact when the mandible translates from centric relation forward to make anterior tooth contact. Other authors[33] have advocated long centric because in healthy natural dentitions, centric relation only rarely coincides with the maximum intercuspation position. However, its length is arbitrary. At given vertical dimensions, long centric lengths ranging from 0.5 to 1.5 mm have been advocated. This occlusal theory presupposes that the condyles can translate horizontally in the fossae over a commensurate trajectory before beginning to translate downward. It also necessitates a greater horizontal space between the maxillary and mandibular anterior teeth (deeper lingual concavity), which would allow horizontal movement before posterior disocclusion (separation of opposing teeth during eccentric movements of the mandible).

Mutually Protected Articulation

In 1963, Stuart and Stallard[34] advocated an occlusal scheme called *mutually protected articulation*, which was based on earlier work by D'Amico.[35] In this arrangement, centric relation coincides with the maximum intercuspation position. The six anterior maxillary teeth, together with the six anterior mandibular teeth, guide all excursive movements of the mandible, and no posterior occlusal contacts occur during any lateral or protrusive excursions.

The relationship of the anterior teeth, or anterior guidance, is critical for the success of this occlusal scheme. In a mutually protected articulation, the posterior teeth come into contact only at the very end of each chewing stroke, minimizing horizontal loading on the teeth. Concurrently, the posterior teeth act as stops for vertical closure when the mandible returns to its maximum intercuspation position. To maximize occlusal function, posterior cusps should be sharp and should pass each other closely without contacting. Investigations of the neuromuscular physiology of the masticatory apparatus indicate advantages associated with a mutually protected occlusal scheme.[8] However, in studies involving unrestored dentitions, relatively few occlusions can be classified as mutually protected.[36]

Optimum Occlusion

In an ideal occlusal arrangement, the load exerted on the dentition should be distributed optimally. Bakke and colleagues[37] showed that occlusal contact influences muscle activity during mastication. Any restorative procedures that adversely affect occlusal stability may affect the timing and intensity of elevator muscle activity. Horizontal forces on any teeth should be avoided or at least minimized, and loading should be parallel predominantly to the long axes of the teeth. This is facilitated when the tips of the functional cusps are located centrally over the roots and when loading of the teeth occurs in the fossae of the occlusal surfaces, rather than on the marginal ridges. Horizontal forces are also minimized if posterior tooth contact during excursive movements is avoided. Nevertheless, to enhance masticatory efficiency, the cusps of the posterior teeth should have adequate height. Stabilizing contacts involves primarily the mandibular buccal cusps, and McDevitt and Warreth[38] suggested that occlusal treatment objectives include maintenance or improvement of the number of such contacts.

The chewing and grinding action of the teeth is enhanced if opposing cusps on the laterotrusive side interdigitate at the end of the chewing stroke. The mutually protected occlusal scheme probably meets this criterion better than the other occlusal arrangements. The features of a mutually protected articulation are as follows[39]:

1. Uniform contact of all teeth around the arch when the mandibular condylar processes are in their most superior position
2. Contact of stable posterior teeth with vertically directed resultant forces
3. Centric relation coincident with maximum intercuspation (intercuspal position)
4. No contact of posterior teeth in lateral or protrusive movements
5. Harmonizing of anterior tooth contacts with functional mandibular movements

To achieve these criteria, it is assumed that (1) a full complement of teeth exists, (2) the supporting tissues are healthy, (3) there is no reverse articulation (crossbite), and (4) the occlusion is Angle class I.

Rationale. At first glance, it might seem illogical to load the single-rooted anterior teeth, as opposed to the multirooted posterior teeth, during chewing. However, the canines and incisors have a distinct mechanical advantage over the posterior teeth[40]: The effectiveness of the force exerted by the muscles of mastication is notably less when the loading contact occurs farther anteriorly.

The mandible is a class III lever (Fig. 4-22), which is the least efficient of lever systems. An example of another class III lever is a fishing pole. The longer the pole, the more effort it takes to pull a fish out of the water. The same holds true for the muscles of mastication and the teeth: The farther anteriorly initial tooth-to-tooth contact occurs (i.e., the longer the lever arm), the less effective the forces exerted by the musculature are, and the smaller the resulting load to which the teeth are subjected. The canine—with its long root, significant amount of periodontal surface area, and strategic position in the dental arch—is well adapted to guiding excursive movements. This function is governed by pressoreceptors in the periodontal ligament: receptors that are very sensitive to mechanical stimulation.[41]

The elimination of posterior contacts during excursions reduces the amount of lateral force to which posterior teeth are subjected. Therefore, molars and premolars in a unilaterally balanced (group function) occlusal arrangement are subjected to greater horizontal and potentially more pathologic force than the same teeth would be in a mutually protected articulation.

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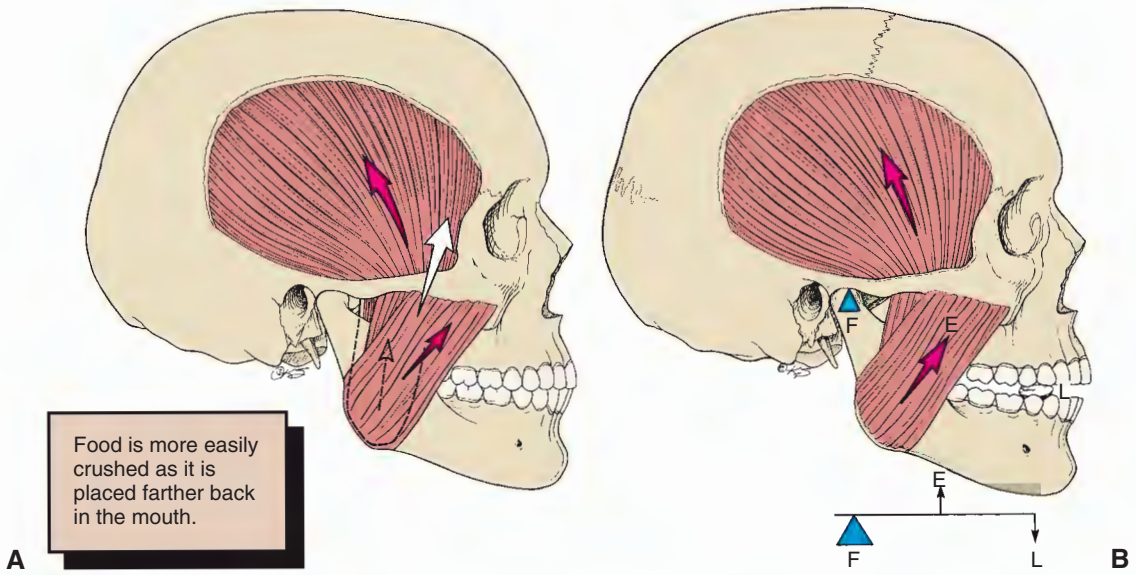

FIGURE 4-22 ■ Lever system of the mandible. **A,** The elevator muscles of the mandible insert anterior to the temporomandibular joints (TMJs) and posterior to the teeth, forming a class III lever system. **B,** The fulcrum *(F)* is the TMJ, the force or effort *(E)* is applied by the muscles of mastication, and the resistance or load *(L)* is food placed between the teeth. The load diminishes as the lever arm increases. Therefore, less load is placed on the anterior teeth than on the posterior teeth.

PATIENT ADAPTABILITY

The adaptive response of individual patients to occlusal abnormalities differs significantly. Some are unable to tolerate seemingly trivial occlusal deficiencies, whereas others are able to tolerate distinct malocclusions without developing obvious symptoms (Fig. 4-23). Most patients seem able to adapt to small occlusal deficiencies without exhibiting acute symptoms.

Lowered Threshold

In patients with a low pain threshold, diagnosis is generally not difficult. They readily identify every pain. A lowered threshold, however, is not to be confused with hypochondria; it is merely an indication of poor adaptability to occlusal discrepancies. The tolerance or adaptability of an individual patient will vary: It is lower at times of emotional stress and general malaise, and clinical symptoms such as severe headaches, muscle spasm, and pain may surface at such times.

Raised Threshold

Individuals who have adapted to existing malocclusions may report being quite comfortable with their dentition, although a number of signs of existing pathologic processes are evident. However, even in the absence of pain or patient complaints, occlusal treatment may be advised to prevent or minimize additional wear on the teeth and further damage to the musculature or TMJs.

PATHOGENIC OCCLUSION

A pathogenic occlusion is an occlusal relationship capable of producing pathologic changes in the stomatognathic system. In such occlusions, disharmony between the teeth and the TMJs is sufficient to result in symptoms that necessitate intervention.

Signs and Symptoms

The presence of a pathogenic occlusion has many indications. Diagnosis is often complicated because patients almost always have a combination of symptoms. Although it is often not possible to prove a direct correlation between specific symptoms and malocclusion, the following symptoms can help confirm this diagnosis.

Teeth

The teeth may exhibit hypermobility, open contacts, or abnormal wear. Hypermobility of an individual tooth or an opposing pair of teeth is often an indication of excessive occlusal force. This may result from premature contact in centric relation or during excursive movements. To detect such contacts, the dentist can place the tip of an index finger on the crown portion of the mobile tooth and ask the patient to repeatedly tap the teeth together. Small amounts of movement (fremitus) that otherwise might not be readily seen can often be felt this way.

Open proximal contacts may be the result of tooth migration because of an unstable occlusion and should prompt further investigation (Fig. 4-24). Diagnostic casts made during previous treatment help the dentist assess any changes in the stability of the occlusion. Abnormal tooth wear, cusp fracture, or chipping of incisal edges may be signs of parafunctional activity.[42,43] However, extensive tooth destruction is often caused by a combination of acid erosion and attrition.[44-46] In these cases, the acid may be present in the diet (e.g., excessive citrus fruit consumption) or endogenous (caused by regurgitation or frequent vomiting).

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FIGURE 4-23 ■ Patient adaptability: None of the four patients described here expressed any functional concern about their occlusion. **A,** Anterior esthetics motivated a 45-year-old woman to seek treatment, although loss of posterior occlusal contact probably contributed to the development of her anterior diastema. **B,** A 26-year-old woman had no complaints or neuromuscular symptoms, despite contacting only on her second and first molars. **C,** A patient with amelogenesis imperfecta sought care for esthetic reasons rather than functional complaints. **D,** A 21-year-old man with congenitally missing lateral incisors had neither functional nor pain complaints when he was referred for fixed prosthodontic care after orthodontic treatment.

FIGURE 4-24 ■ Unstable occlusion. Removal of a tooth without replacement has led to tilting and drifting.

FIGURE 4-25 ■ Widened periodontal ligament space and increased mobility of mandibular molars. Occlusal premature contacts were noted in lateral and protrusive movements.

Periodontium

There is no convincing evidence that chronic periodontal disease is caused directly by occlusal overload. However, a widened periodontal ligament space (detected radiographically) may indicate premature occlusal contact and is often associated with tooth mobility (Fig. 4-25). Similarly, isolated or circumferential periodontal defects are often associated with occlusal trauma. In patients with advanced periodontal disease who have extensive bone loss, rapid tooth migration may occur with even minor occlusal discrepancies. Tooth movement may make it more difficult for these patients to institute proper oral hygiene measures, and the result may be a recurrence of periodontal disease. Precise adjustment of the occlusion is probably more crucial in patients with a compromised crown-to-root ratio than in those with better periodontal support (see Chapter 31).

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Musculature

Acute or chronic muscular pain on palpation can indicate habits associated with tension, such as bruxism or clenching. Chronic muscle fatigue can lead to muscle spasm and pain. In one study,[47] subjects were instructed to grind their teeth for approximately 30 minutes. They experienced muscle pain that typically peaked 2 hours after parafunctioning and lasted as long as 7 days. Asymmetric muscle activity can be diagnosed by observing a patient's opening and closing movements in the frontal plane. A deviation of a few millimeters is quite common, but any deviation larger than this may be a sign of dysfunction and mandates further examination (Fig. 4-26).[48] Restricted opening, or *trismus*, may be a result of the fact that the mandibular elevator muscles are not relaxing.

Temporomandibular Joints

Pain, clicking, or popping in the TMJs can indicate temporomandibular disorders. Clicking and popping may be present without the patient's awareness. A stethoscope is a useful diagnostic aid; one study revealed that joint sounds are generally reliable indicators of temporomandibular disorders.[49] The patient may complain of TMJ pain that is actually of muscular origin and is referred to the joints.

Clicking may also be associated with internal derangements of the joint. A patient with unilateral clicking during opening and closing (reciprocal click) in conjunction with a midline deviation may have a displaced articular disk. The midline deviation typically occurs toward the side of the affected joint because the displaced articular disk can prevent (or slow down) the normal anterior translatory movement of the condyle. For detecting a clicking joint, palpation at the angle of the mandible is generally more effective than palpation over the lateral pole because less tissue is interposed between the clinician's finger and the underlying osseous tissues.

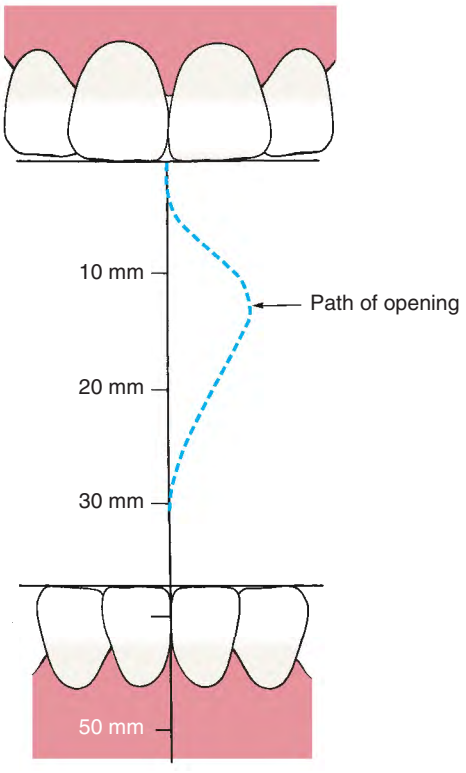

FIGURE 4-26 ■ Midline deviation during opening and closing movements can be indicative of asymmetric muscle activity or joint derangement. In this illustration, during opening, translation is less than optimal on the patient's left side.

Myofascial Pain Dysfunction

The myofascial pain dysfunction (MPD) syndrome manifests as diffuse unilateral pain in the preauricular area, with muscle tenderness, clicking, or popping noises in the contralateral TMJ and limitation of mandibular function. Often the muscles, and not the TMJ, are the primary sites, but over time the functional problem may lead to organic changes in the joint. Three major theories about the cause of MPD are recognized: (1) According to the psychophysiologic theory,[50] MPD results from bruxism and clenching, whereby chronic muscle fatigue leads to muscle spasm and alterations in mandibular movement. Tooth movement may follow, and the malocclusion becomes apparent when spasm is relieved. According to this theory, treatment should focus on emotional rather than physical therapy. (2) According to the muscle theory,[51] continuous muscle hyperactivity is responsible for MPD; pain is referred to the TMJ and other areas of the head and neck region. (3) According to the mechanical displacement theory,[52] malocclusion of the teeth displaces the condyles, and the feedback from the dentition is altered, which results in muscle spasm.

Correct diagnosis and management are often complicated by the concurrent presence of multiple causes. Patients with MPD may require multidisciplinary treatment involving occlusal therapy, medications, biofeedback, and physical therapy. Extensive fixed prosthodontic treatment should be postponed until the patient's conditions have been stabilized at acceptable levels.

OCCLUSAL TREATMENT

When a patient exhibits signs and symptoms that appear to be associated with occlusal interferences (see also section on Definitive Occlusal Treatment in Chapter 6), occlusal treatment should be considered.[53] Such treatment can include tooth movement through orthodontic treatment, elimination of deflective occlusal contacts through selective reshaping of the occlusal surfaces of teeth, or missing tooth restoration and replacement that result in more favorable distribution of occlusal force.

The objectives of occlusal treatment are as follows:

1. To direct the occlusal forces along the long axes of the teeth
2. To attain simultaneous contact of all teeth in centric relation
3. To eliminate any occlusal contact on inclined planes to enhance the positional stability of the teeth
4. To have centric relation coincide with the maximum intercuspation position

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FIGURE 4-27 ■ Occlusal device. **A,** Appearance of device. **B** and **C,** Device in place. (Courtesy Dr. W.V. Campagni.)

5. To arrive at the occlusal scheme selected for the patient (e.g., unilateral balanced versus mutually protected)

In the short term, these objectives can be accomplished with a removable occlusal device (Fig. 4-27) fabricated from clear acrylic resin that overlies the occlusal surfaces of one arch. On a more permanent basis, this can be accomplished through selective occlusal reshaping, tooth movement, the placement of restorations, or a combination of these. Definitive occlusal treatment involves accurate manipulation of the mandible, particularly in centric relation. Because the patient may resist such manipulation as a result of protective muscular reflexes, some type of deprogramming device may be needed (e.g., an occlusal device).

Occlusal Device Therapy

Occlusal devices (sometimes referred to as *occlusal splints*, *occlusal appliances*, or *orthotics*) are used extensively in the management of temporomandibular disorders and bruxism.[1] In controlled clinical trials, they have effectively controlled myofascial pain (i.e., patients report positive changes as a result of the device therapy). However, no clear hypothesis about the mechanism of action has been proved, and none of the various hypotheses (repositioning of condyle or the articular disk, or of both; reduction in masticatory muscle activity; modification of "harmful" oral behavior; and changes in the patient's occlusion) has been consistently supported by scientific studies.[54] From a fixed prosthodontic perspective, occlusal devices are particularly helpful in determining whether a proposed change in a patient's occlusal scheme will be tolerated. The anticipated occlusal scheme is mimicked in an acrylic resin overlay, which allows testing the patient's acceptance through reversible means, although at a slightly increased vertical dimension. If a patient responds favorably to an occlusal device, it is reasonable to assume that the response to restorative treatment will be positive as well. Thus occlusal device therapy can serve as an important diagnostic procedure before initiation of fixed prosthodontic treatment. The device can be made for either the maxillary or mandibular arch. Some clinicians express a preference for one or the other and cite advantages; however, both maxillary and mandibular devices have proved satisfactory.

Fabrication of Device

There are several satisfactory methods for making an occlusal device.[45] One made from heat-polymerized acrylic resin has the advantage of durability, but autopolymerizing resin used alone or in conjunction with a vacuum-formed matrix can serve equally well. Autopolymerizing resin is useful when the dentist needs to make a device at chairside. In Box 4-1, the indirect and direct techniques are compared.

Direct Procedure with a Vacuum-Formed Matrix

1. Adapt a sheet of clear thermoplastic resin to a diagnostic cast, with the use of a vacuum-forming machine. Hard resin (1 mm thick) is suitable. Be sure that excessive undercuts have been blocked out. Trim the excess resin so that all facial soft tissues are exposed. On the facial surfaces of the teeth, the device must be kept well clear of the gingival margins (Fig. 4-28, *A*). On the lingual surface of maxillary devices, the matrix should cover the anterior third of the hard palate for rigidity.
2. Try in the matrix for fit and stability. Add a small amount of autopolymerizing acrylic resin in the incisal region. Using the bimanual manipulation technique, guide the mandible into centric relation (see Chapter 2). Hinge the mandible to make shallow indentations in the resin (see Fig. 4-28, *B*).
3. Add more resin to the incisor and canine regions, and guide the patient's mouth to retrusive, protrusive, and lateral closures in the soft resin. Allow the resin to polymerize. Note that the resin should be allowed to polymerize on the cast or with the appliance in place in the mouth. Otherwise, the

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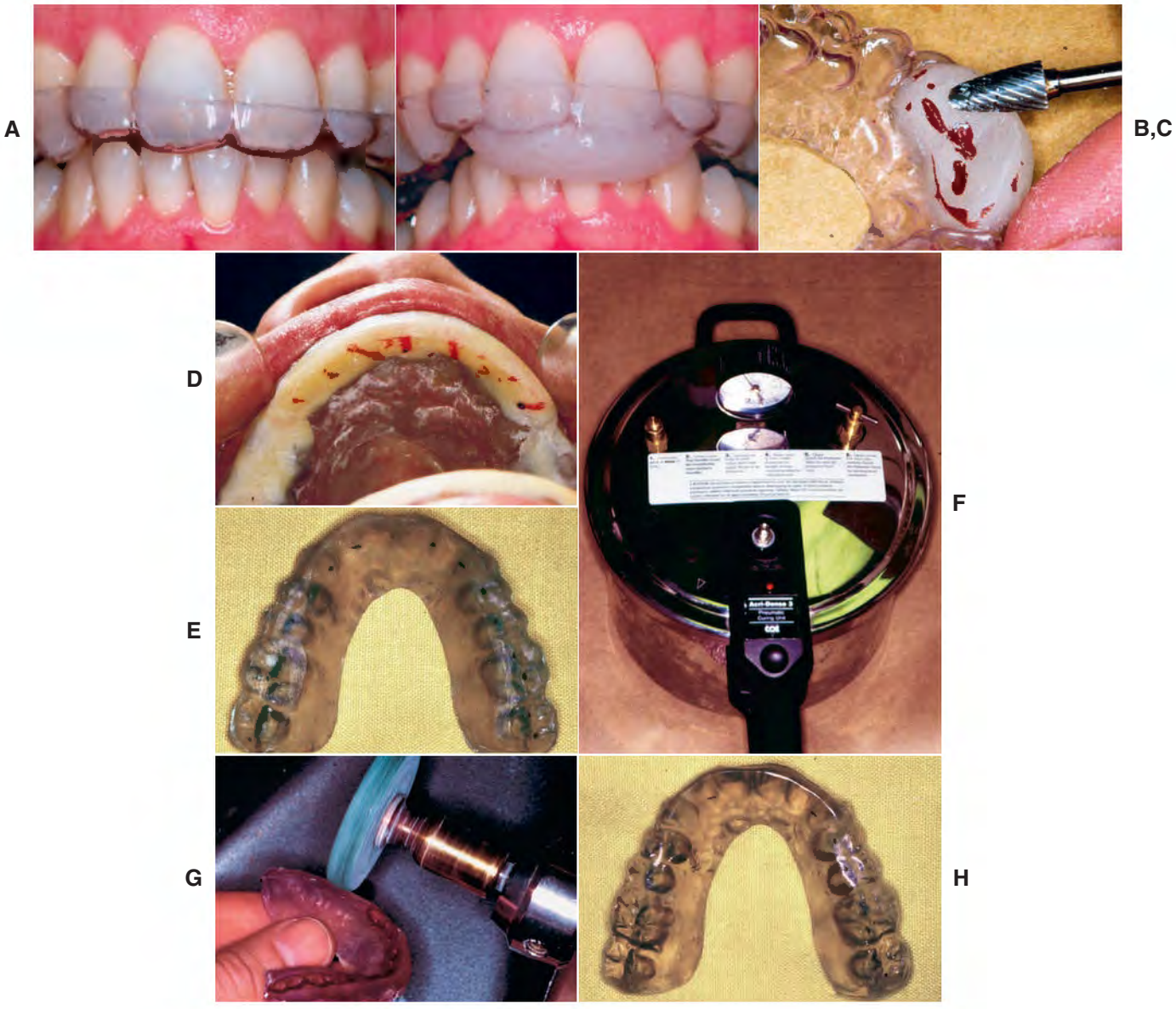

FIGURE 4-28 ■ **A** to **H,** Direct procedure for the fabrication of an occlusal device.

heat generated by polymerization may distort the thermoplastic matrix.

4. With the help of marking ribbon, adjust the resin to provide smooth, even contacts during protrusive and lateral excursions, as well as a definite occlusal stop for each incisor in centric relation (see Fig. 4-28, C). Confine protrusive contacts to the incisors and lateral contacts to the laterotrusive canines (see Fig. 4-28, *D*). All posterior contacts should be relieved at this stage.
5. Have the patient wear the device for a few minutes in the office. Repeated protrusive and lateral movements overcome most problems in mandibular manipulation. On occasion, it is necessary for the patient to wear the device overnight before the acquired protective muscle patterns are overcome. In such cases, if posterior tooth eruption is to be avoided, the patient must be seen again within 24 to 48 hours.
6. Add autopolymerizing acrylic resin to the posterior region of the device, and guide the patient's mouth into centric relation. Hold centric relation until the acrylic resin has polymerized.
7. Remove the device, and examine the impressions of the opposing arch in the resin (see Fig. 4-28, *E*). Polymerization can be accelerated by placement of the device on the cast in warm water in a pressure pot (see Fig. 4-28, *F*).
8. Place pencil marks in the depressions formed by the opposing functional cusps. If a cusp registration is missing, new resin can be added and the device reseated.
9. Remove excess resin with a bur or wheel to leave only the pencil marks (see Fig. 4-28, *G*). All other

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BOX 4-1 Comparison of Occlusal Devices

Indirect Technique (Heat Polymerized)

- More esthetic: plastic is crystal clear
- More dense, less subject to breakage, warping, or wear
- More precise occlusal contacts with use of articulator
- Less chair time at delivery
- Better adaptation to teeth and soft tissues
- Increased laboratory cost (waxing, flasking, finishing)
- Better control of bulk
- Less coverage needed for stability
- Use of ball clasps for retention

Direct Technique (Autopolymerized)

- Can be performed in one appointment
- Involves using the mouth as an articulator, which can introduce errors
- Thinness and flexibility of vacuum-formed matrix, necessitating more coverage for stability
- Chipping and breaking: need for chairside repairs
- Stain, odors, and excess wear because of porosity of acrylic
- Duplicability of device in heat-polymerized resin for greater durability

Courtesy Dr. J.E. Petrie.

contacts must be eliminated if posterior disclusion is to be achieved.

10. Check the device in the patient's mouth for centric relation contacts, marking them with a ribbon. Relieve heavy contacts by continued adjustment until each functional cusp has an even mark.
11. Identify protrusive and lateral excursions with different-colored tape. Adjust excursive contacts as necessary, being careful not to remove the functional cusp stops.
12. Smooth and polish the device, again being careful not to alter the functional surfaces (see Fig. 4-28, *H*).
13. After a period of satisfactory use, the device can be duplicated in heat-polymerized resin with the careful use of a standard denture reline technique.

Indirect Procedure with Autopolymerizing Acrylic Resin

Accurately mounted diagnostic casts are essential for this procedure. A relatively small mounting error can lead to considerable loss of time at try-in. Particular attention must be given to occlusal defects or interfering soft tissue projections on the casts, which could cause errors during mounting.

1. Be sure that the device is made at the same occlusal vertical dimension as the centric relation record. This reduces mounting errors derived from the use of an arbitrary facebow.
2. Fit the articulator with a mechanical incisal guidance table initially set flat.
3. Lower the incisal guide pin until there is approximately 1 mm of clearance between the posterior teeth (Fig. 4-29, *A*). The occlusal vertical dimension should be the same as the one at which the centric relation record was made.
4. Depending on the type of articulator used, it may be necessary to reposition the incisal guidance table after step 3.
5. Check the clearance between opposing casts during protrusive movement of the articulator. Where this is less than 1 mm, increase it by tilting the incisal guidance table.
6. Raise the platform wings of the incisal guidance table so that there is at least 1 mm of clearance in all lateral excursions (see Fig. 4-29, *B*). It may be necessary to raise the incisal pin occasionally to ensure adequate clearance.
7. Mark the height of contour of each tooth on the cast, and block out undercuts with wax (see Fig. 4-29, *C*).
8. Form wire clasps to engage facial undercuts, seal the cast with a separating medium (e.g., Al-Cote), and allow it to dry (see Fig. 4-29, *D*). The opposing cast can be soaked in water to prevent the acrylic resin from sticking to it.
9. Fabricate the device with autopolymerizing clear acrylic resin (see Fig. 4-29, *E*), applied by alternating liquid and powder (see Fig. 4-29, *F*). To avoid porosities, the resin should always be kept wet with monomer and added in small increments (see Fig. 4-29, *G*).
10. While the resin is still soft, close the articulator (see Fig. 4-29, *H*). Add resin where necessary until a slight depression is formed by each functional cusp.
11. Again, while the resin is still soft, close the articulator into protrusive and lateral excursions. Add or remove resin until it is in constant contact with the anterior teeth when the incisal guide pin contacts the incisal guidance table. This adjustment need be only approximate because the working time of the acrylic resin is limited and the occlusal contacts will be refined after the resin has polymerized.
12. Place the device and cast in warm water in a pressure vessel to polymerize. When this is complete, flush wax from the cast with boiling water.
13. Refine the occlusion on the articulator (Fig. 4-29, *I*).
    a. For each functional cusp in centric relation, contact should be even.
    b. A stop should exist for each anterior tooth in centric relation.
    c. Protrusive contact on the incisors should be smooth and even.
    d. Contact should also be smooth and even lateral on the laterotrusive (working side) canines.
14. Remove the device from the cast, and smooth and polish it, taking care not to alter the functional surfaces (see Fig. 4-29, *J*).

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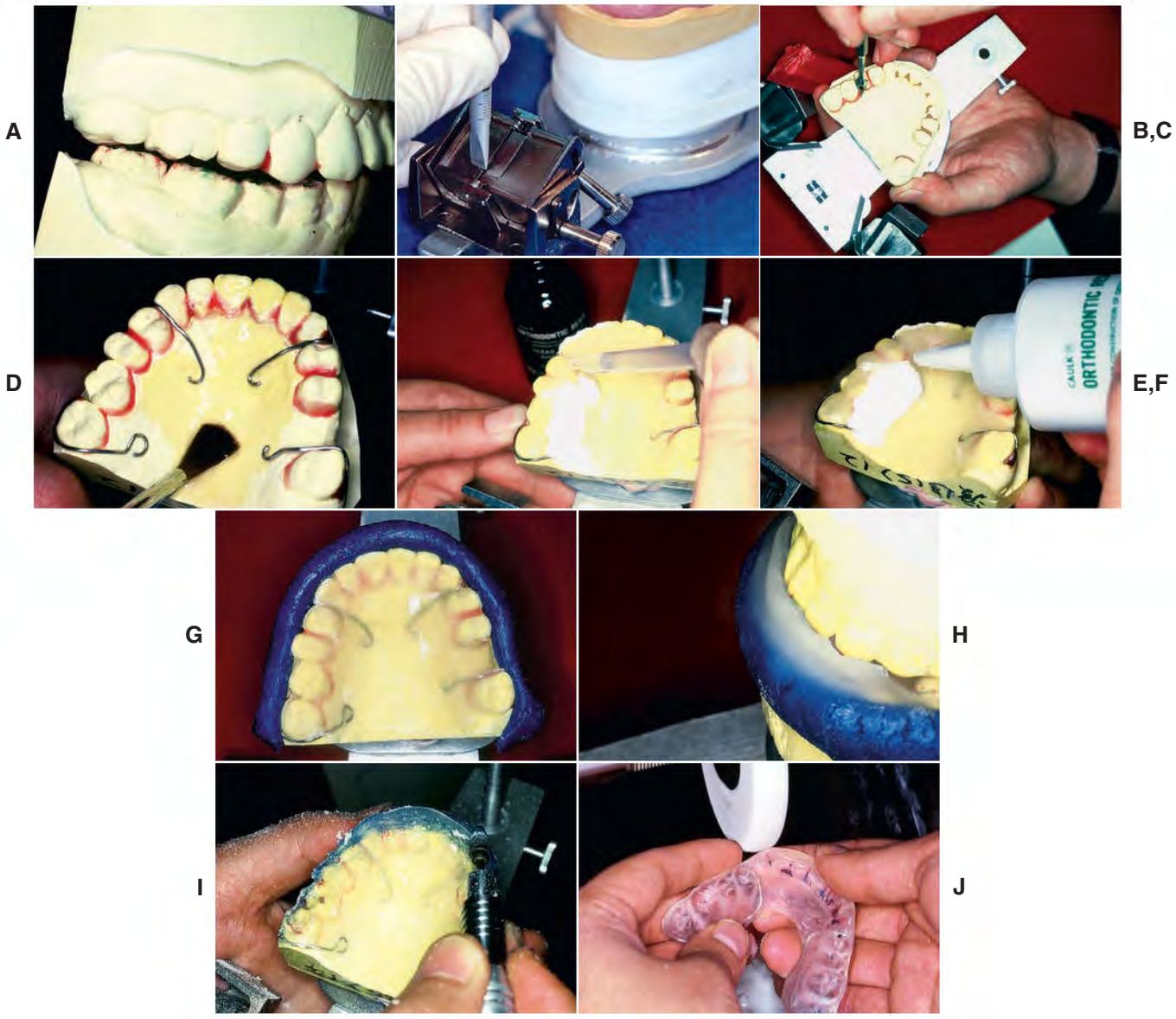

FIGURE 4-29 ■ **A** to **J,** Indirect procedure with autopolymerizing resin for the fabrication of an occlusal device.

15. At try-in, check for fit and stability. Also, check the occlusal contacts and adjust as necessary, using different-colored marking ribbon for centric and eccentric contacts.

Indirect Procedure with Autopolymerizing Resin (Alternative Technique)

1. Obtain accurate casts and an interocclusal record (Fig. 4-30, *A* and *B*).
2. Articulate the casts in centric relation, and adjust the setting of the articulator pin until approximately 2 mm of interocclusal clearance results (see Fig. 4-30, *C* to *E*).
3. Stainless wire clasps (see Fig. 4-30, *F*) and two sheets of baseplate wax are adapted to the maxillary cast (see Fig. 4-30, *G*).
4. Develop an anterior ramp (see Fig. 4-30, *H*), and establish evenly distributed occlusal contact with the mandibular teeth (Fig. 4-30, *I*).
5. Wax sprues are added to the posterior aspect of the completed waxed device (see Fig. 4-30, *J*).
6. Laboratory silicone is adapted over the waxup (see Fig. 4-30, *K* and *L*).
7. After the wax is boiled off the cast, reposition the clasps and lute them in place with some sticky wax (see Fig. 4-30, *M* and *N*).
8. Apply a separating agent to the cast (see Fig. 4-30, *O*).
9. Autopolymerizing resin is then mixed in accordance with manufacturer's instructions; fill the mold cavity between the cast and the repositioned silicone external surface form with the liquid resin (see Fig. 4-30, *P* and *Q*).
10. Place the model in a pressure pot, and allow the resin to cure (see Fig. 4-30, *R*).
11. After the cast is reattached to the articulator, mark and adjust occlusal contacts until a mutually protected articulation is established (see Fig. 4-30, *S* and *T*).

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FIGURE 4-30 ■ **A** to **U,** Alternative technique for occlusal device fabrication with autopolymerizing resin.

12. Remove the completed occlusal device (see Fig. 4-30, *U*) from the cast, and polish it before clinical try-in and delivery.

Indirect Procedure with Heat-Polymerized Acrylic Resin

A more durable device can be made with heat-polymerized acrylic resin. The desired occlusal surface is shaped in wax on articulated diagnostic casts, or the direct device made with a vacuum-formed matrix can be used as a pattern. This is flasked and processed in a manner similar to that for a complete denture. Because of processing errors, it is important to remount the cast and make necessary adjustments before finishing and polishing are completed.

1. Articulate the casts in centric relation. Allow for a remount procedure by notching the base of the cast on which the device will be processed.
2. Create the desired configuration of the device in wax, obtaining centric stops and anterior guidance. Use the mechanical anterior guidance table as for an autopolymerizing resin device.
3. Separate the cast from its mounting and flask as for conventional processing of complete dentures.
4. Process in clear, heat-cured resin.
5. Rearticulate and adjust the occlusion.
6. Remove the stone cast with a shell blaster. Polish the external surfaces on a lathe with pumice and an appropriate polishing compound.
7. Store in 100% humidity.

Attention to Detail

Regardless of the device chosen, success depends very much on meticulous attention to detail during the fabrication and delivery. When a direct device is made, a well-adapted and stable vacuum-formed base should be

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FIGURE 4-30, cont'd

used and the procedure followed exactly. For example, the clinician must be sure that the anterior guidance is properly established and that the patient's mandible can be easily manipulated into the centric relation position before resin is added to the posterior region to record the posterior occlusal stops. When the indirect procedure is used, the casts must articulate to an accurate centric relation record made at the correct occlusal vertical dimension. Inaccurate mounting is probably the most common cause of frustration and excessive adjustments at the time of clinical delivery of the occlusal device.

Follow-up

After the device is delivered to the patient, uniform distribution of occlusal contacts must be verified and the device corrected as necessary. The patient is instructed to wear the device 24 hours a day, removing it only for oral hygiene purposes, and to return at regular weekly and biweekly intervals (or sooner if a problem is perceived) for modification. A reduction in discomfort suggests that definitive occlusal adjustment (see Chapter 6) or restorative dentistry, or both, will probably be successful. If device therapy fails to relieve discomfort, further evaluation and diagnosis of the causes and parameters of the chief complaint should be pursued. A potential diagnostic "red flag" is a patient who initially reports improvement in symptoms but then reports a worsening of the initially resolved complaints. In many of these situations, the possibility of patient noncompliance warrants investigation. In the event that extensive fixed prosthodontics treatment is planned for such an individual, clinicians should proceed cautiously.

DIGITAL SYSTEMS

Manufacturers have made tremendous strides in capturing dynamic mandibular movement and reproducing such in digital format (see Chapter 2). The challenge remains to correctly capture the combined effect of posterior and anterior determinants and to reproduce movement accurately. A limitation of data from computed tomography, magnetic resonance imaging, and cone-beam imaging is that they are static representations. The SICAT Function software system is designed to combine data from three-dimensional radiographic analysis, optical capture, and dynamic mandibular movement recording. This information can be used for diagnostic purposes or to generate a mandibular repositioning device in harmony with the intergraded dataset (Fig. 4-31). Supporting scientific data remain limited at present.

SUMMARY

Mandibular movement depends on certain anatomic limitations. The extremes, called *border movements*, are

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A

B

C

FIGURE 4-31 ■ The SICAT Function software system integrates diagnostic information from a three-dimensional radiographic system, a mandibular motion tracking system with optical impressions (CEREC, Sirona). **A,** The SICAT Jaw Motion Tracker recording equipment. **B,** SiCAT Function software sample screen. The manufacturer reports patient-specific three-dimensional presentation of mandibular motion at any point of the mandible, as well as dynamic reproduction of the condyle-fossa relationship. **C,** SICAT Optimotion treatment device fabricated on the basis of the three-dimensional radiographic data, the optical surface scan data, and the recorded movement data. (Courtesy SICAT GmbH & Co. KG, Bonn, Germany.)

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subject to restriction by the TMJs, ligaments and the teeth. Speech and mastication are examples of *functional movements*. Bruxism and clenching are examples of *parafunctional movements*. These accomplish no purposeful objective and are potentially harmful.

In patients with complete dentures, a balanced occlusion provides stability because there is even contact between all the teeth in each excursion. This is potentially destructive in dentate patients and is contraindicated for fixed prosthodontic treatment. In a unilaterally balanced (group function) occlusion, eccentric occlusal contact occurs only between posterior teeth on the laterotrusive (working) side. This occlusal arrangement may be indicated when it is important to distribute the load over multiple teeth. Mutually protected articulation offers the most desirable load distribution. In this arrangement, centric relation coincides with the maximum intercuspation position, and the relationship of the maxillary and mandibular anterior teeth (the anterior guidance), which results in posterior disclusion in all excursive movements, is instrumental in its success.

In the presence of pathologic processes that are potentially related to malocclusion, occlusal therapy may be indicated. Occlusal devices can serve as useful diagnostic and therapeutic adjuncts to treatment. For such patients, occlusal therapy should be initiated and completed before any substantial restorative care is undertaken.

REFERENCES

1. Okeson JP: Management of Temporomandibular Disorders and Occlusion. 7th ed, St. Louis, Mosby, 2013.
2. Schweitzer JM: Concepts of occlusion: a discussion. Dent Clin North Am 7:649, 1963.
3. Proffit WR, Fields HW Jr: Contemporary Orthodontics, 3rd ed. St. Louis, Mosby, 1999.
4. Bennett NG: A contribution to the study of the movements of the mandible. Odontol Sec R Soc Med Trans 1:79, 1908. (Reprinted in J Prosthet Dent 8:41, 1958.)
5. Posselt U: Movement areas of the mandible, J Prosthet Dent 7:375, 1957.
6. Goldenberg BS, et al: The loss of occlusion and its effect on mandibular immediate side shift. J Prosthet Dent 63:163, 1990.
7. Pelletier LB, Campbell SD: Evaluation of the relationship between anterior and posterior functionally disclusive angles. II. Study of a population. J Prosthet Dent 63:536, 1990.
8. Hayasaki H, et al: A calculation method for the range of occluding phase at the lower incisal point during chewing movements using the curved mesh diagram of mandibular excursion (CMDME). J Oral Rehabil 26:236, 1999.
9. Lundeen HC, Gibbs CH: Advances in Occlusion. Boston, John Wright PSG, 1982.
10. Ogawa T, et al: Inclination of the occlusal plane and occlusal guidance as contributing factors in mastication. J Dent 26:641, 1998.
11. Wickwire NA, et al: Chewing patterns in normal children. Angle Orthod 51:48, 1981.
12. Lavigne G, et al: Evidence that periodontal pressoreceptors provide positive feedback to jaw closing muscles during mastication. J Neurophysiol 58:342, 1987.
13. Burnett CA, Clifford TJ: Closest speaking space during the production of sibilant sounds and its value in establishing the vertical dimension of occlusion. J Dent Res 72:964, 1993.
14. Pound E: The mandibular movements of speech and their seven related values. J Prosthet Dent 16:835, 1966.
15. Pound E: Let /S/ be your guide. J Prosthet Dent 38:482, 1977.
16. Howell PG: Incisal relationships during speech. J Prosthet Dent 56:93, 1986.
17. Rivera-Morales WC, Mohl ND: Variability of closest speaking space compared with interocclusal distance in dentulous subjects. J Prosthet Dent 65:228, 1991.
18. Duckro PN, et al: Prevalence of temporomandibular symptoms in a large United States metropolitan area. Cranio 8:131, 1990.
19. Hathaway KM: Bruxism. Definition, measurement, and treatment. In Fricton JR, Dubner RB, eds: Orofacial Pain and Temporomandibular Disorders. New York, Raven Press, 1995.
20. Hublin C, et al: Sleep bruxism based on self-report in a nationwide twin cohort. J Sleep Res 7:61, 1998.
21. Macaluso GM, et al: Sleep bruxism is a disorder related to periodic arousals during sleep. J Dent Res 77:565, 1998.
22. Madrid G, et al: Cigarette smoking and bruxism. Percept Mot Skills 87:898, 1998.
23. Mongini F, Tempia-Valenta G: A graphic and statistical analysis of the chewing movements in function and dysfunction. J Craniomandib Pract 2:125, 1984.
24. Faulkner KD: Preliminary studies of some masticatory characteristics of bruxism. J Oral Rehabil 16:221, 1989.
25. Mohl ND, et al: Devices for the diagnosis and treatment of temporomandibular disorders. Part I: introduction, scientific evidence, and jaw tracking. J Prosthet Dent 63:198, 1990.
26. Rugh JD, Solberg WK: Electromyographic studies of bruxist behavior before and during treatment. J Calif Dent Assoc 3(9):56, 1975.
27. Lobbezoo F, Lavigne GJ: Do bruxism and temporomandibular disorders have a cause-and-effect relationship? J Orofac Pain 11:15, 1997.
28. Grippo JO: Abfractions: a new classification of hard tissue lesions of teeth. J Esthet Dent 3:14, 1991.
29. Owens BM, Gallien GS: Noncarious dental "abfraction" lesions in an aging population. Compend Contin Educ Dent 16:552, 1995.
30. Sears VH: Balanced occlusions. J Am Dent Assoc 12:1448, 1925.
31. Schuyler CH: Considerations of occlusion in fixed partial dentures. Dent Clin North Am 3:175, 1959.
32. Schuyler CH: An evaluation of incisal guidance and its influence in restorative dentistry. J Prosthet Dent 9:374, 1959.
33. Mann AW, Pankey LD: Concepts of occlusion: the P.M. philosophy of occlusal rehabilitation. Dent Clin North Am 7:621, 1963.
34. Stuart C, Stallard H: Concepts of occlusion. Dent Clin North Am 7:591, 1963.
35. D'Amico A: Functional occlusion of the natural teeth of man. J Prosthet Dent 11:899, 1961.
36. Ogawa T, et al: Pattern of occlusal contacts in lateral positions: canine protection and group function validity in classifying guidance patterns. J Prosthet Dent 80:67, 1998.
37. Bakke M, et al: Occlusal control of mandibular elevator muscles. Scand J Dent Res 100:284, 1992.
38. McDevitt WE, Warreth AA: Occlusal contacts in maximum intercuspation in normal dentitions. J Oral Rehab 24:725, 1997.
39. Dawson PE: Evaluation, Diagnosis, and Treatment of Occlusal Problems, 2nd ed. St. Louis, Mosby, 1989.
40. Stuart CE, Stallard H: Diagnosis and treatment of occlusal relations of the teeth. Texas Dent J 75:430, 1957.
41. Ramfjord S, Ash MM: Occlusion, 4th ed. Philadelphia, WB Saunders, 1994.
42. Ekfeldt A: Incisal and occlusal tooth wear and wear of some prosthodontic materials: an epidemiological and clinical study. Swed Dent J Suppl 65:1, 1989.
43. Imfeld T: Dental erosion. Definition, classification and links. Eur J Oral Sci 104:151, 1996.
44. Lewis KJ, Smith BGN: The relationship of erosion and attrition in extensive tooth loss. Case reports. Br Dent J 135:400, 1973.
45. Rytomaa I, et al: Bulimia and tooth erosion. Acta Odontol Scand 56:36, 1998.
46. Simmons JJ 3rd, Hirsh M: Role of chemical erosion in generalized attrition. Quintessence Int 29:793, 1998.
47. Christensen LV: Facial pain and internal pressure of masseter muscle in experimental bruxism in man. Arch Oral Biol 16:1021, 1971.
48. Ishigaki S, et al: Clinical classification of maximal opening and closing movements. Int J Prosthod 2:148, 1989.
49. Leader JK, et al: The influence of mandibular movements on joint sounds in patients with temporomandibular disorders. J Prosthet Dent 81:186, 1999.
50. Mikami DB: A review of psychogenic aspects and treatment of bruxism. J Prosthet Dent 37:411, 1977.
51. Schwartz LL: A temporomandibular joint pain-dysfunction syndrome. J Chron Dis 3:284, 1956.

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52. Gelb H: An orthopedic approach to occlusal imbalance and temporomandibular dysfunction. Dent Clin North Am 23:181, 1979.
53. Dawson PE: Position paper regarding diagnosis, management, and treatment of temporomandibular disorders. J Prosthet Dent 81:174, 1999.
54. Dao TT, Lavigne GJ: Oral splints: the crutches for temporomandibular disorders and bruxism? Crit Rev Oral Biol Med 9:345, 1998.

STUDY QUESTIONS

1. Discuss the various functions of the mandibular ligaments, and relate them to their respective origins and insertions.

2. Discuss the various functions of the mandibular muscles, and relate them to their respective origins and insertions.

3. What are border movements? Draw and label Posselt's solid.

4. What are the determinants of occlusion, and what do they determine?

5. Give examples of pathologic occlusion, and list five categories with multiple associated symptoms for each category.

6. Describe a mutually protected occlusal scheme, its advantages, and indications. When is a mutually protected articulation undesirable? Why?

7. Discuss typical mandibular movement during normal function and during parafunction. What is the influence of age on chewing patterns?

8. What are the differences between a bilateral balanced occlusion, a unilateral balanced occlusion, and mutual protection?

9. What are the purposes of an occlusal device? Describe a scenario justifying its use, and explain how the device should be designed. Explain your rationale for this design.

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CHAPTER 5

Periodontal Considerations

Robert F. Baima • Rick K. Biethman

Periodontal textbooks comprehensively describe periodontal disease causes, diagnosis, treatment planning, and treatment options and explain in detail the many interactions between oral and systemic health.[1,2] This chapter focuses instead on a review of those portions of periodontal diagnosis and therapy that pertain to comprehensive fixed prosthodontic treatment.

Periodontal therapy is extremely effective. Today, few individuals lose their teeth as a result of untreatable periodontal disease (Fig. 5-1). This statistic may appear to contradict the often-repeated axiom that most tooth loss is caused by periodontal disease. However, individuals with access to proper dental care can retain even compromised teeth for extended periods of time.[3-7] According to data from the 2009 and 2010 National Health and Nutrition Examination Survey (NHANES),[8] only 38.5% of adults in the United States have one or more teeth affected by moderate to severe periodontal disease. The criterion for the diagnosis of moderate to severe periodontal disease was one site with attachment loss of 3 mm or more and pocket depth of 4 mm or more.

Long-term periodontal maintenance studies have shown that of patients with moderate to severe disease referred for periodontal treatment, more than half did not lose a single tooth in two decades of periodontal maintenance, and 75% lost fewer than three teeth.[3,6] This suggests that when proper periodontal treatment is provided, most adults (90% to 95%) will not lose teeth because of periodontal disease. However, although periodontally compromised teeth can be retained over long periods of time, such teeth may not provide a solid foundation to support a fixed dental prosthesis.

When periodontally compromised teeth are lost, it is often as a result of lack of access to effective care. A strong correlation exists between poverty, lack of education, and the presence of periodontal disease.[8,9] The prevalence of periodontal disease among poor patients is 6% higher than in the overall population.[10] Cost of care is a major obstacle in the prevention of tooth loss. Too often, periodontal disease is left untreated because of the patient's inability to afford proper care.

PATHOGENESIS

The pathogenesis of periodontal disease is complex. It involves not only local phenomena in the gingiva, the periodontal ligament, the tooth surface, and the alveolar bone but also a series of complex host response mechanisms modified by the bacterial infection and patient behavioral factors.[11] Implicated in the pathogenic mechanism are phagocytic cells, the lymphoid system, antibodies and immune complexes, complement and clotting cascades, immune reactions, and the microcirculation.

The initial plaque-induced lesion in periodontal disease is termed gingivitis and can be divided into overlapping stages: initial, early, established, and advanced. The salient features and time frame for each stage are presented here.

Initial Lesion

The initial lesion (Fig. 5-2) is localized in the region of the gingival sulcus and is evident after approximately 2 to 4 days of undisturbed plaque accumulation from the baseline of gingival health. The vessels of the gingiva become enlarged, and local vasculitis occurs, allowing a fluid exudate of polymorphonuclear leukocytes to form in the sulcus. Collagen is lost perivascularly, and the resultant space is filled with proteins and inflammatory cells. The most coronal portion of the junctional epithelium becomes altered.

Early Lesion

Although there is no distinct division between the stages of lesion formation, the early lesion (Fig. 5-3) generally appears within 4 to 7 days of plaque accumulation. This stage of development involves further loss of collagen from the marginal gingiva. In addition, gingival sulcular fluid flow increases, with higher numbers of inflammatory cells and accumulation of lymphoid cells subjacent to the junctional epithelium. The basal cells of the junctional epithelium begin to proliferate, and significant alterations are visible in the connective tissue fibroblasts.

Established Lesion

Within 7 to 21 days after plaque accumulation, the lesion enters the established stage (Fig. 5-4). It is still located at the apical portion of the gingival sulcus, and the inflammation is centered in a relatively small area. Loss of connective tissue continues, with persistence of the features of the early lesion. This stage involves a predominance of plasma cells, the presence of immunoglobulins in the connective tissue, and a proliferation of the junctional epithelium (Fig. 5-5). Pocket formation does not necessarily occur.

Advanced Lesion

It is difficult to pinpoint the time at which the established lesion of gingivitis results in a loss of connective tissue attachment to the tooth structure and becomes an advanced lesion, or overt periodontitis (Fig. 5-6). Upon

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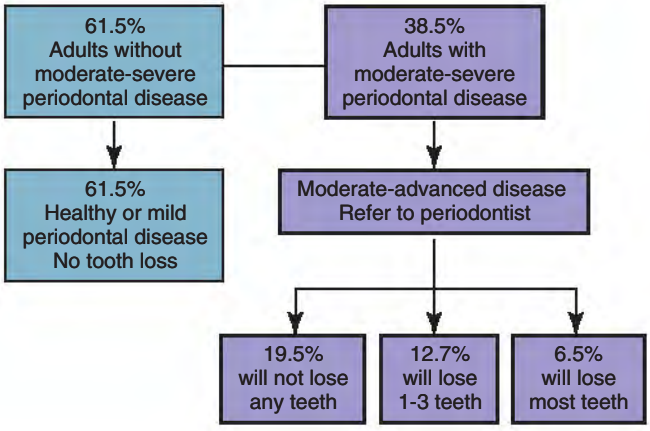

FIGURE 5-1 ■ Combined data from the 2010 National Health and Nutrition Examination Survey (NHANES)[8] and from Hirschfeld and Wasserman's[3] report on 22 years of periodontal maintenance. Approximately 6.5% of the U.S. population have a severe form of periodontal disease that is nonresponsive to current therapy.

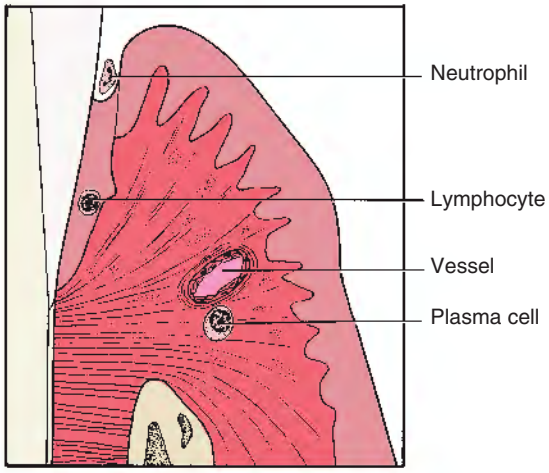

FIGURE 5-2 ■ Illustration of initial lesion of gingivitis-periodontitis. There is a predominance of polymorphonuclear leukocytes in the beginning stages of the inflammation.

conversion to the advanced stage, the features of an established phase persist. The connective tissue continues to lose collagen content, and fibroblasts are further altered. Periodontal pockets are formed, with increased probing depths, and the lesion extends into the alveolar bone. The bone marrow converts to fibrous connective tissue, with a significant loss of connective tissue attachment to the root of the tooth. This conversion is accompanied by the manifestations of immunopathologic tissue reactions and inflammatory responses in the gingiva.

Periodontitis

When connective tissue attachment is lost, the lesion transforms from gingivitis to periodontitis (Fig. 5-7), a disease that may be characterized by alternating periods of quiescence and exacerbation. The extent to which the lesion progresses before it is treated determines the amount of bone and connective tissue attachment loss that occurs. It subsequently affects the prognosis of the tooth with regard to restorative demands.

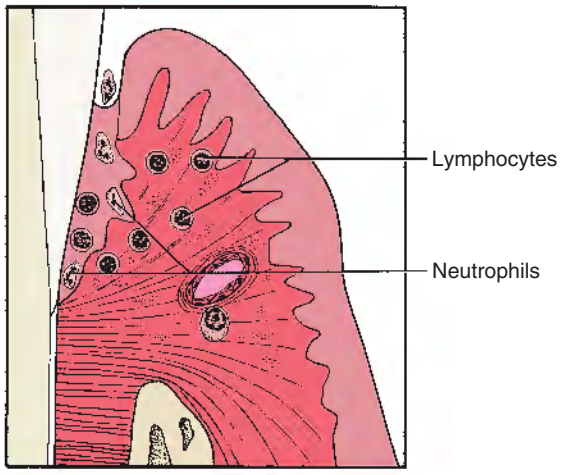

FIGURE 5-3 ■ Illustration of early lesion of gingivitis-periodontitis. The predominant inflammatory cells are lymphocytes subjacent to the junctional epithelium. The epithelium is beginning to proliferate into the rete ridges. (Redrawn from Schluger S, et al: Periodontal Disease: Basic Phenomena, Clinical Management, and Occlusal and Restorative Interrelationships, 2nd ed. Philadelphia, Lea & Febiger, 1990.)

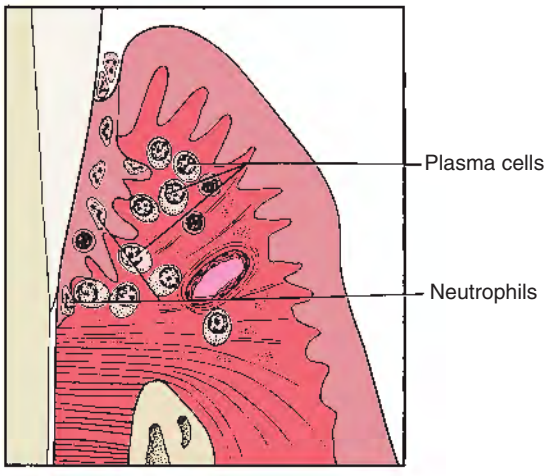

FIGURE 5-4 ■ Illustration of established lesion of gingivitis-periodontitis. The junctional epithelium is converted into pocket epithelium. Pocket formation may begin. The predominant inflammatory cells are plasma cells. (Redrawn from Schluger S, et al: Periodontal Disease: Basic Phenomena, Clinical Management, and Occlusal and Restorative Interrelationships, 2nd ed. Philadelphia, Lea & Febiger, 1990.)

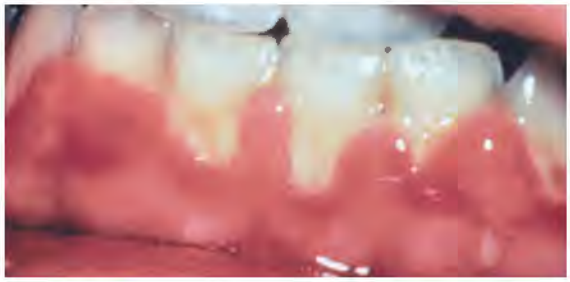

FIGURE 5-5 ■ Advanced gingivitis lesion. The interproximal gingiva is bulbous and inflamed. Note the erythematous and edematous tissue extending onto the labial portion of the lateral incisors.

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Effective periodontal care incorporates three components: (1) effective daily plaque removal by the patient, (2) active therapy to remove calculus and pathologic bacteria from the root surfaces and pocket, and (3) preventive periodontal maintenance therapy (supportive periodontal therapy [SPT]) every 2 to 6 months.[12] Few patients are consistently successful in removing all plaque accumulation. However, a healthy immune system has been shown to be able to compensate for the presence of some residual plaque.[13]

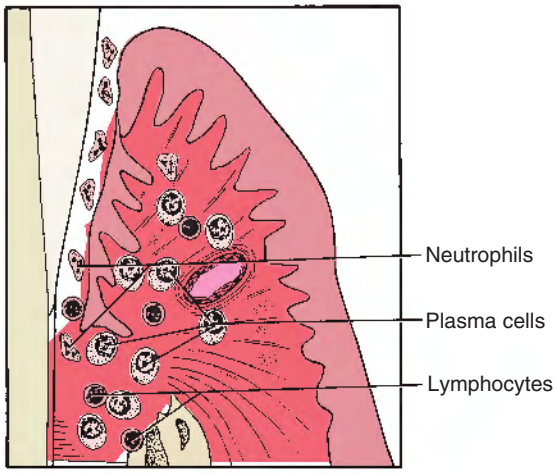

FIGURE 5-6 ■ Illustration of advanced lesion of gingivitis-periodontitis. Pocket formation has begun, with a loss of connective tissue attachment apical to the cementoenamel junction. Bone is converted into fibrous connective tissue and is subsequently lost. The predominant inflammatory cells are plasma cells, and there are scattered lymphocytes present.

FIGURE 5-7 ■ Periodontitis. Plaque and calculus accumulation has resulted in loss of connective tissue attachment apical to the cementoenamel junction.

Periodontal disease is site specific; the distal surface of a tooth may exhibit disease while its mesial surface is healthy (Fig. 5-8).[14] The logical implication is that diagnosis and treatment must also be site specific. Enhanced salivary diagnostic testing has the ability to indicate active bone loss[15] and to detect pathologic bacteria.[16] However, most of these tests are more general, indicating whole mouth values, and high costs preclude their routine use. The most cost-effective, reliable, site-specific indicators of periodontal health are comparison of pocket depths, attachment levels, bleeding on probing (BOP), and tooth mobility over time (Fig. 5-9).[17-19]

Scaling and root planing (SC/RP) remains the foundation of periodontal treatment.[12,20] During active therapy, it results in the greatest gain in attachment level of all possible therapeutic techniques, reasonable pocket depth reduction, decreased BOP, and an improvement in microbial composition. It has been shown to be cost effective, and negative side effects are minimal in comparison with those of all other techniques.[21,22] The objective is to achieve a clean root surface, which can be accomplished with hand instrumentation, an ultrasonic scaler, or a laser. What is important is the quality of the root débridement, not the tool used to achieve the clean surface. Antibiotics are often useful in eliminating pathogenic bacteria not accessible with mechanical therapy.

SC/RP is definitive therapy for most patients. Any therapy that brings about resolution of inflammation—such as improved oral hygiene, antibiotic therapy, SC/RP, laser therapy, or surgery—will result in gingival recession if bone has been lost. This is extremely important to the restorative dentist when precise margin location and gingival symmetry are necessary to achieve a desired esthetic result (Fig. 5-10).

The most frequent indications for surgical periodontal therapy are (1) continued bone loss in a patient who has had SC/RP and is on a 2- to 3-month periodontal maintenance schedule[23] and (2) the need for fixed

FIGURE 5-8 ■ Site-specific nature of periodontal disease. **A,** Pocket depths of teeth #8 to #11. **B,** Severe bone loss is visible on tooth #10, and yet the mesial surface of tooth #11 exhibits only minor changes.

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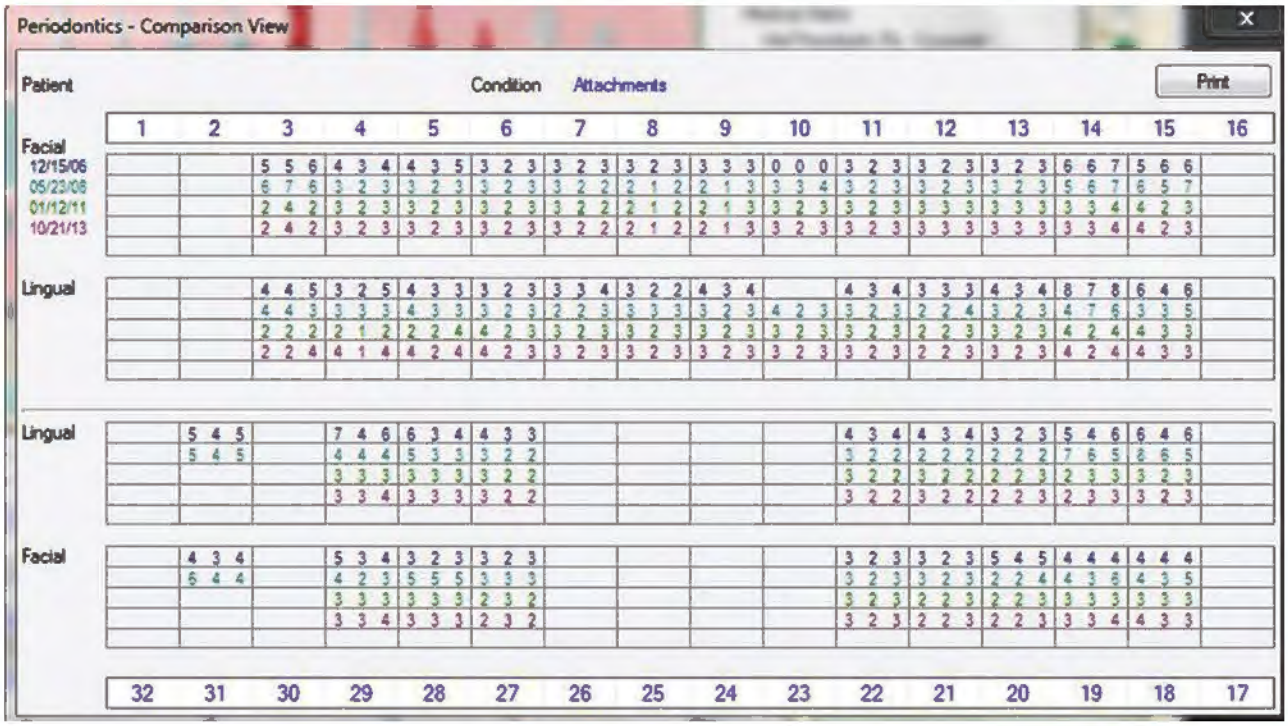

FIGURE 5-9 ■ Comparison of stable attachment levels over a 7-year period of supportive periodontal therapy.

prosthodontic treatment in the posterior quadrants that will result in either a subgingival crown inaccessible for cleaning or a short clinical crown that will have inadequate retention or resistance form.[24] Surgical procedures are designed to allow meticulous cleaning of the root surfaces and to reduce pockets through removal of gingiva or regrowth of bone. However, unless followed by frequent SPT, plaque will reaccumulate in the surgical sites, periodontal disease will recur, and significant attachment will be further lost.[25] Short-term positive changes from various surgical therapies ameliorate over time. After 7 years, results of all therapies, including SC/RP, are similar, with pocket reduction, better attachment levels, and tooth retention.[26,27] Frequent SPT underlies successful periodontal therapy. Without frequent SPT, almost all periodontal therapy will fail.

The time interval for frequent SPT varies according to the individual patient. In most successful long-term studies, 2 to 3 months has been the standard time interval between SPT appointments.[4,28] The appointment interval is then lengthened or shortened according to the results for the individual patient. Treatment at each SPT appointment should be based on comparisons of pocket depths, attachment levels, the presence of BOP, and mobility at the current appointment with those of the previous appointment (Fig. 5-11). An increase of pocket depths or loss of attachment of 2 mm is a reliable indicator that continued periodontal destruction is occurring.[19] The absence of BOP is a reliable indicator of health.[29] Continued BOP at the same site is the best predicator of future attachment loss[30] (Fig. 5-12). Increasing mobility indicates the need for careful analysis of the occlusion and/or endodontic status of the tooth if pocket depths and attachment levels have not changed. Obtaining complete periodontal data at every SPT appointment changes the appointment from a nonspecific teeth cleaning to a site-specific program to maintain periodontal health.

TABLE 5-1 Caries Reduction

Intervention	Significant Reduction in Interproximal Decay
Oral hygiene instruction every 2 weeks	No
Chlorhexidine rinses every 2 weeks	No
Fluoride rinses every 2 weeks	No
Professional tooth cleaning every 2 weeks	Yes

An overlooked benefit of SPT is the concurrent reduction in dental caries that occurs with frequent periodontal maintenance. Several researchers[31,32] evaluated interproximal decay in teenagers. They found that oral hygiene instruction, chlorhexidine rinses, and fluoride rinses performed every 2 weeks had almost no effect on new carious lesions (Table 5-1). A professional cleaning every 2 weeks reduced new decay significantly. In another study,[33] children (aged 3 to 13) of adult patients being treated for periodontal disease were evaluated. These children received cleanings every 6 months for 20 years. No periodontal destruction was seen, and the average rate of caries was one lesion per child over the 20-year interval.

Axelsson and colleagues[34] evaluated the effects of SPT every 2 to 3 months in adults. Fifteen years earlier,

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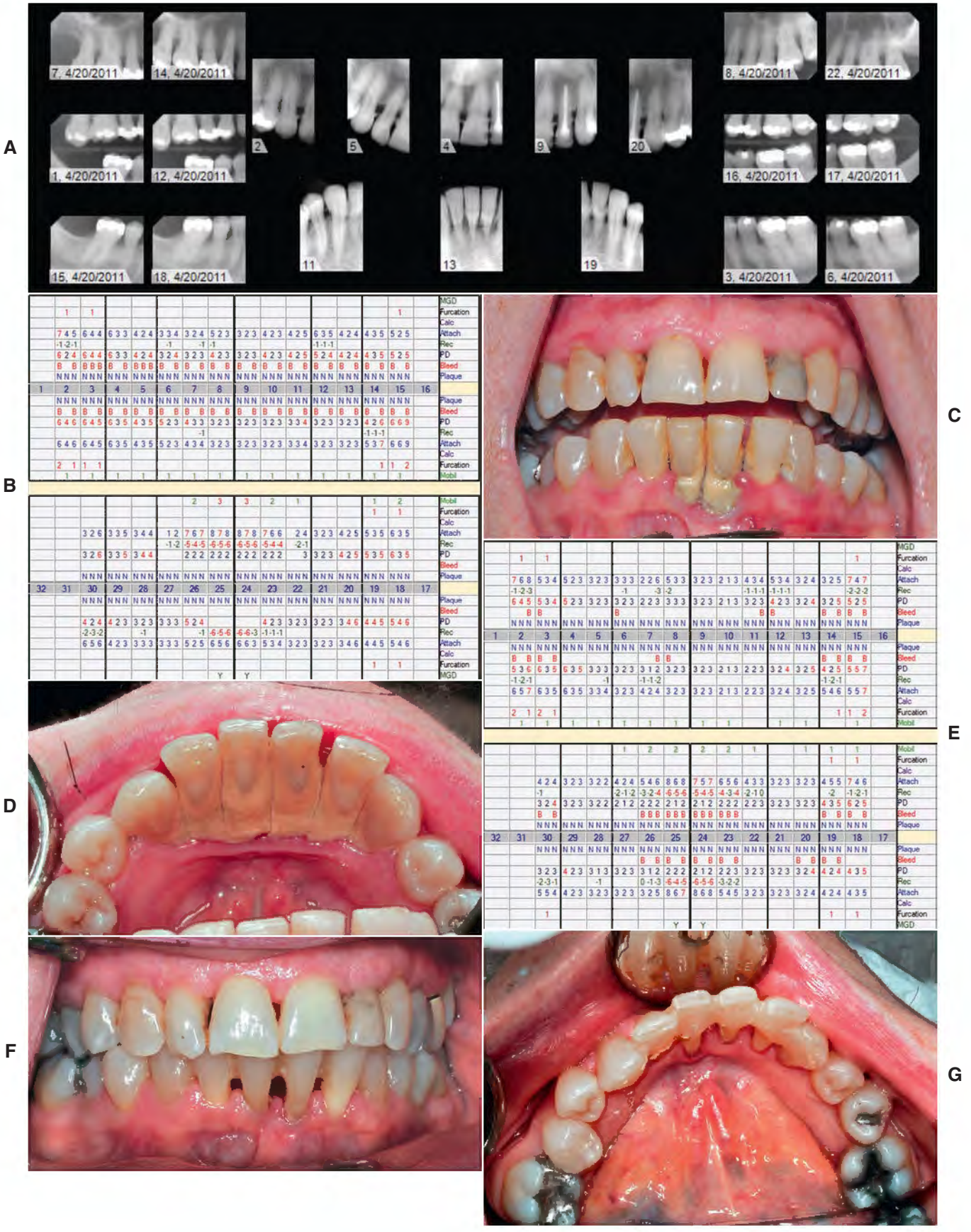

FIGURE 5-10 ■ Resolution of periodontal infection with scaling and root planing (SC/RP) results in a reduction in inflammation and gingival recession. **A** and **B,** Pre-SC/RP radiographs and data showing generalized moderate-to-severe periodontitis. **C** and **D,** Initial presentation. **E,** Post-SC/RP reevaluation data, demonstrating pocket reduction and gingival recession. **F** and **G,** Post-SC/RP appearance, with clinical reduction in inflammation and gingival recession. (**C, D, F,** and **G,** Courtesy Dr. Spencer Shoff.)

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																MGD
		1														Furcation
																Calc
		2 4 2	3 2 3	3 2 3	3 2 3	3 2 2	2 1 2	2 1 3	3 2 3	3 2 3	3 3 3	3 3 3	3 3 4	4 2 3		Attach
		-2									-1	-1	-1			Rec
		2 2 2	3 2 3	3 2 3	3 2 3	3 2 2	2 1 2	2 1 3	3 2 3	3 2 3	3 2 3	3 2 3	3 2 4	4 2 3		PD
																Bleed
		N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N		Plaque
1	2	3	4	5	6	7	8	9 N	10N	11	12	13	14N	15	16	
		N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N	N N N		Plaque
																Bleed
		2 2 4	4 1 4	4 2 4	4 2 3	3 2 3	3 2 3	3 2 3	3 2 3	3 2 3	2 2 3	3 2 3	4 2 4	4 3 3		PD
																Rec
		2 2 4	4 1 4	4 2 4	4 2 3	3 2 3	3 2 3	3 2 3	3 2 3	3 2 3	2 2 3	3 2 3	4 2 4	4 3 3		Attach
																Calc
																Furcation
																Mobil

FIGURE 5-11 ■ Components of a thorough periodontal examination. These items must be evaluated at least on a yearly basis in stable patients and at every periodontal maintenance visit in patients with active disease. *Calc,* calculus; *MGD,* muco gingival defect; *PD,* pocket depth; *Rec,* gingival recession.

Frequency consecutive BOP	Predictive accuracy of future bone loss
0	2%
2	12%
5	93%

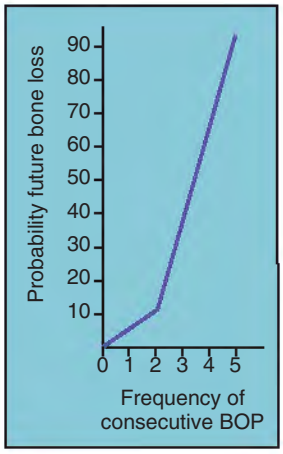

FIGURE 5-12 ■ The absence of bleeding on probing (BOP) is a reliable indicator of periodontal health. Continued BOP at the same site greatly increases the risk of future bone loss.

they had treated 375 adults with SC/RP and caries control. All patients were recalled every 2 to 3 months for 6 years. Of these patients, 95% were stable, with no additional decay or periodontal destruction. For those patients, the recall interval was lengthened to one to two times per year. The 5% of patients who exhibited additional periodontal destruction or new carious lesions continued their recall interval of every 2 to 3 months. After 15 years, all patients who had completed the prescribed recall intervals had maintained a low caries rate and exhibited almost no additional periodontal destruction.[34] A reasonable approach to prevent future decay and periodontal disease is a 2- to 3-month SPT interval for all patients who exhibit active decay or periodontal disease. If the patient experiences no additional decay or periodontal breakdown after 2 years, the SPT interval can be lengthened to 4 to 6 months. The key component of SPT is the meticulous record keeping in which decay, pocket depths, attachment levels, BOP, and mobility at the current appointment was compared with those at the previous appointment; changes are made as necessary.

PROGNOSIS

When prosthetic replacement of missing teeth is necessary, an accurate prognosis of the remaining teeth is essential. The prognosis is the best guess of the course or outcome of the periodontal disease. It comprises (1) the prognosis for the overall dentition and (2) the prognosis for individual teeth. A tentative prognosis is made after a thorough review of the patient's medical and dental histories and clinical findings (Box 5-1). In general, identification of patients with extreme prognoses—either good or hopeless—is reasonably straightforward in comparison with determining a prognosis for patients with prognoses in between. The various guidelines available to predict the future of a tooth with a poor or questionable prognosis are unreliable. Historically, a tooth was considered to have a poor prognosis if it had 50% attachment loss or a class II furcation; a tooth had a questionable prognosis if it had more than 50% attachment loss, a class II or class III furcation, or a poor crown-to-root ratio or poor root form (see Fig. 5-14).[35-38]

The dentist refines the prognosis after observing the response to initial periodontal therapy. Initial therapy includes SC/RP, improvement in oral hygiene, and replacement or recontouring of defective restorations that compromise plaque removal. Initial therapy reduces the bacteria in the sulcus, detoxifies the root surface, and eliminates microenvironments that harbor bacteria, such as calculus and defective restorations. If defective restorations are not corrected during initial therapy, the healing response will be stunted. Decay near the gingiva, marginal overhangs, and open contacts should all be

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corrected before or at the time of SC/RP for maximum gingival healing response (Fig. 5-13). In patients who respond to initial therapy with significant reductions in pocket depths and in BOP, the prognosis is significantly more positive.[39,40]

Time is on the dentist's side in further evaluation of the overall dentition and of specific teeth. When other problems allow, patients should undergo SPT every 2 to 3 months during the first year after initial phase therapy. All urgent dental needs are addressed, and the patient's oral hygiene and maintenance compliance are evaluated during this year. The changes recorded in periodontal health are compared to the reevaluation data. This third refinement of prognosis enables much more accurate planning, allowing comprehensive restorative therapy to be initiated at that time.[41]

Teeth with a poor or questionable prognosis can be maintained for many years. Periodontal disease is site specific, and in most instances, a periodontally compromised tooth does not affect the health of adjacent teeth.[42] When possible, the restorative plan can allow such teeth to remain in place, while only teeth or implants with a good or fair prognosis can be used to support a prosthesis that replaces missing teeth (Fig. 5-14). It may be possible to maintain the teeth in a periodontally compromised but otherwise intact dentition for an extended period of time. However, if that same patient is missing teeth and now requires comprehensive restorative dentistry, strategic extractions may be necessary to improve prosthetic predictability (Fig. 5-15).

If strategic extractions are indicated, it is advisable to consider whether such teeth can serve as interim abutments[43,44] (Fig. 5-16) or for implant site development through orthodontic forced eruption (OFE)[45] (Fig. 5-17). Both procedures may enhance bone and gingival tissue augmentation. Tooth extraction is always followed by

BOX 5-1 Criteria for Consideration in Determining a Periodontal Prognosis

Overall Clinical Factors
- Patient's age
- Disease severity
- Plaque control
- Patient compliance
- Finances available

Local Factors
- Plaque and calculus
- Subgingival restorations
- Tooth crowding
- Root resorption

Tooth Mobility

Systemic and Environmental Factors
- Smoking
- Systemic disease or condition
- Genetic factors
- Stress
- Dry mouth

Anatomic Factors
- Short, conical roots
- Root concavities
- Developmental grooves
- Root proximity
- Furcation involvement

Prosthetic and Restorative Factors
- Abutment selection
- Caries
- Nonvital teeth

FIGURE 5-13 ■ To promote maximum gingival healing after scaling and root planing, open contacts, defective restorations, and decay **(A)** must be corrected **(B)** during the initial phase of periodontal therapy.

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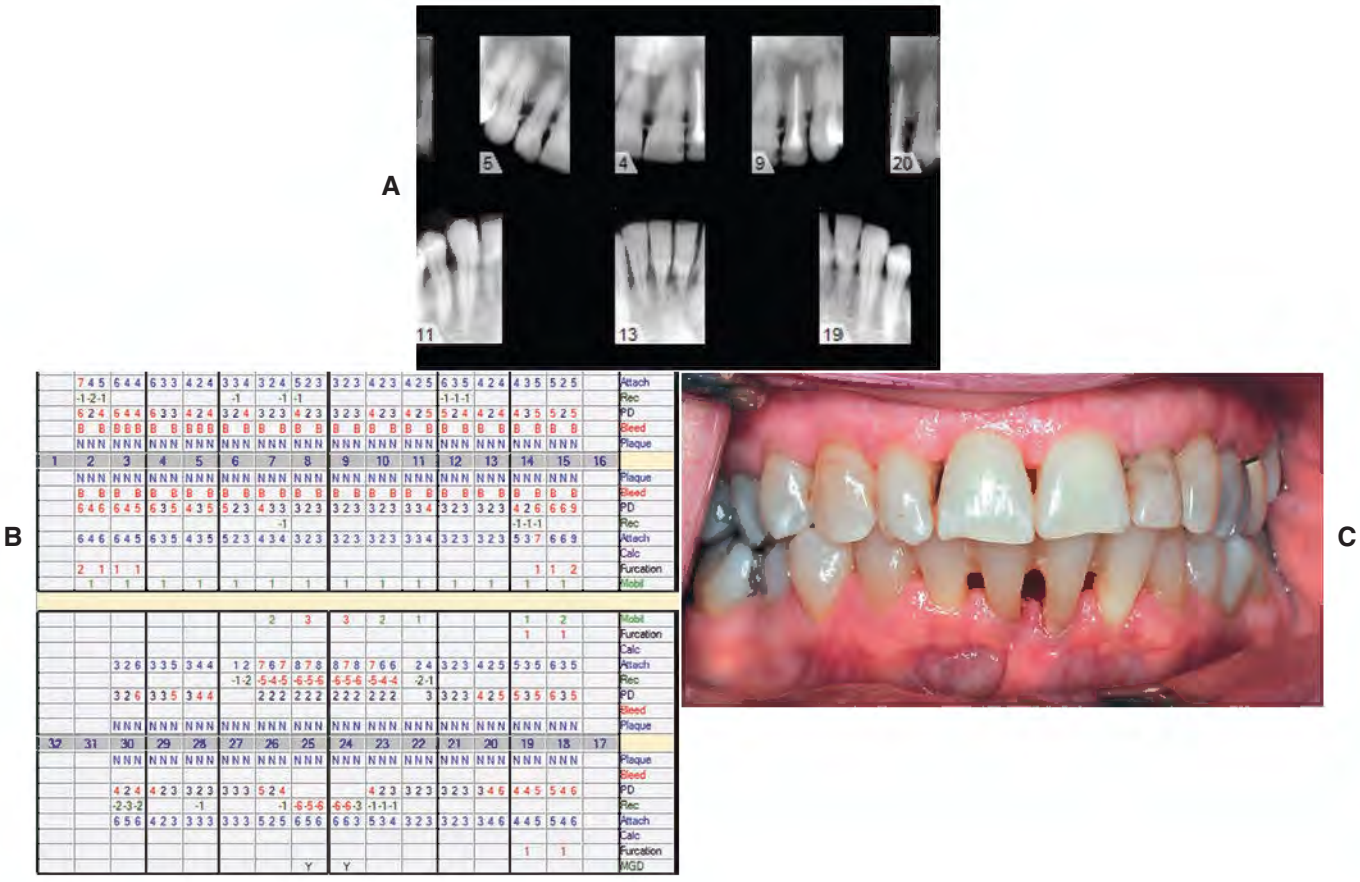

FIGURE 5-14 ■ Teeth with hopeless/poor/questionable prognosis can be successfully maintained for years. **A,** Radiographs indicate that the teeth exhibited minimal restorative needs and were functionally stable after conservative nonsurgical scaling and root planing **(B)** plus resin-bonded splinting of the mandibular anterior teeth **(C)**. Oral hygiene and periodontal maintenance compliance can be evaluated over several years before more definitive treatment is initiated. (Courtesy Spencer J. Shoff)

FIGURE 5-15 ■ Teeth with poor or questionable prognoses. The maxillary right first molar, right first premolar, and left second premolar and the mandibular left first premolar all required extraction. The removal of those teeth was critical for the predictability of the overall restorative plan.

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some loss of crestal bone and gingiva (Fig. 5-18). Before the advent of implants, teeth with a hopeless prognosis were simply extracted. In contrast, retention of teeth, even if temporary, can help retain and augment tissue in anticipated implant sites, improving future esthetics and implant considerations.[46]

BIOLOGIC WIDTH

The normal gingival attachment consists of 1 mm of connective tissue attachment to the root and 1 mm of epithelial adhesion to the root.[47] The combination of connective tissue attachment and epithelial adhesion is termed *biologic width*. Two millimeters is the minimum amount of space that the gingiva needs to attach to the root. In health, sulcus depth varies between 1 mm on the facial and lingual aspects and 2 to 3 mm interproximally (Fig. 5-19). These numbers are averages and do not characterize every patient.[48] Average values are adequate except in situations in which the patient has a thin biotype and anterior esthetic restorations will be placed subgingivally. By probing through the attachment to the bone level and subtracting the sulcus depth, the dentist can determine the biologic width of a specific patient.

FIGURE 5-16 ■ The maxillary right central incisor and maxillary left lateral incisor are used as interim abutments to support a fixed provisional restoration. The fixed provisional restoration protects the surgical site during healing after the bony augmentation procedure. (From Misch CE: Contemporary implant dentistry, 3rd ed. St. Louis, Mosby, 2008.)

Margin Placement

Preparation margins can be supragingival, at the crest, or subgingival. Supragingival and crestal margins are easier to prepare, impress, and finish to a smooth polished surface. This facilitates effective plaque removal and the maintenance of gingival health. In some circumstances, previous restorations, existing decay, esthetics, or retention/resistance needs dictate a subgingival margin.

In comparison with an intact tooth surface, all restorations exhibit open, rough margins that favor plaque retention. The farther the margin is from the gingiva, the easier the access for plaque removal, and the healthier the gingival tissue, will be. A supragingival margin location allows the healthiest gingival response.[49,50] A toothbrush can clean only 0.5 mm subgingivally, floss can clean up to 2.5 mm below the gingiva, and a water irrigation device can clean up to 4 mm below the gingiva (Fig. 5-20; Table 5-2). The majority of patients rely on toothbrushing as their only form of oral hygiene.[51]

Subgingival margins are problematic and should be avoided when possible.[52] Periodontally, a subgingival margin always results in a gingival inflammatory response.[53] This inflammatory response ranges from a mild, subclinical inflammation to an overt inflammatory response with swelling, redness, tenderness, bleeding, and possibly bone loss. The degree of inflammatory response is determined by many factors. Two of these factors, the patient's overall systemic health and the patient's gingival biotype, are beyond a dentist's control. However, by being aware of the patient's systemic health and biotype, the dentist can make choices before the

FIGURE 5-17 ■ A maxillary right central incisor with a hopeless prognosis can be orthodontically forced to erupt in order to develop additional bone and gingiva before extraction. **A,** Initial recession. **B,** Simulated gingival position after 3 months of orthodontic treatment.

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FIGURE 5-18 ■ Congenital absence of maxillary lateral incisors. **A,** The maxillary right central incisor failed and was removed. Note the loss of bone and gingiva *(arrow)* in the right anterior maxilla, where two adjacent teeth are missing. **B,** The bone and gingiva are better preserved *(arrow)* in the left anterior maxilla, where only a single tooth is missing. The patient had a thin biotype; therefore, gingival and bone changes were severe.

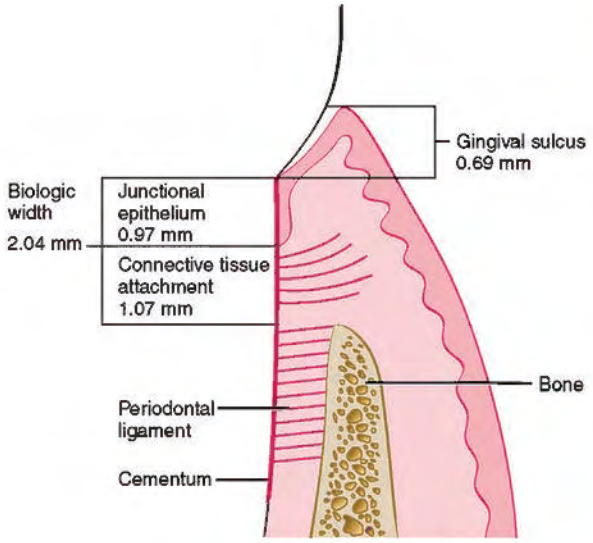

FIGURE 5-19 ■ Average values for biologic width. Any encroachment into this 2.04-mm space will result in an inflammatory reaction. (From Newman MG, et al: Carranza's clinical periodontology, 10th ed. St. Louis, Saunders, 2006.)

TABLE 5-2 **Depths of Plaque Removal for Various Oral Hygiene Devices**

Device	Depth of Subgingival Cleaning
Toothbrush	0.5 mm
Floss	2.5 mm
Water irrigation device	4.0 mm

decision to place a subgingival restoration. The factors under a dentist's control include the extent to which the preparation margin is placed farther apically, the quality of the marginal fit, and the smoothness of the subgingivally placed restorative material.[54]

Margins that fit in the acceptable range and that are placed in a cleansable area provoke only a mild, subclinical inflammatory response. Margins that are significantly open more than 200 µm harbor a large number of bacteria and provoke a larger inflammatory response (Fig. 5-21). Metal, ceramic, and resin margins are equally compatible with gingival health when polished to the same degree of smoothness. The emergence profile of the restoration should follow the tooth anatomy apical to the margin. Gingival health is better maintained if the crown is slightly undercontoured rather than overcontoured.[55] The most frequent reason for overcontouring restoration is insufficient tooth reduction, which forces the technician to overbuild the restoration. A minimum of 3 mm of attached keratinized tissue should be present for gingival health when a restorative margin will be placed subgingivally.[56]

Guidelines for Subgingival Margin Placement

A general guideline is that subgingival margins be placed no more than half the depth of the gingival sulcus. In a healthy periodontal sulcus, the tip of a probe extends approximately 0.5 mm into the epithelial attachment. The base of the healthy sulcus is the most coronal portion of the attachment, and the restorative margin cannot encroach into this attachment. Therefore, if the sulcus probe extends 1 mm, the restoration cannot extend any more than 0.5 mm subgingivally without invading the attachment (biologic width). A shallow healthy sulcus is also less susceptible to recession than are inflamed periodontal tissues. A 3-mm healthy interproximal sulcus allows the margin to be placed 1.0 to 1.25 mm

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FIGURE 5-20 ■ Depths of plaque removal for various oral hygiene devices. Subgingival irrigation with water is more effective than supragingival rinsing with chlorhexidine. **A,** The Waterpik® Classic Water Flosser. **B,** The Waterpik® Cordless Water Flosser. **C,** Pulsation creates two zones of hydrokinetic activity. **D,** Irrigator tips. From left to right: standard jet tip, Pik Pocket subgingival irrigation tip, and cannula. **E,** Study results show that to reduce marginal bleeding and bleeding on probing, oral irrigation *(OI)* with chlorhexidine *(CHX)* or water *(H_2O)* is better than rinsing with chlorhexidine. (**A** and **B,** Courtesy Water Pik, Inc., Fort Collins, Colo. **C** to **E,** From Newman MG, et al: Carranza's clinical periodontology, 10th ed. St. Louis, Saunders, 2006.)

FIGURE 5-21 ■ Open margins noted on mesial and distal maxillary left central and lateral incisors result in a significant inflammatory response with bone loss and destruction of the interdental papilla. **A,** Radiographs. **B,** Appearance.

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FIGURE 5-22 ■ A minimum of 3 mm of attached keratinized tissue must be present when a restorative margin is placed subgingivally. On the facial aspect of the maxillary left anterior teeth, the sulcus depth is 2 mm. Therefore, 5 mm of keratinized tissue must be present.

subgingivally (Fig. 5-22). The deeper the sulcus is, the greater is the potential for gingival recession after any treatment.

Margins at the gingival crest are an acceptable compromise between maintaining gingival health and achieving the esthetic and functional requirements of the restoration. Sometimes it is necessary to compromise further and place the margin 0.5 mm to 1.0 mm subgingivally. Restorative considerations that dictate placement of margins below the gingiva include (1) creating adequate resistance and retention form, (2) allowing the margin to be placed on sound tooth structure below any decay or existing restoration, and (3) masking the tooth/restoration interface in order to mask a color change between the restoration and the tooth. Margins placed deeper than 1 mm create greater difficulty in preparing a smooth margin, in obtaining an accurate impression, and in evaluating the marginal fit of the final restoration; these difficulties will hinder future plaque removal and may impinge on the biologic width.

Tooth preparation margins that are within the attachment create a *biologic width violation* (BWV). The response to the BWV is a function of the bone thickness. BWVs frequently occur at the mesiofacial or the distofacial line angles of maxillary anterior teeth treated with fixed restorations.[47,57]

Gingival Biotype

Variable responses to biologic width invasion are among many responses by different gingival biotypes to trauma. A combination of thin bone with thin gingiva overlying the bone is termed a *thin biotype*.[58] The inflammatory response results in swelling, edema, redness, and bleeding, but in thin biotypes, gingival recession and bone loss occur and a new biologic width is established at a more apical level. A thick gingival biotype characterizes two thirds of the population, and most people with a thick biotype are men (Fig. 5-23). A thin gingival biotype is most often found in women. Thin and thick gingival biotypes can exist within the same mouth. If a probe is placed within the gingival sulcus, and if the biotype is thin, the tip of the probe can be visualized through the sulcus. Patients with thin gingival biotypes are at high risk for gingival recession during any dental procedures (Table 5-3).[59-62]

Correcting or Preventing Biologic Width Violations

BWVs can be corrected either by surgical removal of bone from below the restorative margin and movement of the attachment apically (Fig. 5-24) or by orthodontic movement of the tooth (and preparation margin) coronally away from the attachment (Fig. 5-25). Surgical correction of a BWV is more rapid. The new gingival position is reasonably stable at 3 months. In the posterior quadrants, new margins can be successfully placed 3 months after surgery. In the anterior areas, it is advisable to wait 6 months before final margin placement because of the increased esthetic demands.[24] Surgical correction is seldom done on a single tooth. Bone corrections must be gradual, not an abrupt change. Most often, bone must be removed around three adjacent teeth to correct a single BWV. In the anterior esthetic zone, surgery is often contraindicated unless all teeth would benefit from a longer tooth length (Fig. 5-26). In the posterior quadrants, surgical correction is usually the treatment of choice. Posterior teeth most often demonstrate retention and/or resistance challenges because of short clinical crowns.[63] Frequently existing restorations with subgingival margins are present. The gradual correction of bone over three teeth helps increase crown length and moves many margins from a subgingival position to a crestal or supragingival position, where oral hygiene is more accessible.

Determining the Best Treatment Technique

Lasers and closed surgical techniques have been introduced for selected anterior crown lengthening. Keratinized tissue must be adequate for a gingivectomy to be performed as needed. The bone is removed through the sulcus with hand instruments, rotary instruments, or lasers to reestablish a healthy biologic width 3 mm below

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FIGURE 5-23 ■ **A,** Thick biotype. **B,** Thin bioytpe. Note the minimal amount of keratinized tissue and readily visible blood vessels in the thin biotype.

TABLE 5-3 **Characteristics of Thin Versus Thick Biotype**

Thin Gingival Biotype	Thick Gingival Biotype
Thin marginal bone	Thick marginal bone
Dehiscences and fenestrations found often in underlying bone	Thick bony plates
Narrow zone of keratinized gingiva	Large zone of keratinized gingiva
Gingival thickness: <1.5 mm; width: 3.5-5 mm	Gingival thickness: ≥2.0 mm; width: 5-6 mm
Pronounced scallop of gingiva and bone	Flat gingival and bone scallop
Gingival margins at or below CEJ	Gingival margins above CEJ
Triangular tooth forms	Rectangular tooth forms
Small proximal contacts located near the incisal edge	Broad proximal contacts located more apically
Subtle cervical convexities in crown	Marked cervical convexities in crown
Gingival recession after disease	Deep pocket and intrabony defect formation after disease
>2 mm gingival recession after extraction	Slight (2-mm) gingival recession after extraction
≥2 mm buccal bone loss after extraction	Slight (1-mm) buccal bone loss after extraction
Bone loss and gingival recession after elevation of gingival flap	No apparent bone loss or recession after elevation of gingival flap
Papillas often lost after implant placement	Short, thick papillas maintained after implant placement
Color change of restoration or implant: visible	Color change of restoration or implant: masked in thick tissue

CEJ, Cementoenamel junction.

the restorative margin. This minimally invasive approach is technique sensitive. The resultant root surface is rougher, and troughs are created in thicker bone. Clinically, these findings do not significantly alter the outcomes in comparison to a traditional open-flap approach in carefully selected anterior teeth.[64,65]

An adjunct to surgical crown lengthening is biologic reshaping of the roots during an open-flap approach to crown lengthening. If the previous restorative margins were prepared conservatively, the roots can be reshaped with a diamond bur to eliminate the old margin completely.[66] This technique allows smoothing of rough cement enamel junctions[67] and minimizes root proximities, root grooves, and furcation. Significantly less bone is removed if the roots are biologically shaped. The technique is most effective in the posterior quadrants because of the larger cross-sectional diameter of the posterior teeth.

Teeth requiring surgical crown lengthening must have all caries eliminated, and foundation restorations and interim crowns must be placed before surgery. Complete caries removal is necessary so that the surgeon need not guess where to place the final restorative margin. An interim crown over a solid foundation restoration allows the surgeon complete access to the interproximal bone after the interim restoration is removed.

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FIGURE 5-24 ■ Surgical correction of biologic width violations: interproximal mandibular right second premolar and first molar. **A** and **B,** Initial clinical views. **C,** Provisional restoration in place before surgery. **D,** Short preparations and a lack of ferrule. **E,** Immediate post crown lengthening. **F,** Final restorations placed.

FIGURE 5-25 ■ Orthodontic correction of a biologic width violation (BWV). **A,** Tooth #9 exhibits red, edematous gingiva adjacent to new crown. **B,** Bite-wing radiograph confirms BWV. **C,** Orthodontic treatment is utilized to pull gingiva and bone incisally. **D,** Surgical removal of newly gained gingiva and bone results in correction of BWV and preservation of gingival esthetics. (From Newman MG, et al: Carranza's clinical periodontology, 10th ed. St. Louis, Saunders, 2006.)

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FIGURE 5-26 ■ **A,** Maxillary right central incisor has fractured at the gingiva. **B,** Surgical crown lengthening would necessitate removal of gingiva and bone around all three adjacent teeth (indicated by curved white line). **C,** The result would be longer, uneven teeth.

Crown-lengthening procedures result in a tooth with a thinner cross section at the point where the now-exposed root emerges from the bone and a decreased crown-to-root ratio, both of which leave the tooth more susceptible to fracture. This is especially relevant in the anterior maxilla when subsequent esthetic restorations are planned. A shoulder preparation will now impinge more on the pulpal tissue, and management of larger embrasures interproximally can prove exceptionally challenging.

In the esthetic zones, orthodontic extrusion can minimize the risk for significant gingival changes while correcting BWVs.[68] A slow (1 mm per month), low-force extrusion (15 to 50 g) will bring the alveolar bone and gingiva with the tooth. The tooth is extruded several millimeters beyond the adjacent bone and stabilized for 2 months. The excess gingiva and excess bone are surgically corrected to eliminate the BWV.[69] An alternative approach is rapid orthodontic extrusion, in which the tooth is forced to erupt in the desired location over several weeks. Strong orthodontic forces are used, and a supracrestal fiberotomy (an intrasulcular incision to separate the periodontal ligament from the root surface) is performed every week to prevent the bone and gingiva from following the tooth. The tooth is stabilized for 3 months, and the bone and gingiva are evaluated before the final restoration is undertaken.[70]

PAPILLA

The ideal interdental gingival papilla fills an interproximal embrasure created (1) by the lateral walls of adjacent teeth, (2) coronally by the base of the interproximal contact, and (3) apically by the coronal aspect of the attachment. The clinician can change teeth #1 and #2 with restorative dentistry, with orthodontics, or with both. The tip of the papilla will extend 5 mm above the level of the interproximal bone (3 mm above the attachment) when the interproximal embrasure is ideal.[71]

Spear and Clooney[2] suggested

> *"… viewing the papilla as a balloon of a certain volume sitting on the attachment. The balloon of tissue has a form and height dictated by the gingival embrasure of the teeth. With an embrasure that is too wide, the balloon flattens out, assumes a blunted shape and has a shallow sulcus. If the embrasure is ideal width, the papilla assumes a pointed form, has a sulcus of 2.5 to 3.0 mm and is healthy. If the embrasure is too narrow, the papilla may grow out to the facial and lingual, form a col, and become inflamed."*

This analogy can be applied in evaluating a papilla that does not adequately fill the interproximal embrasure. First, the dentist measures the distance from the papilla tip to the bone crest. If the distance is less than 5 mm, the dentist can compress the balloon by adding restorative material to the mesial and distal tooth walls lateral to the papilla. This will push the balloon (papilla) coronally up to the 5-mm distance from the bone crest. If the distance from the bone to the papilla is 5 mm or greater, the contact point must move apically to the top of the existing papilla (Fig. 5-27). When adjacent roots diverge, the contact point has moved coronally, and the interproximal embrasure is enlarged. Orthodontic movement to parallel the roots will improve the contact location, narrow the embrasure, and result in a taller, more pointed papilla (Fig. 5-28).

OVATE PONTICS

The extraction of a tooth entails removal of the contact point and half the interproximal embrasure; as a consequence, the papilla is not compressed but flattens out, and esthetics are compromised. The papilla can be maintained if at the time of extraction an ovate pontic is created that will provide the contact point and lateral embrasure support that the papilla needs.[2,72] An ovate pontic is inserted 2.5 mm into the extraction site. The size and shape of the ovate pontic should be the same as the tooth that was extracted. A site preservation bone grafting procedure should be performed at the time of the extraction. If the bone levels remain stable, the papilla will also be stable. A well-formed ovate pontic will seal the extraction socket and aid in retaining the bone graft

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FIGURE 5-27 ■ **A,** Papilla does not fill embrasure. **B,** *Arrows* indicate proposed subgingival extension of laminate veneer pushing papilla laterally. **C,** Laminate veneers create long incisal contact. The final result is that the papilla has been forced into a smaller defined shape, which creates a taller, more pointed papilla.

FIGURE 5-28 ■ **A,** The papilla between teeth #8 and #9 does not fill the embrasure. **B,** Radiograph reveals that the roots diverge, which results in a lack of pressure on the papilla. **C,** Brackets are repositioned to bring the roots together. **D,** Radiograph reveals that the roots are now correctly aligned. **E,** The papilla now fills the entire embrasure. (From Newman MG, et al: Carranza's clinical periodontology, 10th ed. St. Louis, Saunders, 2006.)

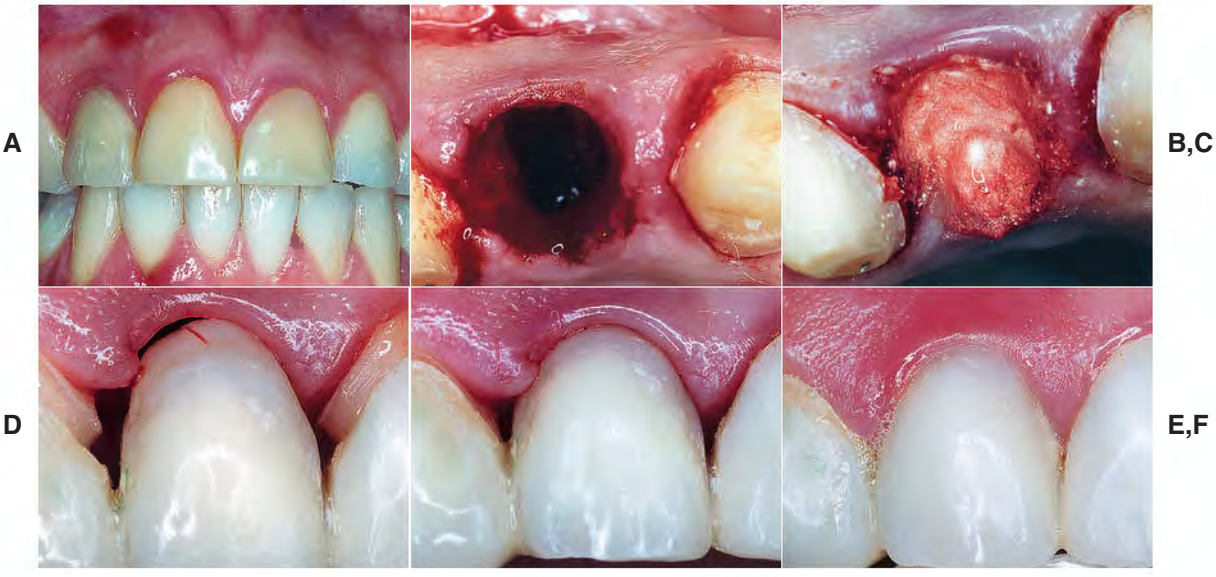

FIGURE 5-29 ■ **A,** Maxillary right lateral incisor has failed despite endodontic treatment. **B,** Socket after atraumatic tooth extraction. **C,** Socket is filled with bone graft. **D,** Provisional fixed partial denture is fabricated. The ovate pontic extends 2.5 mm into the socket and makes an excellent seal of the bone graft, as well as providing lateral support for the gingival papilla. **E,** Healing of extraction site after 8 weeks. **F,** Final restoration with a well-maintained papilla. (From Newman MG, et al: Carranza's clinical periodontology, 10th ed. St. Louis, Saunders, 2006.)

within the socket. After 4 weeks, the ovate pontic should be reduced to extend into the socket 1.5 mm to allow for oral hygiene (Fig. 5-29).

Adequate edentulous ridges can be shaped to support an ovate pontic. The receptor site is created with a diamond rotary instrument, an electrosurgery or radiosurgery unit, or a laser. The receptor site is carved concave in the anterior aspect and slightly flatter in the posterior aspect. For esthetic reasons, the depth should be 1.0 to 1.5 mm on the facial aspect to create the appearance of

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a tooth emerging from a sulcus. The thickness of the gingival tissue between the bone and the newly created site for the ovate pontic must be at least 2 mm, or rebound of the gingiva will occur. If the thickness is less, bone must be removed.

IMPLANT SITE MAINTENANCE AND DEVELOPMENT

Site development for surgical implants in areas with insufficient bone consists of elevation of a gingival flap, placement of a bone graft, covering the bone graft with a barrier membrane, and releasing incisions so that the flap can be elevated over the graft and membrane to allow primary closure. Implant site development is very technique sensitive (Fig. 5-30). The primary closure of the flap has to be maintained for 10 to 12 weeks to ensure maximum bone growth. The gingival tissue is thinned and the blood supply compromised to allow the extra mobility needed for initial primary closure. The placement of a removable prosthesis may inflict additional stress on this delicate area. Similarly, chewing over an unprotected gingival flap increases the risk for exposure of the membrane and bone graft. Teeth that have been deemed to have a poor or hopeless prognosis can often serve as abutments to allow for a fixed provisional restoration that protects the gingival flap.[45]

CONSEQUENCES OF AN EXTRACTION

After a routine extraction, the average bone and gingival loss for a maxillary anterior tooth is 2.0 to 3.5 mm of vertical bone and gingival tissue, along with 1 to 2 mm of buccolingual bone and gingival loss. This loss will cause alterations in gingival margin levels between the prosthetic replacement tooth and the adjacent teeth.[47,73-76] Patients with a thin biotype will develop more recession and bone loss, up to 7.5 mm; those with a thick biotype will have less bone and gingival loss.[77] Various bone grafts alone, or in combination with barrier membranes, have been employed at the time of extraction to prevent bone and gingival loss; collectively, these various techniques are termed *site preservation*. These regenerative measures are partially successful and can minimize bone and gingival loss.[78] In the best-case scenario, a patient with a thick biotype will lose only 1 to 2 mm of vertical bone and gingiva after site preservation techniques in maxillary anterior teeth.[79]

A patient with a thin biotype may lose a severe amount of bone and gingiva (5 to 7 mm) after an atraumatic extraction of a maxillary anterior tooth, in spite of a site preservation procedure.[80] The facial bone thickness is less than 1 mm in thin biotypes, and the compromised blood supply cannot maintain bone vitality during the healing process. In the most challenging scenario, a patient with a thin biotype and a high smile line, displaying 2 to 4 mm of gingiva, is in need of a maxillary anterior extraction. No amount of site preservation or regenerative therapy after an extraction will prevent significant loss of bone and gingiva, which will probably result in an esthetic failure.

In this challenging scenario, OFE can be utilized to force eruption of the "hopeless" tooth 3 mm or more. This will move the gingiva and bone along with the tooth more coronally and loosen the periodontal ligament. As a result, the tooth will be easier to extract, 2 to 4 mm of excessive tissue and bone will undergo the normal post-extraction loss, and gingival levels will match those of the adjacent tooth. This concept of OFE can be taken a step further and used for implant site development in areas lacking sufficient bone, especially in a vertical direction (Fig. 5-31). Amato and colleagues[69] utilized OFE to extrude 32 teeth with hopeless prognoses a mean of 6.2 mm. They were able to gain 4.0 mm of vertical bone height and 3.9 mm of vertical gingival movement. Together with the increase in vertical gingival height, a coronal movement of the papilla was also observed. Light continuous pressure extrudes the teeth 1 to 2 mm per month. Upon completion of the OFE, the tissue should be stabilized for 2 to 3 months before extraction, to allow the bone time to mature and mineralize.[69]

OFE of "hopeless" teeth for implant site development should be considered as equally efficacious as surgical implant site development.[81,82] Augmentation of an edentulous ridge width approximately 3 mm is surgically feasible with particulate bone grafts and barrier membranes. Augmentation of an edentulous ridge height is less feasible unless a vital block of autogenous bone is used.[83-87] Sources of autogenous bone block grafts include the ascending ramus, the chin, the hip, and the femur. Additional tissue to cover the large block grafts is often harvested from the leg before the block graft itself. OFE predictably causes gains in vertical bone height and in keratinized gingival tissue. Lateral augmentation of the newly developed vertical bone height is made much simpler with the additional thick, keratinized gingival tissue.

Orthodontic extrusion results in coronal migration of the gingiva and bone.[69] If the objective is to extrude the tooth but leave the bone and gingiva behind, a supracrestal fiberotomy must be performed every 1 to 2 weeks, along with SC/RP of the remaining periodontal ligament fibers. Light continuous forces should enable orthodontic extrusion of 1 to 2 mm per month. The tooth should be overextruded by 2 mm if it is to be extracted, to allow sufficient bone and soft tissue for subsequent loss.[70]

SUMMARY

Periodontal therapy is successful for most patients. Patients who will lose all or most of their dentition tend to respond poorly to initial periodontal therapy. Likewise, patients who have the most significant periodontal-restorative challenges tend to have a thin gingival biotype. These patients respond in an exaggerated manner to dental care: Often, minor procedures result in gingival recession, and simple extractions may result in severe gingival and bone loss. Early recognition of these difficult situations allows the clinician to plan alternative care to minimize the damage.

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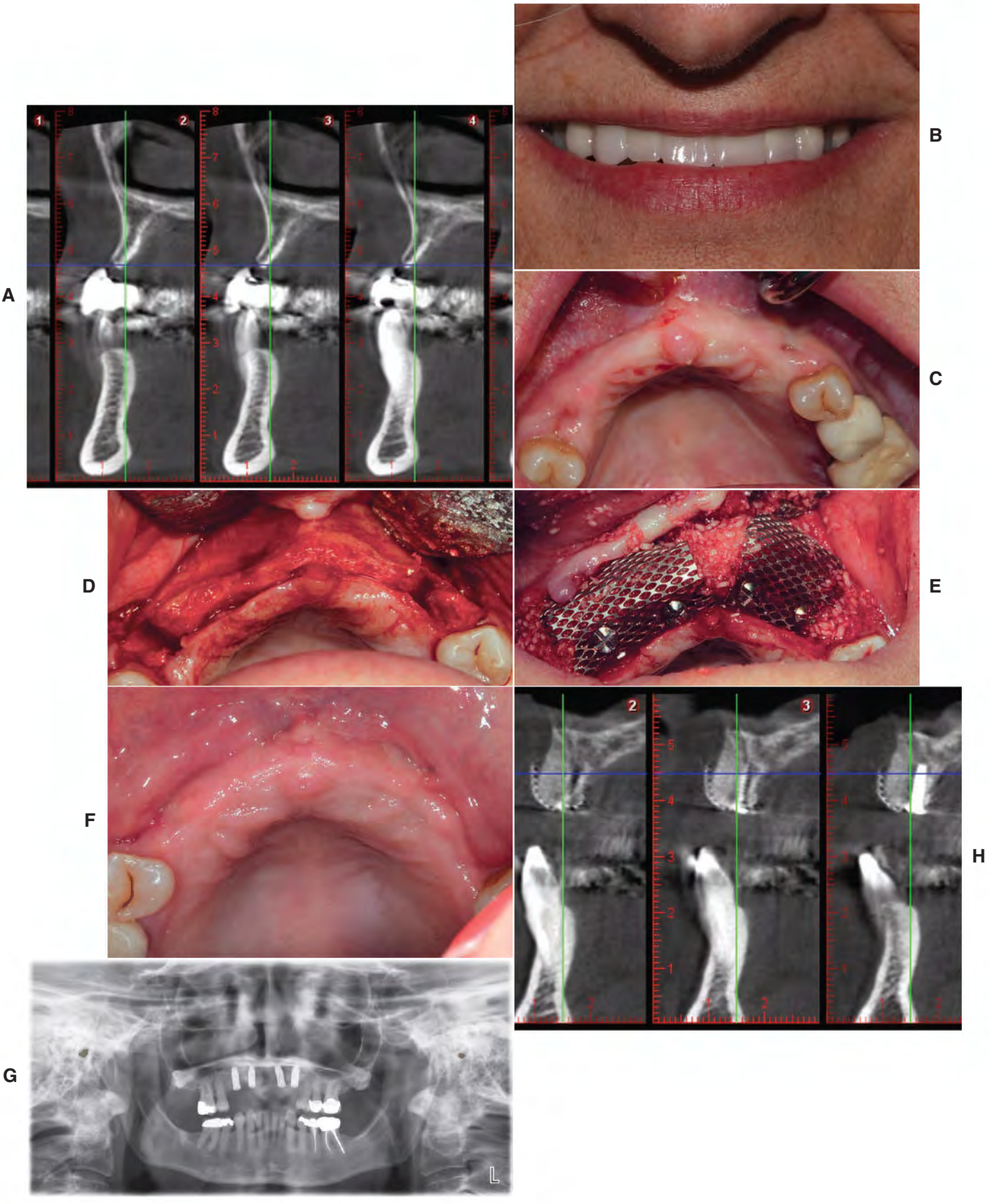

FIGURE 5-30 ■ **A,** Radiographs of severely resorbed maxillary anterior ridge. **B** and **C,** Pretreatment smile and edentulous ridge. **D,** Initial full-thickness flap reflected. **E,** Edentulous ridge has been decorticated, a bone graft has been placed, and two titanium membranes secured with screws provide space and stability. A resorbable membrane will be placed, and the flap will be sutured in layers. **F,** Appearance 4 months after surgery. **G,** Panoramic radiograph of four implants placed in the augmented ridge. **H,** Radiograph of the significant bone growth in comparison with part **A.**

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FIGURE 5-31 ■ **A,** Failing maxillary right central incisor in a patient with a thin biotype and gingival recession. Extraction would create a severe esthetic challenge. **B,** Orthodontic forced eruption (OFE) is initiated to move the tooth incisally and palatally. **C,** Note the improved gingival contour. **D,** Radiographs demonstrating almost 10 mm of OFE. **E,** Illustration of bone development incisally and in width, achieved with OFE. **F,** Implants placed immediately in conjunction with lateral ridge augmentation. **G,** Final esthetic results that would have been very difficult to achieve without the aid of OFE. (From Watanabe T, et al: Creating labial bone for immediate implant placement: a minimally invasive approach by using orthodontic therapy in the esthetic zone. J Prosthet Dent 110:435, 2013.)

REFERENCES

1. Lindhe J, et al: Clinical Periodontology and Implant Dentistry, 5th ed, vol 2. Oxford, U.K., Wiley-Blackwell, 2008.
2. Newman MG, et al, eds: Carranza's Clinical Periodontology, 11th ed. St. Louis, Elsevier/Saunders, 2012.
3. Hirschfeld L, Wasserman B: A long-term survey of tooth loss in 600 treated periodontal patients. J Periodontol 49(5):225, 1978.
4. Bostanci HS, Arpak MN: Long-term evaluation of surgical periodontal treatment with and without maintenance care. J Nihon Univ Sch Dentistry 33(3):152, 1991.
5. Svärdström G, Wennström JL: Periodontal treatment decisions for molars: an analysis of influencing factors and long-term outcome. J Periodontol 71(4):579, 2000.
6. McFall WT Jr: Tooth loss in 100 treated patients with periodontal disease. A long-term study. J Periodontol 53(9):539, 1982.
7. Wood WR, et al: Tooth loss in patients with moderate periodontitis after treatment and long-term maintenance care. J Periodontol 60(9):516, 1989.
8. Eke PI, et al: Prevalence of periodontitis in adults in the United States: 2009 and 2010. J Dent Res 91(10):914, 2012.
9. Kim JK, et al: Prevalence of oral health problems in U.S. adults, NHANES 1999-2004: exploring differences by age, education, and race/ethnicity. Spec Care Dentist 32(6):234, 2012.
10. Dye BA, et al: Trends in oral health status: United States, 1988-1994 and 1999-2004. Vital Health Stat 11 (248):1, 2007.
11. Schroeder HE, Listgarten MA: Fine structure of the developing epithelial attachment of human teeth. Monogr Dev Biol 2:1, 1971.
12. Slots J: Low-cost periodontal therapy. Periodontol 2000 60(1):110, 2012.
13. Drisko CH: Nonsurgical periodontal therapy. Periodontol 2000 25:77, 2001.
14. Reddy MS, et al: Periodontal disease progression. J Periodontol 71(10):1583, 2000.
15. Kinney JS, et al: Oral fluid-based biomarkers of alveolar bone loss in periodontitis. Ann N Y Acad Sci 1098:230, 2007.

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همیار دندانسازان و دندانپزشکان

16. Belstrøm D, et al: Differences in bacterial saliva profile between periodontitis patients and a control cohort. J Clin Periodontol 41(2):104, 2014.
17. Weinberg MA, Hassan H: Bleeding on probing: what does it mean? Gen Dent 60(4):271, 2012.
18. Goodson JM: Diagnosis of periodontitis by physical measurement: interpretation from episodic disease hypothesis. J Periodontol 63(4 Suppl):373, 1992.
19. Listgarten MA: Periodontal probing: what does it mean? J Clin Periodontol 7(3):165, 1980.
20. Heitz-Mayfield LJA, Lang NP: Surgical and nonsurgical periodontal therapy. Learned and unlearned concepts. Periodontol 2000 62(1):218, 2013.
21. Sanz I, et al: Nonsurgical treatment of periodontitis. J Evid Based Dent Pract 12(3 Suppl):76-86, 2012.
22. Hallmon WW, Rees TD: Local anti-infective therapy: mechanical and physical approaches. A systematic review. Ann Periodontol 8(1):99, 2003.
23. McLeod DE: A practical approach to the diagnosis and treatment of periodontal disease. J Am Dent Assoc 131(4):483, 2000.
24. Hempton TJ, Dominici JT: Contemporary crown-lengthening therapy: a review. J Am Dent Assoc 141(6):647, 2010.
25. Nyman S, et al: Periodontal surgery in plaque-infected dentitions. J Clin Periodontol 4(4):240, 1977.
26. Rylander H: Changing concepts of periodontal treatment: surgical and non-surgical. Int Dent J 38(3):163, 1988.
27. Pihlstrom BL, et al: Comparison of surgical and nonsurgical treatment of periodontal disease. A review of current studies and additional results after $6\frac{1}{2}$ years. J Clin Periodontol 10(5):524, 1983.
28. Dentino A, et al: Principles of periodontology. Periodontol 2000 61(1):16, 2013.
29. Lang NP, et al: Absence of bleeding on probing. An indicator of periodontal stability. J Clin Periodontol 17(10):714, 1990.
30. Lang NP, et al: Bleeding on probing. A predictor for the progression of periodontal disease? J Clin Periodontol 13(6):590, 1986.
31. Axelsson P, et al: The effect of various plaque control measures on gingivitis and caries in schoolchildren. Community Dent Oral Epidemiol 4(6):232, 1976.
32. Axelsson P, Lindhe J: Effect of oral hygiene instruction and professional toothcleaning on caries and gingivitis in schoolchildren. Community Dent Oral Epidemiol 9(6):251, 1981.
33. Chambrone L, Chambrone L: Results of a 20-year oral hygiene and prevention programme on caries and periodontal disease in children attended at a private periodontal practice. Int J Dent Hyg 9(2):155, 2011.
34. Axelsson P, et al: On the prevention of caries and periodontal disease. J Clin Periodontol 18(3):182, 1991.
35. Persson GR: Perspectives on periodontal risk factors. J Int Acad Periodontol 10(3):71, 2008.
36. Page RC, Beck JD: Risk assessment for periodontal diseases. Int Dent J 47(2):61, 1997.
37. Garcia RI, et al: Risk calculation and periodontal outcomes. Periodontol 2000 50:65, 2009.
38. Halperin-Sternfeld M, Levin L: Do we really know how to evaluate tooth prognosis? A systematic review and suggested approach. Quintessence Int 44(5):447, 2013.
39. Aimetti M: Nonsurgical periodontal treatment. Int J Esthet Dent 9(2):251, 2014.
40. Segelnick SL, Weinberg MA: Reevaluation of initial therapy: when is the appropriate time? J Periodontol 77(9):1598, 2006.
41. Claffey N, Egelberg J: Clinical indicators of probing attachment loss following initial periodontal treatment in advanced periodontitis patients. J Clin Periodontol 22(9):690, 1995.
42. Wojcik MS, et al: Retained "hopeless" teeth: lack of effect periodontally-treated teeth have on the proximal periodontium of adjacent teeth 8-years later. J Periodontol 63(8):663, 1992.
43. Chronopoulos V, et al: Tooth- and tissue-supported provisional restorations for the treatment of patients with extended edentulous spans. J Esthet Restor Dent 21(1):7, 2009.
44. Cortes A, et al: Transition from failing dentition to full-arch fixed implant-supported prosthesis with a staged approach using removable partial dentures: a case series. J Prosthodont 23(4):328, 2014.
45. Rokn AR, et al: Implant site development by orthodontic forced eruption of nontreatable teeth: a case report. Open Dent J 6:99, 2012.
46. Horowitz F, et al: A review on alveolar ridge preservation following tooth extraction. J Evid Based Dent Pract 1(3 Suppl):149, 2012.
47. Schmidt JC, et al: Biologic width dimensions—a systematic review. J Clin Periodontol 40(5):493, 2013.
48. Smith RG, et al: Variations in the clinical sulcus depth of healthy human gingiva: a longitudinal study. J Periodont Res 31(3):181, 1996.
49. Valderhaug J, Heloe LA: Oral hygiene in a group of supervised patients with fixed prostheses. J Periodontol 48(4):221, 1977.
50. Moretti LAC, et al: The Influence of restorations and prosthetic crowns finishing lines on inflammatory levels after non-surgical periodontal therapy. J Int Acad Periodontol 13(3):65, 2011.
51. Drisko CL: Periodontal self-care: evidence-based support. Periodontol 2000 62(1):243, 2013.
52. Schätzle M, et al: The influence of margins of restorations on the periodontal tissues over 26 years. J Clin Periodontol 28(1):57, 2001.
53. Reeves WG: Restorative margin placement and periodontal health. J Prosthet Dent 66(6):733, 1991.
54. Felton DA, et al: Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent 65(3):357, 1991.
55. Kosyfaki P, et al: Relationship between crowns and the periodontium: a literature update. Quintessence Int 41(2):109, 2010.
56. Maynard JG Jr, Wilson RD: Physiologic dimensions of the periodontium significant to the restorative dentist. J Periodontol 50(4):170, 1979.
57. Nugala B, et al: Biologic width and its importance in periodontal and restorative dentistry. J Conserv Dent 15(1):12, 2012.
58. Sanavi F, et al: Biologic width and its relation to periodontal biotypes. J Esthet Dent 10(3):157, 1998.
59. Esfahrood ZR, et al: Gingival biotype: a review. Gen Dent 61(4):14, 2013.
60. Cook DR, et al: Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. Int J Periodontics Restorative Dent 31(4):345, 2011.
61. Lee A, et al: Soft tissue biotype affects implant success. Implant Dent 20(3):e38, 2011.
62. De Rouck T, et al: The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva. J Clin Periodontol 36(5):428, 2009.
63. Sharma A, et al: Short clinical crowns (SCC)—treatment considerations and techniques. J Clin Exp Dent 4(4):e230, 2012.
64. Braga G, Bocchieri A: A new flapless technique for crown lengthening after orthodontic extrusion. Int J Periodontics Restorative Dent 32(1):81, 2012.
65. McGuire MK, Scheyer ET: Laser-assisted flapless crown lengthening: a case series. Int J Periodontics Restorative Dent 31(4):357, 2011.
66. Tucker LM, et al: Combining perio-restorative protocols to maximize function. Gen Dent 60(4):280, 2012.
67. Satheesh K, et al: The CEJ: a biofilm and calculus trap. Compend Contin Educ Dent 32(2):30, 2011.
68. Sabri R: [Crown lengthening by orthodontic extrusion. Principles and technics]. J Parodontol 8(2):197, 1989.
69. Amato F, et al: Implant site development by orthodontic forced extraction: a preliminary study. Int J Oral Maxillofac Implants 27(2):411, 2012.
70. Kozlovsky A, et al: Forced eruption combined with gingival fiberotomy. A technique for clinical crown lengthening. J Clin Periodontol 15(9):534, 1988.
71. Tarnow DP, et al: The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol 63(12):995, 1992.
72. Zitzmann NU, et al: The ovate pontic design: a histologic observation in humans. J Prosthet Dent 88(4):375, 2002.
73. Malchiodi L, et al: Evaluation of the esthetic results of 64 nonfunctional immediately loaded postextraction implants in the maxilla: correlation between interproximal alveolar crest and soft tissues at 3 years of follow-up: esthetic evaluation of 64 immediately loaded postextraction implants. Clin Implant Dent Relat Res 15(1):130, 2013.
74. Den Hartog L, et al: Treatment outcome of immediate, early and conventional single-tooth implants in the aesthetic zone: a systematic review to survival, bone level, soft-tissue, aesthetics and patient satisfaction. J Clin Periodontol 35(12):1073, 2008.

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75. Thalmair T, et al: Dimensional alterations of extraction sites after different alveolar ridge preservation techniques—a volumetric study. J Clin Periodontol 40(7):721, 2013.
76. Wang RE, Lang NP: Ridge preservation after tooth extraction. Clin Oral Implants Res 23(Suppl 6):147, 2012.
77. Chen ST, Buser D: Clinical and esthetic outcomes of implants placed in postextraction sites. Int J Oral Maxillofac Implants 24(Suppl):186, 2009.
78. Cardaropoli D, et al: Relationship between the buccal bone plate thickness and the healing of postextraction sockets with/without ridge preservation. Int J Periodontics Restorative Dent 34(2):211, 2014.
79. Ferrus J, et al: Factors influencing ridge alterations following immediate implant placement into extraction sockets. Clin Oral Implants Res 21(1):22, 2010.
80. Chappuis V, et al: Ridge alterations post-extraction in the esthetic zone: a 3D analysis with CBCT. J Dent Res 92(12 Suppl):195S, 2013.
81. Eliasova P, et al: Implant site development in the distal region of the mandible: bone formation and its stability over time. Am J Orthod Dentofacial Orthop 145:333, 2014.
82. Barros L, et al: Six-year follow-up of maxillary anterior rehabilitation with forced orthodontic extrusion: achieving esthetic excellence with a multidisclipinary approach. Am J Orthod Dentofacial Orthop 144:607, 2013.
83. Khojasteh A, et al: Clinical importance of recipient site characteristics for vertical ridge augmentation: a systematic review of literature and proposal of a classification. J Oral Implantol 39(3):386, 2012.
84. Zakhary IE, et al: Alveolar ridge augmentation for implant fixation: status review. Oral Surg Oral Med Oral Pathol Oral Radiol 114(5 Suppl):S179, 2012.
85. Urban IA, et al: Vertical ridge augmentation using guided bone regeneration (GBR) in three clinical scenarios prior to implant placement: a retrospective study of 35 patients 12 to 72 months after loading. Int J Oral Maxillofac Implants 24(3):502, 2009.
86. Jensen SS, Terheyden H: Bone augmentation procedures in localized defects in the alveolar ridge: clinical results with different bone grafts and bone-substitute materials. Int J Oral Maxillofac Implants 24(Suppl):218, 2009.
87. Chiapasco M, et al: Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants 24(Suppl):237, 2009.

STUDY QUESTIONS

1. Discuss and compare the 10-year success of surgical pocket reduction surgery versus scaling and root planning.

2. Two- to three-month supportive periodontal maintenance (SPT) is effective in reducing the reoccurrence of periodontal disease in most patients. What other benefits occur as a result of frequent SPT?

3. Teeth with a questionable periodontal prognosis can often be maintained for a considerable time period. Please discuss how this affects the restorative treatment options.

4. Discuss the effect of thick or thin gingival biotype on the amount of anticipated gingival recession after an anterior extraction.

5. Describe the effect on crown-to-root ratio of surgical crown lengthening versus orthodontic forced eruption.

6. At the time of extraction of a maxillary central incisor, is a socket preservation bone graft sufficient to preserve the gingival papilla?

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CHAPTER 6

Mouth Preparation

As the scope of fixed prosthodontics continues to expand, it is increasingly clear that failures often result from inadequate or incomplete mouth preparation. Mouth preparation refers to procedures that must be accomplished before fixed prosthodontic treatment can be properly undertaken. Rarely are crowns or fixed dental prostheses provided without some initial therapy, often of a multidisciplinary nature, because what causes the need for fixed prostheses also promotes other pathologic processes (caries and periodontal disease being the most common). These problems must be corrected in the early preparatory phase of treatment to stabilize the residual dentition and prevent further deterioration. Fixed prosthodontic treatment is successful only if restorations are placed on caries-free, well-restored teeth in a healthy environment, a fact that can become obscured in misguided attempts to try to help a patient by premature fixed prosthodontic treatment; unfortunately, such action often leads to unnecessary or early failure. An example of such a misguided attempt is a well-intended decision to prepare a tooth for a crown without first replacing a preexisting defective amalgam or composite resin restoration. On preparation, the existing old restorative material is dislodged, the presence of significant caries that was radiographically not readily discernible is discovered, and endodontic treatment is indicated, although its outcome appears to be somewhat unpredictable. In contrast, a best-case scenario is an uncomfortable conversation with the patient, whereas a worse outcome might include tooth loss and significant change to the previously developed treatment plan. In the latter case, patient confidence in the dentist is diminished.

This chapter reviews the ways in which treatment within the different dental disciplines relates to fixed prosthodontics. Detailed descriptions of the particular procedures are beyond the scope of this text, but several commonly performed procedures are discussed.

Comprehensive treatment planning ensures that mouth preparation is undertaken in a logical and efficient sequence aimed at bringing the teeth and their supporting structures to optimum health. Equally important is the need to educate and motivate the patient to maintain long-term dental health through meticulous oral hygiene practices. As a general plan, treatment procedures should be performed in the following sequence:

1. Relief of symptoms (chief complaint)
2. Removal of causes (e.g., excavation of caries, calculus removal)
3. Repair of damage
4. Maintenance of dental health

The following list describes a typical sequence in the treatment of a patient with extensive dental disease, including missing teeth, retained roots, caries, and defective restorations:

- Preliminary assessment (Fig. 6-1, *A*)
- Emergency treatment of presenting symptoms (see Fig. 6-1, *B*)
- Oral surgery (see Fig. 6-1, *C*)
- Caries control and replacement of existing restorations (see Fig. 6-1, *D*)
- Endodontic treatment (see Fig. 6-1, *E*)
- Definitive periodontal treatment, possibly in conjunction with preliminary occlusal therapy (see Fig. 6-1, *F*)
- Orthodontic treatment
- Definitive occlusal treatment
- Fixed prosthodontics (see Fig. 6-1, *G* and *H*)
- Removable prosthodontics (see Fig. 6-1, *I*)
- Follow-up care

However, the sequence of preparatory treatment should be flexible. Two or more of these phases are often performed concurrently. Carious lesions or defective, overhanging restorations often prevent proper oral hygiene measures, and their elimination or correction must be a part of preparatory treatment. If caries control results in a pulpal exposure or exacerbates an existing chronic pulpitis, endodontic treatment may be needed earlier than anticipated. When the primary symptoms have been eliminated, the occlusal needs of the patient are carefully evaluated through clinical examination and the study of centric relation articulated diagnostic casts (see Chapter 2).

ORAL SURGERY

Soft Tissue Procedures

During the initial or radiographic examination, the dentist should recognize any soft tissue abnormalities that may necessitate surgical intervention to facilitate prosthodontic treatment. If necessary, the patient can be referred to an oral surgeon for further consultation, treatment, or both. Diagnosis of pathologic conditions can be difficult, and when in doubt, the general practitioner should make the appropriate referral to a specialist. Additional information such as cone-beam computed tomographic imaging may be needed to help identify the best options available (Fig. 6-2).

Elective soft tissue surgery may include alteration of muscle attachments or increasing vestibular depth to accommodate removable prosthodontic treatment, removal of a wedge of soft tissue distal to the molars to enable access during tooth preparation and enhance the

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long-term prognosis, or modification of the shape of edentulous spaces to better accommodate fixed or removable partial prostheses (Fig. 6-3).

Hard Tissue Procedures

Tooth extraction is the most common surgical procedure involving hard tissue. To reduce overall treatment duration, it should be performed as early in treatment as possible, so that other needs can be attended to during healing and osseous recontouring after extraction.

Tuberosity reduction (Fig. 6-4) is also common, especially when space is inadequate to accommodate a prosthesis. Although maxillary or mandibular tori (Fig. 6-5) seldom interfere with the fabrication of a fixed partial dental prosthesis, their excision may make it easier to design a removable partial dental prosthesis and occasionally improves access for oral hygiene measures.

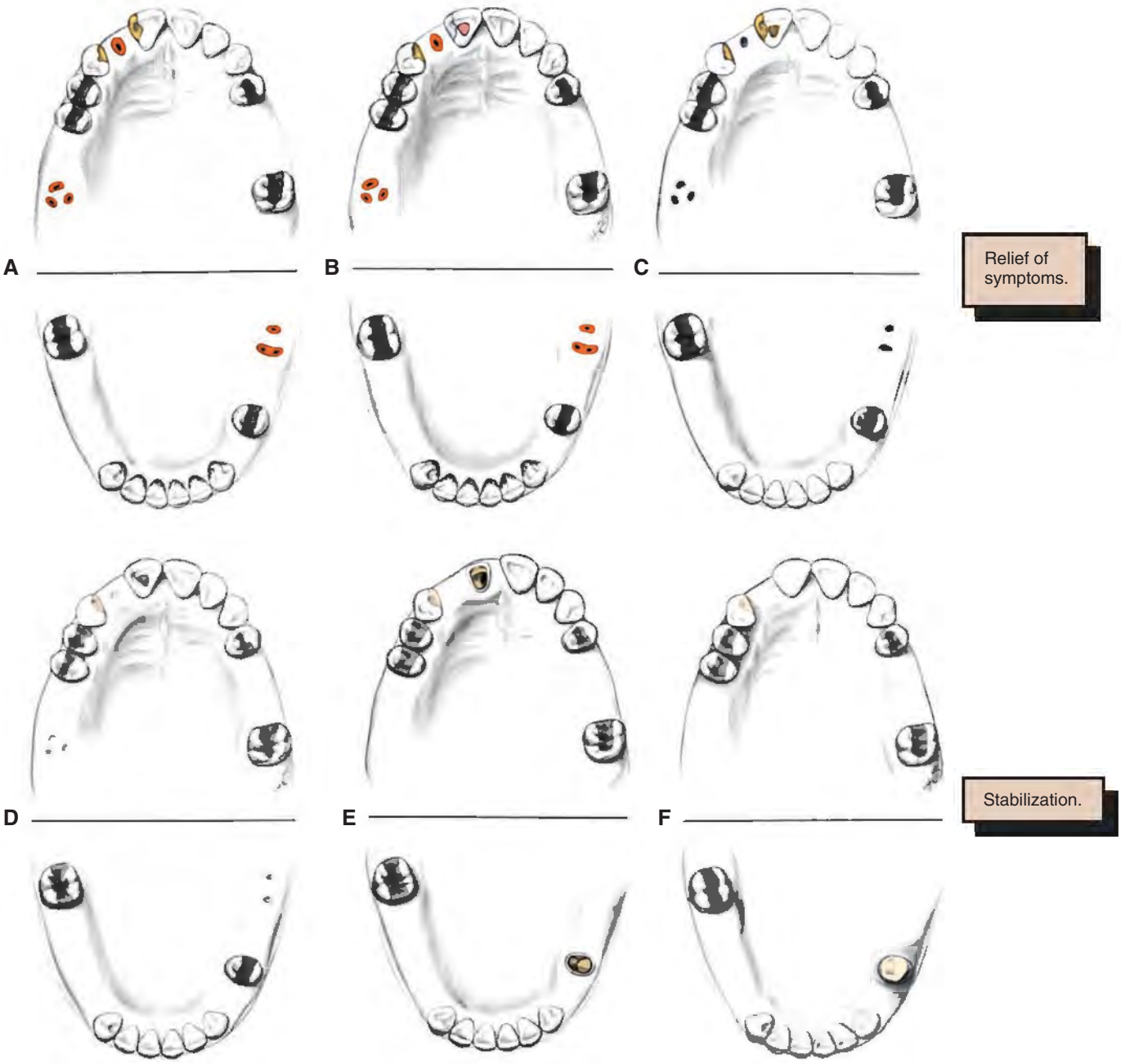

FIGURE 6-1 ■ Illustrated sequence of treatment. **A,** Scenario in which pain seems to originate from the maxillary right central incisor. In addition, several teeth are missing, and retained roots, caries, calculus, and defective restorations are present. **B,** Relief of the acute problem by endodontic treatment of the incisor. **C,** Removal of deposits and unrestorable teeth. **D,** Control of caries and replacement of defective restorations. The progress of ongoing disease has been halted. **E,** Endodontic treatment. Post and core restorations and an interim restoration are placed. **F,** Definitive periodontal treatment.

Continued

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FIGURE 6-1, cont'd ■ **G,** Preparation of teeth for the definitive restoration. **H,** Completed fixed restorations. **I,** End of active phase of the treatment. Note that predictable management of complex prosthodontics involving fixed and removable dental prostheses can be facilitated by adopting the technique described in Chapter 3.

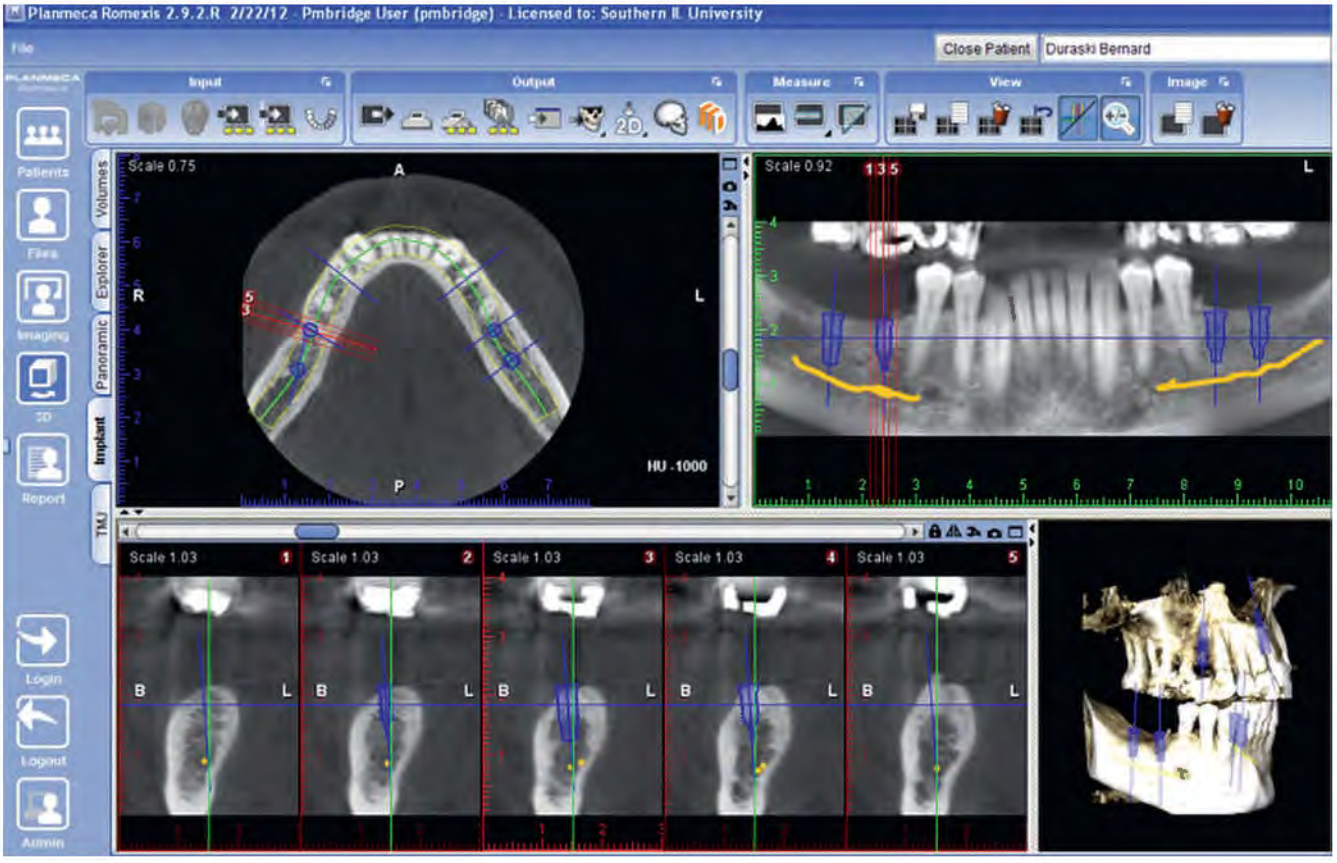

FIGURE 6-2 ■ Cone-beam imaging is particularly useful to determine whether the volume of bone is adequate to accommodate dental implants.

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FIGURE 6-3 ■ Soft tissue surgery to correct an unfavorable edentulous ridge before fixed dental prosthesis fabrication. **A,** Hyperplastic tissue results in unfavorable ridge contours for optimal pontic design. **B,** Soft tissue surgery. **C,** Contours are reevaluated immediately following excision. **D,** After healing, the altered ridge contours permit optimal pontic form.

FIGURE 6-4 ■ Tuberosity reduction was indicated in this case to accommodate a mandibular removable dental prosthesis. (Courtesy Dr. J. Bergamini.)

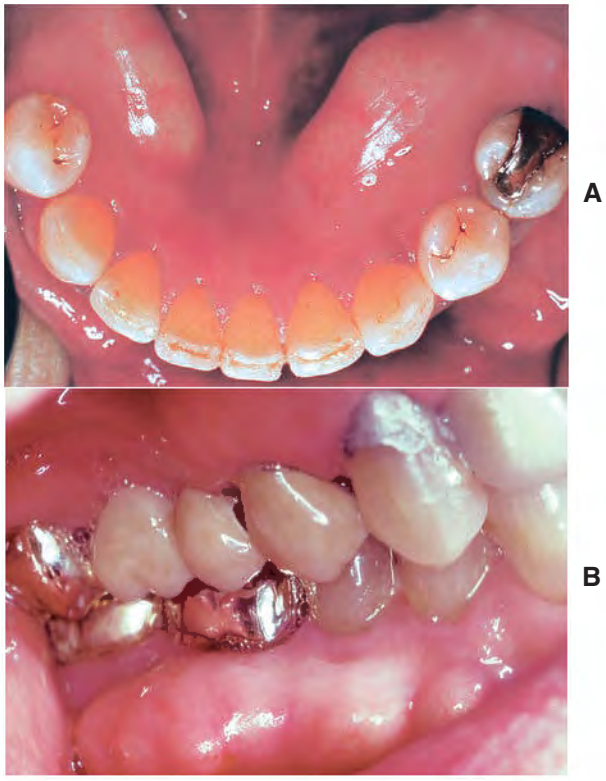

FIGURE 6-5 ■ **A,** Mandibular torus necessitating surgical reduction before the fabrication of a partial removable dental prosthesis. **B,** Buccal torus that was interfering with oral hygiene.

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FIGURE 6-6 ■ **A,** Failure of mandibular premolar, necessitating its atraumatic removal. **B,** After proper surgical management, healthy tissues surround this osseointegrated implant fixture.

Impacted or unerupted supernumerary teeth often should be removed to avoid damage to adjacent structures.

Orthognathic Surgery

Severe skeletal discrepancies may necessitate surgical correction in conjunction with tooth movement before comprehensive prosthodontic treatment. Candidates for such orthognathic surgery require careful restorative evaluation and attention before any treatment is begun. Communication among all members of the treating team of specialists is crucial to achieve success. Otherwise, an expected improvement in the facial skeleton may be accompanied by unexpected occlusal dysfunction. After surgery, the connection among plaque control, caries prevention, and periodontal health should be stressed to the patient.

Implant-Supported Fixed Prostheses

Placement of implant-supported prostheses has become a routine part of general dentistry. The success of this procedure requires meticulous patient selection and skillful execution of the selected technique (Fig. 6-6). Achieving good function while satisfying all other patient expectations can prove especially challenging in the esthetic zone. A team approach to treatment is strongly recommended, with close cooperation between the specialists (see Chapter 13).

CARIES AND EXISTING RESTORATIONS

Crowns and fixed dental prostheses are definitive restorations. They are time-consuming and expensive treatment options and should not be recommended unless the restoration will last a long time. Many teeth that require crowns are severely damaged or have large existing restorations. Any preexisting restoration on such teeth must be carefully examined, and its serviceability should be determined. If any doubt exists, the restoration should be replaced. Time spent replacing an existing restoration that in retrospect might have been serviceable is a modest price to pay for the assurance that the foundation will be caries free and well restored. Studies have shown that accurately detecting caries beneath a restoration without its complete removal is difficult.[1-3] Even on caries-free teeth, an existing restoration may not be a suitable foundation for a crown or a fixed dental prosthetic retainer.

FIGURE 6-7 ■ Small defects *(arrow)* that would create undercuts are best blocked out intraorally with cement or resin.

Preparation design is different for a foundation restoration than for a conventional restoration, particularly with regard to the placement of its retention. In general, when a crown is needed, the dentist should plan to replace any existing restorations. Although most teeth in need of restoration require foundation restorations, small defects resulting from less extensive lesions can often be incorporated in the design of a cast restoration or can be blocked out with cement (Fig. 6-7). The latter is recommended on axial walls where an undercut would otherwise result. If a small defect is present on the occlusal surface, however, it may be better to incorporate it into the definitive restoration than to block it out. The difficulty, of course, is anticipating such future considerations during this preparatory phase of treatment. Predictability is even more challenging when an existing crown or fixed dental prosthesis must be replaced. In those cases, the extent of damage is visible after the defective restoration has been removed. Excellent communication with the patient in advance of such treatments is of paramount importance.

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FOUNDATION RESTORATIONS

A foundation restoration, or *core*, is used to build a damaged tooth to ideal anatomic form before the tooth is prepared for a crown. Foundations may have to serve for an extended time before fabrication of the definitive prosthesis and should provide the patient with adequate function. They should be contoured and finished to facilitate oral hygiene. Subsequent tooth preparation is greatly simplified if the tooth is built up to ideal contour. It can then be prepared as if the tooth were intact. Depth grooves can be used to enable precise evaluation of occlusal and axial reduction (see Chapter 8), and preparation design will be consistent from tooth to tooth.

Selection Criteria

Selection of the correct foundation material depends on the extent of tooth destruction, the overall treatment plan, and the operator's preference (Fig. 6-8). The effect of subsequent tooth preparation for the cast restoration on the retention and resistance of the foundation material must be carefully considered. Retention features such as grooves, wells, or pinholes should be placed sufficiently pulpally to allow for adequate reduction for the definitive restoration without retention loss. Adhesive retention may be helpful in preventing loss of the foundation during subsequent tooth preparation.

Dental Amalgam

Despite its limitations, amalgam remains a material of choice for many foundation restorations on posterior teeth. It has good resistance to microleakage and is therefore recommended when the crown preparation will not extend more than 1 mm beyond the foundation-tooth junction.[4] It can be shaped to ideal restoration form and serves well as a long-term interim restoration. Its strength is superior to that of glass ionomers, and retention can readily be provided by undercuts, pins, or slots. Adhesive bonding systems such as those based on 4-methacryloxyethyl trimellitic anhydride (4-META) are also available[5-8] and may further reduce leakage of the restoration.[9,10] Additional retention may be provided with the use of polymeric beads supplied with the Amalgambond system.[11]

Amalgam requires an absolutely rigid matrix for proper condensation; otherwise, the foundation will break. Achieving proximal contact is straightforward because the material is condensable. Matrix placement can be demanding when a tooth with little remaining coronal tissue is restored (Fig. 6-9). This is discussed in the step-by-step procedure in Chapter 6. When coronal tissues are significantly compromised, a relined and subsequently hollowed-out anodized aluminum shell crown can serve as the matrix. Amalgam has a longer setting time than resin-based foundation materials. This normally delays crown preparation until a subsequent patient visit. When this presents a problem, a rapid-setting, high-copper, spherical alloy may be chosen. These can be prepared for a crown about 30 minutes after placement. Spherical amalgams are advantageous for foundation restorations because they have greater early strength than do other amalgam formulations; fracture soon after placement is thus less of a concern.[12]

Resin-Modified Glass Ionomer Cement

This is a suitable choice to block out a small lesion. The material sets rapidly, enabling crown preparation with minimal delay. When placed correctly, glass ionomer adheres to dentin, although conventional undercut retention may be needed to supplement this. It is important to select a material that has adequate radiopacity. A formulation that is more radiolucent than dentin should not be used as a foundation because its later radiographic appearance may suggest recurrent caries.[13] The presence of fluoride in resin-modified glass ionomers may help prevent recurrent caries. The chief disadvantage of glass ionomers is their comparatively low strength; thus for longer term restoration of more extensive lesions, this material is inferior to amalgam or composite resin.[14,15]

Composite Resin

Composite resin exhibits many of the advantages of glass ionomers. It does not require condensation and sets rapidly. Formulations are available that release fluoride, which may provide an anticariogenic benefit.[16] Bonding is achieved with a dentinal bonding agent or through etching a glass ionomer liner. Neither method develops the bond strengths needed to withstand high

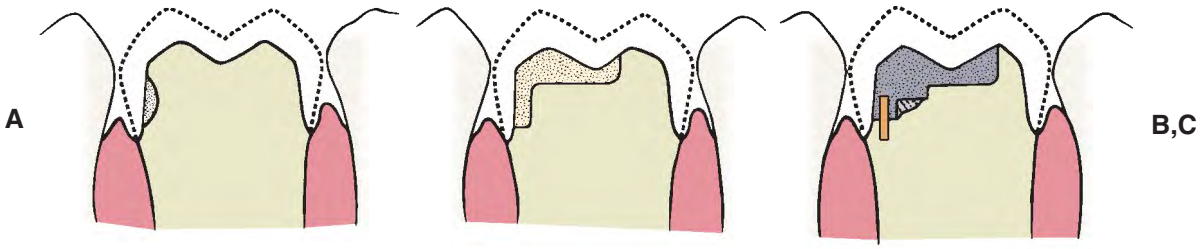

FIGURE 6-8 ■ The placement of a foundation restoration depends on the extent of damage to the tooth and should always be designed with the definitive restoration in mind. **A,** Cement. This is suitable when damage is minimal. **B,** Composite resin. Suitable for restoring larger defects. **C,** Pin-retained amalgam. Suitable for extensively damaged teeth. A retentive well is often used instead of a pin.

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FIGURE 6-9 ■ Amalgam foundation placed with regular matrix. **A,** Alloy being condensed. **B,** Matrix removed. **C,** Completed foundation restoration.

TABLE 6-1 **Foundation Restoration Materials**

Material	Advantages	Disadvantages	Recommended Use	Precautions
Amalgam	Good strength Intermediate restoration	Preparation delay Condensation Corrosion No bonding*	Most foundations	Well-supported matrix
Glass ionomer	Rapid setting Adhesion Fluoride	Low strength Moisture sensitive†	Smaller lesions	Moisture control
Composite resin	Rapid setting Ease of use Bonding	Thermal expansion Setting contraction Delayed expansion	Smaller lesions Anterior teeth	Moisture control
Cast gold	Highest strength Indirect procedure	Two-visit procedure Interim restoration needed	Extensive lesions	Alignment of pinholes

*Bonding can be achieved with 4-methacryloxyethyl trimellitic anhydride (4-META) products.
†Resin-modified formulations are less sensitive.

masticatory forces, and conventional undercut retention is also needed. In general, the enamel bond is easier to accomplish and remains stronger over time than the bond to dentin.[17] The continued polymerization of the resin and its high thermal expansion coefficient, however, may lead to microleakage of the crown.[18] Also of concern is the moisture sorption properties of composite resin that delays expansion and may lead to axial binding of crowns made on composite resin cores.[19,20] Such delayed expansion is not a problem with traditional glass ionomer,[21] but it is a problem with the resin-modified glass ionomers and the compomer materials.[22] Many dentists prefer to use a special colored core material rather than conventional tooth-colored composite resin as a foundation because it allows them to more easily discern the composite-tooth junction.

Pin-Retained Cast Metal Core

A cast metal core may be considered for an extensively damaged tooth. A cemented cast foundation is retained by tapered pins. The preparation requires careful location and placement of the pinholes but is otherwise straightforward. Such foundations are fabricated in the dental laboratory as an indirect procedure. This increases the complexity and expense of treatment but achieves good preparation form.

Advantages and disadvantages of the available materials are summarized in Table 6-1.

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Step-by-Step Procedures

Amalgam Core

1. Isolate the tooth. Rubber dam isolation is strongly recommended for moisture control, infection control, and optimum visibility. Placement follows techniques developed for conventional amalgam restorations, although with extensively compromised teeth, placing the rubber dam can be a problem. Sometimes cotton roll isolation must suffice.
2. Design the tooth preparation for the foundation restoration with the geometry of the intended crown in mind. Be sure that the future preparation for the crown will not eliminate retention of the foundation. The preparation may differ somewhat from that for a conventional amalgam restoration. The ensuing discussion highlights these differences.[22]
3. Limit the extent of the outline form. In contrast to conventional amalgam preparations, which are extended to remove residual unsupported enamel and deep occlusal fissures, a more conservative outline is recommended for foundation restorations because the fissures and contacts will eventually be removed during crown preparation. Although minimizing foundation preparation outline form can help conserve supporting tooth structure, the foundation should be adequately extended for the detection of any carious lesions (Fig. 6-10, *A*).
4. Retain unsupported enamel if convenient. For a conventional amalgam tooth preparation, unsupported enamel must always be removed; otherwise, such enamel may fracture during function and leave a deficient margin. However, for a foundation restoration, the unsupported enamel may be preserved most effectively if it is substantial enough to withstand condensation forces, provided that the enamel-dentin junction is caries free. Preserving unsupported enamel may facilitate matrix placement and improve the ease of amalgam condensation (see Fig. 6-10, *B*).
5. Finish the cavosurface margins. For conventional amalgam restorations, cavosurface margins of 90 degrees are needed to minimize the potential for fracturing the enamel and amalgam during function. However, for foundation restorations, the amalgam-tooth interface will not be subjected to high stresses (they are protected by the crown), and marginal fracture is not likely to be a problem. Therefore, leaving an acute cavosurface margin is often acceptable. Furthermore, such a margin conserves useful tooth substance and improves condensation (see Fig. 6-10, *C*).
6. Remove any carious dentin carefully and thoroughly with a hand excavator or a large round bur in a low-speed handpiece. Discolored but hard dentin can be left on the pulpal wall, but caries-affected areas at the enamel-dentin junction must be removed completely. Use of a caries detection agent helps reveal such areas. If pulpal exposure occurs during preparation, whether carious or mechanical, either endodontic treatment or tooth removal is necessary. A direct pulp cap is not a good choice when a fixed dental prosthesis is required; however, if endodontic treatment is selected and the pulp cannot be extirpated immediately, a suitable interim restoration should be placed.
7. Create optimum resistance form. Good resistance to masticatory forces is as crucial for a foundation as for a conventional restoration. Whenever possible, the tooth preparation should be perpendicular to the occlusal forces. If the axial wall is sloping, it should be modified into a series of steps to enhance resistance form (see Fig. 6-10, *D*).
8. Ensure that the foundation restoration has adequate retention (augmented if necessary by pins, slots, or wells). Proper placement of retention features is essential to the preparation of a successful foundation. The features must be incorporated into the design in such a manner that they will not be eliminated during crown preparation (see Fig. 6-10, *D* and *E*).

This set of procedures can be a particular challenge with the extensive reduction necessary for a metal-ceramic or all-ceramic restoration. Pin location is dictated by root furcations and the size of the pulp chamber. In general, pins should be placed further pulpally than when conventional extensive pin amalgams are being provided; to prevent pulp perforation, they should be positioned at a slight angle to the long axis of the tooth.

Retention can also be provided by slots or wells. In comparison with pins, these create less residual stress in the dentin and thus reduce the risk of pulp exposure or damage.[23-27] They should be placed pulpally to the intended crown margin, at a depth of about 1 mm, with a small carbide bur. Careful condensation of amalgam into the slots ensures improved restoration retention.

Bonding agents can assist amalgam retention, but adhesion is not adequate to resist occlusal loading. Retention is currently best provided by conventional means. An example of the use of bonding agents appears in Figure 6-11. If bonding agents are used, the clinician should carefully adhere to the manufacturer's directions about storage and manipulation.

Bases and Varnishes

A base is necessary to prevent thermal irritation if the preparation extends close to the pulp. A material with good physical properties, such as resin-modified glass ionomer, should be chosen because weaker materials are likely to fracture during amalgam condensation. Excessively thick bases should be avoided if they would leave inadequate thickness of amalgam foundation after tooth preparation. (A minimal amalgam thickness of 1 mm is recommended on all aspects of the completed crown preparation.) Calcium hydroxide liners should be reserved for use in deep cavities when a microscopic pulp exposure is suspected. They generally have low strength and do not resist condensation forces well.

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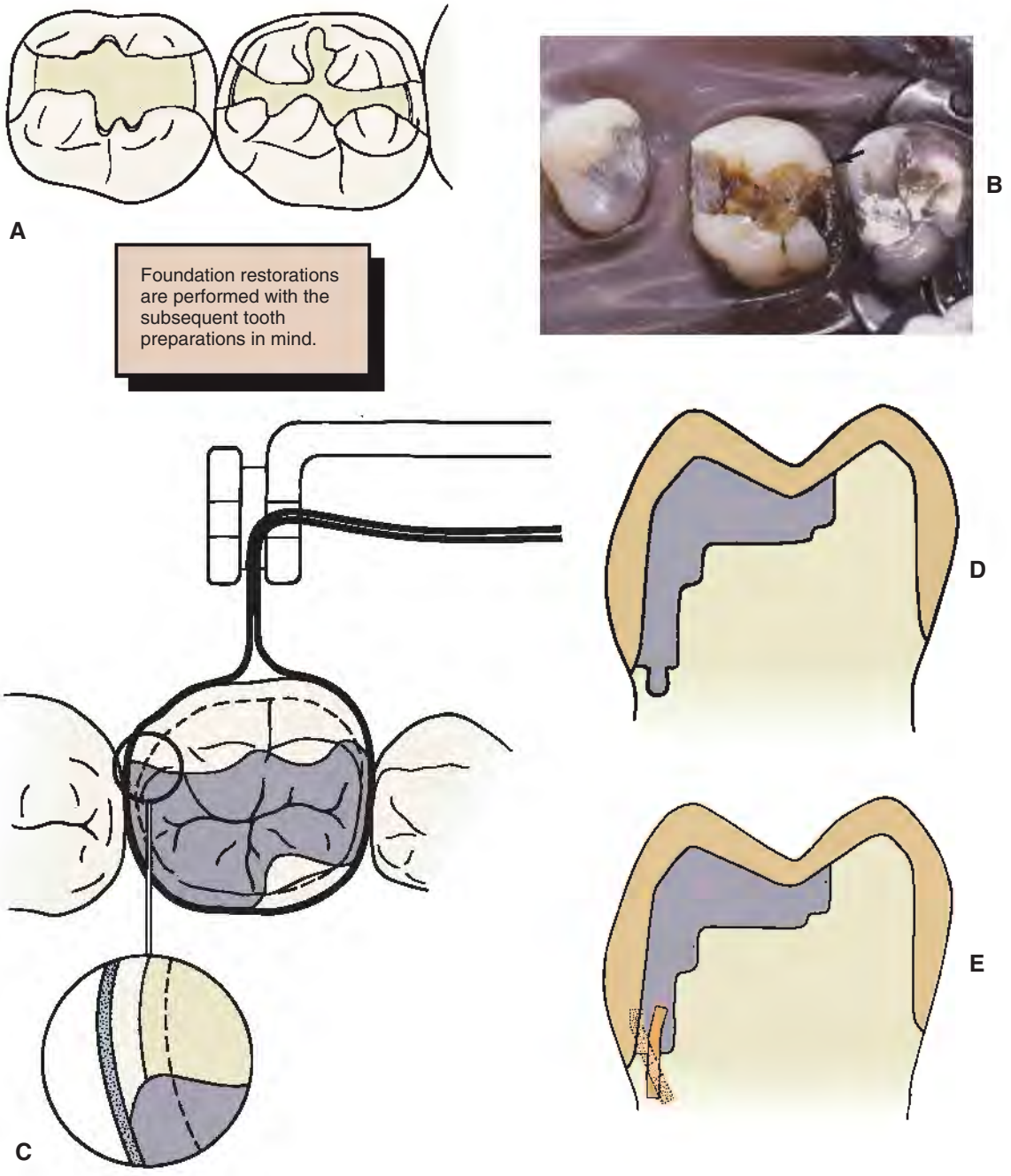

FIGURE 6-10 ■ The principles of preparation design for an amalgam foundation restoration differ slightly from those for a conventional extensive amalgam restoration. **A,** The outline form of a foundation need not include fissures or proximal or occlusal contacts if caries can be removed completely. **B,** Unsupported enamel *(arrow)* can sometimes be left when a foundation restoration is prepared. It may facilitate matrix placement and is removed when the crown is prepared. **C,** Acute cavosurface margins are acceptable for a foundation restoration but not for a definitive amalgam. **D,** Resistance form is improved by preparing the tooth in a series of steps perpendicular to the direction of occlusal force. **E,** When pin retention is used, pinholes should be drilled slightly pulpally and at an angle to the root surface *(solid line),* in comparison with the way they are placed for a conventional extensive amalgam restoration *(dotted outline).* This ensures that foundation is retained after crown preparation.

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FIGURE 6-11 ■ Adhesives such as AmalgamBond, a 4-methacryloxyethyl trimellitic anhydride (4-META) product, may be helpful in retaining amalgam foundations. **A,** Mandibular molar with extensive loss of tooth structure is prepared for foundation restoration. **B,** The dentin conditioner (10% citric acid, 3% ferric chloride) is applied in accordance with the manufacturer's instructions. Then it is rinsed and lightly dried. **C,** The conditioner is primed, and the operator waits for 20 seconds. If puddles remain, the operator blows to eliminate them. It is not necessary to dry the primer. **D** to **F,** The adhesive is mixed, and the powder liner is incorporated and brushed into the prepared cavity. **G,** The amalgam is condensed while the liner is still wet. **H,** The finished restoration. (Courtesy Parkell Inc., Edgewood, N.Y.)

Matrix Placement

A rigid, well-contoured matrix allows the amalgam to be properly condensed and facilitates carving. However, it can present a problem when much tooth structure is missing. Conventional matrix retainers, such as Tofflemire, are unstable if both the lingual and the buccal walls are missing. A circumferential matrix (e.g., the AutoMatrix Retainerless Matrix System, DENTSPLY Caulk) is useful for extensive restorations. Alternatives include copper bands or orthodontic bands. These are removed by cutting with a bur after the amalgam has set. Stability of the matrix is improved by proximal wedging, by crimping to shape, and by using modeling plastic or autopolymerizing acrylic resin for external stabilization[28,29] (Fig. 6-12, *A*). Alternatively, a copper band or suitably relined aluminum anodized crown form may be used to serve as an external matrix.

Condensation

Condensation follows conventional practice, with particular attention to condensing into wells and around pins. If the foundation is to be prepared for a crown during the same appointment, a spherical alloy with a high copper content is chosen. A mechanical condenser is useful for large amalgam restorations.

Contouring and Finishing

Care is needed to prevent amalgam fracture during matrix removal. After allowing time for setting, the dentist trims the amalgam away from the occlusal edge of the matrix and removes the wedges and matrix retainer. At this stage, it is helpful to cut the buccal ends of the matrix band with scissors close to the tooth. Then the band can be pulled through the proximal contacts toward the lingual aspect. Pulling the band occlusally is more likely to fracture the freshly placed amalgam.

Contouring follows conventional practice if the foundation is to serve for any significant period. Such a foundation should also be finished to facilitate plaque control. If the foundation is to be prepared shortly after placement, a more rudimentary occlusal contour is acceptable.

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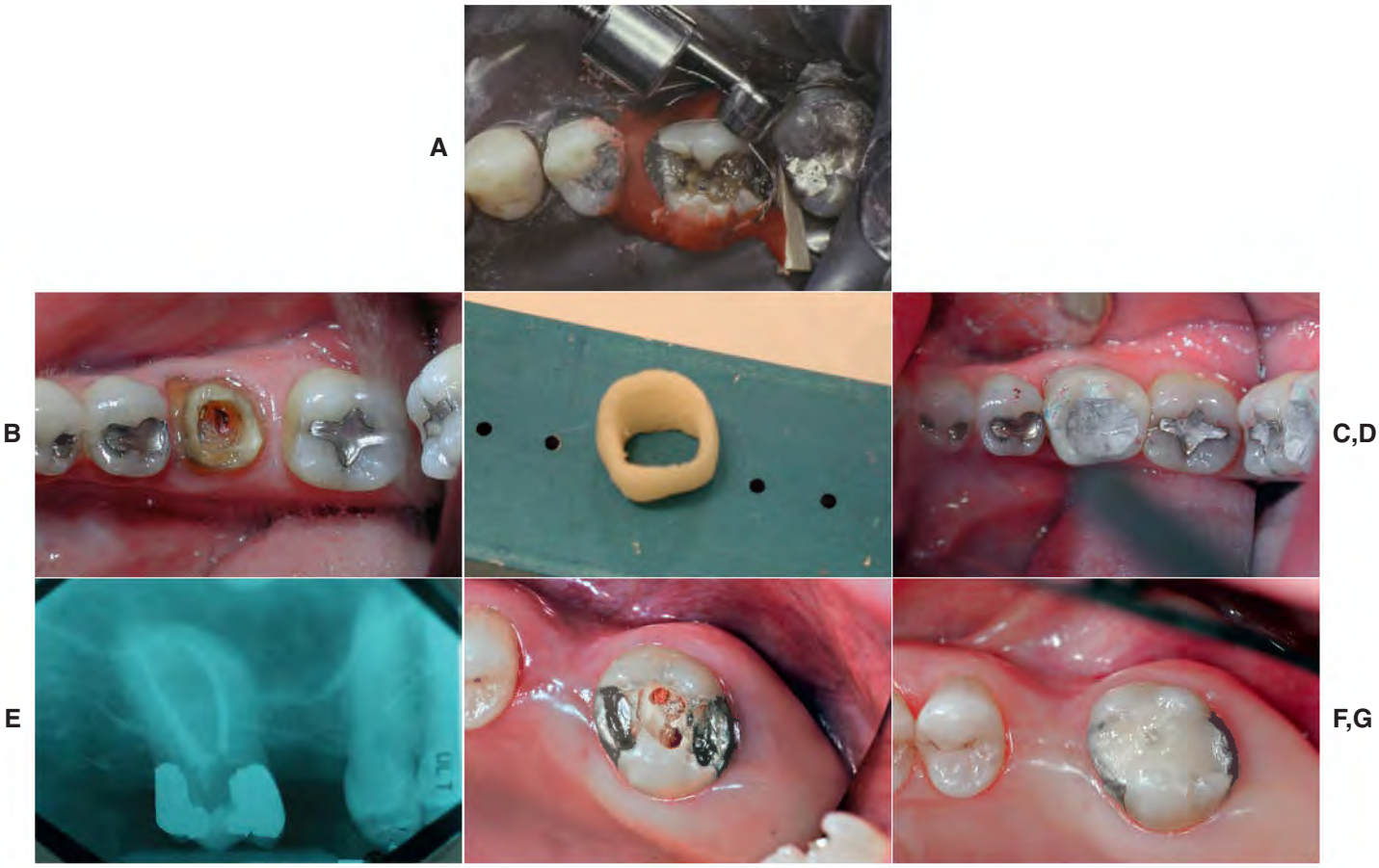

FIGURE 6-12 ■ **A,** Autopolymerizing resin can help stabilize the matrix for an amalgam foundation restoration. **B,** Endodontically treated molar with minimal preparation height does not provide adequate support during placement of the foundation restoration. **C,** Hollowed-out interim crown was fabricated to serve as a matrix. **D,** Amalgam foundation placed into interim crown matrix. **E,** Heavily restored molar required endodontic treatment. **F,** Most of the old alloy was removed, but thin amalgam walls were retained to serve as a matrix. **G.** Composite resin material placed.

However, occlusal form should be adequate to provide proper tooth stability. Moreover, all margins should be carved properly because any residual excess leads to plaque retention and makes preparation and especially crown margin placement difficult.

Glass Ionomer Core

1. Isolate the tooth. As with amalgam, moisture control is critical with glass ionomer preparations (Figs. 6-13 and 6-14). The setting material is very sensitive to moisture. When it is set, it must not be allowed to dry out; otherwise, it deteriorates rapidly. The light-cured, resin-modified glass ionomers are less sensitive to early moisture.[30]
2. Prepare the tooth for a casting; then remove any existing restorations and bases, excavate caries, and create the undercuts needed for additional retention. Glass ionomer is best for small foundations on teeth with at least two axial walls of sound dentin remaining. Currently available glass ionomers are not strong enough to be used for large pin-retained foundations. (Often they are chosen when the foundation and crown preparation are completed during a single office visit.) After tooth preparation and the creation of undercuts, glass ionomer is used to build the tooth up to ideal preparation form, if the defects are relatively small. Adhesion to dentin can be enhanced by removal of some of the smear

FIGURE 6-13 ■ Small foundation restorations in these maxillary lateral incisors were fabricated with a resin-modified glass ionomer.

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FIGURE 6-14 ■ **A,** Glass ionomer has been placed to block out the small proximal defects on the proximal surfaces of the central incisors after caries removal. **B,** Completed preparations. (Courtesy Dr. R.D. Douglas.)

layer with a chemical agent. However, excessive removal of the smear layer is not recommended because it can lead to pulp irritation. A 20-second application with a dentin-conditioning agent that contains 10% polyacrylic acid should be sufficient. Dry the tooth with a cotton pledget before placing the ionomer; do not use an air syringe.

3. Using a syringe, apply the glass ionomer onto the tooth, being careful not to create voids at the cement-tooth interface. Remember that with the conventional self-hardening formulations, adhesion of glass ionomer to tooth structure occurs only if the cement is placed rapidly after mixing; 10 seconds should be allowed for loading the syringe and 10 seconds for placement and manipulation. Some manufacturers provide an encapsulated delivery system that helps place the cement rapidly. A matrix is not normally needed for a small cavity, inasmuch as the core materials do not slump. After injection, the cement can be rapidly manipulated to shape. However, manipulation beyond 3 or 4 seconds disturbs the developing bond and should be avoided. It is better to overfill slightly and reprepare the tooth after it has set (less than 5 minutes for the metal-containing cements). If a resin-modified glass ionomer is used, this is light cured according to the manufacturer's recommendations.
4. Finish the preparation as for other types of cores. Conventional glass ionomers are extremely sensitive to drying, even when they are set, which the dentist should keep in mind when fabricating the crown preparation, the interim restoration, or the impression. Resin-modified formulations are less moisture sensitive. Vital teeth are also sensitive to desiccation, and so this consideration should not modify normal practice.

Composite Resin

Composite resin foundations (Fig. 6-15) are much stronger than glass ionomer foundations, a difference that is correlated with the higher diametral tensile strength of the composite.[31] They are strong enough for

FIGURE 6-15 ■ Composite resin used as a foundation material prior to complete crown preparations. (Courtesy Dr. A. Zonnenberg.)

larger cores. However, the current materials have disadvantages, specifically their absorption of moisture and high thermal expansion. These factors may contribute to the somewhat unpredictable longevity of the resin-dentin bond, which has been shown to decline as a function of time in simulated aging experiments.[32] These considerations have led some dentists to avoid composite resin foundations entirely.

Moisture Control. Composite resins are sensitive to moisture contamination, and careful rubber dam isolation is strongly recommended.

Preparation. The preparation phase for a composite resin foundation restoration is similar to that when amalgam is used. All existing restorations are removed, and caries is carefully excavated. Retention form is needed, although this will be supplemented by the bonding.

Placement. Both light-cured and chemically cured core composite materials are available. Light-cured composite materials have the convenience of extended working time,

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but there is concern about the adequacy of polymerization in deep areas. The autopolymerizing materials need to be mixed and placed quickly, preferably with the aid of a syringe (C-R syringes, Centrix, Inc.). A Mylar matrix is used to confine them and provide good adaptation.

Composite resin core materials are easily prepared with conventional tooth preparation diamonds, although a light touch is needed to avoid gouging the surface.

ENDODONTIC TREATMENT

Assessment

During the initial data collection, attention must be directed toward potential endodontic needs of the patient. The clinical examination should include vitality testing of all teeth in the dental arch. This may be done with an aerosol cryogen spray, an "ice pencil" (conveniently made by filling an anesthetic needle cap with water and freezing), heated gutta-percha, or an electric pulp tester. Thermal testing is considered more useful because it may indicate the degree of pulpal inflammation, whereas electric testing reveals only whether a pulp is nonvital or vital. Tenderness to percussion should also be noted. Any abnormal sensitivity, soft tissue swellings, fistulous tracts, or discolored teeth should prompt suspicion of pulpal involvement.

Patients who have definite symptoms seldom present problems in diagnosis because pain is generally their chief complaint. When pulpal health is in doubt, however, patients should be examined radiographically during the mouth preparation phase, and the images should be carefully inspected for signs of periapical disease (a radiolucency or widening of the periodontal ligament space). When the endodontic prognosis of a tooth is in doubt, radiographic findings (Fig. 6-16) should always be evaluated in reference to the results of percussion vitality and load testing.

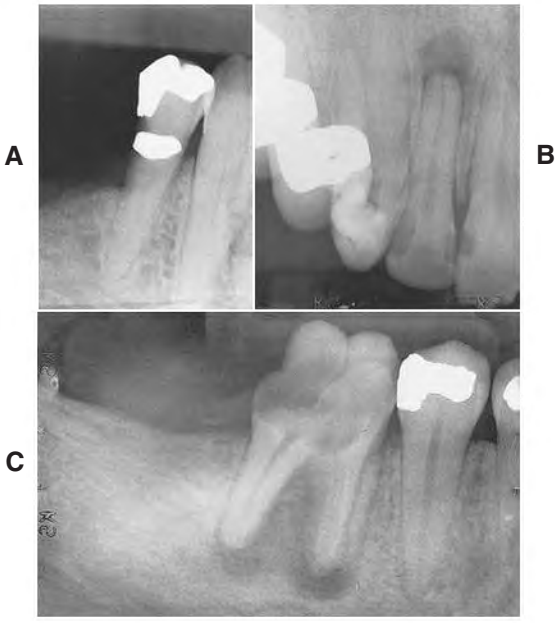

FIGURE 6-16 ■ Common periapical lesions. **A,** Widened periodontal ligament space. **B** and **C,** Large radiolucencies (established granulomas or cysts). (Courtesy Dr. G. Taylor.)

Treatment

As a general rule, conventional (or orthograde) rather than surgical (or retrograde) endodontic treatment should be performed if possible: not only because additional trauma results from the surgical approach but also because apicoectomy adversely affects the crown-to-root ratio and thus the periodontal support for the planned prosthesis. If an existing post prevents access to a recurrent periapical lesion, the post can usually be removed. Fiber composite posts are the easiest to remove, and the use of ultrasonic vibration is helpful in breaking the cement seal of a metal post (a Masserann kit has also shown some success with this; see Chapter 12). When a post and core restoration is needed in an endodontically treated tooth, 3 to 5 mm of apical seal should be retained (see Chapter 12).

Elective endodontic treatment may be desirable when there are problems in obtaining a compatible line of draw between multiple abutments without encroachment on the pulp or when remaining coronal tissue is insufficient to gain adequate retention in a badly worn or damaged tooth.

DEFINITIVE PERIODONTAL TREATMENT

Robert F. Baima • Rick K. Biethman

Unless a patient's existing periodontal disease has been properly diagnosed and treated, fixed prosthodontic treatment is doomed to fail. A careful evaluation of the periodontal health of the patient's dentition is prerequisite to the stabilization phase of treatment. Only once periodontal health has been reestablished does it become feasible to arrive at a definitive fixed prosthodontic treatment plan. During each examination, probing depths, attachment levels, extents of mobility, crown-to-root ratios, furcal involvements, tissue health, the presence of calculus, and the efficacy of plaque control measures by the patient are noted (see Chapter 1). The periodontal treatments presented in Chapter 5 form the basis for an effective approach to management of chronic periodontal disease. In addition, specific periodontal procedures may be indicated to enhance the functional and esthetic outcomes of comprehensive fixed restorative dentistry. The following introductory discussion is augmented by more detailed descriptions of the various procedures in Chapter 5.

Keratinized Gingival Tissue

The amount of keratinized gingiva necessary for long-term periodontal health is open to debate.[33,34] In a healthy mouth, subjected to minimal stress, a total lack of keratinized tissue may be acceptable.[35] In a mouth requiring comprehensive fixed prosthodontics, the stress levels are no longer minimal. For a tooth or implant to be treated with a restoration extending into the gingival sulcus, approximately 5 mm of keratinized gingiva, at least 3 mm of which is attached gingiva, is recommended. Where less keratinized gingiva is present, or in areas of localized gingival recession, a grafting or other gingival augmentation procedure should be considered.[36,37] Intervention must include eliminating

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causes, reeducating the patient in proper oral hygiene practices as needed, and surgical procedures to reestablish a stable and maintainable periodontal status.

Mucosal Reparative Therapy

Details of treatment depend on the specific pathologic processes present. Mucosal reparative therapy is indicated to increase the width of the band of keratinized gingiva through surgical grafting. Grafting techniques are described as follows.

The laterally positioned pedicle graft[38,39] (Fig. 6-17) is used for an area of recession or lack of attached gingiva on a single tooth when amounts of keratinized gingiva in adjacent teeth or edentulous spaces are adequate. The pedicle graft is the most predictable treatment because of maintenance of the blood supply to the pedicle. It was first described in 1956.

A free (detached) autogenous gingival graft (Fig. 6-18) can be used to increase the width of attached gingiva in areas where necessary. The donor site most commonly used is the hard palate, although any area of keratinized tissues, such as an edentulous ridge or the retromolar pad, may be suitable. Healing requires approximately 6 weeks,[40-43] at which time the donor site and the grafted site should appear normal. Multiple teeth can be treated at the same time with the free gingival graft. This technique was the gold standard from 1963 to 1990.[44-46] It is still used today in nonesthetic situations in which the quality and quantity of keratinized tissue is paramount.

A coronally positioned (advanced) pedicle graft[47,48] (Fig. 6-19) is used when a single tooth or multiple teeth

FIGURE 6-17 ■ Laterally positioned pedicle graft. **A** and **B,** Localized recession around the left mandibular central incisor. The lateral incisor has an adequate band (width) of keratinized tissue, and so it is suitable as a donor site. **C,** Bed preparation of the recipient site. An incision is made obliquely toward the site. **D,** Releasing incision at the distal of the donor site. The graft is rotated into position over the recipient site. **E,** Flap sutured in position. A free autogenous gingival graft may be used to cover the donor site. **F,** The healed graft. There is almost always some loss of attachment (average, 1 mm) at the donor site.

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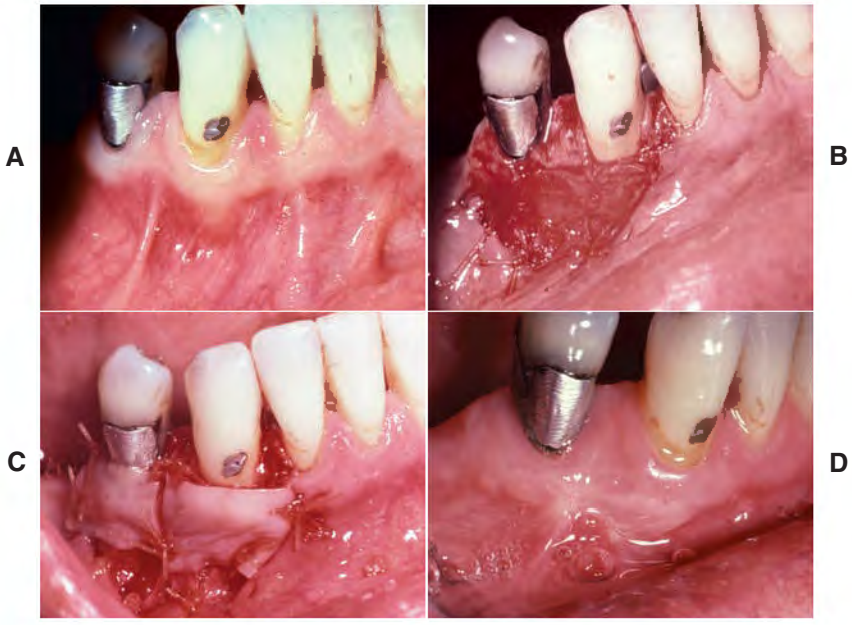

FIGURE 6-18 ■ Free autogenous gingival graft. **A,** Lack of adequate keratinized gingiva around a planned abutment tooth. **B,** The recipient site is prepared. **C,** The graft is sutured into place. Some apical adjustment is needed around the premolar before application of the surgical dressing. **D,** The healed graft. (Compare the width of attached keratinized gingiva here with that in **A.**) The defective restoration can be treated at this stage.

FIGURE 6-19 ■ Coronally positioned pedicle graft. **A,** The position of the free gingival margin after autogenous graft placement. There is approximately 4 mm of recession. **B,** Incisions for the pedicle. Divergence of the incisions ensures an adequate blood supply because the base of the flap is broad. **C,** The pedicle is coronally positioned and sutured snugly in place at the cementoenamel junction with horizontal and suspension sutures. **D,** The healed graft. (Courtesy Dr. S.B. Ross.)

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FIGURE 6-20 ■ Pouch and tunnel technique for root coverage. **A,** Preoperative view. Note gingival recession. **B,** Donor connective tissue from palate. **C,** Donor tissue placed in pouch and tunnel. **D,** Facial gingiva is sutured coronally to cover donor tissue. **E,** Postoperative healing at 2 weeks. **F,** Healing at 3 months. Note root coverage and thick marginal gingiva. (Courtesy Dr. Robert R. Azzi.)

exhibit gingival recession and sensitivity. If the width of the attached keratinized gingiva is inadequate, a free gingival graft may be placed to increase it before the coronal positioning.

The most common gingival augmentation technique since 1990 is the connective tissue graft (Fig. 6-20). This technique involves the use of a subepithelial connective tissue graft harvested from the palate in a split-thickness manner, which allows the wound to be closed after removal of the graft. This approach minimizes patient discomfort at the donor site, and the color match is improved. Connective tissue grafts can be combined with pedicle grafts and tunneling procedures to improve blood supply and survivability. Connective tissue grafts can be utilized to cover exposed roots, to augment deficient ridges, and to attempt to rebuild papillas.[49-51]

Crown-Lengthening Procedures

Surgical crown lengthening (Fig. 6-21) may be indicated when the clinical crown is too short to provide adequate retention without the restoration impinging on the normal soft tissue attachment (biologic width, see Chapter 5).*[52-55] Crown lengthening may improve the appearance of multiple short teeth. In some patients, an apparently unsalvageable tooth with extensive subgingival caries, a subgingival fracture, or root perforation resulting from endodontics can be successfully restored after crown lengthening. Surgical crown lengthening increases the crown-to-root ratio and results in a loss of gingiva and bone from adjacent teeth. A pretreatment decision must be made about whether the tooth should be removed or restored.

Crown lengthening may be accomplished either surgically or with combined orthodontic-periodontic[56-60] techniques, depending on the patient and the dental situation.

Surgical Crown Lengthening

It is sometimes possible to achieve an effective increase in crown length by gingivectomy or removal of gingiva by electrosurgery alone (see Fig. 6-21), although osseous

*The term *biologic width* refers to the combined connective tissue-epithelial attachment from the crest of the alveolar bone to the base of the gingival sulcus.[36]

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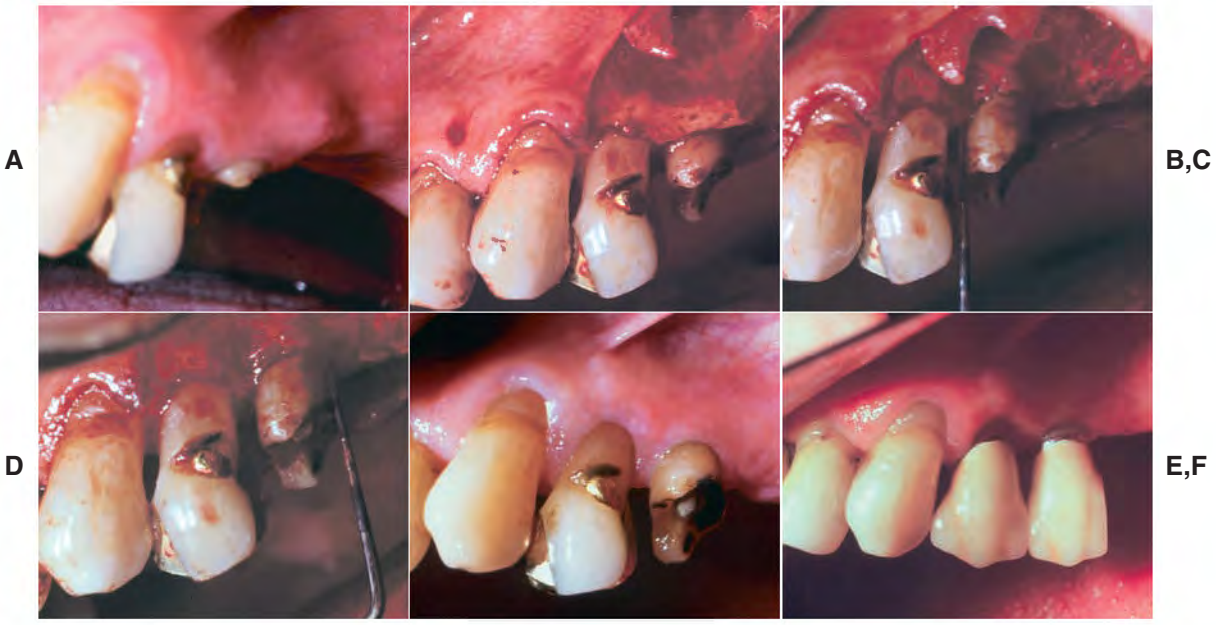

FIGURE 6-21 ■ Surgical crown lengthening. **A,** Fractured and carious second premolar. **B,** Reflection of a flap and removal of granulation tissue. **C,** Bone removed on the mesial aspect to increase the distance to the fracture site to 3.5 mm. **D,** Distally, the bone is removed so that there will be 3.5 mm from the caries to the alveolar crest. **E,** Healing after the surgical crown lengthening. **F,** Definitive crown restoration after cementation, before restoration of the sextant with a removable dental prosthesis.

FIGURE 6-22 ■ Esthetic problems can occur after surgical crown lengthening of an anterior tooth. **A,** Lateral incisor is lengthened to include a mesial periodontal defect. **B,** Esthetics would have been better if the distal aspect had been included and the gingival contour gradually sloped.

recontouring is most often needed to prevent encroachment of the prosthesis on the biologic width. For these procedures, a full-thickness mucoperiosteal flap is reflected, and the osseous resection creates 3.5 to 4.0 mm of space between the gingival crest and the margin of the existing restoration or carious lesion.[52,61] In these instances, however, the following factors should be considered:

1. Esthetics. When surgical crown lengthening (Fig. 6-22) is indicated, it may be difficult to achieve a harmonious transition from the tissue around the lengthened tooth to that around adjacent teeth. Alternatives include orthodontic extrusion or removal and replacement with a prosthesis. If surgery is undertaken, most of the osseous reduction should be on the lingual or palatal side, where there is usually no esthetic problem, with blending on the labial or buccal side only as necessary.
2. Root length within bone. If osseous support is limited, it may be better to remove the tooth and replace it with a prosthesis than to have the patient undergo surgery on a tooth with a doubtful prognosis.
3. Effect on adjacent teeth. Often a fracture or defect is of such depth that it cannot be eliminated without severely endangering the adjacent teeth. In these

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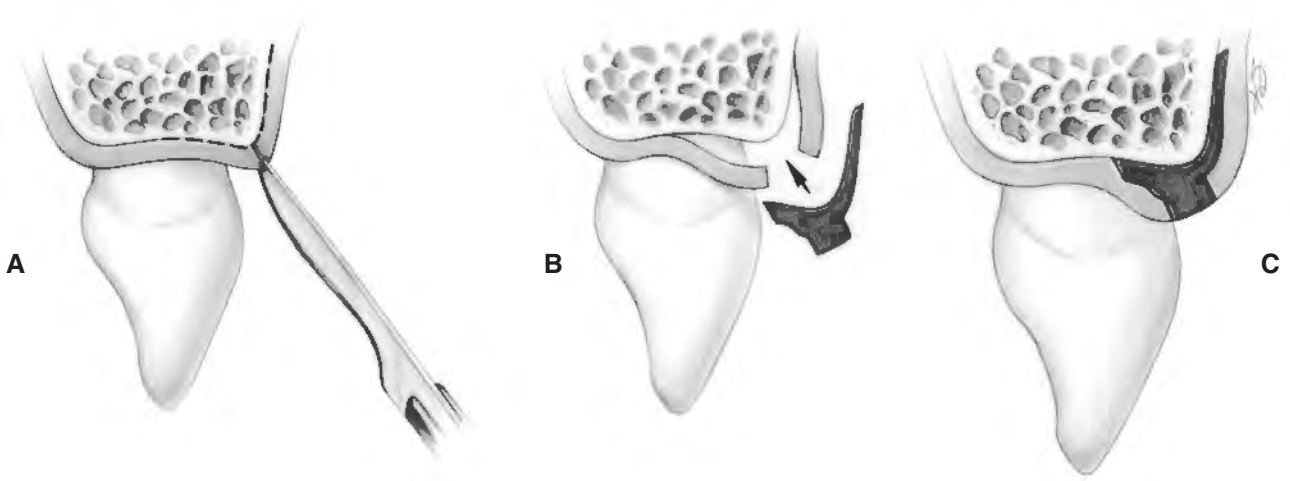

FIGURE 6-23 ■ Technique for surgical reproduction of the interdental papilla. **A,** Intrasulcular and buccal incisions are placed in the interdental papilla; the existing papilla is left attached to the palatal flap. **B,** Split-thickness flap is elevated buccally and palatally. Connective tissue graft is prepared for placement under the buccal and palatal flaps. **C,** Buccal and palatal flaps are sutured after connective tissue from the retromolar area is placed under the flap. (From Azzi R, et al: Surgical reconstruction of the interdental papilla. Int J Periodontics Restorative Dent 18:467, 1998.)

instances, removal or orthodontic extrusion may be preferable.

4. Root furcation exposure in a posterior tooth. If this situation cannot be remedied by osteoplasty or odontoplasty, the tooth may require removal.
5. Mobility. Postsurgical mobility of a tooth with small or conical roots is of concern. If such a tooth cannot support itself or cannot be supported by the adjacent teeth, then removal may be necessary.
6. Extent of the defect. The severity and complications of any fracture, root caries, or cervical wear must be carefully evaluated during the treatment planning phase.
7. Root perforation. This is uncommon, but if it occurs during endodontic therapy, its location determines whether to remove, orthodontically extrude, or lengthen the tooth surgically.[62]
8. Thickness of the soft tissue. In some instances, thick gingival tissue may prompt a regrowth of tissue in a coronal direction. An increased removal of osseous support may be needed at the time of crown lengthening surgery to negate this potential problem.[63]

Restoration of a tooth that has undergone surgical crown lengthening is commonly initiated 4 to 6 weeks after the surgical procedure. A clinical study[64] demonstrated that the biologic width and the position of the free margin of the gingiva exhibited minimal change between 3 and 6 months after surgery. Therefore, it may be advisable to provisionally restore the tooth in question, either before or immediately after surgical crown lengthening, and subsequently fabricate the definitive restoration after 3 months.

Although surgical crown lengthening may not be a panacea for fractured, perforated, or badly decayed teeth, it can help solve difficult or complex restorative problems when used with proper clinical judgment.

Maintenance and Reconstruction of the Interdental Papilla

The presence or absence of the interproximal papilla, especially in the maxillary anterior area, is of concern to the restorative dentist, the periodontist, and the patient. Multiple techniques have been used, with and without the use of guided tissue or bone regeneration, to maintain and reconstruct the interdental papilla (Figs. 6-23 to 6-25).[65-71] The results of these procedures have not been predictable or reproducible. The reconstruction of a papilla is dependent on multiple factors, such as the amount of attachment loss in the area, the blood supply available for the newly created papilla,[72] and the distance from the contact area to the crest of the interproximal bone.[73] The majority of the techniques used for reconstruction of the interdental papilla are both surgical and restorative, and they therefore involve careful coordination and planning of the surgical and restorative procedures. It is more predictable to preserve an existing papilla than to regenerate a lost papilla.

• • •

ORTHODONTIC TREATMENT

Minor orthodontic tooth movement[74-78] can significantly enhance the prognosis of subsequent restorative treatment. Uprighting malpositioned abutment teeth can improve axial alignment, create more favorable pontic spaces, and improve embrasure form in the definitive prosthesis. Tooth movement can also help direct occlusal forces more favorably, parallel to the long axes of the teeth, and often leads to substantial conservation of tooth structure (see Fig. 7-12, *B* and *C*), in as much as teeth can be prepared with more ideal preparation geometry.

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FIGURE 6-24 ■ Computer imaging technology used to envision esthetic changes resulting from treatment with laminate veneers. The resulting papilla compression from increased proximal contact length will result in improved esthetics. The image is manipulated using photo editing software such as Adobe Photoshop. **A,** Premodification. **B,** After simulated diastema closure.

FIGURE 6-25 ■ Reconstruction of the interdental papilla. **A,** Preoperative view of papillary deficiency in the interproximal area of teeth #24 and #25. **B,** Results of papillary graft and final tissue contour. (From Azzi R, et al: Surgical reconstruction of the interdental papilla. Int J Periodontics Restorative Dent 18:467, 1998.)

Assessment

Clinical examination should focus on tooth malpositioning both buccolingually and mesiodistally. Abnormal tooth relationships such as anterior or posterior reverse articulation should alert the dentist to the possible need for orthodontic treatment. Specifically, attempts to correct abnormal tooth relationships or malpositioned tooth contours with fixed prosthodontic treatment alone are rarely successful; orthodontic realignment as part of the mouth preparation is preferred and far more likely to lead to a successful result.

The need for orthodontic referral and treatment is determined through a careful analysis of articulated diagnostic casts, whose usefulness can be enhanced with a dental surveyor (Fig. 6-26). One helpful procedure[79] is to section a duplicate cast (Fig. 6-27) and reassemble it according to the proposed orthodontic modifications. This facilitates assessing the validity of any minor tooth movement (e.g., closing diastemas, uprighting molars, aligning tilted teeth) and is especially valuable in explaining the treatment proposal to the patient. Diagnostic preparations and waxing procedures made on such altered casts often clearly illustrate the benefits of minor tooth movement. Many dentists use computer imaging technology to optimize esthetic treatment planning and improve patient communication[80-83] (Fig. 6-28).

Treatment

In general practice, it is often possible to perform minor tooth movement before fixed prosthodontic treatment without referral to an orthodontist. However, a specialist should be consulted if treatment is more complex than straightforward tipping, uprighting, or extruding of an abutment tooth.

For tipping or extruding a single anterior tooth, bonded brackets can be used with a multistrand elastic wire ligated in place to achieve the desired tooth movement. When any anterior tooth is moved, however, the amount of labial bone should be carefully evaluated and found to be adequate before treatment. Orthodontic treatment should also be considered when restorations are planned to correct a diastema. Often esthetics can be dramatically improved by distributing the space of a midline diastema around all the anterior teeth (Fig. 6-29, *A* to *C*). A diagnostic waxing procedure will help determine the optimum tooth position. Uprighting a mesially

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FIGURE 6-26 ■ Use of diagnostic preparations **(A)** and a dental surveyor **(B)** in assessing the need for orthodontic treatment before fixed prosthodontics.

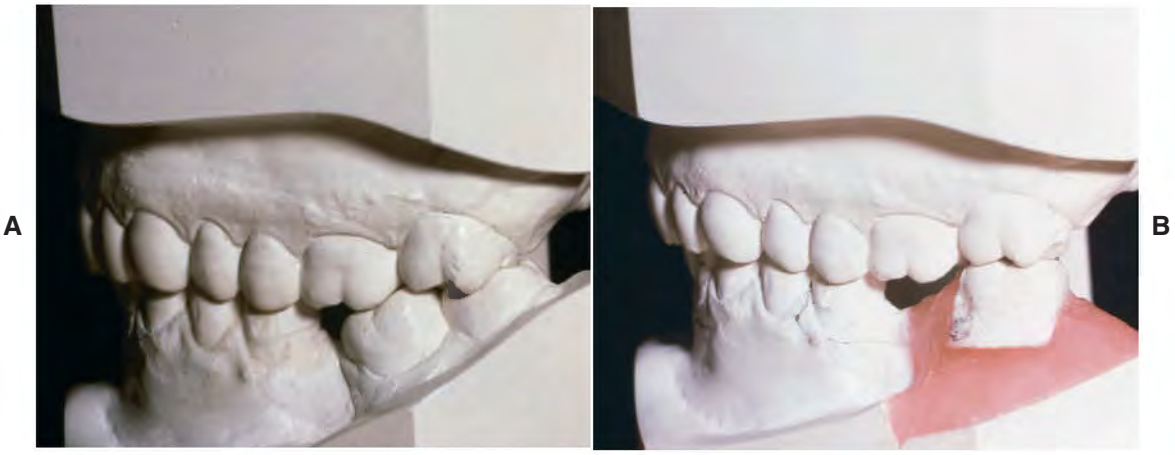

FIGURE 6-27 ■ Diagnostic cast sectioning (**A** and **B**) for determination of desired orthodontic tooth movement. (Courtesy Dr. P. Ngan.)

FIGURE 6-28 ■ Computer imaging technology can assist in treatment planning and communicating the envisioned esthetic changes to the patient. **A,** Before modification **B,** After simulated diastema closure.

tilted molar can be accomplished with a coil spring (see Fig. 6-29, *D* to *G*), but the tooth should first be reshaped so that it is out of occlusal contact. A neglected crown preparation can be salvaged with a simple orthodontic appliance (Fig. 6-30). All orthodontic movement requires adequate anchorage so that inadvertent movement of other teeth is avoided.

DEFINITIVE OCCLUSAL TREATMENT

Mouth preparation often involves reorganization of the patient's occlusion, typically to make maximum intercuspation co-occurrent with centric relation and concurrently remove eccentric interferences (see Chapter 4). This treatment may be therapeutic, principally to relieve myofascial symptoms, or performed as a prerequisite to extensive restorative treatment, ensuring a reproducible stable orthopedic position throughout the course of prosthodontic treatment. When centric relation and maximum intercuspation co-occur, it is much easier to transfer the patient's casts to an articulator accurately. Occlusal reshaping as a therapeutic measure is fraught with controversy. According to current research, occlusion has limited impact on the development of disorders of the temporomandibular joints and associated musculature.[84,85] Also, clinical evidence contraindicates occlusal reshaping.[86-88] However, occlusal problems that have led to development of

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FIGURE 6-29 ■ Orthodontic tooth movement as an adjunct to fixed prosthodontics. **A** to **C,** Minor tooth movement before correction of a diastema. **D** to **G,** A mesially tilted molar uprighted with a coil spring before the provision of a fixed dental prosthesis. (**D** to **G,** Courtesy Dr. P. Ngan.)

FIGURE 6-30 ■ **A,** The maxillary premolar *(arrow)* was prepared for a metal-ceramic crown but was inadequately provisionalized. Unfortunately, the patient did not return when the interim restoration became dislodged. The tooth had moved distally and was in contact with the first molar, making crown placement impossible. **B,** A removable appliance was used to reposition the tooth before impression making. (Courtesy Dr. P. Ngan.)

pathologic processes should be diagnosed and alleviated before definitive fixed prosthodontic treatment is undertaken. This diagnosis can generally be achieved by noninvasive, reversible means.[89] The role of occlusal forces in the progress of periodontal disease is also controversial. The balance of current research indicates that occlusal forces do not initiate periodontitis but may modify attachment loss caused by plaque-induced inflammatory periodontal disease.[90]

When selective reshaping of the natural dentition is being considered, it is important to remember that this is a purely subtractive procedure (tissue is removed), and it is limited by the thickness of the enamel. Before any irreversible changes are made to the dentition, a careful diagnostic process must establish whether restorations are possibly needed in conjunction with occlusal reshaping.

Diagnostic Reshaping

Two sets of articulated diagnostic casts in centric relation (Fig. 6-31) are required for diagnostic occlusal reshaping.

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One set serves as a reference; the second is used to perform a trial adjustment and to evaluate how much tooth structure has been removed. The comparison between the two sets facilitates the determination of how much more tooth structure may need to be removed to meet the treatment objectives. Alternatively, this diagnostic reshaping may reveal that certain teeth must be built up through fabrication of crowns in order to achieve an orthopedically stable endpoint. Thus the efficacy of the treatment plan can be tested, before any clinical treatment is initiated.[91]

The occlusal surfaces of the casts that are to be adjusted are painted with poster paint (which does not soak into the stone) to demonstrate the extent of any planned corrective reshaping. The pin setting on the articulator is recorded at the initial point of occlusal contact in centric relation before reshaping so that the operator can judge the amount of enamel that must be removed. It can be helpful to also record the pin setting at the maximum intercuspation position. The casts are then modified with suitable hand instruments; a discoid-cleoid carver is useful in achieving the desired result in an efficient manner. Each step of the adjustment can be recorded sequentially on a reshaping list or marked on the side of the casts. On completion, the results of the reshaping are reviewed carefully. Areas where enamel is likely to be penetrated are identified so that the patient can be advised of the potential need for additional restorations on those teeth.

The primary objectives of selective occlusal reshaping are as follows:

- To redistribute forces parallel to the long axes of the teeth by eliminating contacts on inclined planes and creating cusp-fossa occlusion
- To eliminate deflective occlusal contacts so that, on completion, centric relation coincides with maximum intercuspation
- To improve worn occlusal anatomy, enhance cuspal form, narrow occlusal tables, and reemphasize proper developmental and supplemental grooves in otherwise flat surfaces

FIGURE 6-31 ■ **A,** Posterior premature contacts are evident in the centric relation position. **B,** The initial point of contact is reproduced on the diagnostic casts. **C,** A duplicate set of diagnostic casts is coated with a thin layer of poster paint. **D,** Initial contact is marked with articulating film.

Continued

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FIGURE 6-31, cont'd ■ **E,** Sequential adjustments are then made until the slide is eliminated. **F** and **G,** On completion of the diagnostic adjustment, the adjusted casts are compared with an intact set of casts. This enables the dentist to determine the viability of the adjustment and whether additional procedures may be necessary (such as restoring teeth where the enamel may have been perforated and dentin exposed). **H,** Clinical adjustment in progress. **I,** Completed adjustment: centric relation equals maximum intercuspation.

- To correct marginal ridge discrepancies and extrusions so that oral hygiene will be easier
- To correct tooth malalignment through selective reshaping

It is not always possible to achieve each of these goals. If a choice must be made, corrective therapy should not be at the expense of functional surfaces and should not destroy any functional contact. In the natural dentition, the preponderance of posterior occlusal contacts are on the buccal cusps of the mandibular posterior teeth.[92]

Clinical Occlusal Reshaping

Patient Selection

Careful analysis of the diagnostic occlusal reshaping is necessary to determine whether the patient is a good candidate for such irreversible subtractive treatment. In general, if initial contact occurs relatively close to the central fossae, adjustment is more predictable than if such contact occurs on the cusp slopes or even close to the location of opposing cusps. Close attention to carefully controlled reduction is essential. If too much tooth structure is removed, it cannot be put back on. The following are contraindications to definitive occlusal reshaping:

1. A patient with bruxism whose habit cannot be (partially) controlled
2. A diagnostic adjustment that shows that too much tooth structure will be removed
3. A complex spatial relationship (e.g., Angle class II occlusion or skeletal class III occlusion)
4. Contact between maxillary lingual cusps and mandibular buccal cusps
5. An open anterior occlusal relationship
6. Excessive wear
7. The period before orthodontic or orthognathic treatment
8. The period before physical or occlusal appliance therapy
9. The presence of temporomandibular joint pain
10. A jaw whose movements cannot be manipulated easily

Occlusal reshaping needs to be undertaken in a logical sequence to avoid repetition and improve the efficacy of treatment. Although different sequences have been proposed, the one described next is successful and predictable. From a neuromuscular standpoint, the patient is capable of being guided into a reproducible hinge movement, and excursive movements can be made without undue difficulty. If these conditions are not present,

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additional deprogramming is necessary, and occlusal reshaping is contraindicated.

Elimination of Centric Relation Interferences

As the mandible rotates around the terminal hinge axis (see Chapter 4), each mandibular tooth follows its own arc of closure. If the intercuspal and centric relation positions do not coincide, premature contacts in centric relation are unavoidable. Such contacts are removed first.

Step-by-Step Procedure

1. Hinge the mandible, and first mark the teeth throughout the pathway of any slide that is present: Both the initial contact in centric relation and the extent and direction of jaw movement to maximum intercuspation should be marked. The movement, or slide, can be in either an anterior or a lateral direction. Mark the initial point of contact next in a contrasting color (black on top of red works well).
2. Find any interferences that cause the condylar processes to be displaced anteriorly (protrusive interferences). These are usually between the mesial inclines of maxillary teeth and the distal inclines of mandibular teeth (Fig. 6-32).
3. Continue reshaping until all teeth contact evenly (except possibly the incisors). If excursive movements are guided adequately by the canines, it may be best to stop reshaping when bilateral canine-to-canine contact has been reestablished, even if some teeth remain out of contact. (It may be preferable to build those up with appropriate restorations.)
4. When a laterally displacing prematurity is present, adjust the buccally facing inclines of the maxillary teeth and the lingually facing inclines of the mandibular teeth. The premature contact is usually on either the laterotrusive or the mediotrusive side of the mandible (lateral slide or medial slide).
5. When dealing with a lateral slide, adjust the buccal inclines of the maxillary lingual cusps and the lingual inclines of the mandibular buccal cusps until there is contact on the cusp tips (Fig. 6-33).
6. When dealing with a medial slide, adjust the buccal inclines of the mandibular buccal cusps or the lingual inclines of the maxillary lingual cusps until there is contact on the cusp tips. At this time, any further refinements can be made through widening of the opposing central grooves by reduction of the internal inclines of the maxillary buccal and mandibular lingual cusps (Fig. 6-34).

Evaluation

The foregoing rules for occlusal reshaping should be followed as closely as possible while normal anatomic tooth

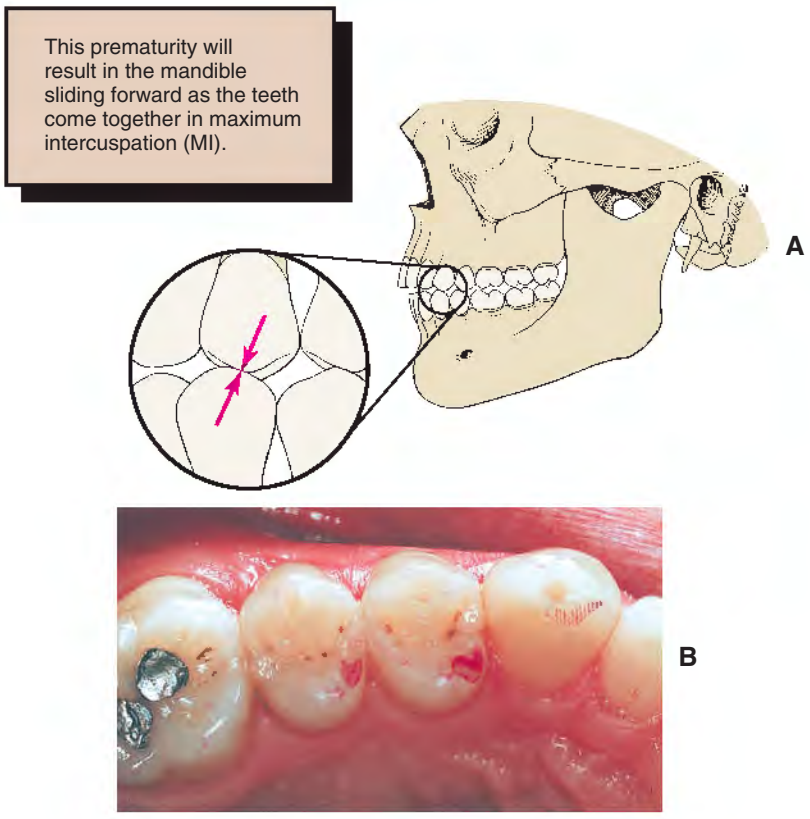

FIGURE 6-32 ■ **A** and **B,** Interferences that deflect the mandible anteriorly (protrusive interferences) are found between the mesial inclines of maxillary teeth and the distal inclines of mandibular teeth.

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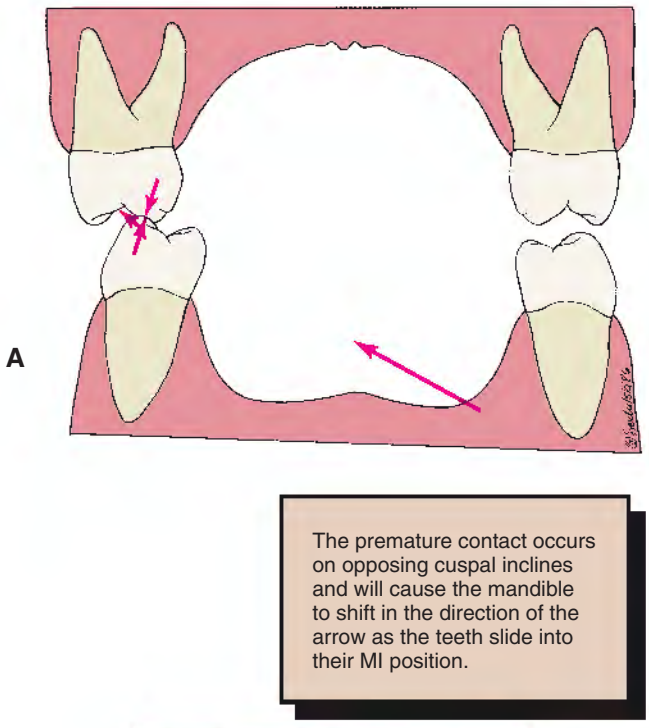

FIGURE 6-33 ■ Laterally displacing contact between the buccal incline of a maxillary lingual cusp and the lingual incline of a mandibular buccal cusp. MI, maximum intercuspation.

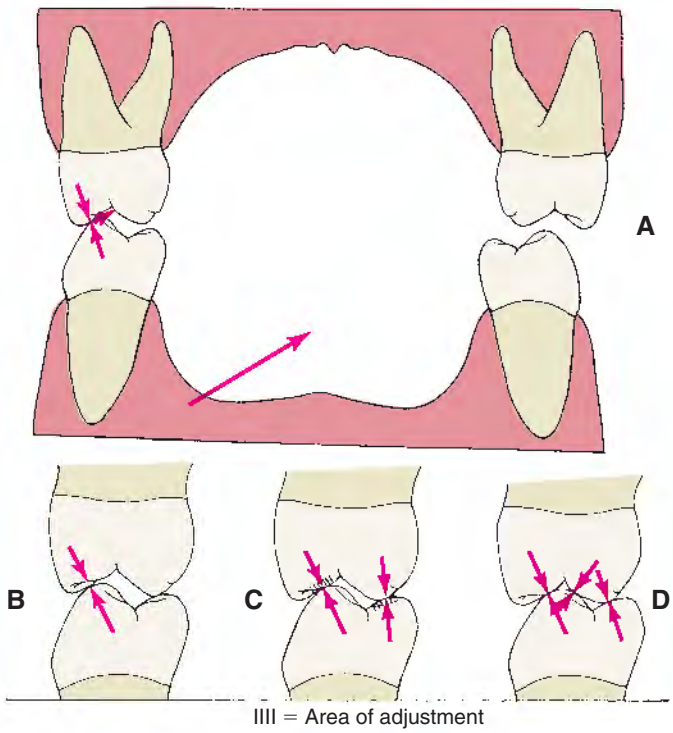

FIGURE 6-34 ■ Correcting a medial slide by selective grinding. The contacting inclines are adjusted **(A)** until the cusp tips are in contact **(B)**. The opposing central grooves are then widened (**C** and **D**).

form is maintained. When the discrepancy between centric relation and maximum intercuspation has been corrected, uniform contact between all posterior teeth should be present. This can be verified with thin Mylar shim stock held in a forceps (Fig. 6-35).

Elimination of Lateral and Protrusive Interferences

The second phase of occlusal reshaping concentrates on laterotrusive, mediotrusive, and protrusive interferences. The dentist uses red and blue marking ribbons to distinguish between centric and eccentric contacts.

The goals of this second phase of reshaping are to eliminate contact between all posterior teeth during protrusive movements and to eliminate any interferences on the nonworking (mediotrusive) side, as well as on the working (laterotrusive) side. In certain patients, group function of the working side contacts should be considered rather than the more ideal mutually protected occlusion (e.g., when there is mobility or poor bone support of the canines). In other patients, group function may be retained because of wear or malpositioning of the canines (see Chapter 4).

During this phase of reshaping, it is essential that no centric contacts be removed. In general, lateral and protrusive interferences are eliminated by the creation of a groove that enables escape of the functional cusp during eccentric movement (Figs. 6-36 and 6-37).

SUMMARY

Planning a logical treatment sequence should precede any fixed prosthodontic intervention. Treatment of unstable, deteriorating conditions such as caries and replacement of faulty restorations must be completed. Such mouth preparation is normally multidisciplinary: It incorporates oral surgery; operative dentistry; and endodontic, periodontic, orthodontic, or occlusal therapies, or a combination of these. Mouth preparation is particularly important for fixed prosthodontics, which, like all dental disciplines, is facilitated and enhanced by meticulous preparatory treatment.

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FIGURE 6-35 ■ Verifying occlusal contacts with thin Mylar shim stock.

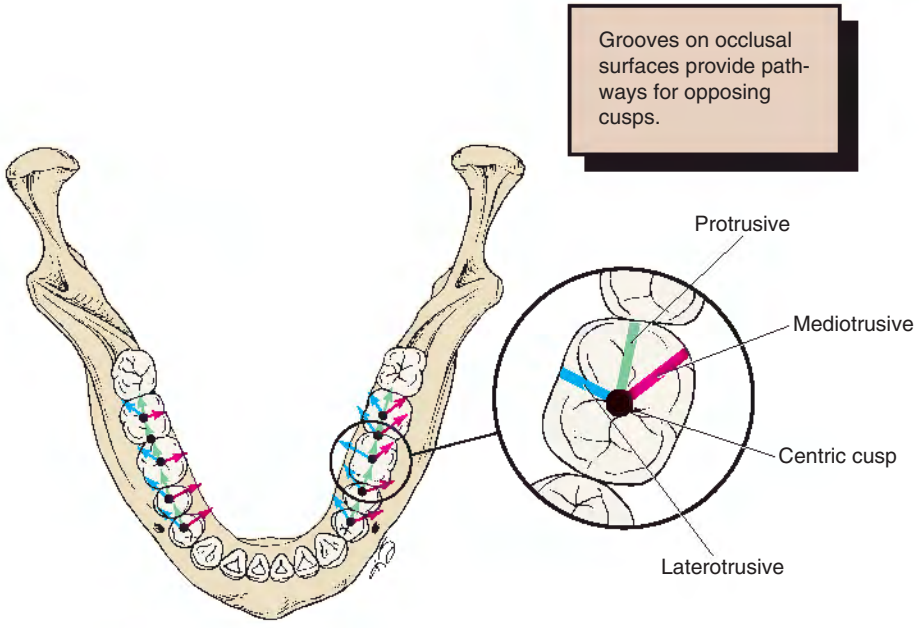

FIGURE 6-36 ■ Detection of eccentric interferences is facilitated by understanding where they normally occur. The *arrows* represent the paths of opposing functional cusps during each excursion (mediotrusive, protrusive, and laterotrusive). Look, for example, to find a mediotrusive interference distobuccal to a centric contact. In the maxillary arch, the pattern is reversed.

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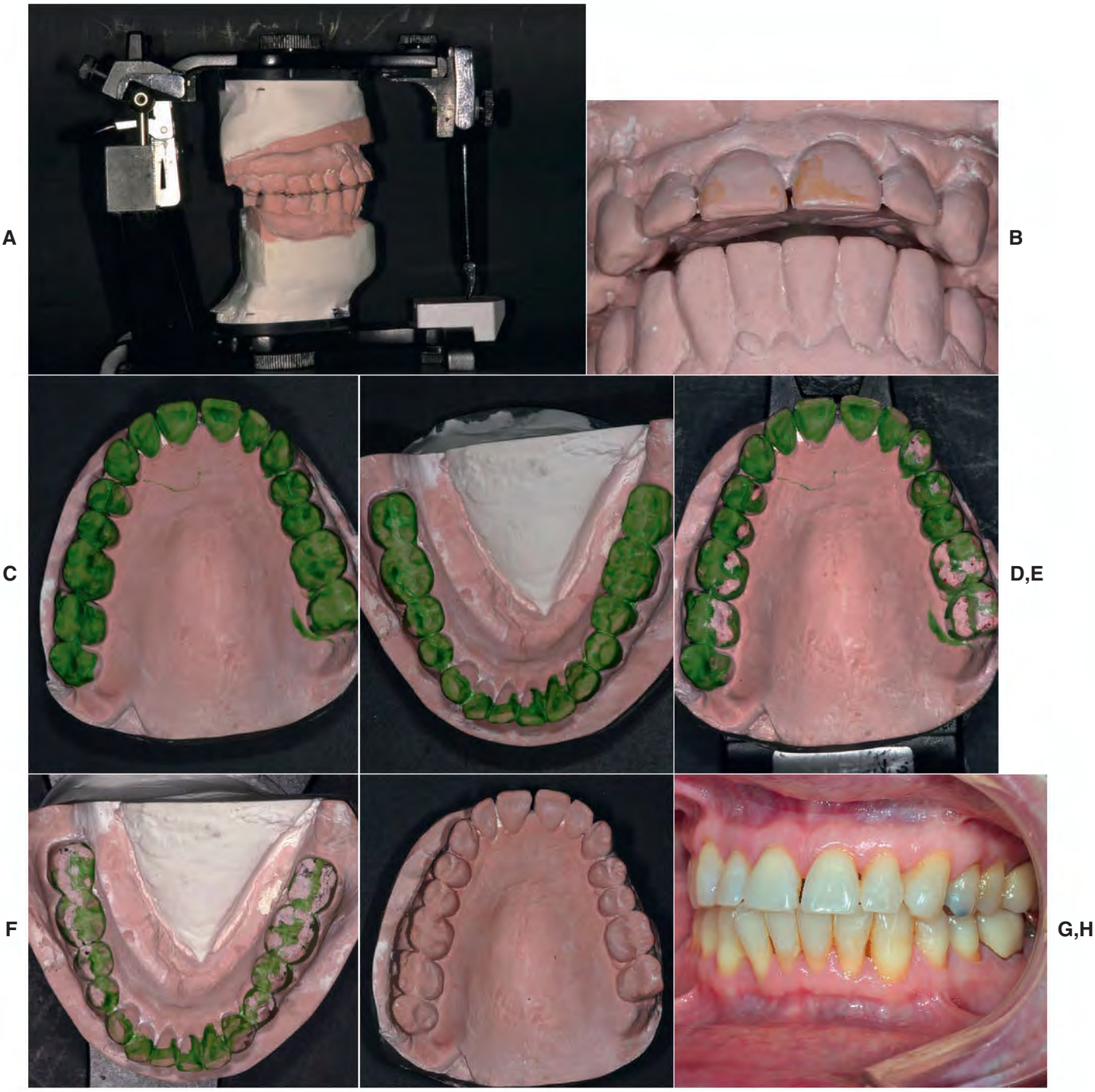

FIGURE 6-37 ■ Diagnostic occlusal reshaping. **A,** Diagnostic casts articulated in centric relation demonstrate initial contact on the right mandibular molars. **B,** Note the absence of anterior coupling in centric relation. **C** and **D,** A duplicate set of articulated casts is coated with poster paint. **E** and **F,** Removal of the poster paint during diagnostic occlusal reshaping shows where modification has occurred as reshaping progresses. **G,** An original, unmodified set of casts serves as a reference to evaluate quantitatively how much tooth structure has been removed. **H,** Once the dentist has determined that occlusal reshaping will improve the prognosis, and after informed consent is obtained and the patient is cautioned about possible need for additional restorations in the event enamel is perforated, the natural dentition can be reshaped, with the diagnostic cast serving as a reference. (Courtesy Dr. Rick Biethman.)

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REFERENCES

1. Kidd EM: Caries diagnosis within restored teeth. Oper Dent 14:149, 1989.
2. Murat S, et al: Visibility of artificial buccal recurrent caries under restorations using different radiographic techniques. Oper Dent 38:197, 2013.
3. Bilgin MS, et al: Post-treatment diagnosis of caries under fixed restorations: A pilot study. J Prosthet Dent 112(6):1364, 2014.
4. Tjan AHL, Chiu J: Microleakage of core materials for complete cast gold crowns. J Prosthet Dent 61:659, 1989.
5. Fischer GM, et al: Amalgam retention using pins, boxes, and Amalgambond. Am J Dent 6:173, 1993.
6. Worskett P: A comparative study of bonded and non-bonded amalgam restorations in general dental practice. Br Dent J 214:E19, 2013.
7. Gupta I, et al: Revisiting amalgam: a comparative study between bonded amalgam restoration and amalgam retained with undercuts. J Contemp Dent Pract 12:164, 2011.
8. Olmez A, et al: Clinical evaluation and marginal leakage of Amalgambond Plus: three-year results. Quintessence Int 28:651, 1997.
9. Tarim B, et al: Marginal integrity of bonded amalgam restorations. Am J Dent 9:72, 1996.
10. Korale ME, Meiers JC: Microleakage of dentin bonding systems used with spherical and admixed amalgams. Am J Dent 9:249, 1996.
11. Ratananakin T, et al: Effect of condensation techniques on amalgam bond strengths to dentin. Oper Dent 21:191, 1996.
12. Schulte GA, et al: Early fracture resistance of amalgapin-retained complex amalgam restorations. Oper Dent 23:108, 1998.
13. Antonijevic D, et al: An in vitro radiographic analysis of the density of dental luting cements as measured by CCD-based digital radiography. Quintessence Int 43:421, 2012.
14. Plasmans PJ, et al: A preliminary study on a resin-modified glass-ionomer cement for transitional restorations and subsequent core buildups. Int J Prosthodont 13:373, 2000.
15. Wilson NH, et al: A short-term clinical evaluation of a tricure glass-ionomer system as a transitional restoration and core buildup material. Quintessence Int 30:405, 1999.
16. Cohen BI, et al: A five year study. Fluoride release of four reinforced composite resins. Oral Health 88:81, 1998.
17. Fennis WM, et al: Randomized control trial of composite cuspal restorations: five-year results. J Dent Res 93:36, 2014.
18. Hormati AA, Denehy GE: Microleakage of pin-retained amalgam and composite resin bases. J Prosthet Dent 44:526, 1980.
19. Oliva RA, Lowe JA: Dimensional stability of composite used as a core material. J Prosthet Dent 56:554, 1986.
20. Martin N, Jedynakiewicz N: Measurement of water sorption in dental composites. Biomaterials 19:77, 1998.
21. Cooley RL, et al: Dimensional stability of glass ionomer used as a core material. J Prosthet Dent 64:651, 1990.
22. Lambert RL, Goldfogel MH: Pin amalgam restoration and pin amalgam foundation. J Prosthet Dent 54:10, 1985.
23. Outhwaite WC, et al: Pin vs. slot retention in extensive amalgam restorations. J Prosthet Dent 41:396, 1979.
24. Shavell HM: The amalgapin technique for complex amalgam restorations. J Calif Dent Assoc 8:48, 1980.
25. Bailey JH: Retention design for amalgam restorations: pins versus slots. J Prosthet Dent 65:71, 1991.
26. Irvin AW, et al: Photoelastic analysis of stress induced from insertion of self-threading retentive pins. J Prosthet Dent 53:311, 1985.
27. Felton DA, et al: Pulpal response to threaded pin and retentive slot techniques: a pilot investigation. J Prosthet Dent 66:597, 1991.
28. Bonilla ED, et al: A customized acrylic resin shell for fabricating an amalgam core on the coronally debilitated, endodontically treated posterior tooth. Quintessence Int 26:317, 1995.
29. Livaditis GJ: Crown foundations with a custom matrix, composites, and reverse carving. J Prosthet Dent 77:540, 1997.
30. Nicholson JW, Croll TP: Glass-ionomer cements in restorative dentistry. Quintessence Int 28:705, 1997.
31. Kerby RE, Knobloch L: Strength characteristics of conventional and silver-reinforced glass-ionomer cements. Oper Dent 17:170, 1992.
32. Peumans M, et al: Clinical effectiveness of contemporary adhesives: a systematic review of current clinical trials. Dent Mater 21: 864, 2005.
33. American Academy of Periodontology: Guidelines for periodontal therapy. J Periodontol 69:405, 1998.
34. American Academy of Periodontology: Parameter on mucogingival conditions. J Periodontol 71:861, 2000.
35. Wennström JL: Lack of association between width of attached gingiva and development of soft tissue recession. A 5-year longitudinal study. J Clin Periodontol 14(3):181, 1987.
36. Maynard JG, Wilson RDK: Physiologic dimensions of the periodontium significant to the restorative dentist. J Periodontol 50: 170, 1979.
37. Wilson RDK, Maynard JG: Intracrevicular restorative dentistry. Int J Periodontics Restorative Dent 1:34, 1981.
38. Grupe HE, Warren RF: Repair of gingival defects by a sliding flap operation. J Periodontol 29:92, 1956.
39. Bjorn H: Coverage of denuded root surfaces with a lateral sliding flap: use of free gingival grafts. Odontol Rev 22:37, 1971.
40. Sullivan HC, Atkins JH: Free autogenous gingival grafts. I. Principles of successful grafting. Periodontics 6:121, 1968.
41. Dordick B, et al: Clinical evaluation of free autogenous gingival grafts placed on alveolar bone. Part I. Clinical predictability. J Periodontol 47:559, 1976.
42. Oliver RC, et al: Microscopic evaluation of the healing and revascularization of free gingival grafts. J Periodontal Res 3:84, 1968.
43. Staffileno H Jr, Levy S: Histological and clinical study of mucosal (gingival) transplants in dogs. J Periodontol 40:311, 1969.
44. Holbrook T, Ochsenbien C: Complete coverage of the denuded root surface with a one-stage gingival graft. Int J Periodontics Restorative Dent 3:9, 1983.
45. Miller PD Jr: Root coverage using the free soft tissue autograft following citric acid application. III. A successful and predictable procedure in areas of deep wide recession. Int J Periodontics Restorative Dent 5:15, 1985.
46. Raetzke PB: Covering localized areas of root exposure employing the "envelope" technique. J Periodontol 56:397, 1985.
47. Bernimoulin JP, et al: Coronally repositioned periodontal flap. Clinical evaluation after one year. J Clin Periodontol 2:1, 1975.
48. Maynard JG: Coronal positioning of a previously placed autogenous gingival graft. J Periodontol 48:151, 1977.
49. Chambrone L, et al: Evidence-based periodontal plastic surgery. II. An individual data meta-analysis for evaluating factors in achieving complete root coverage. J Periodontol 83(4):477, 2012.
50. Chambrone L, et al: Root-coverage procedures for the treatment of localized recession-type defects: a Cochrane Systematic Review. J Periodontol 81(4):452, 2010.
51. Thoma DS, et al: A systematic review assessing soft tissue augmentation techniques. Clin Oral Implants Res 20(Suppl 4):146, 2009.
52. Davarpanah M, et al: Restorative and periodontal considerations of short clinical crowns. Int J Periodontics Restorative Dent 18:5, 1998.
53. Palomo F, Kopczyk RA: Rationale and methods for crown lengthening. J Am Dent Assoc 96:257, 1978.
54. Ochsenbien C, Ross SE: A reevaluation of osseous surgery. Dent Clin North Am 13:87, 1969.
55. Maynard JG: Personal communication, 1993.
56. Ross SB, et al: Orthodontic extrusion: a multidisciplinary treatment approach. J Am Dent Assoc 102:189, 1981.
57. Brown IS: The effect of orthodontic therapy on certain types of periodontal defects: clinical findings. J Periodontol 44:742, 1973.
58. Ingber JS: Forced eruption. I. A method of treating isolated one and two wall infrabony osseous defects: rationale and case report. J Periodontol 45:199, 1974.
59. Delivanis P, et al: Endodontic-orthodontic management of fractured anterior teeth. J Am Dent Assoc 97:483, 1978.
60. Potashnik SR, Rosenberg ES: Forced eruption: principles in periodontics and restorative dentistry. J Prosthet Dent 48:141, 1982.
61. Baima RF: Extension of clinical crown length. J Prosthet Dent 55:547, 1986.
62. Rosenberg ES, et al: Tooth lengthening procedures. Compend Contin Educ Dent 1:161, 1980.
63. Pontoriero R, Carnevale G: Surgical crown lengthening: a 12-month clinical wound healing study. J Periodontol 72:841, 2001.
64. Lanning SK, et al: Surgical crown lengthening: evaluation of the biological width. J Periodontol 74:468, 2003.
65. Evian C, et al: Retained interdental procedure for maintaining anterior esthetics. Comp Contin Educ Dent 6:5, 1985.

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66. Han TJ, Takei HH: Progress in gingival papilla reconstruction. Periodontol 2000 11:65, 1996.
67. Cortellini P, et al: The modified papilla preservation technique with bioresorbable barrier membranes in the treatment of intrabony defects. Case reports. Int J Periodontics Restorative Dent 16:547, 1996.
68. Beagle JR: Surgical reconstruction of the interdental papilla: case report. Int J Periodontics Restorative Dent 12:145, 1992.
69. Azzi R, et al: Surgical reconstruction of the interdental papilla. Int J Periodontics Restorative Dent 18:467, 1998.
70. Tarnow DP, et al: The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal papilla. J Periodontol 63:995, 1992.
71. Pini Prato GP, et al: Interdental papilla management: a review and classification of the therapeutic approaches. Int J Periodontics Restorative Dent 24:246, 2004
72. Johnson GK, Sivers JE: Forced eruption in crown-lengthening procedures. J Prosthet Dent 56:424, 1986.
73. Tuncay OC: Orthodontic tooth movement as an adjunct to prosthetic therapy. J Prosthet Dent 46:41, 1981.
74. Pegoraro LF, et al: Resolution of complex esthetic problems in abnormal anterior teeth: A clinical report. J Prosthet Dent 112(2):94, 2014.
75. Miller TE: Orthodontic therapy for the restorative patient. I. The biomechanic aspects. J Prosthet Dent 61:268, 1989.
76. Celenza F, Mantzikos TG: Periodontal and restorative considerations of molar uprighting. Compendium 17:294, 1996.
77. Shaughnessy TG: Implementing adjunctive orthodontic treatment. J Am Dent Assoc 126:679, 1995.
78. Proffit WR: Contemporary orthodontics, 2nd ed. St. Louis, Mosby, 1993.
79. Ackerman JL, Proffit WR: Communication in orthodontic treatment planning: bioethical and informed consent issues. Angle Orthod 65:253, 1995.
80. Grubb JE, et al: Clinical and scientific applications/advances in video imaging. Angle Orthod 66:407, 1996.
81. Levine JB: Esthetic diagnosis. Curr Opin Cosmet Dent 9, 1995.
82. Goldstein RE, Miller MC: The role of high technology in maintaining esthetic restorations. J Esthet Dent 8:39, 1996.
83. Clark GT, et al: The validity and utility of disease detection methods and of occlusal therapy for temporomandibular disorders. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83:101, 1997.
84. Fricton JR, et al: Critical appraisal of methods used in randomized controlled trials of treatments for temporomandibular disorders. J Orofac Pain 24:139, 2010.
85. Kirveskari P: The role of occlusal adjustment in the management of temporomandibular disorders. Oral Surg 83:87, 1997.
86. Kirveskari P, et al: Occlusal adjustment and the incidence of demand for temporomandibular disorder treatment. J Prosthet Dent 79:433, 1998.
87. Kerstein RB, et al: A comparison of ICAGD (immediate complete anterior guidance development) to mock ICAGD for symptom reductions in chronic myofascial pain dysfunction patients. Cranio 15:21, 1997.
88. McNeill C: Craniomandibular disorders: guidelines for evaluation, diagnosis, and management. In American Academy of Craniomandibular Disorders: Oral and facial pain. Chicago, Quintessence Publishing, 1990.
89. Gher ME: Changing concepts. The effects of occlusion on periodontitis. Dent Clin North Am 42:285, 1998.
90. Meng JC, et al: The effect of equilibrating mounted dental stone casts on the occlusal harmony of cast metal complete crowns. J Prosthet Dent 104:122, 2010.
91. Okeson JP: Management of temporomandibular disorders and occlusion, 7th ed. St. Louis, Elsevier, 2013. pp 399-420.
92. McDevitt WE, Warreth AA: Occlusal contacts in maximum intercuspation in normal dentitions. J Oral Rehabil 24:725, 1997.

STUDY QUESTIONS

1. Discuss in detail the recommended sequence of preparatory treatment procedures before initiation of definitive fixed prosthodontic treatment.

2. Discuss the advantages, disadvantages, indications, and any applicable precautions for the various foundation restoration materials.

3. How does the tooth preparation for an extensive amalgam foundation restoration differ from that for a conventional extensive amalgam restoration? Why?

4. Discuss three types of periodontal grafting procedures, their indications, and their limitations.

5. What are the indications for minor tooth movement before fixed prosthodontic treatment is initiated?

6. What are the indications and contraindications for comprehensive occlusal reshaping? If it is indicated, what is the recommended procedure and sequence of events?

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PART II

CLINICAL PROCEDURES: SECTION 1

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CHAPTER 7

Principles of Tooth Preparation

Teeth do not possess the regenerative ability found in most other tissues. Therefore, once enamel or dentin is lost as a result of caries, trauma, or wear, restorative materials must be used to reestablish form and function. With very rare exceptions, teeth require preparation to receive restorations, and these preparations must be based on fundamental principles from which basic criteria can be developed to help predict the success of prosthodontic treatment. Careful attention to every detail is imperative during tooth preparation. A good preparation ensures that subsequent techniques (e.g., interim fabrication, impression making, fabrication of dies and casts, waxing) can be accomplished.

The principles of tooth preparation may be divided into three broad categories:

1. Biologic considerations, which affect the health of the oral tissues
2. Mechanical considerations, which affect the integrity and durability of the restoration
3. Esthetic considerations, which affect the appearance of the patient

Successful tooth preparation and subsequent restoration depend on simultaneous consideration of all these factors. Improvement in one area often adversely affects another area, and striving for perfection in one may lead to failure in another. For example, in the fabrication of a metal-ceramic crown (see Chapter 24), sufficient thickness of porcelain is necessary for a lifelike appearance. However, if too much tooth structure is removed to accommodate a greater thickness of porcelain for esthetic reasons, the pulpal tissue may be traumatized (biologic consideration) and the tooth unduly weakened (mechanical consideration). In-depth knowledge and understanding of the various criteria are prerequisite to the development of satisfactory tooth preparation skills. Accomplishment of optimum tooth preparation (Fig. 7-1) invariably challenges the dentist to find the best combination of compromises among applicable biologic, mechanical, and esthetic considerations.

BIOLOGIC CONSIDERATIONS

Surgical procedures involving living tissues must be performed carefully to avoid unnecessary damage. The adjacent teeth, soft tissues, and the pulp of the tooth being prepared are easily damaged during preparation. If poor preparation leads to inadequate marginal fit or deficient crown contour, plaque control around fixed restorations becomes more difficult. This, in turn, impedes the long-term maintenance of dental health.

Prevention of Damage during Tooth Preparation

Adjacent Teeth

Iatrogenic damage to an adjacent tooth is a common error in dentistry. Even if a damaged proximal contact area is carefully reshaped and polished, it is more susceptible to dental caries than the original undamaged tooth surface was. This is presumably because the original surface enamel contains higher fluoride concentrations and the interrupted layer is more prone to plaque retention.[1] Sound tooth preparation technique avoids and prevents damage to the adjacent proximal surfaces.

A metal matrix band placed around the adjacent tooth for protection may be helpful; however, the thin band can be perforated and the underlying enamel damaged. The preferred method is to use the proximal enamel of the tooth that is being prepared for protection of the adjacent structures. Teeth are 1.5 to 2 mm wider at the contact area than at the cementoenamel junction. Therefore, a thin, tapered diamond can be passed through the interproximal contact area (Fig. 7-2) while leaving a slight "lip" or "fin" of enamel without resulting in excessive tooth reduction or necessitating undesirable angulation of the rotary instrument. The latter situation, tipping the diamond unnecessarily away from the adjacent proximal surface, is a common clinical error.

Soft Tissues

Damage to the soft tissues of the tongue and cheeks can be prevented by careful retraction with an aspirator tip, a mouth mirror (Fig. 7-3), or a flanged saliva ejector. Great care is needed to protect the tongue when the lingual surfaces of mandibular molars are being prepared.

Pulp

Great care also is needed to prevent pulpal injuries during fixed prosthodontic procedures, especially when significant amounts of tooth structure are being removed. Pulpal degeneration that occurs many years after tooth preparation has been documented.[2] Extreme temperatures, chemical irritation, or microorganisms can cause an irreversible pulpitis,[3] particularly when they occur on freshly sectioned dentinal tubules. Prevention of pulpal damage necessitates selection of techniques and materials that reduce the risk of injury while teeth are prepared.[4]

Tooth preparations must account for the geometry of the pulp chamber. Pulp size can be evaluated on a

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radiograph, and it decreases with age. Up to about age 50, it decreases more so occlusocervically than faciolingually. Average pulp dimensions have been related to coronal contour[3] and are presented in Table 7-1 and Figure 7-4.

Causes of Injury

Temperature. Considerable heat is generated by friction between a rotary instrument and the surface being prepared (Fig. 7-5). Excessive pressure, higher rotational speeds, and the type, shape, and condition of the cutting instrument (Fig. 7-6) may all increase generated heat.[6] With a high-speed handpiece, a feather-light, intermittent touch allows efficient removal of tooth material with minimal heat generation. Nevertheless, even with the lightest touch, the tooth overheats unless a water spray is used. The spray must be accurately directed at the area of contact between tooth and rotary instrument. It also washes away debris, which is important because rotary instrument clogging reduces cutting efficiency (Fig. 7-7). Irrigation also prevents desiccation of the dentin (which may cause severe pulpal irritation).[2,7] Debris accumulation has been shown to vary with rotary instrument shape. Shoulder- and chamfer-shaped diamonds may accumulate less debris. Debris is not readily removed after 5 minutes of ultrasonic cleaning.[8]

If the spray prevents adequate visibility, as may be the case when a margin is being finished, a slow-speed handpiece or hand instrumentation is the safest option. Relying on air cooling alone with a high-speed handpiece is hazardous because a tooth can easily overheat and the pulp can be easily damaged.[9] Finishing the margin dry with the instrument in a high-speed handpiece requires a feather-light touch and very intermittent tooth contact.

Particular care is needed for preparing grooves or pinholes because coolant cannot reach the cutting edge of the rotary instrument. To prevent heat buildup, these retention features should be prepared at low rotational speed or with a high-speed handpiece with a feather-light touch.

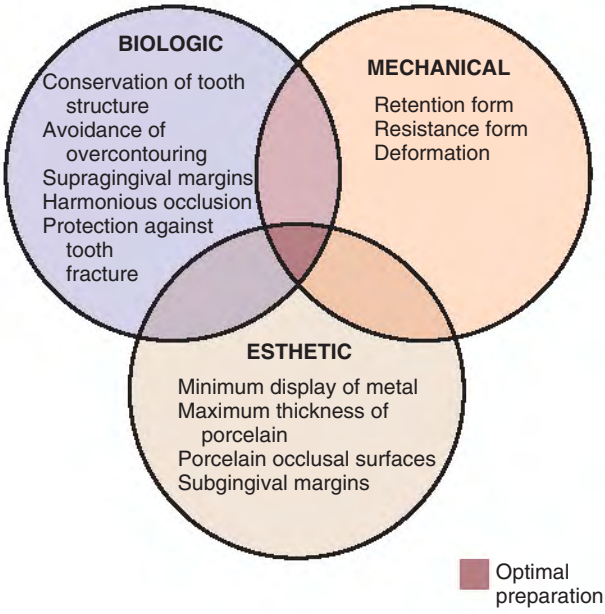

FIGURE 7-1 ■ The optimum preparation enables fabrication of a restoration that satisfies biologic, mechanical, and esthetic requirements.

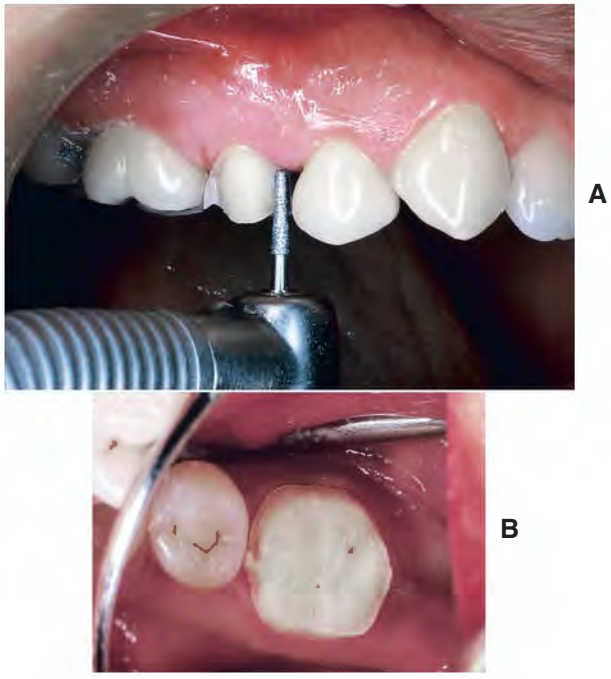

FIGURE 7-2 ■ Damage to adjacent teeth is prevented by positioning the diamond so that a thin "lip" of enamel is retained between the rotary instrument and the adjacent tooth during reduction of the proximal surface. **A,** Note that the orientation of the diamond parallels the long axis of this premolar. **B,** Proximal reduction almost complete. Note that enamel was maintained mesial to the path of the diamond as the reduction progressed.

FIGURE 7-3 ■ Soft tissue protection. Mouth mirror is used to protect the tongue during tooth preparation **(A)** and to displace the cheek and reduce risk of injury **(B)**.

TABLE 7-1 Dimensions of Pulp and the Coronal Contour

Age Range (Years)	Length (Millimeters)								
	CORONAL LENGTH	INCISAL TO MPH	INCISAL TO DPH	MESIAL SURFACE TO MPH	DISTAL SURFACE TO DPH	LABIAL SURFACE TO MPH	LABIAL SURFACE TO DPH	PALATAL SURFACE TO MPH	PALATAL SURFACE TO DPH
Maxillary Central Incisor									
10–19	12.1	4.7	4.8	1.7	2.1	1.8	1.8	1.4	1.3
20–29	11.5	4.8	5.1	2.2	2.3	1.9	1.9	1.4	1.2
30–39	11.2	5.3	5.5	2.1	2.5	2.3	2.4	2.1	2.0
40–49	10.8	6.3	6.2	2.5	2.9	2.0	2.1	2.0	1.8
50–59	12.3	6.3	6.2	2.6	2.6	2.8	2.3	2.2	2.1
Mean ±SD	11.58 ± 0.34	5.5 ± 0.25	5.6 ± 0.28	2.2 ± 0.16	2.5 ± 0.14	2.2 ± 0.12	2.1 ± 0.12	1.8 ± 0.16	1.7 ± 0.19
Range	9.70-14.00	4.0-6.2	4.0-6.2	1.2-3.3	1.4-3.5	1.5-2.9	1.5-2.9	1.0-2.9	1.1-2.9
Maxillary Lateral Incisor									
10-19	10.1	3.9	4.3	2.4	2.6	2.0	2.1	1.3	1.3
20-29	10.2	4.8	5.2	2.5	3.2	2.4	2.4	1.9	1.9
30-39									
40-49									
50-59									
Mean ± SD									
Range									

Age Range (Years)	Length (Millimeters)					
	CORONAL	INCISAL TO PH	MESIAL SURFACE TO PH	DISTAL SURFACE TO PH	LABIAL SURFACE TO PH	PALATAL SURFACE TO PH
Maxillary Canine						
10-19	10.7	4.4	3.4	4.0	2.7	2.3
20-29	10.6	4.6	3.3	3.7	3.1	2.6
30-39	10.5	4.8	3.0	4.0	2.9	2.5
40-49	9.5	4.8	3.0	3.6	2.8	2.8
50-59	9.5	5.4	2.8	3.4	2.9	3.0
Mean ± SD	10.23 ± 0.26	4.8 ± 0.20	3.1 ± 0.13	3.7 ± 0.12	2.9 ± 0.11	2.6 ± 0.15
Range	8.29-12.7	3.8-7.2	2.3-3.6	2.9-4.8	2.5-3.5	1.9-3.7

From Ohashi Y: Research related to anterior abutment teeth of fixed partial denture. Shikagakuho 68:726, 1968.
DPH, Distal pulp horn; *MPH,* mesial pulp horn; *PH,* pulp horn.

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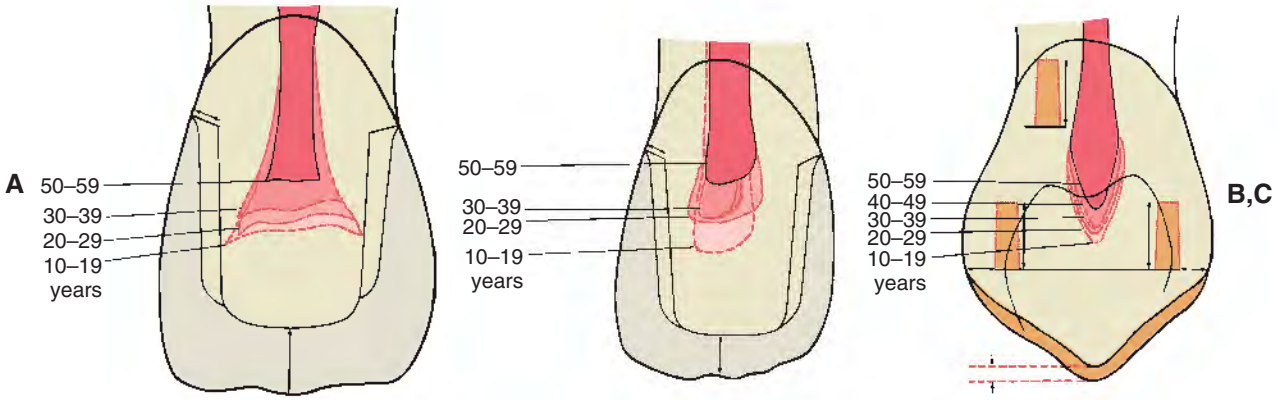

FIGURE 7-4 ■ Illustrations of the relationship between tooth preparation and pulp chamber size. The dashed lines represent pulp chamber structure at various ages. **A,** Maxillary central incisor with a metal-ceramic crown preparation. **B,** Maxillary lateral incisor with a metal-ceramic crown preparation. **C,** Maxillary canine with a pinledge preparation. (Redrawn from Ohashi Y: Research related to anterior abutment teeth of fixed partial denture. Shikagakuho 68:726, 1968.)

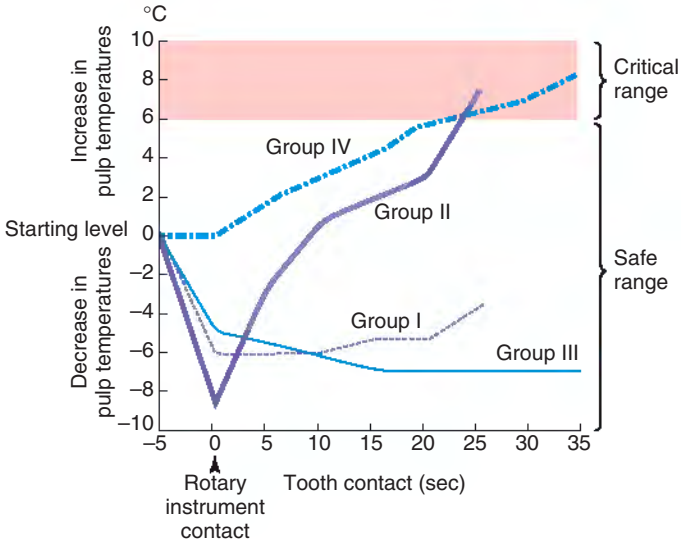

FIGURE 7-5 ■ Pulpal temperature rise during tooth preparation. *Group I,* air turbine, water cooled. *Group II,* air turbine, dry. *Group III,* low speed, water cooled. *Group IV,* low speed, dry. (Redrawn from Zach L, Cohen G: Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 19:515, 1965.)

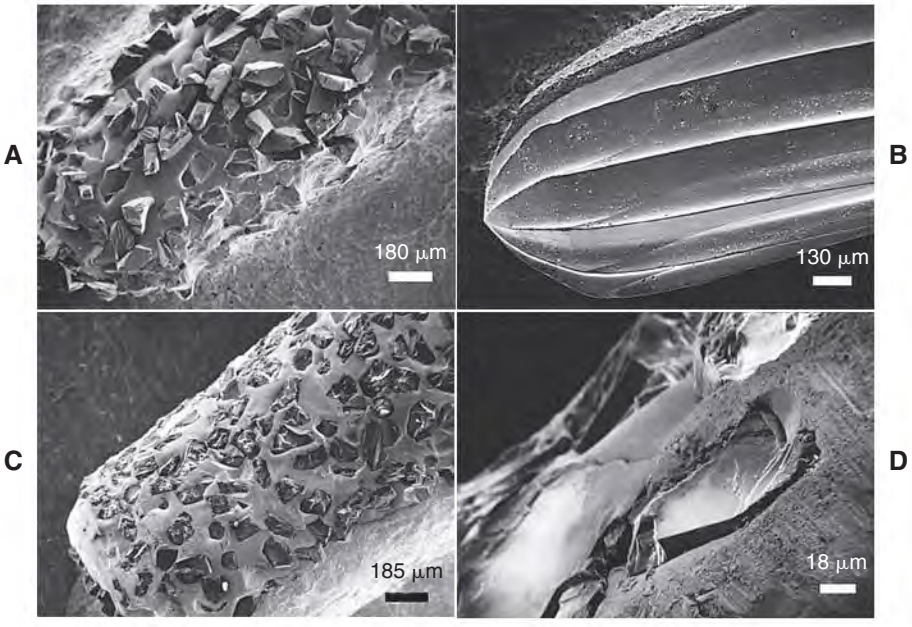

FIGURE 7-6 ■ Scanning electron micrographs of rotary instruments. **A,** Unused diamond rotary instrument. **B,** Unused carbide. **C,** Worn diamond rotary instrument. **D,** Diamond rotary instrument particles that have fractured at the level of the binder. (Courtesy Dr. J.L. Sandrik.)

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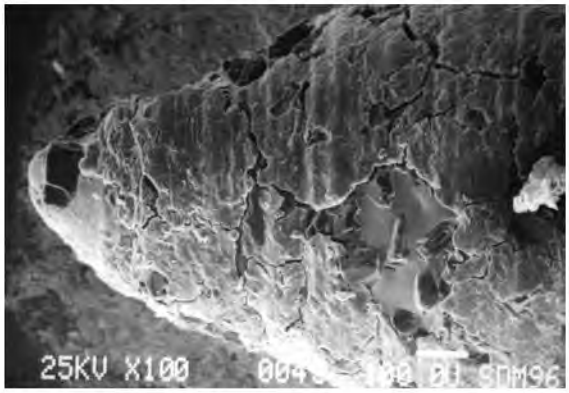

FIGURE 7-7 ■ Clogging on the tapered tip of a diamond after one molar tooth preparation reduces cutting efficiency.

Chemical Action. The chemical action of certain dental materials (bases, restorative resins, solvents, and luting agents) can cause pulpal damage,[10] particularly when applied to freshly cut dentin. Dentin bonding agents form an effective barrier in most instances, but their effect on the retention of cemented restorations is controversial.[11-13]

Chemical solvents and surfactants are sometimes used for cleaning and degreasing tooth preparations. However, some of these have been shown[14] to be pulpal irritants. Thus their use is generally contraindicated, particularly because they do not improve the retention of cemented restorations.[15]

Bacterial Action. Pulpal damage under restorations has been attributed[16,17] to bacteria that either were left behind or gained access to the dentin because of microleakage. However, many dental materials, including zinc phosphate cement, have an antibacterial effect.[18] Because vital dentin seems to resist infection,[19] the routine use of antimicrobial agents may not be advantageous. Many dentists now use an antimicrobial agent, such as chlorhexidine gluconate disinfecting solution (Consepsis, Ultradent Products, Inc.), after tooth preparation and before cementation, although the benefit has not been documented in clinical trials.[20]

Of importance is that all carious dentin must be removed before placement of a restoration that will serve as a foundation for a fixed prosthesis. In general, for teeth that will subsequently receive cast restorations, indirect pulp caps are contraindicated because subsequent failure of the pulp cap is likely to jeopardize costly prosthodontic treatment.

Conservation of Tooth Structure

One of the basic tenets of restorative dentistry is to conserve as much tooth structure as possible while preparation design remains consistent with the mechanical and esthetic principles of tooth preparation. Tissue preservation reduces the harmful pulpal effects of the various procedures and materials used. Remaining dentin thickness has been shown[21] to be inversely proportional to pulpal response, and tooth preparation in close proximity to the pulp should be avoided. Dowden[22] argued that any damage to the odontoblastic processes would adversely affect the cell nucleus at the dentin-pulp interface, no matter how far from the nucleus it occurred. Thus in assessing a possible adverse pulpal response, the amount of residual dentin must be taken into consideration; particular care must be exercised when vital teeth are prepared for complete-coverage restorations (Fig. 7-8).

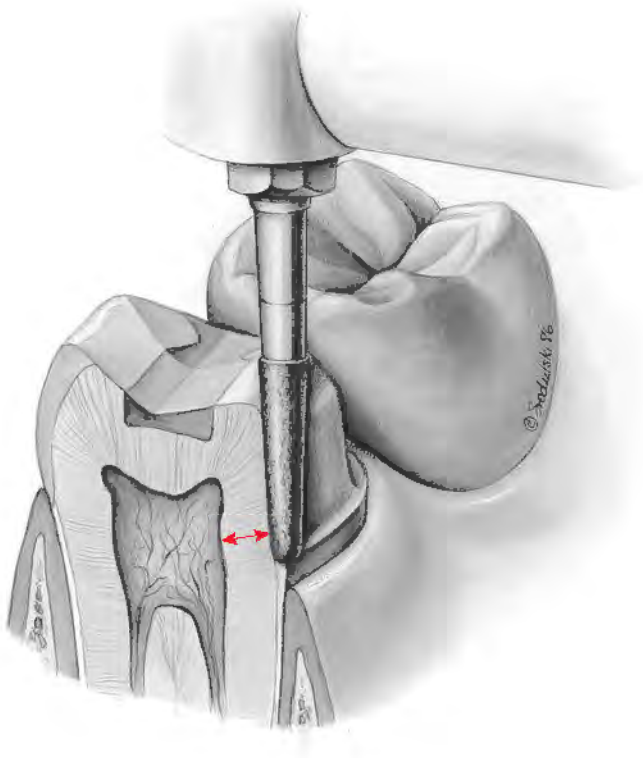

FIGURE 7-8 ■ A considerable amount of care is needed when a tooth is prepared for a complete crown, because of the extensive nature of the reduction, with many dentinal tubules sectioned. Each tubule communicates directly with the dental pulp. Maximal dentin thickness should be maintained *(arrow)*.

Tooth structure is conserved through adherence to the following guidelines:

1. Use of partial-coverage rather than complete-coverage restorations[23] (Fig. 7-9)
2. Preparation of teeth with the minimum practical convergence angle (taper) between axial walls (Fig. 7-10)
3. Preparation of the occlusal surface so that reduction follows the anatomic planes and produces uniform thickness in the restoration (Fig. 7-11)
4. Preparation of the axial surfaces so that a maximal thickness of residual tooth structure surrounding pulpal tissues is retained; if feasible, teeth may be orthodontically repositioned (Fig. 7-12; see Fig. 3-22), which allows less axial convergence than necessary when tooth alignment is less than optimal to accommodate preparations for fixed dental prosthetic retainers
5. Selection of a margin geometry that is conservative and yet compatible with the other principles of tooth preparation (Fig. 7-13)

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FIGURE 7-9 ■ Conservation of tooth structure by using partial-coverage restorations. In this case, they are used as fixed dental prosthetic abutments to replace congenitally missing lateral incisors.

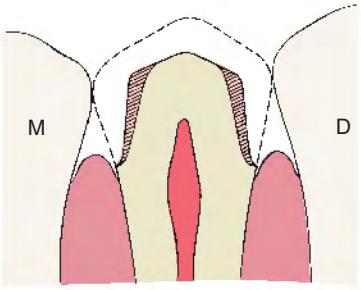

FIGURE 7-10 ■ Excessive taper results in considerable loss of tooth structure *(cross-hatched area).*

6. Avoidance of unnecessary apical extension of the preparation (Fig. 7-14), which would result in loss of additional tooth structure

Considerations Affecting Future Dental Health

Improper tooth preparation may have adverse effects on long-term dental health. For example, insufficient axial reduction inevitably results in overcontoured restorations

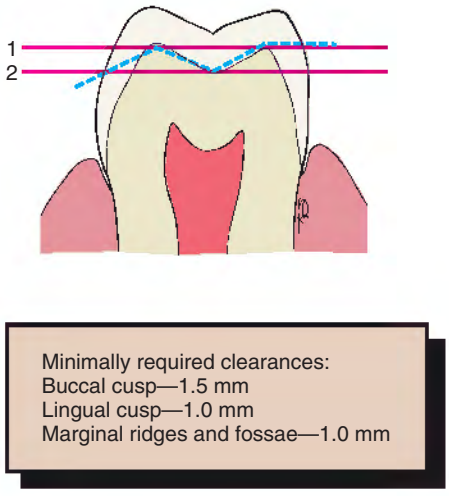

FIGURE 7-11 ■ An anatomically prepared occlusal surface results in adequate clearance without excessive tooth reduction. A flat occlusal preparation will result in either insufficient clearance *(1)* or an excessive amount of reduction *(2).*

that hamper plaque control. This may cause periodontal disease[24] or dental caries. Alternatively, inadequate occlusal reduction may result in poor form and subsequent occlusal dysfunction. Poor choice of margin location, such as in the area of occlusal contact, may cause chipping of enamel or cusp fracture.

Axial Reduction

Gingival inflammation is commonly associated with crowns and fixed dental prosthetic abutments that have excessive axial contours, probably because it is more difficult for the patient to maintain plaque control around the gingival margin[25] (Fig. 7-15). Successful preparations provide sufficient space for the development of anatomically correct axial contours. The junction between the restoration and the tooth must be smooth and free of any ledges or abrupt changes in direction.

In most circumstances, a crown should duplicate the contours and profile of the original tooth (unless the restoration is needed to correct a malformed or malpositioned tooth). If an error is made, a slightly undercontoured flat restoration is better because it is easier to keep free of plaque; however, increasing proximal contour on anterior crowns to maintain the interproximal papilla[26] (see Chapter 5) may be beneficial from an esthetic perspective. Sufficient tooth structure must be removed to allow the development of correctly formed axial contours (Fig. 7-16), particularly in the interproximal and furcation areas of posterior teeth, where periodontal disease often progresses with serious consequences.

Margin Placement

Whenever possible, the margin of the preparation should be supragingival. Subgingival margins of cemented restorations have been identified[27-32] as a major etiologic factor in periodontal disease, particularly where they encroach on the epithelial attachment (see Chapter 5). Supragingival margins are easier to prepare accurately

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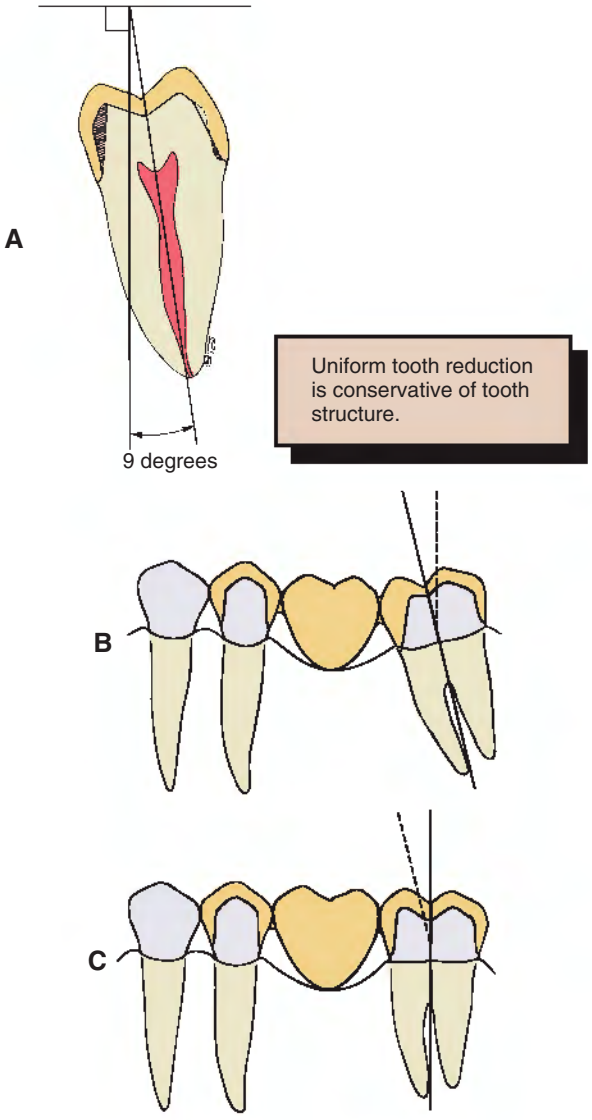

FIGURE 7-12 ■ To conserve tooth structure, the preparation of axial walls should be as uniform as possible. **A,** The path of placement should coincide with the long axis of the tooth, which for a mandibular molar is typically inclined 9 to 14 degrees lingually. Preparing such a tooth with a path of placement that is perpendicular to the occlusal plane of the mandibular arch is a common clinical error that results in additional unnecessary removal of tooth structure *(cross-hatched area).* **B,** Malaligned teeth, such as a mesially tipped molar, necessitate additional removal of tissue on the mesial aspect of the molar abutment to achieve compatible paths of placement for a planned fixed dental prosthesis. **C,** If the molar abutment is orthodontically uprighted before tooth preparation, crown preparation can be more conservative.

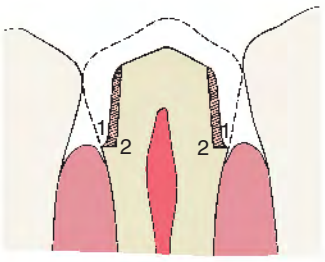

FIGURE 7-13 ■ A shoulder margin *(2)* is indicated when esthetic restorations are planned to achieve sufficient material thickness for a lifelike appearance, but it is much less conservative than a chamfer margin *(1).*

FIGURE 7-14 ■ **A,** Apical extension of the preparation can necessitate additional tooth reduction because coronal diameter becomes smaller. **B,** Preparations for periodontally involved teeth may necessitate considerable reduction if the margins are to be placed subgingivally for esthetic reasons. **C,** Supragingival margins are preferred where applicable.

without trauma to the soft tissues and facilitate impression making or optical capture. They can usually also be situated on hard enamel, whereas subgingival margins are often on dentin or cementum.

Advantages of supragingival margins include the following:

1. They can be easily finished without associated soft tissue trauma.
2. They are more easily kept plaque free.
3. Impressions are more easily made, with less potential for soft tissue damage.
4. Restorations can be easily evaluated at the time of placement and at recall appointments.

Subgingival margins (Fig. 7-17), however, are indicated if any of the following conditions are present:

1. Dental caries, cervical erosion, or restorations extend subgingivally, and a crown-lengthening procedure (see Chapter 6) is contraindicated.

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FIGURE 7-15 ■ **A,** Unhealthy gingival tissue as a result of overcontoured restorations. **B,** The tooth preparations are underreduced. **C,** Once the restorations are recontoured, gingival health returns.

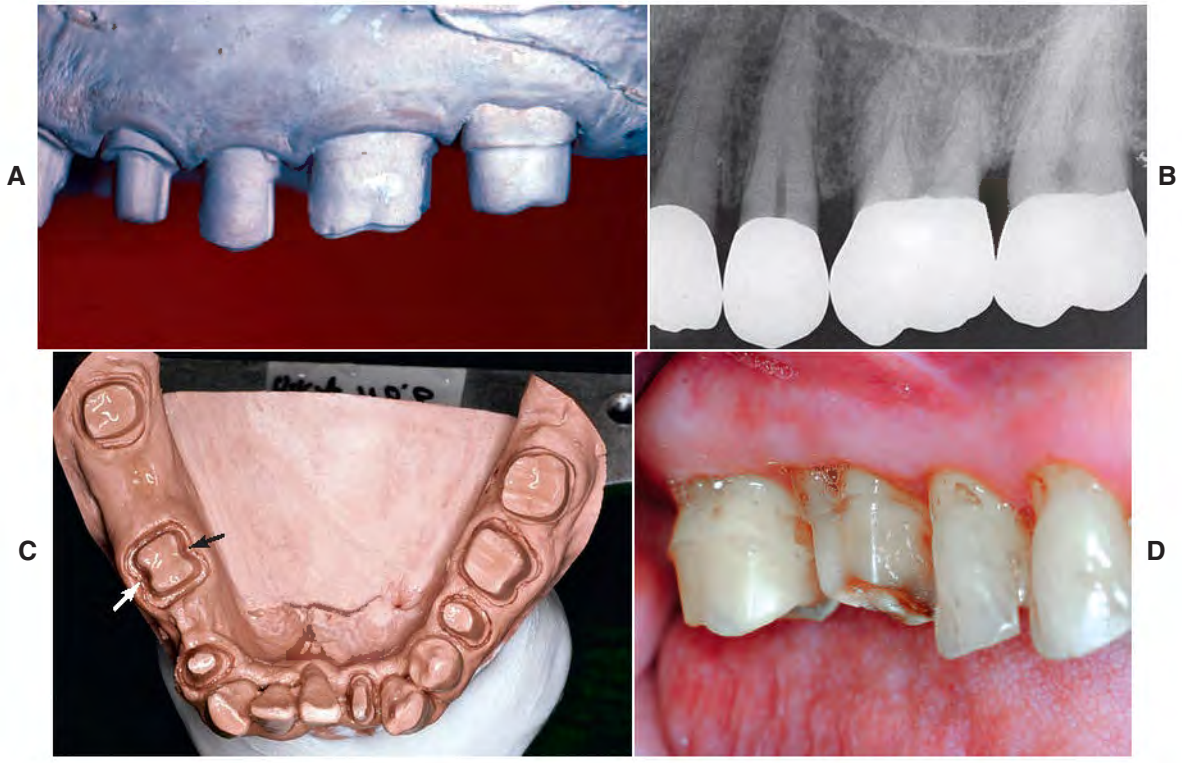

FIGURE 7-16 ■ **A** and **B,** Tooth preparations with adequate axial reduction allow the development of properly contoured embrasures. Tissue is conserved through the use of partial coverage and supragingival margins where possible. **C,** Preparing furcation areas adequately is important *(arrows);* otherwise, the restoration is excessively contoured, which makes plaque control difficult. **D,** Note the additional preparation of the buccal axial wall of the first molar to allow for improved access for plaque control in the furcation area.

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FIGURE 7-17 ■ Examples of situations in which subgingival margins are indicated. **A,** To include an existing restoration. **B,** To extend apical to the proximal contact (adequate proximal clearance). **C** and **D,** To hide the metal collar of metal-ceramic crowns.

2. The proximal contact area extends apically to the level of the gingival crest.
3. Additional retention, resistance, or both are needed (see Mechanical Considerations section later in the chapter).
4. The margin of an esthetic restoration is to be hidden behind the labiogingival crest.
5. Root sensitivity cannot be controlled by more conservative procedures, such as the application of dentin bonding agents.
6. Axial contour modification is indicated: for example, to provide an undercut to provide retention for a partial removable dental prosthesis clasp (see Chapter 21).

Average dimensions for clinical crown height and sulcus depth in young healthy adults are provided in Figure 7-18.

Margin Adaptation

The junction between a cemented restoration and the tooth is always a potential site for recurrent caries because of dissolution of the luting agent and inherent interface roughness. The more precisely the restoration is adapted to the tooth, the lower is the risk for recurrent caries or periodontal disease.[33] Although a precise number for acceptable marginal gap width is not known, a skilled technician can routinely make castings that fit to within 10 µm[34] and porcelain margins that fit to within 50 µm,[35] provided that the tooth was properly prepared. A well-designed preparation has a smooth and even margin. Rough, irregular, or "stepped" junctions between tooth and restoration greatly increase overall margin length and substantially reduce the adaptation accuracy of the restoration (Fig. 7-19).[36,37] The clinical significance of preparing smooth margins cannot be overemphasized. Time spent obtaining smooth margins makes the subsequent steps of tissue displacement, impression making, laboratory communication, die formation, waxing, and finishing much easier and ultimately results in longer lasting restorations. Smooth, accurately placed preparation margins are particularly important when restorations are fabricated with a computer-aided design and computer-aided manufacturing (CAD/CAM) process.[38]

Margin Geometry

The cross-sectional configuration of the margin has been the subject of much analysis and debate.[39-46] Different shapes have been described and advocated (Table 7-2).[47,48] For evaluation, the following guidelines for margin design should be considered:

1. Ease of preparation without overextension or unsupported enamel at the cavosurface line angle
2. Ease of identification in the impression or optical scan and on the (virtual) die
3. A distinct boundary to which the wax pattern can be finished or the design terminated
4. Sufficient bulk of material (to enable the pattern to be handled without distortion and to give the restoration strength and, when porcelain is used, esthetic appearance)
5. Conservation of tooth structure (assuming the above criteria are met)

Proposed margin designs are presented in Table 7-3.

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TABLE 7-2 Margins Produced by Various Types of Rotary Instruments

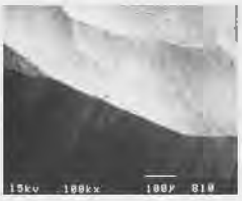
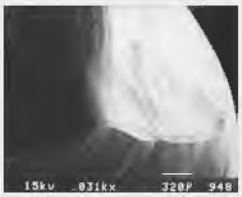
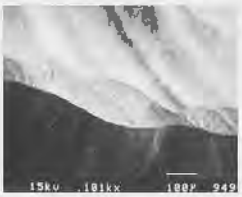
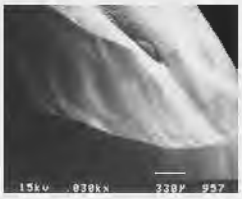
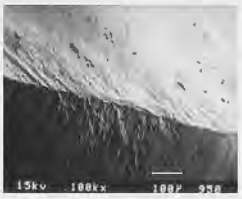
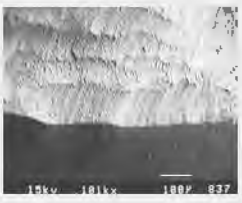
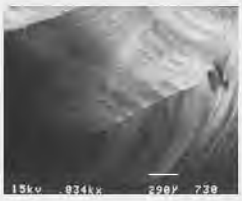
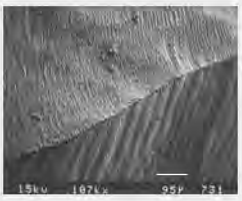
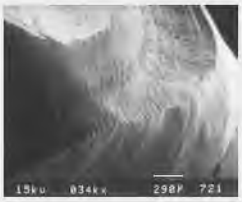
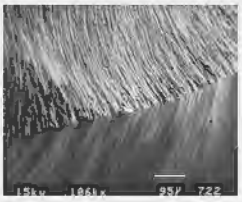
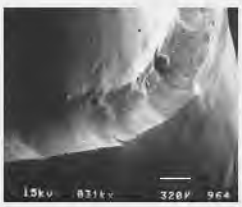
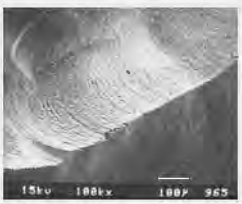
Rotary Instrument Appearance	Low Magnification of the Prepared Margin	High Magnification of the Prepared Margin
Chamfer Margins		
Chamfer carbide (high speed)		
Chamfer carbide (high speed) Finishing carbide (high speed)		
Chamfer carbide (high speed) Finishing carbide (low speed)		
Chamfer coarse diamond (high speed)		
Chamfer coarse diamond (high speed) Fine diamond (high speed)		
Chamfer coarse diamond (high speed) Chamfer fine diamond (low speed)		
Shoulder Margins		
Cross-cut fissure (high speed)		

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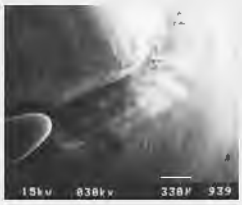
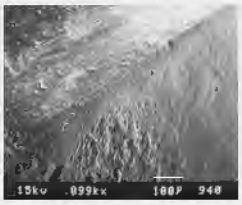
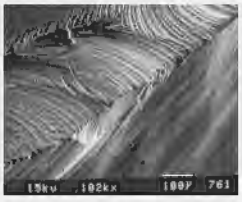
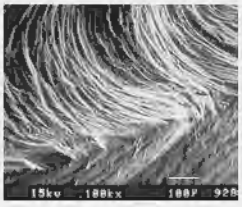
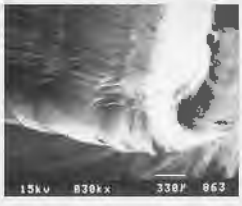
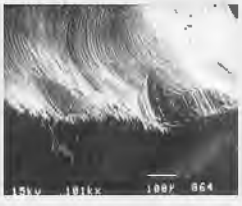
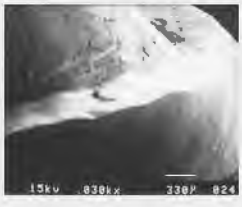
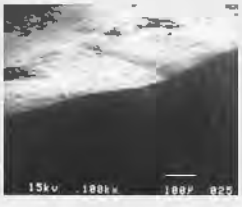
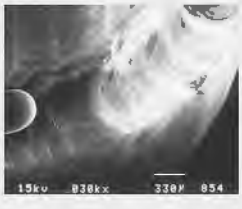
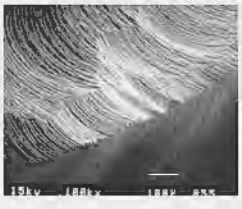
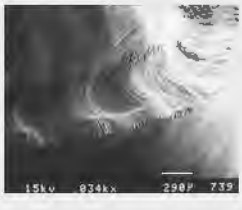
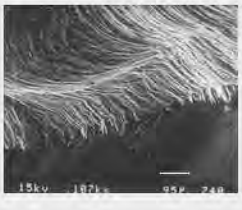
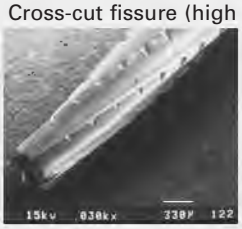
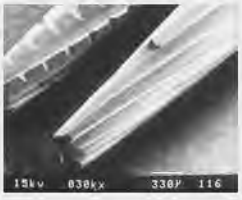
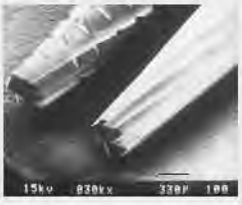
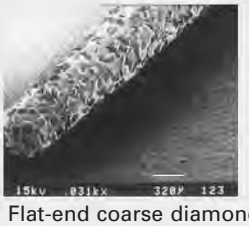
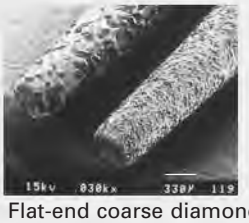
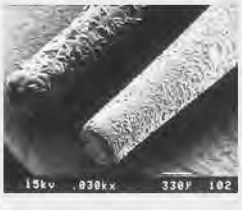
TABLE 7-2 **Margins Produced by Various Types of Rotary Instruments—cont'd**

Rotary Instrument Appearance	Low Magnification of the Prepared Margin	High Magnification of the Prepared Margin
Shoulder Margins, cont'd		
Cross-cut fissure (high speed) and hoe		
Cross-cut fissure carbide (high speed) Finishing carbide (high speed)		
Cross-cut fissure carbide (high speed) Finishing carbide (low speed)		
Flat-end coarse diamond (high speed)		
Flat-end coarse diamond (high speed) and hoe		
Flat-end coarse diamond (high speed) Fine-grit diamond (high speed)		
Flat-end coarse diamond (high speed) Fine-grit diamond (low speed)		

Courtesy Dr. H. Lin.

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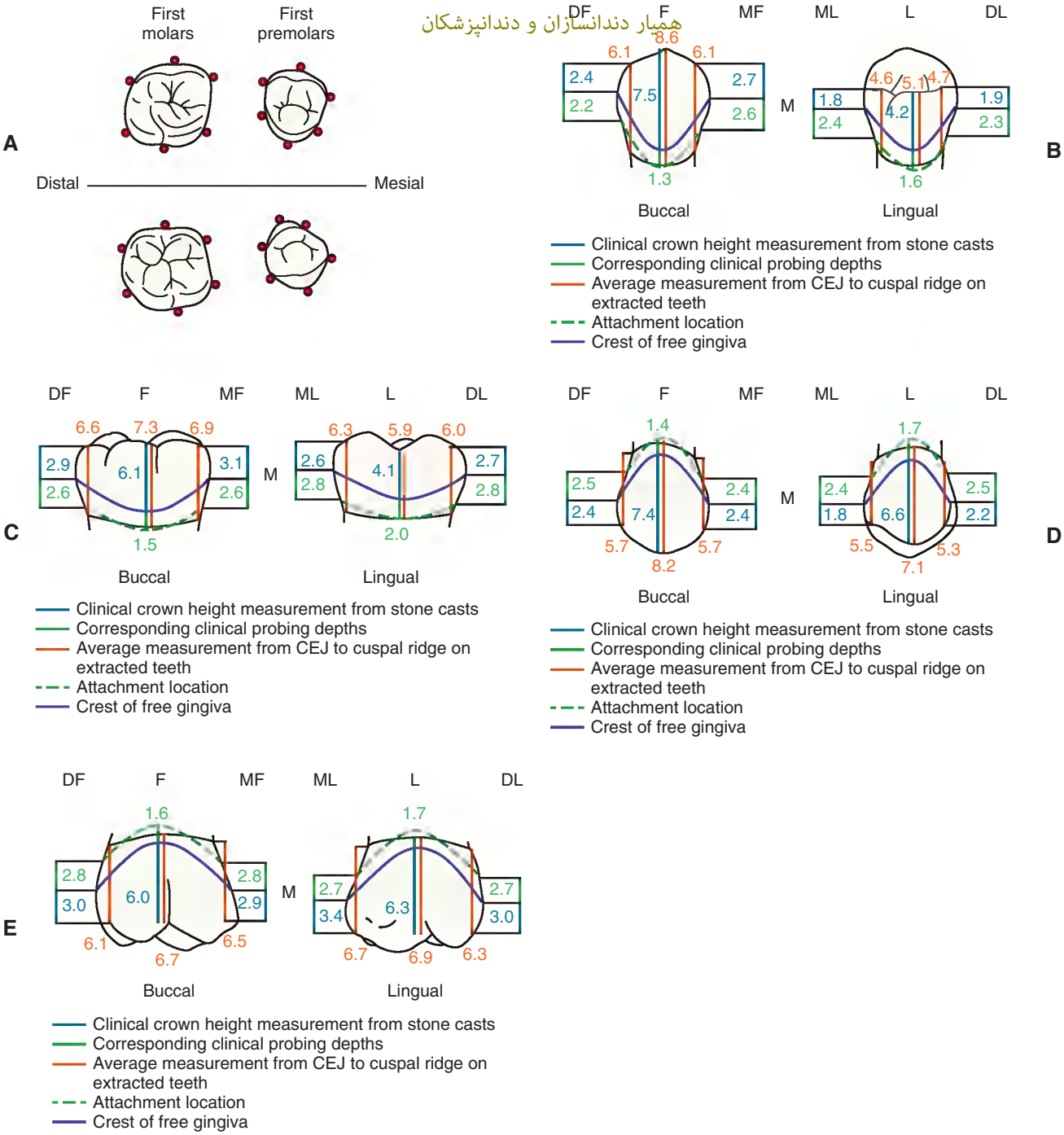

FIGURE 7-18 ■ Average normal dimensions for clinical crown height and sulcus depth. **A,** Occlusal view of measurement locations. **B,** Mandibular first premolars. **C,** Mandibular first molars. **D,** Maxillary first premolars. **E,** Maxillary first molars. *CEJ,* Cementoenamel junction; *DF,* distofacial; *DL,* distolingual; *F,* facial; *L,* lingual; *M,* mesial; *MF,* mesiofacial; *ML,* mesiolingual. (Data from Land MF: Unpublished data.)

TABLE 7-3 **Advantages and Disadvantages of Different Margin Designs**

Margin Design	Advantages	Disadvantages	Indications
Feather edge	Conservative of tooth structure	Does not provide sufficient bulk	Not recommended
Chisel edge	Conservative of tooth structure	Location of margin difficult to control	Occasionally on tilted teeth
Beveled	Removes unsupported enamel, allows finishing of metal	Extends preparation into sulcus if used on apical margin	Facial margin of maxillary partial-coverage restorations and inlay/onlay margins
Chamfer	Distinct margin, adequate bulk, easier to control	Care needed to avoid unsupported lip of enamel	Cast metal restorations, lingual margin of metal-ceramic crowns
Shoulder	Bulk of restorative material	Less conservative of tooth structure	Facial margin of metal-ceramic crowns, complete ceramic crowns
Sloped shoulder	Bulk of material, advantages of bevel	Less conservative of tooth structure	Facial margins of metal-ceramic crowns
Beveled shoulder	Bulk of material, advantages of bevel	Less conservative, extends preparation apically	Facial margin of posterior metal-ceramic crowns with supragingival margins

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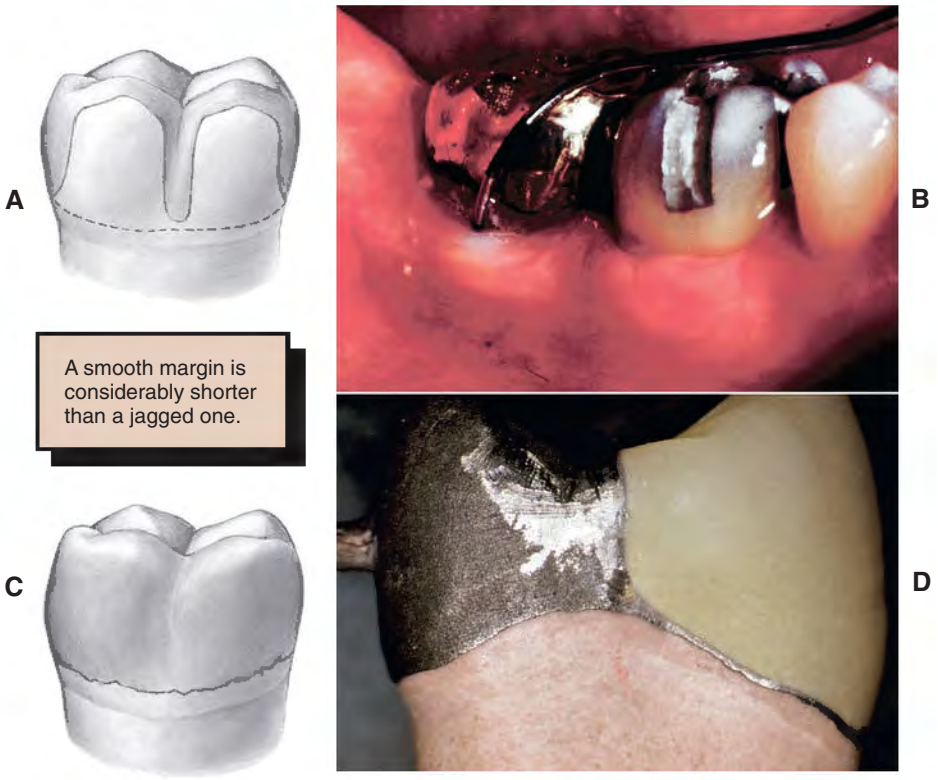

FIGURE 7-19 ■ **A** and **B,** Poor preparation design, leading to increased margin length. **C,** A rough, irregular margin makes the fabrication of an accurately fitted restoration almost impossible. **D,** An accurately fitting margin is possible only if it is prepared smoothly.

Although conservative of tooth structure, feather edge or shoulderless crown preparations (Fig. 7-20, *A*) should be avoided because they do not provide adequate bulk at the margins. These margin designs were frequently used before the development of elastomeric impression materials. However, overcontoured restorations often resulted from feather edge margins because reduction was insufficient to make restorations of adequate thickness within the confines of correct anatomic form. When a cast restoration is planned, the technician can handle the wax pattern without distortion only by increasing its bulk beyond the original contours. For milled restorations, in most esthetic materials, minimal thickness requirements approaching 1 mm apply. The feather edge margin does not allow for such. A variation of the feather edge, the chisel edge margin (see Fig. 7-20, *B*), is formed when the angle between the axial surfaces and the unprepared tooth structure is larger. Unfortunately, this margin is frequently associated with preparations with excessive angles of convergence (taper) and preparations in which the orientation of the axial reduction is not correctly aligned with the long axis of the tooth.

Feather edge preparations may be the best option for porcelain laminate veneer preparations (see Chapter 11), inasmuch as maintaining enamel for the bonded restoration is important for the longevity of the bond. Bulk of the ceramic at the margin can be reduced after bonding (see Chapter 25), and because laminate veneer margins are accessible to the patient, plaque control around veneers is rarely a problem, in contrast to complete crowns.

Under most circumstances, however, feather edges and chisel edges are unacceptable. Historically, their main advantage was that they facilitated impression making with rigid modeling compound in copper bands (a technique rarely used today). They were useful for that purpose because there was no ledge on which a band could catch. A chamfer margin (see Fig. 7-20, *C*) is particularly suitable for cast metal crowns and the metal-only portion of metal-ceramic crowns (Fig. 7-21). It is distinct and easily identified, and it provides room for adequate bulk of material and the development of anatomically correct axial contours. Chamfer margins can be placed expediently and with precision, although care is needed to avoid leaving a lip of unsupported enamel (see also Fig. 7-24).

The most suitable instrument for making a chamfer margin is probably a tapered diamond with a rounded tip; the resulting margin is the exact image of the instrument (Fig. 7-22). Marginal accuracy depends on having a high-quality diamond and a true-running handpiece. The gingival margin is prepared with the diamond held precisely in the intended path of placement of the restoration (Fig. 7-23).

Tilting it away from the tooth produces an undercut, whereas angling it toward the tooth leads to excessive convergence and reduction and loss of retention. The chamfer margin should never be prepared wider than half the tip of the diamond; otherwise, an unsupported lip of enamel may result (Fig. 7-24). Some authorities have recommended the use of a diamond with a noncutting guide tip to aid accurate chamfer margin placement.[49] However, such guides have been shown to damage tooth structure beyond the intended preparation margin.[50]

In some circumstances, a beveled margin (see Fig. 7-20, *D*) is more suitable for cast restorations, particularly if a

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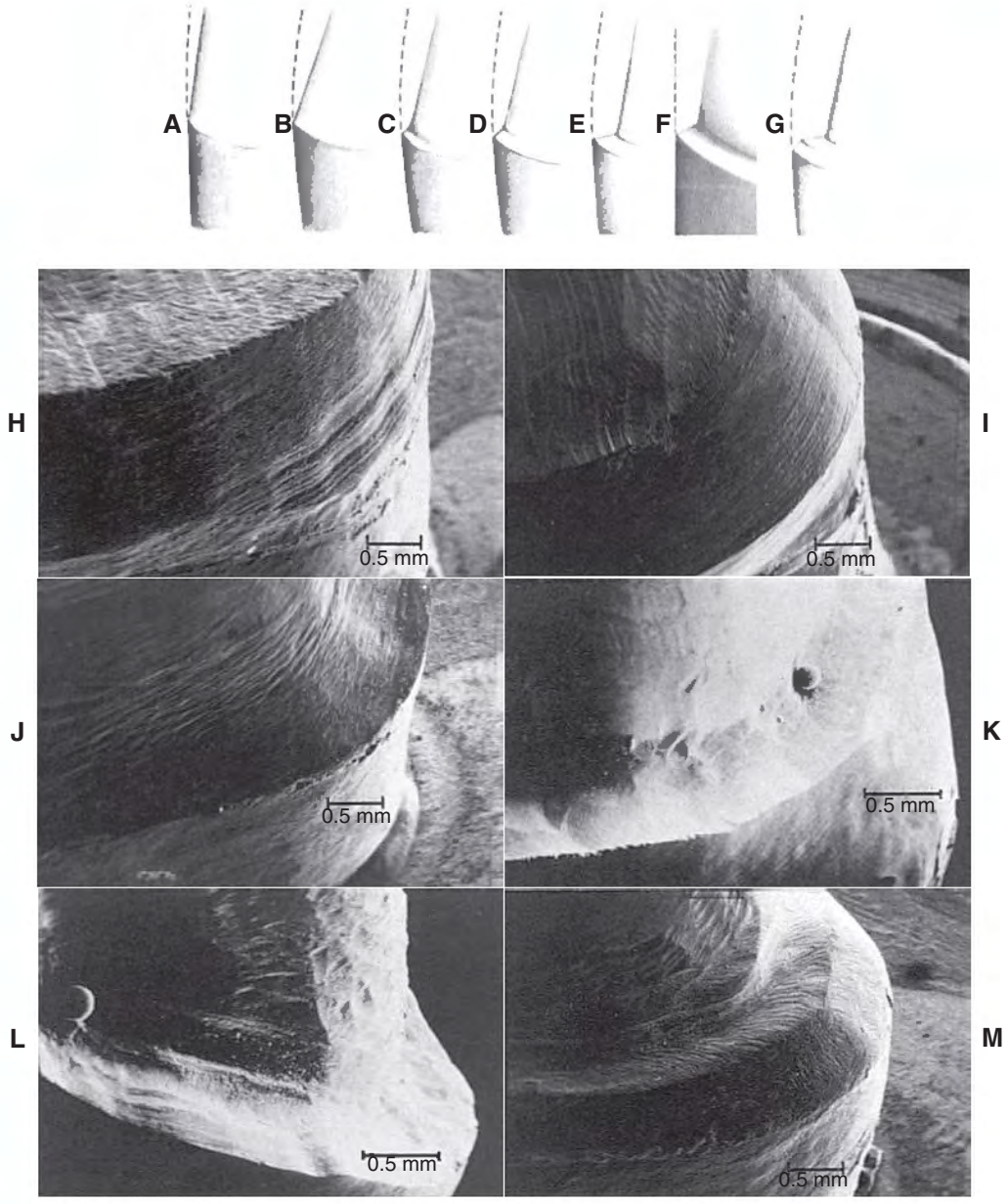

FIGURE 7-20 ■ Margin designs: illustrations (**A** to **G**) and scanning electron micrographs (**H** to **M**). **A,** Feather edge. **B,** Chisel. **C,** Chamfer. **D,** Beveled. **E,** Shoulder. **F,** Sloped shoulder. **G,** Beveled shoulder. **H,** Feather or chisel edge. **I,** Beveled. **J,** Chamfer. **K,** Shoulder. **L,** Sloped shoulder. **M,** Beveled shoulder. (Courtesy Dr. H. Lin.)

FIGURE 7-21 ■ Chamfer margins are recommended for cast metal crowns **(A)** and the lingual margin of a metal-ceramic crown **(B)**.

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ledge or shoulder margin already exists, possibly as a result of dental caries, cervical erosion, or a previous restoration. The objective in beveling is threefold: (1) to allow the cast metal margin to be bent or burnished against the prepared tooth structure; (2) to minimize the marginal discrepancy[39] caused by a complete crown that fails to seat completely (however, Pascoe[44] showed that when an oversized crown is considered, the discrepancy is increased rather than decreased; Fig. 7-25); and (3) to protect the unprepared tooth structure from chipping (e.g., by removing unsupported enamel). Of note is that when access for burnishing is limited, there is little advantage in beveling. This applies particularly to a gingival margin, in which beveling would lead to subgingival extension of the preparation or placement of the margin on dentin rather than on enamel. Facial margins of maxillary partial-coverage restorations should be beveled to eliminate all unsupported enamel, to protect the remaining tooth structure from fracture, and to allow for burnishing of the casting.

Because a shoulder margin (see Fig. 7-20, *E*) allows room for porcelain, it is recommended for the facial part of metal-ceramic crowns, especially when the porcelain margin technique is used. It should form a 90-degree angle with the unprepared tooth surface. An acute angle is likely to chip (Fig. 7-26, *A*). In practice, dentists tend to underprepare the facial shoulder margin,[51,52] which leads to restorations with inferior esthetics or poor (excessive) axial contour.

Some authorities[48] have recommended a heavy chamfer margin rather than a shoulder margin, and some find a chamfer margin easier to prepare with precision. Earlier workers[42,43] found less distortion of the metal framework during porcelain application with a shoulder margin, although with modern alloys, these results could not be replicated.[53-56]

A 120-degree sloped shoulder margin (see Fig. 7-20, *F*) is sometimes used as an alternative to the 90-degree shoulder margin for the facial margin of metal-ceramic crowns. The sloped shoulder margin reduces the possibility of leaving unsupported enamel but leaves sufficient bulk to allow thinning of the metal framework to a knife-edge for acceptable esthetics.

FIGURE 7-22 ■ A chamfer margin is formed as the negative image of a round-ended tapered diamond.

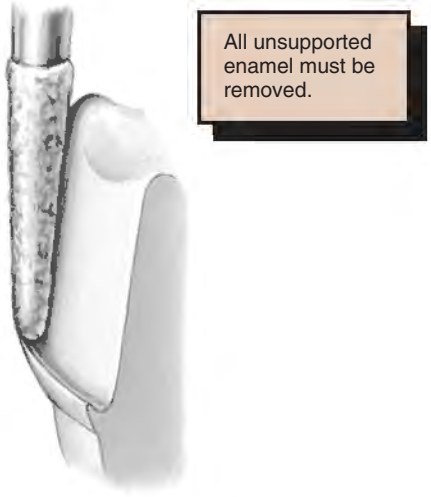

FIGURE 7-24 ■ A chamfer margin should not be wider than half the rotary instrument used to form it. Otherwise, a "lip" of unsupported enamel will be left.

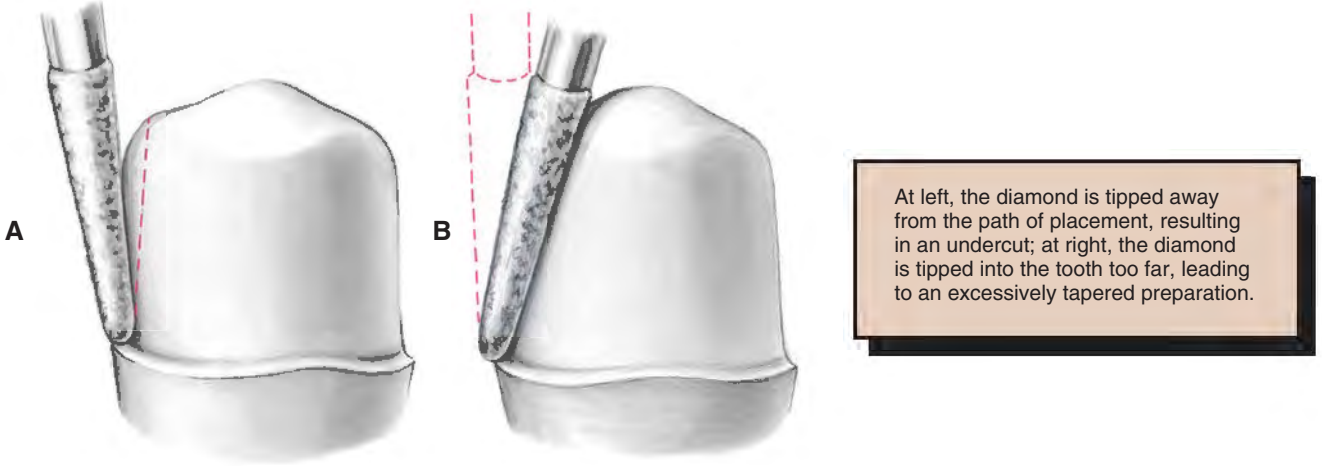

FIGURE 7-23 ■ Precise control of the orientation of the diamond is very important. **A,** Tilting away from the tooth creates an undercut: Opposing axial preparation walls diverge in an occlusal direction. **B,** Tilting toward the tooth results in an excessive convergence angle of the preparation.

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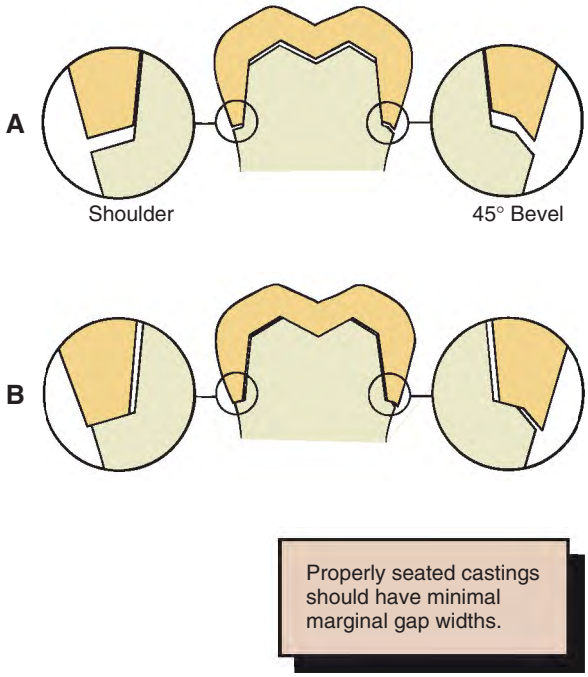

FIGURE 7-25 ■ Effect on marginal fit of beveling the gingival margin. **A,** If the internal cross section of a crown is the same as or less than that of the prepared tooth, a 45-degree bevel decreases the marginal discrepancy by 70%. **B,** If the internal diameter is slightly larger than the prepared tooth, beveling increases the marginal discrepancy. In practice, crowns are made slightly larger than the prepared tooth to allow for the luting agent.

A beveled shoulder margin (see Fig. 7-20, *G*) has been recommended by some authorities for the facial surface of a metal-ceramic restoration if a metal collar is planned (as opposed to a porcelain labial margin). The beveling removes unsupported enamel and may allow some finishing of the metal. However, a shoulder or sloped shoulder margin is preferred for biologic and esthetic reasons. This allows improved esthetics because the metal margin can be thinned to a knife edge and hidden in the sulcus without the need for positioning the margin closer to the epithelial attachment (see Fig. 7-26, *B*). Table 7-2 illustrates chamfer and shoulder margin preparations obtained with selected instruments.

A comprehensive literature review of current scientific knowledge on complete coverage tooth preparations suggests that margin design should be selected on the basis of type of crown, applicable esthetic requirements, ease of formation, and operator experience. Research has not validated the expectation of enhanced fit being associated with selection of certain types of finish line geometry.[57]

Occlusal Considerations

A satisfactory tooth preparation allows sufficient space to develop a functional occlusal scheme in the finished restoration. Sometimes the patient's occlusion is disrupted by supra-erupted or tilted teeth (Fig. 7-27; see Fig. 3-14). When such teeth are prepared for crowns, the eventual occlusal plane must be carefully analyzed and the teeth reduced accordingly. Considerable reduction is often needed to compensate for the supra-eruption of abutment teeth. In turn, this may shorten tooth preparation axial wall height to the extent that mechanical properties such as retention and resistance are compromised (see the later section on Mechanical Considerations), which would necessitate preparation modification with additional internal features such as grooves or boxes.

Sometimes even endodontic treatment is necessary to make enough room. However, in these circumstances, compromising the principle of conservation of tooth structure is preferable to the potential harm that might result from a restoration that incorporates a traumatic occlusal scheme. Careful judgment is obviously needed. Diagnostic tooth preparations and diagnostic waxing procedures are essential to help determine the exact amount of reduction necessary to develop an optimum occlusion (see Chapter 4).

Preventing Tooth Fracture

No tooth is unbreakable. If teeth are suddenly smashed together (as in an automobile accident, sports injury, or biting unexpectedly on a hard object), a cusp may break. Cuspal fracture can also result from parafunctional habits such as bruxism.

The likelihood that a restored tooth will fracture can be lessened if the tooth preparation is designed to minimize potentially destructive stresses (Fig. 7-28). For example, an intracoronal cast restoration (inlay) has a greater potential for fracture because when occlusal forces are applied to the restoration, it tends to serve as a wedge between opposing walls of the preparation. This wedging must be resisted by the remaining tooth structure; if the remaining tooth structure is thin (as with a wide preparation isthmus), the tooth may fracture during function. A cuspal coverage restoration (onlay) rather than an inlay lessens the chance of such fracture.[58] A complete crown, however, is often a better solution, because it offers the greatest protection against tooth fracture, tending to "hold" the cusps of the tooth together.

MECHANICAL CONSIDERATIONS

Tooth preparation design for fixed prosthodontics must adhere to certain mechanical principles; otherwise, the restoration may dislodge, distort, or fracture during service. These principles have evolved from theoretical and clinical observations and are supported by experimental studies.

Mechanical considerations can be divided into three categories:

1. Providing retention form
2. Providing resistance form
3. Preventing deformation of the restoration

Retention Form

Certain forces (e.g., when the jaws are moved apart after biting on very sticky food) act on a cemented restoration in the same direction as the path of placement. The quality of a preparation that prevents the restoration

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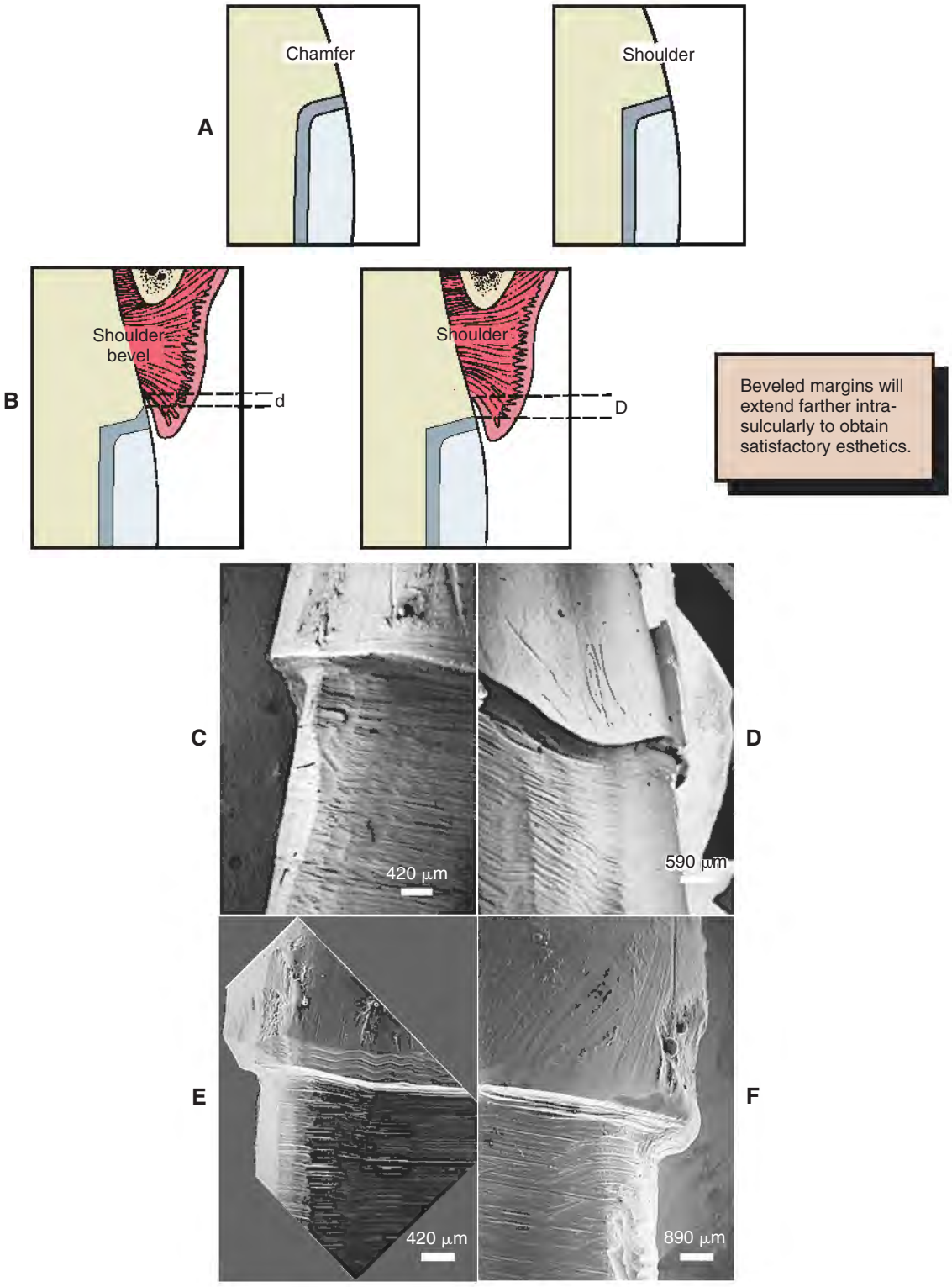

FIGURE 7-26 ■ **A,** A shoulder margin provides more bulk of metal than a heavy chamfer margin, which may facilitate the laboratory steps. **B,** A disadvantage of the beveled shoulder margin is that it must be placed deeper in the gingival sulcus so that the wider band of metal will be hidden (compare depth *d* with depth *D*). **C,** Scanning electron micrograph of a shoulder margin prepared with a high-speed diamond. **D,** Scanning electron micrograph of a margin refined with a sharp chisel. **E,** Scanning electron micrograph of a margin beveled with a tungsten carbide bur. **F,** Scanning electron micrograph of a bevel placed with a sharp hand instrument. (Microscopy by Dr. J. Sandrik; teeth prepared by Dr. G. Byrne.)

from becoming dislodged by such forces parallel to the path of placement is known as its *retention form*. Only dental caries and porcelain failure cause more failure of crowns and fixed dental prostheses than does lack of retention.[59,60]

The dentist must consider the following factors when deciding whether retention is adequate for a given fixed restoration:

1. Magnitude of the dislodging forces
2. Geometry of the tooth preparation

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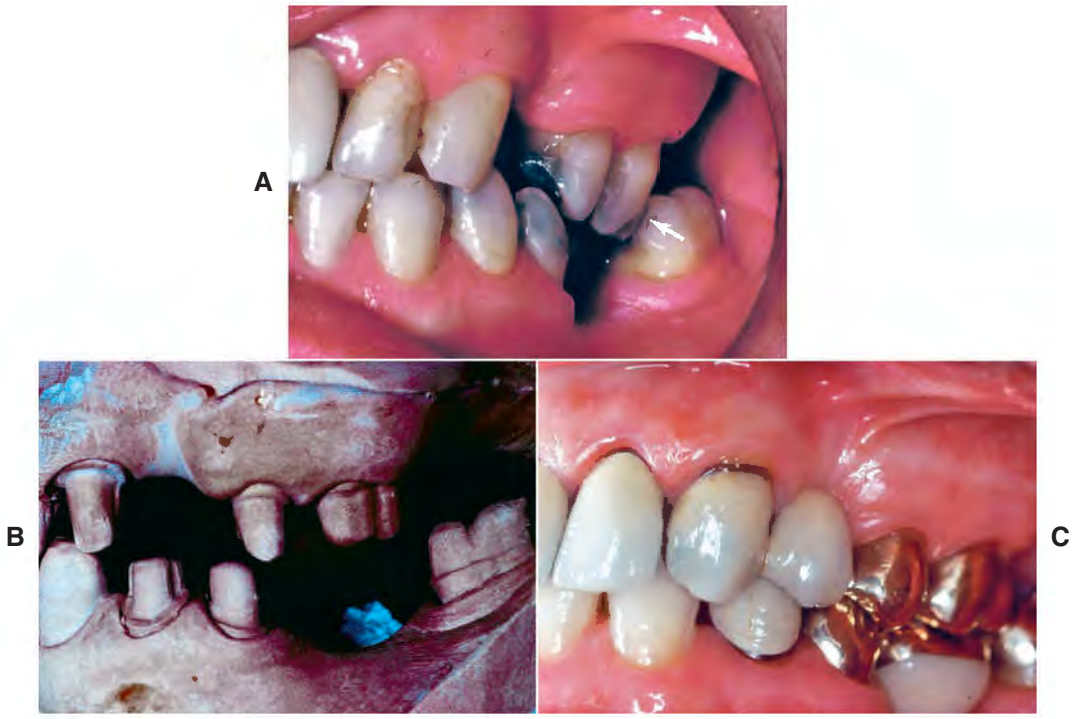
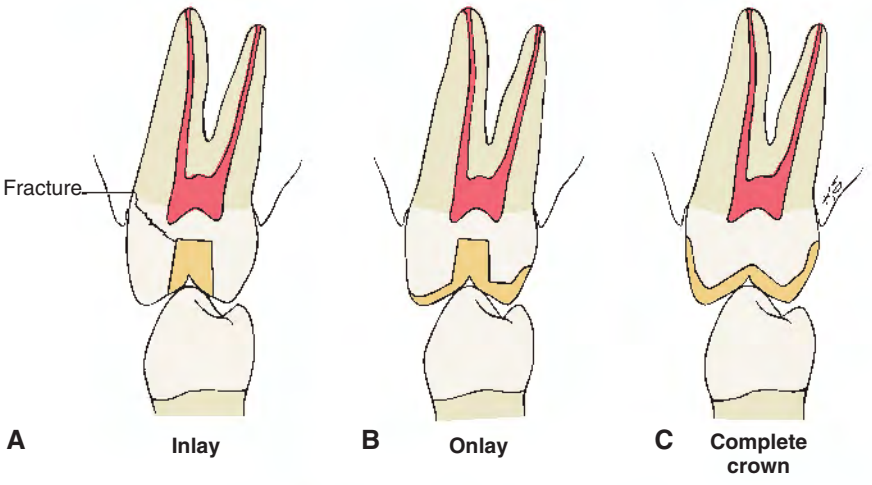


FIGURE 7-27 ■ **A,** Nonreplacement of missing teeth has led to supra-occlusion and a protrusive interference *(arrow).* **B,** Teeth reduced with the help of trial tooth preparations and diagnostic waxing. **C,** Restorations with anterior guidance.



Cuspal protection becomes more important as the structural durability of the cusps is compromised.

FIGURE 7-28 ■ **A,** An intracoronal cast restoration (inlay) can act as a wedge during cementation or function. If the cusps are weakened, fracture will occur. **B,** A cuspal-coverage onlay provides better protection but often lacks retention. **C,** A complete crown provides the best protection against fracture. It also has the best retention, but it can be associated with periodontal disease and poor esthetics. (Redrawn from Rosenstiel SF: Fixed bridgework—the basic principles. In Rayne J, ed: General dental treatment. London, Kluwer Publishing, 1983.)

3. Roughness of the fitting surface of the restoration
4. Materials being cemented
5. Film thickness and properties of the luting agent

Magnitude of the Dislodging Forces

Forces that tend to remove a cemented restoration along its path of placement are small in comparison with those that tend to seat or tilt it. A fixed dental prosthesis or splint can be subjected to such forces by pulling with floss under the connectors; however, the greatest removal forces generally arise when exceptionally sticky food (e.g., caramel) is eaten. The magnitude of the dislodging forces exerted by the elevator muscles depends on the stickiness of the food and on the surface area and surface texture of the restoration.

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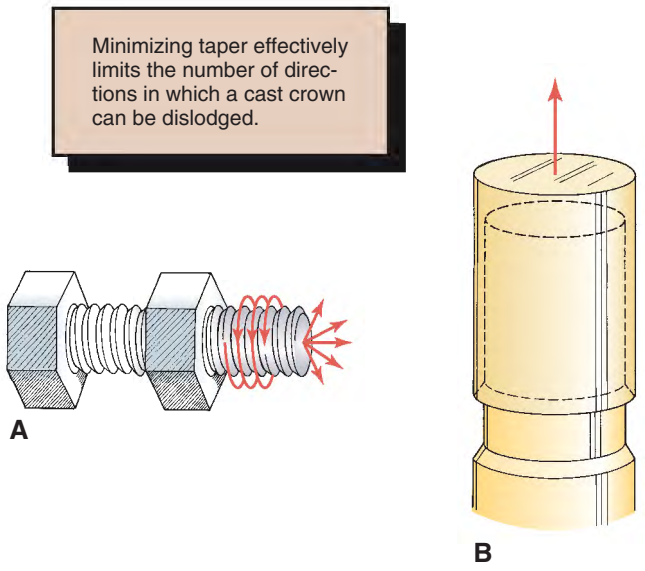

FIGURE 7-29 ■ **A,** The relationship between a nut and a bolt is an example of restrained movement: The nut can move only along a precisely defined helical path *(arrows)*. **B,** For effective retention, a tooth preparation must constrain the movement of a restoration; therefore, it must be cylindrical. (See Fig. 7-30.)

Geometry of the Tooth Preparation

Most fixed dental prostheses depend on the geometric form of the preparation rather than on adhesion for retention because most of the traditional luting agents (e.g., zinc phosphate) are nonadhesive (i.e., they act by increasing the frictional resistance between tooth and restoration). The grains of luting agent prevent two surfaces from sliding, although they do not prevent one surface from being lifted from another. This is analogous to the effect of particles of sand or dust within machinery: They do not adhere specifically to metal, but they increase the friction between sliding metal parts. If sand or dust gets into a mechanical camera or watch, the increase in friction can effectively jam the mechanism.

Traditional luting agents are effective only if the restoration has a single path of placement (i.e., the tooth is shaped to restrain the free movement of the restoration). The relationship between a nut and a bolt is an example of restrained movement (Fig. 7-29): The nut is not free to move in just any direction; it can move only along the precisely determined helical path of the threads on the bolt.

The relationship between two bodies, one (in this case, a tooth preparation) restraining movement of the other (a luted restoration), has been studied mathematically and is known in analytical mechanics as a *closed lower pair of kinematic elements*.[61] In fixed prosthodontics, a sliding pair is the only pair that has relevance. It is formed by two cylindrical* surfaces constrained to slide along one another. The elements are constrained if the curve that defines the cylinder is closed or shaped to prevent movement at right angles to the axis of the cylinder (Fig. 7-30).

A tooth preparation is cylindrical if the axial surfaces are prepared by a cylindrical rotary instrument held at a constant angle. The fixed curve of the mathematical definition is the gingival margin of the preparation, and the occlusoaxial line angle of the tooth preparation should be a replica of the gingival margin geometry. The curve of a complete crown preparation is closed, whereas the grooves of a partial crown preparation prevent movement at right angles to the long axis of the cylinder. However, if one wall of the complete crown preparation is overtapered, it is no longer cylindrical, and the cemented restoration is not constrained by the preparation because the restoration then has multiple paths of withdrawal. Under these circumstances, the cement particles tend to lift away from rather than slide along the preparation, and the only retention is a result of the cement's limited adhesion (Fig. 7-31).

Taper. *Taper* is defined as the convergence of two opposite-facing external walls of a crown preparation as viewed in a given plane (e.g., taper between a mesial wall and a distal wall, or between a buccal wall and a lingual wall of a crown preparation). The extension of those planes forms an angle described as the *angle of convergence*. Theoretically, maximum retention is obtained if a tooth preparation has parallel walls. However, it is neither desirable nor practical to prepare a tooth this way with current techniques and instrumentation because (1) some convergence is desirable to allow escape of excess luting agent during seating of the crown and (2) slight undercuts are often present in preparations that are too cylindrical and prevent the restoration from seating.

An *undercut* on a complete crown preparation is defined as any irregularity in the wall of a prepared tooth that prevents the withdrawal or seating of a wax pattern or crown. Such is the case when divergence is inadvertently created between opposite facing external axial walls, or wall segments, in a cervico-occlusal direction (Fig. 7-32, *A*). In other words, if the cervical diameter of a tooth preparation at the margin is narrower than at the occlusoaxial junction (reverse taper), it is impossible to seat a complete cast crown of similar geometry (see Figs. 7-23, *A*, and 7-32, *B*). Undercuts can be present whenever two axial walls face opposite directions (see Fig. 7-32, *C*). Thus the mesial wall of a complete cast crown preparation can be undercut in relation to the distal wall, or the buccal wall can be undercut in relation to the lingual wall, and the mesiobuccal wall can be undercut in relation to the distolingual wall. In a partial veneer preparation, in accordance with the same principle, the lingual wall of a proximal groove can be undercut in relation to the lingual wall of the preparation, but the buccal wall of the same groove cannot be undercut in relation to the lingual axial preparation wall; either of these walls may, however, restrict the number of directions in which a casting can be placed on the preparation in relation to the other.

A slight convergence, or taper, is clinically desirable in complete crown preparations. As long as this taper is small, the movement of the luted restoration will be

**Cylinder* is defined in its mathematical sense as the solid generated by a straight line parallel to another straight line and moving so that its ends describe a fixed curve.

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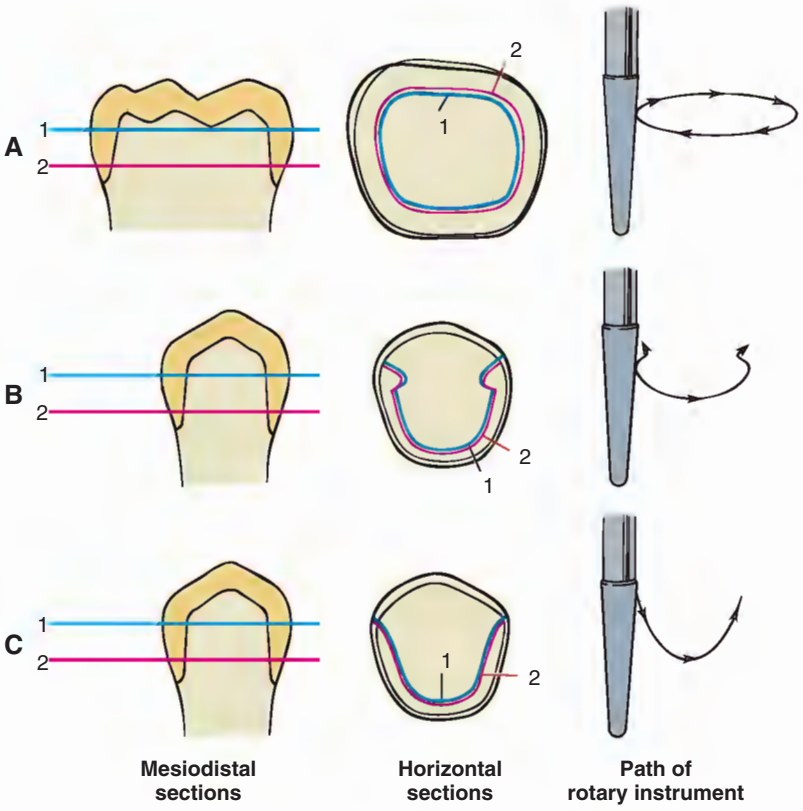

FIGURE 7-30 ■ A preparation is cylindrical if the two horizontal cross sections of the prepared axial tooth surface (*1* and *2*) are coincident. **A,** This complete crown is cylindrical and therefore retentive. **B,** A partial crown is retentive if its sections are coincident and perpendicular movement is prevented by grooves. **C,** This preparation is cylindrical (*1* and *2* coincide), but because it can move perpendicularly to the axis of the cylinder, it is not retentive. (Redrawn from Rosenstiel E: The retention of inlays and crowns as a function of geometrical form. Br Dent J 103:388, 1957.)

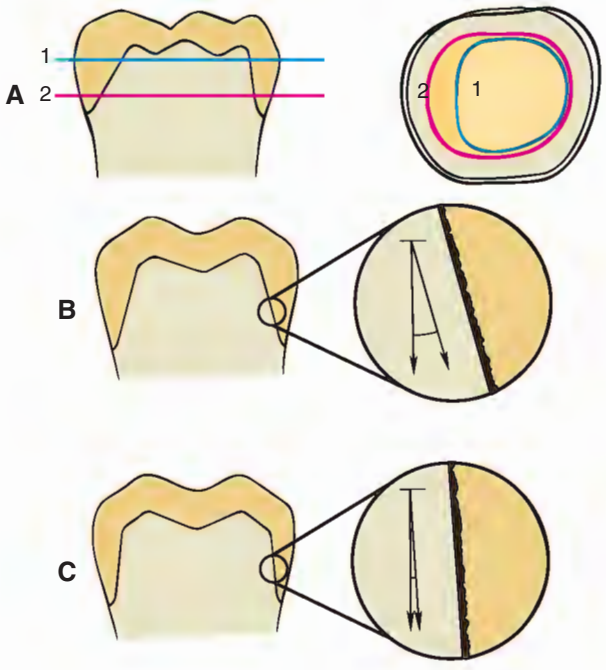

FIGURE 7-31 ■ **A,** Cross sections *1* and *2* do not coincide, and the preparation thus has little retention. **B,** Under these circumstances, very little friction develops between the cement and the axial walls, and the cement is subjected to tensile stress. **C,** A retentive near-parallel preparation with frictional resistance. The cement is placed under shear stress. (**A,** Redrawn from Rosenstiel E: The retention of inlays and crowns as a function of geometrical form. Br Dent J 103:388, 1957.)

effectively restrained by the preparation and will have what is known as a *limited path of placement*. As taper increases, however, so does the free movement of the restoration, and consequently, retention will be reduced.

The relationship between the degree of axial wall taper and the magnitude of retention was first demonstrated experimentally by Jørgensen[62] in 1955. He cemented brass caps on Galalith cones of different tapers and measured retention with a tensile-testing machine. The relationship was found to be hyperbolic, with retention rapidly becoming less as taper increased (Fig. 7-33), although the relationship was no longer hyperbolic when the internal surfaces of the caps were roughened. The retention of a cap with 10 degrees of taper[†] was approximately half that of a cap with 5 degrees. Similar results have been reported by other workers.[63-65]

Selection of the appropriate degree of taper for tooth preparation involves compromise. Too small a taper may lead to unwanted undercuts; too large leads to a lack of retention. The recommended convergence between opposing walls is 6 degrees, which has been shown to optimize retention for zinc phosphate cement.[66] Being able to recognize this angle is important (Fig. 7-34). It is necessary to be able to quickly quantify the approximate angle of convergence between preparation walls. It is not

[†]In this discussion, as is generally the case in the dental literature, taper and convergence are used interchangeably and refer to the angle between diametrically opposed axial walls.

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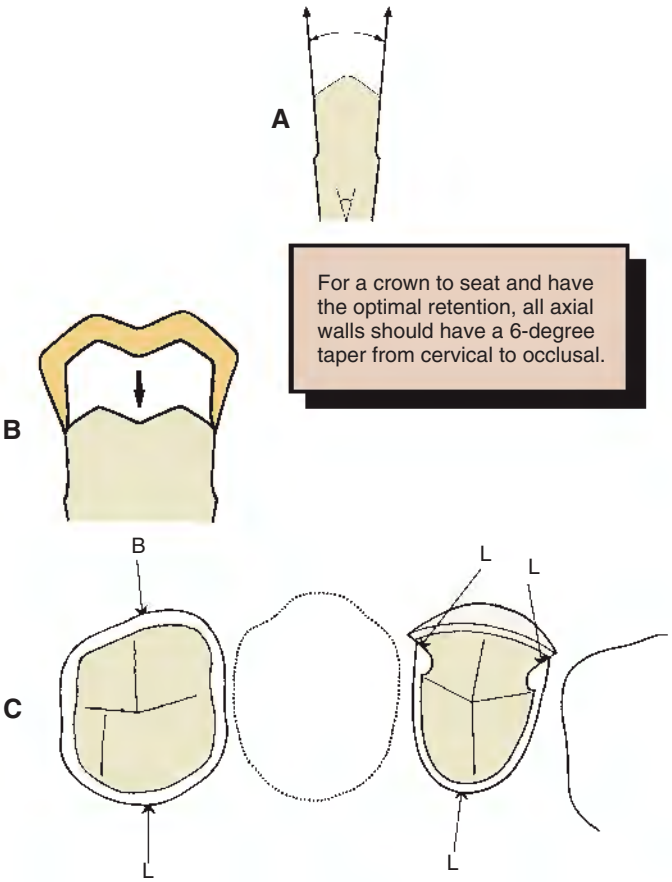

FIGURE 7-32 ■ **A,** An undercut is formed if opposing walls diverge. **B,** A tooth prepared with an undercut does not allow the crown to seat, inasmuch as it cannot pass over the divergent walls. **C,** Undercuts are possible in other locations when fixed dental prostheses or restorations with preparation features such as grooves or boxes are prepared. In this example, one buccally facing wall *(B)* can be undercut in relation to (four) lingual facing walls *(L)*.

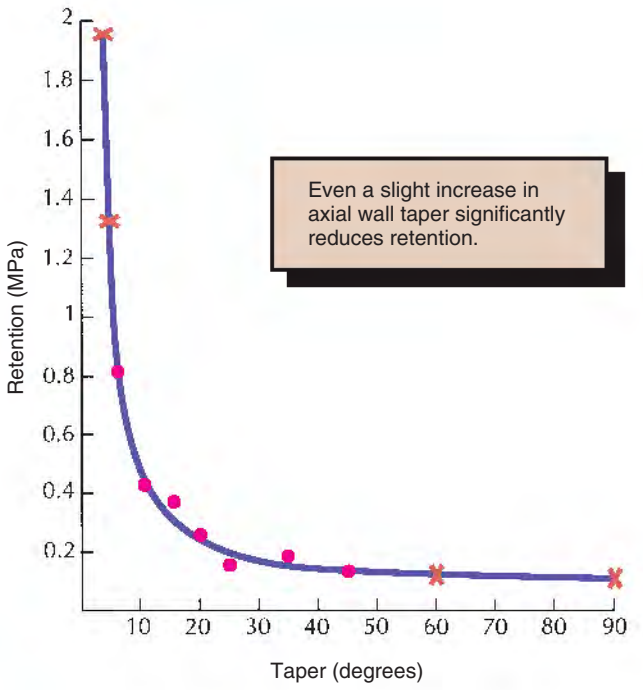

FIGURE 7-33 ■ Relationship between retention and convergence angle. •, Experimental values; *x,* calculated values outside the experimental range. (Redrawn from Jørgensen KD: The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 13:35, 1955.)

FIGURE 7-34 ■ The recommended convergence angle is 6 degrees; this is a very slight taper. For illustrative purposes, the hands of this clock show 12:01, which is an angle of 5½ degrees.

necessary to deliberately tilt a rotary cutting instrument to create a taper because this invariably leads to overpreparation. Rather, teeth are easily prepared with a rotary instrument of the desired taper held at a constant angulation. The tapered rotary instrument is moved through a cylindrical path as the tooth is prepared, and the taper of the instrument should produce the desired axial wall taper on the completed preparation. In practice, many dentists experience difficulty consistently in avoiding excessively tapered preparations, particularly when preparing posterior teeth with limited access.[67-69]

Clinicians have a tendency to overtaper preparations in a buccolingual direction more so than mesiodistally, and abutments for fixed dental prostheses tend to be prepared with greater taper than do single crown preparations.[70]

Some authorities recommend the routine use of grooves to reduce the incidence of restoration displacement. It is unclear, however, whether accurate groove alignment is achieved more easily than axial wall convergence. Skillfully prepared axial walls at a minimal convergence are mechanically desirable, while being very conservative of tooth structure.

Surface Area. If the restoration has a restricted taper, and thus a limited path of placement, its retention depends on the length of this path or, more precisely, on the surface area that is in sliding contact. Therefore, crowns with tall axial walls are more retentive than those with short axial walls,[71] and molar crowns are more retentive than premolar crowns of similar taper, because of the greater diameter of molar teeth. Surfaces from which the crown is essentially being pulled away (rather than sliding along the tooth), such as the occlusal surface, do not add significantly to total retention.

Stress Concentration. When a retentive failure occurs, luting agent often adheres to both the tooth preparation and the fitting surface of the restoration. In these cases, cohesive failure occurs through the cement layer because

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the strength of the luting agent is less than that of the induced stresses. A computerized analysis of these stresses[72,73] reveals that they are not uniform throughout the luting agent but are concentrated around the junction of the axial and occlusal surfaces. Sharp occlusoaxial line angles should be rounded to minimize these stresses, which can precipitate retentive failure.[72,73] Changes in preparation geometry may thus indirectly increase the retention of the restoration.

Type of Preparation. Different types of preparation have different retentive values that correspond fairly closely to the total surface area of the axial walls with restricted taper, as long as other factors (e.g., preparation height) are kept constant. Thus the retention of a complete crown is more than double that of partial-coverage restorations[74] (Fig. 7-35).

Adding grooves or boxes (Fig. 7-36) to a preparation with a limited path of placement does not markedly affect its retention because the surface area is not increased significantly. However, where the addition of a groove limits the paths of placement, retention is increased.[75,76]

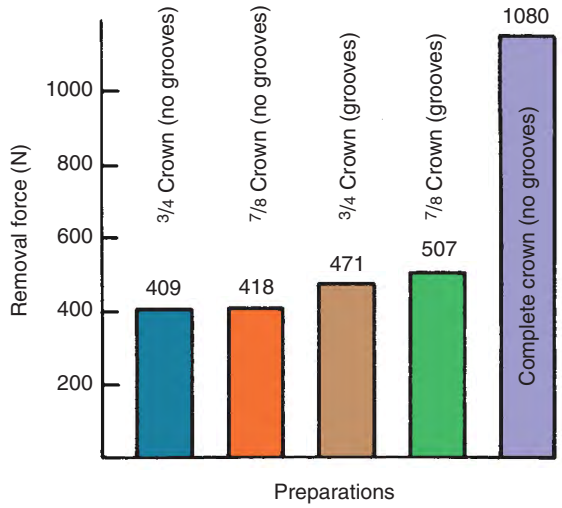

FIGURE 7-35 ■ Retention of different preparation designs. (Redrawn from Potts RG, et al: Retention and resistance of preparations for cast restorations. J Prosthet Dent 43:303, 1980.)

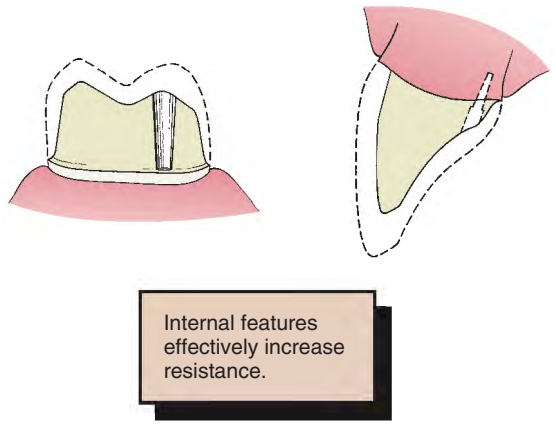

FIGURE 7-36 ■ Retention form of an excessively tapered preparation can be increased by adding grooves or pinholes because these limit the paths of withdrawal.

Roughness of the Surfaces Being Cemented

When the internal surface of a restoration is very smooth, retentive failure occurs not through the cement but at the interface between the luting agent and the restoration. Under these circumstances, retention is increased if the restoration is roughened or grooved.[77-79] Metal castings are most effectively prepared by air abrading the fitting surface with 50 μm of alumina. This should be done carefully to avoid abrading the polished surfaces or margins. Airborne particle abrasion has been shown[80] to increase in vitro retention by 64%. Similarly, acid etching of the fitting surface of restorations can improve retention with certain luting agents.

Failure rarely occurs at the interface between the luting agent and the tooth. Therefore, deliberately roughening the tooth preparation hardly influences retention and is not recommended because roughness adds to the difficulty of subsequent technical steps in crown fabrication such as imaging, impression making, and waxing (see Chapters 14 and 18).

Materials Being Cemented

Retention is affected by both the type of casting alloy and any core or buildup material that is present on the axial walls of the crown preparation. The clinical significance of laboratory testing results have yet to be confirmed by longer term clinical studies, but it appears that the more reactive the alloy is, the better adhesion there is with selected luting agents. Therefore, base metal alloys are better retained than are less reactive metals with high gold content.[81] The effect of adhesion to different core materials also has been tested, with conflicting results. In one laboratory study,[82] researchers examining adhesion between luting agents and core materials found that the luting agent adhered better to amalgam than to composite resin or cast gold. However, when other researchers[83] tested crowns for retention, they found higher values with the composite resin cores than with amalgam cores. The differences may have resulted from dimensional changes of the core materials, although the clinical implications of this finding are not clear.

Luting Agent

Type. The type of luting agent chosen affects the retention of a cemented restoration.[84-86] However, the decision regarding which agent to use is also based on other factors. In general, the data suggest that adhesive resin cements are the most retentive[87,88] (Fig. 7-37), although long-term clinical evidence about the durability of the bond is not available. Of concern is that long-term in vitro studies have shown deterioration of the resin-dentin bond in association with so-called nanoleakage (ability of small ions or molecules to permeate the hybrid layer).[89,90]

Film Thickness. There is conflicting evidence[91-94] about the effect of increased thickness of the cement film on

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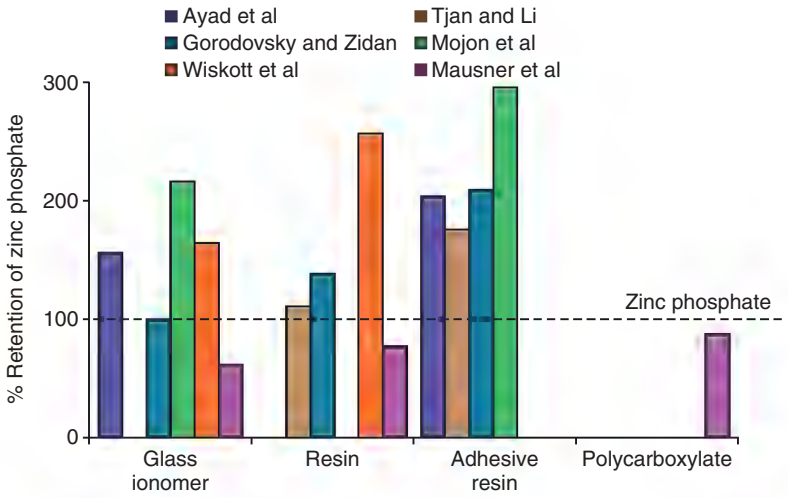

FIGURE 7-37 ■ Crown retention studies. Effect of luting agent. In six in vitro studies,[13,86,88,96,116,117] researchers evaluated the effect of luting agent on crown retention. The data were normalized as a percentage of the retention value with zinc phosphate cement. Adhesive resins had consistently greater retention than did zinc phosphate. Conventional resins and glass ionomers yielded less consistent results. (Redrawn from Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)

retention of a restoration. This may be important if a slightly oversized restoration is made (as when the die-spacer technique is used; see Chapter 18), or when milled crowns are fabricated (see Chapter 21). The factors that influence the retention of a cemented restoration are summarized in Table 7-4.

Resistance Form

Certain features must be present in the preparation to prevent dislodgment of a cemented restoration. Mastication and parafunctional activity may subject a prosthesis to substantial horizontal or oblique forces. These forces are normally much greater than the ones overcome by retention, especially if the restoration is loaded during eccentric contact between posterior teeth. Lateral forces tend to displace the restoration by causing rotation around the gingival margin, effectively tipping the crown off its preparation. Rotation is prevented by any areas of the tooth preparation that are placed in compression, called *resistance areas* (Fig. 7-38). Multiple resistance areas cumulatively make up the *resistance form* of a tooth preparation, which is defined as the features of a tooth preparation that enhance the stability of a restoration and resist dislodgment along any axis other than the path of placement.

Adequate resistance depends on the following:

1. Magnitude and direction of the dislodging forces
2. Geometry of the tooth preparation
3. Physical properties of the luting agent

When quantifying resistance, ask yourself the following question: How much tooth structure needs to break, or how much does the crown have to deform in order to dislodge this restoration?

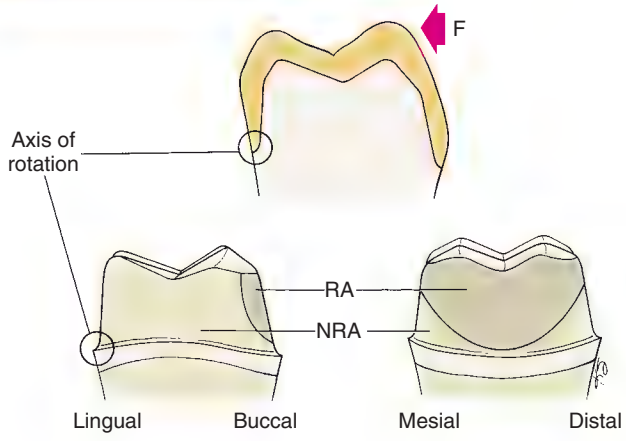

FIGURE 7-38 ■ The resistance area *(RA)* of a complete crown is placed under compression when a lateral force *(F)* is applied. *NRA,* Nonresisting area. (Redrawn from Hegdahl T, Silness J: Preparation areas resisting displacement of artificial crowns. J Oral Rehabil 4:201, 1977.)

Magnitude and Direction of the Dislodging Forces

Some patients can develop enormous biting forces. Gibbs and colleagues[95] described one individual (Fig. 7-39) who had a biting force of 4340 N (443 kg).[‡] Although this is considered extraordinary, restorations should nevertheless be designed to withstand forces approaching such magnitude. In one laboratory study,[72] a complete crown cemented on a nickel-chromium test die was found to be capable of withstanding more than 13,500 N (1400 kg)—a far greater force than would occur in the mouth—before becoming displaced (Fig. 7-40).

In a normal occlusion, biting force is distributed over all the teeth; most of it is axially directed. If a fixed dental

[‡]In comparison, the world record super heavyweight (>105 kg) snatch is 213 kg.

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TABLE 7-4 **Factors Influencing the Retention of a Cemented Restoration**

Factor	Greater Retention → Lesser Retention
Taper	Parallel → 6 degrees → Excessive
Surface area	Large → Small
Type of preparation	Molar complete crown → Premolar complete crown → Partial crown → Intracoronal restoration
Surface texture	Rough → Smooth
Film thickness	Effect uncertain
Luting agent	Adhesive resin → Glass ionomer → Polycarboxylate/Zinc oxide–eugenol → Zinc phosphate

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FIGURE 7-39 ■ Mr. H. sitting beside 443 kg of gymnasium weights to illustrate the magnitude of his biting strength. (From Gibbs CH, et al: Limits of human bite strength. J Prosthet Dent 56:226, 1986.)

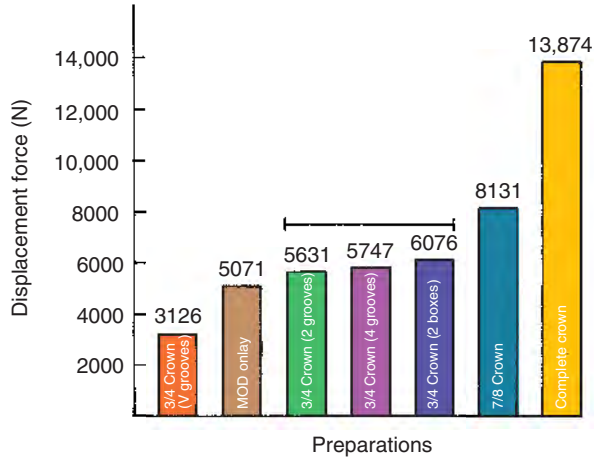

FIGURE 7-40 ■ Resistance of different preparation designs. The line connects preparations with statistically similar displacement forces ($P > .05$). *MOD,* Mesio-occluso-distal. (Modified from Kishimoto M, et al: Influence of preparation features on retention and resistance. Part II: three-quarter crowns. J Prosthet Dent 49:188, 1983.)

prosthesis is carefully made with a properly designed occlusion, the load should be well distributed and favorably directed (see Chapter 4). However, if a patient has a biting habit such as pipe smoking or bruxism, it may be difficult to prevent fairly large oblique forces from being applied to a restoration. Consequently, the successful tooth preparation and restoration must be able to withstand considerable oblique forces, as well as the normal axial ones, and it has been argued that from a clinical durability perspective, adequate resistance form may be more crucial than overall preparation retentiveness.[96,97]

Geometry of the Tooth Preparation

As with retention, preparation geometry plays a key role in attaining desirable resistance form. The tooth preparation must be shaped so that specific areas of the axial wall prevent rotation of the crown. A good way to determine whether tooth preparation geometry provides adequate resistance form is to answer a specific question: "How much tooth structure needs to break off in order for this crown to be displaced by tipping off the tooth?"

Resistance is a function of the relationship between axial wall taper, preparation diameter, and preparation height. It decreases as taper or diameter increases or as preparation height is reduced.[98] The relationship between preparation height, or diameter, and resistance to displacement is approximately linear.[99]

Preparation taper of 5 to 22 degrees has been suggested as being within a clinically acceptable range.[100,101] However, at the higher end of this range, the tipping resistance of both cemented and uncemented cast restorations is inadequate but increases significantly as taper is reduced.[100,102]

Short tooth preparations with large diameters were found to have very little resistance form.[103] In general, molar teeth require more parallel preparation than do premolar or anterior teeth to achieve adequate resistance form.[103] A 3-mm preparation height provides adequate resistance if taper is restricted to 10 degrees or less,[102] but additional height is necessary as tooth diameter increases. On molar crown preparations in which many more preparations are observed that lack resistance,[104] minimal preparation wall height should thus be in the range of 3.5 to 4 mm. A fairly simple way to quantify this at chairside is to evaluate whether the height-to-width ratio of a preparation is 4:10 or greater. If so, resistance is probably adequate.

Hegdahl and Silness[104] analyzed how the areas that provide resistance form change as the geometry of the tooth preparation is modified. They demonstrated that increasing preparation taper and rounding of axial angles tend to reduce resistance; pyramidal preparations thus have greater resistance than do conical ones. Proximal grooves or boxes placed in healthy tooth structure are particularly effective in enhancing the resistance form of crown preparations because these interfere with rotational movement (tipping) of the crown and thereby subject additional areas of the luting agent to compression. Therefore, the resistance form of an excessively tapered preparation can be improved by adding such grooves or boxes. As an alternative, pinholes can be prepared to achieve the same effect by making use of dentin that surrounds the pin.

Preparation modifications appear not to be used as often[99] as clinical failure data suggest they should be.[97]

A partial-coverage restoration may have less resistance (Fig. 7-41) than a complete crown because it has no buccal resistance areas. In this case, resistance is provided by proximal boxes or grooves (Fig. 7-42) and is greatest if the groove, box walls, or both are perpendicular to the direction of the applied force. Thus, U-shaped grooves or flared boxes provide more resistance than do V-shaped ones.[74] On short preparations, the reverse scenario can apply: Short complete crown preparations may lack resistance, where proximal grooves, in comparison, will then result in better resistance on a partial veneer crown. In general, ideal groove height is 4 mm, which is not always easy to accomplish. Placing proximal grooves as close as possible to the location of the original proximal contact offers the opportunity to maintain as much dentin

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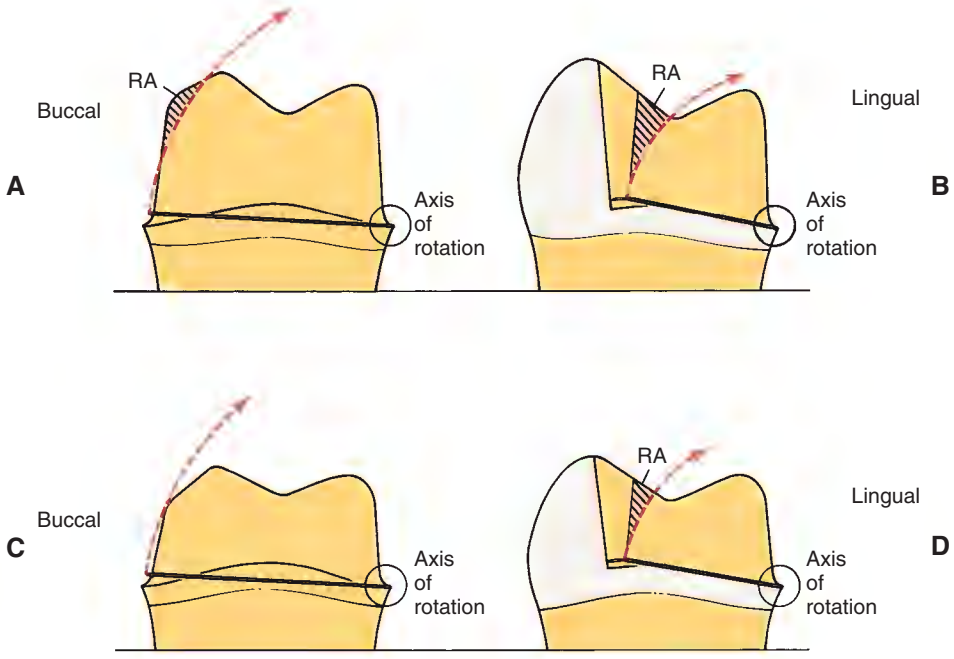

FIGURE 7-41 ■ Resistance form of partial and complete crowns. **A,** The buccoaxial wall of a complete crown should be a good resistance area *(RA)* for preventing rotation around a lingual axis. **B,** In a partial crown, resistance must be furnished by mesial and distal grooves. **C,** In a short or excessively tapered complete crown, resistance form is minimal because most of the buccal wall is missing. A mesiodistal groove should be placed to increase resistance form. **D,** Poor resistance form is less a problem in a short partial crown if the grooves have sufficient definition. However, lack of retention form may indicate the need for complete coverage.

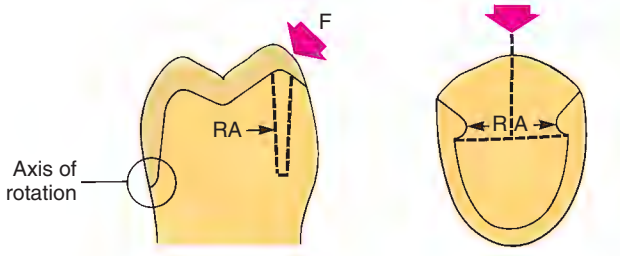

FIGURE 7-42 ■ **A,** The grooves of a partial crown should provide the maximum resistance to rotation around an axis situated at the linguogingival margin. **B,** The lingual walls of the groove—the resistance areas *(RA)*—should be prepared perpendicular to the direction of force *(F)*.

as possible because this is where the tooth has its greatest mesiodistal dimension. Grooves and boxes should be prepared so that their buccal and lingual walls are located in healthy tooth structure.

Similarly, in order to more effectively enhance resistance, grooves that are placed in excessively inclined preparation walls should be prepared to greater depth in their cervical aspect than in their occlusal aspect. Taper restriction in the cervical aspect of an excessively tapered crown preparation has been shown to enhance resistance more effectively than do grooves that are prepared flush into excessively inclined preparation walls.[105]

Physical Properties of the Luting Agent

Resistance to deformation is affected by physical properties of the luting agent, such as compressive strength and modulus of elasticity.[106] To satisfy American Dental Association/American National Standards Institute specification no. 96 (International Standards Organization specification no. 9917), the compressive strength of zinc phosphate cement must exceed 70 MPa[§] at 24 hours (Fig. 7-43).[118-121] Glass ionomer cements and most resins have higher compressive strength, whereas polycarboxylates have values similar to those of zinc phosphate.[106]

Increasing temperature has a dramatic effect on the compressive strength of luting agents, particularly weakening reinforced zinc oxide–eugenol cement (Fig. 7-44). An increase from room temperature (23° C) to body temperature (37° C) halves the compressive strength of reinforced zinc oxide–eugenol cements, and a rise in temperature to 50° C (equivalent to hot food) reduces the compressive strength by more than 80%.[107] Equivalence testing of more modern luting agents has not been reported.

Zinc phosphate cements have a higher modulus of elasticity than do polycarboxylate cements, which exhibit relatively large plastic deformation.[108] This may account for the observation that the retentive ability of polycarboxylate cement is more dependent on the taper of the preparation than is the retention with zinc phosphate cement.[109]

The factors that affect the resistance to displacement of a cemented restoration are summarized in Table 7-5.

Preventing Deformation

A restoration must have sufficient strength to prevent permanent deformation during function (Fig. 7-45);

[§]One megapascal equals 1 million N/m^2, or about 145 pounds per square inch (psi).

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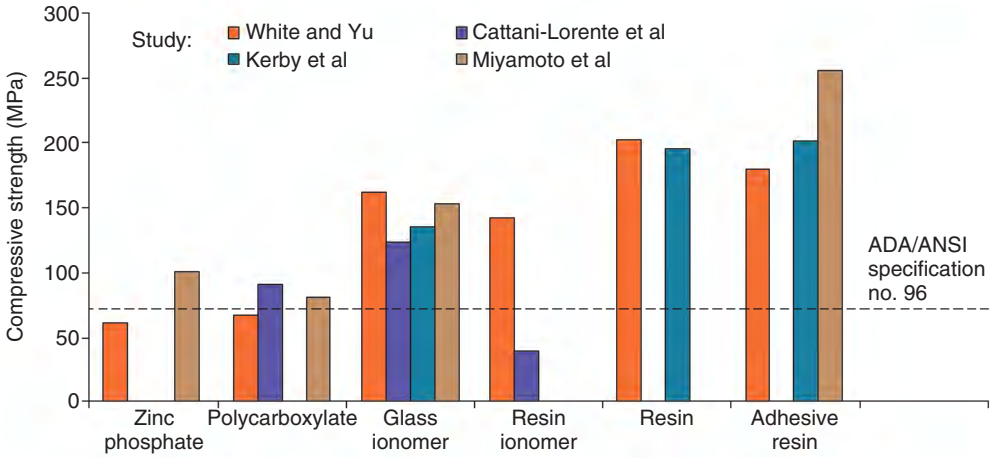

FIGURE 7-43 ■ Compressive strength of luting agents. Higher-strength values were reported in these studies[118-121] with the resin cements and glass ionomers than with zinc phosphate or polycarboxylate. Resin-modified glass ionomer exhibited greater variation than other cements. *ADA,* American Dental Association; *ANSI,* American National Standards Institute. (Redrawn from Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)

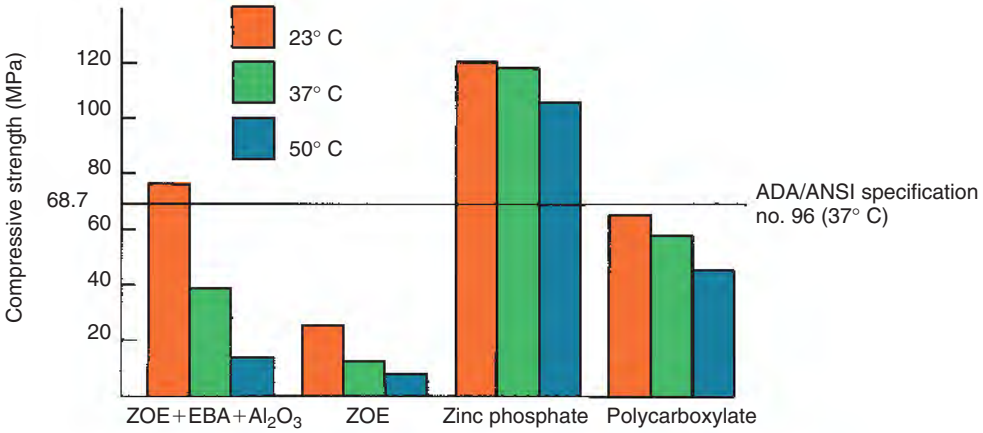

FIGURE 7-44 ■ Compressive strength of luting agents at different temperatures. *ADA,* American Dental Association; *ANSI,* American National Standards Institute; *EBA,* ethoxybenzoic acid; *ZOE,* zinc oxide–eugenol. (Redrawn from Mesu FP: The effect of temperature on compressive and tensile strengths of cements. J Prosthet Dent 49:59, 1983.)

FIGURE 7-45 ■ Ceramic failure resulting from deformation of the metal substructure.

otherwise, it will fail (typically at the restoration-cement interface or at the metal-porcelain interface). This may be a result of inappropriate alloy selection, inadequate tooth preparation, or poor metal-ceramic framework design (see Chapter 19).

Alloy Selection

Although type I and type II gold alloys (see Chapter 22) are satisfactory for intracoronal cast restorations, they are too soft for crowns and fixed dental prostheses, for which type III or type IV gold alloys (or an appropriate low-gold alternative) are chosen. These are harder, and their strength and hardness can be further increased by heat treatment.

Metal-ceramic alloys with high noble metal content have a hardness equivalent to that of type IV gold alloys, whereas nickel-chromium alloys are considerably harder yet. These may be indicated when large forces are

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TABLE 7-5 **Factors Influencing the Resistance of Cemented Restorations**

Factor	Higher Resistance → Lower Resistance
Dislodging forces	Habits → Eccentric interferences → Anterior guidance
Taper	Minimum → 6 degrees → Excessive
Diameter	Small (premolar) → Large (molar)
Height	Long → Average → Short
Type of preparation	Complete coverage → Partial coverage → Onlay
Luting agent	Adhesive resin → Glass ionomer → Zinc phosphate → Polycarboxylate → Zinc oxide–eugenol

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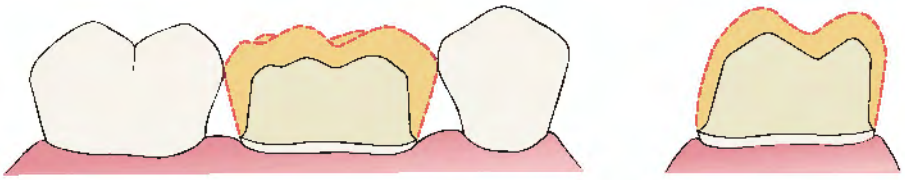

FIGURE 7-46 ■ Anatomic occlusal reduction is conservative of tooth structure and provides rigidity to the restoration.

FIGURE 7-47 ■ This molar relationship is a result of extreme occlusal wear. When a tooth preparation is designed, the eventual occlusal plane must be considered. This is done with the aid of a diagnostic tooth preparation and waxing procedures.

FIGURE 7-48 ■ Putty index made before tooth preparation facilitates evaluation of tooth reduction uniformity.

anticipated, as with a long-span fixed dental prosthesis, although their use presents certain challenges (see Chapter 19).

Adequate Tooth Reduction

Even the stronger alloys need sufficient bulk if they are to withstand occlusal forces (see Figs. 8-4, 9-1, *B*, and 32-13).

Largely according to empirical data, there should be a minimum alloy thickness of about 1.5 mm over functional cusps (buccal in the mandible, lingual in the maxilla). The less stressed nonfunctional cusps can be protected with less metal (1 mm is adequate in most circumstances) for a strong and long-lasting restoration. Occlusal reduction should be as uniform as possible, following the cuspal planes of the teeth; this ensures that sufficient occlusal clearance is combined with preservation of as much tooth structure as possible. In addition, an anatomically prepared occlusal surface (Fig. 7-46) gives rigidity to the crown because of the "corrugated effect"[110] of the planes.

When teeth are malaligned or overerupted, the occlusal surface needs to be prepared with the thickness requirements of the eventual restoration in mind. For example, a supra-erupted tooth may need considerably more than 1.5 mm of reduction to establish adequate clearance so that optimal occlusal form and the appropriate plane can be reestablished and adequate restoration thickness ensured (Fig. 7-47). Diagnostic tooth preparation and waxing are helpful in determining the correct tooth reduction. A practical approach is to reshape the supra-erupted tooth on the diagnostic cast to the desired occlusal plane that is anticipated. Diagnostically, the opposing teeth and, if necessary, the target tooth itself can be waxed to final form. An external matrix is then fabricated over the diagnostic endpoint from a suitable elastomeric putty. After sectioning, this can be used intraorally as a reduction guide to ensure that optimal, yet conservative tooth reduction is achieved (Fig. 7-48).

Margin Design

To prevent distortion of the restoration margin occlusally, the dentist should design the preparation outline form so that occlusal contact is avoided in this area. Keeping preparation margins approximately 1 to 1.5 mm away from occlusal contact locations satisfies this requirement.

Cervically, tooth reduction must provide sufficient room for bulk of restorative material at the margin to prevent distortion. For example, as discussed previously, one disadvantage of the feather edge margin preparation is that the resulting thin layer of gold is not as strong as the comparatively thicker restoration of a chamfer margin preparation. When teeth have been prepared with increased taper, however, it is advisable to reduce margin width in order to maintain adequate dentin thickness between the axial preparation wall and the pulpal tissues.[111]

Quantitatively, the amount of reduction in the cervical part of a preparation is a function of the restorative material selected. For gold castings or high-strength anatomic contour zirconia, 0.3 to 0.5 mm is adequate; for metal-ceramic crowns, 1 to 1.2 mm of shoulder margin width is desirable but not easily achieved on small teeth or teeth

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with large pulps. Lower strength ceramic crowns can be fabricated successfully on shoulder margin preparations with a margin width of 0.8 to 1.0 mm, although minimum dimensions may increase for certain materials and fabrication techniques.[112] With the advent of CAD/CAM–designed restorations, the limitations of the milling systems used may influence specific reduction requirements, which should be weighed carefully against the biologic criteria discussed in the beginning of this chapter.

The grooves and ledges incorporated in a partial-coverage preparation provide essential strengthening for such castings that are inherently weaker than their complete-coverage counterparts; in particular, anterior pinledge retainers benefit from the beamlike reinforcement that results from the incorporation of ledges in the tooth preparation design (Fig. 7-49).

ESTHETIC CONSIDERATIONS

The restorative dentist should develop skill in determining the esthetic expectations of the patient. Most patients prefer their dental restorations to look as natural as possible. However, esthetic considerations should not be pursued at the expense of the prognosis of the patient's long-term oral health or function.

At the initial examination, the dentist fully assesses the appearance of each patient, noting which areas of which teeth show during speech, smiling, and laughing (Fig. 7-50). The patient's esthetic expectations must be discussed in relation to oral hygiene needs and to the potential for development of future disease. Simply asking the question "Are you happy with the way your teeth look?" and observing the patient while carefully listening to the response is important and helpful. The final decision regarding an appropriate restoration can then be made with the full cooperation and informed consent of the patient.

Options for esthetic restorations include partial veneer crowns, which maintain an intact labial or buccal surface in original tooth structure; metal-ceramic restorations, which consist of a metal cast substructure that in visible areas has an esthetic porcelain veneer; and all-ceramic restorations (Fig. 7-51).

All-Ceramic Restorations

Some of the most pleasing esthetic restorations are all-ceramic crowns, inlays, onlays, and veneers (see Chapter 25). They can mimic original tooth color better than the other restorative options can. Although all-ceramic restorations are at somewhat greater risk of brittle fracture than are other restorations, the newest materials have improved physical properties and can be strengthened through the use of resin-bonded luting agents.

Not all ceramic crown preparations are conservative of tooth structure, inasmuch as a wide 90-degree heavy chamfer margin must be prepared around the entire tooth to ensure increased material thickness and material strength. For the same reason, additional reduction on

FIGURE 7-50 ■ Smile analysis.

FIGURE 7-49 ■ **A** to **C,** Grooves and ledges provide added rigidity to pinledge restorations. **D,** This partial veneer crown preparation benefits from added material thickness in the central groove area and in the location of the mesial and distal proximal grooves.

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FIGURE 7-51 ■ Ceramic inlays are an esthetic replacement for more readily visible amalgam restorations. **A,** Defective amalgam restorations. **B,** Two all-ceramic inlays. **C** and **D,** Teeth restored with ceramic inlays. (From Freedman G: Contemporary esthetic dentistry. St. Louis, Mosby, 2012.)

the lingual surface is needed for these restorations. A minimal material thickness of approximately 1 to 1.2 mm is necessary to ensure optimal esthetics. This limits the use of these restorations on faciolingually thin teeth and on teeth with large pulps, as in young individuals.

Metal-Ceramic Restorations

The appearance of some metal-ceramic restorations (see Chapters 19 and 24) is often compromised by insufficient porcelain thickness. On the other hand, adequate porcelain thickness is sometimes obtained at the expense of proper axial contour (such overcontoured restorations almost invariably lead to periodontal disease). In addition, the labial margin of a metal-ceramic crown is not always accurately placed. To correct all these deficiencies, certain principles are recommended during tooth preparation that ensures sufficient room for porcelain and accurate placement of the margins. Otherwise, good appearance would be achievable only at the expense of periodontal health.

Facial Tooth Reduction

If there is to be sufficient bulk of porcelain for appearance and metal thickness for strength, adequate reduction of the facial surface is essential. The exact amount of reduction depends to some extent on the physical properties of the alloy used for the substructure, as well as on the manufacturer and the shade of the porcelain. A good color match for some restorations in older individuals typically requires a slightly greater porcelain thickness than is needed in younger patients. A minimum reduction of 1.5 mm is typically required for optimal appearance. Adequate thickness of porcelain (Fig. 7-52) is needed to create a sense of color depth and translucency. Shade problems are frequently encountered in maxillary incisor crowns at the incisal and cervical thirds of the restoration, where direct light reflection from the opaque layer can make the restoration very noticeable. Because opaque porcelains generally have a shade different from that of body porcelains, they often need to be modified with special stains in these areas[113] (see Chapter 24).

With very thin teeth (e.g., mandibular incisors), it may be impossible to achieve adequate tooth reduction without exposing the pulp or leaving the tooth preparation severely weakened. Under these circumstances, a less-than-ideal appearance may have to be accepted.

The labial surfaces of anterior teeth should be prepared for metal-ceramic restorations in two distinct planes (Fig. 7-53). If they are prepared in a single plane, the reduction in either the cervical or the incisal area of the preparation is insufficient.

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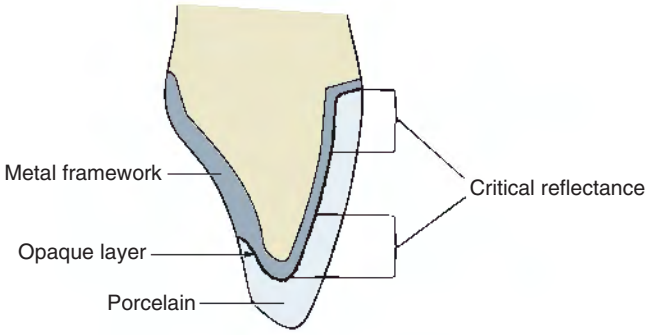

FIGURE 7-52 ■ Adequate porcelain thickness is essential for preventing direct light reflection from the highly pigmented opaque porcelain. The most critical areas are the gingival and incisal thirds; in practice, opaque modifying stains are often used in these areas. (Redrawn from McLean JW: The science and art of dental ceramics, vol 1. Chicago, Quintessence Publishing, 1979.)

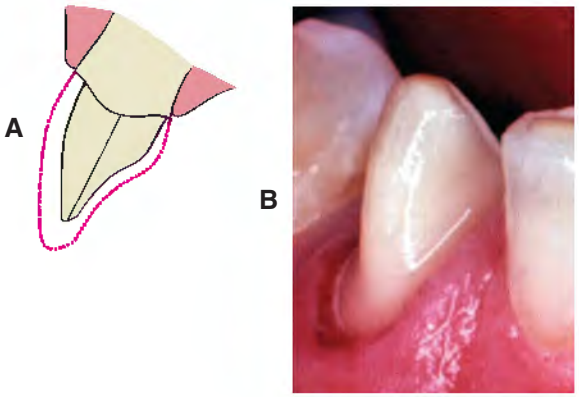

FIGURE 7-53 ■ Recommended tooth preparation for maxillary **(A)** and mandibular **(B)** metal-ceramic restoration. In each case, the facial reduction has two distinct planes.

Incisal Reduction

The incisal edge of a metal-ceramic restoration has no metal backing and can be made with a translucency similar to that of natural tooth structure. An incisal reduction of 2 mm is recommended for good esthetics. Excessive incisal reduction must be avoided because it reduces the resistance and retention form of the preparation.

Proximal Reduction

The extent of proximal reduction is contingent on exact predetermination of the location of the metal-ceramic junction in the completed restoration. The proximal surfaces of anterior teeth look most natural if they are restored at the incisal edges, without metal backing. This allows some light to pass through the restoration in a manner similar to what occurs on a natural tooth (Fig. 7-54). Obviously, if the restoration is part of a fixed dental prosthesis, the need for connectors makes this impossible.

FIGURE 7-54 ■ Optimal esthetics require proximal light transmission through the esthetic veneer. Occluding lingual surfaces are in metal, which extends into the proximal aspect.

Labial Margin Placement

Supragingival margin placement has many biologic advantages. The restorations are easier to prepare properly and easier to keep clean. Nevertheless, subgingival margins may be indicated for esthetic reasons, particularly when the patient has a high lip line and when the use of a metal collar labial margin is contemplated.

The patient's smile is observed as part of the initial examination (see Chapter 1). It is important to record which teeth and which parts of each tooth are exposed. Patients with a high lip line, which exposes considerable gingival tissue, present the greatest problem if complete crowns are needed. Where the root surface is not discolored, appearance can be restored with a metal-ceramic restoration with a supragingival porcelain labial margin (see Chapter 24). If the patient has a low lip line, a metal supragingival collar may be placed because the metal is not seen during normal function. Metal margins generally have a more accurate fit than porcelain margins.

However, it cannot be assumed that the patient will be happy with a supragingival metal collar just because the metal is not visible during normal function. Some patients have reservations about exposed metal, and the advantages of such supragingival margins must be carefully explained before treatment.

Metal collars can be hidden below the gingival crest, although there is some discoloration if the gingival tissue is thin. Successful margin placement within the gingival sulcus requires care to ensure that inflammation and recession, with resulting metal exposure, are avoided or minimized. The periodontium must be healthy before the tooth is prepared. If periodontal surgery is needed, the sulcular space should not be eliminated completely; rather, a postsurgical depth of about 2 mm should be the objective. Sufficient time should be allowed after surgery for the periodontal tissues to stabilize. Wise[114] found that the gingival crest does not stabilize until 20 weeks after surgery (see Chapter 5).

Margins should not be placed so far apically that they encroach on the attachment; extension to within 1.5 mm of the alveolar crest leads to bone resorption.[115] The margin should follow the contour of the free gingiva,

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FIGURE 7-55 ■ Poor preparation design. **A,** The treatment plan for these badly damaged incisors was to use metal-ceramic crowns. **B** and **C,** The apical margin of the preparation does not follow the free gingival contours. **D,** The restoration displays a metal collar labially, and the deep proximal margins have led to periodontal disease.

being further apical in the middle of the tooth and further incisal interproximally. A common error (Fig. 7-55) is to prepare the tooth so that the margin lies almost in one plane, with exposure of the collar labially and irreversible loss of bone and papilla proximally.

Partial-Coverage Restorations

Whenever possible, an esthetically acceptable result without the use of complete crowns is preferred because tooth structure is conserved and because no restorative material can approach the appearance of intact tooth enamel. Esthetic partial-coverage restorations (see Chapter 10) depend on accurate placement of the potentially visible facial and proximal margins. A visible display of metal is not esthetic and is thus unacceptable to many patients. If a partial-coverage restoration is poorly prepared, the patient may demand that it be replaced by a metal-ceramic crown, and the result is unnecessary loss of tooth structure and a greater potential for tissue damage.

Proximal Margin

Precise placement of the proximal margins (particularly the mesial, generally more visible, margin) is crucial for the esthetic result of a partial-coverage restoration. The rule is to place the margin just buccal to the proximal contact area, where metal is hidden by the distal line angle of the neighboring tooth and yet provides adequate access to the tooth-restoration interface for plaque control. Tooth preparation angulation is critical and should normally follow the long axes of posterior teeth and the incisal two thirds of the facial surface of anterior teeth. If a buccal or lingual tilt is given to the tooth preparation, the likelihood that metal will be visible increases significantly (Fig. 7-56).

The distal margin of posterior partial-coverage restorations is less visible than the mesial margin. In this area, it is often advantageous to extend the preparation farther beyond the contact point for easier preparation and finishing of the restoration and to facilitate access for oral hygiene.

Facial Margin

The facial margin of a maxillary partial-coverage restoration should be extended just beyond the occlusofacial line angle. A short bevel is needed to prevent enamel chipping. A chamfer margin can be placed in areas where appearance is less important (e.g., on molars) because this provides greater bulk of metal for strength.

If the facial margin of metal is correctly shaped (Fig. 7-57), it does not reflect light to an observer. As a result, the tooth appears to be merely a little shorter than normal and not as though its buccal cusp is outlined in metal. If the buccal margin is skillfully placed so as to follow the original cuspal contour, the appearance of the final restoration is acceptable.

When mandibular partial cast crowns are made, metal display is unavoidable because the occlusal surface of mandibular teeth can be seen during speech. A chamfer margin, rather than a beveled margin, is recommended for the buccal margin because it provides a greater bulk of metal around the highly stressed functional cusp (Fig. 7-58). If the appearance of metal is unacceptable to the patient, a metal-ceramic restoration with porcelain coverage on the occlusal surface can be made.

Anterior partial-coverage restorations can be fabricated to show no metal (Fig. 7-59), but their preparation

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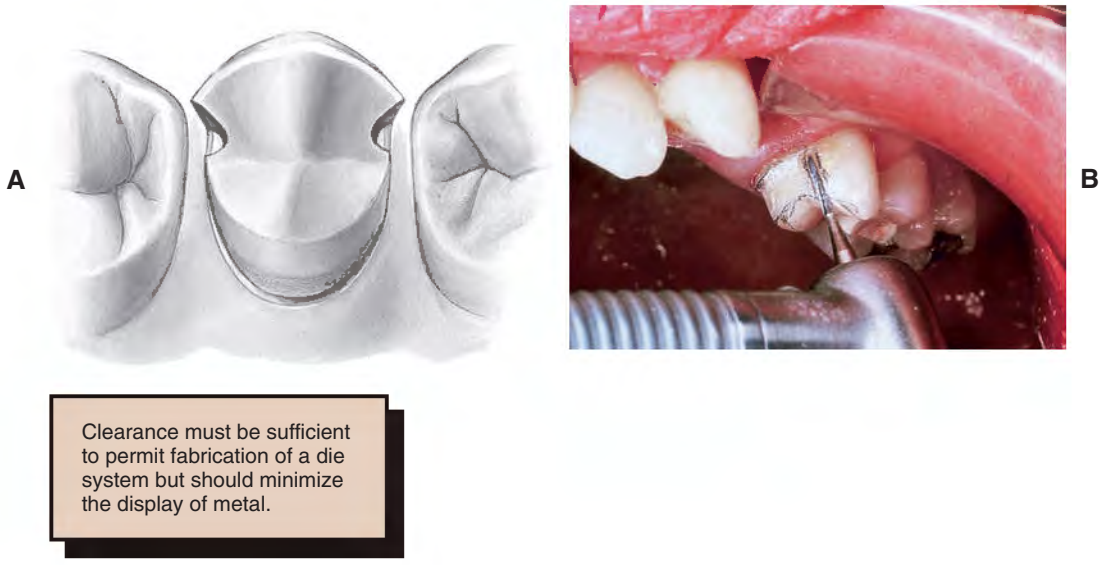

FIGURE 7-56 ■ **A,** Correct placement of the mesial margin of a partial-coverage restoration is essential for good esthetics. To allow proper access for finishing, the restoration must extend just beyond the contact area, but the metal must remain hidden from the casual observer. **B,** The tooth should be prepared in its long axis; otherwise, metal is displayed.

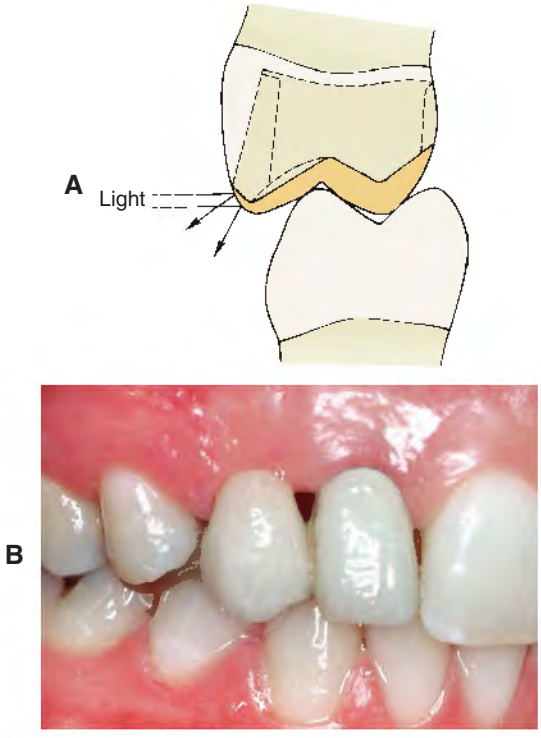

FIGURE 7-57 ■ **A,** The facial margin of a partial cast crown should be shaped so that light is not reflected directly to the observer. **B,** A three-unit fixed dental prosthesis. The mesial abutment is a canine, shaped to look like a lateral incisor. The distal abutment is a partial cast crown, which proved to be esthetically acceptable because the metal had been correctly contoured.

requires considerable care. The facial margin is extended just beyond the highest contour of the incisal edge but not quite to the incisolabial line angle. In this case, the metal protects the tooth from chipping but is not visible.

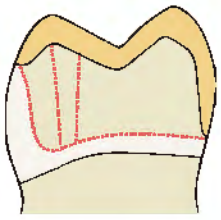

FIGURE 7-58 ■ A substantial chamfer margin is recommended for the functional buccal cusp of a mandibular partial cast crown. It provides greater bulk of metal in a stressed area.

PLANNING AND EVALUATING TOOTH PREPARATIONS

Tooth preparation is a precise, technically complicated, and irreversible procedure. Thus, it is the practitioner's responsibility to carry it out properly, every time. Mistakes are often difficult, if not impossible, to correct. Rehearsing the planned preparations on diagnostic casts invariably proves helpful in achieving a better quality preparation.

Diagnostic Tooth Preparations

Diagnostic tooth preparations are performed on articulated casts before the actual clinical preparation. They yield information about the following:

- Selecting the appropriate path of placement for a fixed dental prosthesis, particularly for abutment teeth that are tilted, are rotated, or have an atypical coronal contour (Figs. 7-60 and 7-61).
- Deciding on the amount of tooth reduction necessary to accomplish a planned change in the occlusion.
- Determining the best location for the facial and proximal margins of a partial-coverage restoration so that the metal is not visible.

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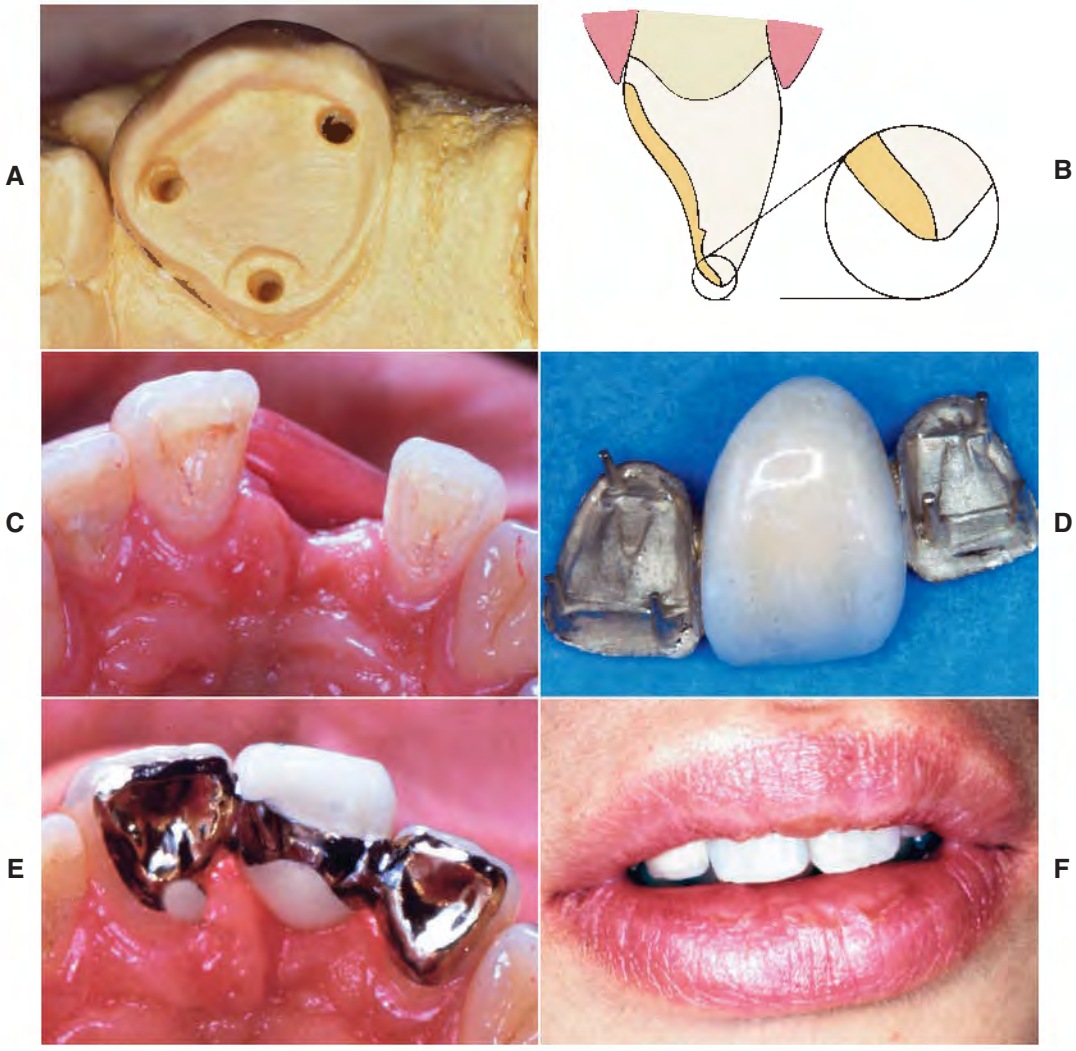

FIGURE 7-59 ■ **A,** Teeth can be prepared for partial-coverage restorations that do not show any metal. Success depends on very careful margin placement. **B,** The incisal edge is not completely covered. The restoration margin is located between the highest point of the incisal contour and the incisofacial angle. **C,** Intact anterior teeth on either side of an edentulous space. **D,** Three-unit fixed dental prosthesis with pinledge retainers and a metal-ceramic pontic. **E,** Occlusal view of fixed dental prosthesis. **F,** Acceptable esthetic result is obtained.

FIGURE 7-60 ■ Selecting the best path of placement for a fixed dental prosthesis with the aid of diagnostic tooth preparations.

An important advantage of diagnostic tooth preparations is that the operator can practice each step of the intended restoration. Mistakes are not permanently destructive. Also, diagnostic preparations can be used in the prefabrication of interim restorations, which significantly reduces appointment time duration after the clinical tooth preparation has been completed (the indirect/direct interim restoration fabrication technique is described in Chapter 15).

Diagnostic Waxing Procedures

For all but the most straightforward prosthodontic treatment plans, a diagnostic waxing procedure (Fig. 7-62) should be performed. This is done on diagnostic costs and helps determine optimal contour and occlusion of the eventual prosthesis. The procedure is of particular benefit if the patient's occlusal scheme or anterior (incisal) guidance requires alteration.

Evaluative Procedures during Tooth Preparation

Each step of a tooth preparation should be carefully evaluated with direct vision or indirectly with a dental mirror.

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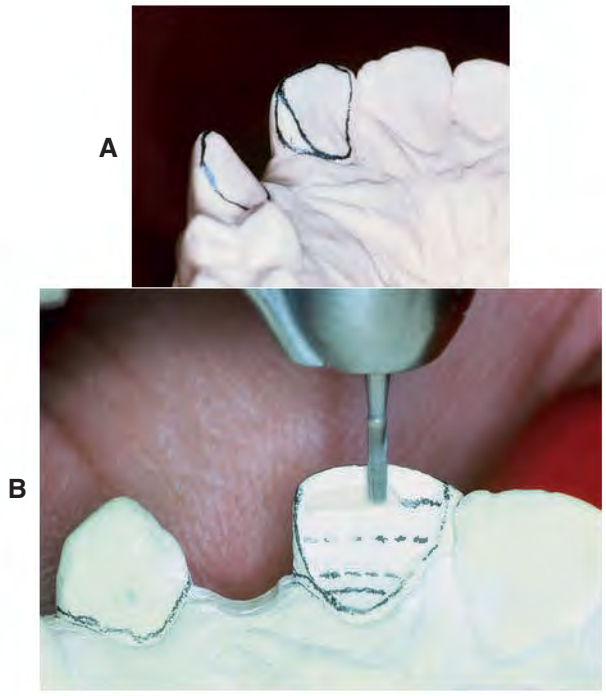

FIGURE 7-61 ■ **A** and **B,** Diagnostic tooth preparations are extremely helpful in determining the ideal reduction for esthetic partial-coverage restorations.

FIGURE 7-62 ■ **A** and **B,** Diagnostic waxing for extensive treatment. (Courtesy Dr. M. Padilla.)

FIGURE 7-63 ■ A dental surveyor can be used to evaluate the axial alignment of tooth preparations.

Alignment of multiple abutment teeth can be problematic, and use of the mirror helps superimpose the image of adjacent abutment teeth. To evaluate complex preparations, the dentist should make an alginate impression and pour it in fast-setting stone. A dental surveyor (Fig. 7-63) can then be used to precisely measure the axial inclinations of the tooth preparation. Making such an impression may appear to take unnecessary time; however, the information obtained often saves time in subsequent procedures by identifying problems that can then be addressed immediately. For tooth preparation, the contra-angle handpiece can be used for both measuring and cutting. This is done by concentrating on the top surface of the turbine head, which is perpendicular to the shank of the rotary instrument. If the top surface is kept parallel to the occlusal surface of the tooth being prepared, the rotary instrument is automatically in the correct orientation (Fig. 7-64). To prevent undercuts or excessive convergence during axial reduction, the handpiece must be maintained at the same angulation. The correct taper is imparted by the diamond instrument. Keeping the turbine head at its correct angulation initially is often most effectively done by supporting it with a finger of the opposite hand.

Patient and Operator Positioning

Learning the proper patient and operator positions is as beneficial as learning the proper preparation steps. Of particular importance are the advantages of obtaining a direct view of the preparation, which is always preferred to an indirect or mirror view. However, certain areas (e.g., the distal surfaces of maxillary molars) cannot be seen directly.

Inexperience, coupled with a hesitation to move the patient's head into a more favorable position, can unnecessarily complicate tooth preparation. For instance, having the patient rotate the head to the left or right side can considerably improve the visibility of molar teeth that

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are being prepared. In most instances, a direct view can be obtained by subtly changing the operator's or the patient's position. Having the patient open maximally does not necessarily provide the best view. If the jaws are only partially open, the cheek may be retracted more easily (Fig. 7-65), and if the patient is encouraged to make a lateral excursion, the distobuccal line angle, together with the buccal third of the distal wall, may be seen directly. In practice, the mirror is essential only for visualizing a small portion of the distal surface. When a complete crown is prepared, the parts of the tooth most easily seen should be prepared first; the other areas can be prepared with the help of the mirror in a final stage.

Figure 7-66 shows positioning of the patient and a right-handed dentist for tooth preparation of the less accessible maxillary posterior teeth.

It can be fatiguing for the patient to have the mouth opened for longer periods of time, which is not only uncomfortable during the appointment but can also cause some discomfort after the appointment. It is helpful to use a bite block on the opposite side of the arch. This allows the patient to relax by closing down onto the block and maintaining slight positive pressure, which eliminates or minimizes the concern.

SUMMARY

The principles of tooth preparation can be categorized into biologic, mechanical, and esthetic considerations. Often these principles conflict, and the practitioner must decide how the restoration should be designed. One area may be given too much emphasis, and the long-term success of the procedure may be limited by a lack of consideration of other factors.

Experience helps in determining whether preparations are "complete." Each tooth preparation must be measured by clearly defined criteria, which can be used to identify and correct problems. Diagnostic tooth preparations and evaluative impressions are often very helpful. The types of preparation described in the following chapters are explained in a step-by-step format. Understanding the pertinent theories underlying each step is crucial. Successful preparation can be obtained most easily by systematically following the steps. It is crucial to refrain from "jumping ahead" before the previous step has been evaluated and, if necessary, corrected. If the clinician proceeds too rapidly, precious chair time will be lost, and the quality of the preparation will probably suffer.

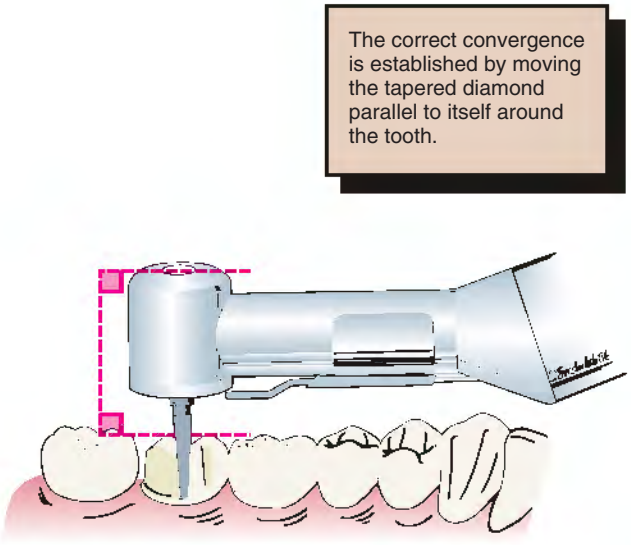

FIGURE 7-64 ■ Top surface of the handpiece held parallel to the occlusal surface. In this illustration, the rotary instrument is in correct axial alignment.

FIGURE 7-65 ■ Careful patient positioning can help obtain a direct view during tooth preparation. **A,** Often access is better if the mouth is not open maximally because partial opening allows the cheek to be more easily retracted. **B,** Access to the buccal surface.

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FIGURE 7-66 ■ Positioning of patient and right-handed dentist for tooth preparation of the maxillary posterior teeth. **A,** Maxillary right posterior sextant. Buccal or buccal half of occlusal surface reduction. The dentist is at the 9 to 11 o'clock position in relation to the chair. The patient turns the head to the left to improve the dentist's direct vision. **B,** Maxillary right posterior sextant. Palatal or palatal half of occlusal surface reduction, including functional cusp bevel. The dentist is at the 11 o'clock position. The patient turns the head to the right to improve the dentist's direct vision. **C,** Maxillary left posterior sextant. Buccal or buccal half of occlusal surface reduction. The dentist is at the 9 o'clock position. The patient turns the head to the right to improve the dentist's direct vision. **D,** Maxillary left posterior sextant. Palatal or palatal half of occlusal surface reduction, including functional cusp bevel. The dentist is at the 9 o'clock position. The patient turns the head to the left to improve the dentist's direct vision. **E,** Maxillary left posterior sextant. Distal surface reduction. The dentist is at the 9 o'clock position. The dentist's access is improved by having the patient tilt the head, partially close the jaws, and move the mandible in a left lateral excursion.

REFERENCES

1. Qvist V, et al: Progression of approximal caries in relation to iatrogenic preparation damage. J Dent Res 71:1370, 1992.
2. Zoellner A, et al: Histobacteriology and pulp reactions to long-term dental restorations. J Marmara Univ Dent Fac 2:483, 1996.
3. Langeland K, Langeland LK: Pulp reactions to crown preparation, impression, temporary crown fixation, and permanent cementation. J Prosthet Dent 15:129, 1965.
4. Baldissara P, et al: Clinical and histological evaluation of thermal injury thresholds in human teeth: a preliminary study. J Oral Rehabil 24:791, 1997.
5. Ohashi Y: Research related to anterior abutment teeth of fixed partial denture. Shikagakuho 68:726, 1968.
6. Morrant GA: Dental instrumentation and pulpal injury. II. Clinical considerations. J Br Endod Soc 10:55, 1977.
7. Brännström M: Dentinal and pulpal response. II. Application of an air stream to exposed dentine, short observation period: an experimental study. Acta Odontol Scand 18:17, 1960.
8. Land MF, et al: SEM evaluation of differently shaped diamond burs after tooth preparation. Abstract #344 (oral presentation), AADR General Session. J Dent Res 76(Special Issue):56, 1997.
9. Laforgia PD, et al: Temperature change in the pulp chamber during complete crown preparation. J Prosthet Dent 65:56, 1991.
10. Hume WR, Massey WL: Keeping the pulp alive: the pharmacology and toxicology of agents applied to dentine. Aust Dent J 35:32, 1990.
11. Johnson GH, et al: Crown retention with use of a 5% glutaraldehyde sealer on prepared dentin. J Prosthet Dent 79:671, 1998.
12. Felton DA, et al: Effect of cavity varnish on retention of cemented cast crowns. J Prosthet Dent 57:411, 1987.

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13. Mausner IK, et al: Effect of two dentinal desensitizing agents on retention of complete cast coping using four cements. J Prosthet Dent 75:129, 1996.
14. Going RE: Status report on cement bases, cavity liners, varnishes, primers and cleansers. J Am Dent Assoc 85:654, 1972.
15. Dahl BL: Effect of cleansing procedures on the retentive ability of two luting cements to ground dentin in vitro. Acta Odontol Scand 36:137, 1978.
16. Brännström M, Nyborg H: Cavity treatment with a microbicidal fluoride solution: growth of bacteria and effect on the pulp. J Prosthet Dent 30:303, 1973.
17. Watts A: Bacterial contamination and the toxicity of silicate and zinc phosphate cements. Br Dent J 146:7, 1979.
18. Dahl BL: Antibacterial effect of two luting cements on prepared dentin in vitro and in vivo. Acta Odontol Scand 36:363, 1978.
19. Mjör IA: Bacteria in experimentally infected cavity preparations. Scand J Dent Res 85:599, 1977.
20. Quarnstrom F, et al: A randomized clinical trial of agents to reduce sensitivity after crown cementation. Gen Dent 46(1):68, 1998.
21. Seltzer S, Bender IB: The dental pulp: biologic considerations in dental procedures, 2nd ed, p 180. Philadelphia, JB Lippincott, 1975.
22. Dowden WE: Discussion of methods and criteria in evaluation of dentin and pulpal responses. Int Dent J 20:531, 1970.
23. Al-Fouzan AF, Tashkandi EA: Volumetric measurements of removed tooth structure associated with various preparation designs. Int J Prosthodont 26:545, 2013.
24. Sorensen JA: A rationale for comparison of plaque-retaining properties of crown systems. J Prosthet Dent 62:264, 1989.
25. Perel ML: Axial crown contours. J Prosthet Dent 25:642, 1971.
26. Han TJ, Takei HH: Progress in gingival papilla reconstruction. Periodontol 2000 11:65, 1996.
27. Silness J: Periodontal conditions in patients treated with dental bridges. III. The relationship between the location of the crown margin and the periodontal condition. J Periodont Res 5:225, 1970.
28. Karlsen K: Gingival reactions to dental restorations. Acta Odontol Scand 28:895, 1970.
29. Newcomb GM: The relationship between the location of subgingival crown margins and gingival inflammation. J Periodontol 45:151, 1974.
30. Bader JD, et al: Effect of crown margins on periodontal conditions in regularly attending patients. J Prosthet Dent 65:75, 1991.
31. Block PL: Restorative margins and periodontal health: a new look at an old perspective. J Prosthet Dent 57:683, 1987.
32. Ackerman MB: The full coverage restoration in relation to the gingival sulcus. Compendium 18:1131, 1997.
33. Felton DA, et al: Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent 65:357, 1991.
34. Byrne G, et al: Casting accuracy of high-palladium alloys. J Prosthet Dent 55:297, 1986.
35. Belser UC, et al: Fit of three porcelain-fused-to-metal marginal designs in vivo: a scanning electron microscope study. J Prosthet Dent 53:24, 1985.
36. Ayad MF: Effects of tooth preparation burs and luting cement types on the marginal fit of extracoronal restorations. J Prosthodont 18:145, 2009.
37. Asavapanumas C, Leevailoj C: The influence of finish line curvature on the marginal gap width of ceramic copings. J Prosthet Dent 109:227, 2013.
38. Renne W, et al: Predicting marginal fit of CAD/CAM crowns based on the presence or absence of common preparation errors. J Prosthet Dent 108:310, 2012.
39. Rosner D: Function, placement, and reproduction of bevels for gold castings. J Prosthet Dent 13:1160, 1963.
40. Rosenstiel E: The marginal fit of inlays and crowns. Br Dent J 117:432, 1964.
41. Hoard RJ, Watson J: The relationship of bevels to the adaptation of intracoronal inlays. J Prosthet Dent 35:538, 1976.
42. Shillingburg HT Jr, et al: Preparation design and margin distortion in porcelain-fused-to-metal restorations. J Prosthet Dent 29:276, 1973.
43. Faucher RR, Nicholls JI: Distortion related to margin design in porcelain-fused-to-metal restorations. J Prosthet Dent 43:149, 1980.
44. Pascoe DF: Analysis of the geometry of finishing lines for full crown restorations. J Prosthet Dent 40:157, 1978.
45. Gavelis JR, et al: The effect of various finish line preparations on the marginal seal and occlusal seat of full crown preparations. J Prosthet Dent 45:138, 1981.
46. Hunter AJ, Hunter AR: Gingival crown margin configurations: a review and discussion. I. Terminology and widths. J Prosthet Dent 64:548, 1990.
47. Dykema RW, et al: Johnston's modern practice in crown and bridge prosthodontics, 4th ed, p 27. Philadelphia, WB Saunders, 1986.
48. Shillingburg HT, et al: Fundamentals of fixed prosthodontics, 3rd ed, p 128. Chicago, Quintessence Publishing, 1997.
49. Dimashkieh MR: Modified rotary design instruments for controlled finish line crown preparation. J Prosthet Dent 69:120, 1993.
50. Ramp MH, et al: Tooth structure loss apical to preparations for fixed partial dentures when using self-limiting burs. J Prosthet Dent 79:491, 1998.
51. Seymour K, et al: Assessment of shoulder dimensions and angles of porcelain bonded to metal crown preparations. J Prosthet Dent 75:406, 1996.
52. Hoffman EJ: How to utilize porcelain fused to gold as a crown and bridge material. Dent Clin North Am 9:57, 1965.
53. Richter-Snapp K, et al: Change in marginal fit as related to margin design, alloy type, and porcelain proximity in porcelain-fused-to-metal restorations. J Prosthet Dent 60:435, 1988.
54. Byrne G: Influence of finish-line form on crown cementation. Int J Prosthodont 5:137, 1992.
55. Syu JZ, et al: Influence of finish-line geometry on the fit of crowns. Int J Prosthodont 6:25, 1993.
56. Hamaguchi H, et al: Marginal distortion of the porcelain-bonded-to-metal complete crown: an SEM study. J Prosthet Dent 47:146, 1982.
57. Goodacre CJ, et al: Tooth preparations for complete crowns: an art form based on scientific principles. J Prosthet Dent 85:363, 2001.
58. Farah JW, et al: Effects of design on stress distribution of intracoronal gold restorations. J Am Dent Assoc 94:1151, 1977.
59. Walton JN, et al: A survey of crown and fixed partial denture failures: length of service and reasons for replacement. J Prosthet Dent 56:416, 1986.
60. Lindquist E, Karlsson S: Success rate and failures for fixed partial dentures after 20 years of service. I. Int J Prosthodont 11:133, 1998.
61. Rosenstiel E: The retention of inlays and crowns as a function of geometrical form. Br Dent J 103:388, 1957.
62. Jørgensen KD: The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 13:35, 1955.
63. Kaufman EG, et al: Factors influencing the retention of cemented gold castings. J Prosthet Dent 11:487, 1961.
64. Dodge WW, et al: The correlation of resistance and retention to convergence angle [Abstract no. 880]. J Dent Res 62:267, 1983.
65. Hovijitra S, et al: The relationship between retention and convergence of full crowns when used as fixed partial denture retainers. J Indiana Dent Assoc 58(4):21, 1979.
66. Wilson AH, Chan DC: The relationship between preparation convergence and retention of extracoronal retainers. J Prosthodont 3:74, 1994.
67. Nordlander J, et al: The taper of clinical preparations for fixed prosthodontics. J Prosthet Dent 60:148, 1988.
68. Ohm E, Silness J: The convergence angle in teeth prepared for artificial crowns, J Oral Rehabil 5(4):371, 1978.
69. Ayad MF, et al: Assessment of convergence angles of tooth preparations for complete crowns among dental students. J Dent 33:633, 2005.
70. Mack J: A theoretical and clinical investigation into the taper achieved on crown and inlay preparations. J Oral Rehabil 7:255, 1980.
71. Reisbick MH, Shillingburg HT: Effect of preparation geometry on retention and resistance of cast gold restorations. Calif Dent Assoc J 3:51, 1975.
72. Nicholls JI: Crown retention. I. Stress analysis of symmetric restorations. J Prosthet Dent 31:179, 1974.
73. Nicholls JI: Crown retention. II. The effect of convergence angle variation on the computed stresses in the luting agent. J Prosthet Dent 31:651, 1974.
74. Potts RG, et al: Retention and resistance of preparations for cast restorations. J Prosthet Dent 43:303, 1980.
75. Kishimoto M, et al: Influence of preparation features on retention and resistance. Part II: three-quarter crowns. J Prosthet Dent 49:188, 1983.
76. Galun EA, et al: The contribution of a pinhole to the retention and resistance form of veneer crowns. J Prosthet Dent 56:292, 1986.

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77. Worley JL, et al: Effects of cement on crown retention. J Prosthet Dent 48:289, 1982.
78. Smith BGN: The effect of the surface roughness of prepared dentin on the retention of castings. J Prosthet Dent 23:187, 1970.
79. Arcoria CJ, et al: Effect of undercut placement on crown retention after thermocycling. J Oral Rehabil 17:395, 1990.
80. O'Connor RP, et al: Effect of internal microblasting on retention of cemented cast crowns. J Prosthet Dent 64:557, 1990.
81. Saito C, et al: Adhesion of polycarboxylate cements to dental casting alloys. J Prosthet Dent 35:543, 1976.
82. Chan KC, et al: Bond strength of cements to crown bases. J Prosthet Dent 46:297, 1981.
83. DeWald JP, et al: Crown retention: a comparative study of core type and luting agent. Dent Mater 3:71, 1987.
84. McComb D: Retention of castings with glass ionomer cement. J Prosthet Dent 48:285, 1982.
85. Arfaei AH, Asgar K: Bond strength of three cements determined by centrifugal testing. J Prosthet Dent 40:294, 1978.
86. Tjan AHL, Li T: Seating and retention of complete crowns with a new adhesive resin cement. J Prosthet Dent 67:478, 1992.
87. el-Mowafy OM, et al: Retention of metal ceramic crowns cemented with resin cements: effects of preparation taper and height. J Prosthet Dent 76:524, 1996.
88. Ayad MF, et al: Influence of tooth surface roughness and type of cement on retention of complete cast crowns. J Prosthet Dent 77:116, 1997.
89. Prati C, et al: Permeability of marginal hybrid layers in composite restorations. Clin Oral Investig 9(1):1, 2005.
90. Chersoni S, et al: Water movement in the hybrid layer after different dentin treatments. Dent Mater 20:796, 2004.
91. Jørgensen KD, Esbensen AL: The relationship between the film thickness of zinc phosphate cement and the retention of veneer crowns. Acta Odontol Scand 26:169, 1968.
92. Hembree JH, Cooper EW: Effect of die relief on retention of cast crowns and inlays. Oper Dent 4:104, 1979.
93. Gegauff AG, Rosenstiel SF: Reassessment of die-spacer with dynamic loading during cementation. J Prosthet Dent 61:655, 1989.
94. Carter SM, Wilson PR: The effect of die-spacing on crown retention. Int J Prosthodont 9:21, 1996.
95. Gibbs CH, et al: Limits of human bite strength. J Prosthet Dent 56:226, 1986.
96. Wiskott HW, et al: The relationship between abutment taper and resistance of cemented crowns to dynamic loading. Int J Prosthodont 9:117, 1996.
97. Trier AC, et al: Evaluation of resistance form of dislodged crowns and retainers. J Prosthet Dent 80:405, 1998.
98. Weed RM, Baez RJ: A method for determining adequate resistance form of complete cast crown preparations. J Prosthet Dent 52:330, 1984.
99. Wiskott HW, et al: The effect of tooth preparation height and diameter on the resistance of complete crowns to fatigue loading. Int J Prosthodont 10:207, 1997.
100. Dodge WW: The effect of convergence angle on retention and resistance form. Quintessence Int 16:191, 1985.
101. Shillingburg HT, et al: Fundamentals of fixed prosthodontics, 3rd ed, p. 120. Chicago, Quintessence Publishing, 1997.
102. Woolsey GD, Matich JA: The effect of axial grooves on the resistance form of cast restorations. J Am Dent Assoc 97:978, 1978.
103. Parker MH, et al: New guidelines for preparation taper. J Prosthodont 2:61, 1993.
104. Hegdahl T, Silness J: Preparation areas resisting displacement of artificial crowns. J Oral Rehabil 4:201, 1977.
105. Proussaefs P, et al: The effectiveness of auxiliary features on a tooth preparation with inadequate resistance form. J Prosthet Dent 91:33, 2004.
106. Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.
107. Mesu FP: The effect of temperature on compressive and tensile strengths of cements. J Prosthet Dent 49:59, 1983.
108. Branco R, Hegdahl T: Physical properties of some zinc phosphate and polycarboxylate cements. Acta Odontol Scand 41:349, 1983.
109. McLean JW: Polycarboxylate cements: five years' experience in general practice. Br Dent J 132:9, 1972.
110. Guyer SE: Multiple preparations for fixed prosthodontics. J Prosthet Dent 23:529, 1970.
111. Doyle MG: The effect of tooth preparation design on the breaking strength of Dicor crowns: 3. Int J Prosthodont 3:327, 1990.
112. Seydler B, et al: In vitro fracture load of monolithic lithium disilicate ceramic molar crowns with different wall thicknesses. Clin Oral Investig 18:1165, 2014.
113. McLean JW: The science and art of dental ceramics, vol 1, p 136. Chicago, Quintessence Publishing, 1979.
114. Wise MD: Stability of gingival crest after surgery and before anterior crown placement. J Prosthet Dent 53:20, 1985.
115. Palomo F, Kopczyk RA: Rationale and methods for crown lengthening. J Am Dent Assoc 96:257, 1978.
116. Gorodovsky S, Zidan O: Retentive strength, disintegration, and marginal quality of luting cements. J Prosthet Dent 68:269, 1992.
117. Mojon P, et al: Maximum bond strength of dental luting cement to amalgam alloy. J Dent Res 68:1545, 1989.
118. Kerby RE, et al: Some physical properties of implant abutment luting cements. Int J Prosthodont 5:321, 1992.
119. Cattani-Lorente M-A, et al: Early strength of glass ionomer cements. Dent Mater 9:57, 1993.
120. Miyamoto S, et al: [Study on fatigue toughness of dental materials. I. Compressive strength on various luting cements and composite resin cores]. Nippon Hotetsu Shika Gakkai Zasshi 33:966, 1989.
121. White SN, Yu Z: Compressive and diametral tensile strengths of current adhesive luting agents. J Prosthet Dent 69:568, 1993.

STUDY QUESTIONS

1. Discuss how the manipulation and condition of the armamentarium being used can contribute to injury.

2. Discuss optimal occlusocervical margin placement. What are some reasons for deviating from the ideal? Why?

3. Discuss the difference between retention and resistance. What can be done to enhance retention, and what can be done to improve the resistance form of a tooth preparation?

4. Discuss six different margin configurations. Discuss their advantages, disadvantages, indications, and contraindications as applicable.

5. What is an undercut? How is an undercut eliminated? Can a buccal and lingual wall be undercut in relation to each other? Why or why not?

6. What are the differences in retention and resistance form between a partial veneer crown preparation and a complete cast crown preparation on the same tooth? How do clinical crown length and tooth size influence either? Why?

7. List six different means of conserving tooth structure during tooth preparation design, and explain why they achieve the objective.

8. What is the purpose of diagnostic waxing? Give four indications for a diagnostic waxing procedure.

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CHAPTER 8

The Complete Cast Crown Preparation

Although esthetic factors can limit its application, the all-metal complete cast crown should always be considered for patients requiring restorations for badly damaged posterior teeth. Longevity of complete cast crowns is superior to that of all other fixed restorations. Such a crown can be used to restore a single tooth or as a retainer for a fixed dental prosthesis. As its name implies, it covers all axial walls and the occlusal surface of the tooth (Fig. 8-1).

Preparation for any restoration requires that adequate tooth structure be removed to allow restoring the tooth to its original contours, while ensuring sufficient thickness for the restorative material. Whenever possible, tooth structure should be preserved (see Chapter 7), but reduction must be adequate to enable the dentist to fabricate a crown of acceptable strength and optimal contours.

ADVANTAGES

Because all axial surfaces of the tooth are included in the preparation, the complete cast crown has greater retention than do more conservative restorations on the same tooth (e.g., a seven-eighths or three-quarter crown [see Fig. 7-35]).

Normally, a complete cast crown preparation has greater resistance form than does a partial-coverage restoration on the same tooth. If the axial walls of a complete cast crown have been prepared with reasonable axial wall height and the proper convergence, a significant amount of tooth structure must fail before the crown can be displaced.

For a partial veneer crown to rotate off a tooth, in comparison, only the tooth structure immediately lingual to the occlusal portion of the proximal groove or box needs to fail (see Fig. 7-41). Complete cast crown strength is superior to that of other restorations. Its cylindrical configuration encircles the tooth and is reinforced by a corrugated occlusal surface. Just as an O-shaped link in a chain resists deformation better than a C-shaped link, this restoration is less easily deformed than its partial veneer counterparts, which, however, more conservative of tooth structure.

A complete cast crown allows the operator, within reason, to modify axial tooth contour. This can be helpful with malaligned teeth, although the extent of possible recontouring is limited by periodontal considerations. Similarly, it is possible to allow improved access for oral hygiene for teeth with furcal involvement through alteration of buccal and lingual wall contours. This is sometimes referred to as *fluting* or *barreling* (Fig. 8-2). When special requirements exist for axial contours—such as when retainers are needed for partial removable dental prostheses for which locations for heights of contour are very specific—a complete crown is often the only restoration that allows achieving properly shaped survey lines, guide planes, and occlusal rests in the restored tooth (Fig. 8-3) (see Chapter 21).

Complete crowns facilitate modification of the occlusion, which can prove challenging when a more conservative restoration is made. This is especially important when teeth are supra-erupted or when the occlusal plane needs to be reestablished.

DISADVANTAGES

Preparation for complete cast crowns involves all coronal surfaces. Thus removal of tooth structure is extensive and can have adverse effects on the pulp and periodontium. Because of the proximity of the margin to the gingiva, inflammation of gingival tissues is not uncommon (although a properly adapted complete cast crown with good axial contour should minimize this).

The display of metal associated with complete cast crowns may be objectionable, and in patients with a normal smile line, such restorations may be restricted to maxillary molars, mandibular molars, and premolars.

INDICATIONS

The complete cast crown is indicated on heavily restored teeth that have extensive coronal destruction by caries or trauma. It is the restoration of choice whenever maximum retention and resistance are needed: for instance, in posterior, high-load locations that are not readily visible. To further enhance its prognosis, grooves should be included to further increase resistance form on short clinical crowns or when high displacement forces are anticipated (such as for a retainer of a long-span fixed dental prosthesis).

This restoration is indicated when correction of axial contours is sought but is not achievable with a more conservative technique. Similarly, complete cast crowns

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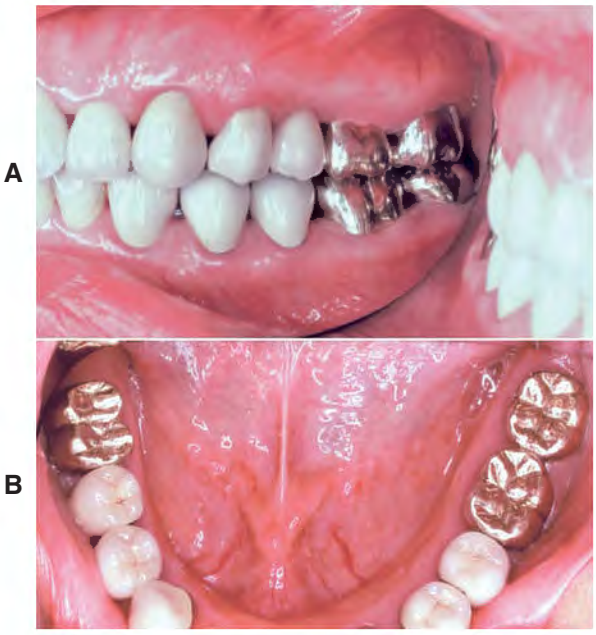

FIGURE 8-1 ■ **A** and **B,** Complete cast crowns used to restore molar teeth subject to high loads. The canines and premolars, which are more visible, and loaded to a lesser extent because of their more anterior arch position, have been restored with metal-ceramic crowns.

FIGURE 8-2 ■ Fluting of buccal walls of maxillary and mandibular first molars to enable better access to the furcations for plaque control to improve the long-term prognosis of the restorations.

can support a partial removable dental prosthesis. It is occasionally possible to use a partial-coverage restoration, but obtaining the necessary contours is more difficult. Although proximal guide planes can sometimes be prepared through simple enamel modification, obtaining properly oriented reciprocal guide planes and survey contours through enamoplasty is often impractical. The minimum dimensions required for occlusal rests of a partial removable dental prosthetic framework necessitate removing significant amounts of enamel and, if the

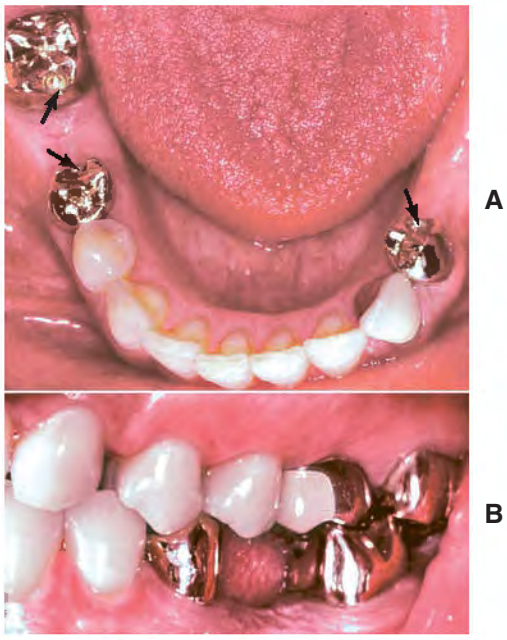

FIGURE 8-3 ■ Complete cast crowns used as retainers to accommodate a mandibular partial removable dental prosthesis. Metal-ceramic crowns have been placed on the mandibular left canine **(A)** and the maxillary first molar **(B).** Note the occlusal rests (**A,** *arrow*s) and the survey contours **(B),** which extend to form reciprocating guide planes. (See Chapter 21.)

dentin is exposed, restoring the tooth with a cast crown.*

Complete crowns are indicated on endodontically treated posterior teeth. The superior strength of complete cast crowns compensates for the loss of tooth structure that results from previous restorations, carious lesions, and endodontic access.

CONTRAINDICATIONS

The complete cast crown is contraindicated if treatment objectives can be met with a more conservative restoration. For wherever the buccal or lingual wall is intact, use of a partial-coverage restoration should be considered. If less than maximum retention and resistance are needed (e.g., on a short-span fixed dental prosthesis), a preparation more conservative of tooth structure is indicated. Similarly, if a removable partial denture is planned and an adequate buccal contour exists or can be obtained through enamel modification (enameloplasty), a complete crown is not warranted. If the esthetic need is high (e.g., for anterior teeth or for posterior teeth in the esthetic zone), a complete cast crown is also contraindicated.

CRITERIA

The occlusal reduction must allow adequate room for the restorative material from which the cast crown is to be

*On mandibular premolars, a rest can sometimes be placed on top of the modified occlusal surface without interfering with the occlusion or articulation.

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fabricated. Therefore, the material that is selected to fabricate the restoration has a direct effect on the minimal amount of tooth structure that must be removed. Typically, type III or IV gold casting alloy or its low–gold content equivalent is used for complete cast crown fabrication. Anatomic-contour zirconia crowns (see Chapters 11 and 25) offer an esthetic alternative to cast metal crowns. The preparation design for anatomic-contour zirconia is similar to that for cast metal, although additional occlusal clearance is usually required. The difference between occlusal clearance and reduction should be noted: *Clearance* is the amount of space between the completed preparation and the opposing tooth; *reduction* is the amount of tooth structure that is removed to establish the desired clearance.

Minimum recommended clearance is 1 mm on nonfunctional (noncentric) cusps and 1.5 mm on functional (centric) cusps. The occlusal reduction should generally follow normal anatomic contours to be as conservative of tooth structure as possible. Axial reduction should parallel the long axis of the tooth but allow for the recommended 6-degree taper or total included convergence, which is the angle measured between opposing axial surfaces.

The preparation margin should have a chamfer configuration, and its ideal location is supragingival. The chamfer margin should be smooth and distinct and allow for approximately 0.5 mm of metal thickness at the margin. It is typically an exact replica of half the rotary instrument that was used to prepare it. (The recommended dimensions for reduction are shown in Fig. 8-4.)

Special Considerations

Functional (Centric) Cusp Bevel

Reasonably uniform tooth reduction results in a preparation that somewhat mimics the form of the original clinical crown (see Fig. 7-46).

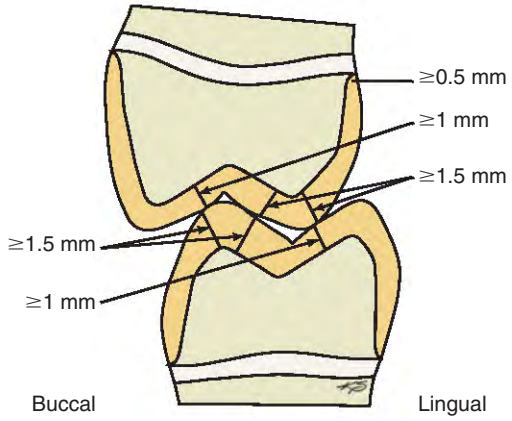

FIGURE 8-4 ■ Recommended minimal dimensions for a complete cast crown. On functional cusps (buccal mandibular and lingual maxillary), occlusal clearance should be 1.5 mm or greater. On nonfunctional cusps, the clearance should be at least 1 mm. The chamfer margin should allow for approximately 0.5 mm of metal thickness at the margin. Note that the buccal wall of the maxillary molar is prepared in two planes.

Proper placement of a *functional cusp bevel* achieves this. Because additional reduction is needed for the functional cusps (to provide a minimum of 1.5 mm of occlusal clearance), the functional cusp bevel must be angled flatter than the external surface of the original tooth (Fig. 8-5). On most posterior teeth, the functional cusp bevel is placed at an angle of approximately 45 degrees to the long axis of the prepared tooth.

Nonfunctional (Noncentric) Cusp Bevel

Complete crown preparations should be assessed for adequate reduction at the occlusoaxial line angles of the nonfunctional cusps. In this location, metal thickness must be at least 0.6 mm for adequate strength. Maxillary molars in particular often require additional reduction in this area (Fig. 8-6). Typically, the occlusal half of the buccal wall is reduced to be parallel to the original buccal contour of the original tooth. Without such two-plane buccal reduction, the result can be either a restoration that is too thin or, more likely, an overcontoured restoration that does not follow normal anatomic form. Such additional reduction is often unnecessary for mandibular molars, however, because their relatively straight or slightly lingually inclined profile allows fabrication of restoration that has good anatomic form and meets minimal material thickness requirements.

Chamfer Margin Width

Adequate chamfer margin width (minimum, 0.5 mm) is important for developing optimum axial contour. Insufficient chamfer margin width forces the dental technician to overcontour the restoration. Such increased faciolingual width of a complete crown is a common error in practice and a leading cause of periodontal disease in association with restorations. On small teeth (e.g., selected premolars), however, it may be advantageous to prepare a slightly more conservative chamfer margin to preserve tooth structure. This requires increasingly careful manipulation of the wax pattern during fabrication of the restoration and careful assessment at clinical evaluation (see Chapter 29) to ensure that the crown is not overcontoured.

PREPARATION

In addition to the armamentarium (Fig. 8-7 and Table 8-1), the clinical tooth preparation for a complete cast crown consists of the following steps:

- Occlusal depth grooves
- Occlusal reduction and functional cusp bevel
- Axial alignment grooves
- Axial reduction
- Finishing and evaluation

Step-by-Step Procedure

In this chapter, the tooth preparation steps are described for a mandibular second molar in good alignment. Depending on the tooth to be prepared (e.g., a premolar versus a molar), the exact number of depth grooves may

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FIGURE 8-5 ■ The functional cusp bevel is prepared by slanting the rotary instrument at a flatter angle *(dashed line)* than the cuspal angulation. This ensures the necessary clearance over the functional cusp.

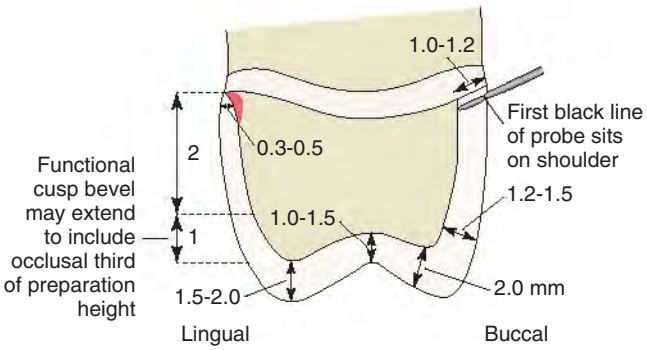

FIGURE 8-6 ■ The configuration of the facial wall of the maxillary molars may necessitate slight additional reduction in the occlusal half to prevent overcontouring of the restoration. This reduction is referred to as a *second plane reduction.* All dimensions in millimeters.

vary. Similarly, if a tooth is tipped, the actual depth of these depth grooves will vary from what is described. The recommended sequence remains otherwise identical, however.

Guiding Grooves for Occlusal Reduction

Once the desired reduction depth has been determined, a tapered tungsten carbide or a narrow tapered or small round-ended diamond is recommended for placing the depth grooves for occlusal reduction. Depth grooves are helpful in guiding occlusal reduction only if the tooth is in good occlusal relationship before preparation. Depth grooves can be placed when a foundation restoration has been placed during the mouth preparation phase of the treatment (see Chapter 6). When this is not practical (e.g., for correcting occlusal discrepancies such as supraeruptions, or for replacing an existing crown), a reduction guide can be made from a diagnostic waxing procedure (see Figs. 2-41 and 7-62), which can be used during the tooth preparation to evaluate whether optimal reduction has been achieved.)

1. Place depth holes approximately 1 mm deep in the central, mesial, and distal fossae, and connect them so that a channel runs the length of the central groove and extends into the mesial and distal marginal ridge.
2. Place depth grooves in the buccal and lingual developmental grooves and in each triangular ridge; they should extend approximately from the cusp tip to the center of its base (Figs. 8-8 and 8-9).
3. To ensure that the centric or functional cusp will be protected by an adequate thickness of metal, place depth grooves for the functional cusp bevel in the area of occlusal contact with the opposing tooth. The depth of these grooves should be slightly less than 1.5 mm (to allow for smoothing) in the area of the centric stop, and their depth should gradually diminish in a cervical direction.
4. Use the depth grooves to ensure that occlusal reduction generally follows anatomic configuration and thus minimizes the loss of tooth structure while ensuring adequate clearance, as dictated by the mechanical properties of the alloy from which the restoration will be fabricated. Depth grooves must be placed with accuracy; the practitioner should concentrate on position, depth, and angulation of each groove. Mesiodistally, a groove should be placed in the low point and high point of each cusp. The low points are the central and developmental

FIGURE 8-7 ■ Armamentarium for the complete cast crown preparation.

TABLE 8-1 **Armamentarium for a Complete Cast Crown**

Instrument	Use
Tapered tungsten carbide bur or diamond	Occlusal guiding grooves Additional retentive features
Round-ended diamond	Occlusal guiding grooves
Narrow, round-ended, tapered diamond (regular grit) (0.8 mm)	Occlusal reduction Axial alignment grooves Axial reduction Chamfer margin preparation
Wide, round-ended, tapered diamond (fine grit) (1.2 mm)	Finishing
Utility wax and wax caliper Occlusal reduction gauge	Verification of occlusal clearance
High- and low-speed friction grip contra-angle handpieces	

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FIGURE 8-8 ■ Guiding grooves are placed on the occlusal surface. They are deeper on the functional cusp, and for the functional cusp bevel. They diminish in depth from the cusp tip to the cervical margin.

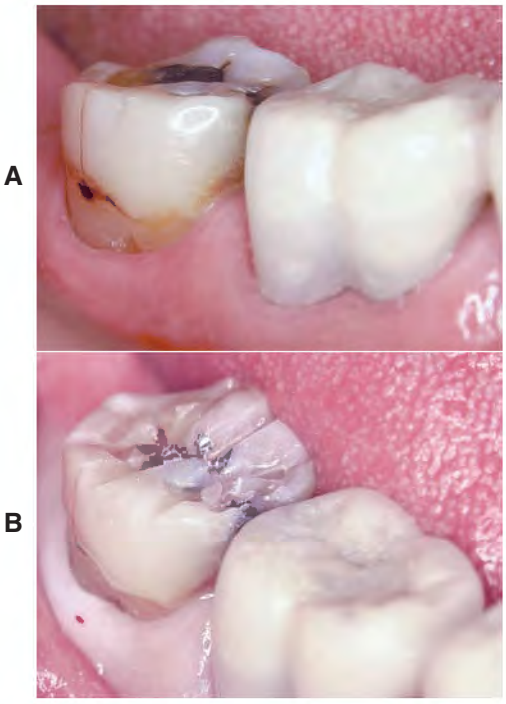

FIGURE 8-9 ■ **A,** A complete cast crown is indicated on this mandibular second molar with occlusal, proximal, and cervical lesions, as well as a buccal longitudinal fracture. **B,** Initial depth grooves placed for occlusal reduction. Note that they have not yet been extended onto the buccal surface, where the functional cusp bevel will be placed.

grooves; the high points are the cusp tips and triangular ridges. To achieve correct depth—0.8 mm for the central groove and nonfunctional cusps and 1.3 mm for the functional cusps (allowing approximately 0.2 mm for preparation finishing and smoothing)—the clinician must know the dimensions of the instruments being used. Memorizing the diameters of the rotary instruments facilitates assessment of the adequacy of the reduction during

FIGURE 8-10 ■ After the guiding grooves are placed, the occlusal reduction is performed. Either the mesial or the distal half is maintained initially as a reference to facilitate evaluation of adequacy of the reduction.

preparation. If necessary, a periodontal probe can be used to measure the extent of the reduction that has been achieved. Correct groove angulation is necessary to ensure that the occlusal reduction will allow appropriate crown form and thickness. On the nonfunctional cusp, depth grooves parallel the intended cuspal inclination; on the functional cusp, they should be angled slightly flatter to ensure additional clearance that must be achieved on the functional cusp.

Occlusal Reduction

Once the depth grooves have been deemed satisfactory, the remaining tooth structure between the grooves is removed with the tungsten carbide or the narrow, round-ended, tapered diamond. Proper placement of the grooves automatically results in adequate occlusal clearance.

5. Complete the occlusal reduction in two stages (Fig. 8-10). Half the occlusal surface is reduced first so that the other half can be maintained as a reference. When the necessary reduction of the first half has been accomplished, reduction of the remaining half can be completed (Fig. 8-11).
6. On completion, verify that a minimum clearance of 1.5 mm has been established on functional cusps and one of at least 1.0 mm on nonfunctional cusps in the occluded position. These clearances must also be verified in all excursive movements that the patient can make. If any uncertainty remains, as is often the case in evaluations of clearance on the lingual aspect of a tooth preparation, the patient should be asked to close into several layers of dark-colored utility wax in maximum intercuspation (Fig. 8-12, *A*).

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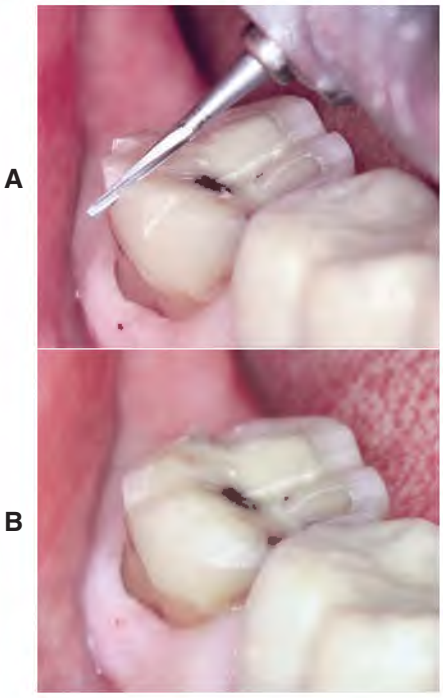

FIGURE 8-11 ■ **A,** Note the angulation of the bur as the functional cusp bevel is placed, angled slightly flatter than the original cusp angle to provide more clearance for the centric cusp than for the axial wall. **B,** Completed occlusal reduction. Note that it follows normal occlusal form. Three distinct slopes can be seen buccolingually.

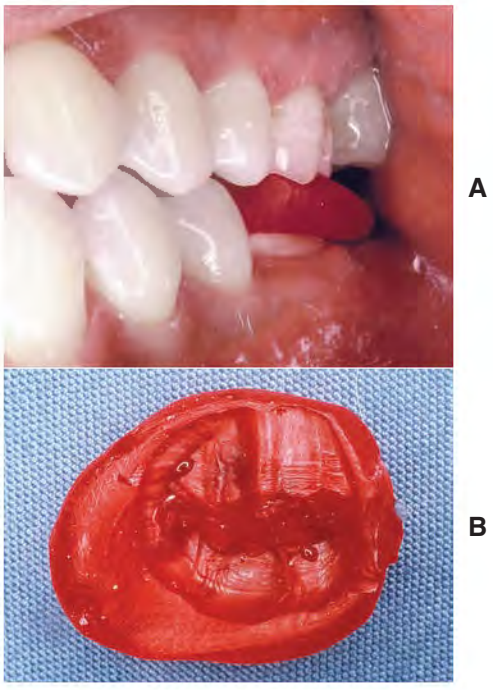

FIGURE 8-12 ■ Evaluation of the adequacy of occlusal clearance. **A,** The patient closes the teeth into softened wax. **B,** After the wax has been removed from the mouth, its thickness is assessed visually and measured with a wax caliper.

7. Remove the wax from the mouth and evaluate it for thin spots, which can be measured with a wax caliper (see Fig. 8-12, *B*). Alternatively, the thickness of the wax can be measured intraorally before removal with a periodontal probe.
8. Place the wax back in the patient's mouth and ask the patient to close. Guide the patient's mandible into protrusive and excursive positions. On removal, the thickness of the utility wax is again evaluated, this time to verify that adequate clearance exists throughout the dynamic range, as was previously verified in maximum intercuspation. A convenient alternative method is to use an occlusal reduction gauge (Hu-Friedy Mfg. Co.) (Fig. 8-13).

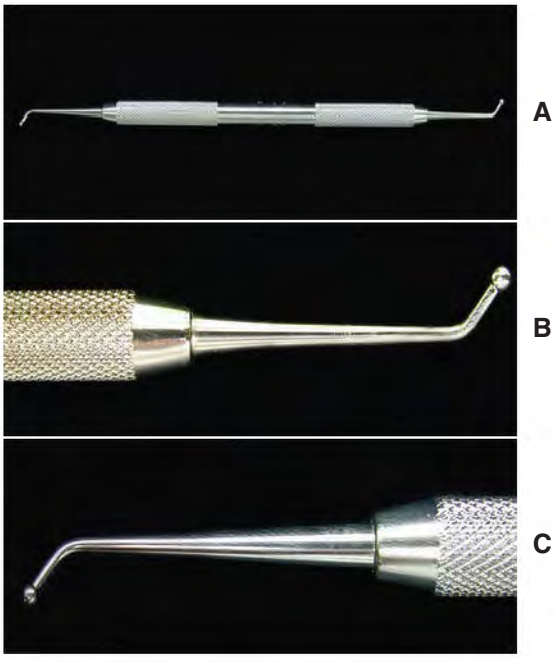

FIGURE 8-13 ■ Occlusal clearance can be judged intraorally with a reduction gauge. This instrument **(A)** has two spherical tips: one that is 1.5 mm in diameter **(B)** and one that is 1.0 mm in diameter **(C)**.

Alignment Grooves for Axial Reduction

Once the occlusal reduction has been completed, alignment grooves are placed in each buccal and lingual wall with a narrow, round-ended, tapered diamond. On molars, one alignment groove may be placed in the center of the wall, and one in each mesial and distal transitional line angle (Fig. 8-14).

1. As these alignment grooves are placed, verify that the shank of the diamond is parallel to the proposed path of placement of the restoration. Such positioning automatically produces a convergence between the axial walls of the alignment grooves that is identical to the taper of the diamond. If a diamond with a 6-degree taper is used, the identical 6-degree axial convergence will result on the preparation wall.
2. The diamond tip should not cut into the tooth beyond its midpoint; otherwise, a "lip" of tooth

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When placing these grooves, keep reduction to a minimum at the tip of the diamond.

FIGURE 8-14 ■ Alignment grooves for axial reduction are placed in the buccal and lingual surfaces parallel to the long axis of the tooth buccolingually and mesiodistally. Note that they are deep occlusally but shallower toward the cervical margin.

FIGURE 8-15 ■ **A,** The diamond is aligned parallel to the long axis of the tooth as the buccal guiding grooves for axial alignment are placed. **B,** All six grooves have been placed.

enamel will be unsupported (see Fig. 7-24). Gingivally, the depth of the alignment grooves should therefore be no more than half the width of the tip of the diamond. Occlusocervically, the position of the tip of the diamond rotary instrument determines the location of the margin (Fig. 8-15).

3. Note that the alignment grooves determine the path of placement of the restoration. They should be placed parallel to the proposed path of placement, which is typically the long axis of the tooth.
4. Use a periodontal probe to assess the relative parallelism of the alignment grooves with one another and with the proposed path of placement of a secondary retainer if the prepared tooth is to serve as an abutment for a fixed dental prosthesis. When the correct placement of alignment grooves is uncertain (as is likely on abutments for long-span fixed dental prostheses), an impression made with irreversible hydrocolloid alginate; (see Chapter 2) is especially helpful. This can be poured in rapid-setting stone, and the resulting cast can be analyzed with a dental surveyor (see Fig. 7-63). (The same cast can be used to fabricate the interim restoration; see Chapter 15.) At this time, corrections may still be made in a straightforward manner before irreversible, unnecessary tooth reduction has occurred.

Axial Reduction

The technique for axial reduction is similar to that for occlusal reduction. The residual islands of tooth structure between the alignment grooves are removed; concurrently, the chamfer margin is created, and the same

FIGURE 8-16 ■ If axial reduction is completed first on either the distal or the mesial half of the tooth, evaluation is simplified because the remaining intact half of the tooth can serve as a reference.

narrow, round-ended diamond is used for the procedure (Figs. 8-16 and 8-17).

5. Like the occlusal reduction, the axial reduction may be performed for half the tooth at a time, while the other half is maintained as a reference to simplify assessing the adequacy of the reduction.
6. When breaking interproximal contact, pay special attention to prevent unintentional damage to the adjacent teeth. This often results if the practitioner attempts to force the diamond into the proximal aspect too rapidly. Sufficient time must be allowed

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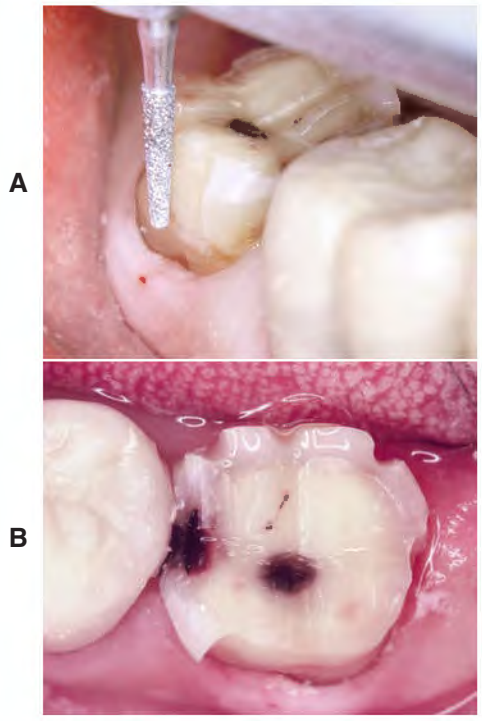

FIGURE 8-17 ■ **A,** Note the alignment of the diamond as tooth structure between the alignment grooves is removed. **B,** Axial reduction. The distobuccal axial reduction has been completed.

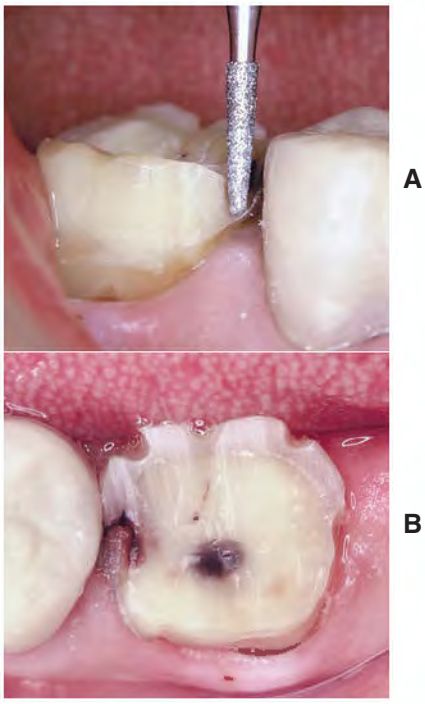

FIGURE 8-18 ■ **A,** As the mesiobuccal axial surface is reduced, a cervical chamfer margin is placed. **B,** The chamfer margin should be of relatively even width and maintain the somewhat rectangular preparation outline form to enhance resistance form.

for the cutting instrument to create space for its passage (Fig. 8-18). Typically, if the proper cervical placement of the margin has been selected with correct axial alignment of the instrument, a "lip" of tooth enamel is maintained between the diamond and the adjacent tooth, protecting the latter from iatrogenic damage (Fig. 8-19).

7. If desired, protect the adjacent teeth by placing a metal matrix band. The interproximal areas most difficult to reduce are those with significant buccolingual dimension and on teeth with root proximity. However, the challenging area is typically only a few millimeters in length.
8. Cut into the proximal area from both sides until only a few millimeters of interproximal island remain (Fig. 8-20). If necessary, this area can then be removed (and proximal contact broken) by using thinner, tapered diamonds. If the adjacent proximal surface is accidentally damaged, it must be polished with white stones, silicone points, and prophylaxis paste before impression making. Ideally, a fluoride application is given to improve caries resistance and to prevent demineralization of the surface enamel.
9. Place the cervical chamfer margin concurrently with axial reduction. Finished chamfer margin width should be approximately 0.5 mm, which allows for adequate bulk of metal at the margin. The chamfer margin must be smooth and continuous mesiodistally, and a distinct resistance against vertical displacement should be detected when the margin is probed with the tip of an explorer. The chamfer margin must be at least 0.6 mm from the proximal surface of the adjacent tooth (Fig. 8-21); more distance will simplify subsequent technique steps. Unsupported enamel cannot be tolerated on the chamfer margin because it is likely to fracture when the restoration is evaluated or cemented, which, if undetected, will result in an open margin and premature restoration failure.

FIGURE 8-19 ■ A "lip" of enamel *(arrow)* protects the adjacent tooth from iatrogenic damage as the axial reduction is completed.

Finishing

A smooth surface finish and continuity of all prepared surfaces aid most phases of fabrication of the restoration. Smooth transitions blend occlusal and axial surfaces. This facilitates many subsequent laboratory steps such as

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As the axial reduction is performed, eventually a small island of tooth structure will remain in the interproximal area. When removing this, maintain a narrow "lip" of tooth structure between the diamond and the adjacent tooth to protect the latter from damage.

FIGURE 8-20 ■ Breaking proximal contact.

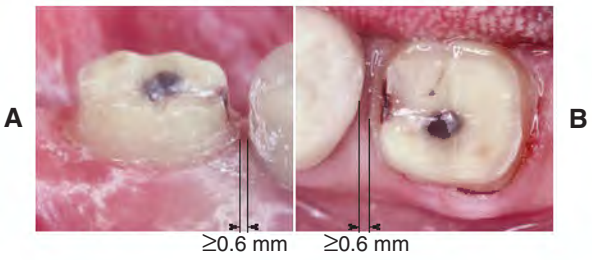

FIGURE 8-21 ■ **A,** Note that adequate clearance (≥0.6 mm) exists between the external surface of the proximal chamfer margin and the adjacent tooth. **B,** Occlusal view of the preparation.

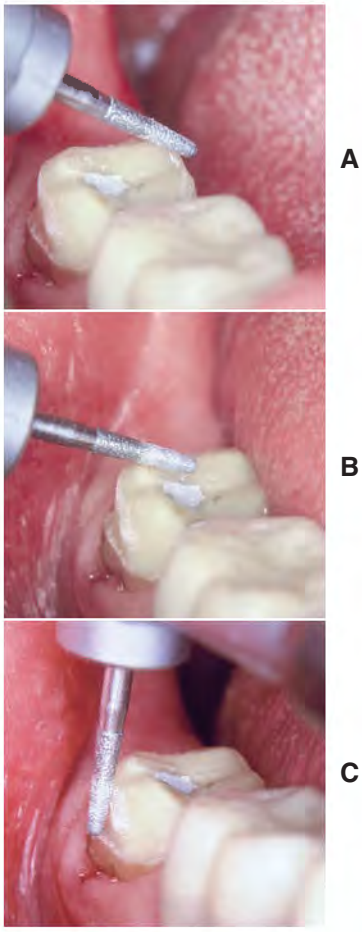

FIGURE 8-22 ■ **A,** The transition from lingual to occlusal surfaces is rounded with a fine-grit diamond. **B,** All sharp line angles between occlusal reduction and functional cusp bevel are similarly rounded. **C,** The margin is refined, and any remaining irregularities are removed.

impression making, waxing, investing, and casting because the risk of bubble formation is reduced (Fig. 8-22).

1. Use a fine-grit diamond or tungsten carbide rotary instrument of slightly greater diameter to finish the chamfer margin. This should be done as smoothly as possible, with a high-speed handpiece operating at reduced speed (see Summary Chart, p. 221). Some clinicians favor using a low-speed contra-angle handpiece for the finishing steps. A properly finished margin should be smooth as glass, as verified with a touch by the tip of an explorer.
2. Finish all prepared surfaces, and slightly round all line angles. During margin finishing, the use of air cooling alone is recommended to improve visibility. However, when only air cooling is used, a water spray should be applied from time to time to prevent the tooth from dehydrating, to avoid the possible development of pulpal damage, and to wash away debris. The larger diamond is recommended because it will eliminate any unwanted ripples that were created during axial reduction while any unsupported enamel at the margin was eliminated (Fig. 8-23).
3. Place additional retentive features as needed (e.g., grooves or boxes) with the tapered tungsten carbide bur and the slow-speed handpiece (Fig. 8-24).

The criteria used to determine the need for such features to enhance retention and resistance are described in Chapter 7.

Evaluation

Upon completion, the preparation is evaluated to verify that all the criteria have been met (Fig. 8-25). The following sequence is recommended:

1. Verify that adequate occlusal clearance has been achieved.
2. View the preparation from the buccal and lingual aspects to verify that appropriate mesiodistal taper exists. It is helpful to view from both directions to reduce the possibility of missing a possible undercut.
3. View the preparation from the mesial aspect: This allows evaluation of the buccolingual path of placement. Depending on the original alignment of the tooth, the lingual wall should be perpendicular to

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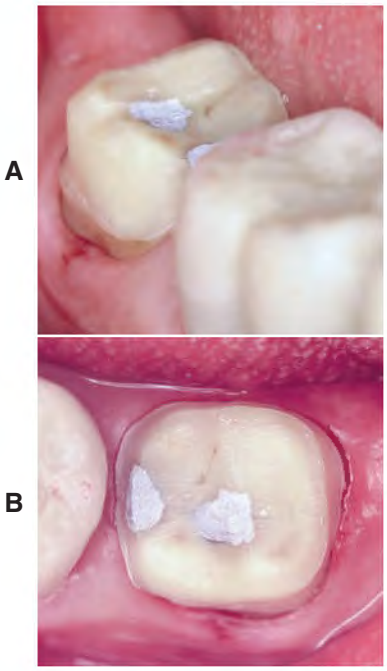

FIGURE 8-23 ■ Completed preparation. The carious lesions have been excavated, and the resulting irregularities have been restored with amalgam. **A,** Buccal appearance. **B,** Occlusal appearance.

the occlusal plane or have a slight lingual inclination. Evaluate the buccolingual angle of convergence next, followed by the angulation of the functional cusp bevel. Lastly, in this mesial view, evaluate that the occlusal reduction is adequate next to the marginal ridges of the adjacent teeth.

4. View the preparation from the occlusal aspect to evaluate that concentricity has been achieved between the outline form of the cervical and occlusal aspects of the axial walls (see Figs. 7-30 and 7-31). If more vertical wall is visible on one side of the preparation, the preparation is probably overtapered. Conversely, if it is impossible to see part of the axial wall in the occlusal view, an undercut may be present.

A common error in complete cast crown preparations is overtapering of the opposing axial walls. This significantly reduces the retention of the completed restoration. If a tooth preparation has been inadvertently overreduced through excessive tapering of axial walls, it should be carefully evaluated to determine how it can be corrected. If a band of several millimeters of tooth structure can be prepared circumferentially with a restricted taper of approximately 6 degrees, it is probably unnecessary to modify the preparation farther to compensate for areas of excessive reduction in the occlusal third. If this is not the case, an approach slightly less conservative of tooth structure may be warranted: (1) uprighting overtapered axial walls to obtain the mechanical advantage of increased retention or (2) using grooves, boxes, or pinholes as needed.

No undercuts between any opposing axial walls are acceptable. When the diamond is placed against the axial

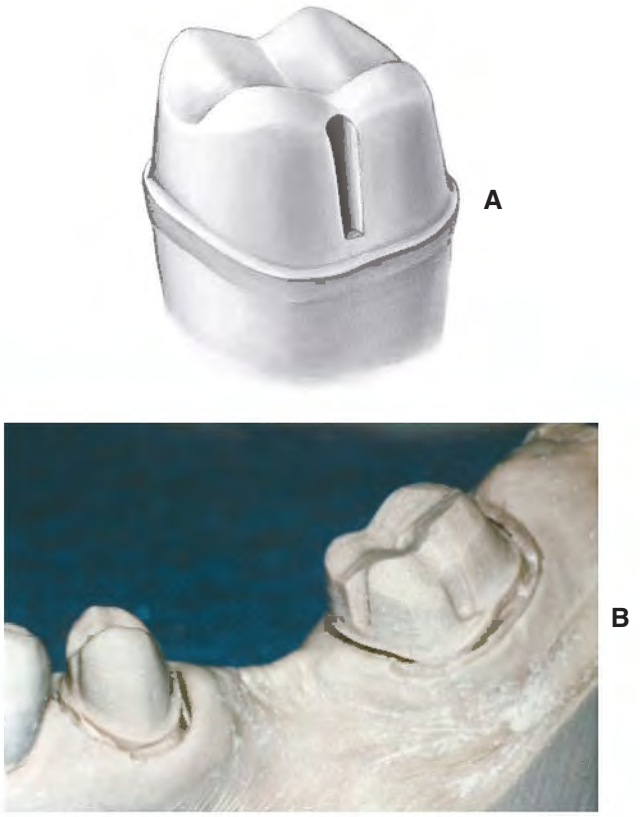

FIGURE 8-24 ■ **A,** When opposing axial walls are excessively tapered, internal features such as this buccal groove can be used to improve resistance form. **B,** Mesially tipped molars and short premolars often benefit from grooves or boxes, or both, incorporated in the preparation design.

FIGURE 8-25 ■ The completed preparation is characterized by a smooth, even chamfer margin; a 6-degree taper; and gradual transitions between all prepared surfaces.

surface of the prepared tooth, parallel to the path of placement, it should be possible to move the instrument around the tooth so that the entire height of the preparation is touching the diamond at all times. The tip of the diamond should rest on the chamfer margin throughout this movement, and no light should be visible between the instrument and the axial surface.

5. Evaluate margin width, smoothness, and continuity. An explorer moved circumferentially along a

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properly finished chamfer margin should not encounter any bumps or irregularities, whereas when it is pushed in an apical direction, distinct resistance to vertical displacement of the instrument should be felt. The margin must be placed sufficiently apically to result in adequate proximal clearance (see Fig. 8-21). It may be necessary to extend the preparation farther apically to achieve the minimally required clearance from the adjacent proximal walls.

Any noted deficiencies must be corrected before fabrication of the interim restoration (Fig. 8-26) and the definitive impression. On occasion, it can prove helpful to evaluate the thickness of a properly contoured interim restoration with a thickness gauge to verify that reduction was indeed adequate in the completed preparation.

FIGURE 8-26 ■ **A,** Acrylic resin interim restoration is cemented. **B** and **C,** Complete cast crown is cemented.

SUMMARY

The complete cast crown, an all-metal restoration often used on single posterior tooth or as a retainer for a fixed dental prosthesis, provides greater strength, retention, and resistance than any other type of restoration. It is not indicated for every restorative circumstance, however. It is unnecessary if the buccal or lingual walls of a tooth are intact or if less than maximum retention is needed. The rather extensive removal of tooth structure required in its preparation can have adverse pulpal and periodontal effects. The high strength of the complete cast crown makes it especially suitable for restoring second molars and endodontically treated posterior teeth, although in patients who find visible metal a significant drawback, the metal-ceramic or a more conservative partial-coverage restoration may be preferred.

A well-organized approach to preparation for a complete cast crown should be based on the selective use of depth and alignment grooves of predetermined dimensions correlated with specific properties of the selected restorative material. Adequate occlusal reduction is necessary, in accordance with normal anatomic tooth form, and axial reduction should also conform to the normal configuration of the tooth, with minimum taper (6 degrees). Under no circumstances should undercuts remain in the proximal walls. These must be removed by additional tooth preparation or blocked out with a suitable material. The chamfer margin is the margin of choice for a complete cast crown. It must be distinct and of adequate width. No enamel should be left unsupported. Occlusocervically, the margin ideally should be supragingival, and it should be smooth and continuous circumferentially. When the dentist assesses the adequacy of the chamfer margin, an explorer or a periodontal probe should encounter distinct resistance against vertical displacement.

STUDY QUESTIONS

1. What are the indications for and contraindications to complete cast crowns?
2. What are the advantages and disadvantages of complete cast crowns?
3. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for a complete cast crown?
4. What are the minimum criteria for each step described in question 3?

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SUMMARY CHART

Complete Cast Crown

Indications	Contraindications	Advantages	Disadvantages
• Extensive destruction from caries or trauma	• No need for maximum retention	• Strong	• Removal of large amount of tooth structure
• Endodontically treated teeth	• Esthetics	• High retentive qualities	• Adverse effects on tissue
• Existing restoration	• —	• Usually easy to obtain adequate resistance form	• Vitality testing not readily feasible
• Necessity for maximum retention and strength	• —	• Option to modify form and occlusion	• Display of metal
• To provide contours to receive a removable appliance	• —	• —	• —
• Other recontouring of axial surfaces (minor corrections of malinclinations)	• —	• —	• —
• Correction of occlusal plane		• —	

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Preparation Steps	Recommended Armamentarium	Criteria
Depth grooves for occlusal reduction	Tapered tungsten carbide or diamond	Minimum clearance on noncentric cusps: 1 mm
Functional cusp bevel	Tapered tungsten carbide or diamond	Minimum clearance on centric cusps: 1.5 mm
Occlusal reduction (half at a time)	Regular-grit, round-ended diamond	Flatter than cuspal plane, to allow additional reduction at functional cusp
Alignment grooves for axial reduction	Tapered diamond	Following normal anatomic configuration of occlusal surface
Axial reduction (half at a time)	Tapered diamond	Chamfer margin allows 0.5 mm of thickness of wax at margins
Finishing of chamfer margin	Tapered diamond	Reduction performed parallel to long axis
Additional retentive features if needed	Wide, round-ended diamond or tungsten carbide	Smooth mesiodistally and buccolingually; resistance to vertical displacement by tip of explorer or periodontal probe
Finishing	Tapered tungsten carbide; fine-grit diamond or finishing tungsten carbide	Grooves, boxes, and pinholes as described for partial-coverage restorations Rounding of all sharp line angles to facilitate impression making, die pouring, waxing, and casting

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CHAPTER 9

The Metal-Ceramic Crown Preparation

In many dental practices, the metal-ceramic crown remains one of the most widely used fixed restorations. This restoration offers a predictable esthetic result, coupled with sound physical properties. Metal-ceramic crowns consist of a complete-coverage metal crown (or substructure) that is veneered with a layer of fused porcelain to mimic the appearance of a natural tooth. The extent of the veneer can vary. In comparison with cast crown preparation, successful metal-ceramic crown preparation requires substantial additional tooth reduction wherever the metal substructure is to be veneered with dental porcelain. Only when a crown is sufficiently thick can the darker color of the metal substructure be masked and the veneer duplicate the appearance of a natural tooth. The porcelain veneer must have a certain minimum thickness for esthetics. Consequently, much tooth reduction is necessary, and the metal-ceramic preparation is one of the methods least conservative of tooth structures (Fig. 9-1).

Historically, attempts to veneer metal restorations with porcelain had several problems. A major challenge was the development of an alloy and a ceramic material with compatible physical properties that would provide adequate bond strength. In addition, it was initially difficult to obtain a natural appearance.

The technical aspects of the fabrication of this restoration are discussed in detail in Chapters 19 and 24. In this chapter, only a brief summary is provided: The metal substructure is fabricated in a special metal-ceramic alloy that has a higher fusing range and a lower thermal expansion than do conventional gold alloys. After preparatory finishing procedures, this substructure, or framework, is veneered with multiple layers of dental porcelain. The porcelain is fused onto the framework in much the same manner as household articles are enameled. Modern dental porcelains fuse at a temperature of about 960°C (1760°F). Because conventional gold alloys would melt at this temperature, the special alloys are necessary.

INDICATIONS

The metal-ceramic crown is indicated on teeth that require complete coverage and for which esthetic demands are significant (e.g., the anterior teeth). If esthetic considerations are a priority, however, an all-ceramic crown (see Chapters 11 and 25) has cosmetic advantages over the metal-ceramic restoration. However the metal-ceramic crown may be a better choice to serve as a retainer for fixed dental prostheses because its metal substructure can accommodate cast or soldered connectors. Particularly for long-span fixed dental prostheses, metal-ceramic crowns offer a more predictable prognosis than what can be achieved with all-ceramic crowns, which are generally not efficacious for long spans. Also, all-ceramic restorations cannot as predictably accommodate a rest for a removable prosthesis. Metal-ceramic crowns may successfully be modified to incorporate occlusal and cingulum rests and milled proximal and reciprocal guide planes in their metal substructure (see Chapter 21).

Typical indications are similar to those for all-metal complete crowns with the addition of an esthetic concern: extensive tooth destruction—as a result of caries, trauma, or existing previous restorations—that precludes the use of a more conservative restoration; the need for superior retention and strength; an endodontically treated tooth in conjunction with a suitable supporting structure (a post and core); and the need to recontour axial surfaces or correct minor malinclinations. Within certain limits, metal-ceramic restorations can also be used to alter the occlusal plane.

CONTRAINDICATIONS

Contraindications for the metal-ceramic crown, as for all fixed restorations, include the presence of active caries or untreated periodontal disease. In young patients with large pulp chambers, the metal-ceramic crown is contraindicated because of the high risk of pulp exposure (see Fig. 7-4). If possible, a more conservative restorative option such as a composite resin or porcelain laminate veneer (see Chapter 25) or an all-ceramic crown with less axial reduction (see Chapter 11) is preferred.

A metal-ceramic restoration should not be considered whenever a more conservative retainer is feasible, unless maximum retention and resistance form are needed, as for a long-span fixed dental prosthesis. If the facial or buccal wall is intact, the dentist should consider whether involving all axial tooth surfaces in the proposed restoration is truly necessary. Although perhaps technically more demanding and time consuming, a more conservative solution that satisfies the patient's needs while providing superior long-term service can usually be found.

ADVANTAGES

The metal-ceramic restoration combines, to a large degree, the strength of cast metal with the esthetics of ceramics. The underlying principle is to reinforce a brittle, more cosmetically pleasing material through support derived from the stronger metal substructure. Natural appearance can be matched closely by good technique

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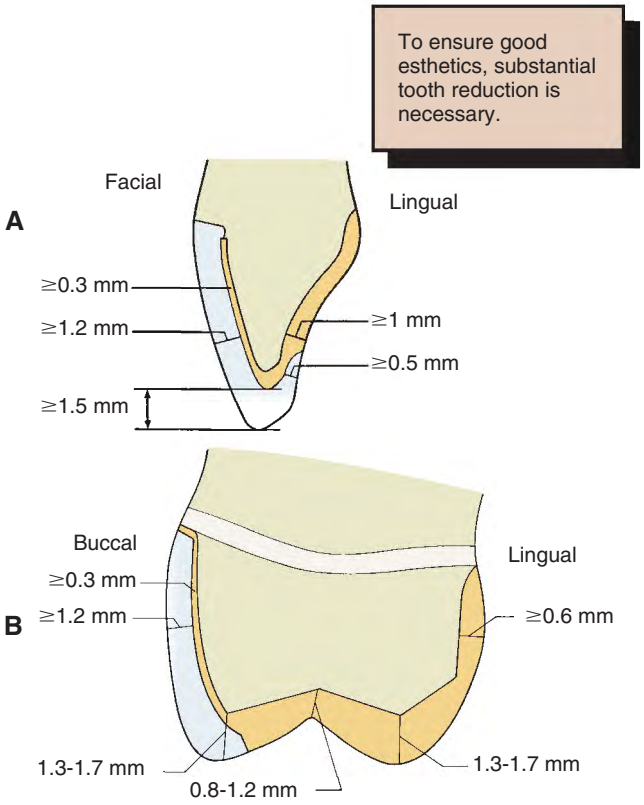

FIGURE 9-1 ■ Recommended *minimum* dimensions for a metal-ceramic restoration on an anterior tooth **(A)** and a posterior tooth **(B)**. Note the significant reduction needed in comparison with that for a complete cast or partial veneer crown (see Fig. 8-4).

and, if desired, through characterization of the restoration with internally or externally applied stains. Retentive qualities are excellent because all axial walls are included in the preparation, and it is usually straightforward to achieve adequate resistance form in the tooth preparation. The complete-coverage aspect of metal-ceramic crowns enables easy correction of axial form. Also, the preparation is much less demanding than for partial-coverage retainers. In general, the degree of difficulty of a metal-ceramic preparation is comparable with that of preparing a posterior tooth for a complete cast crown.

DISADVANTAGES

The metal-ceramic crown preparation requires significant tooth reduction to provide sufficient space for the restorative materials. To achieve better esthetics, the facial margin of an anterior restoration is often placed subgingivally, which increases the potential for periodontal disease. However, a supragingival margin can be used if significant cosmetic concerns do not preclude its use or if the restoration incorporates a porcelain labial margin (see Fig. 9-1, *A* and Chapter 24).

In comparison with all-ceramic restorations, metal-ceramic crowns may have slightly inferior esthetics: they may appear slightly grayish in comparison with the translucency that can be achieved with all-ceramic crowns. Also, with all-ceramic crowns, a somewhat greater range of brightness can be achieved. However, the superior strength of the metal-ceramic crowns allows their use in higher stress situations and on teeth that would not provide adequate support for an all-ceramic restoration.

Because of the glasslike nature of the veneering material, a metal-ceramic crown is subject to brittle fracture (although such failure is usually attributable to poor substructure design or poor fabrication technique). A frequent problem is the difficulty of accurate shade selection and its communication to the dental ceramist. The difficulty in achieving an accurate shade match is often underestimated by novice dentists. Because many procedural steps are required for both metal casting and porcelain application, laboratory costs generally render the metal-ceramic restoration among the more expensive of dental procedures.

PREPARATION

The recommended preparation sequence is described for a maxillary right central incisor (Fig. 9-2); however, the same step-by-step approach can be applied to other teeth (Fig. 9-3). As with all tooth preparations, a systematic and organized approach to tooth reduction saves time.

Armamentarium

The instruments needed to prepare teeth for a metal-ceramic crown (Fig. 9-4) include the following:

- Round-ended rotary diamonds (regular grit for bulk reduction, fine grit for finishing) or tungsten carbide burs
- Football- or wheel-shaped diamond (for lingual reduction of anterior teeth)
- Flat-ended, tapered diamond (for shoulder margin preparation)
- Finishing stones
- Explorer and periodontal probe
- Off-angle hatchets (see Fig. 9-4, *B* to *D*)

The actual sequence of steps can be varied slightly, depending on the operator's preference.

Step-by-Step Procedure

The preparation is divided into five major steps: depth grooves, incisal or occlusal reduction, labial or buccal reduction in the area to be veneered with porcelain, axial reduction of the proximal and lingual surfaces, and final finishing of all prepared surfaces.

Depth Grooves

1. Place three depth grooves (Fig. 9-5), one in the center of the facial surface and one each in the approximate locations of the mesiofacial and distofacial line angles (see Fig. 9-2, *A* to *E*). These are placed in two planes: The cervical portion parallels the long axis of the tooth, and the incisal (occlusal) portion follows the normal facial contour (see Fig. 9-2, *D* and *E*).

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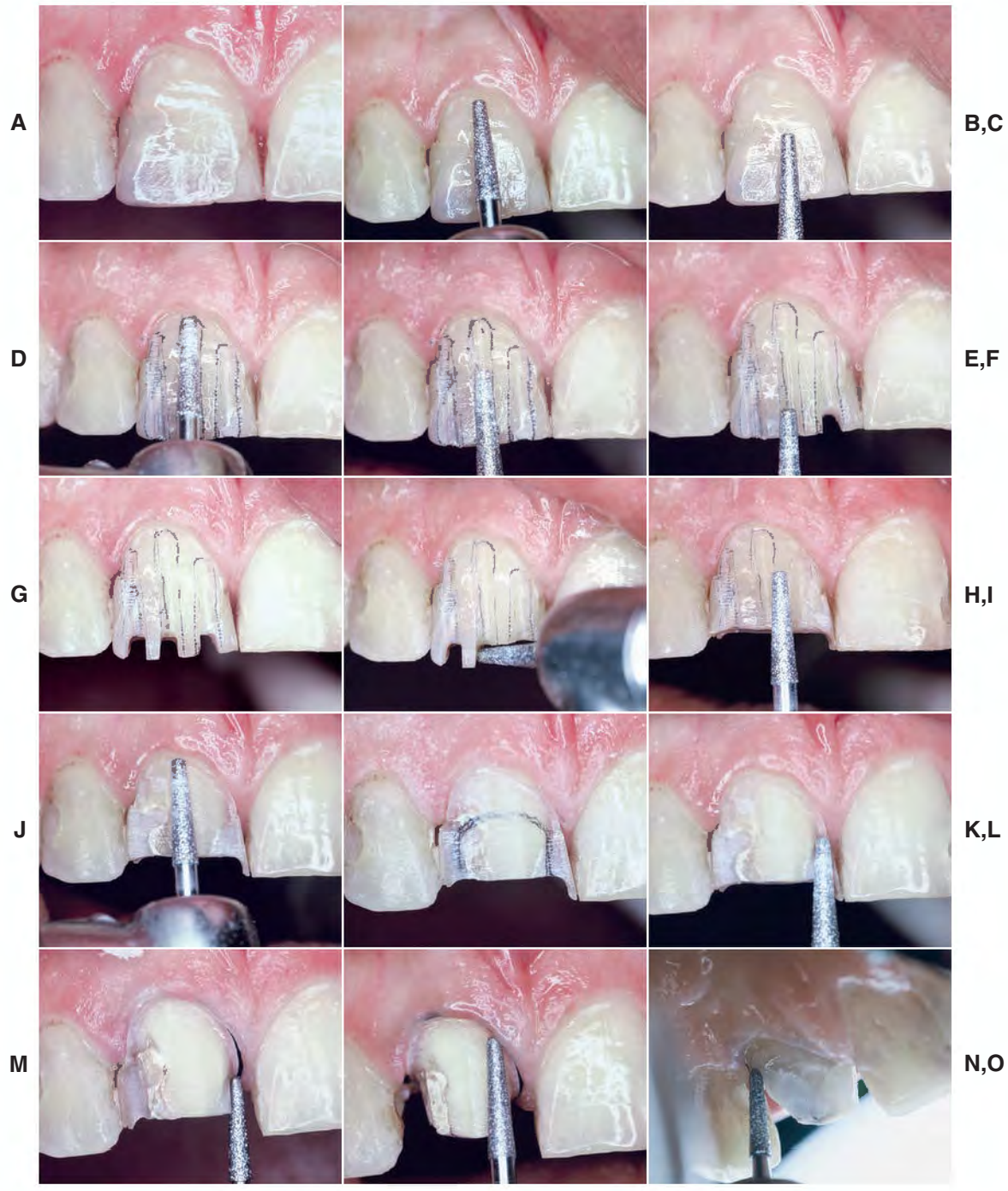

FIGURE 9-2 ■ Preparation of a maxillary incisor for a metal-ceramic crown. **A,** Heavily restored maxillary central incisor. **B** and **C,** Rotary instrument aligned with the cervical one third and incisal two thirds to gauge correct planes of reduction. **D** and **E,** Placement of depth grooves in the two planes. The cervical groove is made parallel to the path of placement, which usually coincides with the long axis of the tooth. The secondary facial depth groove is prepared parallel to the facial contour of the tooth. **F** and **G,** Placement of incisal depth grooves. **H,** Incisal edge reduction. **I** to **K,** Facial reduction accomplished in two planes. **L,** Breaking proximal contact, maintaining a "lip" of enamel to protect the adjacent tooth from inadvertent damage. **M** and **N,** Proximal reduction. **O,** Placing a 0.5-mm lingual chamfer margin.

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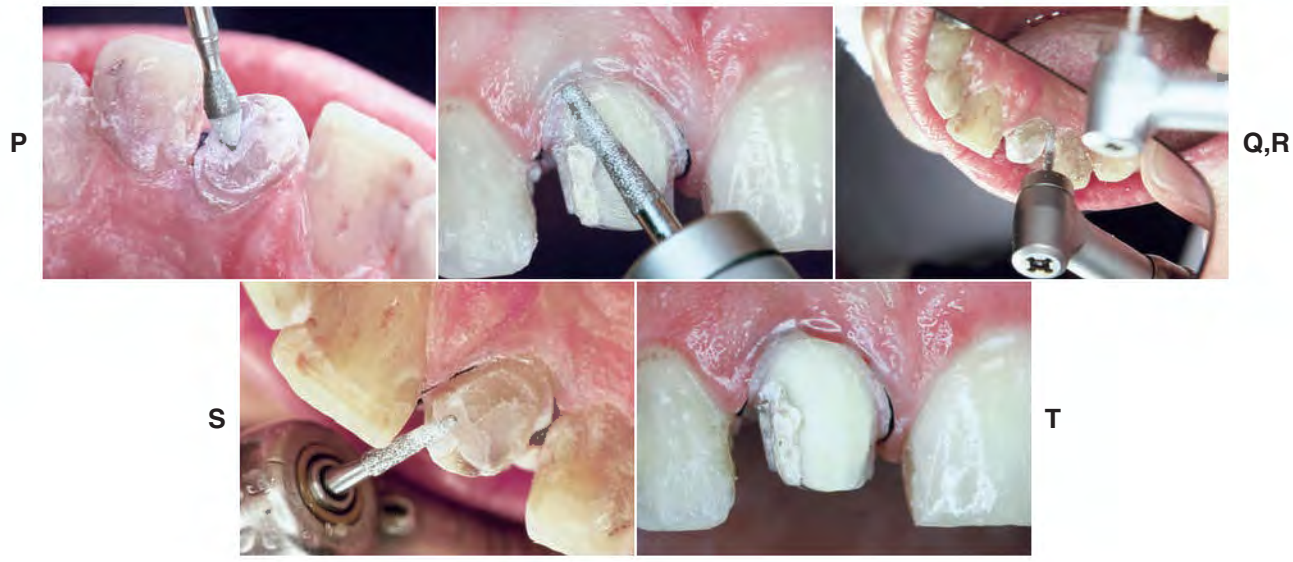

FIGURE 9-2, cont'd ■ **P,** Lingual reduction of anterior teeth with a football-shaped diamond. **Q** to **S,** Finishing the preparation with a fine-grit diamond. **T,** The completed preparation.

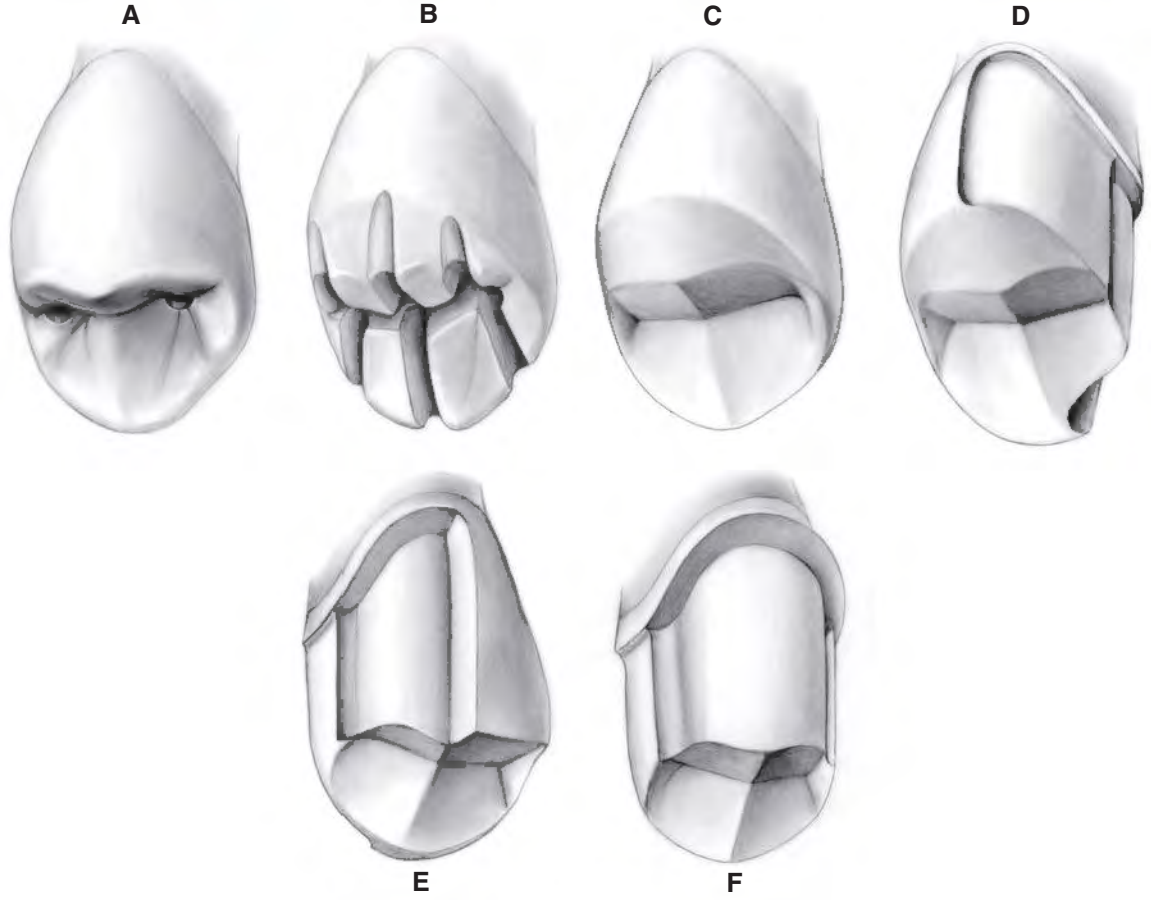

FIGURE 9-3 ■ Preparation of a maxillary premolar for a metal-ceramic crown. **A,** Depth holes. **B,** Occlusal depth cuts. **C,** Completed occlusal reduction. Lingual chamfer margin **(D)** and facial shoulder margin **(E)** are prepared on half the tooth. **F,** Completed preparation.

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2. Perform the facial reduction in the cervical and incisal planes. The cervical plane determines the path of placement of the completed restoration. The incisal or occlusal plane provides the space needed for the porcelain veneer; facial reduction should be uniform and approximately 1.3 mm deep, in the understanding that some additional reduction will occur during finishing. The incisal portion of the facial grooves usually extends half to two thirds of the way down the facial surface, depending on the shape of the tooth. The cervical third of the facial reduction parallels the long axis of the tooth. Slight adjustments to these guidelines are feasible; for example, a slight labial inclination can improve retention on a tooth with little cingulum height. On small teeth, it may be advisable to keep the cervical grooves somewhat shallower than 1.3 mm near the margin: 1.0 mm labial reduction in the cervical third still allows the fabrication of an esthetically acceptable restoration.
3. In order to achieve the necessary 2-mm clearance on the incisal aspect of an anterior tooth, place three depth grooves (about 1.8 mm deep) in the incisal edge of an anterior tooth, if it is normally aligned (see Fig. 9-2, *F* and *G*). Verify groove depth with a periodontal probe. On a posterior tooth, if the occlusal surface is to be established in porcelain, clearance must be a minimum of 2 mm. If posterior occlusion is to be established in metal, the same minimum clearances are needed as for a complete cast crown. On maxillary teeth, posterior occlusal reduction incorporates a functional cusp bevel on the lingual cusp, similar to that for a complete cast crown. When the diamond is initially positioned for anterior teeth, it is helpful to observe the long axis of the opposing tooth in maximum intercuspation and to orient the instrument perpendicular to that axis (Fig. 9-6). The grooves must not be too deep, to avoid an overreduced and possibly undulating surface.

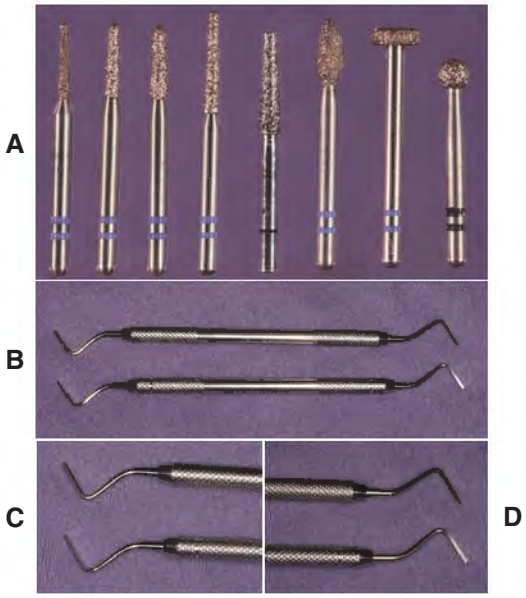

FIGURE 9-4 ■ Armamentarium for the metal-ceramic crown preparation. **A**, Diamond rotary instruments. **B** to **D**, Off-angle hatchets. These are useful for smoothing the shoulder margins of metal-ceramic crown preparations.

Incisal (Occlusal) Reduction

The completed reduction of the incisal edge on an anterior tooth should allow 2 mm of clearance for adequate material thickness to allow translucency in the completed restoration. Posterior teeth may be still restorable with less reduction because esthetics is not as critical. Caution must be used during the occlusal preparation

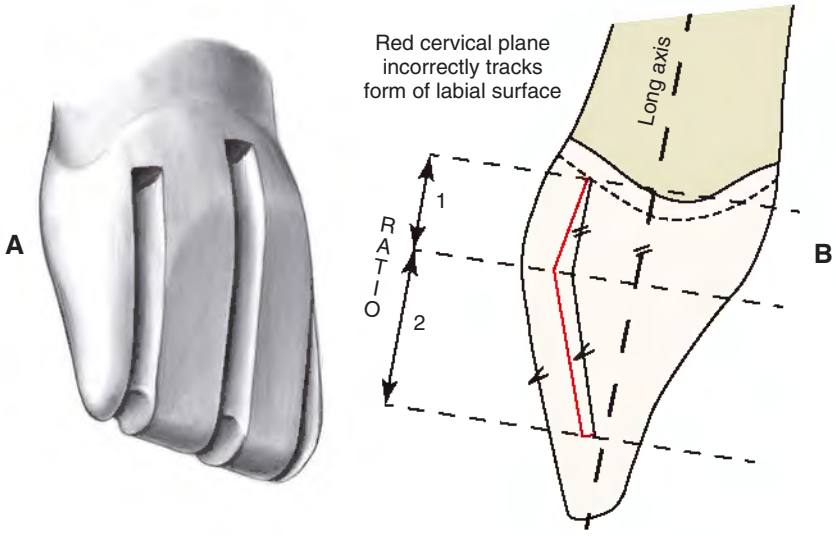

FIGURE 9-5 ■ **A**, Depth grooves in the facial wall are placed in two directions: incisally, parallel to the tooth contour, and cervically, parallel to the long axis of the tooth (i.e., the path of placement). The grooves should be prepared initially to a depth of about 1.3 mm. **B,** A common fault is to place the cervical groove at too labial an angle *(red line).* This will lead to inadequate space for porcelain and may create an undercut.

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FIGURE 9-6 ■ **A,** Depth grooves 1.8 mm deep placed in the incisal edges to ensure adequate and even reduction. **B,** Incisal reduction completed on the left central and lateral incisors. Note the angulation of the diamond, perpendicular to the direction of loading by the mandibular anterior teeth.

phase because excessive occlusal reduction will shorten the axial preparation walls and thus is a common cause of inadequacies in retention and resistance form in the completed preparation. Loss of retention form can be especially problematic on anterior teeth (on which, as a consequence of tooth form, most of the retention is derived from the proximal walls).

4. Remove the islands of remaining tooth structure. On anterior teeth, access is usually unrestricted, and the thickest portion of the cutting instrument can be used to maximize cutting efficiency (see Fig. 9-2, *H*). On posterior teeth, the same protocol is followed as in preparing depth grooves for a complete cast functional (see Chapter 8). This includes the use of a functional cusp bevel, although additional occlusal reduction is needed where the porcelain is to be applied (see Fig. 9-3, *A* to *C*).

Labial (Buccal) Reduction

When completed, the facial reduction should have produced sufficient space to accommodate the metal substructure and porcelain veneer. A minimum of 1.2 mm is necessary for the ceramist to produce a restoration with satisfactory appearance (1.5 mm is preferable). This requires significant tooth reduction. For comparison, the cervical diameter of a maxillary central incisor averages between 6 and 7 mm.

In the cervical area of small teeth, obtaining optimal reduction is not always feasible (see Fig. 7-4). A compromise is often made with less reduction in the area of the cervical shoulder margin.

5. Remove the tooth structure that remains between the depth grooves (see Fig. 9-2, *I* to *L*), creating a shoulder margin at the cervical margin (Fig. 9-7). If a restoration with a narrow subgingival metal collar is to be fabricated and sulcular depth is sufficient, place the shoulder margin approximately 0.5 mm apical to the crest of the free gingiva at this time. Additional finishing will place the margin further subgingivally. Use adequate water spray during the entire phase of preparation because a significant amount of tooth structure is being removed and copious irrigation (along with intermittent strokes) expedites the preparation process while reducing the risk of pulpal trauma. The resulting shoulder margin should be approximately 1 mm wide and should extend well into the proximal embrasures when viewed from the incisal (occlusal) side (Fig. 9-8). Where access allows, refining this shoulder margin from the proximal gingival crest toward the middle of the facial wall is preferred. This minimizes the risk of preparing the initial shoulder margin too close to the epithelial attachment. If the margin is prepared from the

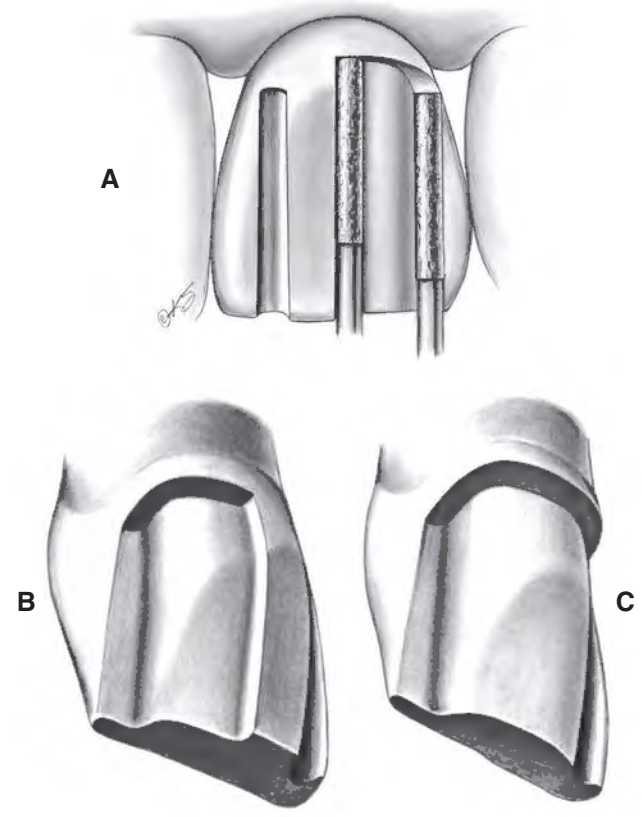

FIGURE 9-7 ■ **A,** The cervical shoulder margin is established as the tooth structure between the depth grooves is removed. The rotary instrument is moved parallel to the intended path of placement during this procedure. **B,** The facial reduction should be completed in two phases; initially, one half is maintained intact for evaluation of the adequacy of reduction. Note the two distinct planes of reduction on the facial aspect. The proximal aspect parallels the cervical reduction on the facial wall. **C,** Facial reduction completed. A 6-degree taper has been established between the proximal walls.

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To ensure esthetics, the shoulder margin must extend into the interproximal area.

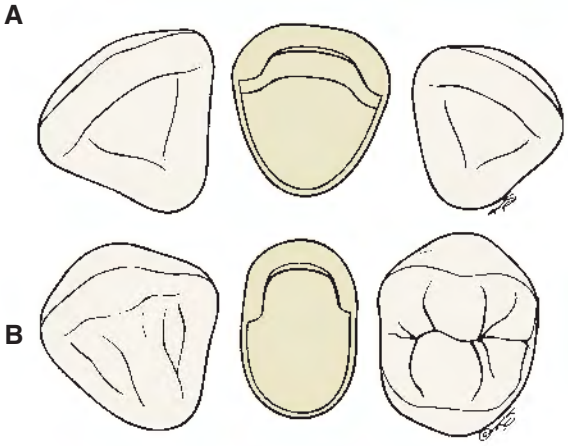

FIGURE 9-8 ■ **A,** The facial shoulder margin preparation should wrap around into the interproximal embrasure and extend at least 1 mm lingual to the proximal contact. **B,** The shoulder margin preparation extends adequately to the lingual side of the proximal contact. Note that on the mesial (visible) side, the preparation extends slightly farther than on the distal (cosmetically less critical) side.

facial to proximal aspects, there is a tendency to "bury" the instrument and encroach on the epithelial attachment. Proper margin position must be maintained in relation to the crest of the free gingiva (see Fig. 7-55). The location and specific configuration of the facial margin depend on several factors: the type of metal-ceramic restoration selected, the cosmetic expectations of the patient, and the operator's preference.

To prevent periodontal disease, a supragingival margin is preferable. Its application is restricted, however, because of mechanical and esthetic considerations. Mechanically, it may be necessary to extend the preparation farther in an apical direction to ensure adequate vertical wall height. Patients often object to the sight of a visible metal collar or discolored root surface. Such objections are common, even when the gingival margin is not visible during normal function, as in patients with a low lip line. In general, this esthetic drawback limits the use of supragingival margins to posterior teeth (Fig. 9-9) and to undiscolored anterior teeth (in which case a porcelain labial margin is indicated; see Chapter 24). The optimum location of the margin should be carefully determined with the full cooperation of the patient. Where a subgingival margin is to be placed, careful tissue manipulation is essential; otherwise, the resulting damage will lead to permanent gingival recession and subsequent exposure of the tooth-restoration interface. This is most effectively avoided through meticulous gingival displacement with a cord before finishing (Fig. 9-10). The configuration of the margin is also finalized at this time (Fig. 9-11).

FIGURE 9-9 ■ Supragingival margins on the maxillary premolars. They were possible because of a favorable lip line hiding the cervical aspect of these posterior teeth. The subgingival margins on the mandibular premolars were prepared only because of previously existing restorations.

Axial Reduction of the Proximal and Lingual Surfaces

Sufficient tooth structure must be removed to provide a distinct, smooth chamfer margin of about 0.5 mm in width (see Fig. 9-2, *M* to *P*).

6. Reduce the proximoaxial and linguoaxial surfaces with the diamond held parallel to the intended path of placement of the restoration. These walls should converge slightly from cervical to incisal or occlusal. A taper of approximately 6 degrees, measured as the angle between opposing axial walls, is recommended. On anterior teeth, a lingual concavity is prepared for adequate clearance for the restorative materials. Typically, a 1-mm thickness is required if the centric contacts in the completed restoration are to be located on metal. When contact is planned on porcelain, additional reduction is necessary. For anterior teeth, usually only a single depth groove is placed in the center of the lingual surface. For molars, three grooves can be placed in a manner similar to that described for the all-metal complete cast crown (see Chapter 8).
7. Make a lingual alignment groove by positioning the diamond parallel to the cervical plane of the facial reduction. When the round-ended diamond of appropriate size and shape is aligned properly, it is submerged almost halfway into the tooth structure. Verify the alignment of the resulting orientation groove, and carry the axial reduction from the groove along the lingual surface into the proximal aspect; maintain the originally selected alignment of the diamond at all times.
8. As the lingual chamfer margin is developed, extend it buccally into the proximal area to blend with the interproximal shoulder margin that was placed earlier (Fig. 9-12). Alternatively, a facial approach may be used. Although this is slightly more difficult initially, after some practice it should be easy to eliminate the lingual orientation groove and to perform the proximal and lingual axial reduction in one step; however, this requires the diamond to be held freehand, parallel to the path of placement. The proximal flange that resulted from the shoulder margin preparation can be used as a reference

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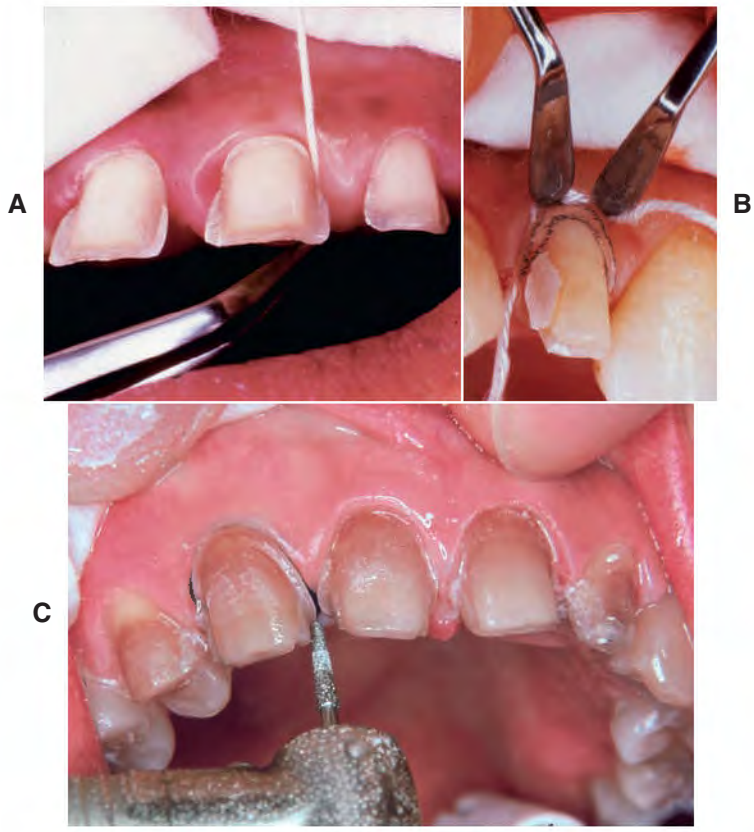

FIGURE 9-10 ■ **A,** Gingival displacement cord (under tension) is placed in the interproximal sulcus. **B,** A second instrument can be used to prevent the cord from rebounding from the sulcus after it has been packed. **C,** The preparation margin is extended apically. The cord must not engage with the diamond rotary instrument because extensive tissue trauma would result.

FIGURE 9-11 ■ **A,** After tissue displacement, the facial margin is extended apically. Caution is needed because if the diamond inadvertently grabs the cord, it may be ripped out of the sulcus and injure the epithelial attachment. **B,** Note the additional apical extension of the shoulder margin on the distal aspect. **C,** The entire facial shoulder margin is placed at a level that will be subgingival after the tissue rebounds. **D,** The facial margin has been prepared to the level of the previously placed cord.

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FIGURE 9-12 ■ A lingual chamfer margin is prepared to allow adequate space for metal. The transition from interproximal shoulder margin to chamfer margin must be smooth.

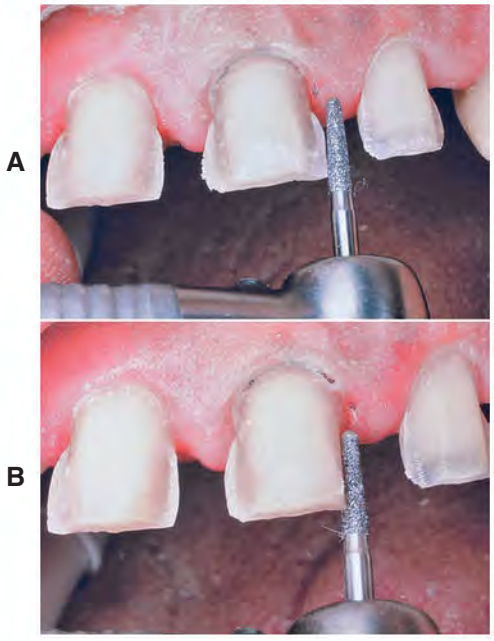

FIGURE 9-13 ■ **A,** Proximal reduction of the flange with a facial approach. **B,** Once sufficient tooth structure has been removed, the cervical chamfer margin is prepared simultaneously with the lingual axial surface. After the distolingual preparation has been completed, the mesial chamfer margin is blended into a smooth transition with the shoulder margin. The dentist must be especially careful not to encroach on the biologic width interproximally. It is easiest to start the margin preparation interproximally and move toward the facial aspect. Preparing from the facial aspect to the proximal aspect may easily lead to margin placement that is too far subgingival.

for judging alignment of the rotary instrument (Fig. 9-13). The interproximal margin should not be inadvertently placed too far subgingivally and thereby infringe on the attachment apparatus. It must follow the soft tissue contour (see p. 201). On posterior teeth, occlusally, the lingual wall reduction blends into the functional cusp bevel placed during the occlusal reduction. Anterior teeth require an additional step: After preparation of the cingulum wall, one or more depth grooves are placed in the lingual surface. In teeth that are well aligned and in occlusal contact, these depth grooves are approximately 1 mm deep.

9. Use a football-shaped diamond to reduce the lingual surface of anterior teeth (see Fig. 9-2, *P*). When half this reduction has been completed, it is helpful to stop and evaluate clearance in maximum intercuspation and all excursions. The remaining intact tooth structure can serve as a reference. Once clearance is deemed satisfactory, the lingual reduction is then completed.

FIGURE 9-14 ■ Controlled tissue displacement can be helpful when the margin is finished with a fine-grit diamond or another rotary instrument.

Finishing. The margin must provide distinct resistance to vertical displacement of the tip of a periodontal probe or an explorer, and it must be smooth and continuous circumferentially. (A properly finished margin should feel like running an explorer over a smooth glass surface.) All other line angles should be rounded, and the completed preparation should have a satin finish, free from obvious diamond scratch marks. Tissue displacement is especially helpful when subgingival margins are being finished (Fig. 9-14). Sometimes this step is postponed until just before definitive impression making after initial tissue displacement (see Chapter 14).

10. Finish the margins with diamonds, hand instruments such as the off-angle hatchets (see Fig. 9-4, *B*), or tungsten carbide burs (see Fig. 9-2, *Q* and *R*). All internal line angles should be rounded to facilitate the impression-making and die-pouring steps (see Fig. 9-2, *S*). The finishing steps for the facial margin depend on the design of margin chosen (Figs. 9-15 and 9-16; see also Table 7-3). A shoulder margin for a crown with a porcelain labial margin must be shaped to support the brittle ceramic properly. A shoulder margin with a 90-degree cavosurface angle is recommended. This type of shoulder margin can also be used for a crown with a conventional metal collar and enables the dentist to make a restoration with a narrower collar than when a bevel is added to the shoulder margin preparation (see Fig. 7-26). However, if residual unsupported enamel remains, its potential for fracture during cementation may

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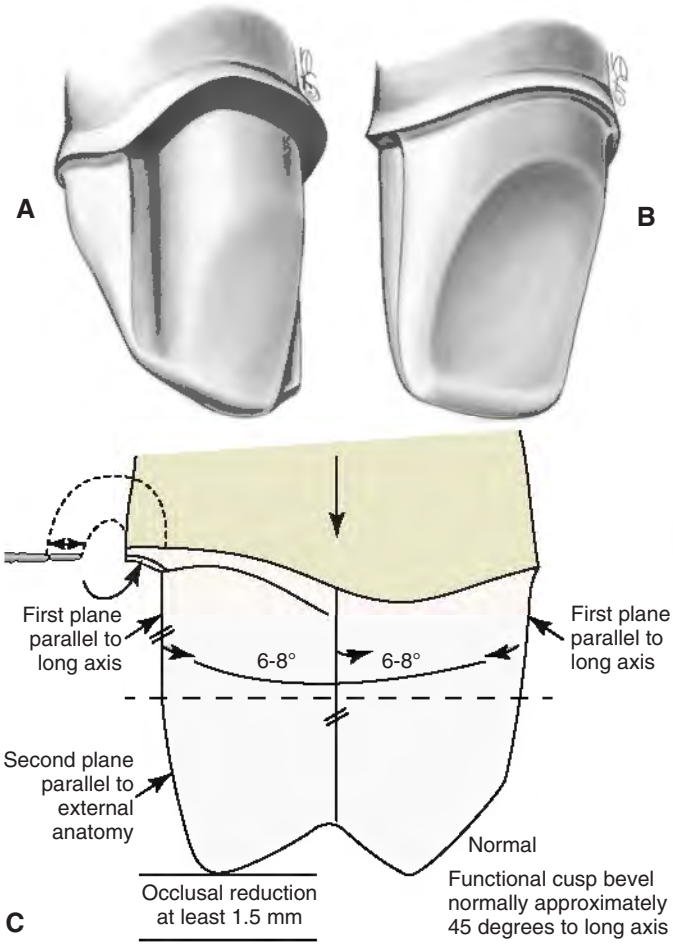

FIGURE 9-15 ■ **A,** Completed preparation. Note that the transition from incisal to axial walls is rounded, and a distinct 90-degree or slightly sloped shoulder margin has been established. It is important that the proximal axial reduction of both the shoulder and chamfer margins of the preparation are exactly in the same plane. **B,** An even chamfer margin width and a smooth transition between lingual and axial surfaces. The chamfer margin is distinct and blends smoothly into the facial shoulder margin. **C,** When a maxillary molar is prepared for a metal ceramic crown, note the two-plane facial reduction to provide both adequate retention and space for the ceramic material.

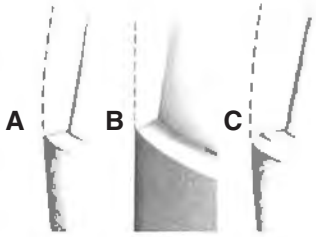

FIGURE 9-16 ■ **A,** A 90-degree shoulder margin. **B,** A 120-degree shoulder margin. **C,** A beveled shoulder margin.

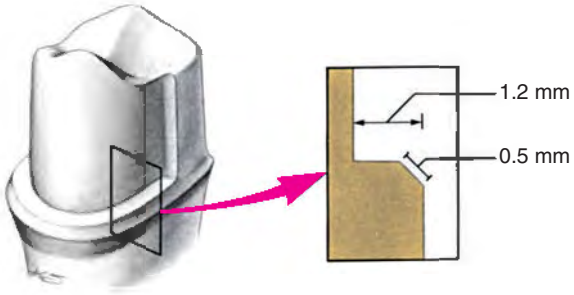

FIGURE 9-17 ■ The beveled shoulder margin.

jeopardize the restoration's longevity. For this reason, the margin is often beveled or sloped to create a slightly obtuse cavosurface angle (Fig. 9-16). A flat-ended diamond in a low-speed handpiece creates the 90-degree shoulder margin. Any unsupported enamel must be removed subsequently by careful planing with a sharp chisel. Care must also be taken to adjust the alignment of the rotary instrument properly as it moves around the tooth if inadvertent undercuts are to be avoided. When a metal-ceramic crown with a metal collar is planned, a 90-degree shoulder margin is less crucial. A sloped shoulder margin has been advocated to ensure the elimination of unsupported enamel and to minimize marginal gap width (see Chapter 7). Such a shoulder margin (cavosurface angle of about 120 degrees) can be accomplished with a flat-ended diamond by changing its alignment, with particular attention to the configuration of the tooth structure cervical to the margin. Alternatively, a hatchet can be used to plane the margin to the desired angulation. Again, be careful to avoid undercutting the axial wall of the preparation where it meets the shoulder margin during finishing. A beveled shoulder margin is most effectively achieved with a flame-shaped tungsten carbide bur or hand instrument, depending on the length of bevel desired (Fig. 9-17). In general, a short beveled margin with a cavosurface angle of 135 degrees is advocated, although longer beveled margins have been recommended for improved marginal fit. Special care must be exerted where the beveled margin meets the interproximal chamfer margin. The chamfer and beveled margins should be continuous with each other. Care must be taken not to damage the epithelial attachment during beveling; tissue displacement before preparation of subgingival beveled margins is recommended.

11. After a satisfactory facial margin has been obtained, round all sharp line angles within the preparation (see Fig. 9-2, *S*). This facilitates surface wetting and expedites subsequent procedures (impression making, pouring of casts, waxing, and investing). A fine-grit diamond operating at low speed is particularly useful. However, where access allows, a slightly larger tapered diamond may be preferred because the greater diameter of its tip prevents "lipping" of the chamfer margin (see Fig. 7-24). Blend all surfaces together, and remove any sharp transitions (Figs. 9-18 and 9-19; see also Fig. 9-2, *T*).

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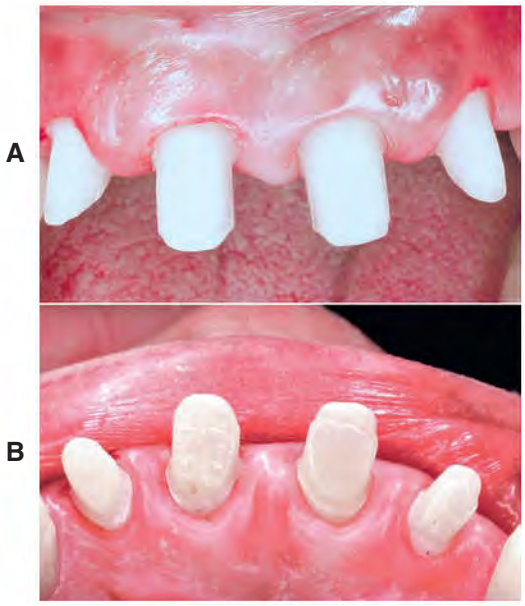

FIGURE 9-18 ■ Facial **(A)** and lingual **(B)** views of metal-ceramic preparations.

FIGURE 9-19 ■ The "wingless" variation does not exhibit the defined transition from chamfer margin to shoulder margin seen in Figure 9-15. Rather, the shoulder margin gradually narrows toward the lingual side. Interproximally, the same criteria for minimum extension of the shoulder margin apply as for the wing-type or flange preparation.

Evaluation. Areas often missed during finishing are the incisal edges of anterior preparations and the transition from occlusal to axial wall of posterior preparations. Incisally or occlusally, a 2-mm reduction should allow adequate clearance. If an occlusal surface is planned in metal, reduction may be more conservative. Clearances should be verified in the static occluded position, as well as in all excursive positions of the mandible.

Axial walls should exhibit a restricted angle of convergence. Restricted taper between the proximal walls, particularly on anterior teeth, contributes significantly to retention form. Resistance form is usually achievable on most anterior teeth because of their relatively small diameter. On larger posterior teeth, a wing-type preparation may be preferable because it has better resistance form than does its wingless counterpart.

The facial and buccal walls on maxillary teeth in the esthetic zone should exhibit two plane reductions. On incisors and canines, the cervical plane is typically about one third of the preparation height, whereas the second plane is approximately two thirds of the preparation height and follows the geometry of the desired anatomic form in the completed restoration. On premolars and molars, cervical and occlusal planes often approximate each other in height. Care is also needed to avoid creating an undercut between the facial and lingual walls. This aspect of the preparation should be thoroughly evaluated. Excessive convergence should also be avoided because this may lead to pulpal exposure.

The completed chamfer margin should provide 0.5 mm of space for the restoration at the margin. The chamfer margin must be smooth and continuous, and when it is evaluated, the dentist should feel distinct resistance to vertical displacement of the tip of an explorer or periodontal probe. The chamfer margin should be continuous with the interproximal shoulder margin or beveled shoulder margin. The cavosurface angle of the chamfer margin should be slightly obtuse or 90 degrees. Under no circumstances should any unsupported tooth structure remain, especially at the facial margin. All residual debris is removed with thorough irrigation. (Various examples of metal-ceramic preparations are shown in Fig. 9-20.)

STUDY QUESTIONS

1. What are the indications for and contraindications to metal-ceramic crowns?
2. What are the advantages and disadvantages of metal-ceramic crowns?
3. What is the recommended armamentarium, and in what sequence should a maxillary central incisor be prepared, for a metal-ceramic crown?
4. What are the minimal criteria for steps 1, 2, and 3? Why?
5. Discuss how to determine the buccolingual position of a proximal groove to precisely obtain the desired position of the facial finish line.

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FIGURE 9-20 ■ **A,** Failing, nonesthetic restorations. **B** to **D,** Existing restorations have been removed and teeth re-prepared after foundation restorations were placed. **E** to **J,** Completed metal-ceramic crowns after delivery.

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SUMMARY CHART

Metal-Ceramic Crown

Indications	Contraindications	Advantages	Disadvantages
• Esthetics • If all-ceramic crown is contraindicated • Gingival involvement • Esthetics	• Large pulp chamber • Intact buccal wall • When more conservative retainer is technically feasible • Large pulp chamber	• Superior esthetics in comparison with complete cast crown • — • — • Superior esthetics in comparison with complete cast crown	• Removal of substantial tooth structure • Subject to fracture because porcelain is brittle • Difficulty obtaining accurate occlusion in glazed porcelain • Shade selection can be difficult • Inferior esthetics in comparison with all-ceramic crown • Expensive • Removal of substantial tooth structure

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Preparation Steps	Recommended Armamentarium	Criteria
Incisal (occlusal) reduction guide grooves	Tapered, round-ended diamond	1.5 to 2 mm of clearance in intercuspal positions and all excursions
Incisal (occlusal) reduction	Tapered, round-ended diamond	1.2 to 1.5 mm of reduction for metal and porcelain (see Fig. 9-1)
Labial reduction guide grooves (two planes)	Tapered, round-ended diamond	6 degrees of convergence, measured as the angle between opposing axial walls
Labial reduction (two planes)	Tapered, flat-ended diamond	Should provide 1 mm of clearance in all excursions and intercuspal positions (1.5 mm if occlusal surface is porcelain)
Axial reduction	Tapered, round-ended diamond	Shoulder margin must extend at least 1 mm lingual to proximal contact area; beveled margin, if selected, should be as far incisally as possible in relation to epithelial attachment
Lingual reduction	Football-shaped diamond	All line angles rounded and preparation surfaces smooth
Finishing of shoulder (or beveled shoulder) margin	Tapered, flat-ended diamond	—
Finishing	Hand instrument Tapered, round-ended diamond or tungsten carbide bur	—

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CHAPTER 10

The Partial Veneer Crown, Inlay, and Onlay Preparations

An extracoronal metal restoration that covers only part of the clinical crown is considered a partial veneer crown. It can also be referred to as a *partial-coverage restoration*. An intracoronal cast metal restoration is called an *inlay* or an *onlay* if one or more cusps are restored. Examples of these restorations are presented in Figure 10-1. Partial veneer crowns generally include all tooth surfaces except the buccal or labial wall in the preparation. Therefore, these restorations preserve more of the tooth's coronal tissue than does a complete crown. However, the preparation is more demanding and is not routinely provided by practitioners. Buccolingual displacement of the restoration is prevented by internal features (e.g., proximal boxes and grooves). Partial veneers can be used as single-tooth restorations or as retainers for a fixed dental prosthesis (FDP). They can be used on both anterior and posterior teeth. Because they cover less of the coronal surface, partial coverage restorations tend to be less retentive than complete crowns and also less resistant to displacement. Inlays and onlays are even less retentive than partial veneer crowns. However, they provide the advantages of cast restorations, and less enamel is removed than for a crown. Margins are generally more accessible, allowing improved finishing and cleaning by the patient. When carefully executed, inlays and onlays can be exceptionally long-lasting restorations (Fig. 10-1).

PARTIAL VENEER CROWNS

Several types of partial veneers are available: for posterior teeth, there are three-quarter, modified three-quarter, and seven-eighths crowns; for anterior teeth, three-quarter crowns and pinledges.

The indications, contraindications, advantages, and disadvantages of partial veneer crowns are discussed as follows, and any specific deviations that pertain to a given preparation or location are identified with that type.

Indications

Partial veneer crowns can often be used to restore posterior teeth that have lost moderate amounts of tooth structure, if the buccal wall is intact and well supported by sound tooth structure. They may be used as retainers for an FDP or wherever restoration or alteration of the occlusal surface is needed. Anterior partial veneers are rarely suitable for restoring damaged teeth, but they can be used as retainers, offer a conservative approach to reestablish anterior guidance, and can be used to splint teeth. They are particularly suitable for teeth with sufficient bulk because they can accommodate the necessary retentive features.

Contraindications

Partial veneer restorations are contraindicated on teeth that have a short clinical crown because retention may not be adequate. They are also contraindicated as retainers for long-span FDPs. They are rarely suitable for endodontically treated teeth, especially anterior teeth, because the remaining tooth structure is insufficient for the retentive features. Likewise, they should not be used on endodontically treated posterior teeth if the buccal cusps are weakened by the access cavity or on teeth with extensively damaged crowns. As is true of all cast restorations, partial veneer restorations are contraindicated in the presence of active caries or periodontal disease.

The shape and alignment of teeth are important determinants of the feasibility of partial veneer crowns. The alignment of axial surfaces should be evaluated, and partial veneer crowns should not be prepared on teeth that are proximally bulbous. Making the necessary proximal grooves on these teeth will leave unsupported enamel. Similarly, it is often not possible to prepare adequate grooves on thin teeth with restricted faciolingual dimension.

Partial veneer crowns are usually prepared parallel to the long axis of the tooth, and poorly aligned abutment teeth are a contraindication. When poorly aligned teeth are prepared for a partial-coverage restoration, problems with unsupported enamel often result.

Advantages

The primary advantage associated with partial veneer crowns is conservation of tooth structure. Another advantage is reduced pulpal and periodontal insult during tooth preparation. Access to supragingival margins is rather easy, and the operator can perform selected finishing procedures that are more difficult or impossible with complete coverage restorations. Access is also better for oral hygiene. Because less of the margin approximates the soft tissues subgingivally, there is less gingival involvement than with complete coverage.

During cementation of a partial veneer, the luting agent can escape more easily than during cementation of complete cast crowns, which facilitates seating of the restoration. Because of direct visibility, verification of seating and cement removal are simple. When the restoration is in service, the remaining intact facial or buccal tooth structure enables electric vitality testing.

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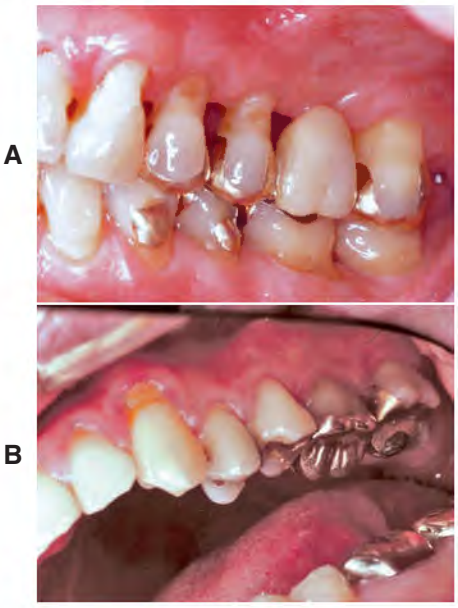

FIGURE 10-1 ■ **A,** Partial veneer crowns serving as retainers on the premolars for a four-unit fixed dental prosthesis replacing the maxillary first molar. **B,** Maxillary premolars restored with gold inlays, and a molar restored with a gold onlay. At the time this photograph was made, these restorations had served for approximately 35 years.

Disadvantages

Partial veneer restorations have less retention and resistance than do complete cast crowns. Tooth preparation is more challenging because only limited adjustments can be made in the path of placement. The preparation of grooves, boxes, and pinholes requires dexterity of the operator. Some metal is displayed in the completed restoration, which may be unacceptable to patients.

Preparation

The following discussions cover the teeth most commonly prepared for partial veneer restorations. Partial veneers are rarely applied on anterior teeth because of the difficulty in achieving an esthetic result. The technique illustrated may be suitable for posterior teeth and, with minimal variation, for other teeth. On both posterior and anterior teeth, meticulous care and precision are required if partial veneer restorations are to be a successful (conservative) alternative to complete-coverage restorations.

Armamentarium

The necessary instruments for a partial veneer crown preparation include the following (Fig. 10-2):

- Narrow (approximately 0.8 mm), round-ended, tapered diamond (regular or coarse grit)
- Regular-size (approximately 1.2 mm), round-ended, tapered diamond (fine grit) or tungsten carbide bur
- Football-shaped or wheel-shaped diamond (regular grit)
- Tapered and straight tungsten carbide fissure burs
- Small, round tungsten carbide bur

FIGURE 10-2 ■ Armamentarium for a partial veneer crown preparation.

- Small-diameter twist drill
- Inverted-cone tungsten carbide bur
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels

The regular- or coarse-grit diamonds are used for bulk reduction, and the fine-grit diamonds or tungsten carbide burs for finishing. Pinholes are prepared with the twist drill and then shaped with a tapered tungsten carbide fissure bur. The tungsten carbide fissure burs are recommended for preparing boxes and ledges, and the inverted-cone tungsten carbide bur is recommended for preparing incisal offsets. Hand instruments can be used to finish proximal flares and bevels. A periodontal probe is invaluable for assessing the alignment and dimension of the various preparation features.

Posterior Partial Veneer Crown Preparations

Maxillary Premolar Three-quarter Crown

The three-quarter crown preparation (Fig. 10-3) derives its name from the number of axial walls involved. Except for a slight bevel or chamfer margin placed along the bucco-occlusal line angle, the buccal tooth surface remains intact. The other surfaces (including the occlusal surface) are prepared to accommodate a casting in the same manner as a complete crown preparation (see Chapter 8), differing only in the need for proximal axial grooves for resistance.

Occlusal Reduction. Upon the completion of occlusal reduction, the clearance on the functional cusp should be at least 1.5 mm, and those on the nonfunctional cusp and in the central groove should be at least 1.0 mm. Simultaneously, the tooth should be prepared so that metal display is minimal; the original outline form of the buccal wall should be preserved as well as possible.

1. Before starting the preparation, mark the proposed margin location of the completed restoration on the tooth with a pencil (Fig. 10-4).
2. Place depth grooves for the occlusal reduction. These may be made with a tapered tungsten carbide bur or a narrow diamond in the developmental grooves of the mesial and distal fossae and

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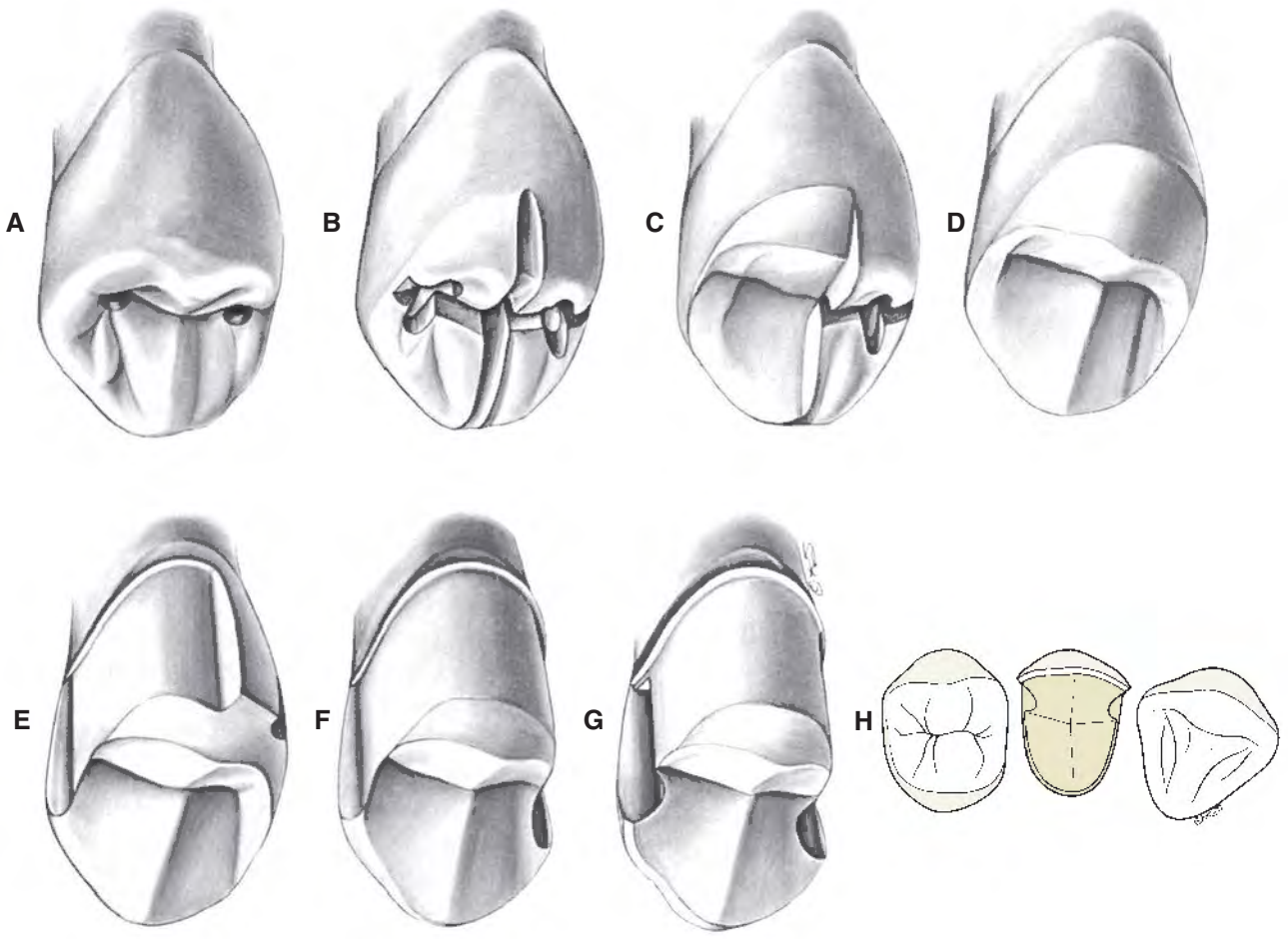

FIGURE 10-3 ■ The maxillary premolar three-quarter crown. **A,** Initial depth holes approximately 0.8 mm deep are placed in the mesial and distal fossae. **B,** They are connected by a guiding groove that extends through the central groove. Additional guiding grooves similar to those for a complete cast crown (see Fig. 8-8) are placed on the lingual cusp. The depth cut placed on the triangular ridge of the buccal cusp becomes shallower as it approaches the cusp tip. **C,** Half the occlusal reduction is completed. Note the functional cusp bevel. The occlusocervical height of the buccal surface is not reduced at this stage. **D,** Occlusal reduction completed. **E,** After guiding grooves are placed in the lingual surface of the tooth parallel to the proposed path of placement, the proximoaxial and linguoaxial reductions are initiated. Simultaneously, a smooth and even-width cervical chamfer margin is created. **F,** When the axial reduction of the first half is considered acceptable, reduction of the other half can begin. **G,** Proximal grooves are placed perpendicular to the prepared surface, and the buccal wall of each groove is flared to leave no unsupported enamel. The proximal flares are connected with a narrow contrabevel. After rounding of the line angles, the preparation is complete. **H,** The interproximal clearance in relation to adjacent teeth extends both cervically and near the occlusal aspect of the buccal flares of the proximal grooves.

FIGURE 10-4 ■ The anticipated location of the completed preparation is marked with a sterilized pencil.

on the crest of the triangular ridge. In the central groove, they should be kept slightly shallow to allow for finishing; similarly, on the functional (lingual) cusp, they should be slightly less than 1.5 mm deep in the location of the occlusal contacts.

3. Place three depth grooves on the lingual incline of the buccal cusp. Initially, these should be kept somewhat shallow as they approach the buccal cusp ridge (see Fig. 10-3, *B*). In the area of occlusal contact, groove depth should accommodate at least 1 mm of clearance after finishing.
4. Verify groove depth with a periodontal probe. When acceptable, remove the islands of tooth structure remaining between the grooves (see Fig. 10-3, *C* and *D*).
5. Assess the amount of occlusal clearance in maximum intercuspation (Fig. 10-5) and in all

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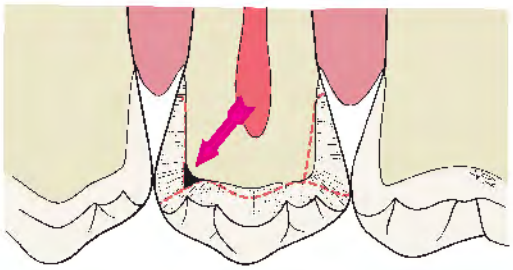

FIGURE 10-5 ■ A common error is insufficient reduction of tooth structure in the marginal ridge area *(arrow)*.

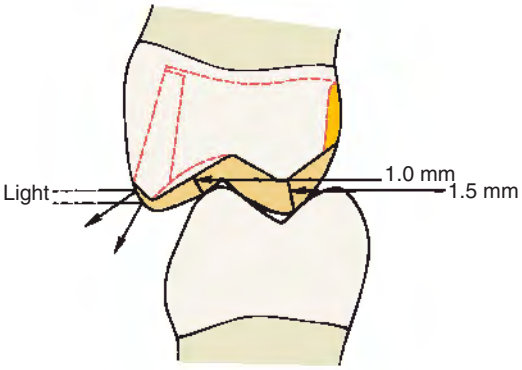

FIGURE 10-6 ■ Recommended minimum clearances for reduction of a partial veneer crown preparation. Slight hollow grinding of the lingual incline of the buccal cusp results in an acceptable clearance with the least display of metal. Also, the final restoration retains the normal contours of the cuspal ridge; thus incident light is not reflected and the restoration is less evident.

FIGURE 10-7 ■ Proximal and linguoaxial reduction is performed with a round-ended diamond. The proximal reduction is stopped short of the proposed location of the buccal margin.

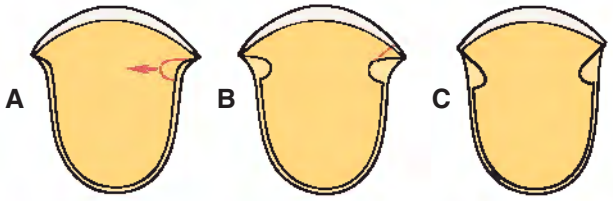

FIGURE 10-8 ■ **A,** Upon completion of the proximoaxial reduction, a groove is placed perpendicular to the prepared surface. **B,** Note that some unsupported tooth structure remains at the cavosurface angle. **C,** After the buccal wall of the proximal groove is flared, no unsupported tooth structure remains. *Note:* It is important to anticipate the influence of the buccal extent of the proximoaxial reduction **(A)** on the ultimate location of the margin **(C)**.

excursive movements of the mandible. Concave preparation of the lingual incline of the buccal cusp is helpful for obtaining sufficient clearance while maintaining the original occlusocervical dimension of the buccal tooth surface (Fig. 10-6).

Axial Reduction

6. Depth grooves for axial alignment are prepared in the center of the lingual surface and in the mesiolingual and distolingual transitional line angles. These parallel the long axis of the tooth and should initially be kept shallow to avoid inadvertently creating a lip of unsupported enamel.
7. Because the path of placement of a partial veneer is critical, the orientation grooves must be critically evaluated when correction is still possible. A common mistake is to angle the path of placement toward the buccal aspect. This reduces retention, leads to excessive display of metal, or both. A periodontal probe placed in each groove should be carefully viewed in both mesiodistal and buccolingual planes. It often helps to pour an irreversible hydrocolloid (alginate) impression in fast-setting plaster and to evaluate the cast with a dental surveyor, particularly if multiple partial veneers are being used as retainers for an FDP.
8. After alignment verification and, if necessary, correction, the tooth structure between the orientation grooves is removed with a smooth continuous motion, simultaneously with development of a cervical chamfer margin (Fig. 10-7).
9. Carry the diamond into the proximal embrasure to reduce the proximal wall (see Fig. 10-3, *E* and *F*). For proper reduction of the axial tooth surface, it is critical to understand the factors that affect the correct position of the proximal groove. A proximal groove is placed parallel to the path of placement. Normally, unsupported tooth structure remains on the buccal side of the groove, and this side is flared to remove it. Figure 10-8 illustrates the relationship among the initial axial reduction, groove placement, and location of the cavosurface angle where the flare meets the intact buccal wall. The cavosurface angle is especially significant when a tooth is prepared for a partial veneer that should display a minimum of metal; the farther to the buccal aspect the margin is, the more visible it is. A subtle but important variable that affects the final location of the buccal margin is the apical extension of the preparation. As the cervical chamfer margin extends closer to the cementoenamel junction, more axial tooth structure is removed. Consequently, the deepest portion of the groove (its pulpal wall) is located slightly closer to the mesiodistal center of the tooth. This results in a flare that will extend

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farther onto the facial or buccal surface than may be desirable. Marking the location of the intended facial flare on the tooth with a sterilized pencil before initiating the proximoaxial reduction is helpful. The intersection of this mark with the reduced proximal surface is a convenient reference point (see Fig. 10-4).

10. Stop the proximal reduction well short of the pencil mark and usually slightly short of breaking the proximal contact (Fig. 10-9). The resulting flange should parallel the linguoaxial preparation, with the chamfer margin placed sufficiently cervical to provide at least 0.6 mm of clearance with the adjacent tooth and axial wall height, allowing for a proximal groove at least 4 mm long occlusocervically (see Fig. 10-3, *F*).

Groove Placement. The proximal grooves are best prepared with a tapered tungsten carbide bur.

11. Position the bur against the interproximal flange parallel to the path of placement, and make a groove perpendicular to the axial surface. The groove need not be deeper than 1 mm at its cervical end but may be deeper near its occlusal end (Fig. 10-10). During this stage, the bur must be held precisely parallel to the selected path of placement. Allowing it to tip axially results in excessive taper between opposing proximal grooves, a common error. The criteria that need to be met consist of the following (see Fig. 10-9):
    - The grooves should resist lingual displacement of a periodontal probe or explorer (Fig. 10-11).
    - The walls of the grooves should not be undercut in relation to the selected path of placement.
    - The walls should be flared toward the intact buccal surface of the tooth (see Fig. 10-3, *G* and *H*).

Depending on available access, it may be feasible to complete the flaring with the same rotary instrument that was used to place the groove (Fig. 10-12). However, removing the last "lip" of unsupported tooth structure with a chisel is often a better option because this minimizes the risk of damage to the adjacent tooth.

FIGURE 10-9 ■ The distal proximal reduction is stopped before proximal contact is broken. After groove placement and subsequent flaring, interproximal clearance results.

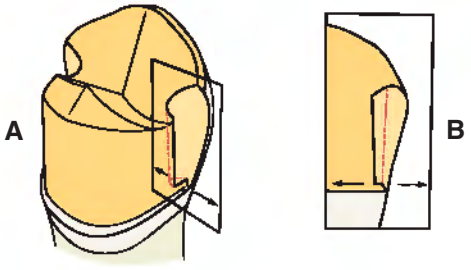

FIGURE 10-10 ■ Because of the rotary instrument's taper, the proximal groove is deeper near the occlusal table **(A)**. The floor of the groove should be flat and smooth. The proximal chamfer margin often extends slightly cervically to the floor of the groove. If only minimal difference exists **(B)**, the cervical margin adjacent to the groove can be beveled. The recommended occlusocervical height for a proximal groove is 4 mm.

Bucco-occlusal Contrabevel

12. Connect the mesial and distal flares with a narrow contrabevel that follows the buccal cusp ridges. This can be placed with a diamond, a tungsten carbide bur, or even a hand instrument. Its primary purpose is to remove any unsupported enamel and thereby protect the buccal cusp tip from chipping during function. If group function is planned (as opposed to a mutually protected occlusion), a heavier bevel, a chamfer margin, or an occlusal offset is needed because tooth contact occurs in this area during excursive movement. The bevel should remain within the curvature of the cusp tip, rather than extend onto the buccal wall (Fig. 10-13). This results in a convex shape of the restoration, and light is prevented from reflecting back to a casual observer (see Fig. 10-6). Thus the restoration is less obvious, and the outline form of remaining buccal enamel is perceived as the shape of the tooth.

Finishing

13. With the exception of the junction between grooves and proximal walls, round all sharp internal line angles to facilitate subsequent procedures. A fine-grit diamond or tungsten carbide bur can be used to blend the surfaces (Fig. 10-14).
14. Reevaluate the flares, paying particular attention to any remaining undercuts, which must be removed. The flares should be monoplane,

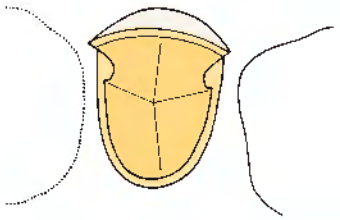

FIGURE 10-11 ■ The 90-degree angle between the lingual walls of the proximal grooves and the axial walls resists lingual displacement. Because the buccal aspect of the grooves has been adequately flared, no unsupported tooth structure remains.

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FIGURE 10-12 ■ **A,** Initial preparation of the mesioproximal groove. Note that the tungsten carbide bur is oriented parallel to the path of placement as dictated by the lingual surface of the tooth. **B,** Initial flaring has resulted in elimination of most unsupported tooth structure. **C,** Hand or rotary instruments are used to refine these proximal flares and remove all unsupported enamel.

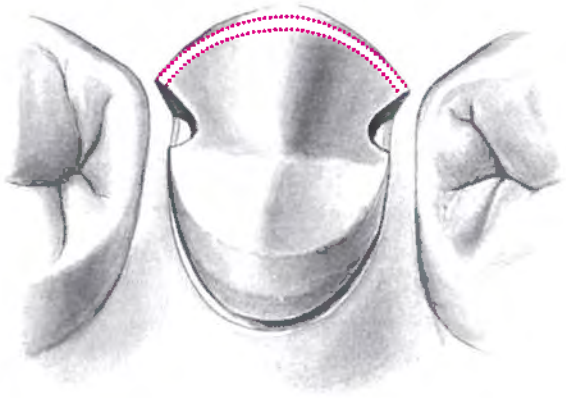

FIGURE 10-13 ■ The bucco-occlusal contrabevel remains within the curvature of the cusp tip rather than extending onto the buccal surface.

straight, and smooth, with sufficient clearance between them and the adjacent tooth. A minimum clearance of 0.6 mm is recommended. The mesial flare cannot extend beyond the transitional line angle. However, because the distal margin is less visible, it may extend slightly farther to the buccal margin, allowing easier access.

Maxillary Molar Three-quarter Crown

The principles used in a premolar preparation also apply for a maxillary molar (Figs. 10-15 and 10-16). However, some additional leeway may exist for groove placement because tooth structure on molars has comparatively more bulk. Also, because of their less prominent position in the dental arch, molars are less visible. As a result, the mesioproximal flare can sometimes be extended slightly onto the buccal surface without affecting esthetics.

Maxillary Molar Seven-eighths Crown

The seven-eighths crown preparation (Fig. 10-17) includes, in addition to the surfaces covered by the three-quarter crown, the distal half of the buccal surface. Therefore, the mesial aspect of this preparation resembles that of a three-quarter crown; the distal aspect resembles that for a complete crown. The mesial half of the buccal tooth surface remains intact and is protected

FIGURE 10-14 ■ **A** and **B,** A fine-grit diamond in a low-speed contra-angle handpiece is used to place the bucco-occlusal contrabevel that connects the mesioproximal and distoproximal flares.

by a narrow contrabevel or chamfer margin similar to the one used in the three-quarter crown preparation described previously. A distal groove can be placed, although it is generally not necessary. A groove in the middle of the buccal surface is placed parallel to the path of placement. Distal to this groove, the buccal surface is reduced in two planes, as described for complete cast crowns (see Chapter 8); the cervical plane parallels the path of placement, whereas the occlusal plane parallels the original anatomic tooth contour. The lingual aspect of the tooth is also reduced in two planes because preparation of the functional cusp must be beveled to ensure adequate restoration thickness.

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FIGURE 10-15 ■ Three-quarter crown preparation on a maxillary molar. Note that the occlusal reduction follows normal anatomic form.

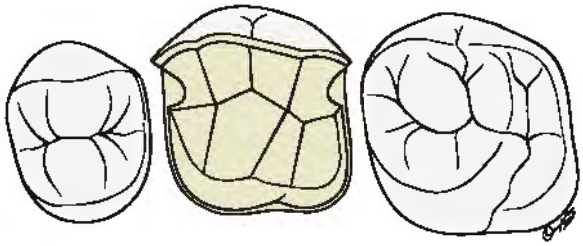

FIGURE 10-16 ■ The three-quarter crown preparation on a maxillary first molar.

Occlusal Reduction. On completion of the occlusal reduction, adequate clearance should exist in all excursive movements of the mandible. Minimum measurements are the same as for the three-quarter crown preparation.

1. Place depth grooves in the central and developmental grooves, and on the crests of the triangular ridges. To delineate the extent of the lingual functional cusp bevel, the depth grooves should extend onto the lingual surface of the tooth. On the lingual incline of the mesiobuccal cusp, they resemble depth cuts for the three-quarter crown preparation. On the distobuccal cusp, they should be approximately 0.8 mm deep to provide sufficient occlusal clearance for this nonfunctional cusp (see Fig. 10-17, *A*).
2. Remove the tooth structure between the depth grooves. Concave shaping of the resulting mesiobuccal incline may again prove useful because it enables the occlusocervical height of the cusp to be maintained. When completed, this bevel should provide 1.5 mm of clearance in maximum intercuspation, as well as throughout all excursive movements of the mandible (see Fig. 10-17, *B* and *C*).

Axial Reduction. In principle, the steps for axial reduction follow those for occlusal reduction.

3. Place three alignment grooves in the lingual wall, and transfer the selected path of placement to the distobuccal transitional line angle area, where a fourth alignment groove can be placed.
4. Start the reduction in the middle of the lingual surface. The mesial half is prepared in the same way as for a three-quarter crown and the distal half as for a complete crown (see Fig. 10-17, *D*).
5. Carry the facial reduction sufficiently mesial to include the buccal groove. Occlusally, the buccal surface of maxillary molars is rather flat; therefore, some additional reduction may be necessary in the occlusal half. This follows the normal anatomic configuration of the tooth and is thus prepared at a different angle than is the lingual functional cusp bevel. If correctly performed, the reduction allows for contouring of the restoration so that when viewed from the mesial aspect, the distal half of the restoration is hidden behind the intact mesiobuccal cusp. A frequent error is to overtaper the buccal wall segment, with resulting loss of both retention and buccolingual resistance form.

Groove Placement, Flaring, and Contrabevel

6. Prepare the mesial groove in the same way as described for the three-quarter crown (see Fig. 10-17, *E* and *F*).
7. Place the buccal groove parallel to the mesial groove and perpendicular to the buccoaxial wall. It is often not necessary to flare the buccal groove because the flat configuration of this area of the tooth precludes any unsupported enamel after the groove is placed. The buccal groove should resist mesiodistal displacement of a probe.
8. Connect the two grooves with a smooth contrabevel that follows the ridge of the mesiobuccal cusp (see Fig. 10-17, *G*). This bevel should meet the same criteria as described in the three-quarter crown preparation. Adequate clearance must be established interproximally upon completion (Fig. 10-18). All surfaces are finished to the same specifications as the preceding preparations (Fig. 10-19).

Mandibular Premolar Modified Three-quarter Crown

Mandibular partial veneer preparations (Fig. 10-20) are made more often on premolars than on molars. They differ from maxillary molar three-quarter crown preparations in two respects: (1) Additional retention is required because of the shorter crown length of mandibular teeth. This can be obtained by extension of the preparation buccally; because of their rather prominent position in the dental arch, however, these teeth should be modified only distal to their height of contour (Fig. 10-21). (2) The axial surface that is not prepared (the buccal aspect) includes the functional cusp. This means that additional tooth structure must be removed to accommodate sufficient bulk of metal for strength.

Occlusal Reduction

1. Place 0.8-mm-deep grooves on the buccal inclines of the lingual cusp and 1.3-mm-deep grooves on the lingual inclines of the buccal cusp (see

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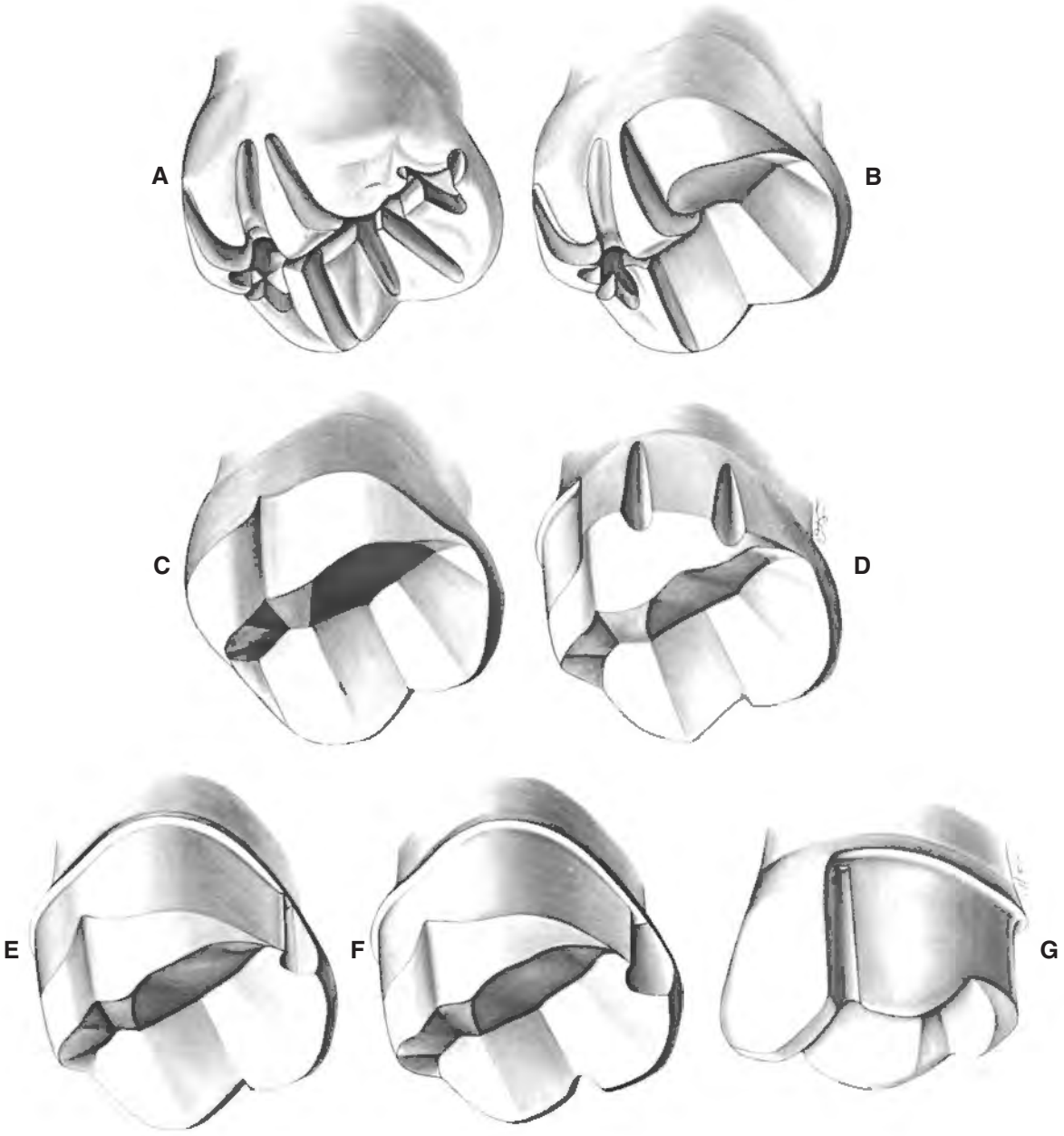

FIGURE 10-17 ■ The maxillary molar seven-eighths crown preparation. **A,** Occlusal depth grooves. On the lingual aspect of the mesiobuccal cusp, they are identical to grooves for any functional cusp. On the buccal aspect, note their difference from grooves placed on the triangular ridges. The mesial groove becomes shallower as it approaches the cuspal ridge; the distal groove extends through the cuspal ridge. **B,** Mesial half of the occlusal reduction is completed. Normal occlusal form can be recognized in the reduced area. **C,** Occlusal reduction is completed. **D,** Distal half of the axial reduction is completed. This is comparable with the preparation for a complete cast crown. The rotary instrument is moved parallel to the guiding grooves placed in the lingual tooth surface. **E,** Mesial half of the axial reduction is completed, and a proximal groove is placed. **F,** The buccal groove, with flaring of the mesial groove. Note the monoplane of the flare, extending from the deepest portion of the groove to the cavosurface angle. **G,** A contrabevel connects the mesial flare with the buccal groove. The mesial wall of the buccal groove is smooth and has a 90-degree cavosurface angle, leaving no unsupported enamel.

Fig. 10-20, *A* and *B*). These guiding grooves also are placed to follow the basic groove and fissure pattern of the occlusal surface. Only one depth cut needs to be placed to accommodate the functional cusp bevel on the distal aspect of the distal cuspal ridge.

2. Reduce the occlusal surface by removing the tooth structure between the grooves (see Fig. 10-20, *C*).

Axial Reduction

3. Place guiding grooves on the lingual surface to parallel the proposed path of placement and the long axis of the tooth.
4. Prepare the mesial half as already described for the three-quarter and seven-eighths crowns (see Fig. 10-20, *D*).

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5. Reduce the distal surface as for a complete crown, extending the preparation to the transitional line angle and onto the buccal surface. However, it should not extend mesially beyond the middle of the distal half of the buccal surface, and the chamfer margin should not extend too far cervically; otherwise, the distobuccal line angle is unnecessarily reduced, which would decrease the resistance form (see Fig. 10-20, *E*).

Finishing. The modified three-quarter crown preparation can include two or three grooves.

6. Place the mesial and buccal grooves as described for the seven-eighths crown (see Fig. 10-20, *F*). An additional distal groove may be placed. In general, to gain as much length as possible, the mesial groove of the three-quarter crown should be placed in the buccal third of the proximal walls. Care must be taken to position the distal groove slightly closer to the center of the distal wall so that the distobuccal line angle is not undermined.
7. Connect the mesial and buccal grooves with a heavy functional cusp chamfer margin after the grooves and mesial flare have been placed and evaluated. The chamfer margin must be wide enough to allow 1.5 mm of clearance in the area of occlusal contact (see Fig. 10-20, *G*). A regular or thick diamond is used to place the chamfer margin, which should connect the grooves and provide a protective "staple" linkage of alloy in the completed restoration. Insufficient tooth reduction where this chamfer margin meets the mesial flare is a common error. Finally, all prepared surfaces are smoothed, and the internal line angles are rounded.

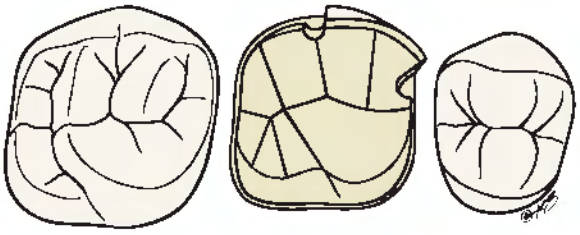

FIGURE 10-18 ■ The seven-eighths crown preparation. Note that adequate clearance has been established. From this perspective, it is evident why little or no flaring is necessary for the buccal groove, as opposed to the considerable flaring needed for the mesial groove.

Anterior Partial Veneer Crown Preparations

With the advent of metal-ceramic and all-ceramic restorations, the use of partial veneer restorations on anterior teeth has become rare. Nevertheless, two anterior partial veneer crown preparations, the maxillary canine three-quarter crown and the pinledge, are worthy of study (Figs. 10-22 and 10-23).

Maxillary Canine Three-quarter Crown

The three-quarter crown on a maxillary canine (Figs. 10-24 and 10-25) is probably the most demanding of all tooth preparations. As with partial veneer preparations on other teeth, it involves the proximal and lingual surfaces but leaves the facial surface intact. However, the

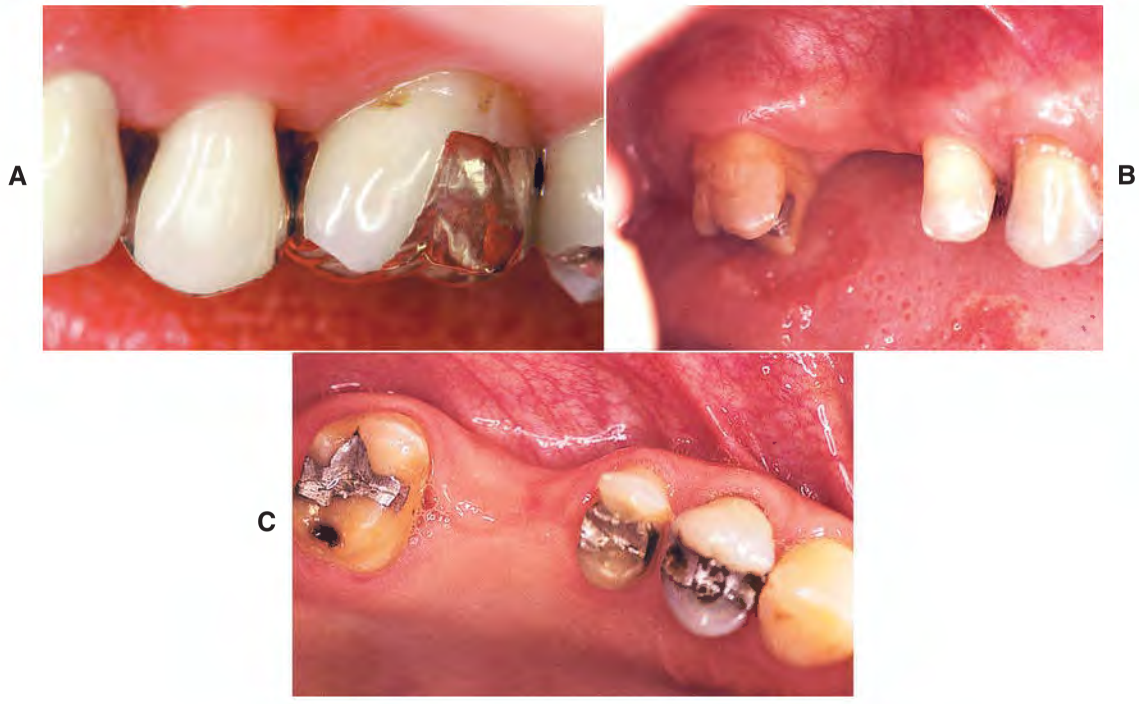

FIGURE 10-19 ■ **A,** Three-quarter crown restoring maxillary premolar and seven-eighths crown restoring maxillary molar. **B** and **C,** Fixed dental prosthetic retainers: a seven-eighths crown as the distal retainer and a three-quarter crown as the mesial retainer.

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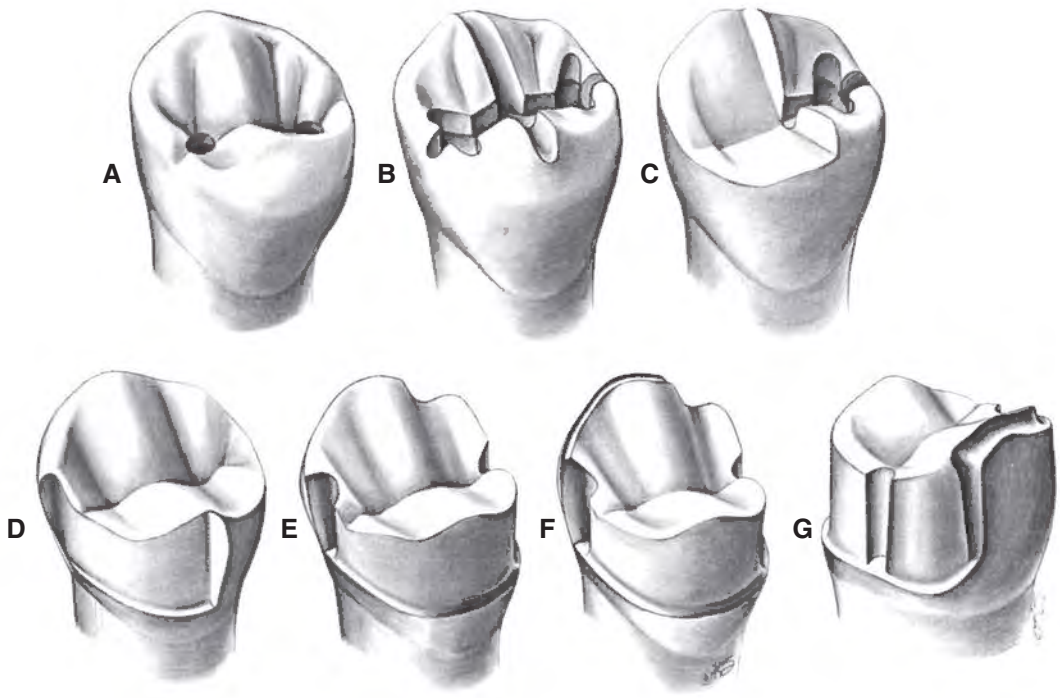

FIGURE 10-20 ■ The mandibular premolar modified three-quarter crown preparation. **A,** Depth holes are placed in the mesial and distal fossae approximately 0.8 mm deep. **B,** The holes are connected by a guiding groove that extends through the central groove and the mesial and distal marginal ridges. Guiding grooves are also placed in the buccal and lingual triangular ridges, extending through the cuspal ridges on both sides. **C,** Half the occlusal reduction is completed. **D,** Occlusal reduction and the mesial half of the axial reduction are completed. **E,** Axial reduction is completed. The proximal grooves have been placed. Note that the distal groove is close to the buccolingual center of the tooth. This enables retention of considerable tooth structure in the area of the distobuccal line angle, enhancing the resistance form of the preparation. **F,** The mesial groove has been flared and the functional cusp chamfer margin placed. **G,** Facial view. There is considerable width of the chamfer margin on the functional cusp. Note that the distobuccal cervical margin angles occlusally as it progresses mesially. This enables a more conservative tooth preparation in the area of the distobuccal modification that is placed to improve resistance form.

FIGURE 10-21 ■ Modified three-quarter crown restoring a mandibular second premolar. **A** to **C,** The three-quarter crown is serving as the anterior retainer for a three-unit fixed dental prosthesis. Because the distobuccal modification remains in the distal fourth of the buccal preparation, it is hidden behind the normal height of contour of the buccal tooth surface. Note the considerable thickness of gold that protects the buccal cusp.

FIGURE 10-22 ■ **A,** Deficient anterior guidance resulting from years of parafunctional activity. **B,** An anterior partial veneer crown has reestablished guidance, allowing the intact sound labial tooth structure to be retained as a conservative alternative to a metal-ceramic restoration.

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FIGURE 10-23 ■ **A,** Caries-free canine and lateral incisor of adequate bulk: excellent candidates for anterior partial veneer crowns. **B,** The canine restored with a three-quarter crown, serving as the anterior retainer for a three-unit fixed dental prosthesis (FDP) to replace the first premolar. The lateral incisor has been restored with a modified pinledge that serves as a retainer for an anterior four-unit FDP. **C,** Satisfactory esthetic appearance with minimal display of metal.

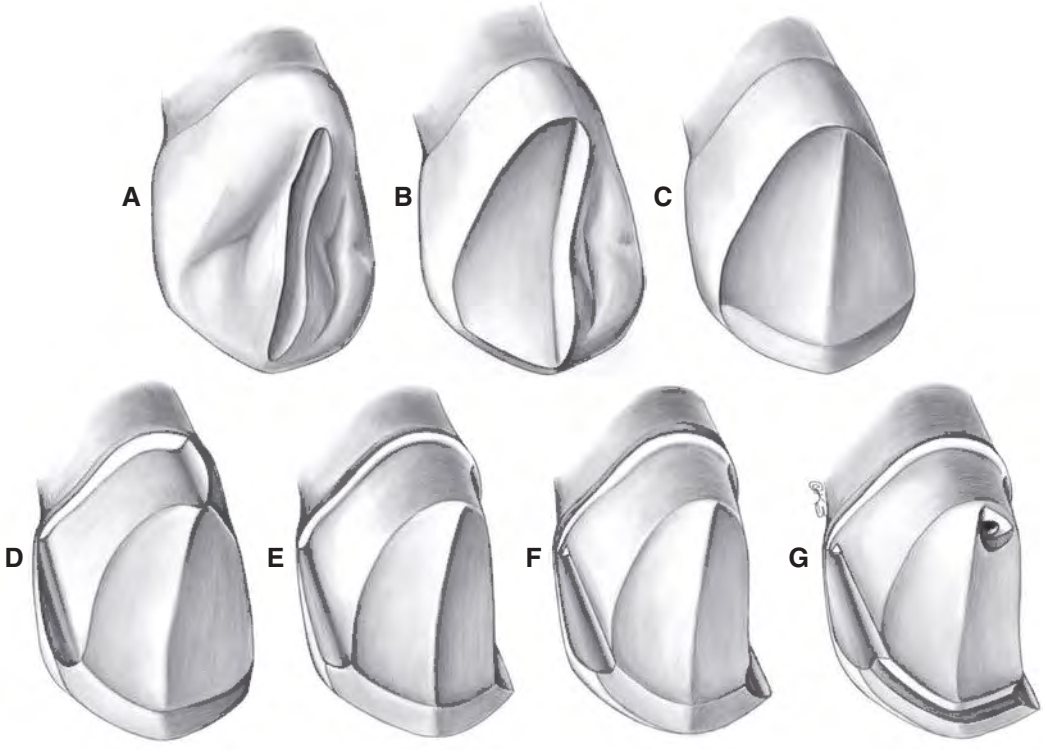

FIGURE 10-24 ■ The maxillary canine three-quarter crown preparation. **A,** A guiding groove is placed on the lingual surface. **B,** Half the lingual surface is reduced. Clearance is verified before reduction of the other half. **C,** Lingual reduction is completed, with an incisal bevel placed. No significant change has occurred in the incisocervical height. **D,** After an alignment groove is placed in the center of the cingulum wall, half the axial reduction is complete. Note that the path of placement parallels the incisal or middle third of the labial surface. As a result, the lingual chamfer margin is quite wide, perhaps even resembling a shoulder margin. This enables paralleling of the cingulum wall, with the proximal grooves and pinhole providing additional retention. **E,** Axial reduction is completed. Any final modification of the path of placement is done at this time before groove placement. **F,** Proximal grooves. The visible mesial groove has been flared, but unsupported enamel remains on both grooves where they meet the incisal bevel. **G,** Completed preparation. The lingual pinhole is surrounded by adequate dentin. Note the horizontal ledge prepared before pinhole placement.

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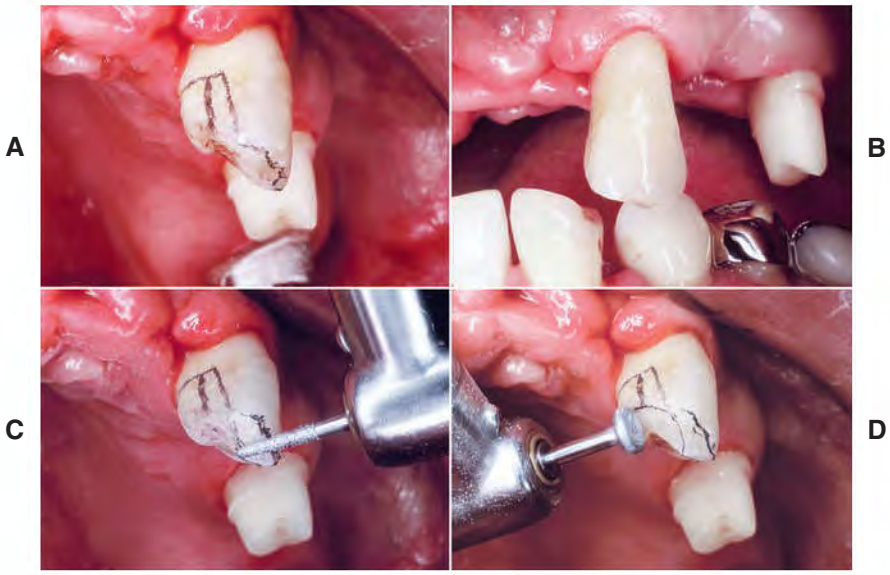

FIGURE 10-25 ■ **A,** Proposed margin location outlined on the tooth with a pencil. **B,** The anticipated outline must be carefully assessed from as many directions as possible at this time. **C,** Preparing the incisal bevel. A lingually tilted bevel is typically prepared at a 45-degree angle to the long axis of the tooth. **D,** The lingual surface is reduced with a wheel- or football-shaped diamond.

greater degree of difficulty stems from the different shape of the canine tooth. Unless groove placement is determined very precisely in advance, there will be an undesirable display of metal in the interproximal embrasures (see Fig. 10-25, *A* and *B*). The relatively short proximal walls do not allow much correction after initial groove placement. Similarly, the greater degree of curvature in each proximal wall immediately adjacent to the contact area significantly influences the location of the preparation's facial margin after flaring.

Incisal and Lingual Reduction

1. Remove enough enamel to allow 1 mm of metal thickness. The design of the incisal bevel should prevent contact between opposing teeth and the incisal margin. However, the original configuration of the facial surface should be preserved without significant incisal reduction of the tooth. Outlining the anticipated location of the margin with a pencil is helpful.
2. Place depth grooves for both the incisal bevel and the lingual reduction (see Fig. 10-24, *A*). Bevel angulation may vary, depending on the configuration of the tooth. In general, it makes an angle of approximately 45 degrees to the long axis of the tooth.
3. After the depth has been verified, perform the reduction. A football- or wheel-shaped diamond is used to reduce the concave lingual wall (see Figs. 10-24, *B*, and 10-25, *D*). The completed reduction is shown in Figure 10-24, *C*.

Axial Reduction and Groove Placement. The path of placement of the restoration must be accurately determined before axial reduction. Mesiodistally, it should parallel the long axis of the tooth; buccolingually, it ideally parallels the middle third or incisal two thirds of the facial surface. This allows the preparation of proximal grooves of optimum length in an area of the tooth where sufficient bulk is present.

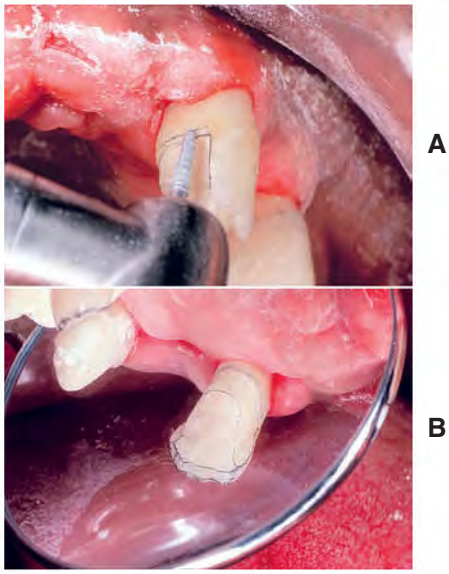

FIGURE 10-26 ■ **A,** A regular-grit diamond is used to complete the axial reduction. Mesiodistally, the diamond is oriented parallel to the long axis of the tooth. **B,** When the reduction is completed, a mesial and distal flange results; these serve as guides during preparation of the proximal grooves.

4. To enhance the retention and resistance form of the preparation, place a slightly exaggerated chamfer margin on the lingual aspect of the tooth (see Fig. 10-24, *D*) and a guiding groove in the middle of the lingual wall. When alignment has been verified, the axial reduction can be performed in the same manner as the other preparations (Fig. 10-26). It is important to understand the difference between

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this phase of the preparation on a canine, with little bulk of lingual tooth structure as opposed to a premolar or molar. After completion, a proximal flange should result; this guides the rotary instrument during groove placement (see Figs. 10-24, *E*, and 10-26, *B*). The technical aspects of the preparation of proximal grooves are like those described for the other partial veneer preparations (Figs. 10-27 and 10-28). The primary difference is the direction in which the groove is prepared. Because the groove is placed perpendicular to the proximal wall, its deepest portion will be slightly labial to the proximal flange that results when proximoaxial reduction is completed. As a result, the proximal flares extend slightly farther onto the facial surface. This is further accentuated by the curvature of the proximal wall (Fig. 10-29). Meticulous assessment of the needed extent of the initial axial reduction is a prerequisite for successful preparation (Fig. 10-30; see also Fig. 10-24, *F*). (The required interproximal clearance is illustrated in Fig. 10-31.)

Incisal Offset and Lingual Pinhole. Anterior partial veneer crowns require a means of reinforcement to preserve restoration integrity. Posterior three-quarter crowns usually do not need much additional reinforcement because the solid "corrugated" occlusal surface provides rigidity. For an anterior tooth, an incisal offset or groove is needed to create a band of thicker metal to produce a "staple" configuration that provides additional rigidity and resistance against flexure of the casting.

5. Connect the mesial and distal grooves with a V-shaped incisal offset. This will also improve the general resistance form of the preparation against lingual displacement. Sufficient dentin must be preserved facially to the offset to prevent the metal from being visible through the translucent labial tooth enamel. This is accomplished most effectively with an offset that is slightly narrower labiolingually than incisocervically. Offset geometry follows the contours of the incisal edge, and transitions smoothly into the proximal flares. An inverted-cone diamond or tungsten carbide rotary instrument (Fig. 10-32) can be used to prepare the offset.
6. Place a pinhole in the cingulum area slightly off center to improve the retention and resistance form of this preparation. The pinhole is prepared in five stages: (1) A small horizontal ledge is made with a large, tapered or cylindrical tungsten carbide bur; (2) a slight dimple is created with a small round bur at the intended pinhole location; (3) a pilot hole

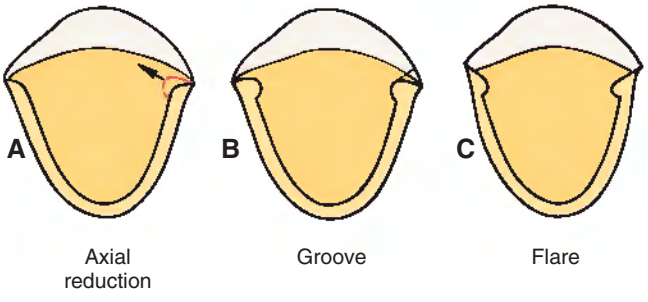

FIGURE 10-27 ■ **A,** Because the groove is prepared perpendicular to the proximal surface of the tooth, its deepest portion is slightly buccal to where axial reduction was halted. **B,** The *black dashed line* indicates the proposed flare. Note that the curvature of the tooth causes the final margin to be located a considerable distance facial to where the initial axial reduction stopped. **C,** Completed flare.

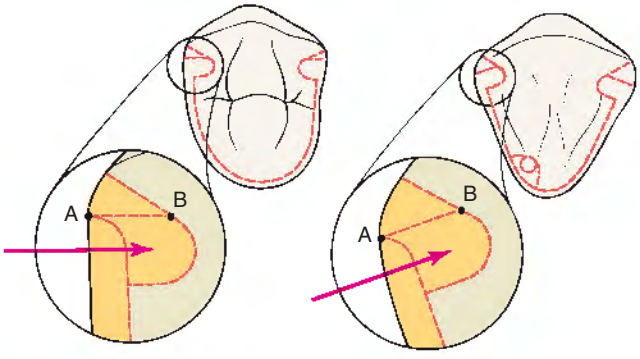

FIGURE 10-29 ■ Differences between the proximal flares on premolars **(left)** and canines **(right).** In both images, label *A* designates where the initial proximal reduction is halted. Because a facial component is present in the direction of groove placement on the canine, as opposed to the premolar, the starting point *(B)* for the flare is located farther to the facial aspect. In conjunction with the greater degree of proximal curvature of canines, it is crucial that the initial proximal axial reduction not be carried too far facially; otherwise, the final margin will extend too far onto the labial surface of the tooth and result in excessive display of metal.

FIGURE 10-28 ■ **A,** A tapered tungsten carbide bur is used to place the proximal groove. **B,** Initial groove preparation is completed. **C,** The tungsten carbide bur is moved parallel to itself. **D,** Mesial and distal grooves must be prepared in strict alignment.

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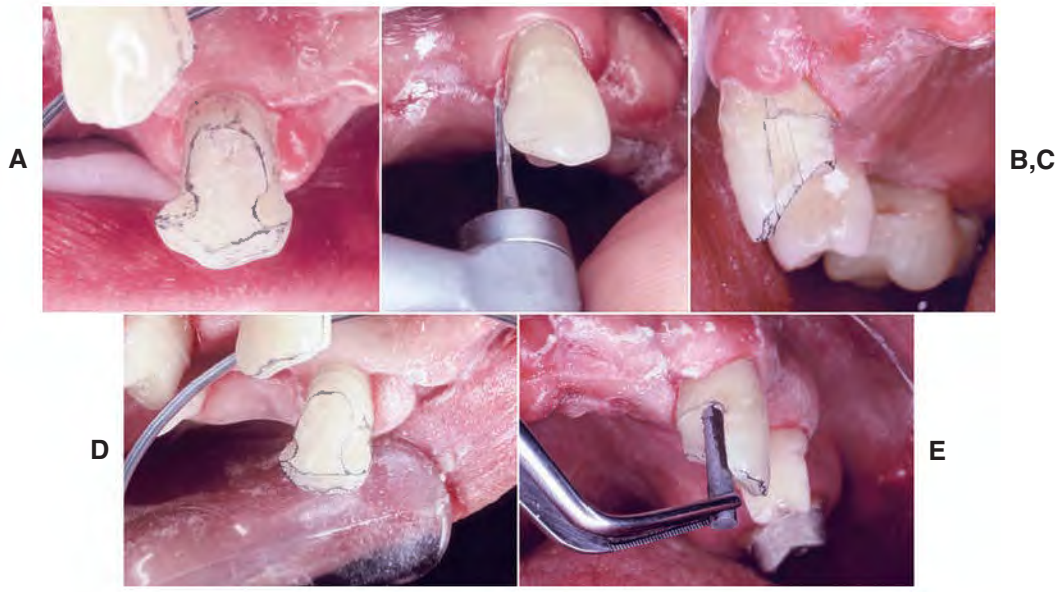

FIGURE 10-30 ■ **A,** Unsupported enamel remaining after initial groove placement. **B,** A tungsten carbide bur can be used to flare the grooves. **C,** The flared groove. Note the irregularity of the margin near the cervical aspect of the groove. **D,** After the flaring. Note that a mesial box, rather than a groove, has been prepared. This restoration is designed to contain an intracoronal partial removable dental prosthesis rest; hence, the box. Nevertheless, there is adequate resistance to lingual displacement. **E,** A special mandrel is placed in the box to ensure that it fits within its confines. It is identical in size to the male attachment (patrix) of the partial removable dental prosthesis (see Chapter 21).

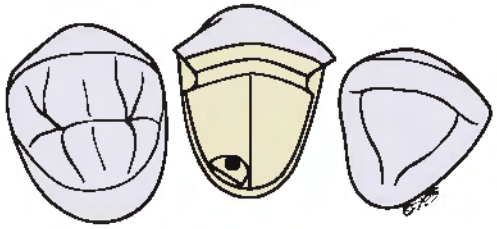

FIGURE 10-31 ■ Completed three-quarter crown preparation. Note the location of the labial margin in relation to the adjacent teeth. Sufficient interproximal clearance has been established, but unnecessary display of metal is avoided.

FIGURE 10-32 ■ An inverted-cone diamond or tungsten carbide rotary instrument can be used to prepare the incisal offset. Note the faciolingual inclination of the rotary instrument.

is prepared with a small-diameter twist drill* (it must be parallel to the precise path of placement of the restoration); (4) the preparation is completed with a tapered tungsten carbide bur to a pinhole depth of approximately 2 mm; and (5) a larger, round bur is used to countersink or bevel the junction between pinhole and ledge.

The completed preparation (Fig. 10-33) is carefully assessed for any remaining undercuts. The flares are commonly sites of undercuts, and all surfaces should be smoothed as previously described.

Pinledge Preparations

A pinledge (Fig. 10-34) may be used as a single restoration, generally to reestablish anterior guidance, in which case only the lingual surface is prepared. Pinledges have a history of successful service as FDP retainers (Fig. 10-35) or to splint periodontally compromised teeth (Fig. 10-36). In such cases, one or more of the proximal surfaces are included in the preparation design to accommodate the required connector or connectors. Retention and resistance are provided primarily by pins that extend 2 mm into dentin. In comparison with other retainers, the pinledge preparation is among the most conservative of tooth structure.

The preparation steps themselves are not difficult, but advance planning and a thorough understanding of the various steps are essential. Diagnostic preparation on an accurate cast is particularly useful during the planning phase. Preparation of a number of parallel pinholes with a common path of placement can be intimidating. With some practice, however, most operators can accomplish this freehand, especially with the use of a tapered tungsten

*The twist drills supplied with threaded pin kits for amalgam retention are suitable.

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FIGURE 10-33 ■ **A,** Completed three-quarter crown preparation on a maxillary canine. **B,** The contralateral canine. **C,** A three-quarter crown serves as the anterior retainer for a three-unit fixed dental prosthesis (FDP); its female intracoronal rest (matrix) is incorporated in the mesial box (see Chapter 21). **D,** Note the connector and the open embrasures on the contralateral side. **E** to **G,** Labial views of the cemented FDP. **H,** The definitive RDP.

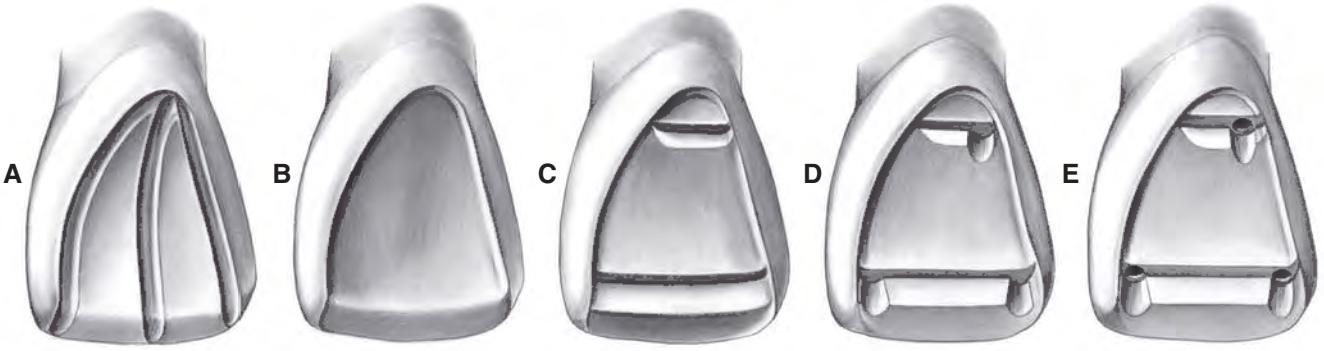

FIGURE 10-34 ■ The pinledge preparation on a maxillary central incisor. **A,** Guiding grooves are placed for lingual reduction. **B,** The lingual reduction is completed, and an incisal bevel is placed. **C,** Incisal and cervical ledges are prepared. **D,** Indentations have been made. Note the spacing of the ledges in relation to each other and to the pulp. All pinholes will be in sound dentin. **E,** Pinholes are prepared to a depth of 2 mm. The junction between the ledge and the pinholes has been countersunk.

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FIGURE 10-35 ■ **A,** Modified pinledge serving as a retainer for a four-unit fixed dental prosthesis (FDP). An additional pinhole was placed in the cingulum and in the cervical aspect of the proximal groove; in the latter instance, this was done because the remaining tooth structure was insufficient to provide resistance against lingual displacement. **B,** The FDP on the definitive cast. **C,** A four-unit FDP consisting of a modified pinledge, two metal-ceramic pontics, and a metal-ceramic crown.

FIGURE 10-36 ■ **A,** Periodontally compromised but caries-free teeth of adequate buccolingual width are excellent candidates for a pinledge retained fixed splint. **B,** The definitive cast. **C,** Pinledge splint consisting of six separate castings that were soldered together and seated. **D,** As a result, display of metal is minimal. The pinledge preparations allow retention of the intact labial enamel of all six anterior teeth.

carbide bur. Paralleling devices are available for practitioners who do not feel comfortable preparing multiple pinholes. In general, pinledges are highly esthetic restorations. Plaque control after treatment is easier because of short margin length and largely supragingival margin location.

Indications

The pinledge is indicated for undamaged anterior teeth in dentitions with little or no caries. The presence of a small proximal carious lesion does not preclude its use. If esthetic appearance is highly important, the advantage of this restoration is that the labial tooth surface remains intact, although this is sometimes offset by the display of a very slight amount of metal along the incisal edge. Pinledges can be prepared on bulbous teeth that are unsuitable for three-quarter crowns; on such teeth, a significant amount of unsupported enamel interproximally would result. The lingual concavity of a maxillary anterior tooth can be modified successfully with a pinledge restoration (see Fig. 10-22) to establish or reestablish the desired anterior guidance.

Contraindications

Patients with poor oral hygiene or extensive caries are not good candidates for any type of cast restoration. Young patients with large pulps generally are better served by a resin-retained FDP (see Chapter 26). It is often not possible to place pinholes of adequate size and length in teeth that are thin labiolingually (Fig. 10-37). Pinledges are contraindicated on nonvital teeth and when the alignment of the abutment conflicts with the proposed path of placement of a planned FDP. Because less surface area is involved in the preparation, pinledges are not as retentive as their less conservative counterparts. Therefore, they should not be used when optimum retention is needed.

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Maxillary Central Incisor Pinledge

Three designs of pinledge preparations are summarized: the conventional pinledge (see Fig. 10-34), which involves only the lingual surface of the tooth; the pinledge with a proximal slice (Fig. 10-38); and the pinledge with a proximal groove (Fig. 10-39, *A*). The latter two can serve equally well as retainers for an FDP; the choice of one over the other depends primarily on tooth configuration and the presence or absence of caries. A tooth with a slight proximal convexity can often be prepared successfully with a proximal slice, whereas one with a small carious lesion often lends itself better to the proximal groove variation. The pinledge preparation with proximal slice is described first.

FIGURE 10-37 ■ Where incisors are thin labiolingually and insufficient dentin remains facial to the casting, appearance is compromised by a pinledge restoration.

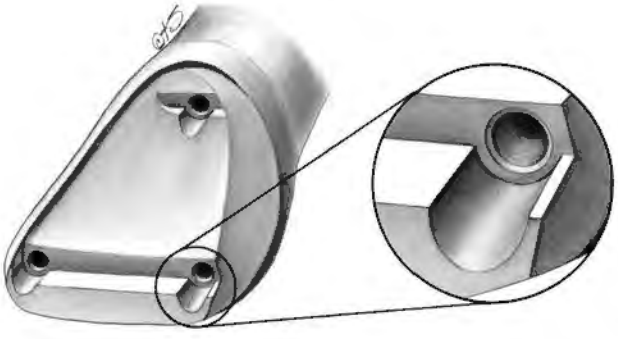

FIGURE 10-38 ■ Pinledge preparation with a proximal slice. The slice provides room for a fixed dental prosthesis connector. Sufficient tooth structure should remain between the slice and the pinhole adjacent to it. Note that the junction between pinhole and ledge has been beveled or countersunk.

Design

1. Draw the outline of the proposed preparation onto the tooth (Fig. 10-40). A line is marked along the height of contour of the incisal edge and on the proximal wall to include the area needed for a connector. The lingual chamfer margin is placed immediately adjacent to the crest of the marginal ridge. The cervical extent of the margin is on the height of contour of the cingulum, but it may be extended farther cervically at a later stage to blend into the proximal aspect of the preparation.

Proximal Reduction

2. Prepare the proximal slice with a tapered diamond. The diamond is either held parallel to the path of placement or positioned at a slight lingual inclination. The primary purpose of this step is to provide sufficient reduction to allow adequate metal in the area for a subsequent connector. The proximal reduction includes the proximal contact area, but care must be taken not to extend the reduction too far facially because this alters the outline form of the tooth. For esthetic reasons, the reduction must not extend onto the labial surface.

Incisal and Lingual Reduction

3. Prepare the incisal bevel with the diamond inclined slightly toward the lingual aspect. It extends just beyond the previously placed pencil line on the crest of the incisal edge, but it must remain within the curvature of the incisal edge to minimize display of metal. Sufficient clearance provides functional contact on metal rather than on the junction between metal and tooth structure. Desired metal thickness is 1 mm.

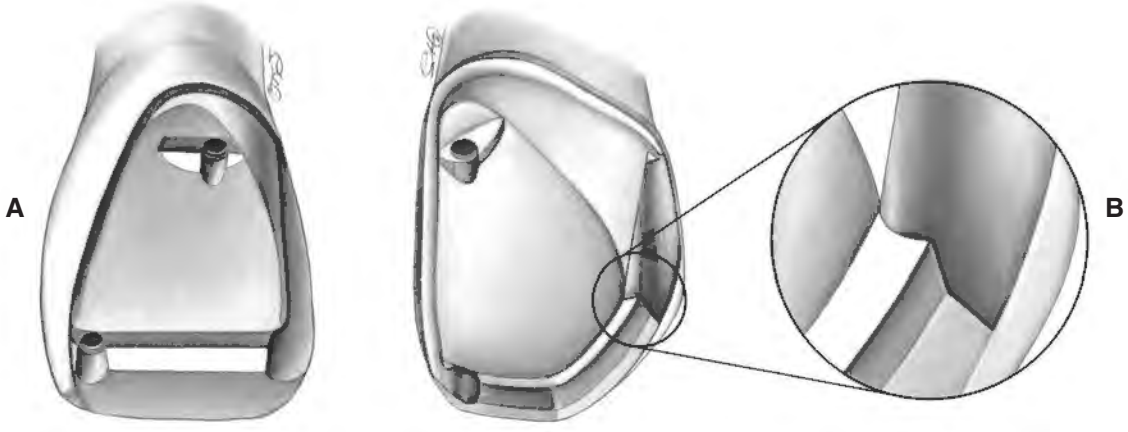

FIGURE 10-39 ■ **A,** Modified pinledge preparation with a proximal groove. The path of placement of this groove is compatible with the preparation as well as with the pinholes. **B,** A similar preparation on a maxillary canine. Note two similarities with the three-quarter crown: the heavy lingual chamfer margin and the incisal offset blending into the proximal groove to provide additional bulk for reinforcement (see enlargement).

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FIGURE 10-40 ■ **A,** Although periodontally compromised and malpositioned, these six caries-free anterior teeth are excellent candidates for pinledge preparations. **B,** After orthodontic repositioning of the teeth, an outline of the proposed preparations is drawn on the teeth.

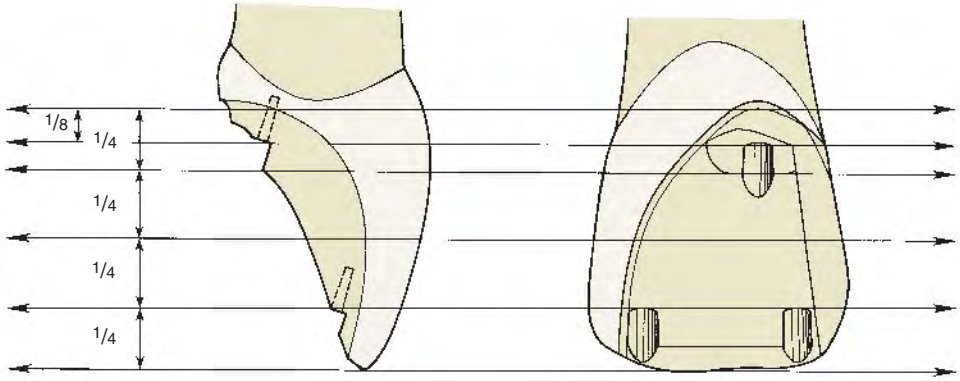

FIGURE 10-41 ■ Proximal and lingual views of the location of ledges in relation to the height of the crown. The incisal ledge is placed so that its floor is one fourth of the preparation's height from the incisal edge. The cervical ledge is placed so its floor bisects the cervical fourth. Note that the path of insertion is parallel to the incisal two thirds of the labial wall. Adequate offset of the cervical pinhole either mesially or distally is needed to prevent pulpal exposure.

4. Perform the lingual reduction with a football- or wheel-shaped diamond after placing reduction grooves, as described previously. Metal thickness must be 1 mm in maximum intercuspation. Reduction follows the lingual marginal ridge and continues its chamfer configuration cervically until it meets the proximal reduction. To facilitate subsequent stages of the preparation, care must be taken to maintain as much tooth structure as possible in the incisal third.
5. Smooth the incisal and lingual reduction with fine-grit diamonds and stones before preparing the ledges and pinholes.

Ledges and Indentations. Two ledges are prepared across the reduced lingual surface. These provide room for additional bulk of metal to ensure rigidity. Without them, the restoration would not be very strong because it would consist of only a thin sheet of metal.

The ledges are prepared parallel to the incisal edge of the tooth, as viewed from the lingual aspect, and parallel to one another, as viewed from the incisal aspect. In selected areas, they are widened to provide indentations of sufficient size to accommodate the pinholes. The determination of the incisocervical location of the ledges depends on the configuration of the pulp and the available bulk of tooth structure (Fig. 10-41). The incisal ledge is prepared 2 to 2.5 mm cervical to the incisal edge, or one fourth of the total height of the preparation from the incisal edge. The cervical ledge is placed on the crest of the cingulum at the center of the cervical one fourth of the preparation.

6. Prepare two ledges with a cylindrical tungsten carbide bur. Recommended minimum ledge width is 0.7 mm. Drawing the proposed location of the ledges on the lingual surface of the tooth is helpful. Ledge design must be compatible with the path of placement of the restoration, which parallels the incisal two thirds of the labial surface of the tooth.
7. Make indentations in the left and right sides of the incisal ledge and slightly off center in the cervical ledge to prevent subsequent pulp exposure when the pinholes are placed. These incisal indentations are as widely spaced as possible to retain as much dentin as possible between the pinholes and the pulp. Because the completed pinhole must be surrounded by sound dentin and yet away from the pulp, it is not possible to place holes in the extreme corners. The relationship between recommended pinhole locations and the pulp is illustrated in Figure 10-42. In general,

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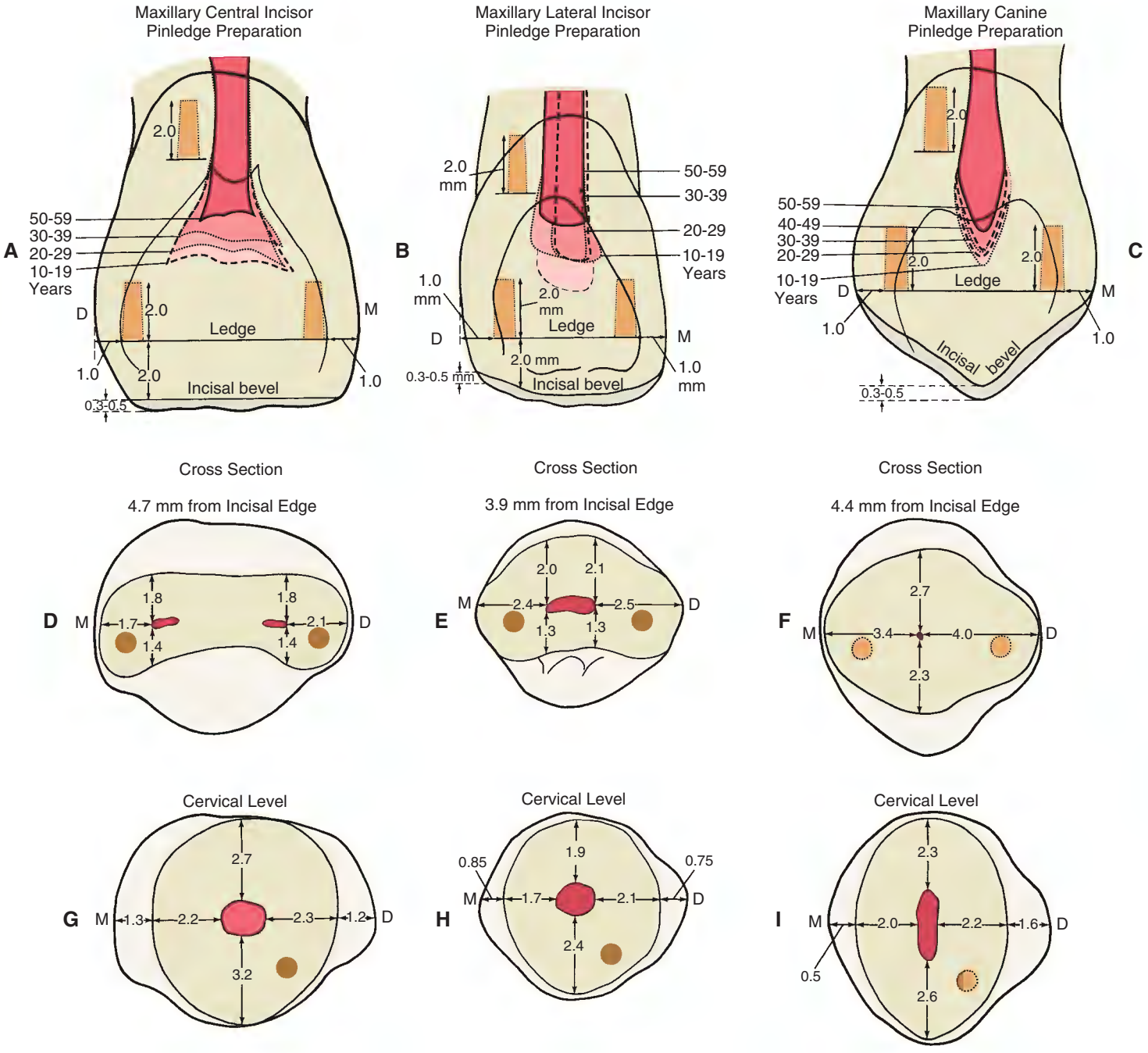

FIGURE 10-42 ■ Relationship between pinhole placement and pulp configuration. **A** to **C,** Lingual views. **D** to **F,** Cross-sectional views through incisal pinholes. **G** to **I,** Cross-sectional views through cervical pinholes. *Dashed lines* show the mean pulp chamber sizes of various age groups. *D,* Distal; *M,* mesial. (Data from Ohashi Y: Research related to anterior abutment teeth of fixed partial denture. Shikagakuho 68:726, 1968.)

this means that the indentations are just within the mesial and distal marginal ridges, about 1.5 mm inside the external tooth contour. The same tungsten carbide bur can be used to prepare the indentations. On completion, the configuration of the indentations should resemble a half cylinder. Again, their orientation is parallel to the selected path of placement, and their floor should be smooth and continuous with the floor of the ledges. When combined, they should provide a flat area 1.0 to 1.2 mm wide buccolingually.

Pinhole Preparation

8. Sink pilot channels with either a small, round bur or a small twist drill. The resulting shallow indentations prevent skating of the bur used to prepare the pinhole. Completed pinhole depth should be at least 2 mm but no more than 3 mm. Enlarge and deepen the pilot channels with a tapered tungsten carbide bur when their placement and orientation are satisfactory. At this stage, any small corrections in orientation can be made. Less experienced operators may spend a great deal of time attempting to

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determine the correct alignment of the bur. However, the design and location of the pinholes have already been determined by the placement of the ledges and indentations; therefore, the only remaining concern should be verification of the position of the rotary instrument and attainment of the minimum depth of the pinholes. Some operators find it helpful to place a second bur in a prepared pinhole to help transfer the path of placement, although precautions must be taken to prevent its being swallowed or inhaled. For multiple pinholes, preparing each a little at a time—moving from one to the next and gradually deepening each—may also be helpful. This enables alignment verification as the pinholes are prepared.

9. Bevel the junction between pinhole and indentation with a round bur slightly larger than the largest diameter of the pinhole (Fig. 10-43). (The required interproximal clearance is illustrated in Fig. 10-44.)
10. Inspect all surfaces of the preparation for smoothness and evaluate the margin. Correct any area that requires more distinct delineation (Fig. 10-45).

INLAYS AND ONLAYS

Indications

An inlay can be used instead of amalgam for patients with a low caries rate who require a small interproximal restoration in a tooth with ample supporting dentin. It is among the least complicated cast restorations to make and can be very durable when it is done carefully. An onlay allows the damaged occlusal surface to be restored with a casting in the most conservative manner. It should be considered in the restoration of a severely worn dentition when the teeth are otherwise minimally damaged or for the replacement of a mesio-occlusal–distal (MOD) amalgam restoration when sufficient tooth structure remains for retention and resistance form.

Contraindications

Because these restorations rely on intracoronal (wedging) retention, inlays and onlays are contraindicated unless there is sufficient bulk to provide resistance and retention form. MOD inlays may increase the risk of cusp fracture and are generally not recommended. Extensive onlays, required where caries or existing restorations extend beyond the facial or lingual line angles, are contraindicated unless pins are used to supplement retention and resistance.

Advantages

Cast inlays and onlays can be extremely long-lived restorations because of the excellent mechanical properties of the gold alloy. Low creep and corrosion mean that if inlay or onlay margins are accurately cast and finished, they will not deteriorate. The lack of corrosion may be an esthetic advantage. Gold does not lead to the tooth discoloration sometimes associated with dental amalgam. Unlike an inlay or amalgam, an onlay can support cusps, reducing the risk of tooth fracture.

Disadvantages

In the restoration of a small carious lesion, an inlay is not very conservative of tooth structure. This is because additional tooth removal is necessary after minimal proximal extension to achieve a cavity preparation without undercuts and to enable access for impression making. This extension may lead to additional display of metal and to gingival encroachment, which is undesirable for periodontal health. Because inlays do not encircle the tooth, the bulk of the buccal and lingual cusps must provide resistance and retention form. Of concern is that high occlusal force may lead to cusp fracture as a result of wedging from the inlay.

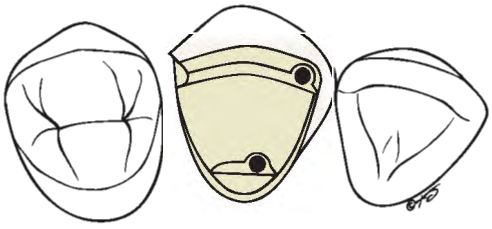

FIGURE 10-44 ■ Modified pinledge preparation with a proximal groove. Adequate interproximal clearance has resulted from the proximal flare.

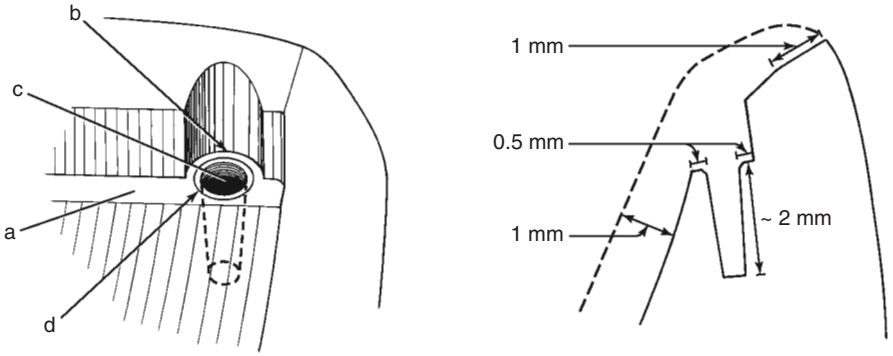

FIGURE 10-43 ■ Note the relation among the ledge, the indentation, and the pinhole. Recommended dimensions are given in the buccolingual cross section on the right. *a,* Ledge; *b,* indentation; *c,* pinhole; *d,* countersink.

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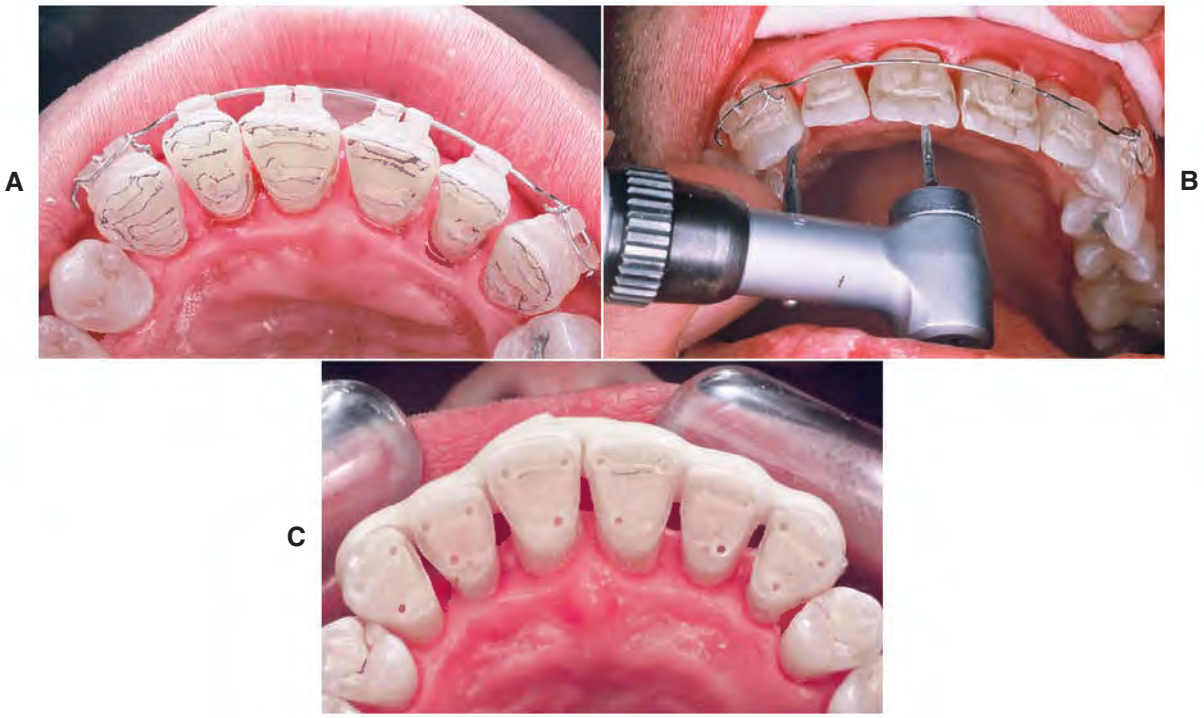

FIGURE 10-45 ■ **A,** Ledges and indentations have been prepared. **B,** Pinholes are prepared with a low-speed handpiece. **C,** The completed pinledge preparations. Utility wax has been placed over the brackets for impression making.

Preparation

Armamentarium

Tungsten carbide burs are usually used for inlay or onlay preparations (Fig. 10-46), but diamonds can be substituted if preferred:

- Tapered tungsten carbide burs
- Round tungsten carbide burs
- Cylindrical tungsten carbide burs
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels
- Hatchet
- Gingival margin trimmers
- Excavators
- High- and low-speed handpieces
- Articulating film

FIGURE 10-46 ■ Armamentarium for inlays and onlays.

Mesio-occlusal or Distal-occlusal Inlay Preparation

The MO or DO inlay preparation follows a series of steps (Fig. 10-47).

Occlusal Analysis

1. Carefully assess the occlusal contact relationship and mark it with articulating film. The margins of the restoration should not be too close (≥1.0 mm) to a centric contact; otherwise, there will be damaging stresses at the gold-enamel junction.
2. Apply rubber dam. Because good visibility and moisture control are essential during tooth preparation and caries excavation, the use of a rubber dam is strongly recommended.

Outline Form

3. Penetrate the central groove just to the depth of the dentin (typically about 1.8 mm) with a small round or tapered tungsten carbide bur held in the path of placement of the inlay. In general, this is perpendicular to an imaginary line connecting the buccal and lingual cusps, not necessarily perpendicular to the occlusal plane. For example, on mandibular premolars, it is angled toward the lingual aspect.
4. Extend the occlusal outline through the central groove with the tapered tungsten carbide bur. The bur should be held in the same path of placement

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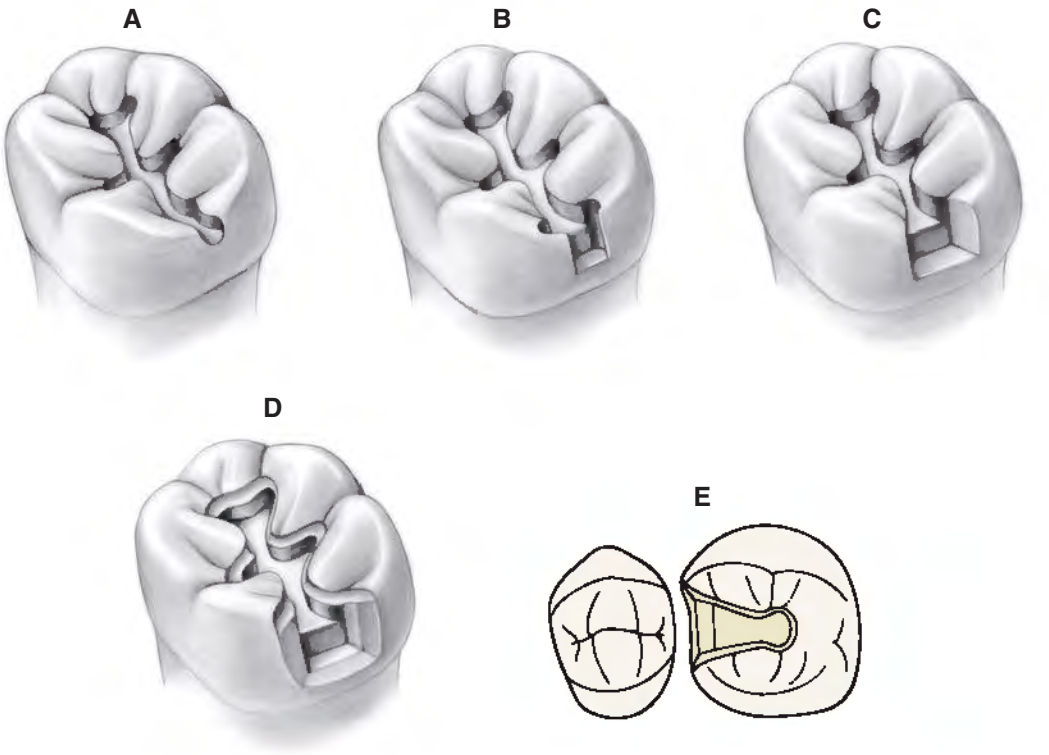

FIGURE 10-47 ■ The mesio-occlusal inlay preparation. **A,** An occlusal outline is prepared, following the central groove and extending proximally. **B,** Gingival extension undermines the marginal ridge during caries removal. **C,** Unsupported enamel is removed, and the walls of the proximal box are defined. This is easily accomplished with hand instruments. **D,** An occlusal bevel or chamfer margin completes the preparation. **E,** Occlusal view of the completed preparation.

FIGURE 10-48 ■ Preparation of a mandibular premolar tooth for a disto-occlusal inlay. **A,** Occlusal outline. **B,** Proximal box initiated. **C,** Proximal box extended to remove contact. **D,** Completed preparation. (Courtesy Dr. H. Bowman.)

and kept at the same depth: just into dentin. The buccolingual extension should be as conservative as possible to preserve the bulk of the buccal and lingual cusps. Resistance to proximal displacement is achieved with a small occlusal dovetail or pinhole. The outline should avoid the occlusal contacts.

5. Extend the outline proximally, undermining the marginal ridge, and stop it at the height of contour of the ridge (Fig. 10-48, *A*).
6. Advance the bur cervically to the carious lesion and then lingually and buccally, taking care to hold it in the precise path of placement. A thin layer of enamel should remain between the side of the bur and the adjacent tooth (see Fig. 10-48, *B*). This prevents accidental damage. The bur should move parallel to the original unprepared proximal surface, creating a convex axial wall in the interproximal preparation or box. The opposing buccal and lingual walls contribute significantly to retention; therefore, great care must be taken not to tilt the bur during this step. It should be held in the path of placement throughout. The width of the gingival floor of the box should be about 1.0 mm (mesiodistally). Correct cervical, lingual, and buccal extension at this stage is just beyond the proximal contact area. The completed inlay will require a minimum proximal clearance of 0.6 mm to allow an impression to be made, but some of this will be achieved with the proximal flares and gingival bevels. Sharp line angles between the occlusal outline and proximal box are rounded at this time (see Fig. 10-48, *C*).

Caries Excavation

7. Identify and remove any caries not eliminated by the proximal box preparation, with the use of an excavator or a round bur in the low-speed handpiece.
8. Place a cement base to restore the excavated tissue in the axial wall, pulpal floor, or both. If necessary,

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the preparation can be extended buccally or lingually. An inlay is not a suitable restoration for extensive caries, and carrying it beyond the line angles will lead to a significant loss of retention and resistance form.

Axiogingival Groove and Bevel Placement

9. Prepare a small, well-defined groove at the junction of the axial and gingival walls at the base of the proximal box to enhance resistance form and prevent distortion of the wax pattern during manipulation. It is easily placed with a gingival margin trimmer held in contact with the axial wall to prevent creating an undercut.
10. Place a 45-degree gingival margin bevel with a thin, tapered tungsten carbide bur or a fine-grit diamond. Correct orientation is achieved by holding the instrument parallel to the gingival third of the proximal surface of the adjacent tooth. The bur should not be tilted buccally or lingually to the path of placement; otherwise, an undercut will be created at the corners of the box (a common error in inlay preparations).
11. Prepare proximal bevels on the buccal and lingual walls with the tapered bur oriented in the path of placement. There should be a smooth transition between the proximal and gingival bevels.
12. Place an occlusal bevel to improve marginal fit and allow finishing of the restoration. When the cuspal anatomy is steep, a conventional straight bevel produces too little metal near the margin for strength and durability. A hollow-ground bevel or chamfer margin is normally preferred and can be conveniently placed with a round bur or stone.
13. As a final step, smooth the preparation where necessary, paying particular attention to the margin (see Fig. 10-48, *D*).

Mesio-occlusal–distal Onlay Preparation

The occlusal outline and proximal boxes of an onlay preparation (Fig. 10-49) are similar to those of an inlay. The additional steps are the occlusal reduction and a functional (centric) cusp ledge.

Outline Form

1. Prepare the occlusal outline with a tapered tungsten carbide bur just beyond the enamel-dentin junction (approximately 1.8 mm deep) and extend it through the central groove, incorporating any deep buccal or lingual grooves. Existing amalgam restorations are removed as part of this step (Fig. 10-50, *A*).
2. Extend the outline both mesially and distally to the height of contour of the marginal ridge. As with an inlay, prepare the boxes with an MOD onlay by advancing the bur gingivally and then buccally and lingually, always holding it in the precise path of placement of the preparation. If a thin section of proximal enamel remains as the bur advances, damage to the adjacent tooth will be prevented (see Fig. 10-50, *B*). Correct gingival, buccal, and lingual

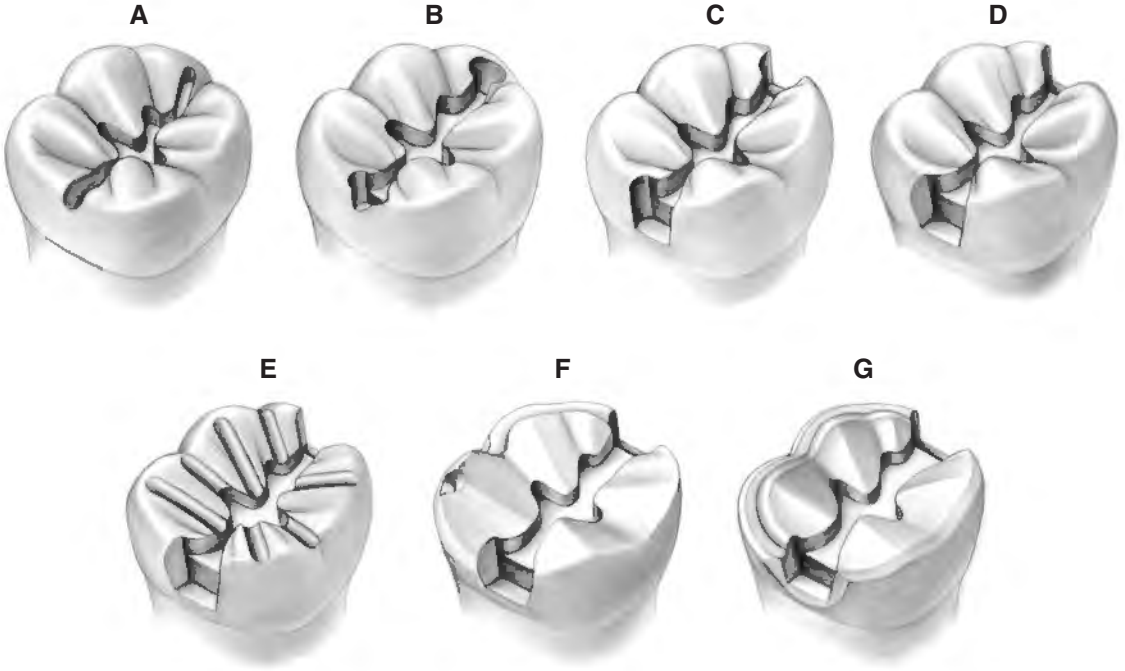

FIGURE 10-49 ■ The mesio-occlusal–distal (MOD) onlay preparation. **A,** An occlusal outline is prepared to follow the central fossa. **B,** The marginal ridges are undermined. **C** and **D,** The proximal boxes are refined. They should extend just beyond the proximal contact area. **E,** Depth grooves are placed for occlusal reduction: 0.8 mm on the nonfunctional cusp and 1.3 mm on the functional cusp. **F,** Note the buccal functional cusp bevel as part of the completed occlusal reduction. A buccal shoulder margin is prepared, approximately at the level of the pulpal floor. **G,** A continuous bevel completes the preparation. The bevel on the buccal shoulder margin makes a smooth transition into the proximal bevel of the box. A small contrabevel is placed on the lingual cavosurface margin.

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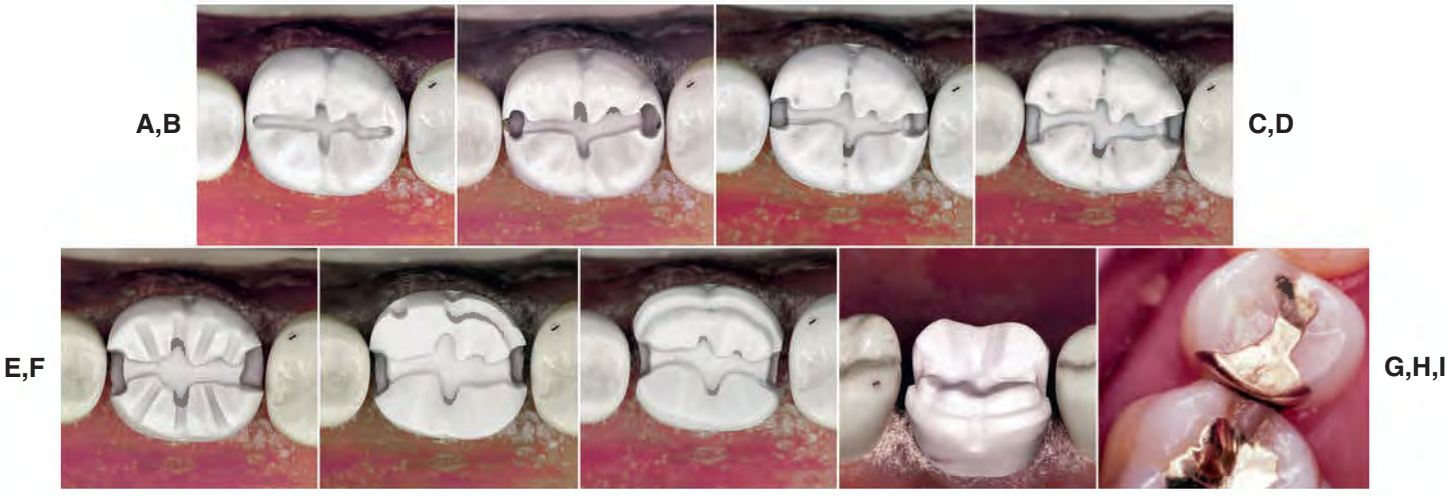

FIGURE 10-50 ■ Preparation of a mandibular molar tooth for a mesio-occlusal–distal (MOD) onlay. **A,** Preparation outline. **B,** Proximal boxes are extended to remove contacts. **C,** Unsupported enamel is removed with hand instruments. **D,** Proximal boxes are extended to form a 90-degree cavosurface angle. **E,** Occlusal reduction grooves. **F,** Functional cusp ledge is placed for distal half. **G** and **H,** Completed preparation. **I,** Two-surface intracoronal cast restoration that served for 66 years. (**A-H,** Courtesy Dr. H. Bowman.)

extension of the preparation normally depends on the contact area with the adjacent tooth. A minimum clearance of 0.6 mm is needed for impression making. Sometimes existing restorations or caries necessitate that a box be extended beyond optimal. However, if a box requires extension beyond the transitional line angle, the preparation will have little resistance form, and an alternative restoration, such as a complete crown, should be considered. Preparing the boxes is a key step when an onlay is fabricated (see Fig. 10-50, *C* and *D*). The tapered bur should be held precisely in the planned path of placement throughout. Tilting, often caused by attempts to advance the bur too quickly, is common and is difficult to correct.

3. Round sharp line angles between the occlusal outline and proximal boxes.

Caries Excavation

4. Remove any remaining caries by using an excavator or a round bur in the low-speed handpiece.
5. Place a cement base to restore the excavated tissue. Good judgment is needed to ensure that sound dentin on the axial walls is adequate for providing retention and resistance.

Occlusal Reduction

6. Place depth grooves on the functional cusps. To provide additional clearance at the cusp tip, the bur must be oriented more horizontally than the intended restoration cusp. The grooves should be 1.3 mm deep, allowing 0.2 mm for smoothing (see Fig. 10-50, *E*).
7. Place 0.8-mm grooves on the nonfunctional cusps. The bur is oriented parallel to the cuspal inclines. As with all depth grooves, it is assumed that the tooth is in good occlusal relation before preparation. If it is not, a vacuum-formed matrix made from the diagnostic waxing procedure is recommended as a guide.
8. Connect the grooves to form the occlusal reduction, maintaining the general contour of the original anatomy.
9. Prepare a 1.0-mm functional cusp ledge with the cylindrical tungsten carbide bur (see Fig. 10-50, *F*). This provides the restoration bulk in a high-stress area, preventing deformation during function. The ledge should be placed about 1 mm apical to the opposing centric contacts. It extends into the proximal boxes but should not be positioned too far apically; otherwise, the resistance form from the boxes will be lost.
10. Round any sharp line angles, particularly at the junction of the ledge and occlusal surface.
11. Check for adequate occlusal reduction by having the patient close the jaws into soft wax and measuring with a thickness gauge.

Margin Placement

12. Establish a smooth, continuous bevel on all margins. The gingival bevel is placed, as for an inlay, with the thin tungsten carbide bur or diamond held at a 45-degree angle to the path of placement, or approximately parallel to the adjacent tooth contour. This will blend smoothly with the buccal and lingual bevels, which have been prepared with the bur held in the path of placement.
13. Bevel the nonfunctional and functional cusps. Where additional bulk at the margin is needed, a chamfer margin should be substituted for the straight bevel margin. This can be placed with a round-ended diamond.
14. Complete the preparation by rechecking the occlusal clearance in all excursions and assessing for smoothness (see Fig. 10-50, *G* and *H*).

A restoration that served for 66 years is shown in Figure 10-50, *I*.

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STUDY QUESTIONS

1. What are the indications for and contraindications to partial veneer crowns?
2. What are the advantages and disadvantages of partial veneer crowns?
3. What is the recommended armamentarium, and in what sequence should a maxillary premolar be prepared, for a partial veneer crown?
4. What are the minimal criteria for each step just described?
5. What are the indications for and contraindications to inlay/onlay restorations?
6. What are the advantages and disadvantages of inlay/onlay restorations?
7. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for an inlay/onlay restoration?
8. What are the minimal criteria for steps 5, 6, and 7? Why?

SUMMARY CHART

Partial Veneer Crown Preparation

Indications	Contraindications	Advantages	Disadvantages
Posterior Teeth			
• Sturdy clinical crown of average length or longer • Intact buccal surface not in need of contour modification and well supported by sound tooth structure • No conflict between axial relationship of tooth and proposed path of placement	• Short teeth • Extensive caries • Extensive destruction • Poor alignment • Bulbous teeth • Thin teeth	• Conservation of tooth structure • Easy access to margins • Less gingival involvement than with complete cast crown • Easy escape of cement and good seating • Easy verification of seating • Electric vitality test feasible	• Less retentive than complete cast crown • Limited adjustment of path of withdrawal • Some display of metal • — • — • —
Anterior Teeth			
• Sturdy clinical crown of average length or longer • Intact labial surface that is not in need of contour modification and that is supported by sound tooth structure • No discrepancy between axial relationship of tooth and proposed path of placement of FDP	• Short teeth • Nonvital teeth • Extensive caries • Extensive destruction • Poor alignment with path of withdrawal of FDP • Cervical caries • Bulbous teeth • Thin teeth	• Conservation of tooth structure • Easy access to margins for finishing (dentist) and cleaning (patient) • Less gingival involvement than with complete cast crown • Easy escape of cement and good seating • Easy verification of complete seating • Electric vitality test feasible • — • —	• Less retentive than complete cast crown • Limited adjustment of path of insertion • Some display of metal • Not indicated on nonvital teeth • — • — • — • —

FDP, Fixed dental prosthesis.

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Preparation Steps	Recommended Armamentarium	Criteria
Depth grooves for occlusal reduction	Tapered tungsten carbide fissure bur or tapered, round-ended diamond	Clearance of 0.8 mm on nonfunctional cusps, 1.3 mm on functional cusps
Occlusal reduction	Round-ended diamond	Clearance of 1 mm on nonfunctional cusps, 1.5 mm on functional cusps
Depth grooves for axial reduction	Round-ended diamond	Chamfer margin depth of 0.5 mm (no more than half the width of diamond)
Axial reduction	Round-ended diamond	Axial reduction parallel to long axis of tooth
Chamfer margin finishing	Large, round-ended diamond	Smooth and continuous to minimize marginal length and facilitate finishing; distinct resistance to vertical displacement by periodontal probe
Proximal groove	Tapered tungsten carbide fissure bur	Distinct resistance to lingual displacement by probe; parallel to path of placement of restoration; 90-degree angle between prepared axial wall and buccal or lingual aspect of groove
Buccal and occlusal bevel margins (maxilla), chamfer margins (mandible)	Round-ended diamond	Maxillary teeth: bevel extends just beyond cusp tip but remains within curvature of cusp tip
Finishing	Large, round-ended diamond or tungsten carbide bur	Mandibular teeth: minimum of 1 mm of cast gold in area of centric stops All sharp internal line angles (except grooves) rounded to smooth transitions
Depth grooves for lingual reduction	Round-ended diamond	Should allow for 1 mm of clearance
Lingual reduction	Football-shaped diamond	Should have 1 mm of clearance
Incisal bevel	Round-ended diamond	Allows for metal thickness ≥0.7 mm
Depth grooves for axial reduction	Round-ended diamond	Allows for 0.5 mm of metal thickness at margin
—	Round-ended diamond	Extends into interproximal about 0.4 mm lingual of contact area; parallel to incisal two thirds of labial surface
Axial reduction	Tapered tungsten carbide fissure bur and half-round bur	Grooves parallel to incisal two thirds of labial surface; should resist lingual displacement; pinhole should be between 2 and 3 mm deep
Retention form (proximal grooves and lingual pinhole)	Fine-grit, tapered diamonds (large and small) or tungsten carbide bur	Lingual wall of groove meets proximoaxial wall at angle of 90 degrees
Finishing and flare	Fine-grit, tapered diamonds or finishing stones.	All surfaces smooth; buccal wall of groove flared to break proximal contact; resulting cavosurface angle is 90 degrees; no unsupported enamel remaining

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SUMMARY CHART

Pinledge Preparation

Indications	Contraindications	Advantages	Disadvantages
• Undamaged anterior teeth in caries-free mouth • Alteration of lingual contour of maxillary anterior teeth or alteration of occlusion • Anterior splinting	• Large pulps • Thin teeth • Nonvital teeth • Carious involvement • Problems with proposed path of placement of FDP	• Minimal tooth reduction • Minimal margin length • Minimum gingival involvement • Optimum access for margin finishing and hygiene • Adequate retention	• Less retentive than complete coverage • Possible difficulty with alignment • Technically demanding • Not usable on nonvital teeth • —

FDP, Fixed dental prosthesis.

SUMMARY CHART

MO or DO Inlay Preparation

Indications	Contraindications	Advantages	Disadvantages
• Small carious lesion in otherwise sound tooth • Adequate dentinal support • Low caries rate • Patient's request for gold instead of amalgam or composite resin	• Extensive caries • Poor plaque control • Small teeth • Adolescents • MOD restorations • Poor dentinal support necessitating a wide preparation	• Superior material properties • Longevity • No discoloration from corrosion • Least complex cast restoration • — • —	• Less conservation of tooth structure than amalgam • May display metal • Gingival extension beyond ideal • "Wedge" retention summary chart • — • —

MOD, Mesio-occlusal–distal.

SUMMARY CHART

MOD Onlay Preparation

Indications	Contraindications	Advantages	Disadvantages
• Worn or carious teeth with intact buccal and lingual cusps • Need to replace MOD amalgam • Low caries rate • Patient's request for gold instead of amalgam	• Extensive caries • Poor plaque control • Short clinical crown or extruded teeth • Lesions extending beyond transitional line angles • —	• Support of cusps • High strength • Longevity • — • —	• Lacks retention • Less conservation of tooth structure than amalgam • May display metal • Gingival extension beyond ideal • —

MOD, Mesio-occlusal–distal.

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Preparation Steps	Recommended Armamentarium	Criteria
Reduction of marginal ridge and contact area adjacent to edentulous space	Round-ended, tapered diamond	Should provide space for adequate bulk of metal in area of connector
Lingual reduction	Football-shaped diamond	Should provide for clearance of at least 0.7 mm
Ledges	Straight tungsten carbide fissure bur	Ledges must be parallel to one another when viewed from lingual and from incisal aspects; maximum width, 1 mm
Indentations	Straight tungsten carbide fissure bur	Indentation should provide at least 0.5 mm of space for metal reinforcement around opening of pinhole
Pilot channels and pinholes	Tapered tungsten carbide bur	Pinholes must be between 2 and 3 mm deep; minimal width of ledge around pinholes is 0.5 mm
Finishing	Finishing stones or tungsten carbide burs	All surfaces must be as smooth as possible (accomplish with fine-grit rotary instruments) to facilitate removal of this delicate wax pattern from die

Preparation Steps	Recommended Armamentarium	Criteria
Occlusal outline	Tapered tungsten carbide bur	Includes central groove, avoids centric contacts, includes dovetail or pinhole for resistance; approximately 1.8 mm deep
Proximal box	Tapered tungsten carbide bur	Follows curvature of original tooth surface
Caries removal	Excavator or round bur	Tissue replaced with base
Axiogingival groove	Gingival margin trimmer	Detectable with explorer tip (0.2 mm deep)
Gingival and proximal bevels	Thin, tapered tungsten carbide bur or diamond	Placed at 45 degrees to tooth surface; approximately 0.8 mm wide
Occlusal bevel	Round tungsten carbide bur or finishing stone	Hollow ground, avoid centric contacts

Preparation Steps	Recommended Armamentarium	Criteria
Occlusal outline	Tapered tungsten carbide bur	Includes central, buccal, and lingual grooves; about 1.8 mm deep
Proximal boxes Caries removal	Tapered tungsten carbide bur Excavator or round bur	Follows curvature of original tooth surface Tissue replaced with base
Occlusal reduction	Tapered tungsten carbide bur	Adequate dentin for resistance and retention
Centric cusp ledge	Tapered tungsten carbide bur	Following anatomic contours
Gingival and proximal bevels	Thin, tapered tungsten carbide bur	1.5-mm functional cusp; 1.0-mm nonfunctional cusp About 1.0 mm wide (before beveling) About 1.0 mm apical to centric contact at 45-degree angle; about 0.8 mm wide

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CHAPTER 11

Tooth Preparation for All-Ceramic Restorations

All-ceramic inlays, onlays, veneers, and crowns can be some of the most esthetically pleasing prosthodontic restorations. Because they have no underlying metal to block light transmission, they can resemble natural tooth structure better in terms of color and translucency than any other restorative option. Their chief disadvantage is their susceptibility to fracture, although this can be lessened by use of the resin-bonded technique and higher strength ceramics.

All-ceramic restorations may be fabricated in several ways. The original technique (first developed more than 100 years ago) called for a platinum foil matrix to be intimately adapted to a die. This supported the porcelain during firing and prevented distortion. The foil was removed before cementation of the restoration.

Today, popular fabrication processes for the restorations include hot-pressing, slip-casting, and milling. Available fabrication techniques for the various materials are discussed in Chapter 25.

COMPLETE CERAMIC CROWNS

Complete ceramic crowns should have reasonably uniform thickness circumferentially. For the hot-pressed ceramic crown (e.max press [Ivoclar Vivadent] or OPC [Pentron Ceramics, Inc.]) (Fig. 11-1), usually about 1.0- to 1.5-mm thickness is needed to create an esthetically pleasing restoration. Incisally, a greater ceramic thickness is helpful, especially when the restoration needs to exhibit translucency.

Only minor differences in tooth preparation design exist among the restorations fabricated with the various techniques. Therefore, the preparation for a hot-pressed crown preparation is described in detail, and the necessary variations are discussed when pertinent.

Advantages

The advantages of a complete ceramic crown include its superior esthetics in comparison with metal-ceramic crowns, its excellent translucency (similar to that of natural tooth structure), and the generally good soft tissue response to it. Lack of reinforcement by a metal substructure enables slightly more conservative reduction of the facial surface than is necessary for a metal-ceramic crown, although the lingual surface needs additional reduction to allow adequate material thickness for strength. Depending on the inherent translucency of the chosen material, the appearance of the completed restoration can be influenced and modified by the use of different colors of luting agent. However, changing cement color under restorations that rely on an opaque core for strength, such as a zirconia core system or monolithic zirconia (see Chapter 25), is ineffective.

Disadvantages

Disadvantages of a complete ceramic crown include reduced strength of the restoration because of the absence of a reinforcing metal substructure. Table 11-1 lists the properties of the various material options. Because of the need for a circumferential shoulder-type margin, significant tooth reduction is necessary on the proximal and lingual aspects. Porcelain brittleness, in combination with the lack of a reinforcing substructure, necessitates the incorporation of a circumferential support with a shoulder margin. In comparison, the proximal and lingual reductions are thus less conservative than those needed for a metal-ceramic crown.

Difficulties may be associated with obtaining a well-fitting margin when certain techniques are used. The unforgiving nature of porcelain, if an inadequate tooth preparation goes uncorrected, can result in fracture.

Proper preparation design is critical for mechanical success. A 90-degree cavosurface angle is needed to prevent unfavorable distribution of stresses and to minimize the risk of fracture (Fig. 11-2). The preparation should provide support for the porcelain along its entire incisal edge, unless the ceramic system chosen includes a high-strength core (see Chapter 25).

Wear has been observed on the functional surfaces of natural teeth that oppose porcelain restorations. This also applies to teeth opposed by metal-ceramic restorations, especially the mandibular incisors, which can exhibit significant wear over time (see Fig. 19-1).

Indications

The complete ceramic crown is indicated in areas with a high esthetic requirement, where a more conservative restoration would be inadequate (Fig. 11-3). Usually such a tooth has proximal or facial caries, or both, and can no longer be effectively restored with composite resin.

The tooth should be relatively intact with sufficient coronal structure to support the restoration, particularly in the incisal area, where porcelain thickness must not exceed 2 mm; otherwise, the brittle material will fail.

Because of the relative weakness of the restoration, the occlusal load should be favorably distributed (Fig. 11-4).

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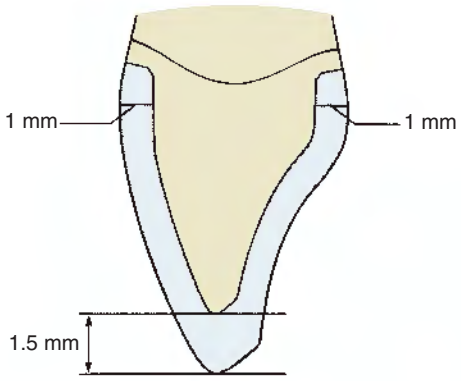

FIGURE 11-1 ■ Recommended reduction for all-ceramic crowns.

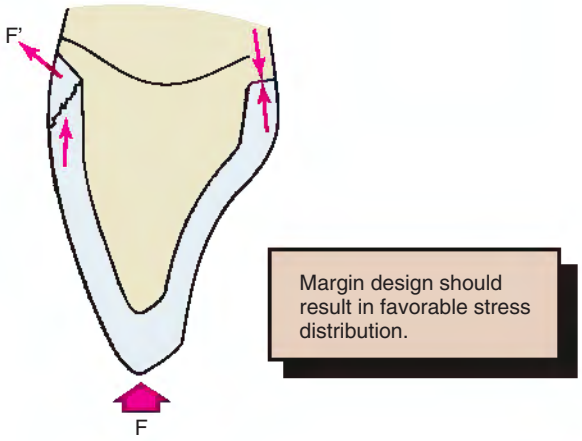

FIGURE 11-2 ■ A sloping shoulder margin is not recommended for the all-ceramic crown. It does not support the porcelain. Incisal loading leads to tensile stresses near the margin if the forces are not reciprocated *(arrows)*, which may cause brittle failure. *F,* Force.

TABLE 11-1 Properties of Three Types of Ceramics

Property	Leucite	Lithium Disilicate	Zirconia (Y-TZP)
Crystallinity (volume %)	35	70	≥97.5 (may also include crystalline HfO_2, Al_2O_3, Na_2O, SiO_2, Fe_2O_3, and so forth)
Flexural strength (MPa)	85-112	215-400	900
Fracture toughness (MPa • $m^{½}$)	1.3-1.7	2.2-3.3	8-10.3
Vickers hardness (GPa)	5.9	6.3	8.8-11.8
Expansion coefficient (10^{-6}/K)	15.0-15.4	9.7-10.6	10.0-11.0
Elastic modulus (GPa)	65-86	95-103	210
Chemical durability (μg/cm²)	100-200	30-50	30

Adapted from Anusavice KJ: Phillips' science of dental materials, 12th ed. St. Louis, Saunders, 2013.

FIGURE 11-3 ■ **A,** Inadequately fitting all-ceramic crowns have led to recurrent caries and gingival recession around these central incisors. The patient had exceptionally high esthetic requirements. **B,** The gingival defect was corrected by minor periodontal recontouring, the teeth were reprepared, and new all-ceramic crowns provided.

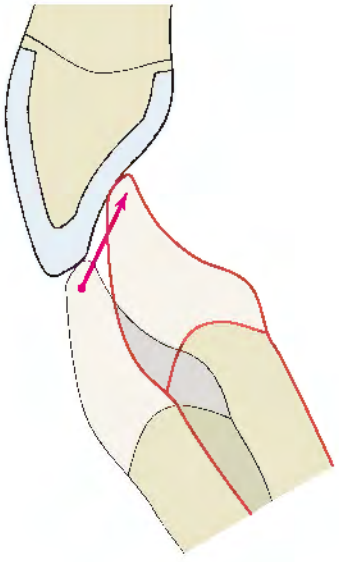

FIGURE 11-4 ■ The design of the occlusion on an all-ceramic crown is crucial to avoid fracture. Centric contacts are best confined to the middle third of the lingual surface. Anterior guidance should be smooth and consistent with contact on the adjacent teeth. Leaving the restoration out of contact is not recommended. Future eruption may lead to new protrusive interferences, precipitating fracture.

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FIGURE 11-5 ■ Unfavorable occlusal loading, such as this edge-to-edge relationship on the lateral incisor, is a contraindication to the all-ceramic crown, particularly in view of the parafunctional activity of this patient, evidenced by multiple wear facets.

In general, this means that centric contact must be in an area where the porcelain is supported by tooth structure (i.e., in the middle third of the lingual wall).

Contraindications

The ceramic crown is contraindicated when a more conservative restoration can be used. Although certain ceramic materials may offer additional strength in comparison with some of the original ceramic materials, the strongest solution for a molar remains a metal casting, which may be partially veneered with ceramic material if the molar is visible when the patient smiles. Because of the increased occlusal load and the reduced esthetic demand, metal-ceramic restorations are then the treatment of choice. If occlusal loading is unfavorable (Fig. 11-5) or if it is not possible to provide adequate support or an even shoulder margin width of at least 1 mm circumferentially, a metal-ceramic restoration should be considered instead. Ideally, all-ceramic crowns have occlusal contact in an area that is well supported by the tooth preparation (i.e., the middle third of the lingual wall on an anterior tooth). Teeth with short clinical crowns often do not offer adequate support for all-ceramic crowns.

Preparation

Armamentarium

The instruments needed for preparing an all-ceramic crown (Fig. 11-6) include the following:

- Round-ended, tapered diamonds, regular and coarse grit (0.8 mm)
- Square-ended, tapered diamond, regular grit (1.0 mm), or end-cutting diamond
- Football-shaped diamond
- Fine grit finishing diamonds or carbides
- Mirror
- Periodontal probe
- Explorer
- Chisels and/or hatchets
- High- and low-speed handpieces

FIGURE 11-6 ■ Armamentarium for an all-ceramic crown preparation.

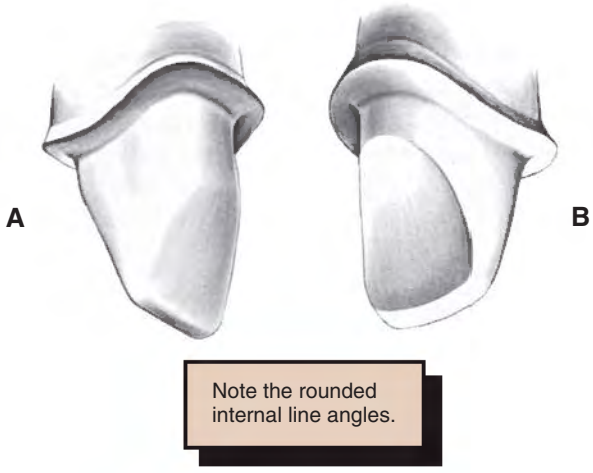

FIGURE 11-7 ■ All-ceramic crown preparation. **A,** Labial view. **B,** Lingual view. To prevent stress concentrations in the ceramic, all internal line angles should be rounded. The shoulder margin should be as smooth as possible to facilitate the technical aspects of fabrication.

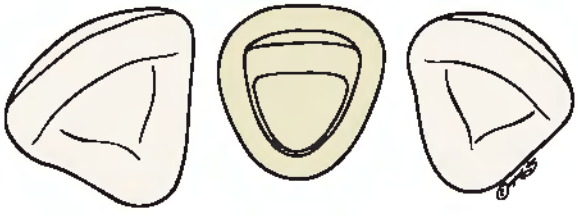

FIGURE 11-8 ■ Note the uniform chamfer margin width of 1 mm on this all-ceramic crown preparation.

Step-by-Step Procedure

The preparation sequence for a ceramic crown (Fig. 11-7) is similar to that for a metal-ceramic crown; the principal difference is the need for a 1-mm-wide circumferential chamfer margin (Fig. 11-8).

Incisal (Occlusal) Reduction. On completion, the incisal edge reduction should provide 1.5 to 2.0 mm of

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clearance for porcelain in all excursive movements of the mandible. This renders the restoration translucent and cosmetically pleasing, with adequate strength. If the restoration is used for posterior teeth (rare), 2 mm of clearance is needed on all cusps.

1. Place two or three depth grooves in the incisal edge, initially keeping them approximately 1.3 mm deep to allow for additional loss of tooth structure during finishing. The grooves are oriented perpendicular to the long axis of the opposing tooth to provide adequate support for the porcelain crown.
2. Complete the incisal reduction, reducing half the incisal edge at a time. Verify on completion that the desired clearance has been achieved.

Facial Reduction

3. After placing depth grooves, reduce the labial or buccal surface, and verify that clearance is adequate for 1 mm of porcelain thickness. One depth groove is placed in the middle of the facial wall and one each in the mesiofacial and distofacial transitional line angles. The reduction is then performed with a cervical component parallel to the proposed path of placement (typically, the long axis of the tooth) and an incisal component parallel to the original external facial contour of the tooth. The depth of these grooves should be approximately 0.8 mm, again slightly shallow to allow for finishing. Perform the reduction on half of the facial surface, evaluate its adequacy, and then complete the second half.
4. Accomplish the bulk reduction with the round-ended, tapered diamond (which results in a heavy chamfer margin). Ensure copious irrigation throughout the procedure.

Lingual Reduction

5. Use the football-shaped diamond for lingual reduction after placing depth grooves approximately 0.8 mm deep. Perform the lingual reduction in the same way as for other anterior tooth preparations (see Chapters 9 and 10) until clearance in all mandibular excursive movements is 1 mm, to ensure adequate room for the porcelain in all load-bearing areas.
6. After the selected path of placement has been transferred from the cervical wall of the facial preparation, place a depth groove in the middle of the cingulum wall.
7. Repeat the shoulder margin preparation, this time from the center of the cingulum wall into the proximal aspect, until the lingual shoulder margin meets the facial shoulder margin. This margin should follow the free gingival crest and should not extend too far subgingivally. It is recommended that initial placement be slightly above the intended endpoint. Once it is possible to position the bur in the interproximal area, refine the margin and extend it to its final location, working in the direction of proximal to mid-lingual (downslope) because such reduces the risk of encroaching on the epithelial attachment.

Chamfer Margin Preparation. For subgingival margins, displace the tissue with cord before proceeding with the chamfer margin preparation. The ultimate objective is to direct stresses optimally in the completed porcelain restoration. This is accomplished when the chamfer margin or rounded shoulder margin completely supports the crown; any forces exerted on the crown are then in a direction parallel to its path of placement. A sloping shoulder margin results in unfavorable loading of the porcelain, with a greater likelihood of tensile failure through the ceramic. A 90-degree cavosurface angle is optimal; however, no residual unsupported enamel must be overlooked because it easily chips off.

The completed heavy chamfer margin should be 1 mm wide, have a rounded internal angle, be smooth, be continuous, and be free of any irregularities.

Finishing

8. Finish the prepared surfaces to a final smoothness as described for the other tooth preparations. Round any remaining sharp line angles to prevent a wedging action, which can cause fracture.
9. Perform any additional margin refinement as needed, using either the diamond or a carbide rotary instrument of choice.

CERAMIC INLAYS AND ONLAYS

Christa D. Hopp

The application of ceramic as a restorative material is not limited to complete coverage crowns or esthetic veneers. Posterior teeth with moderate-sized defects can be restored with inlays or onlays as an alternative to amalgam, gold, or resin. For esthetic restorations, ceramic inlays and onlays provide a durable alternative to posterior composite resins. The esthetic quality of ceramic is rarely disputed, inasmuch as it is the material capable of matching the appearance of natural tooth structure most closely. The indirect fabrication of these restorations can eliminate potential issues associated with operator error, polymerization shrinkage, and layering composite resin in association with the direct technique. Bonding the ceramic restoration to tooth structure can help reinforce areas of weakened tooth structure and enable more conservative tooth preparation.

The procedure consists of bonding the ceramic restoration to the prepared tooth with an acid-etch technique. The bonding mechanism relies on acid etching of the enamel and the use of composite resin, as in the resin-retained fixed dental prosthesis technique (see Chapter 26). Bonding to porcelain is achieved by etching with hydrofluoric acid and the use of a silane-coupling agent (materials are identical to those marketed as porcelain repair kits). A similar restoration entails the use of laboratory-processed composite resin instead of the ceramic.

Bonded ceramic inlays are showing promising longevity: 8- to 10-year performance. In a 10-year prospective study on IPS Empress inlays, survival probability was reported as 80% to 95%.[1-5]

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Indications

A ceramic inlay can be used instead of amalgam or a gold inlay for patients with a low caries rate who require a class II restoration and wish to restore the tooth to its original appearance. It is the most conservative ceramic restoration and enables most of the remaining enamel to be preserved. When an esthetic restoration is required in a posterior tooth and the size of the defect is beyond what can predictably be restored with composite resin, but small enough not to warrant a complete crown, a ceramic inlay or onlay is indicated. In general, when cuspal coverage is required for restoration of a tooth, composite resin is not a viable long-term restorative material.

Contraindications

Because these restorations are time consuming and expensive, they are contraindicated in patients with poor oral hygiene or active caries. Because of their brittle nature, ceramic restorations may be contraindicated in patients with excessive occlusal loading, such as those with bruxism. When more than two thirds of the occlusal table requires restoration, a complete crown is generally preferred over a ceramic onlay.

Advantages

The obvious advantage of the ceramic inlay and onlay over alternative restorative materials is esthetics. The esthetic durability of ceramic restorations over time is superior to that of composite resin restorations, which stain over time. Ceramic inlays and onlays can be fabricated with the indirect technique in the dental laboratory, although chairside fabrication is possible with an in-office milling system (see Chapter 25). Restoration wear associated with posterior composite restorations is not a problem with ceramic restorations. Marginal leakage associated with polymerization shrinkage and with the high thermal coefficient of expansion of the resin is reduced because the luting layer is comparatively thin. In some situations, this restoration enables the clinician to conserve tooth structure. When a significant amount of tooth structure is already missing and retention form is limited, the ceramic restoration offers the advantage of bonding. For instance, if a premolar with a fractured cusp requires restoration, the defect is often treated with a complete crown, sometimes preceded by endodontic treatment and a suitable buildup (see Chapter 12). Such treatment necessitates removal of a significant amount of tooth structure and compromises the tooth's long-term prognosis. However, with a ceramic onlay, only the missing cusp need be replaced by bonding the ceramic material to a circumferential band of enamel; minimal if any additional retention form is required, and a significant amount of tooth structure is conserved, in comparison to the previously described approach (Fig. 11-9).

Disadvantages

Ceramics can be abrasive. If care is not taken to achieve a smooth, well-polished restoration, opposing enamel that is in sliding contact with the restoration can produce wear. Rough porcelain is extremely abrasive of the opposing enamel. Castable glass-ceramic restorations (see Chapter 25) are less abrasive than the traditional feldspathic porcelain. Wear of the composite resin luting agent can be a problem, leading to marginal gaps. These eventually allow chipping or recurrent caries.

Achieving accurate occlusion can be challenging with ceramic inlays and onlays. Because they are fragile, occlusal adjustment needs to occur intraorally, after cementation. Accurate adjustment of the occlusion can occur only after the restoration has been bonded with an adhesive resin. Therefore, any roughening of the surface must receive the final polish intraorally, which can prove time

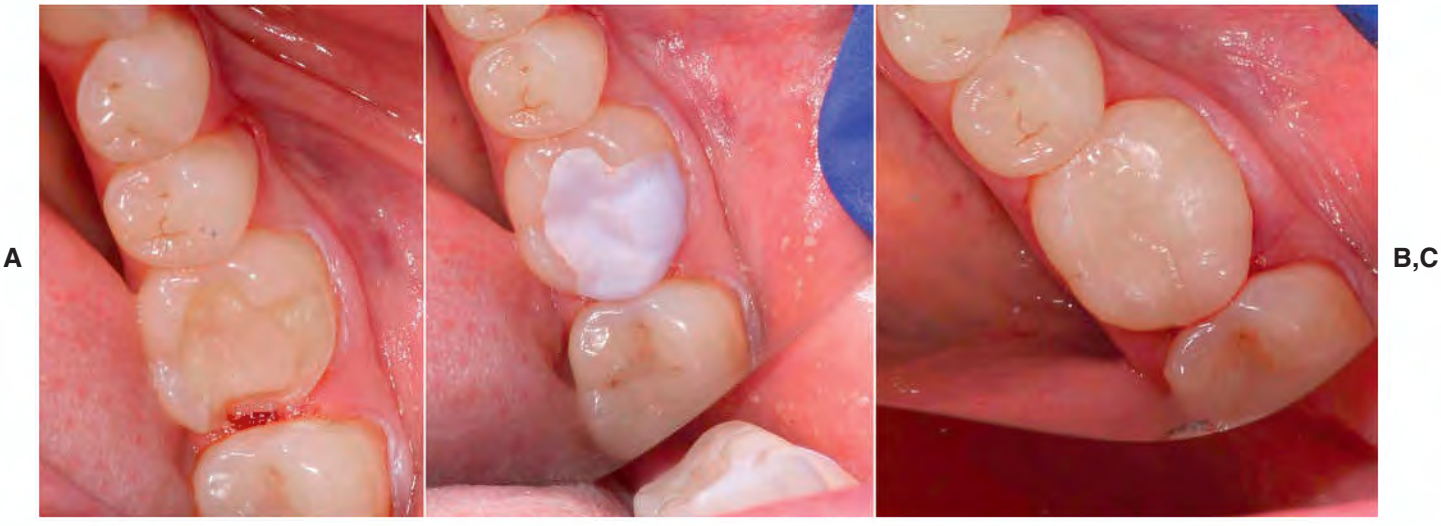

FIGURE 11-9 ■ Nontraditional preparation design for all-ceramic partial coverage. For this onlay preparation, the wide circumferential band of enamel provides for bonding. **A,** Tooth preparation. **B,** Clinical evaluation of lithium disilicate restoration before the crystallization step. **C,** Completed restoration.

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consuming. Similarly, finishing of the margins can be difficult in the less accessible interproximal areas. Resin flash or overhangs can be difficult to detect and may initiate periodontal disease.

Ceramics are brittle. A thin area of ceramic can be subject to fracture because of its brittle nature.[6] Therefore, in some clinical scenarios, removal of sound tooth structure may be necessary in order to ensure adequate strength.

Bonding is highly technique sensitive. Achieving an excellent bond between the tooth and the ceramic material is achievable, but not simple. The dentist must ensure excellent isolation, adhere precisely to the resin manufacturer's directions, and bond to tooth structure that is free of defects (i.e., sclerotic, decalcified, or otherwise compromised).

Accuracy is important with these restorations because accurately fitting restorations (marginal gaps less than 100 µm) have been shown to improve clinical outcomes. A study on adaptation differences between pressed and milled inlay and onlay restorations showed minimal differences after luting, ranging from 136 to 278 µm.[7] Similarly, for milled ceramic inlays and onlays, the challenge associated with overmilling is well recognized. The clinical significance of the larger internal and marginal gap widths, in comparison to the classic cast gold inlay restorations, requires further study.

Preparation

As with any indirect restoration, a path of draw must be established while undercuts and inconsistencies are avoided in the margin. Tapered diamond burs can produce the needed divergence to the internal walls and create the defined 90-degree cavosurface margins that help maintain the necessary bulk and strength. A slightly rounded end to a flat-ended tapered cylinder facilitates an internal form without sharp angles. A rounded internal form prevents stress concentrations or voids in the resin-bonding luting agent. It also enables the dentist to achieve excellent definition of the cavosurface margins.

Armamentarium

As for metal inlays, diamonds or carbide burs can be used for the preparation (Figs. 11-10 and 11-11), but diamonds may be substituted:

- Tapered carbide burs
- Round carbide burs
- Cylindrical carbide burs
- Finishing stones
- Mirror
- Explorer and periodontal probe
- Chisels
- Gingival margin trimmers
- Excavators
- High- and low-speed handpieces
- Articulating film

Step-by-Step Procedure

Rubber dam isolation is recommended to improve visibility and moisture control. Before applying the dam, the dentist should mark and assess the occlusal contact relationship with articulating film. To avoid chipping or wear of the luting resin, the margins of the restoration should not be at a centric contact. The specified dimensions are minimal values to achieve adequate ceramic thickness to reduce the risk of fracture. In general, weaker materials require additional bulk (Table 11-2).

Outline Form

1. Prepare the outline form. Preparation is generally governed by the existing restorations and caries and is broadly similar to that for conventional metal inlays and onlays (see Chapter 10). Because of the resin bonding, axial wall undercuts can sometimes be blocked out with resin-modified glass ionomer cement, which can allow preservation of additional enamel for adhesion. However, undermined or weakened enamel should always be removed. The central groove reduction (typically 2 mm) follows the anatomy of the unprepared tooth rather than a monoplane. This provides additional bulk for the ceramic. The outline should avoid occlusal contacts. Areas to receive onlays need 1.5 mm of clearance in all excursions to allow for adequate ceramic thickness and prevent fracture.
2. Extend the box to allow a minimum proximal clearance of 0.6 mm for impression making. The margin should be kept supragingival, which makes isolation during the crucial luting procedure easier and improves access for finishing. If necessary, electrosurgery or crown lengthening (see p. 153) can be performed. The pulpal depth of the gingival floor of the box should be approximately 1 mm.
3. Round all internal line angles. Sharp angles lead to stress concentrations and increase the likelihood of voids during the luting procedure.

Caries Excavation

4. With an excavator or a round bur in the low-speed handpiece, remove any caries not included in the outline form preparation.
5. Place a resin-modified glass ionomer cement base to restore the excavated tissue in the gingival wall.

TABLE 11-2 Preparation Guidelines for All Ceramic Inlays and Onlays

Internal Dimensions	External Dimensions
Pulpal depth: 1.5-2.0 mm	Cavosurface margins: 90 degrees
Rounded internal line angles	Isthmus width: 2 mm
Axial wall convergence: 10-12 degrees	Occlusal reduction: 2 mm
Axial wall reduction (boxes): 1.0-1.5 mm	Smooth margins, no sharp transitions

Adapted from Hopp CD, Land MF: Considerations for ceramic inlays in posterior teeth: a review. Clin Cosmet Investig Dent 18;(5):21, 2013.

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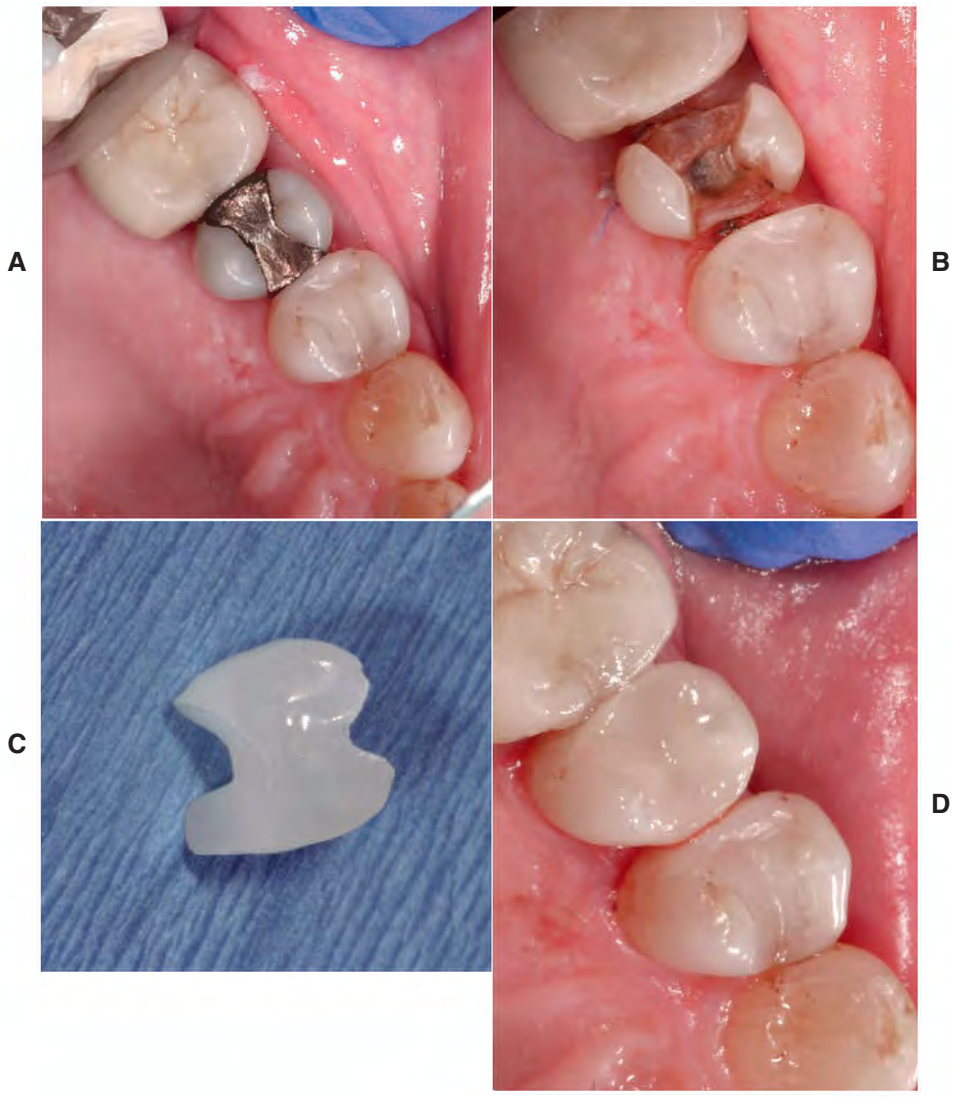

FIGURE 11-10 ■ **A,** Large mesial-occlusal–distal (MOD) amalgam restoration on a maxillary premolar that had to be replaced. **B,** Defective restoration and caries removed. **C,** Leucite-reinforced ceramic restoration milled after CEREC Omnicam scan (see Chapters 14 and 25). **D,** Bonded restoration. (Courtesy Dr. James L. Schmidt.)

FIGURE 11-11 ■ Armamentarium for the ceramic inlay preparation.

Margin Design

6. Use a 90-degree butt joint for ceramic inlay margins. Beveled margins are contraindicated because bulk is needed to prevent fracture. A distinct heavy chamfer margin is recommended for ceramic onlay margins.

Finishing

7. Refine the margins with finishing burs and hand instruments, trimming back any glass ionomer base. Margins in enamel must be smooth and distinct for a ceramic restoration to fit accurately.

Occlusal Clearance (for Onlays)

8. Check the occlusal clearance after the rubber dam is removed. Clearance must be a minimum of 1.5 mm to prevent fracture in all excursions. This can be easily evaluated by measuring the thickness of the resin interim restoration with a dial caliper.

Evaluation

9. On completion, verify that minimally desired clearance has been achieved to ensure adequate material thickness. Undercuts should be avoided, although minor undercuts may occasionally be blocked out. A cervico-occlusal wall divergence of approximately 10 to 12 degrees is consistent with guidelines for cast inlays and onlays and will allow excellent visual access to facilitate optical capture. Isthmus width

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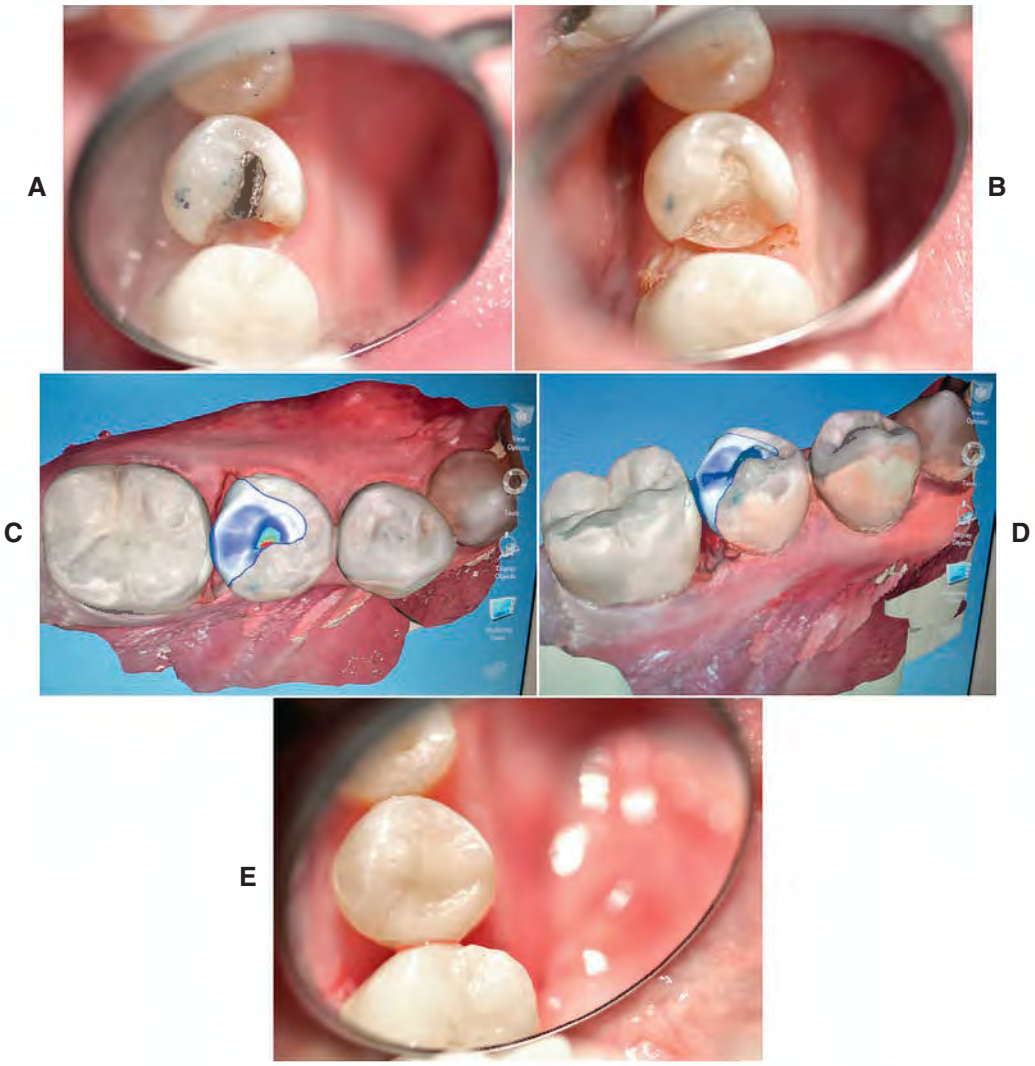

FIGURE 11-12 ■ Mandibular first premolar ceramic inlay. **A,** Defective restoration and caries. **B,** Preparation for disto-occlusal inlay. **C** and **D,** Computer-aided designs of occlusal and buccal views of proposed ceramic restoration. **E,** Bonded definitive restoration. (Courtesy Dr. James L. Schmidt.)

should be at least 2 mm to reduce fracture risk[7] (Fig. 11-12).

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PORCELAIN LAMINATE VENEERS

Laminate veneering (Fig. 11-13) is a conservative method of restoring the appearance of discolored, pitted, or fractured anterior teeth. It consists of bonding thin ceramic laminates onto the labial surfaces of affected teeth. The bonding procedure is the same as that for ceramic inlays except that a photopolymerizing luting resin is usually used (see Chapter 30).

Advantages and Indications

The main advantage of laminate veneers is that they are conservative of tooth structure. Typically, only about 0.5 mm of labial reduction is needed. Because this is confined to the enamel layer, local anesthesia is not usually required. The main disadvantage of the procedure relates to difficulty in obtaining restorations that are not excessively contoured. This is almost inevitable in the gingival area if enamel is left for bonding. Little has been reported about the effect of the restorations on long-term gingival health or how often they need replacement over a patient's lifetime.

Esthetic veneers should always be considered as a conservative alternative to cemented crowns. In many practices, they have largely replaced metal-ceramic crowns in the treatment of multiple discolored but otherwise sound anterior teeth. Extensive existing restorations are a contraindication to porcelain laminate veneers.

Preparation

Armamentarium

The instruments needed for preparing a porcelain laminate veneer include the following:

- 1-mm round bur or 0.5-mm depth cutter
- Narrow, round-ended, tapered diamonds, regular and coarse grit (0.8 mm)

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FIGURE 11-13 ■ Esthetic labial veneers. **A** and **B,** Unesthetic maxillary incisors with crowding. The 50-year-old patient was not prepared to pursue an orthodontic option. **C,** Diagnostic waxing to optimal incisor form. **D,** Vacuum-formed matrix used to place interim restoration resin directly on the unprepared teeth to simulate the definitive esthetics. **E,** Tooth preparations. **F,** Restorations in place.

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FIGURE 11-14 ■ Porcelain facial veneer preparation. **A,** The proximal contact areas and incisal edge are preserved, and the preparation is limited to enamel. Normally, a reduction depth of about 0.5 mm is recommended, but making a series of depth holes with a round bur guards against penetrating thin enamel. **B,** Tetracycline-stained teeth. Composite resin veneers were placed earlier but failed to mask the discoloration satisfactorily. Six maxillary porcelain labial veneers would be provided. **C** and **D,** Completed tooth preparations. **E,** Interim restorations made directly with composite resin, which are retained by etching small areas of enamel (see Chapter 15).

- Finishing strip
- Finishing stones
- Mirror
- Periodontal probe
- Explorer

Step-by-Step Procedure

The gingival third and proximal line angles are often overcontoured with these restorations Therefore, maximum reduction should be achieved with minimum penetration into the dentin (Figs. 11-14 and 11-15).

1. The use of a self-limiting rotary instrument is a practical way to make initial depth grooves while avoiding undesired penetration of abnormally thin enamel. The amount of reduction required depends to some degree on the extent of discoloration. A minimum of 0.5 mm is usually adequate. The reduction should follow the anatomic contours of the tooth. Where the labial contour of the tooth requires alteration, a carefully made putty reduction guide from the diagnostic waxing is essential for determining optimum reduction (Fig. 11-16).
2. Place the long chamfer margin while removing the islands of remaining tooth structure between the depth grooves (Fig. 11-17). This design has an obtuse cavosurface angle, which exposes the enamel prism ends at the margin for better etching. The margin should closely follow the gingival crest so that all discolored enamel prisms are veneered without undue encroachment on the gingival sulcus.
3. Wherever possible, place the preparation margin labial to the proximal contact area to preserve it in enamel. However, slight clearance is essential for separating the definitive cast and for accessing the proximal margins for finishing and polishing. A diamond finishing strip helps create the necessary clearance. Sometimes the proximal margins are extended lingually to include existing restorations. This can necessitate considerable tooth reduction to avoid creating an undercut. Some authorities advocate placing the ceramic margin on composite resin material rather than extending the preparation to enamel.
4. It is preferable not to reduce the incisal edge (Fig. 11-18), although it cannot always be avoided; keeping it helps support the porcelain and makes chipping less likely. If the incisal edge length is to be altered or increased, the preparation should extend to the lingual aspect. Care is needed to avoid undercuts with this modification. Visualizing the path of placement of the restoration is important because an undercut prevents placement of the veneer.
5. To prevent areas of stress concentration in the porcelain, be sure that all prepared surfaces are rounded.

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FIGURE 11-15 ■ **A,** Patient's smile before treatment with porcelain laminate veneers. **B,** Incisal view of the maxillary teeth to be veneered. **C,** Application of 0.5-mm depth cuts. **D,** Reduction of depth cuts with chamfer-ended diamond. **E,** Facial reduction complete. **F,** A 1.5-mm incisal reduction. **G,** "Elbow" preparation to the proximal contact. **H,** Interproximal stripping with diamond strip. **I,** Horizontal seating groove. **J,** Finished preparations, facial view. **K,** Lateral view of finished preparations. **L,** Incisal view of finished preparations. (Courtesy Dr. Ross Nash. In Freedman G: Contemporary esthetic dentistry. St. Louis, Mosby, 2012.)

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FIGURE 11-16 ■ **A,** A putty reduction guide is essential for ensuring adequate and uniform porcelain thickness for veneers if the labial contours require modification. **B,** Maxillary incisors prepared for porcelain laminate veneers. (Courtesy Dr. R.D. Douglas.)

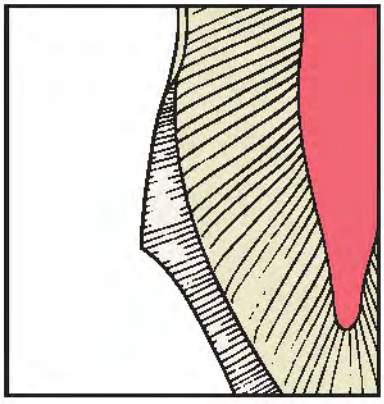

FIGURE 11-17 ■ The recommended margin (long chamfer) for facial veneers has an obtuse cavosurface angle, and so the ends of the enamel prisms are exposed for differential etching.

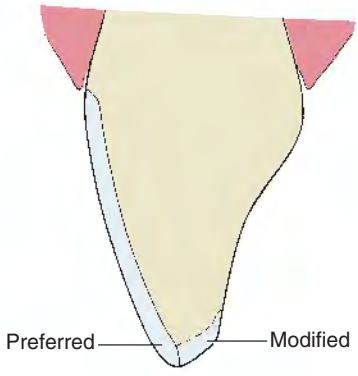

FIGURE 11-18 ■ The preferred design for porcelain laminate veneers maintains part of the incisal edge in enamel. If the edge is to be lengthened, a modified preparation with lingual extension is needed *(dashed line).*

REFERENCES

1. Stoll R, et al. Survival of inlays and partial crowns made of IPS Empress after a 10-year observation period and in relation to various treatment parameters. Oper Dent 21:262, 2007.
2. Krämer N, Frankenberger R: Clinical performance of bonded leucite-reinforced glass ceramic inlays and onlays after eight years. Dent Mater 21:262, 2005.
3. Otto T, De Nisco S: Computer-aided direct ceramic restorations: a 10-year prospective clinical study of Cerec CAD/CAM inlays and onlays. Int J Prosthodont 15:122, 2002.
4. Federlin M, et al: Controlled, prospective clinical split-mouth study of cast gold vs. ceramic partial crowns: 5-year results. Am J Dent 23:161, 2010.
5. Beier US, et al: Clinical long-term evaluation and failure characteristics of 1,335 all-ceramic restorations. Int J Prosthodont 25:70, 2012.
6. Heymann H, et al: Sturdevant's art and science of operative dentistry, 6th ed, p 287. St. Louis, Mosby, 2013.
7. Addi S, et al. Interface gap size of manually and CAD/CAM-manufactured ceramic inlays/onlays in vitro. J Dent 30:53, 2002.

STUDY QUESTIONS

1. What are the indications for and contraindications to all-ceramic crowns and porcelain laminate veneers?
2. What are the advantages and disadvantages of all-ceramic crowns and porcelain laminate veneers?
3. What is the recommended armamentarium, and in what sequence should a maxillary central incisor be prepared, for an all-ceramic crown and a porcelain laminate veneer?
4. What are the minimal criteria for steps 1 to 3? Why?
5. For ceramic inlays and onlays, discuss their advantages, disadvantages, indications, and contraindications.
6. What is the recommended armamentarium, and in what sequence should a mandibular molar be prepared, for a ceramic inlay and onlay?
7. What are the minimal criteria for steps 5 and 6? Why?

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SUMMARY CHART

All-Ceramic Crown Preparation

Indications	Contraindications	Advantages	Disadvantages
• High esthetic requirement • Considerable proximal caries • Incisal edge reasonably intact • Endodontically treated teeth with post and cores • Favorable distribution of occlusal load	• When superior strength is warranted and metal-ceramic crown is more appropriate • Extensive caries • Insufficient coronal tooth structure for support • Thin teeth faciolingually • Unfavorable distribution of occlusal load • Bruxism	• Esthetically unsurpassed • Good tissue response even for subgingival margins • Slightly more conservative of facial wall than metal-ceramic restorations • — • — • —	• Reduced strength in comparison with metal-ceramic crown • Proper preparation extremely crucial • Among least conservative preparations • Brittle nature of material • Can be used only as single restoration • —

SUMMARY CHART

Ceramic Inlay and Onlay Preparation

Indications	Contraindications	Advantages	Disadvantages
• Demand for esthetics • Low caries rate • Intact buccal and lingual enamel	• Extensive caries • Poor plaque control • Bruxism	• Superior esthetics • Conservation of tooth structure • Durable	• Abrasive of opposing tooth • Occlusion difficult to adjust • Wear of luting agent • Expensive • Long-term success rate unknown

SUMMARY CHART

Porcelain Laminate Veneers

Indications	Contraindications	Advantages	Disadvantages
• Discolored or damaged anterior teeth	• Extensive caries • Poor plaque control • Extensive existing restorations • Bruxism	• Superior esthetics • Wear and stain resistant • — • —	• Increased tooth contour • Expensive • — • —

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Preparation Steps	Recommended Armamentarium	Criteria
Depth grooves for incisal reduction	Tapered diamond	Approximately 1.3 mm deep to allow for additional reduction during finishing; perpendicular to long axis of opposing tooth
Incisal reduction	Tapered diamond	Clearance of 1.5 mm; check excursions
Depth grooves for facial reduction	Tapered diamond	Depth of 0.8 mm needed for additional reduction during finishing
Labial reduction	Tapered diamond	Reduction of 1.2 mm needed; two planes, as for metal-ceramic crown preparation
Depth grooves and lingual reduction	Tapered and football-shaped diamonds	Initial depth, 0.8 mm; recreate concave configuration; do not maintain any convex configurations (stress)
Depth grooves for cingulum reduction	Tapered diamond	Parallel to cervical aspect of facial preparation; 1 mm of reduction; shoulder margin follows free gingival margin
Depth grooves and lingual reduction	Square-ended diamond	Rounded shoulder margin 1 mm wide; minimize "peaks and valleys"; 90-degree cavosurface angle
Depth grooves for cingulum reduction	Fine-grit diamond or carbide	All surfaces smooth and continuous; no unsupported enamel; 90-degree cavosurface angle
Lingual shoulder margin preparation		
Finishing		

Preparation Steps	Recommended Armamentarium	Criteria
Outline	Tapered carbide	Includes existing restorations and caries; about 1.8 mm deep; small undercuts tolerated
Proximal box	Tapered carbide	Gingival floor 1 mm wide
Caries removal	Excavator or round bur	Clearance for impression: 0.6 mm
Margins	Finishing burs	Block out undercuts with glass ionomer
Occlusal clearance	Hand instruments	90-degree butt joint
Finishing	Round-ended diamond Finishing burs Fine-grit diamonds	Heavy chamfer margin for onlays Clearance in all excursions of 1.5 mm Rounded internal angles Smooth margins

Preparation Steps	Recommended Armamentarium	Criteria
Depth cuts	1-mm round bur or 0.5-mm depth cutter	A series of depth cuts to determine dentin exposure
Labial reduction	Round-ended diamond	Follows curvature of original tooth surface
Proximal reduction	Round-ended diamond	Extended to gingival crest, leaving contact area intact
Incisal and lingual reduction	Round-ended diamond	None unless incisal margin is extended to lingual to allow lengthening
Margins	Round-ended diamond	Long chamfer margin
Finishing	Fine-grit diamonds, carbides, or finishing stones	No sharp internal margins

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CHAPTER 12

Restoration of the Endodontically Treated Tooth

An endodontically treated tooth should have a good prognosis. It can resume full function and serve satisfactorily as an abutment for a fixed or removable dental prosthesis. However, special techniques are needed to restore such teeth. Usually a considerable amount of tooth structure has been lost because of caries, the placement of previous restorations, and the endodontic treatment. This loss of tooth structure complicates subsequent restoration and increases the likelihood of fracture during function.

Two factors influence the choice of technique: the type of tooth (whether it is an incisor, a canine, a premolar, or a molar) and the amount of remaining coronal tooth structure. The latter is probably the most important indicator of prognosis.

A number of different clinical techniques have been proposed to solve these problems, and opinions and preferences vary. Experimental data have improved the understanding of the difficulties inherent in restoring endodontically treated teeth. This chapter offers a rational and practical approach to the challenge.

TREATMENT PLANNING

Because of extensive caries or periodontal disease, tooth removal may make more sense than treating it endodontically, although such a severely damaged tooth occasionally can be restored after orthodontic repositioning or root resection (Fig. 12-1; see also Fig. 16-7). This should be done if loss of the tooth will significantly jeopardize the patient's occlusal function or the total treatment plan, particularly when dental implants are not an option. The decision to treat the tooth endodontically can be made only after its restorability has been confirmed. Before being restored, teeth that have been endodontically treated must be evaluated carefully for the following[1]:

- Good apical seal
- No sensitivity to pressure
- No exudate
- No fistula
- No apical sensitivity
- No active inflammation

Inadequate root fillings should be re-treated before fixed prosthodontic treatment is begun. If any doubt about their adequacy remains, or if the tooth remains sensitive after such re-treatment, it should be observed for several months until there is definite evidence of success or failure of treatment.

If the coronal structures are largely intact and loading is favorable, as on anterior teeth that are farther removed from the fulcrum than are molars (see Chapter 4), a simple filling can be placed in the access cavity (Fig. 12-2, *A*). However, if a substantial amount of coronal structure is missing, a cast post and core restoration is indicated instead (see Fig. 12-2, *B*). Molars are often restored with amalgam or composite resin, and a post is rarely needed (see Fig. 12-2, *C* and *D*).

Although one-piece post crowns were once made, such prostheses are of only historical interest, although the idea has been reintroduced for the restoration of posterior teeth with computer-aided design and computer-aided manufacturing (CAD/CAM) ceramic restorations.[2] Typically, dentists use a two-step technique (Fig. 12-3) consisting of initial placement of a post and core foundation restoration, followed by placement of a separately fabricated crown. In the past, a metal post was used most often, although esthetic concerns have increased the use of tooth-colored glass fiber and zirconia ceramic posts,[3,4] which provide the necessary retention for the core. The core replaces any lost coronal tooth structure, enabling optimal tooth preparation geometry. Thus the shape of the residual coronal tooth structure, in combination with the core, should result in an ideal shape for the preparation design that was selected (Fig. 12-4).

Typically, prefabricated posts are used in a two-step procedure in conjunction with a plastic material such as composite resin, glass ionomer, or amalgam: First the post is cemented; then the selected core material is applied. After shaping of the core and remaining tooth structure to optimal crown preparation form, an impression is made and a crown fabricated.

A cast post and core restoration needs to be slightly undersized in comparison with the canal to achieve optimal internal seating; a crown, in contrast, needs to be slightly larger to achieve optimal seating (see Chapter 7). Thus the two-step technique simplifies achieving a satisfactory marginal adaptation because the expansion rate of the two castings can be controlled individually. An added benefit is that it is possible to fabricate a replacement crown, if necessary, without the need for post removal, which can be extremely difficult and can jeopardize the prognosis of the tooth. Finally, making a post and core restoration and a separate crown allows selection of a path of placement for the crown that is different from the one selected for the post and core restoration. This is often helpful when the tooth is restored to serve as an abutment for a fixed dental prosthesis (FDP).

Clinical Failure

Because of morphologic and functional differences between anterior teeth and posterior teeth, they must be

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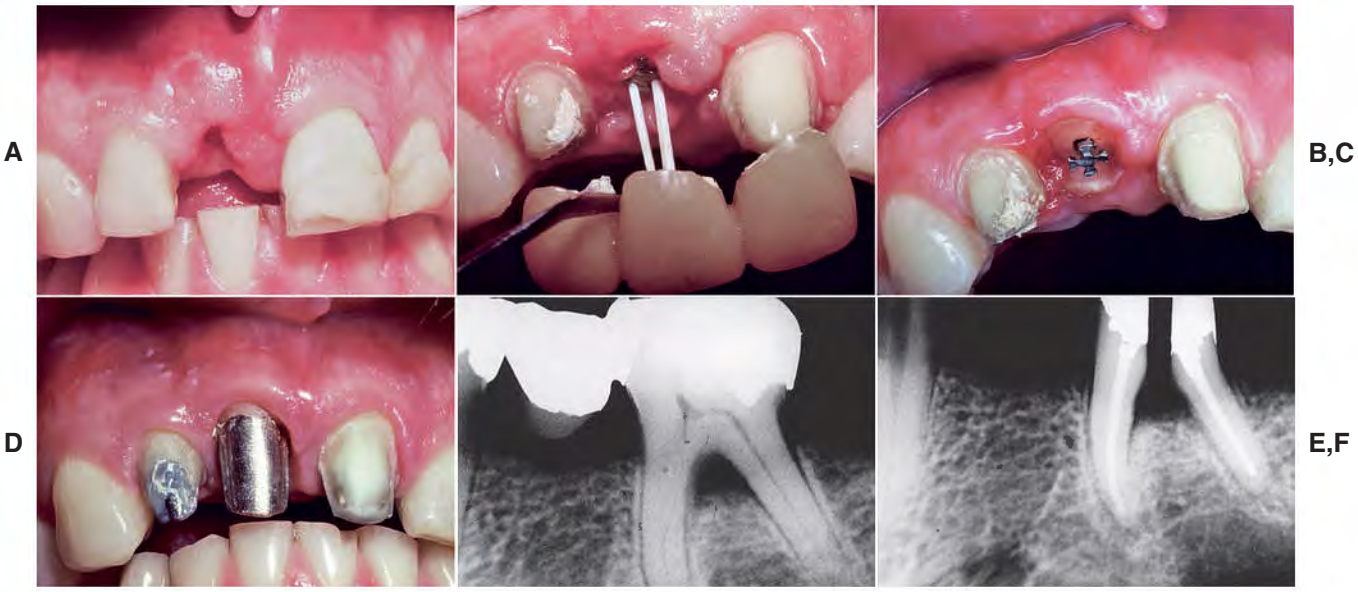

FIGURE 12-1 ■ **A** and **B,** A severely damaged tooth can sometimes be retained after orthodontic extrusion (see Chapter 6). **C,** Post with retentive head fitted. Elastics were used to extrude the tooth. **D,** Cast post and core placed on extruded root. **E** and **F,** Plaque control around periodontally compromised teeth may be improved after hemisectioning (see Chapter 5). (**E** and **F,** Courtesy Dr. H. Kahn.)

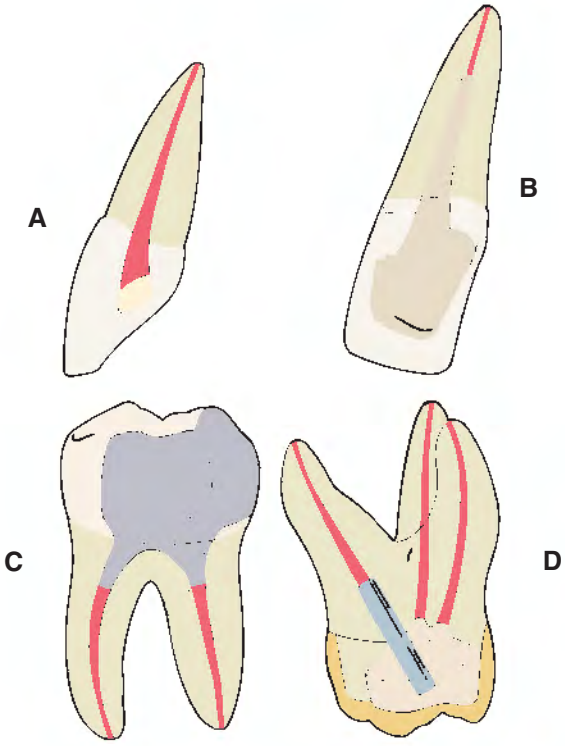

FIGURE 12-2 ■ **A,** An anterior tooth with an intact clinical crown can be predictably restored with a composite restoration in the access cavity. **B,** When most coronal tissue is missing, a cast post and core restoration is indicated to obtain optimal tooth preparation form. **C** and **D,** In molars, a composite resin or amalgam foundation is used. Additional retention from posts is rarely needed in molars.

FIGURE 12-3 ■ The first molar and second premolar have post and core restorations. Note the margins, optimally located on sound tooth structure, cervical to the castings.

FIGURE 12-4 ■ The second premolar has been restored with a cast post and core restoration, in preparation for a metal-ceramic crown. (Courtesy Dr. R. Webber.)

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treated differently after endodontic therapy, mainly because different loading considerations apply.

In one retrospective analysis[5] involving 638 patients, investigators evaluated 788 post and core restorations: 456 custom cast post and core restorations and 332 foundations restored with prefabricated ParaPosts. Four to five years after cementation, reported failure rates were significantly higher in male patients than in female patients, and failure rates were three times higher in patients older than 60 than for younger patients. Maxillary failure rates (15%) were three times as high as mandibular failure rates (5%) and more prevalent in lateral incisors, canines, and premolars than in central incisors and molars. The failure rate of restorations under FDPs was significantly lower than that of restorations under single crowns. The latter finding may have been caused by load reduction resulting from bracing by the FDP. No correlation was apparent between failure and reduced marginal height of the encasing bone. Custom cast post and core restorations exhibited slightly higher failure rates than did amalgam foundations. This observation was also made by Sorensen and Martinoff.[6] However, Torbjörner and colleagues[5] suggested that custom cast post and core restorations tend to be used more often in teeth that already have considerably weakened root structure. Therefore, regardless of the technique selected for subsequent restoration, the teeth themselves probably are already more prone to failure. Distal cantilevers appear to contribute to failure of a post and core restoration in endodontically treated abutment teeth that support the cantilever.

Most of the failures just discussed are influenced by load. In general, as loading increases, failure rates appear to increase concomitantly. Failure has been shown to occur at lower loads as teeth are loaded obliquely, rather than parallel to their long axes.[7] This suggests that clinical failure occurs more readily under lateral loading. The choice of post material will influence the clinical failure rates: Glass fiber posts have somewhat higher failure rates than do metal posts.[8]

In the planning of the restoration of endodontically treated teeth, the practitioner must account for the strength of the remaining tooth structure, comparing it carefully against the load to which the restored tooth will be subjected.

Considerations for Anterior Teeth

Endodontically treated anterior teeth do not always need a complete crown, except when the size of plastic restorative materials limits their prognosis (e.g., if the tooth has large proximal composite restorations and unsupported labial tooth structure). Many otherwise intact teeth function satisfactorily with a composite resin restoration (see Fig. 12-2, *A*).

Although it is commonly believed that endodontically treated teeth are weaker or more brittle than vital teeth, this has not been demonstrated experimentally. However, their moisture content may be reduced.[9] Laboratory testing[10] has actually revealed that untreated and endodontically treated anterior teeth are similarly resistant to fracture. Nevertheless, clinical fracture does occur, and attempts have been made to strengthen the tooth by removing part of the root canal filling and replacing it with a metal post. In reality, placement of a post requires the removal of additional tooth structure (Box 12-1), which actually weakens the tooth.

Cementing a post in an endodontically treated tooth to enhance its prognosis is a fairly common clinical procedure, despite the paucity of data to support its success. In fact, one laboratory study[11] and two stress analyses[12,13] revealed that no significant reinforcement results. This might be explained by the hypothesis that when the tooth is loaded, stresses are greatest at the facial and lingual surfaces of the root, and an internal post, being only minimally stressed, does not help prevent fracture (Fig. 12-5). Results of other studies, however, contradict this assumption.[10,14] Cemented posts may further limit or complicate endodontic re-treatment options, if these are necessary, because of the difficulties encountered in removing them. In addition, if additional coronal destruction occurs after the post is cemented, post removal may be necessary to provide adequate support for a future core.

BOX 12-1 Disadvantages to the Routine Use of a Cemented Post

- Placing the post requires an additional operative procedure.
- Preparing a tooth to accommodate the post entails removal of additional tooth structure.
- It may be difficult to restore the tooth later, when a complete crown is needed, because the cemented post may have failed to provide adequate retention for the core material.
- The post can complicate or preclude future endodontic re-treatment that may be necessary.

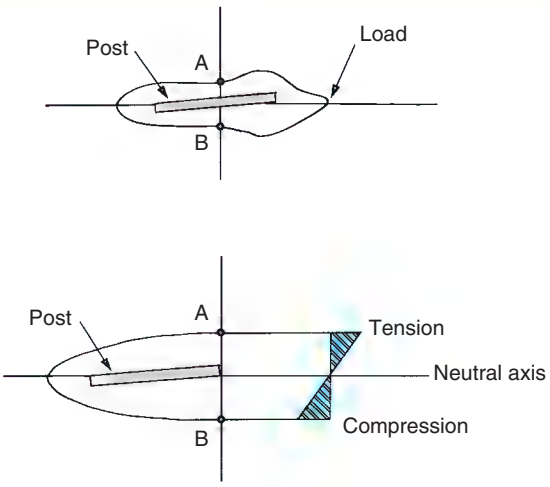

FIGURE 12-5 ■ Experimental stress distributions in an endodontically treated tooth with a cemented post. When the tooth is loaded, the lingual surface **(A)** is in tension, and the buccal surface **(B)** is in compression. The centrally located cemented post lies in the neutral axis (i.e., is not in tension or compression). (Redrawn from Guzy GE, Nicholls JI: In vitro comparison of intact endodontically treated teeth with and without Endo-Post reinforcement. J Prosthet Dent 42:39, 1979.)

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For these reasons, a metal post is not recommended in anterior teeth that do not require complete crowns. This is supported by results of a retrospective study[15] that did not show any improvement in prognosis for endodontically treated anterior teeth restored with a post. In another study, post placement did not influence the position or angle of radicular fracture.[16] A conflicting report, however, suggests that endodontically treated teeth not crowned after obturation were lost six times more frequently than teeth that were crowned after obturation.[17]

Discoloration in the absence of significant tooth loss may be more effectively treated by bleaching[18] than by the placement of a complete crown, although not all stained teeth can be bleached successfully. Resorption can be an unfortunate side effect of nonvital bleaching.[19] However, when loss of coronal tooth structure is extensive or the tooth will be serving as an abutment for an FDP or for a partial removable dental prosthesis, a complete crown is mandatory. Retention and support then must be derived from within the canal, because a limited amount of coronal dentin remains once the reduction for complete coverage has been completed. This outcome, coupled with the loss of internal tooth structure necessary for endodontic treatment, causes the remaining walls to become thin and fragile (Fig. 12-6), which often necessitates substantial reduction in height.

Considerations for Posterior Teeth

Posterior teeth are subject to greater loading than are anterior teeth because they are closer to the transverse horizontal axis. This, combined with their morphologic characteristics (having cusps that can be wedged apart), makes them more susceptible to fracture. Careful occlusal reshaping reduces potentially damaging lateral forces during excursive movements. Nevertheless, endodontically treated posterior teeth should receive cuspal coverage to prevent biting forces from causing fracture. Possible exceptions are mandibular premolars and first molars with intact marginal ridges and conservative access cavities not subjected to excessive occlusal forces (i.e., posterior disclusion in conjunction with normal muscle activity).

Complete coverage is recommended on teeth with a high risk of fracture. This is especially true for maxillary premolars, which have been shown to have fairly high failure rates if two or three surfaces are restored with amalgam.[20] Complete coverage gives the best protection against fracture because the tooth is completely encircled by the restoration. However, when a metal-ceramic crown is to be used, considerable additional buccal tooth reduction is required, which results in further weakening of the remaining tooth structure. In general, when significant coronal tooth loss has occurred, a cast post and core restoration (Fig. 12-7) or an amalgam foundation restoration is needed.

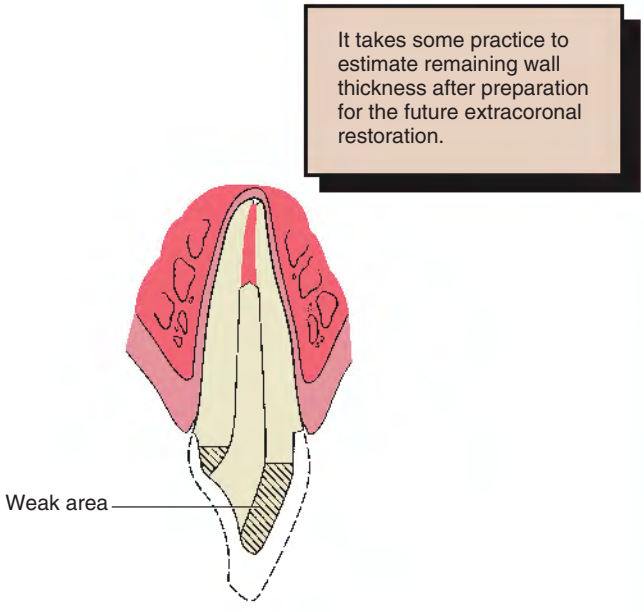

FIGURE 12-6 ■ Cross section through a central incisor. The *dashed line* indicates the original tooth contour before preparation for a metal-ceramic restoration. Even with minimum reduction for the extracoronal restoration, the buccal wall is weakened and would not be able to support a prosthesis successfully. The sharp lingual wall would complicate pattern fabrication.

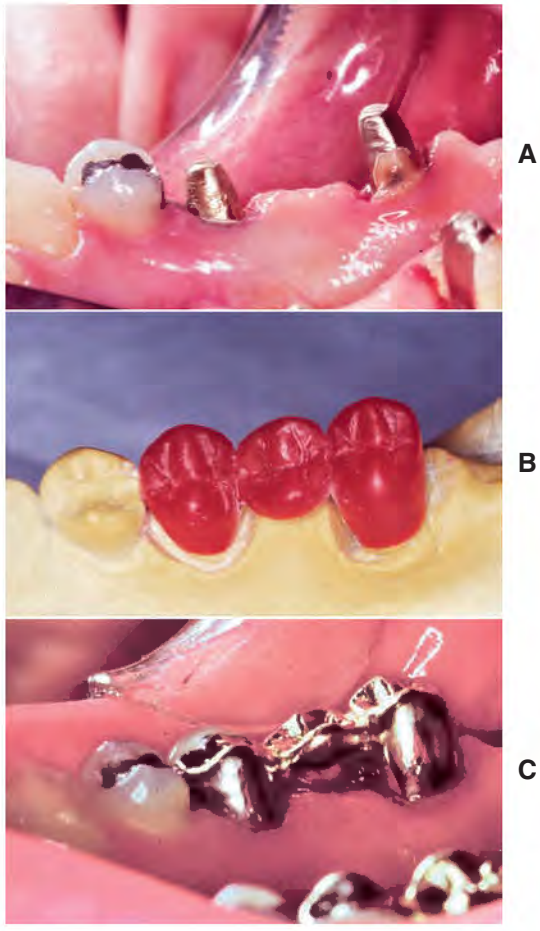

FIGURE 12-7 ■ **A,** Mandibular premolar and hemisected molar with cast post and core restorations. **B,** Waxed three-unit fixed dental prosthesis (FDP). **C,** The FDP cemented in place. (Courtesy Dr. F. Hsu.)

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PRINCIPLES OF TOOTH PREPARATION

Many of the principles of tooth preparation discussed in Chapter 7 apply equally to the preparation of endodontically treated teeth, although certain additional concepts must be understood in order to avoid failure.

Conservation of Tooth Structure

Preparation of the Canal

When post space is created, only minimal tooth structure should be removed from the canal (Fig. 12-8). Excessive enlargement can perforate or weaken the root, which then may split during either cementation of the post or subsequent function. Remaining dentin thickness is the prime variable in fracture resistance of the root. Experimental impact testing of teeth with cemented posts of different diameters[9] showed that teeth with a thicker (1.8-mm) post (thinner dentin walls) fractured more easily than those with a thinner (1.3-mm) one (thicker dentin walls).

Photoelastic stress analysis confirms that internal stresses are reduced with thinner posts. The root can be compared to a ring: The strength of a ring is proportional to the difference between the fourth powers of its internal and external radii. This implies that the strength of a prepared root is derived from its periphery, not from its interior, and so a post of reasonable size should not weaken the root significantly.[21] Nevertheless, it is difficult to enlarge a root canal uniformly and to judge with accuracy how much tooth structure has been removed and how thick the remaining dentin is. Most roots are narrower mesiodistally than faciolingually and often have proximal concavities that cannot be seen on a periapical radiograph. In laboratory testing, most root fractures originate from these concavities where the remaining dentin thickness is minimal.[22] Therefore, the root canal should be enlarged only enough to enable the post to fit accurately while strength and retention are ensured. Along the length of a tapered post space, enlargement seldom needs to exceed what would have been accomplished with one or two additional file sizes beyond the largest size used for endodontic treatment. Because of the length of the maintained apical seal, and the consequently more coronal position of the post space, a file size much larger than that used during the endodontic treatment must be used to accomplish this (Fig. 12-9).

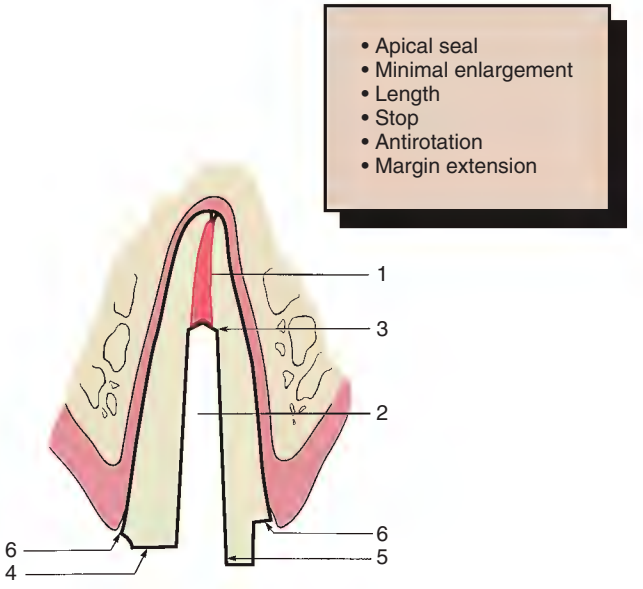

FIGURE 12-8 ■ Faciolingual cross section through a maxillary central incisor prepared for a post and core restoration. Six features of successful design are identified: *1,* adequate apical seal; *2,* minimum canal enlargement (no undercuts remaining); *3,* adequate post length; *4,* positive horizontal stop (to minimize wedging); *5,* vertical wall to prevent rotation (similar to a box); and *6,* extension of the final restoration margin onto sound tooth structure.

Preparation of Coronal Tissue

Endodontically treated teeth often have lost much coronal tooth structure for several reasons: as a result of caries, because of the size of previously placed restorations, or in the preparation of the endodontic access cavity. However, if a cast core is to be used, further reduction is needed internally to remove undercuts from the chamber and internal walls to accommodate the post and core restoration and externally to accommodate a complete crown. This may leave tall thin walls and very little coronal dentin. Every effort should be made to save as much of the coronal tooth structure as possible because this helps reduce stress concentrations at the gingival margin.[23] The amount of remaining tooth structure is probably the most important predictor of clinical success. However, when a cast post and core restoration is planned, such walls must have adequate structural integrity to prevent their fracture during the try-in and evaluation of the cast post and core restoration. Often, this means that the walls must be shortened to ensure strength. If more than 2 mm of coronal tooth structure remains, the post design probably has a limited role in the fracture resistance of the restored tooth.[24,25] Coronal reduction to the gingival level before fabrication of a post and core

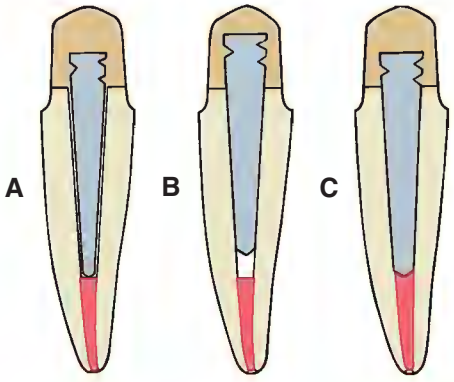

FIGURE 12-9 ■ Use of a prefabricated post entails enlarging the canal one or two file sizes to obtain a good fit at a predetermined depth. **A,** Incorrect; the prefabricated post is too narrow. **B,** Incorrect; the prefabricated post does not extend to the apical seal. **C,** Correct; the prefabricated post is fitted by enlarging the canal slightly.

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FIGURE 12-10 ■ **A,** It is preferable to maintain as much coronal tooth structure as possible, if it is sound and of reasonable strength. **B,** Extensive caries has resulted in the loss of all coronal tooth structure. This is less desirable than the situation in **A** because greater forces are transmitted to the root.

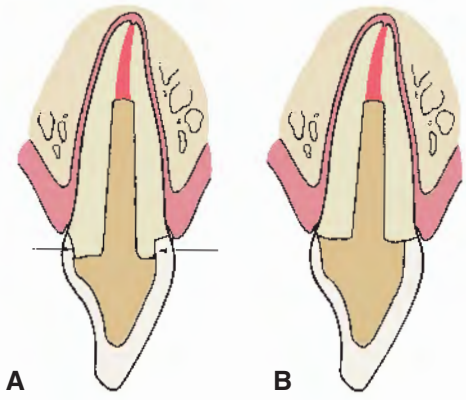

FIGURE 12-11 ■ Extending a preparation apically creates a ferrule and helps prevent fracture of an endodontically treated tooth during function. **A,** Preparation with a ferrule *(arrows).* **B,** Preparation without a ferrule.

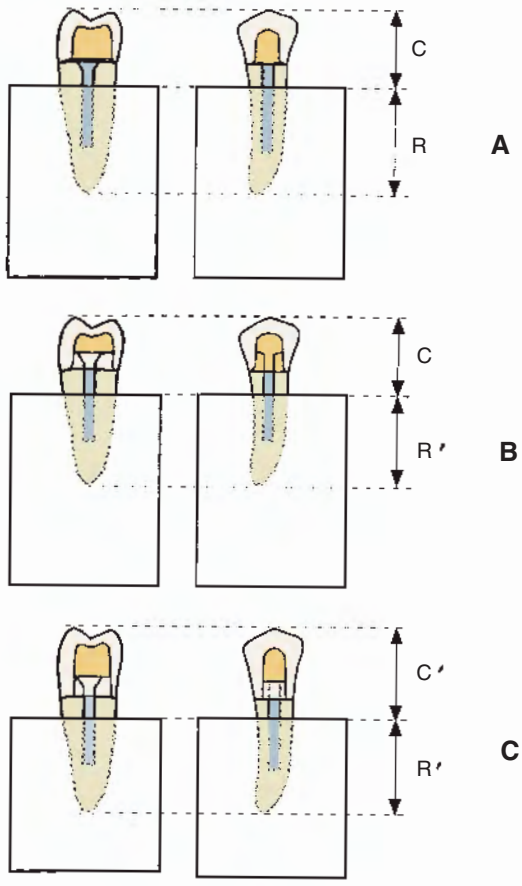

FIGURE 12-12 ■ Effect of apical preparation on crown-to-root ratio. **A,** Schematic of extensively damaged premolar tooth. Apical extension of the gingival margin would encroach on the biologic width (see Chapter 5). This preparation has no ferrule. *C,* crown length; *R,* root length. **B,** Creating a ferrule with orthodontic extrusion reduces root length *(R′),* whereas crown length remains unchanged. **C,** Surgical crown lengthening (see Fig. 6-21) also reduces root length *(R′)* but increases crown length *(C′).* This results in a much less favorable crown-to-root ratio, which may, in fact, weaken the restoration. (Courtesy Dr. A.G. Gegauff. From Gegauff AG: Effect of crown lengthening and ferrule placement on static load failure of cemented cast post-cores and crowns, J Prosthet Dent 84:169, 2000.)

restoration, once common and routine, is poor practice and should be avoided (Fig. 12-10). Extension of the axial wall of the crown apical to the missing tooth structure provides what is known as a restoration with a *ferrule*, which is defined as a metal band or ring used to fit the root or crown of a tooth (Fig. 12-11), as opposed to a crown that merely encircles core material. This is thought to help bind the remaining tooth structure together, while simultaneously preventing root fracture during function.[26-28] Although there is evidence that preserving as much coronal tooth structure as possible enhances prognosis, it is less clear whether the prognosis is improved by creation of a ferrule in an extensively damaged tooth through a surgical crown-lengthening procedure. In this latter circumstance, although the crown lengthening allows fabrication of a crown with a ferrule, it also leads to a much less favorable crown-to-root ratio and therefore to increased leverage on the root during function (Fig. 12-12).

One laboratory study showed that creating a ferrule through surgical crown lengthening resulted in a weaker, rather than a stronger, restored tooth.[29] In comparison, creating a ferrule with orthodontic extrusion may be preferred because even though the root is effectively shortened, the crown is not lengthened (see Fig. 12-12, *B*) which results in a more favorable crown-to-root ratio.

Retention Form

Anterior Teeth

An anterior crown and the post and core restoration that retains it are frequently dislodged simultaneously as a result of inadequate retention form of the prepared tooth.[15,30] The normal labiolingual convergence of anterior teeth, coupled with smaller tooth size, complicates achieving such retention form. Post retention is affected by the preparation geometry, post length, post diameter, post surface texture, and the luting agent.

Preparation Geometry. Some canals, particularly in maxillary central incisors, have a nearly circular cross section (see Table 12-4). These can be prepared with a

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twist drill or reamer to provide a cavity with parallel walls or minimal taper, which allows the use of a preformed post of corresponding size and configuration. Conversely, canals with elliptical cross sections must be prepared with a restricted amount of taper (usually 6 to 8 degrees) to ensure adequate retention while undesired undercuts are eliminated. This is analogous to an extracoronal preparation (see Chapter 7). With extracoronal preparations, retention increases rapidly as vertical wall taper is reduced (see Chapter 7).

In accordance with this explanation, laboratory testing[31–33] has confirmed that parallel-sided posts are more retentive than tapered posts, whereas threaded posts that actively engage radicular dentin are the most retentive (Fig. 12-13). These comparisons are relevant only if the post fits the root canal properly, however, because retention is proportional to the total surface area.

Circular parallel-sided post systems are effective only in the most apical portion of the post space because the majority of prepared post spaces demonstrate considerable flare in the occlusal half. Similarly, when the root canal is elliptical, a parallel-sided post is not effective unless the canal is considerably enlarged, which would significantly weaken the root unnecessarily (Fig. 12-14).

Although retention can be further increased by use of a threaded post, which screws into dentin, this procedure is not recommended because of residual stress in the dentin. If this procedure is used, however, threaded posts must be "backed off" to ensure passivity; otherwise, the root will fracture.

Post Length. Studies[31,33,34] have shown that as post length increases, so does retention. However, the relationship is not necessarily linear (Fig. 12-15). A post that is too short will fail (Fig. 12-16), whereas one that is too

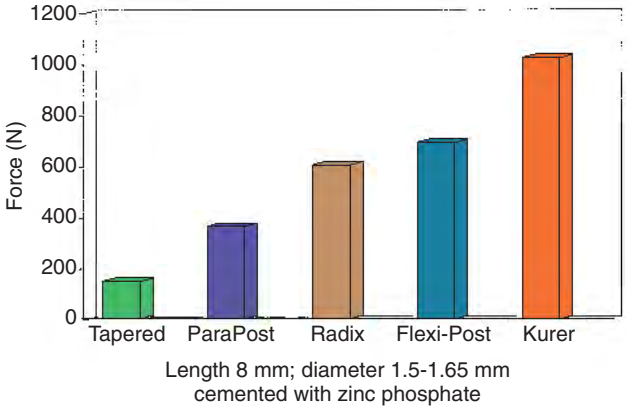

FIGURE 12-13 ■ **Comparison of forces needed to remove different prefabricated post systems.** (Redrawn from Standlee JP, Caputo AA: The retentive and stress distributing properties of split threaded endodontic dowels. J Prosthet Dent 68:436, 1992.)

FIGURE 12-14 ■ **The use of a parallel-sided post in a tapered canal requires considerable enlargement of the post space, which can weaken the root significantly.** (Courtesy Dr. R. Webber.)

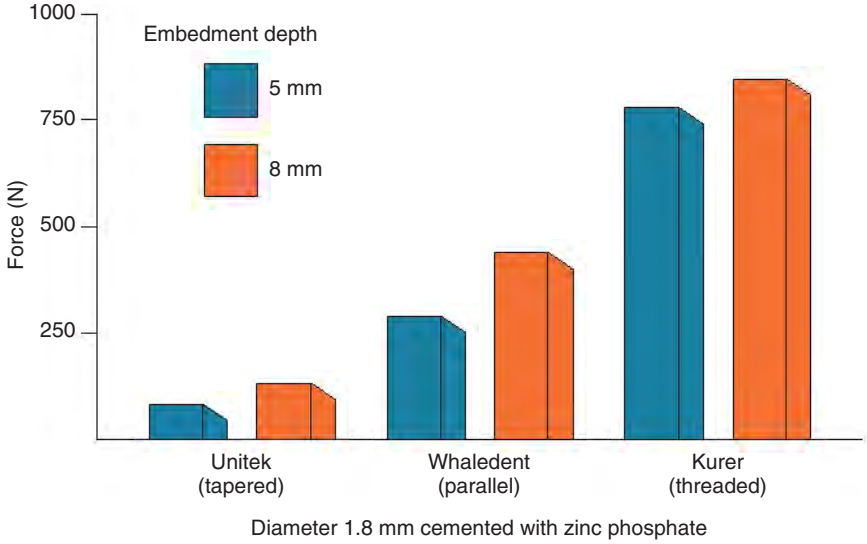

FIGURE 12-15 ■ **Effect of the depth of embedding a post on its retentive capacity.** (Data from Standlee JP, et al: Retention of endodontic dowels: effects of cement, dowel length, diameter, and design. J Prosthet Dent 39:401, 1978.)

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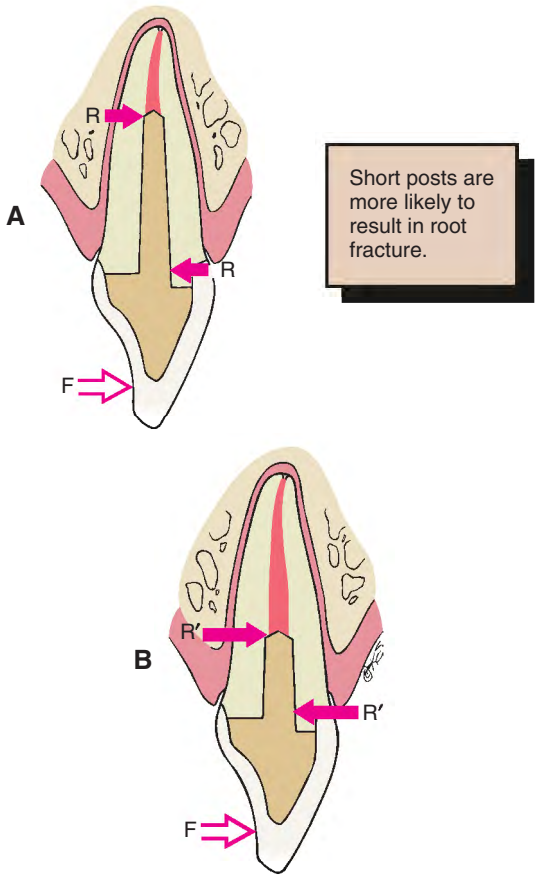

FIGURE 12-16 ■ Labiolingual longitudinal sections through a maxillary central incisor. **A,** With a post of the correct length, a force *(F)* applied near the incisal edge of the crown generates a resultant couple *(R)*. **B,** When the post is too short, this couple is greater *(R′),* which increases the possibility of root fracture.

long may damage the seal of the root canal fill or increase the risk of root perforation if the apical third is curved or tapered (Fig. 12-17). Absolute guidelines for optimal post length are difficult to define (Table 12-1). Ideally, the post should be as long as possible without jeopardizing the apical seal or the strength or integrity of the remaining root structure. Most endodontic texts advocate maintaining a 5-mm apical seal. However, if a post is shorter than the coronal height of the clinical crown of the tooth, the prognosis is considered unfavorable because stress is distributed over a smaller surface area, which increases the probability of root fracture. A short root and a tall clinical crown present the clinician with the dilemma of having to compromise the mechanics, the apical seal, or both. Under such circumstances, a shortened apical seal of a minimum of 3 mm is considered acceptable.

Post Diameter. Increasing the post diameter in an attempt to increase retention is not recommended because retentive gain is minimal and the remaining root is weakened unnecessarily. Although one group of investigators[35] reported that increasing the post diameter increased retention, other reports have not confirmed this.[31,32] Empirical evidence suggests that the overall prognosis is good when post diameter does not exceed one third of the cross-sectional root diameter.

Post Surface Texture. A serrated or roughened post is more retentive than a smooth one,[32] and controlled grooving of the post and root canal[36] (Fig. 12-18) considerably increases the retention of a tapered post.

Luting Agent. With regard to traditional water-based cements, the choice of luting agent seems to have little effect on post retention[37,38] or the fracture resistance of dentin.[39] However, adhesive resin luting agents (see Chapter 30) have the potential to improve the performance of post and core restorations; laboratory studies have shown improved retention.[40,41] Resin cements may be indicated if a post becomes dislodged. Resin cements are affected by eugenol-containing root canal sealers, which should be removed by irrigation with ethanol or by etching with 37% phosphoric acid if the adhesive is to be effective.[42] Resin bonding within the root canal has been shown to be effective but can be expected to decrease over time.[43] Zinc phosphate and glass ionomer have comparable retentive properties, whereas polycarboxylate and composite resin cements have slightly less.[44] Some resin and glass ionomer cements have demonstrated significantly higher retention than resin-ionomer cements,[45] although the choice of luting agent may become more important if the post has a poor fit within the canal.[46] A post and core restoration should be remade if any rocking, rotation, or wobbling is present.

Posterior Teeth

Relatively long posts with a circular cross section provide good retention and support in anterior teeth, but long posts should be avoided in posterior teeth, which often have curved roots and elliptical or ribbon-shaped canals (Fig. 12-19). For these teeth, retention is better provided by two or more relatively short posts in divergent canals.

When amalgam is used as the core material, it can be condensed either around cemented metal posts or directly into short, prepared post spaces. If a reasonable amount of coronal tissue remains, use of a single metal post that is cemented in the largest canal can provide adequate retention for the core material. When more than 3 to 4 mm of coronal tooth structure with reasonable wall thickness remains, use of a post in the root canals for retention is not necessary, and not having to prepare post space reduces the risk of perforation.[47] When a post is not used, the chamber must provide adequate retention for the core material. It may then be advantageous to prepare several short divergent post spaces into which the core material extends. Use of the canals for retention can provide good results,[48] although once a complete crown has been provided, the strength of the tooth is not dramatically influenced by differences in technique.[49]

In mandibular premolars and molars with a reasonable amount of remaining coronal tooth structure, foundation restorations, coupled with a circumferential cervical band

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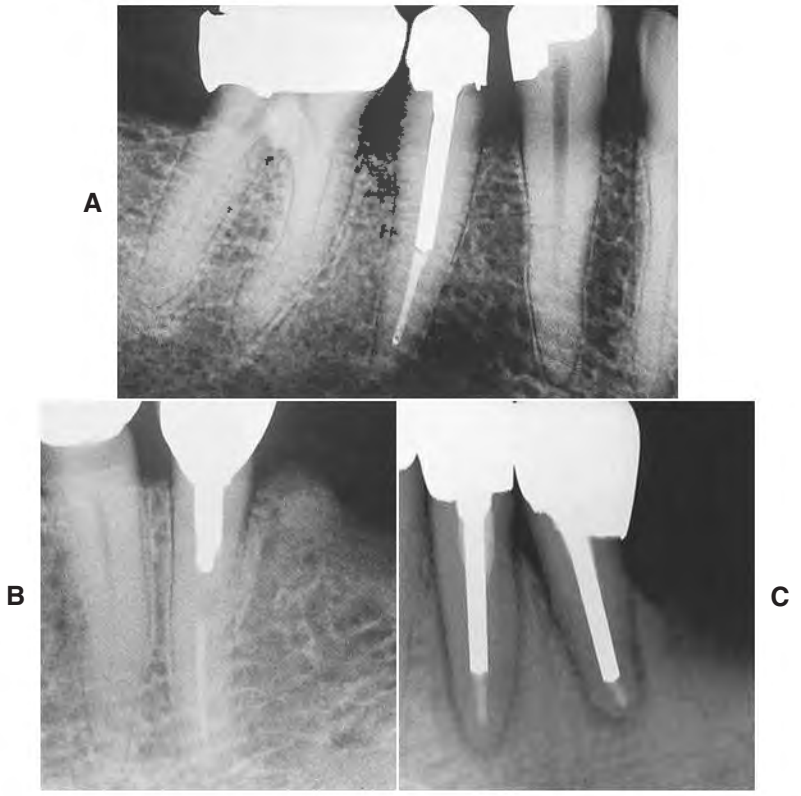

FIGURE 12-17 ■ **A,** Correct post length. **B,** The post is too short; the consequences are inadequate retention and increased risk of root fracture. **C,** These posts are too long, jeopardizing the apical seal.

TABLE 12-1 **Historical Prospective of Post Length**

Post Length	Year	Reference
Should equal the occlusocervical dimension of the crown	1839	Harris C: The dental art, a practical treatise on dental surgery. Baltimore, Armstrong & Berry, 1839.
	1871	Austen PH: The principles and practice of dentistry, including anatomy, physiology, pathology, therapeutics, dental surgery and mechanism, 10th ed. Philadelphia, Lindsay & Blakiston, 1871.
	1940	Tylman SD: Theory and practice of crown and bridge prosthesis. St. Louis, Mosby, 1940.
	1977	Kantor ME, Pines MS: A comparative study of restorative techniques for pulpless teeth. J Prosthet Dent 38:405, 1977.
	1979	Guzy GE, Nicholls JI: In vitro comparison of intact endodontically treated teeth with and without Endo-Post reinforcement. J Prosthet Dent 42:39, 1979.
	1985	Trope M, et al: Resistance to fracture of restored endodontically treated teeth. Endod Dent Traumatol 1:108, 1985.
	1987	Eissmann HF, Radke RA Jr: Postendodontic restoration. In Cohen S, Burns RC, eds: Pathways of the pulp, 4th ed, pp 640-643. St. Louis, Mosby, 1987.
	1989	Ziebert GJ: Restoration of endodontically treated teeth. In Malone WF, et al, eds: Tylman's theory and practice of fixed prosthodontics, 8th ed, pp 407-417. St. Louis, Ishiyaku EuroAmerica, 1989.
	1989	Barkhordar RA, et al: Effect of metal collars on resistance of endodontically treated teeth to root fracture. J Prosthet Dent 61(6):676, 1989.
Two thirds of the root length	1959	Hamilton AI: Porcelain dowel crowns. J Prosthet Dent 9:639, 1959.
	1966	Larato DC: Single unit cast post crown for pulpless anterior tooth roots. J Prosthet Dent 16:145, 1966.
	1967	Christy JM, Pipko DJ: Fabrication of a dual-post veneer crown. J Am Dent Assoc 75:1419, 1967.
	1968	Bartlett SO: Construction of detached core crowns for pulpless teeth in only two sittings. J Am Dent Assoc 77:843, 1968.
	1969	Dewhirst RB, et al: Dowel-core fabrication. J South Calif Dent Assoc 37:444, 1969.
Four fifths of the root length	1984	Sorensen JA, Martinoff JT: Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 51(6):780, 1984.
Ending halfway between crestal bone and apex	1984	Sorensen JA, Martinoff JT: Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 51(6):780, 1984.
	1986	Randow K, Glantz PO: On cantilever loading of vital and non-vital teeth. An experimental clinical study. Acta Odontol Scand 44(5):271, 1986.
	1992	Gutmann JL: The dentin-root complex: anatomic and biologic considerations in restoring endodontically treated teeth. J Prosthet Dent 67:458, 1992.

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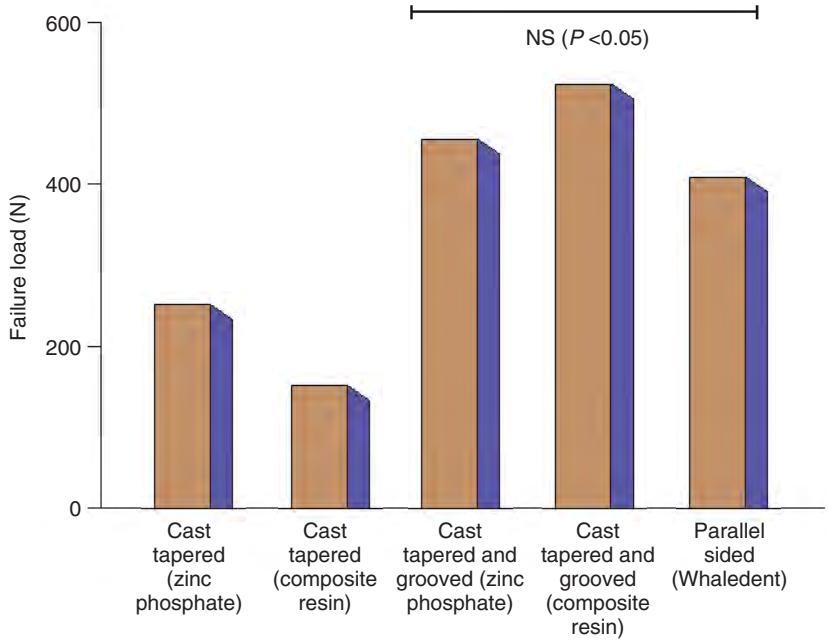

FIGURE 12-18 ■ Effect of horizontal grooving on the retention of tapered posts. *NS,* Not significant. (Redrawn from Wood WW: Retention of posts in teeth with nonvital pulps. J Prosthet Dent 49:504, 1983.)

FIGURE 12-19 ■ When preparing posterior teeth for intracoronal retention, the practitioner must be careful to avoid perforation, especially on the distal surface of mesial roots and the mesial surface of distal roots, where residual tooth structure is normally thinnest and where concavities are often present *(arrows)*.

of tooth structure with restricted taper of about 2 mm, can typically be placed in composite resin or with amalgam directly condensed into the chamber.

Resistance Form

Stress Distribution

One of the functions of a post and core restoration is to improve resistance to laterally directed forces by distributing them over as large an area as possible. However, roots are weakened by excessive internal preparation, and the risk of failure increases. Post design should enable stresses to be distributed as evenly as possible. Glass fiber posts have an elastic modulus (flexibility) similar to that of dentin and therefore result in lower stress concentrations than do metal or ceramic posts; this concept is termed *monoblock*.[50]

The influence of post design on stress distribution has been tested with photoelastic materials,[22,34,51–53] strain gauges,[54,55] and finite element analysis.[56,57] Although it is always challenging to base clinical decisions on the results of in vitro studies, the following conclusions have been drawn:

- The greatest stress concentrations are found at the shoulder margin, particularly interproximally, and at the apex. Dentin should be conserved in these areas if possible.
- Stresses are reduced as post length increases.
- Parallel-sided posts may distribute stress more evenly than do tapered posts, which may have a wedging effect. However, parallel-sided posts heighten stresses at the apex.
- Sharp angles should be avoided because they heighten stresses during loading.
- High stress can be generated during insertion, particularly with smooth, parallel-sided posts that have no vent for cement escape.
- Threaded posts can heighten stress concentrations during insertion and loading, but they have been shown to distribute stress evenly if the posts are backed off a half-turn.[40]
- The cement layer results in a more even stress distribution to the root with lower stress concentrations.
- Glass fiber posts lead to lower stresses during in vitro testing, with less catastrophic failures: Fractures may occur in posts rather than in the remaining tooth structure.[58]

Rotational Resistance

To minimize the risk of dislodgment, it is important that preparation geometry prevents a post with a circular cross section from rotating during function (Fig. 12-20).

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This usually does not present a problem when the remaining coronal tooth structure is sufficient because a vertical coronal wall prevents rotation. Where coronal dentin has been completely lost, a small groove placed in the canal wall can serve as an antirotational element. The groove is normally located where the root is bulkiest, usually on its lingual surface. Alternatively, rotation can be prevented by an auxiliary pin in the root surface. Rotation of a threaded post can also be prevented[33] by preparation of a small cavity (half in the post, half in the root) and condensing amalgam into it after the post is cemented.

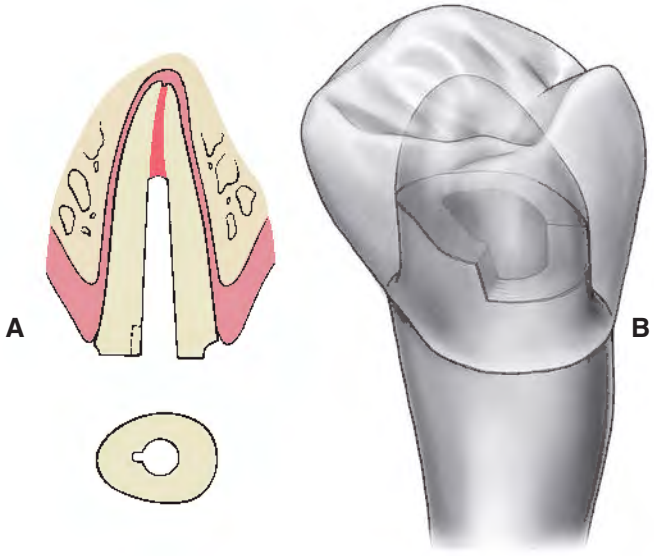

FIGURE 12-20 ■ Rotational resistance in an extensively damaged tooth can be obtained from preparation of a small groove in the root canal. This must be in the path of placement of the post and core restoration.

PROCEDURES

Tooth Preparation

Tooth preparation for endodontically treated teeth is a three-stage operation:

1. Removal of the root canal filling material to the appropriate depth
2. Enlargement of the canal
3. Preparation of the coronal tooth structure

Removal of the Endodontic Filling Material

The root canal system is first completely filled to ensure that lateral canals are sealed; space is then made for a post. If the canal is filled with a full-length silver point, a post cannot be placed, and so the point must be removed and the tooth re-treated with gutta-percha. It is not advisable to shorten previously cemented silver points because leakage will result even if only a small portion is removed.[59,60]

Two methods are commonly used to remove gutta-percha (Fig. 12-21): (1) using a warmed endodontic

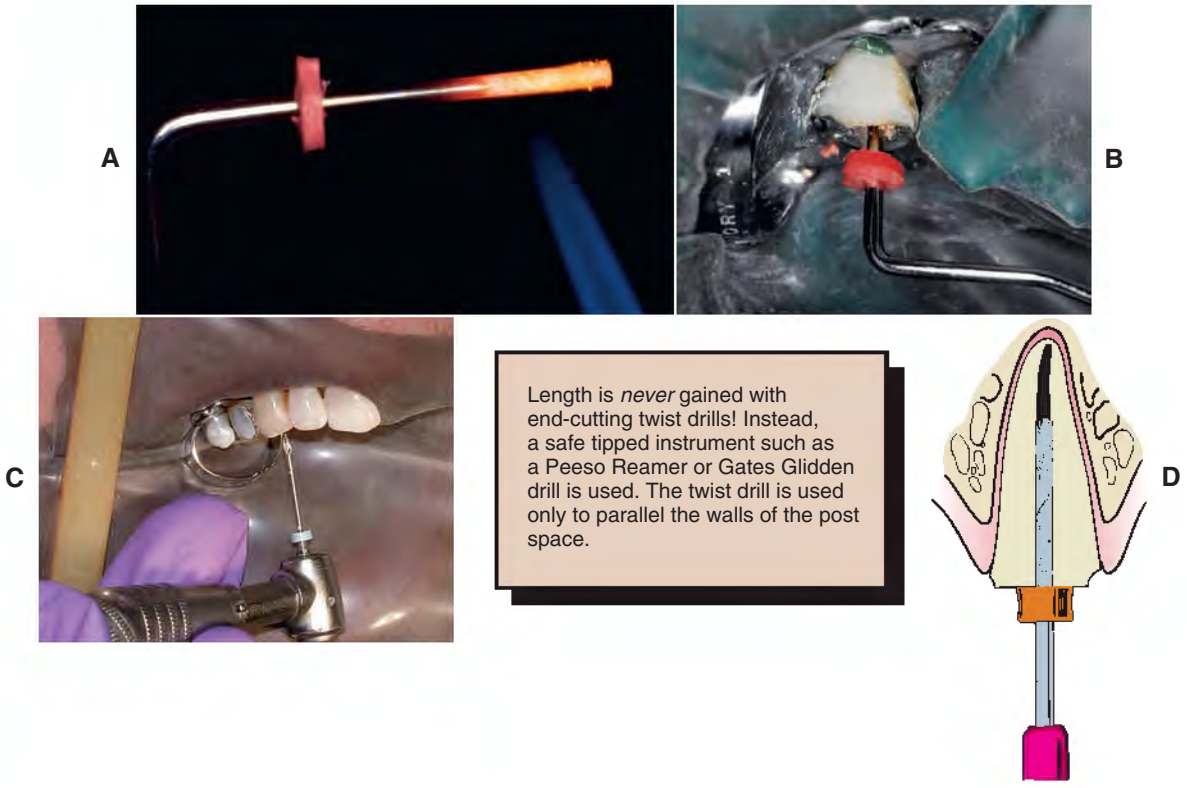

FIGURE 12-21 ■ Gutta-percha can be removed from the canal with a heated endodontic plugger (**A** and **B**) or a non–end-cutting bur, such as a Gates Glidden twist drill **(C)**. A ParaPost twist drill **(D)** can be used to parallel the post space wall (with a rubber stop to ensure accuracy of the preparation depth). (**A** and **B,** Courtesy Dr. D.A. Miller.)

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plugger and (2) using a rotary instrument, sometimes in conjunction with chemical agents. Although more time consuming, the warmed endodontic plugger method is preferred because it eliminates the possibility that the rotary instrument will inadvertently damage the dentin. If it is convenient, the gutta-percha can be removed with a warmed condenser immediately after obturation. This does not disturb the apical seal.[61,62] This method offers the additional advantage of allowing the operator to work in an area where the root canal anatomy is still familiar.

The procedure is as follows:

1. Before removing gutta-percha, calculate the appropriate post length. It should be adequate for retention and resistance but not long enough to weaken the apical seal. As a guide, make the post length equal to the height of the anatomic crown (or two-thirds the length of the root), but leave 5 mm of apical gutta-percha. On short teeth, it is not possible to meet both these conditions, and a compromise must be made. An absolute minimum of 3 mm of apical fill is needed. If this cannot be achieved while the post remains very short, the tooth's prognosis is poor, and extraction may be the best treatment choice.
2. If possible, avoid the apical 5 mm, where curvatures and lateral canals are prevalent. Average values for crown and root lengths are given in Table 12-2. If the working length of the canal is known, desired post space length can be determined easily. Therefore, the incisal or occlusal reference point used during obturation must not be lost as a result of premature removal of coronal tooth structure.
3. To prevent aspiration of an endodontic instrument, apply a rubber dam before preparing the post space.
4. Select an endodontic condenser large enough to hold heat well but not so large that it binds against the canal walls.
5. Mark it at the appropriate length (normally endodontic working length, −5 mm), heat it, and place it in the canal to soften the gutta-percha.
6. If the gutta-percha is old and has lost much of its thermoplasticity, use a rotary instrument; ensure that it follows the gutta-percha and does not engage dentin, which causes a root perforation (for this reason, high-speed instruments and conventional burs are contraindicated). Special post preparation instruments are available (Fig. 12-22). Peeso Reamer drills and Gates Glidden drills are often used for this purpose. The convex football shape of the cutting head of the Gates Glidden drill often results in small divots in the wall of the post space. These are avoided with the more cylindrically shaped Peeso Reamer drill. Both are considered safe-tip instruments because neither is end-cutting. The friction generated between the fill and the tip

TABLE 12-2 **Average Crown and Root Lengths (In Millimeters)**

Tooth	Mean Crown Length*	Mean Root Length*	Two Thirds of Root Length	Root Length (to 4 mm from Apex)
Maxillary Teeth				
Central incisor	10.8 ± 0.7	12.5 ± 1.6	8.3	8.5
Lateral incisor	9.7 ± 0.9	13.1 ± 1.4	8.7	9.1
Canine	10.2 ± 0.8	15.8 ± 2.1	10.5	11.8
First premolar	8.6 ± 0.8	12.7 ± 1.7	8.5	8.7
Second premolar	7.5 ± 0.6	13.5 ± 1.4	9.0	9.5
First molar	7.4 ± 0.5			
Mesiofacial		12.5 ± 1.2	8.3	8.5
Distofacial		12.0 ± 1.3	8.0	8.0
Lingual		13.2 ± 1.4	8.8	9.2
Second molar	7.4 ± 0.5			
Mesiofacial		12.8 ± 1.5	8.5	8.8
Distofacial		12.0 ± 1.4	8.0	8.0
Lingual		13.4 ± 1.3	8.9	9.4
Mandibular Teeth				
Central incisor	9.1 ± 0.5	12.4 ± 1.4	8.3	8.4
Lateral incisor	9.4 ± 0.7	13.0 ± 1.5	8.7	9.0
Canine	10.9 ± 0.9	14.3 ± 1.4	9.5	10.3
First premolar	8.7 ± 0.7	13.4 ± 1.3	8.9	9.4
Second premolar	7.8 ± 0.6	13.6 ± 1.7	9.1	9.6
First molar	7.4 ± 0.5			
Mesial		13.5 ± 1.3	9.0	9.5
Distal		13.4 ± 1.3	8.9	9.4
Second molar	7.5 ± 0.5			
Mesial		13.4 ± 1.2	8.9	9.4
Distal		13.3 ± 1.3	8.9	9.3

Data from Shillingburg HT, et al: Root dimensions and dowel size. Calif Dent Assoc J 10(10):43, 1982.
For each tooth, $n = 50$.
*Standard deviation listed after mean length.

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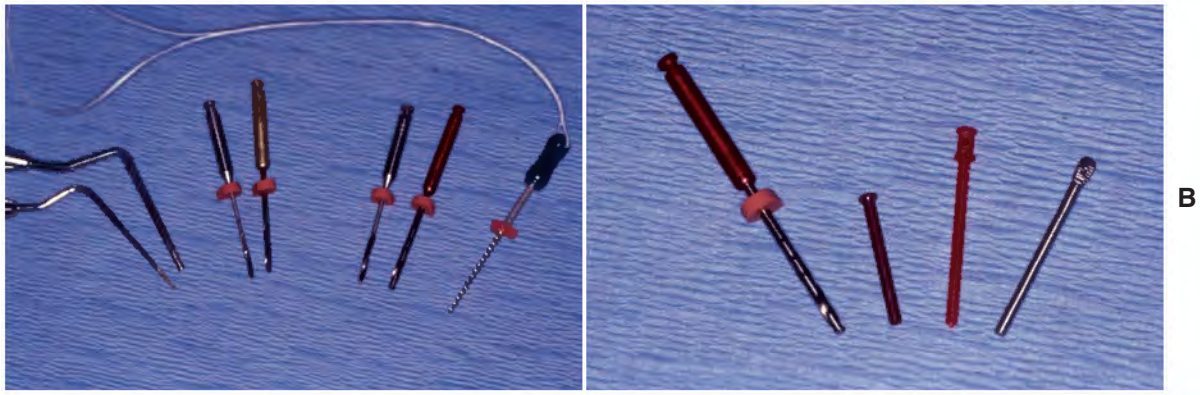

FIGURE 12-22 ■ Commonly used instruments for gutta-percha removal and canal enlargement. **A,** Endodontic pluggers, two sizes of Peeso Reamer drills with corresponding twist drills, and endodontic file. Note floss attached to the file as a safety precaution. **B,** The ParaPost twist drill corresponds in size to an aluminum post used to fabricate interim restorations, a plastic post for patterns, and a stainless steel or titanium post. (Courtesy Dr. J.A. Nelson.)

of these burs softens the gutta-percha, allowing the rotary instrument to track the canal with reasonable predictability. In one comparison of rotary instruments,[63] investigators concluded that the Gates Glidden drill conformed to the original canal more consistently than did the ParaPost drill, which is an end-cutting instrument. The latter is a twist drill and should be used only to parallel the walls of the post space. Considerable heat can be generated by these rotary instruments, especially during the ParaPost preparation stage.[64] Of importance: Never use end-cutting instruments to gain length because root perforation will result.

7. If you are using a rotary instrument, choose one that is slightly narrower than the canal.
8. Ensure that the instrument follows the center of the gutta-percha and does not cut dentin. In many cases, only a part of the root canal fill needs to be removed with a rotary instrument, and the remainder can be removed with the heated condenser.
9. When the gutta-percha has been removed to the appropriate depth, shape the canal as needed. This can be accomplished with an endodontic file or a low-speed drill. In this procedure, undercuts are removed, and the canal is prepared to receive an appropriately sized post without excessive enlargement of the canal. Files are a conservative approach to shaping the canal walls and enable simultaneous removal of any small residual undercuts in the chamber. If a parallel-sided post is desired, a matching-size low-speed twist drill that is set to the same length as the most recently used Peeso Reamer drill can be used.

The post should be no more than one third the root diameter,[1,65] with the root and walls at least 1 mm thick circumferentially. Obviously, for deciding on appropriate post diameters, knowledge of average root dimensions is important. These have been calculated[66] and are presented in Table 12-3. Knowledge of root canal cross section also is significant in post selection. Prefabricated posts are circular in cross section, but many root canals are elliptical, which makes uniform reduction with a drill impossible. Canal shapes are summarized in Table 12-4.

Canal Enlargement

Before the canal is enlarged, the type of post system that will be used for fabrication of the post and core restoration must be chosen.

The advantages and disadvantages of different post types are summarized in Table 12-5. Because no system is universally applicable, familiarity with more than one technique is a significant advantage. Prefabricated posts range widely in shape and size with varying radiopacity that may assist in their identification on radiographs (Table 12-6; Figs. 12-23 and 12-24).

The popular prefabricated posts are listed by diameter in Table 12-7. Parallel-sided prefabricated posts are recommended for conservatively prepared root canals in teeth with roots of circular cross section. Excessively flared canals (i.e., those found in young persons or in individuals after re-treatment of an endodontic failure) are most effectively managed with a custom post. However, each situation should be evaluated on its own merits.

Prefabricated Posts. Many prefabricated posts are available in kits that include rotary instruments for post space preparation that correspond in size to the posts. Alternatively, some of these posts are manufactured to match standard sizes of endodontic files.

1. Enlarge the canal one or two sizes with a drill, an endodontic file, or a reamer that matches the configuration of the post (Fig. 12-25). When using rotary instruments, alternate between the Peeso Reamer drills and twist drills that correspond in size. Gain length with the Peeso Reamer drill, and then make the walls parallel with the twist drill.
2. Use a prefabricated post that matches standard endodontic instruments. A tapered post conforms better to the canal than does a parallel-sided post and requires less removal of dentin to achieve an adequate fit.

Text continued on p. 298

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TABLE 12-3 **Average Root Diameters and Recommended Post Sizes (In Millimeters)***

Tooth	CEJ	Furcation†	Midpoint	Diameter 4 mm from Apex‡	Recommended Post Diameter
Maxillary Teeth					
Central incisor					1.5
Mesiodistal	6.3 ± 0.5	—	5.2 ± 0.5	3.8 ± 0.4	
Faciolingual	6.4 ± 0.4	—	5.8 ± 0.4	4.3 ± 0.4	
Lateral incisor					1.3
Mesiodistal	4.9 ± 0.5	—	4.0 ± 0.5	3.2 ± 0.5	
Faciolingual	5.7 ± 0.5	—	5.4 ± 0.5	4.2 ± 0.4	
Canine					1.5
Mesiodistal	5.4 ± 0.5	—	4.4 ± 0.5	3.3 ± 0.5	
Faciolingual	7.7 ± 0.6	—	7.2 ± 0.6	4.8 ± 0.6	
First premolar					
Mesiodistal	4.1 ± 0.3	Facial MD	3.6 ± 0.4	2.6 ± 0.4	0.9
Faciolingual	8.1 ± 0.7	— FL —	3.4 ± 0.4	2.4 ± 0.4	
		Lingual MD	3.3 ± 0.3	2.5 ± 0.4	0.9
		— FL —	3.3 ± 0.4	2.4 ± 0.5	
Second premolar					
Mesiodistal	4.9 ± 0.3	—	3.8 ± 0.4	3.2 ± 0.6	1.1
Faciolingual	7.9 ± 0.5	—	7.0 ± 0.7	5.0 ± 0.7	
First molar					
Mesiodistal	7.7 ± 0.4	Mesio- MD 3.4 ± 0.3	3.1 ± 0.3	2.9 ± 0.4	1.1
Faciolingual	10.5 ± 0.5	Facial FL 6.8 ± 0.5	5.8 ± 0.7	4.8 ± 0.7	
		Disto- MD 3.1 ± 0.2	2.8 ± 0.3	2.6 ± 0.4	1.1
		Facial FL 5.0 ± 0.4	4.4 ± 0.5	3.8 ± 0.5	
		Lingual MD 5.7 ± 0.5	5.0 ± 0.5	4.4 ± 0.5	1.3
		FL 4.3 ± 0.4	3.7 ± 0.4	3.3 ± 0.4	
Second molar					
Mesiodistal	7.3 ± 0.4	Mesio- MD 3.4 ± 0.3	3.1 ± 0.3	2.7 ± 0.4	1.1
Faciolingual	10.4 ± 0.6	Facial FL 6.6 ± 0.5	5.6 ± 0.7	4.5 ± 0.7	
		Disto- MD 3.1 ± 0.4	2.8 ± 0.3	24 ± 0.4	0.9
		Facial FL 4.3 ± 0.4	3.8 ± 0.4	3.2 ± 0.4	
		Lingual MD 4.9 ± 0.5	4.2 ± 0.5	3.6 ± 0.5	1.3
		FL 4.5 ± 0.4	3.9 ± 0.4	3.1 ± 0.4	
Mandibular Teeth					
Central incisor					
Mesiodistal	3.3 ± 0.3	—	2.7 ± 0.3	2.1 ± 0.2	0.7
Faciolingual	5.5 ± 0.5		5.6 ± 0.4	4.3 ± 0.6	
Lateral incisor					
Mesiodistal	3.6 ± 0.3	—	2.7 ± 0.4	2.0 ± 0.2	0.7
Faciolingual	5.9 ± 0.4		5.7 ± 0.5	4.3 ± 0.5	
Canine					
Mesiodistal	5.2 ± 0.6	—	4.0 ± 0.5	3.2 ± 0.7	1.5
Faciolingual	7.8 ± 0.8		7.3 ± 0.6	5.0 ± 0.5	
First premolar					
Mesiodistal	5.1 ± 0.4	—	4.0 ± 0.4	3.2 ± 0.4	1.3
Faciolingual	6.6 ± 0.4		6.0 ± 0.5	4.3 ± 0.5	
Second premolar					
Mesiodistal	5.3 ± 0.3	—	4.3 ± 0.3	3.5 ± 0.5	1.3
Faciolingual	7.0 ± 0.5		6.0 ± 0.6	4.4 ± 0.5	
First molar					
Mesiodistal	8.9 ± 0.6	Mesio- MD 3.7 ± 0.2	3.2 ± 0.3	2.8 ± 0.3	1.1
Faciolingual	8.3 ± 0.6	Facial FL 3.4 ± 0.3	3.1 ± 0.3	2.8 ± 0.4	
		Mesio- MD 3.4 ± 0.3	2.9 ± 0.3	2.5 ± 0.3	0.9
		Lingual FL 3.5 ± 0.4	3.2 ± 0.3	2.7 ± 0.4	
		Distal MD 3.6 ± 0.3	2.8 ± 0.3	2.6 ± 0.3	0.9
		Facial FL 3.2 ± 0.3	2.8 ± 0.3	2.4 ± 0.4	
		Mesio- MD 3.6 ± 0.4	3.0 ± 0.4	2.5 ± 0.4	0.9
		Lingual FL 3.2 ± 0.5	2.8 ± 0.4	2.3 ± 0.4	
		Distal MD 4.1 ± 0.4	3.5 ± 0.4	3.0 ± 0.4	1.1
		FL 6.8 ± 0.8	5.9 ± 0.9	4.7 ± 0.7	

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TABLE 12-3 **Average Root Diameters and Recommended Post Sizes (In Millimeters)—cont'd**

Tooth	CEJ	Furcation†	Midpoint	Diameter 4 mm from Apex‡	Recommended Post Diameter
Second molar	MD 9.3 ± 0.7	Mesio- MD 3.6 ± 0.3	3.1 ± 0.3	2.6 ± 0.3	0.9
	FL 8.3 ± 0.7	Facial FL 3.2 ± 0.3	2.8 ± 0.3	2.4 ± 0.4	
		Mesio- MD 3.6 ± 0.4	3.0 ± 0.4	2.5 ± 0.4	0.9
		Lingual FL 3.2 ± 0.5	2.8 ± 0.4	2.3 ± 0.4	
		Distal MD 4.1 ± 0.4	3.5 ± 0.4	3.0 ± 0.4	1.1
		FL 6.8 ± 0.8	5.9 ± 0.9	4.7 ± 0.7	

Data from Shillingburg HT, et al: Root dimensions and dowel size. Calif Dent Assoc J 10(10):43, 1982.
CEJ, Cementoenamel junction; *FL,* faciolingual; *MD,* mesiodistal.
*For each tooth, $n = 50$.
†Furcation distance from the CEJ: maxillary first molar, 4.1 mm; maxillary second molar, 3.2 mm; mandibular first molar, 3.1 mm; mandibular second molar, 3.3 mm.
‡Because of greater root length, the mean distance from the apex on maxillary canine measurements is 5.1 mm.

TABLE 12-4 **Root Canal Configurations**

	Elliptical	
Circular	**Buccolingual**	**Mesiodistal**
Maxillary central incisor	Maxillary lateral incisor Maxillary canine Mandibular incisors Mandibular canine	
Maxillary first premolar (two roots)	Maxillary first premolar (single root) Mandibular first premolar	
Mandibular second premolar	Maxillary second premolar	
Maxillary molars (distobuccal roots)	Maxillary molars (mesiobuccal roots) Mandibular molars (mesial and distal roots)	Maxillary molars (palatal roots)

From Weine FS: Endodontic therapy, 4th ed, pp 225-269. St. Louis, Mosby, 1989.

TABLE 12-5 **Available Post and Core Restoration Systems**

Material	Advantages	Disadvantages	Recommended Use	Precautions
Amalgam	Conservative of tooth structure Straightforward technique	Low tensile strength Corrosion with base metal	Molar with adequate coronal tooth structure	Not recommended for teeth under lateral load (anterior teeth)
Glass ionomer	Conservative of tooth structure Straightforward technique	Difficult condensation Low strength	Minimal missing tooth structure	Not recommended for teeth under lateral load
Composite resin	Conservative of tooth structure Straightforward technique	Low strength Continued polymerization Microleakage	Minimal missing tooth structure	Not recommended for teeth under lateral load
Custom cast post and core restoration	High strength Better fit than prefabricated restoration	Less stiff than wrought materials Time-consuming, complex procedure	Elliptical or flared canals	Care to remove nodules before try-in
Wire post and cast core	High strength High stiffness	Corrosion of base metal Pt-Au-Pd wire expensive	—	Care to avoid perforation during preparation

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TABLE 12-5 Available Post and Core Restoration Systems—cont'd

Material	Advantages	Disadvantages	Recommended Use	Precautions
Tapered prefabricated post	Conservative of tooth structure High strength and stiffness	Less retentive than parallel-sided or threaded system	Small circular canals	Not recommended for excessively flared canals
Parallel-sided prefabricated post	High strength Good retention Comprehensive system	Precious metal post expensive Corrosion of stainless steel Less conservative of tooth structure	Small circular canals	Care during preparation
Threaded post	High retention	Stresses generated in canal may lead to fracture Not conservative of coronal and radicular tooth structure	Only when maximum retention is essential	Care to avoid fracture during seating
Carbon fiber post	Dentin bonding Easy removal	Low strength Microleakage Black color	Minimal missing tooth structure Uncertain endodontic prognosis	Not recommended for teeth under lateral load
Zirconia ceramic posts	Esthetics High stiffness	Uncertain clinical performance	High esthetic demand	—
Woven fiber post	Esthetics Dentin bonding	Low strength Uncertain clinical performance	High esthetic demand	Not recommended for teeth under lateral load
Glass fiber posts	Esthetics Dentin bonding	Low strength Uncertain clinical performance	High esthetic demand	Not recommended for teeth under lateral load

Pt-Au-Pd, Platinum-gold-palladium.

TABLE 12-6 Currently Available Prefabricated Posts[a]

Example[b]	Product (Vendor)	Shank COMPOSITION[c]	Shank DENSITY (%)[d]	Shank DIAMETER (mm)[e]	Shank CHARACTERISTICS
Tapered Smooth-sided Posts					
	EndoSequence Fiber Post (Brasseler USA)	ZGF (unidirectional, LT)	20	0.8 to 1.4	Flat tip, 0.04 and 0.06 taper[f]
	FibreKleer 4X Tapered Fiber Post (Pentron)	GF (unidirectional, LT)	44	1.2 to 1.5	Flat tip, 0.04 taper[f]
	LuxaPost (DMG America)	GF (unidirectional, LT)	20	1.2 to 1.5	Flat tip
	FRC Postec Plus (Ivoclar Vivadent)	GF (unidirectional, LT)	42	1.5 to 1.7	Flat tip
	Glass Fibre Post (Ellman International)	GF (unidirectional, LT)	15	0.9 to 2.0	Flat tip
	EUROPOST FIBIO Aesthetic Post (Dental Anchor Systems)	GF (unidirectional)	29	1.2 to 1.5	Flat tip
	EXACTA Fiber Post (EXACTA Dental Direct)	GF (braided)	30	1.2 to 1.5	Flat tip
	C-I White Glass Fiber Post (Parkell)	GF (braided)	12	1.3 and 1.6	Blunt tip
	C-I Plastic Pattern Post (Parkell)	PB[g]		1.3 and 1.6	Blunt tip
	Master Endopost (Sterngold)	PB[g]		1.7 and 1.8	Blunt tip
	Filpost (Filhol Dental USA)	Ti	62	1.3 and 1.6	Blunt tip
	ER C-Post (Komet USA)	ZrO_2	92	1.1 to 1.7	Blunt tip
	RelyX Fiber Post (3M ESPE Dental)	ZGF (unidirectional, LT)	50	0.8 to 1.3	Blunt tip
	FluoroPost (Dentsply Caulk)	ZGF (unidirectional, LT)	48	1.3 to 1.7	Blunt tip
	ER DentinPost X (Komet USA)	GF (unidirectional, LT)	51	1.1 to 1.7	Blunt tip
	ER DentinPost (Komet USA)	GF (unidirectional, LT)	50	1.1 to 1.7	Blunt tip

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TABLE 12-6 **Currently Available Prefabricated Posts—cont'd**

Example[b]	Product (Vendor)	Shank: COMPOSITION[c]	Shank: DENSITY (%)[d]	Shank: DIAMETER (mm)[e]	Shank: CHARACTERISTICS
	Achromat-THP (Axis|SybronEndo)	GF (unidirectional, LT)	51	1.0 to 1.4	Blunt tip
	Achromat-THP Arrow Head (Axis|SybronEndo)	GF (unidirectional, LT)	31	1.0 to 1.4	Blunt tip
	Rebilda Post (VOCO America)	GF (unidirectional, LT)	52	1.0 to 2.0	Blunt tip, apical 8 mm is tapered
	Luscent Anchors (Dentatus USA)	GF (unidirectional, LT)	12	1.1 to 1.6	Pointed tip
	Twin Luscent Anchors (Dentatus USA)	GF (unidirectional, LT)	11	1.4 to 1.8	Pointed tip, hourglass shape
	D.T. Light-Post (Bisco)	QF (unidirectional, LT)	31	1.0 to 1.6	Pointed tip, double taper
	D.T. Light-Post ILLUSION X-RO (Bisco)	QF (unidirectional, LT)	50	1.0 to 1.6	Pointed tip, double taper
	UniCore (Ultradent Products)	QF (unidirectional, LT)	39	1.1 to 1.7	Pointed tip
	Endowel (Star Dental)	PB		1.0 to 1.6	Pointed tip, ISO[f] sizes: 80 to 140
Tapered Serrated Posts					
	PeerlessPost (Axis|SybronEndo)	GF (unidirectional)	37	1.1 to 1.2	Inverse ledges, flat tip
	Macro-Lock Illusion X-RO (Clinician's Choice)	GF (unidirectional, LT)	51	1.3 to 1.7	Spiraling grooves, blunt tip
	Mirafit Clear (Hager Worldwide)	GF (unidirectional, LT)	41	0.5 to 1.0	Spiraling grooves, pointed tip
	Tri-R Post System (Integra Miltex)	SS	90	1.0 to 1.6	Spiraling grooves, pointed tip
	C-I Stainless Steel Post (Parkell)	SS	91	1.3 and 1.6	Shallow narrow grooves, flat tip
	NuBond (Ellman International)	SS	84	0.9 to 2.0	Shallow narrow grooves, blunt tip
Tapered Threaded Posts					
	Surtex (Dentatus USA)[h]	Ti, SS, Brass	93 (Brass)	1.1 to 1.8	Tightly threaded
	Ancorex (E. C. Moore)[h]	Ti	63	1.1 to 1.8	Tightly threaded
Parallel Smooth-sided Posts					
	FibreKleer 4X Parallel Fiber Post (Pentron)	GF (unidirectional, LT)	51	1.0 to 1.5	Flat tip
	GT Fiber Post (Dentsply Tulsa Dental)	GF (unidirectional, LT)	23	1.0 to 1.5	Flat tip
	IntegraPost System (Premier)	Ti alloy	66	0.9 to 1.5	Fine diamond-shaped grooves, flat tip
	CTH Beta Post (CTH)	SS	90	1.1 to 1.6	Vertical grooves, flat tip
	CTH R-Series (CTH)	SS	85	1.1 to 1.6	Vertical grooves, flat tip
	GT Post (Dentsply Tulsa Dental)	SS	84	1.0 to 1.5	Flat tip
	Pro-Post (Dentsply Tulsa Dental)	SS	89	1.0 to 1.7	Tapered apical end, flat tip

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TABLE 12-6 **Currently Available Prefabricated Posts—cont'd**

Example[b]	Product (Vendor)	Shank COMPOSITION[c]	Shank DENSITY (%)[d]	Shank DIAMETER (mm)[e]	Shank CHARACTERISTICS
	CosmoPost (Ivoclar Vivadent)	ZrO_2	96	1.4 and 1.7	Tapered apical end, flat tip
	GC Fiber Post (GC America)	GF (unidirectional, LT)	31	0.8 to 1.6	Tapered apical end, flat tip
	DentFlex Fiber Post (Brasseler USA)	ZGF (unidirectional, LT)	26	1.0 to 1.6	Tapered apical end, blunt tip
	Cure-Thru IntegraPost (Premier USA)	ZGF (unidirectional, LT)	30	1.0 to 1.5	Tapered apical end, blunt tip
	ICELight (Danville Materials)	GF (unidirectional, LT)	31	1.0 to 1.6	Tapered apical end, blunt tip
	ICEPost (Danville Materials)	GF (unidirectional)	25	1.0 to 1.6	Tapered apical end, blunt tip
	Core-Post Glass Fiber (DenMat)	GF (unidirectional)	7	1.0 to 2.0	Flat tip
	Core-Post Carbon Fiber (DenMat)	CF	3	1.0 to 2.0	Flat tip
	Mirafit White (Hager Worldwide)	GF (braided)	56	1.2 to 1.6	Pointed tip
	Mirafit Carbon (Hager Worldwide)	CF	3	1.2 to 1.6	
	GF Glass Fiber Post (J. Morita USA)	GF (braided)	26	1.1 to 1.6	Blunt tip
	CF Carbon Fiber Post (J. Morita USA)	CF	4	1.1 to 1.6	Blunt tip
Parallel Serrated Posts					
	ParaPost (Coltène/ Whaledent)	Ti alloy, PB, SS	88 (SS)	0.9 to 1.8	Numerous shallow grooves, flat tip
	ParaPost XP (Coltène/ Whaledent)	Ti alloy, PB, SS	63 (Ti alloy)	0.9 to 1.8	Diamond-shaped grooves, flat tip
	ParaPost XH (Coltène/ Whaledent)	Ti alloy	54	0.9 to 1.8	Diamond-shaped grooves, flat tip
	ParaPost Plus (Coltène/ Whaledent)	Ti alloy, SS	87 (SS)	0.9 to 1.8	Inverse ledges, flat tip
	ParaPost Fiber White (Coltène/Whaledent)	GF (unidirectional)	19	1.1 to 1.5	Inverse ledges, flat tip
	FibreKor Post System (Pentron)	GF (unidirectional)	24	1.0 to 1.5	Inverse ledges, flat tip
	FibreKleer 4X Original Fiber Post (Pentron)	GF (unidirectional, LT)	50	1.0 to 1.5	Inverse ledges, flat tip
	ParaPost Fiber Lux (Coltène/ Whaledent)	GF (unidirectional, LT)	23	1.1 to 1.5	Inverse ledges, flat tip
	ParaPost Taper Lux (Coltène/Whaledent)	GF (unidirectional, LT)	30	1.1 to 1.5	Inverse ledges, tapered apical end
	Achromat (AxisISybronEndo)	GF (unidirectional, LT)	27	1.3 and 1.6	Wide grooves, flat tip
	Achromat-HP (AxisISybronEndo)	GF (unidirectional, LT)	26	1.1 to 1.6	Wide grooves, flat tip
	Vlock Passive Post (Brasseler USA)	Ti alloy	56	1.2 to 1.6	Wide grooves, flat tip

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TABLE 12-6 **Currently Available Prefabricated Posts—cont'd**

Example[b]	Product (Vendor)	Shank			
		COMPOSITION[c]	DENSITY (%)[d]	DIAMETER (mm)[e]	CHARACTERISTICS
	Luminex (Dentatus USA)	PB		1.1 to 1.8	Wide grooves, tapered tip
	SB Post (J. Morita USA)	SS	82	0.8 to 1.6	Shallow grooves, tapered tip
	AccessPost (Essential Dental Systems)	SS	83	0.8 to 1.6	Deep spiraling groove, flat tip
	AccessPost Overdenture (Essential Dental)	SS	77	1.1 to 1.6	Deep spiraling groove, flat tip
	ERA Direct Overdenture (Sterngold)	SS	87	1.4 and 1.7	Numerous shallow grooves, flat tip
	LOCATOR Attachment (Zest Anchors)	SS	91	1.8	Numerous shallow grooves, flat tip
	EZ-Fit (Essential Dental Systems)	GF (proprietary S-glass)	7	0.9 to 1.4	Shallow grooves, flat tip
Parallel Threaded Posts					
	Surtex (Dentatus USA)[h]	Ti, SS, Brass	88 (SS)	1.1 to 1.8	Tightly threaded, threaded tapered tip
	Ancorex (E. C. Moore)[h]	Ti	62	1.1 to 1.8	Tightly threaded, threaded tapered tip
	AZtec (Dentatus USA)	Ti	68	1.5 to 1.8	Tightly threaded, smooth tapered tip
	Boston Post (Roydent Dental Products)	Ti	62	1.0 to 1.6	Tightly threaded, pointed tip
	Titanium Screw Post (E.C. Moore)	Ti	58	1.1 to 1.8	Tightly threaded, pointed tip
	Golden Screw Post (E.C. Moore)	Brass	92	1.1 to 1.8	Tightly threaded, pointed tip
	Compo-Post (Sullivan-Schein)	Brass	92	1.1 to 1.8	Tightly threaded, pointed tip
	Kurer K4 Anchor System—Ready Core (Standard) Anchor (Marie Reiko)	SS, Ti alloy	90 (SS)	1.6 to 2.0	Tightly threaded, flat tip
	Kurer K4 Anchor System—Universal (Crown Saver) Anchor (Marie Reiko)	SS, Ti alloy	93 (SS)	1.5 to 2.0	Tightly threaded, flat tip
	Kurer K4 Anchor System—Custom Core (Fin Lock) Anchor (Marie Reiko)	SS, Ti alloy	89 (SS)	1.7 to 2.0	Tightly threaded, flat tip
	Kurer K4 Anchor System—Denture Anchor (Marie Reiko)	SS, Ti alloy	89 (SS)	1.8 to 2.0	Tightly threaded, flat tip
	Cytco-K (Dentsply Maillefer)	Ti alloy	60	0.9 and 1.2	Four coronal threads, long tapered tip
	EUROPOST (RVS) Headless Post (Dental Anchor Systems)	Ti alloy	68	1.1 to 1.8	Sparsely threaded, blunt tip
	EUROPOST (RVS) Headed Post (Dental Anchor Systems)	Ti alloy	67	1.1 to 1.8	Sparsely threaded, blunt tip
	Vlock Active Post (Brasseler USA)	Ti alloy	77	1.3 to 1.8	Sparsely threaded, blunt tip
	Vario Active Post (Brasseler USA)	Ti alloy	57	1.3 to 1.8	Sparsely threaded, blunt tip
	Radix-Anchor (Dentsply Maillefer)	Ti alloy	66	1.2 to 1.6	Sparsely threaded, flat tip

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TABLE 12-6 Currently Available Prefabricated Posts—cont'd

Example[b]	Product (Vendor)	Shank COMPOSITION[c]	Shank DENSITY (%)[d]	Shank DIAMETER (mm)[e]	Shank CHARACTERISTICS
	ParaPost XT (Coltène/Whaledent)	Ti alloy	61	0.9 to 1.5	Sparsely threaded, grooves, flat tip
	Flexi-Post (Essential Dental Systems)	Ti alloy, SS	82 (SS)	1.0 to 1.9	Sparsely threaded, split shank
	Flexi-Flange (Essential Dental Systems)	Ti alloy, SS	81 (SS)	1.1 to 1.9	Sparsely threaded, split shank
	Flexi-Overdenture (Essential Dental Systems)	Ti alloy, SS	58 (Ti alloy)	1.4 to 1.9	Sparsely threaded, split shank
	Flexi-Post Fiber (Essential Dental Systems)	GF (proprietary S-glass)	18	1.2 to 1.7	Sparsely threaded, pointed tip
	Flexi-Flange Fiber (Essential Dental Systems)	GF (proprietary S-glass)	22	1.2 to 1.7	Sparsely threaded, pointed tip

Photographic services by Brodie Sturm Photography, Chicago, Illinois.
[a]Posts are categorized by their radiographic silhouette from the apical 8 mm of the shank.
[b]Posts are not photographed to scale.
[c]Composition key: *Brass,* alloy of copper and zinc (brass posts are gold-plated); *CF,* carbon fibers bound by resin matrix; *GF,* glass fibers bound by resin matrix (glass fibers are either braided or unidirectional in orientation); *LT,* light transmission through the post; *PB,* plastic burnout for a cast post; *QF,* quartz fibers bound by resin matrix (quartz fibers are unidirectional in orientation); *SS,* stainless-steel; *Ti,* titanium (*Ti* indicates approximately 99% pure titanium; *Ti alloy* indicates a content of approximately 90% titanium); *ZGF,* zirconia glass fibers bound by resin matrix; ZrO_2, zirconium oxide or zirconia.
[d]Relative density recorded with a Dexis platinum sensor and software (9.0.4 version) with the Progeny JB-70 Dental X-Ray System (70 kVp, 7 mA, 8-inch cone, 0.233 seconds, 60 Hz). Obturated gutta-percha in the main pulp canal had a density percentage of 66.
[e]Shank diameter includes the threads of relevant posts; diameters of tapered posts are measured 8 mm from the apical tip.
[f]Post shape corresponds to the taper of an endodontic file (0.04 and 0.06 taper found under ANSI/ADA Specification No. 101, which is an increase in diameter by 0.04 mm and 0.06 mm respectively for each millimeter from the tip; ISO [International Standards Organization] indicates a conventional standard file taper of 0.02, which is an increase in diameter by 0.02 mm for each millimeter from the tip).
[g]The density of the cast post will depend on the metal selected during the fabrication from the plastic burnout post.
[h]Surtex and Ancorex post categorization is dependent on the length of the post: The medium and longer sizes are parallel-sided threaded posts; the shorter sizes are tapered threaded posts.

TABLE 12-7 Diameters of Eight Commonly Used Prefabricated Posts

Post										
Diameter (in mm)	**0.80**	**0.90**	**0.95**	**1.00**	**1.05**	**1.15**	**1.20**	**1.25**	**1.35**	**1.40**
Boston*				X			X			
Surtex*					X		X		X	
Flexi-Post*			X		X					X
Endowel, size 80		†		‡						
Kurer K4 Anchor System—Universal (Crown Saver) Anchor										
ParaPost		X		X				X		
Radix*						X			X	
Vlock Passive Post						X			X	
Diameter (in mm)	**1.45**	**1.50**	**1.60**	**1.65**	**1.75**	**1.80**	**1.85**	**1.90**	**2.00**	
Boston*			X							
Surtex*	X		X		X					
Flexi-Post*				X				X		
Stress-free post size 70										
Kurer K4 Anchor System—Universal (Crown Saver) Anchor	X		X	X			X		X	
ParaPost		X			X					
Radix*			X	X						
Vlock Passive Post			X							

X, Available size.
*Diameter includes threads.
†Five millimeters from tip.
‡Ten millimeters from tip.

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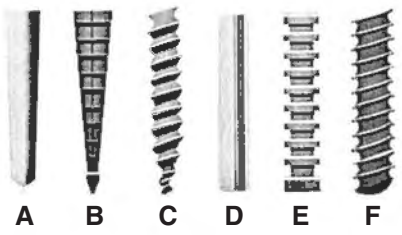

FIGURE 12-23 ■ Classification of prefabricated posts. **A,** Tapered smooth post. **B,** Tapered serrated post. **C,** Tapered threaded post. **D,** Parallel-sided smooth post. **E,** Parallel-sided serrated post. **F,** Parallel-sided threaded post. (Redrawn from Shillingburg HT, Kessler JC: Restoration of the endodontically treated tooth. Chicago, Quintessence Publishing, 1982.)

However, it is slightly less retentive and results in greater stress concentrations, although retention may be improved by controlled grooving.[36]

3. Be especially careful not to remove more dentin at the apical extent of the post space than is necessary (see Figs. 12-14 and 12-25).

Of importance is that if measurements have been made carefully, radiographs are not normally necessary to verify the post space preparation.

Most of the time, a preformed parallel-sided post fits only in the most apical portion of the canal. Modified posts are available with tapered ends, and these conform better to the shape of the canal, although they have slightly less retention than parallel-sided posts do, particularly in restoration of shorter roots.[34] In the absence of a vertical stop on sound tooth structure, such posts can also create an undesirable wedging effect.

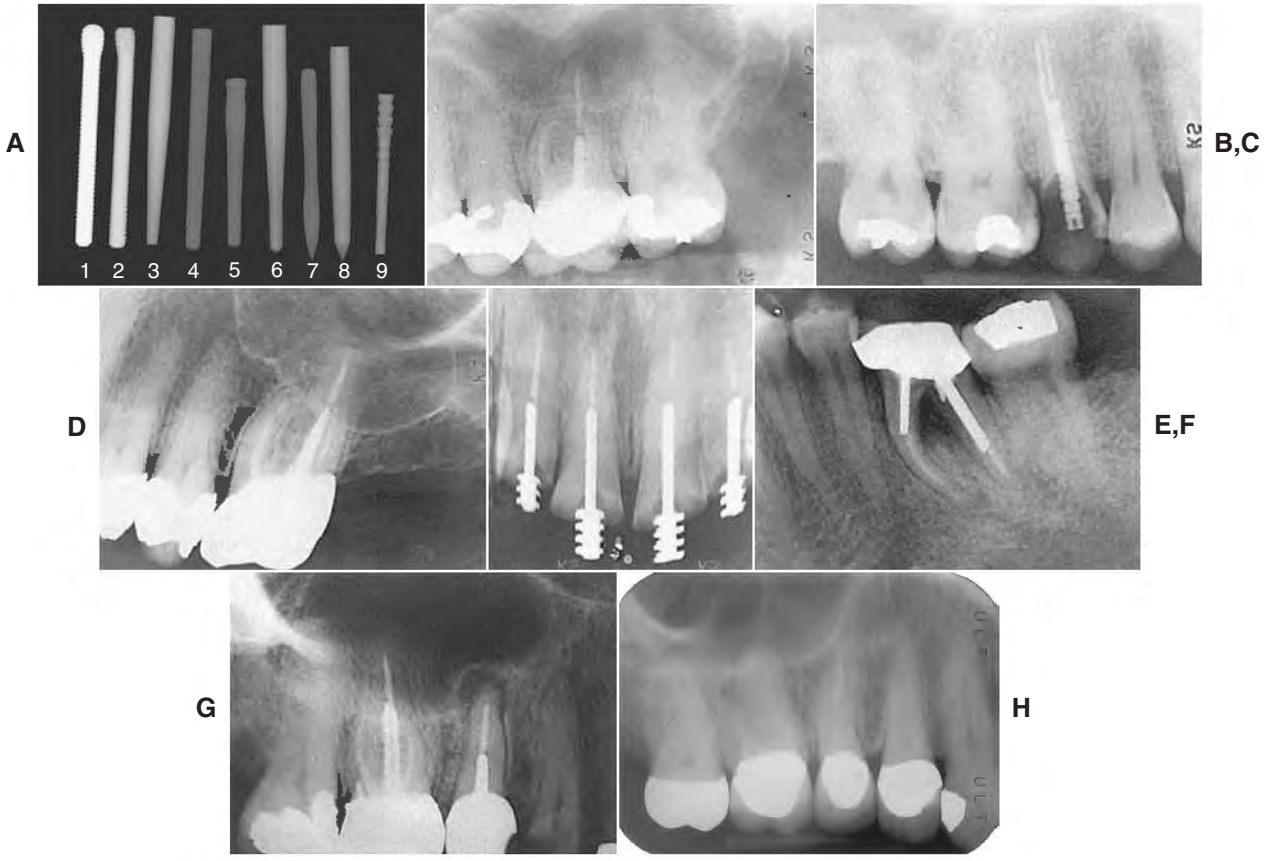

FIGURE 12-24 ■ The various endodontic posts encountered in clinical practice have varying degrees of radiopacity. Dentists accustomed to seeing traditional stainless steel and titanium posts may be deceived by more recently introduced systems. **A,** Nine representative posts: (1) ParaPost, stainless steel (Coltène/Whaledent); (2) ParaPost, titanium (Coltène/Whaledent); (3) FRC Postec Plus (Ivoclar Vivadent); (4) Glass Fiber Post (Ellman International, Inc.); (5) C-I White Glass Fiber Post (Parkell); (6) D. T. Light-Post (Bisco, Inc.); (7) Twin Luscent Anchors (Dentatus USA); (8) UniCore (Ultradent Products, Inc.); and (9) PeerlessPost (SybronEndo Corporation). The pure carbon fiber posts (not included in part **A**) are completely radiolucent. The type of cement that is used has a role in the radiopacity of the post (see Fig. 30-6). **B** to **I,** Radiographs of the six categories: **B,** Endowel (Star Dental), tapered and smooth sided. **C,** Unimetric (Dentsply Maillefer), tapered and serrated. **D,** Surtex (Dentatus USA), tapered and threaded. **E,** CTH Beta Post (CTH), parallel-sided and smooth. **F,** ParaPost (Coltène/Whaledent) (two sizes), parallel-sided and serrated. **G,** Flexi-Post (Essential Dental Systems) (in the right maxillary first molar), parallel-sided and threaded (note the split shank). **H,** ParaPost Fiber Lux (Coltène/Whaledent) cemented with RelyX Luting Plus (3M ESPE Dental). Note the radiolucency of the post in comparison with the radiopacity of the gutta-percha endodontic fill. (**B,** Courtesy Dr. D.A. Miller and Dr. H.W. Zuckerman. **C,** Courtesy Dr. I.A. Roseman. **D,** Courtesy Dr. F.S. Weine and Dr. S. Strauss. **E,** Courtesy Dr. J.F. Tardera. **F,** Courtesy Dr. J.L. Wingo. **G,** Courtesy Dr. L.R. Farsakian. **H,** Courtesy Dr. D.A. Miller and Dr. G. Freebeck.)

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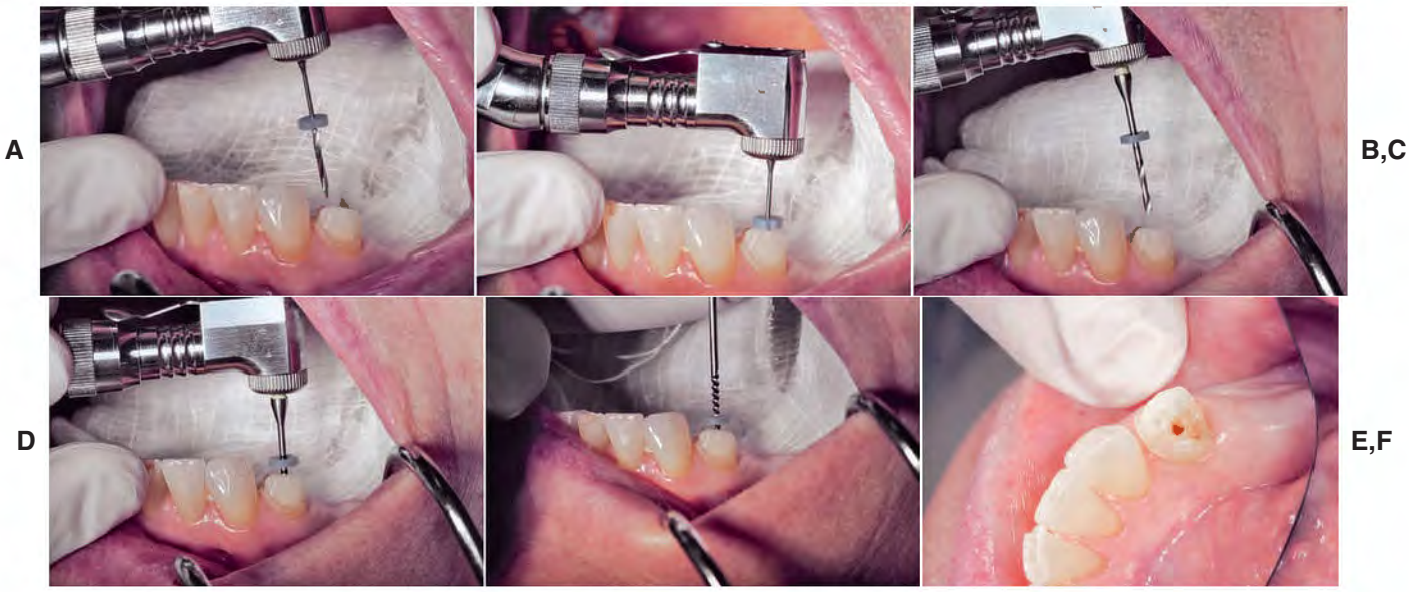

FIGURE 12-25 ■ Enlargement of the root canal for a prefabricated post. **A** and **B,** Peeso Reamer drill used to remove gutta-percha to desired depth. **C** and **D,** Twist drill is used to parallel the apical portion of the post space. No depth should be gained with the twist drill because perforation may result. **E,** File is used to flare the coronal portion of the post space and to remove any undercuts. A file is used to verify both length of post space and placement of prefabricated post. **F,** Completed postspace preparation.

Custom-Made Posts

1. Use custom-made posts (Fig. 12-26) in canals that have a noncircular cross section or extreme taper. Enlarging canals to conform to a preformed post may lead to perforation. Often very little preparation is needed for a custom-made post. However, undercuts within the canal must be removed, and some additional shaping is usually necessary.
2. Be most careful on molars to avoid root perforation. In mandibular molars, interradicular root concavities make the distal wall of the mesial root and the mesial wall of the distal root particularly susceptible. In maxillary molars, the curvature of the mesiobuccal root increases the chance of mesial or distal perforation[67] (Fig. 12-27). Therefore, neither post size nor length should be excessive.

FIGURE 12-26 ■ Custom-made posts are indicated for teeth with root canals whose cross section is not circular or is extremely tapered. Further enlargement of the root canal is often not necessary on these teeth. (Courtesy C. Poeschl.)

Preparation of the Coronal Tooth Structure

After the post space has been prepared, the remaining coronal tooth structure is reduced for the extracoronal restoration. Specific reduction depends on the type of crown that is planned. When esthetic requirements apply, as for anterior teeth, metal-ceramic crowns or all-ceramic crowns are indicated (see Chapters 9, 11, 24, and 25).

1. Ignore missing coronal tissue (from previous restorative procedures, caries, fracture, or endodontic access) and prepare the remaining tooth structure as if the coronal portion of the tooth is intact. The same specifications should be met (i.e., if a metal-ceramic crown with a porcelain labial margin is planned, a facial shoulder margin and a lingual chamfer margin are placed). The prepared walls are the starting point for the core materials, and ensuring that the interface is correct

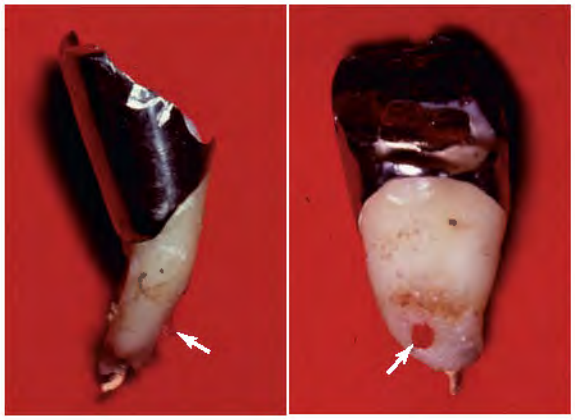

FIGURE 12-27 ■ **A** and **B,** Distal root curvature contributed to this mesial perforation *(arrows)* of a mandibular molar and necessitated removal of the distal root segment. (Courtesy Dr. J. Davila.)

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facilitates achieving correct preparation form in the core.
2. Be sure that the facial structure of the tooth is adequately reduced for good esthetics.
3. Remove all internal and external undercuts that will prevent withdrawal of the pattern.
4. Remove any unsupported tooth structure, but preserve as much of the crown as possible. Because tooth structure has been removed internally and externally, the remaining walls often are thin and weakened. Defining absolute measurements for the dimensions of the residual coronal walls is difficult, but ideally they should probably be at least 1 mm wide. Wall height is reduced in proportion to the remaining wall thickness because tall, thin walls tend to fracture when the interim restoration is removed and during evaluation and seating of the casting.
5. In addition, be sure that at least part of the remaining coronal tissue is prepared perpendicular to the path of placement of the post (see step 4 in Fig. 12-8) because this creates a horizontal flat surface that will serve as a positive stop to minimize wedging and potential splitting of the tooth. Similarly, prevent rotation of the post by preparing a flat surface parallel to the post (see step 5 in Fig. 12-8). If remaining tooth structure is insufficient for this feature, an antirotation groove should be placed in the canal (see Fig. 12-22).
6. Complete the preparation by eliminating sharp angles and establishing a smooth finish line.

Post Fabrication

Prefabricated Posts

Technique simplicity and treatment expediency are advantages of prefabricated posts. A post is selected to match the dimensions of the canal, and only minimum adjustment is needed to seat it to the full depth of the post space. The coronal part of the post may have an inadequate fit because the root canal has been flared. This the dentist can correct by adding material when the core is made.

Available Materials. Prefabricated metal parallel-sided posts are made of platinum-gold-palladium (Pt-Au-Pd), nickel-chromium (Ni-Cr), cobalt-chromium, or stainless steel wire (see Table 12-6). Serrated posts come in stainless steel, titanium, or nonoxidizing noble alloy. Tapered metal posts are available in Pt-Au-Pd, Ni-Cr, and titanium alloys. All these posts have a high modulus of elasticity and an elongated grain structure; thus they are more rigid than cast posts and therefore more suitable.

Bending has been attributed to failure of posts cast in type III gold when loaded at a 45-degree angle.[68] Although posts cast in stiffer (type IV) gold or Ni-Cr alloys can be expected to resist bending better, prefabricated posts should possess even more desirable physical properties, although their properties can deteriorate when a core is cast to a wrought post.[69]

The popularity of fiber composite posts has increased. These posts consist of bundles of stretched aligned glass or carbon fibers (C-Posts, Bisco) embedded in a resin matrix. The resulting post is strong but has significantly less stiffness and strength than ceramic and metal posts do.[70] Retrospective studies of the fiber post systems generally have shorter longevity than metal posts do,[8] but the improved esthetics necessitates their use in many situations (Fig. 12-28). However, in a laboratory study in which teeth restored with carbon fiber posts and composite-resin foundations were compared with teeth restored with custom post and core restorations cast in type III alloy, there were significantly higher fracture thresholds for the cast post and core restorations.[71] One advantage of fiber composite posts is their ease of removal if endodontic re-treatment is necessary. The preferred technique involves drilling in an apical direction with a Gates Glidden drill after a small pilot hole has been prepared with a round bur. Because significant heat is generated during removal, irrigation should be used. The very strong carbon fibers prevent the drill from tracking laterally, precludes penetration of the dentin, and prevents the post from shattering easily into small fragments (Fig. 12-29). Glass fiber posts embedded in an epoxy matrix have properties that are somewhat comparable with those of carbon fiber posts, and translucent posts are available that can aid in light polymerization of resin luting agents.

Manufacturers have also developed high-strength ceramic[3,72] (zirconia) posts (CosmoPost, Ivoclar Vivadent; Fig. 12-30) and ceramic composite (AEstheti-Post, Bisco, Inc.; Fig. 12-31) and woven fiber (e.g., polyethylene) posts (Fibre-Kor, Pentron Clinical), all of which have excellent esthetic properties (see also Chapters 25 and 27). Ceramic is very strong and rigid; woven fiber is weaker and more flexible.[73]

Corrosion Resistance. In several reports,[74-76] root fracture has been linked to corrosion of base metal prefabricated post and core systems. In a report on 468 teeth with vertical or oblique root fracture,[72] investigators attributed 72% of these failures to electrolytic action of dissimilar metals used for the post and the core (reaction occurring between tin in the amalgam core and stainless steel, German silver, or brass in the post). The authors suggested that volume changes produced by corrosion products split the root. Although possible fracture mechanisms have been suggested,[72,74] these studies appear to confuse cause with effect: The corrosion may have occurred after root fracture rather than causing it.[77]

Further study is needed to answer the question conclusively. However, in the meantime, avoiding the use of potentially corrodible dissimilar metals for post, core, and crown is recommended.

Custom-Made Posts

A custom-made post and core restoration can be made of cast metal or from zirconia fabricated with CAD/CAM technology. A cast metal post and core restoration can be made from a direct pattern fabricated in the patient's mouth or from an indirect pattern fabricated in the dental laboratory. A direct technique with autopolymerizing (Fig. 12-32) or light-polymerized resin is recommended for single canals with good clinical access, whereas an indirect procedure is more appropriate when access is more

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FIGURE 12-28 ■ Fiber composite posts. **A** and **B,** The ParaPost Fiber Lux system is available in various sizes. **C,** Gutta-percha is removed with hot instruments or a Gates Glidden drill. The canal is prepared sequentially with the drills provided by the manufacturer. **D,** The post is seated in the canal. **E,** The canal is prepared by etching and priming according to the manufacturer's recommendations. **F,** The luting resin is introduced into the canal with a paper point. **G,** The post is coated with resin luting agent and seated. **H,** The resin is polymerized. The translucent post allows light transmission to the luting agent. **I,** The core is built up with the recommended core resin. **J,** Final appearance of the preparation. (Courtesy Coltène/Whaledent AG, Altstatten, Switzerland.)

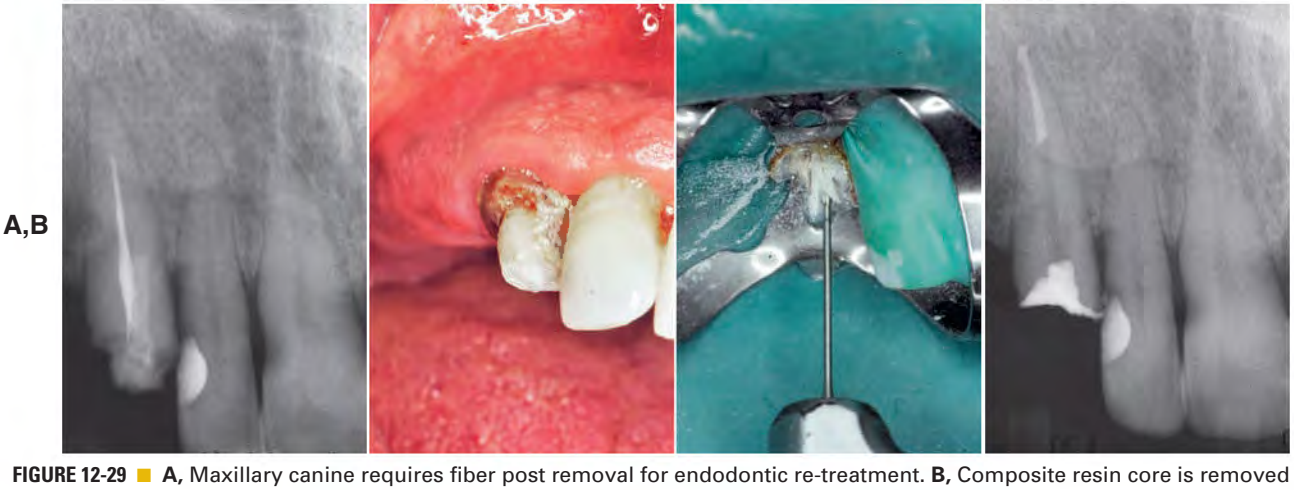

FIGURE 12-29 ■ **A,** Maxillary canine requires fiber post removal for endodontic re-treatment. **B,** Composite resin core is removed first. **C,** Gates Glidden drill used to remove the fiber post. **D,** Endodontically re-treated tooth before fabrication of a new post and core restoration and a new extracoronal restoration. If concern exists about the long-term prognosis of an endodontically treated tooth, a carbon fiber post should be considered. The chief disadvantage of a carbon fiber post is its black appearance, which presents an esthetic problem (as can metal posts). (Courtesy Dr. D.A. Miller.)

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problematic or for multiple canals. An alternative to autopolymerizing resin is thermoplastic resin (Fig. 12-33).

Direct Pattern Procedure

1. Fit a prefabricated plastic dowel to the root canal. For a flared canal, the fit will only be adequate in the apical half of the prepared post space (Fig. 12-32, *A*). It must extend to the full depth of the prepared canal. Lightly lubricate the canal (Fig. 12-32, *B*). Dry the canal by directing air across the root surface (Fig. 12-32, *C*). Never blow air directly into a root canal for fear of introducing air into the tissues.
2. Use the "brush-bead" technique to add resin to the occlusal half dowel (Fig. 12-32, *D*) and seat it in the prepared canal (Fig. 12-32, *E*). Push the resin into the canal with a small condenser (Fig. 12-32, *F*).
3. Do not allow the resin to harden fully within the canal. Loosen and reseat it several times while it is still rubbery.
4. Once the resin has polymerized, remove the pattern (Fig. 12-32, *G*).
5. Form the core part of the post by adding additional autopolymerizing resin (Fig. 12-32, *H*) or light-polymerized resin (Palavit G LC, Heraeus).

FIGURE 12-30 ■ Zirconia posts, such as the CosmoPost, shown with the corresponding rotary instruments, are esthetic and strong. Special pressable ceramics are available to form the core (composite resin can also be used). (Courtesy Ivoclar Vivadent, Amherst, N.Y.)

Pattern Fabrication with Thermoplastic Resin

1. Fit the plastic rod to the prepared post space. Trim the rod until the bevel area is approximately 1.5 to 2 mm occlusal to the finish line for the core.
2. Lubricate the canal with a periodontal probe and petroleum jelly (Fig. 12-33, *A*).
3. Heat the thermoplastic resin over a flame until the material turns clear (Fig. 12-33, *B*), or heat the resin in a low-temperature glue gun (Thermogrip, Black & Decker)
4. Apply a small amount of the heated resin to the apical end of the rod to cover two thirds of the anticipated length of the post pattern (Fig. 12-33, *C*).
5. Fully insert the rod into the prepared post space (Fig. 12-33, *D*). Lift after 5 to 10 seconds and reseat. Inspect the post pattern for completeness and, with

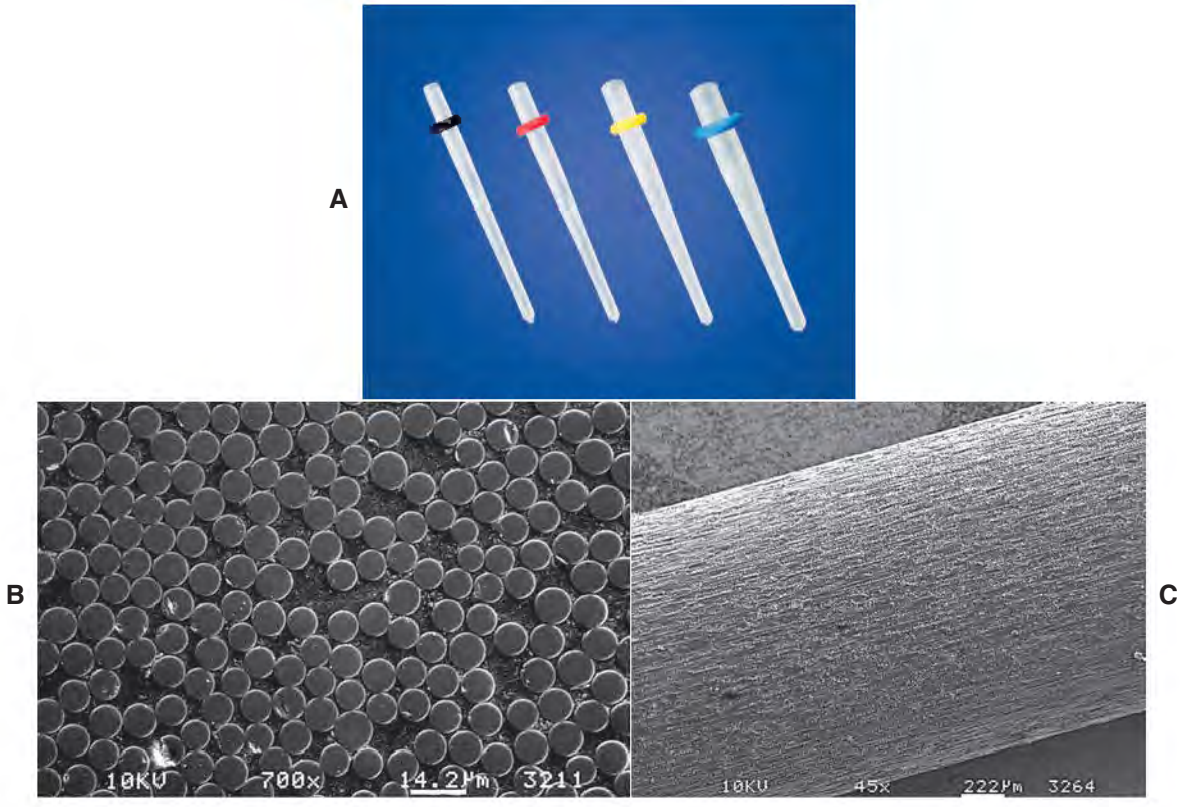

FIGURE 12-31 ■ Ceramic composite post. **A,** In the D.T. Light-Post system, quartz fibers are used in an epoxy resin matrix. Cross-sectional **(B)** and longitudinal **(C)** views of the fiber composite. (Courtesy Bisco, Inc., Schaumburg, Ill.)

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FIGURE 12-32 ■ Fabrication of a custom-made pattern for a custom-made post. **A,** Prefabricated plastic post is tried in. The post should seat the full length of the prepared post space. Lubricant is carried into the post space on a paper point **(B),** and compressed air is used to remove any excess **(C). D,** A small brush is used to pick up some pattern resin and added at the level of the chamber. The plastic post is seated **(E),** and a small condenser can be used to ensure adequate adaptation of the resin **(F). G,** Completed post pattern after additional resin has been added. Note that the apical portion of this prefabricated plastic post corresponds in size to the twist drill used. Therefore, the tip of the pattern is not covered with resin. **H,** The core portion of the pattern can now be developed through addition of more resin.

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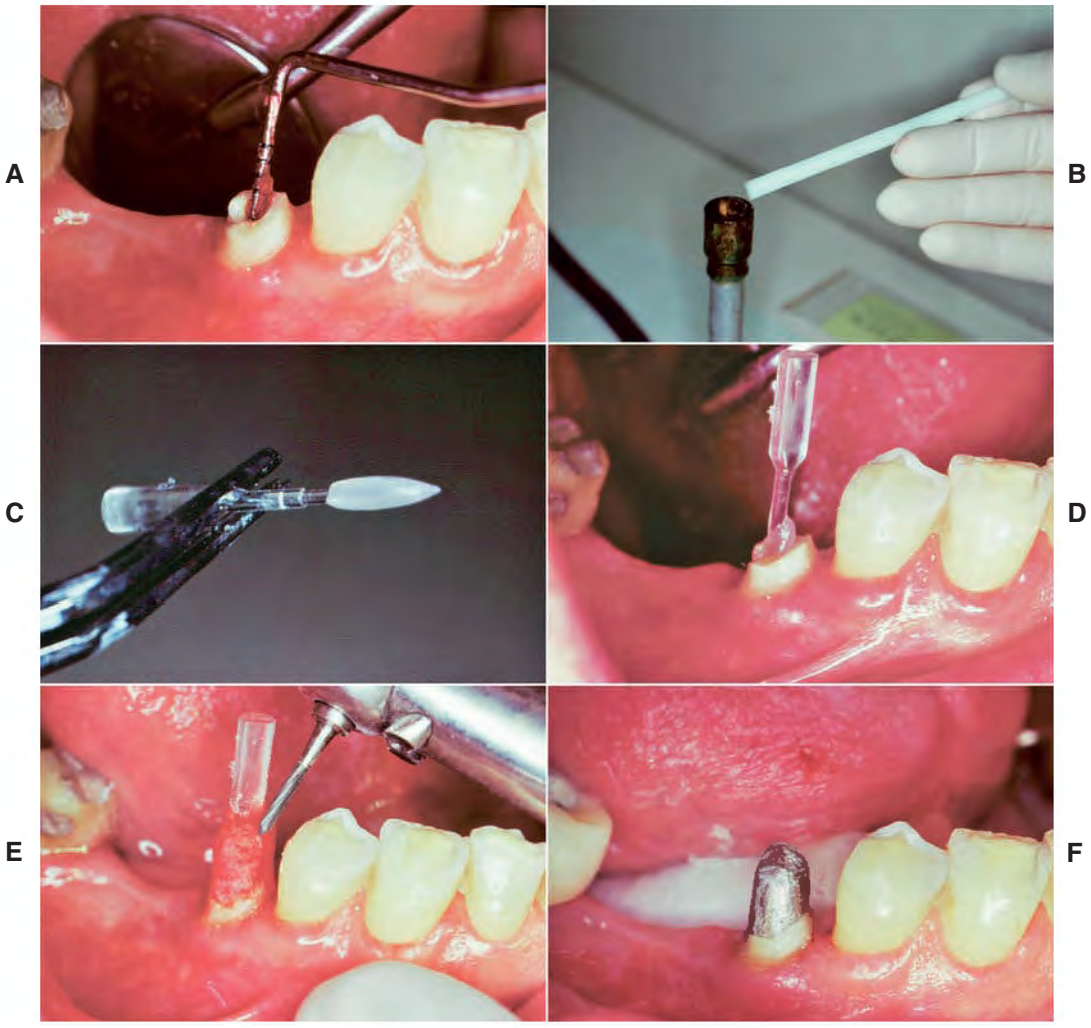

FIGURE 12-33 ■ The Merritt EZ Cast Post system. **A,** The canal is lubricated, and excess lubricant removed with paper points. The post was previously trimmed until its beveled portion protruded about 1.5 to 2 mm above the tooth preparation. **B,** A stick of the thermoplastic material is heated. **C,** The plastic rod is covered for about two thirds of the anticipated post length. **D,** The coated post is inserted and can be removed in 5 to 10 seconds. **E,** After any protrusions have been removed, the core is built from autopolymerizing resin and trimmed to ideal tooth preparation form. **F,** The completed custom post and core restoration. (From Rosenstiel SF, et al: Custom-cast post fabrication with a thermoplastic material. J Prosthet Dent 77:209, 1997.)

a scalpel blade, remove any projections that result from undercuts in the canal.

6. For the direct technique, fabricate the core with conventional autopolymerizing resin (Fig. 12-33, *E*), using the "brush-bead" technique, or use a syringe to apply a light-polymerized pattern resin (an easier technique).
7. If the indirect technique is preferred, pick up the pattern with an elastomeric impression material, which can be poured in the conventional manner. Soak the cast in warm water to help release the pattern. Reseat the post pattern, and wax the core.
8. Invest and cast (Fig. 12-33, *F*) the post and core restoration. Phosphate-bonded investment is recommended because of its higher strength.

Indirect Procedure. Any elastomeric material will make an accurate impression of the root canal (Fig. 12-34, *A*) if wire reinforcement is placed to prevent distortion.

1. Cut pieces of orthodontic wire to length and shape them like the letter J (see Fig. 12-34, *B*).
2. Verify the fit of the wire in each canal. It should fit loosely and extend to the full depth of the post space. If the fit is too tight, the impression material will be stripped away from the wire when the impression is removed.
3. Coat the wire with tray adhesive. If subgingival margins are present, tissue displacement may be helpful. Lubricate the canals to facilitate removal of the impression without distortion (die lubricant is suitable).
4. Using a Lentulo spiral (Dentsply Maillefer), fill the canals with elastomeric impression material. Before loading the impression syringe, verify that the Lentulo spiral will cause the material to spiral in an apical direction (clockwise). Pick up a small amount of material with the largest Lentulo spiral that fits into the post space. Insert the Lentulo spiral with the handpiece set at low rotational speed to slowly carry

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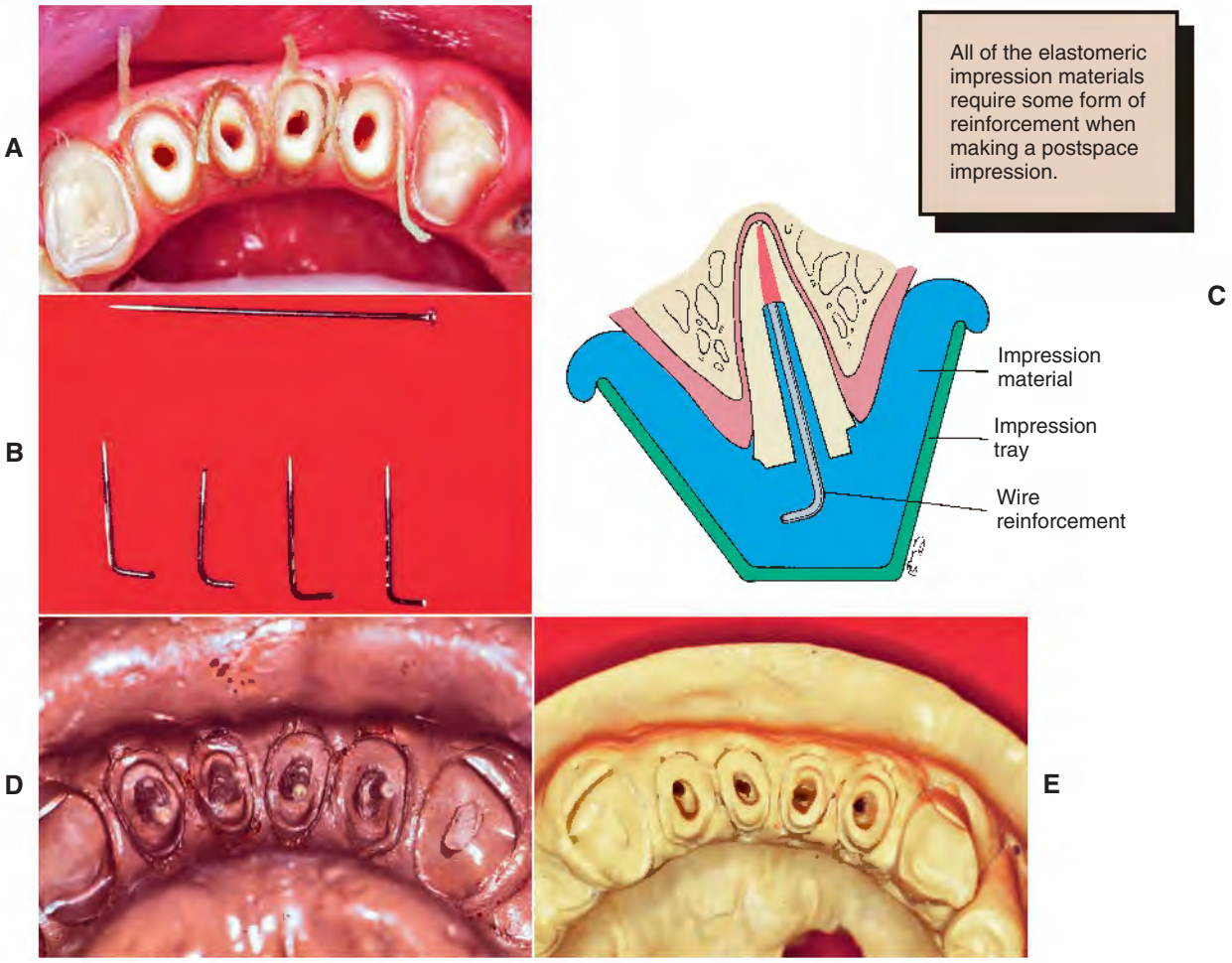

FIGURE 12-34 ■ Indirect procedure for post and core restorations. **A,** mandibular incisors prepared for post and cores. **B,** Wire reinforcement coated with tray adhesive. **C,** Cross-section through indirect post space impression. **D,** Completed impression. **E,** Definitive cast.

material into the apical portion of the post space. Then increase handpiece speed and slowly withdraw the Lentulo spiral from the post space. This technique prevents the impression material from being dragged out. Repeat until the post space is filled.

5. Seat the wire reinforcement to the full depth of each post space, use a syringe to fill in more impression material around the prepared teeth, and insert the impression tray (see Fig. 12-34, *C*).
6. Remove the impression (see Fig. 12-34, *D*), evaluate it, and pour the definitive cast (see Fig. 12-34, *E*) as usual (see Chapter 17). Access for waxing is generally adequate without placement of dowel pins or sectioning of the cast.
7. Roughen a loose-fitting plastic post (a plastic toothpick is suitable) and, using the impression as a guide, make sure that it extends into the entire depth of the canal.
8. Apply a thin coat of sticky wax to the plastic post and, after lubricating the stone cast, add soft inlay wax in increments (Fig. 12-35). Start from the most apical point, and make sure that the post is correctly oriented as it is seated to adapt the wax. When this post pattern has been fabricated, the wax core can be added and shaped.
9. Use the impression to evaluate whether the wax pattern is completely adapted to the post space.

CAD/CAM ZIRCONIA POST AND CORE RESTORATION

Strong, esthetic post and core restorations can be fabricated from strong zirconia with CAD/CAM technology. Typically, the dentist makes an impression of the prepared tooth, which is scanned and digitized by the dental laboratory before the zirconia is milled and sintered.[73] One disadvantage of a custom-milled zirconia system is the difficulty of removal if an endodontic re-treatment is indicated.

Core Fabrication

The core of a post and core restoration replaces missing coronal tooth structure and, in combination with the remaining coronal tissue, forms the shape of the optimal tooth preparation. It can be shaped in resin or wax and added to the post pattern before the assembly is cast in one piece. It is cast directly onto a prefabricated post. There is some concern that the casting process may unfavorably affect the physical properties of wrought metal posts. A third

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FIGURE 12-35 ■ **A** and **B,** Post and core restoration patterns made by adding wax to prefabricated plastic posts.

alternative is to make the core from a plastic restorative material, such as amalgam, or from composite resin or glass ionomer.

Plastic Filling Materials

The advantages of amalgam, glass ionomer, or resin[68,78,79] include the following:

- Maximum tooth structure can be conserved because undercuts do not need to be removed.
- Treatment requires one fewer patient visit.
- There are fewer laboratory procedures.
- Testing has generally revealed good resistance to fatigue testing[80] and good strength characteristics,[81] possibly because of the good adaptation to tooth structure. However, these plastic restorative materials, especially the glass ionomers, have lower tensile strength than do cast metals.

Disadvantages include the following:

- Long-term success may be affected by corrosion of amalgam cores, the low strength of glass ionomer,[82] or the continued polymerization[83] and high thermal expansion coefficients of composite resin cores.
- Microleakage with temperature fluctuations (thermocycling) is greater under composite resin and amalgam cores than under conventional crown preparations[84] (however, the extent of leakage under cast cores has yet to be determined).
- Difficulty may be encountered with certain operative procedures such as rubber dam or matrix application (particularly on badly damaged teeth).

Amalgam cores are suitable for restoring posterior teeth, particularly when some coronal structure remains. The procedure described by Nayyar and associates,[48] in which amalgam is also used for the posts, is conservative of tooth structure (Fig. 12-36). The cores are placed during the same appointment as the root canal obturation because then the teeth are still isolated by the rubber dam, the practitioner is still familiar with the root canal structure, and the cores can serve as a support for the interim restoration (Fig. 12-37).

Step-by-Step Procedure for Amalgam. See also Chapter 6.

1. Apply the rubber dam, and, using a warmed endodontic instrument, remove gutta-percha from the pulp chamber, as well as 2 to 4 mm into each root canal if less than 4 mm of coronal height remains.
2. Remove any existing restoration, undermined enamel, or carious or weakened dentin. Establish the cavity form by using conventional principles of resistance and retention form. Even if cusps are missing, pins are not normally required, because adequate retention can be obtained by extension of the amalgam into the root canals.
3. If the floor of the pulp chamber could be thin, protect it from condensing pressures with a cement base.
4. Fit a matrix band. Where lack of tooth structure makes the application of a conventional matrix system difficult, an orthodontic or annealed copper band may be used.
5. Condense the first increments of amalgam (select a material with high early strength) into the root canals with an endodontic plugger.
6. Fill the pulp chamber and coronal cavity in the conventional manner.
7. Carve the alloy to shape. The impression can be made immediately. Alternatively, the amalgam can be built up to anatomic contour and later prepared for a complete crown. Under these circumstances, the patient must be cautioned to avoid forces that would fracture the tooth or the newly placed restoration.

Cast Metal

Cast metal cores have the following advantages:

- They can be cast directly onto a prefabricated post, which will provide the restoration with good strength characteristics.
- Conventional high noble-metal content alloys can be used.
- An indirect procedure can be used, which will facilitate restoration of posterior teeth.

Direct Procedure for Single-Root Teeth. Direct patterns can be formed by combining a prefabricated post with autopolymerizing resin. Alternatively, a thermoplastic material can be used to create a post pattern,[85] and the core portion can be developed in autopolymerizing resin, light polymerized resin, or wax.

Pattern Fabrication with Autopolymerizing Resin

1. Use a prefabricated metal or custom acrylic resin post.
2. Add resin by the "brush-bead" technique, dipping a small brush in monomer and then into polymer

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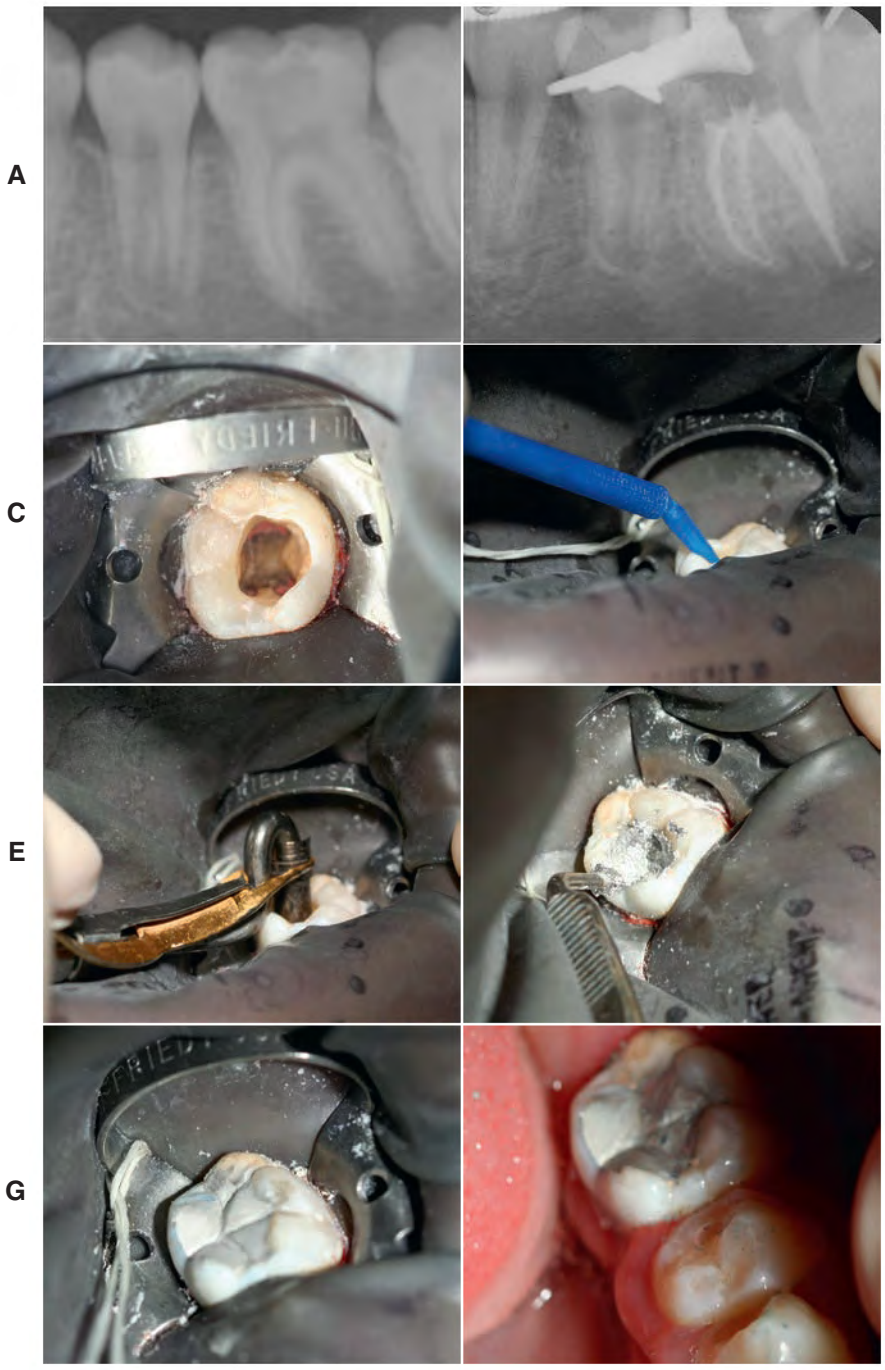

FIGURE 12-36 ■ Amalgam core technique. **A** and **B,** Extensive caries resulted in need for endodontic treatment. **C,** Chamber preparation may include slight extension into canals. **D,** After etching, bonding agent is applied under rubber dam isolation. **E,** Amalgam is carried into the chamber. **F,** Alloy being condensed. **G** and **H,** Completed amalgam foundation restoration. (Courtesy Dr. R.D. Douglas.)

and applying it to the post. Alternatively, light-cured resin can be used to facilitate this step.[86]

3. Slightly overbuild the core, and let it polymerize fully (Fig. 12-38, *A*).
4. Shape the core with carbide finishing burs or diamonds (see Fig. 12-38, *B*). Use water spray to prevent overheating of the acrylic resin. Correct any small defects with wax.
5. Remove the pattern (see Fig. 12-38, *C*); sprue and invest it immediately.

Interim Restorations

To reduce the need for endodontic re-treatment, endodontically treated teeth should be restored as soon as practical after completion of the endodontic procedure. Zinc oxide–eugenol (ZOE) luting materials have been used for many years to achieve a seal of the endodontic access cavity before initiation of prosthetic treatment. However, such ZOE materials have been shown to leak at the dentin-material interface.[87] Thus if definitive

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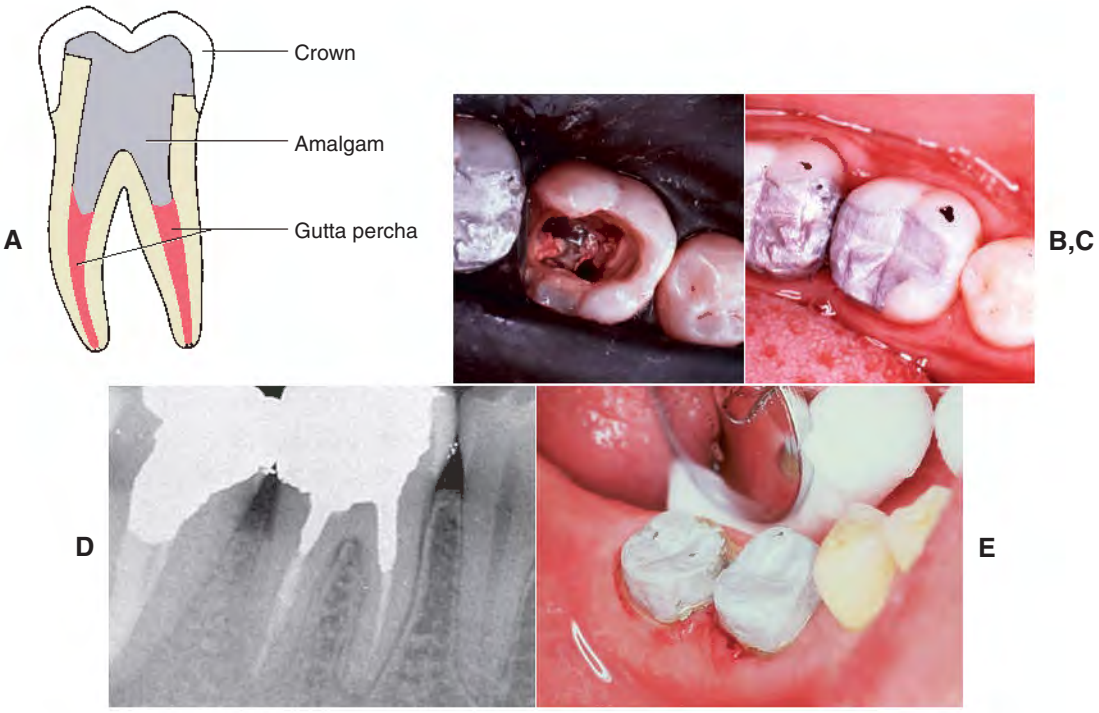

FIGURE 12-37 ■ Retention for an amalgam foundation can be obtained from the root canal system, preserving as much tooth structure as possible. **A,** Cross-section of chamber-retained amalgam foundation. **B,** Gutta-percha removed from pulp chamber and root canals for amalgam foundation restoration. **C,** Amalgam condensed and contoured. **D,** Radiograph showing extent of amalgam. **E,** Teeth prepared for complete crowns. (**B** to **D,** Courtesy Dr. M. Padilla.)

restoration of the tooth is delayed, it is appropriate to etch and seal the access cavity with an adhesive resin to reduce the risk of microleakage. Nonetheless, teeth in the esthetic zone often require a well-adapted interim restoration (see Chapter 15).

Such interim restorations prevent drifting of the tooth itself and of opposing or adjacent teeth after completion of endodontic treatment (Fig. 12-39). Of particular importance are good proximal contacts to prevent tooth migration that leads to unwanted root proximity. If a cast post and core restoration is made, the tooth will require an interim restoration while the post and core restoration is being fabricated. To retain tooth position, a wire of suitable diameter, or an interim post that matches the size of the selected post and core restoration system, can be fitted into the prepared canal. The restoration is then fabricated with autopolymerizing resin by the direct technique.

Investing and Casting

A cast post and core restoration should be slightly undersized in relation to the prepared post space in order to ensure full seating. However, the fit should not be so loose that light finger pressure causes rocking, rotation, or wobbling. On the other hand, a tight fit may cause root fracture. The casting should be slightly undersized, which the dentist can accomplish by appropriately restricting expansion of the investment (e.g., by omitting the usual ring liner or by casting at a lower mold temperature; see Chapter 22). An accelerated casting technique may facilitate the laboratory phase.[88] CAD/CAM technology can also be used for the rapid fabrication of a post and core restoration (Fig. 12-40).[89] The casting alloy should have suitable physical properties. Extra-hard partial dental prosthetic gold (American Dental Association type IV) or Ni-Cr alloys have high moduli of elasticity and are recommended for cast posts (see Chapter 19). A sound casting technique is essential because any undetected porosity can lead to weakening, and then failure, of the casting (Fig. 12-41).

Evaluation

The practitioner must be particularly careful that casting defects such as small nodules do not interfere with seating of the post; otherwise, root fracture can result. Post and core restorations should be inserted with gentle pressure. Should any resistance be encountered, the practitioner must remove the casting and determine what prevents full seating before proceeding. Once the casting is seated, however, the marginal fit of a cast foundation is not as crucial as that of extracoronal restorations because the margins will be covered by the final crown. Air-abrading the surface to a matte finish may help detect interferences at try-in (Fig. 12-42).

The shape of the foundation is evaluated and adjusted as necessary until tooth preparation geometry is optimal.

Cementation

The luting agent must fill all space within the root canal system (Fig. 12-43). Voids may be a cause of periodontal inflammation via lateral canals.

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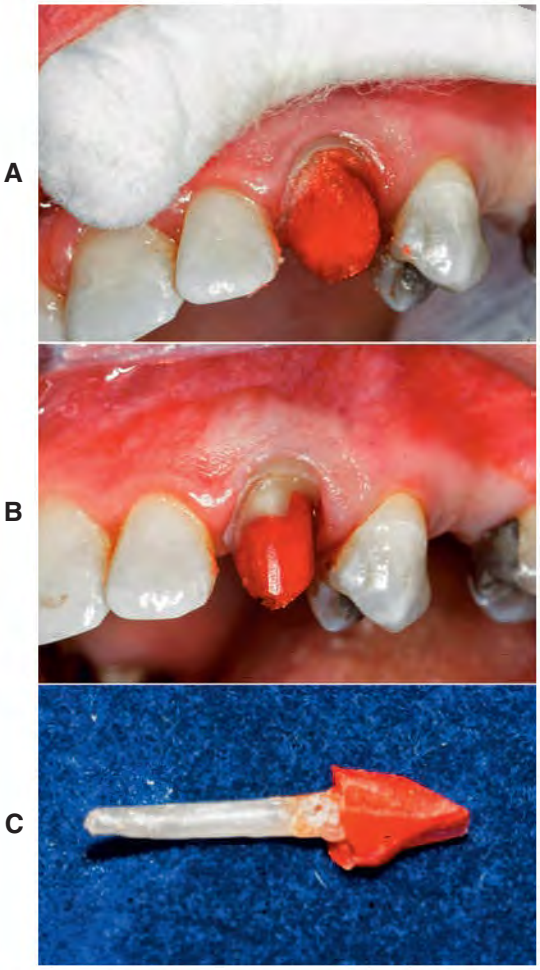

FIGURE 12-38 ■ Direct pattern for a single-root tooth. **A,** Pattern slightly overbuilt with brush-bead technique. **B,** Pattern prepared with tungsten carbide finishing bur. **C,** Direct post and core pattern.

A rotary (Lentulo) spiral filler or cement tube (Fig. 12-44) is used to fill the canal with cement. The post and core restoration is inserted gently to reduce hydrostatic pressure, which could cause root fracture. Many prefabricated parallel-sided posts have longitudinal grooves incorporated into their design to allow for improved escape of excess cement. If needed, such a groove may be added with a small bur. Use of such venting procedures has also been shown to reduce the necessary seating force, although the latter is probably cement specific.[90]

It is not essential that the reline material extend all the way down the post space. By engaging the apical portion of the post space, the wire will enhance resistance of the interim restoration.

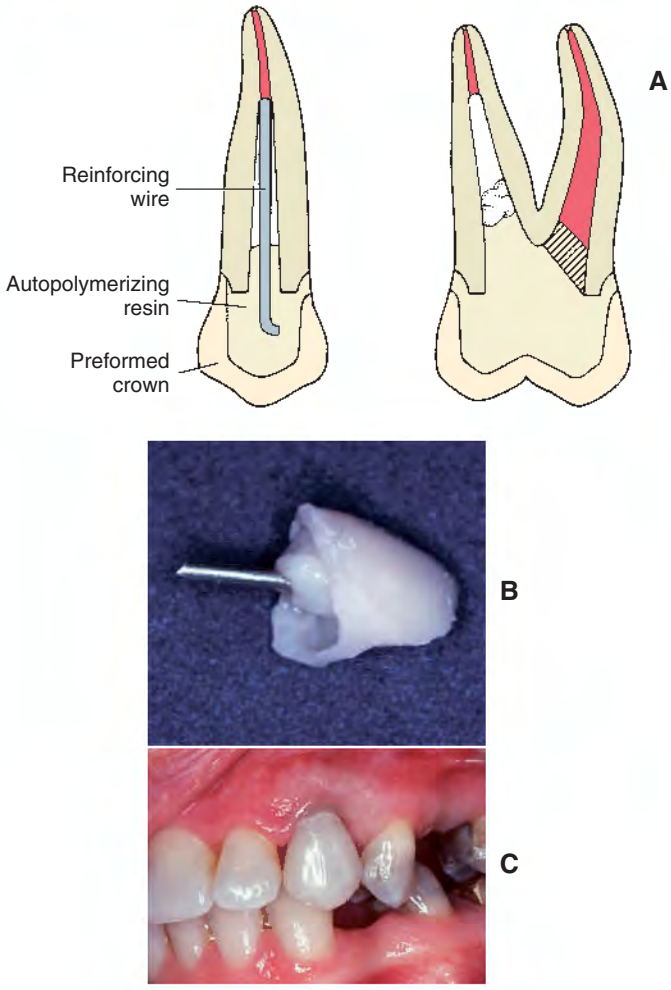

FIGURE 12-39 ■ **A** and **B,** Interim restorations made for endodontically treated teeth by lining a polycarbonate crown with autopolymerizing resin. The post is made of metal wire (orthodontic wire or a paper clip; see Chapter 15). **C,** Restoration seated. (**A,** Redrawn from Taylor GN, Land MF: Restoring the endodontically treated tooth and the cast dowel. In Clark JW, ed: Clinical dentistry, vol 4. New York, Harper & Row, 1985.)

Removal of Existing Posts

On occasion, an existing post and core restoration must be removed (e.g., for re-treatment of a failed root canal filling). Patients must understand in advance that post removal is a risky process and occasionally results in radicular fracture and tooth loss. If sufficient length of post is exposed coronally, the post can be retrieved with thin-beaked forceps. Causing the post to vibrate first with an ultrasonic scaler weakens brittle water-based cements and facilitates removal. A thin scaler tip or special post removal tip is recommended (Fig. 12-45). Although histologic examination with animal models reveals no harmful effect in the periodontal tissues,[91] ultrasonic removal is slower than other methods and may result in an increased number of canal and intradentin cracks.[92] An alternative method is to use a a post puller.[93] One of these devices consists of a vise to grip the post and legs that bear on the root surface. A screw activates the vise and extracts the post.

A post that has fractured within the root canal cannot be removed with a post puller or forceps. The post may possibly be drilled out, but great care is needed to avoid

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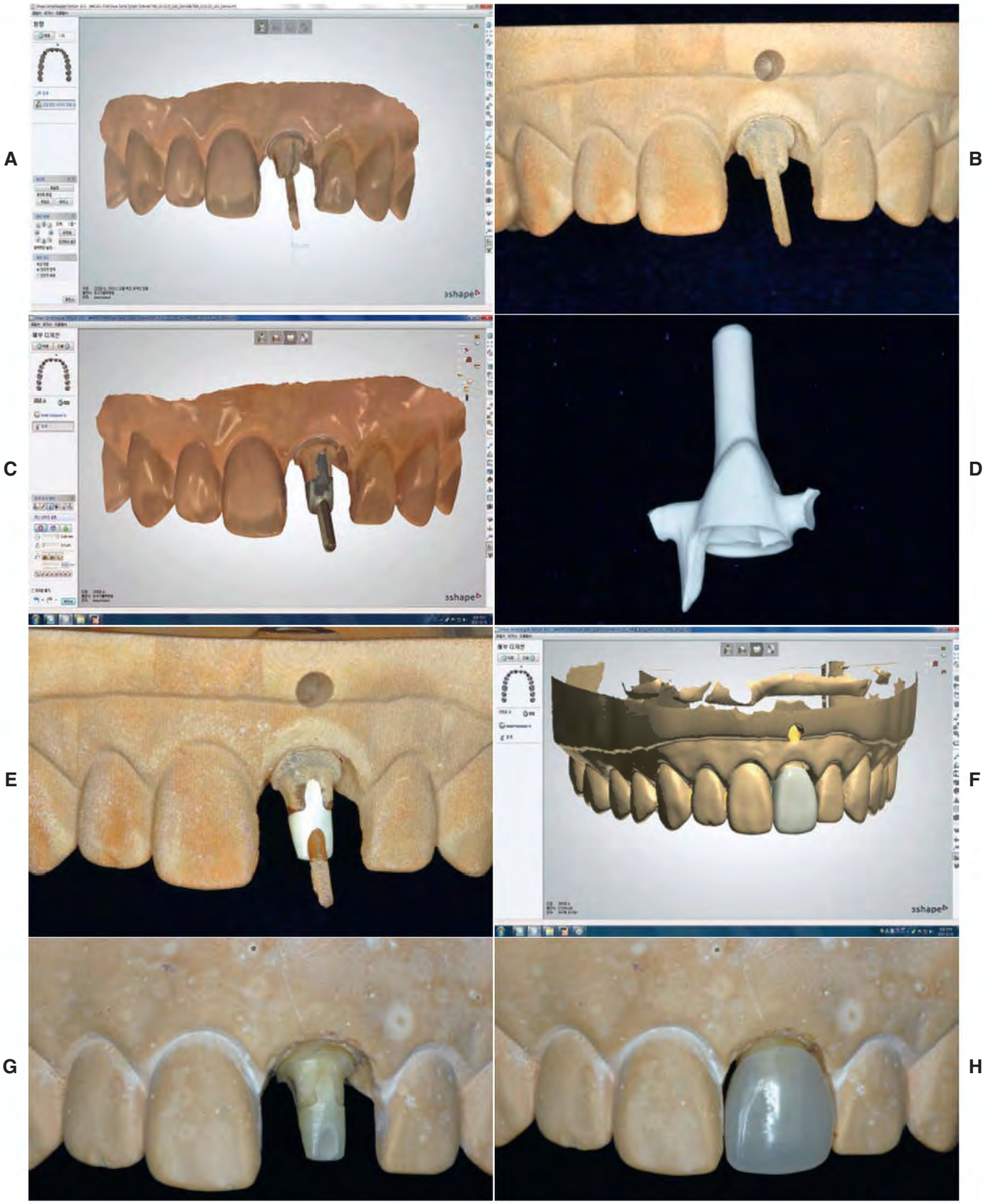

FIGURE 12-40 ■ **A,** Software view of digital impression by intraoral digital scanner. **B,** Polyurethane cast. **C,** Software view of computer-assisted design of anatomically correct core that is based on contralateral tooth. **D,** Milled zirconia core before sintering. **E,** Zirconia core fitted in polyurethane cast. **F,** Software view of computer-assisted design of anatomically correct crown that is based on contralateral tooth. **G,** Fiber-reinforced composite resin post and zirconia core in place. **H,** Interim restoration milled from high-density polymer.

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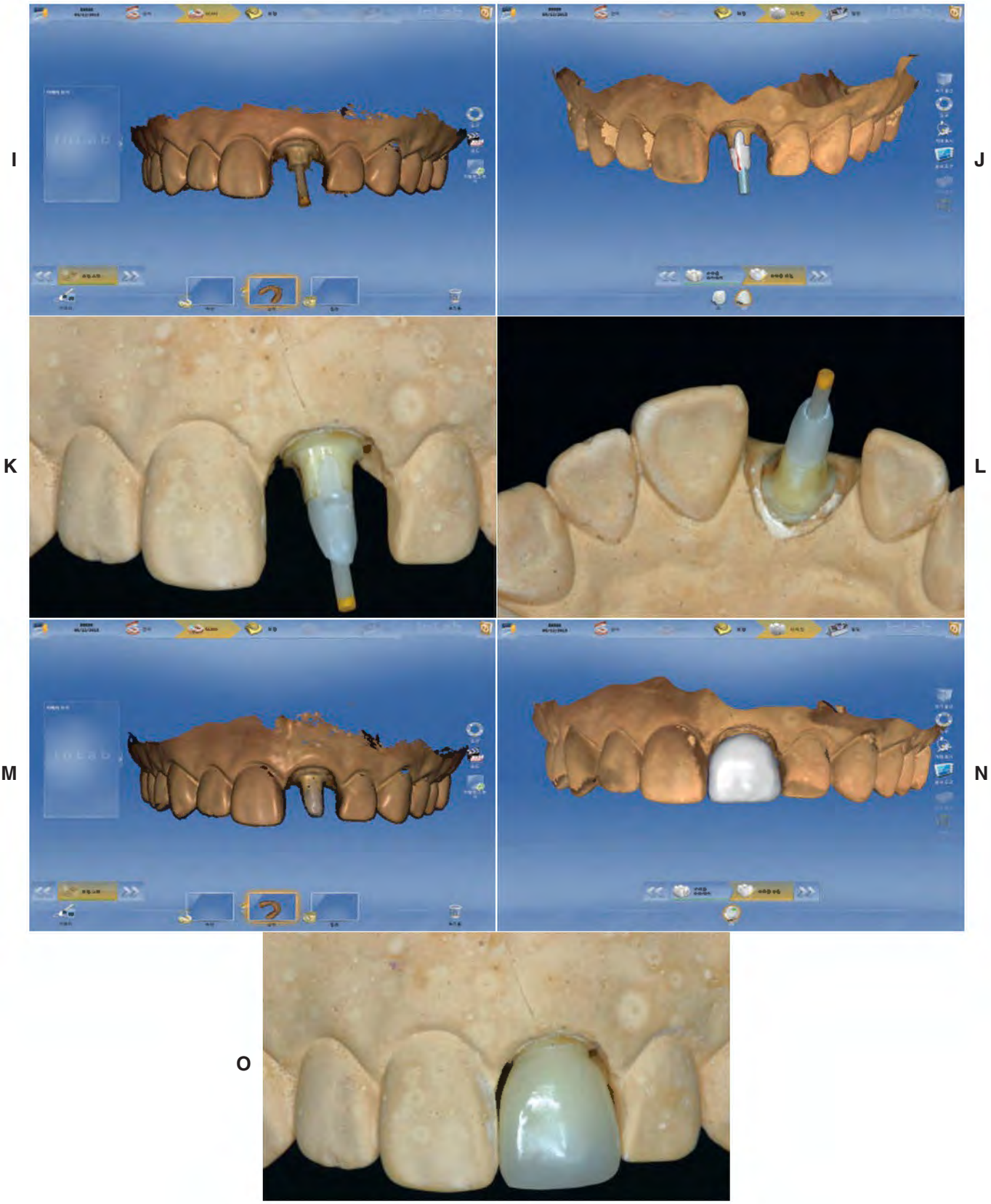

FIGURE 12-40, cont'd ■ **I,** Software view of digital impression by intraoral digital scanner. **J,** Software view of computer-assisted design of anatomically correct core that is based on tooth anatomy library. **K,** Frontal view of fiber-reinforced composite resin (FRC) post and ceramic core fitted in abutment tooth. **L,** Occlusal view of FRC post and ceramic core fitted in abutment tooth. **M,** Software view of digital impression by intraoral digital scanner. **N,** Software view of computer-assisted design of anatomically correct crown form that is based on the tooth anatomy library incorporated in the software. **O,** Definitive restoration milled from ceramic block. (From Lee JH: Accelerated techniques for a post and core restoration and a crown restoration with intraoral digital scanners and CAD/CAM and rapid prototyping. J Prosthet Dent 112[5]:1024, 2014.)

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perforation. The technique is best limited to relatively short fractured posts (Fig. 12-46).

Another means of handling an embedded fractured post (described by Masserann[94] in 1966) is to use special hollow end-cutting tubes (or trephines) to prepare a thin trench around the post (Fig. 12-47). This technique has been successful.[95] Retrieval can be facilitated by using an adhesive to attach a hollow tube extractor[96] or by using a threaded extractor[97] (Fig. 12-48).

SUMMARY

Although the rationale for restoration of endodontically treated teeth is supported considerably by laboratory research data, information from controlled long-term clinical trials is still necessary and difficult to obtain. Different clinical procedures have been advocated, many of which are successful if properly used. When the crown is preserved and circumferentially largely intact, an anterior tooth can be safely restored with a plastic filling. To prevent fracture of posterior teeth, cast restorations providing cuspal coverage are recommended.

Preserving as much tooth structure as possible is important, particularly within the root canal, in which the amount of remaining dentin may be difficult to assess.

A post and core restoration is used to provide retention and support for a cast restoration. It should be of adequate length for good stress distribution but not so long that it jeopardizes the apical seal. The safest method to create post space is to use a heated endodontic plugger to remove the gutta-percha. Anterior teeth, particularly those with flared or elliptical canals, should be built up with a custom cast post and core restoration, which is extremely strong, although prefabricated posts can be used successfully when the plastic material provides adequate retention and resistance form. Esthetic post materials should be considered if a dark post would compromise the esthetics of a restoration. Amalgam core material can be used satisfactorily on posterior teeth when one or more cusps have been lost, although a casting may be preferred if substantial coronal tooth structure is missing.

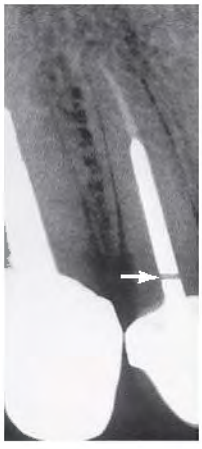

FIGURE 12-41 ■ **Fractured post.** (Courtesy Dr. D. Francisco.)

FIGURE 12-43 ■ **Residual voids after cementation can cause inflammation.** (Courtesy Dr. D. Francisco.)

FIGURE 12-42 ■ **A,** The fitting surface of the casting must be carefully evaluated. **B,** Nodules, as seen here, could easily lead to root fracture and tooth loss.

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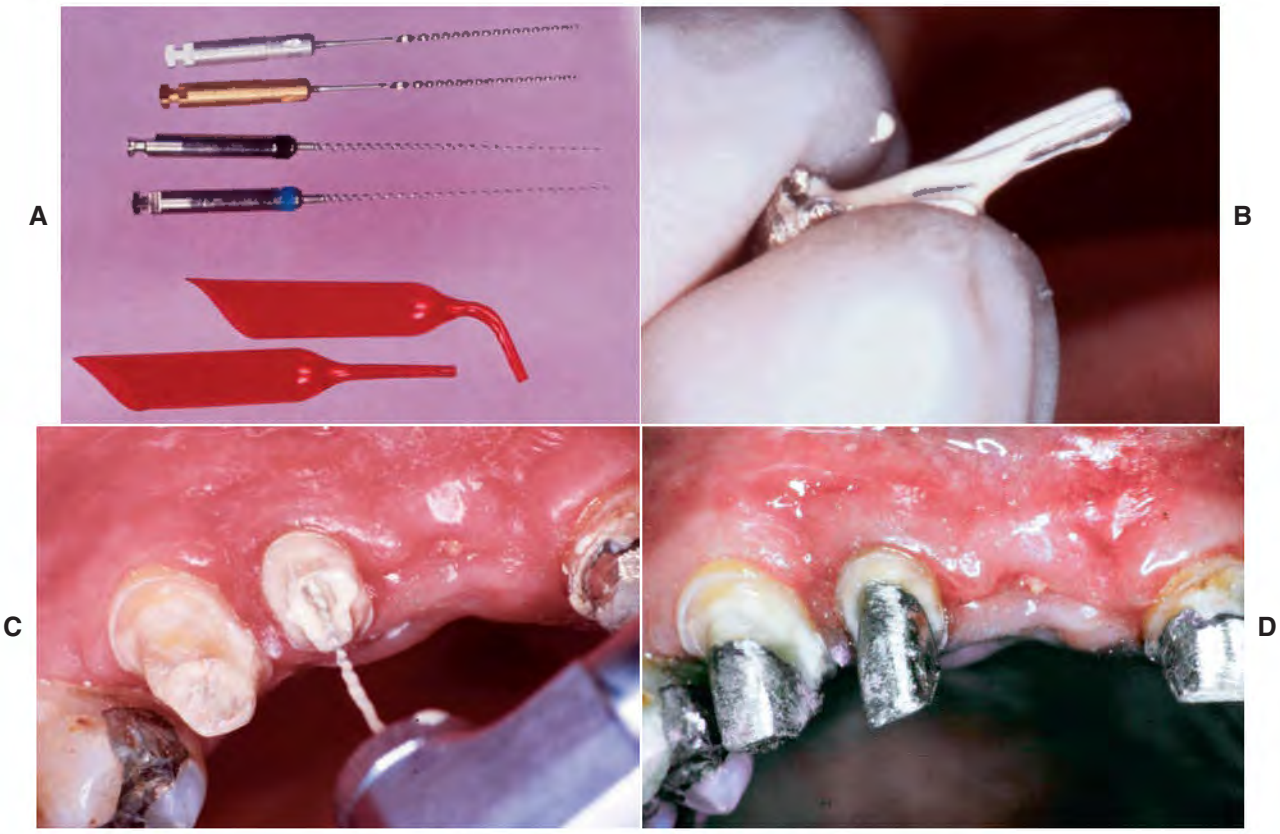

FIGURE 12-44 ■ **A,** Rotary spiral fillers or a cement tube are used to fill the post space completely. **B,** The post is first coated with cement. **C,** The canal is filled with cement. **D,** To avoid the risk of fracture, the post and core restoration is very gently seated. A small cement line is not usually significant because dissolution is prevented by the presence of the definitive restoration. (**B** to **D,** Courtesy Dr. M. Padilla.)

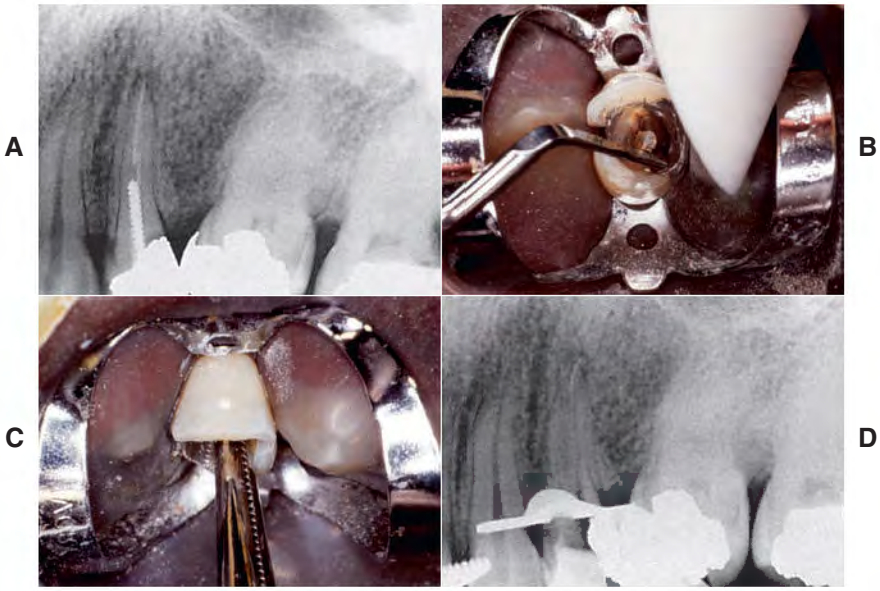

FIGURE 12-45 ■ Post removal by ultrasonic device. **A,** Preoperative radiograph of the left maxillary first premolar with a parallel-sided threaded post that had to be removed for endodontic re-treatment. **B,** After the coronal portion of the post has been well isolated, the tip of the ultrasonic device is placed against it, and energy is applied to disrupt the cement interface. Note the suction tip, which removes water spray used with the ultrasonic handpiece. **C,** After a time, the post becomes loose within the canal and can be retrieved by forceps. **D,** Radiograph of the premolar after post removal. (Courtesy Dr. L.L. Lazare.)

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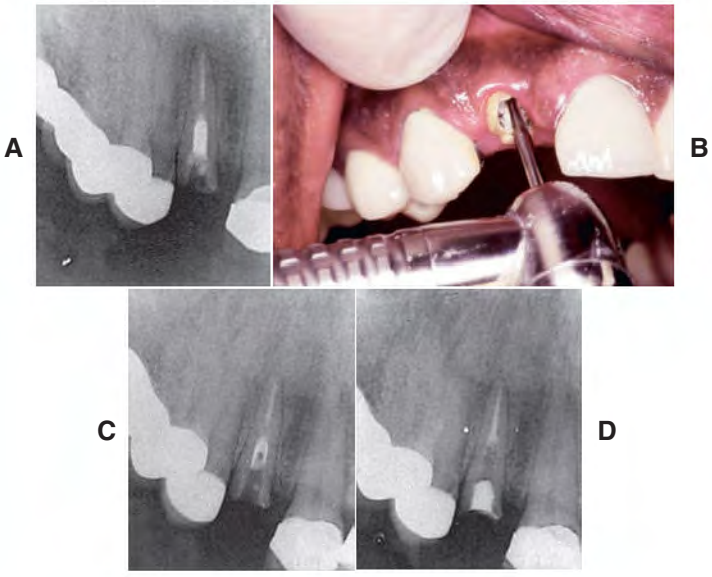

FIGURE 12-46 ■ Post removal by high-speed bur. **A,** Preoperative radiograph of the right maxillary lateral incisor, in which both the crown and part of a post have been fractured off. A portion of the parallel-sided, threaded post remains within the canal. **B,** Because of the large diameter of the post and its position within the canal, a high-speed handpiece was chosen to drill it out. **C,** Radiograph to verify the correct orientation of the bur's progress inside the canal. With this method of post removal, the operator must be extremely careful not to let the high-speed bur contact the canal wall, which would seriously compromise tooth structure. **D,** Radiograph of the incisor after post removal and re-treatment. (Courtesy Dr. D.A. Miller.)

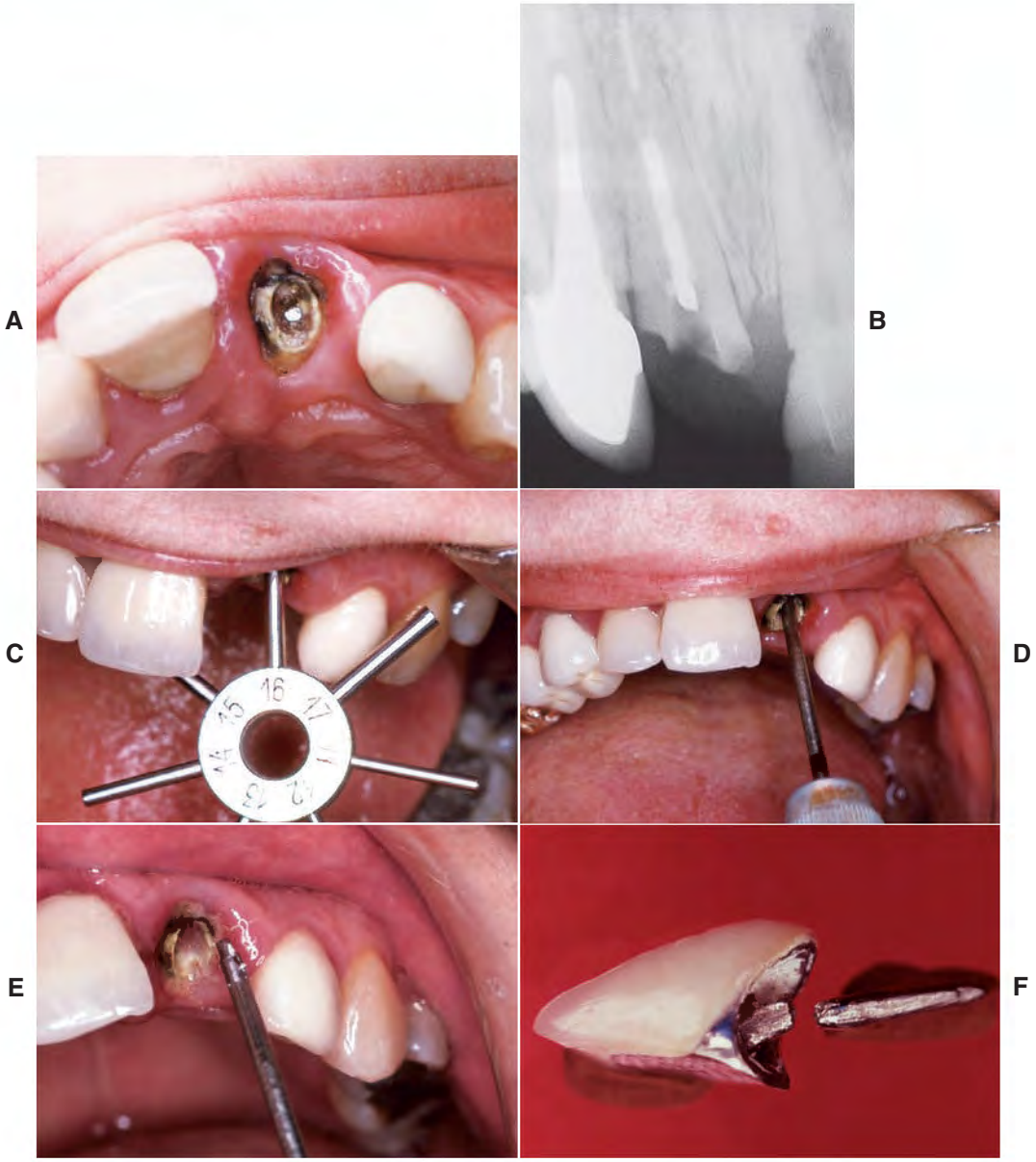

FIGURE 12-47 ■ Masserann technique for the removal of fractured posts. **A** and **B,** Maxillary incisor with a post that has fractured inside the canal. **C,** The diameter of the post is gauged with a sizing tool. **D,** The selected trephine is carefully rotated counterclockwise to create a narrow channel around the post. **E,** When the instrument has removed sufficient material, the post is recovered. **F,** The fractured crown and post after removal.

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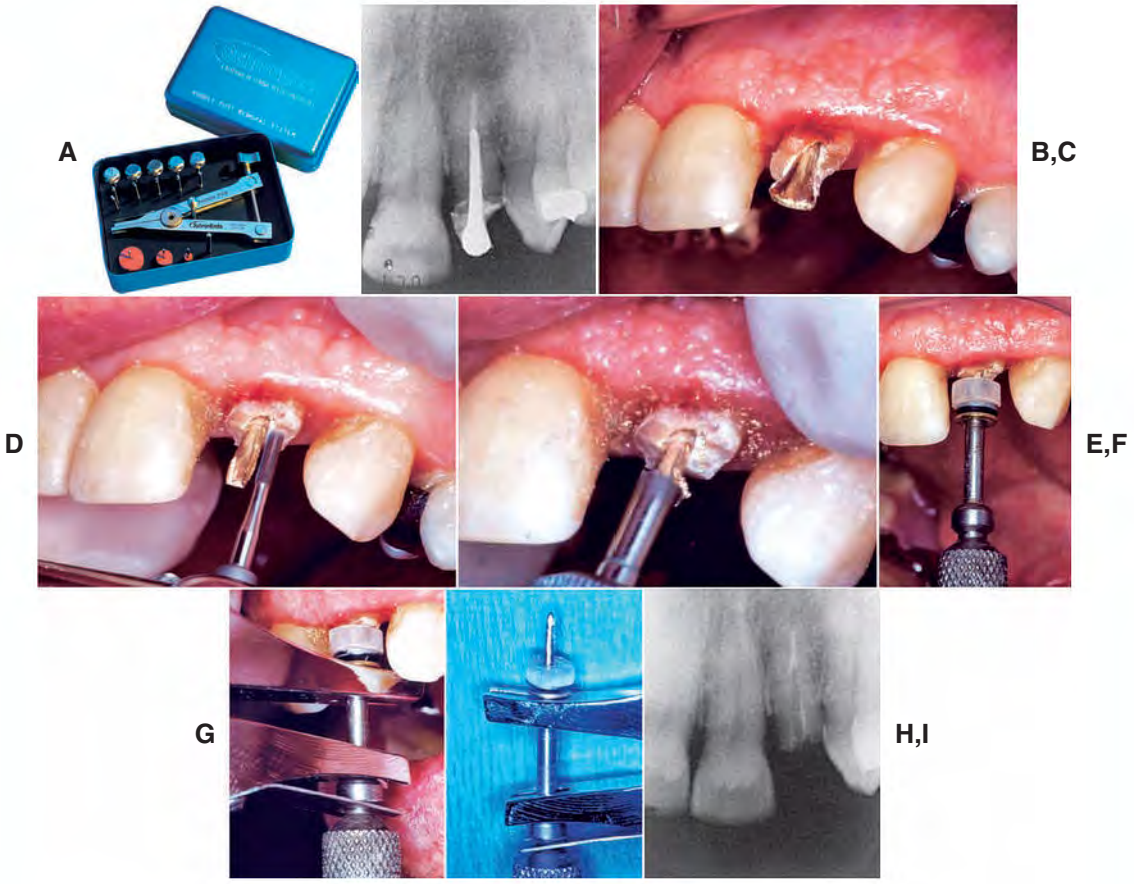

FIGURE 12-48 ■ Post removal by extractor. **A,** Ruddle Post Removal System. It includes pliers, trephine burs, mandrels, and washers. **B,** Preoperative radiograph of the left maxillary lateral incisor with a post. **C,** Note the flared shape of the post in this preoperative view and the height of the surrounding tooth structure. **D,** A high-speed bur is used to free the post from coronal tooth structure and parallel its sides. (Note: An ultrasonic device may be used at this point to disturb the cement interface.) **E,** A trephine bur machines the post to the correct diameter and places threads for the mandrel. **F,** The mandrel is threaded onto the post with special washers, which distribute the forces from the extractor evenly over the tooth. **G,** The beaks of the pliers are fitted onto the mandrel; the knob of the pliers is then rotated, which separates the beaks, and the post is extruded from the tooth. **H,** The removed post, still attached to the mandrel and pliers. **I,** Radiograph of the lateral incisor after post removal. (**A,** Courtesy SybronEndo Corporation, Orange, CA. **B** to **H,** Courtesy Dr. D.A. Miller.)

REFERENCES

1. Johnson JK, et al: Evaluation and restoration of endodontically treated posterior teeth. J Am Dent Assoc 93:597, 1976.
2. Decerle N, et al: Evaluation of Cerec endocrowns: a preliminary cohort study. Eur J Prosthodont Restor Dent 22:89, 2014.
3. Kakehashi Y, et al: A new all-ceramic post and core system: clinical, technical, and in vitro results. Int J Periodontics Restorative Dent 18:586, 1998.
4. Blitz N: Adaptation of a fiber-reinforced restorative system to the rehabilitation of endodontically treated teeth. Pract Periodont Aesthet Dent 10:191, 1998.
5. Torbjörner A, et al: Survival rate and failure characteristics for two post designs. J Prosthet Dent 73:439, 1995.
6. Sorensen JA, Martinoff JT: Clinically significant factors in dowel design. J Prosthet Dent 52:28, 1984.
7. Loney RW, et al: The effect of load angulation on fracture resistance of teeth restored with cast post and cores and crowns. Int J Prosthodont 8:247, 1995.
8. Baba NZ, et al: Nonmetallic prefabricated dowels: a review of compositions, properties, laboratory, and clinical test results. J Prosthodont 18:527, 2009.
9. Helfer AR, et al: Determination of the moisture content of vital and pulpless teeth. Oral Surg Oral Med Oral Pathol 34:661, 1972.
10. Trabert KC, et al: Tooth fracture: a comparison of endodontic and restorative treatments. J Endod 4:341, 1978.
11. Guzy GE, Nicholls JI: In vitro comparison of intact endodontically treated teeth with and without Endo-Post reinforcement. J Prosthet Dent 42:39, 1979.
12. Hunter AJ, et al: Effects of post placement on endodontically treated teeth. J Prosthet Dent 62:166, 1989.
13. Ko CC, et al: Effects of posts on dentin stress distribution in pulpless teeth. J Prosthet Dent 68:421, 1992.
14. Kantor ME, Pines MS: A comparative study of restorative techniques for pulpless teeth. J Prosthet Dent 38:405, 1977.
15. Sorensen JA, Martinoff JT: Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 51:780, 1984.
16. Lu YC: A comparative study of fracture resistance of pulpless teeth. Chin Dent J 6:26, 1987.
17. Aquilino SA, Caplan DJ: Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent 87:256, 2002.
18. Warren MA, et al: In vitro comparison of bleaching agents on the crowns and roots of discolored teeth. J Endod 16:463, 1990.
19. Madison S, Walton R: Cervical root resorption following bleaching of endodontically treated teeth. J Endod 16:570, 1990.
20. Hansen EK, et al: In vivo fractures of endodontically treated posterior teeth restored with amalgam. Endod Dent Traumatol 6:49, 1990.
21. McKerracher PW: Rational restoration of endodontically treated teeth. I. Principles, techniques, and materials. Aust Dent J 26:205, 1981.

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22. Felton DA, et al: Threaded endodontic dowels: effect of post design on incidence of root fracture. J Prosthet Dent 65:179, 1991.
23. Henry PJ: Photoelastic analysis of post core restorations. Aust Dent J 22:157, 1977.
24. Assif DF, et al: Photoelastic analysis of stress transfer by endodontically treated teeth to the supporting structure using different restorative techniques. J Prosthet Dent 61:535, 1989.
25. Milot P, Stein RS: Root fracture in endodontically treated teeth related to post selection and crown design. J Prosthet Dent 68:428, 1992.
26. Sorensen JA, Engelman MJ: Ferrule design and fracture resistance of endodontically treated teeth. J Prosthet Dent 63:529, 1990.
27. Libman WJ, Nicholls JI: Load fatigue of teeth restored with cast posts and cores and complete crowns. Int J Prosthodont 8:155, 1995.
28. Isidor F, et al: The influence of post length and crown ferrule length on the resistance to cyclic loading of bovine teeth with prefabricated titanium posts. Int J Prosthodont 12:78, 1999.
29. Gegauff AG: Effect of crown lengthening and ferrule placement on static load failure of cemented cast post-cores and crowns. J Prosthet Dent 84:169, 2000.
30. Turner CH: Post-retained crown failure: a survey. Dent Update 9:221, 1982.
31. Standlee JP, et al: Retention of endodontic dowels: effects of cement, dowel length, diameter, and design. J Prosthet Dent 39:401, 1978.
32. Ruemping DR, et al: Retention of dowels subjected to tensile and torsional forces. J Prosthet Dent 41:159, 1979.
33. Kurer HG, et al: Factors influencing the retention of dowels. J Prosthet Dent 38:515, 1977.
34. Cooney JP, et al: Retention and stress distribution of tapered-end endodontic posts. J Prosthet Dent 55:540, 1986.
35. Krupp JD, et al: Dowel retention with glass-ionomer cement. J Prosthet Dent 41:163, 1979.
36. Wood WW: Retention of posts in teeth with nonvital pulps. J Prosthet Dent 49:504, 1983.
37. Hanson EC, Caputo AA: Cementing mediums and retentive characteristics of dowels. J Prosthet Dent 32:551, 1974.
38. Chapman KW, et al: Retention of prefabricated posts by cements and resins. J Prosthet Dent 54:649, 1985.
39. Driessen CH, et al: The effect of bonded and nonbonded posts on the fracture resistance of dentin. J Dent Assoc S Afr 52:393, 1997.
40. Mendoza DB, Eakle WS: Retention of posts cemented with various dentinal bonding cements. J Prosthet Dent 72:591, 1994.
41. O'Keefe KL, et al: In vitro bond strength of silica-coated metal posts in roots of teeth. Int J Prosthod 5:373, 1992.
42. Tjan AH, Nemetz H: Effect of eugenol-containing endodontic sealer on retention of prefabricated posts luted with adhesive composite resin cement. Quintessence Int 23:839, 1992.
43. Bitter K, et al: Analysis of resin-dentin interface morphology and bond strength evaluation of core materials for one stage post-endodontic restorations. PLoS One 9(2):e86294, 2014.
44. Radke RA, et al: Retention of cast endodontic posts: comparison of cementing agents. J Prosthet Dent 59:318, 1988.
45. Love RM, Purton DG: Retention of posts with resin, glass ionomer and hybrid cements. J Dent 26:599, 1998.
46. Assif D, et al: Retention of endodontic posts with a composite resin luting agent: effect of cement thickness. Quintessence Int 19:643, 1988.
47. Kane JJ, et al: Fracture resistance of amalgam coronal-radicular restorations. J Prosthet Dent 63:607, 1990.
48. Nayyar A, et al: An amalgam coronal-radicular dowel and core technique for endodontically treated posterior teeth. J Prosthet Dent 43:511, 1980.
49. Bolhuis HPB, et al: Fracture strength of different core build-up designs. Am J Dent 14:286, 2001.
50. Tay FR, Pashley DH: Monoblocks in root canals: a hypothetical or a tangible goal. J Endod 33:391, 2007.
51. Mentink AG, et al: Qualitative assessment of stress distribution during insertion of endodontic posts in photoelastic material. J Dent 26:125, 1998.
52. Standlee JP, et al: The retentive and stress-distributing properties of a threaded endodontic dowel. J Prosthet Dent 44:398, 1980.
53. Thorsteinsson TS, et al: Stress analysis of four prefabricated posts. J Prosthet Dent 67:30, 1992.
54. Dérand T: The principal stress distribution in a root with a loaded post in model experiments. J Dent Res 56:1463, 1977.
55. Leary JM, et al: Load transfer of posts and cores to roots through cements. J Prosthet Dent 62:298, 1989.
56. Peters MCRB, et al: Stress analysis of a tooth restored with a post and core. J Dent Res 62:760, 1983.
57. Yaman SD, et al: Analysis of stress distribution in a maxillary central incisor subjected to various post and core applications. J Endod 24:107, 1998.
58. Rippe MP, et al: Effect of root canal preparation, type of endodontic post and mechanical cycling on root fracture strength. J Appl Oral Sci 22:165, 2014.
59. Zmener O: Effect of dowel preparation on the apical seal of endodontically treated teeth. J Endod 6:687, 1980.
60. Neagley RL: The effect of dowel preparation on the apical seal of endodontically treated teeth. Oral Surg Oral Med Oral Pathol 28:739, 1969.
61. Schnell FJ: Effect of immediate dowel space preparation on the apical seal of endodontically filled teeth. Oral Surg Oral Med Oral Pathol 45:470, 1978.
62. Bourgeois RS, Lemon RR: Dowel space preparation and apical leakage. J Endod 7:66, 1981.
63. Gegauff AG, et al: A comparative study of post preparation diameters and deviations using Para-Post and Gates Glidden drills. J Endod 14:377, 1988.
64. Hussey DL, et al: Thermographic assessment of heat generated on the root surface during post space preparation. Int Endod J 30:187, 1997.
65. Caputo AA, Standlee JP: Pins and posts: why, when, and how. Dent Clin North Am 20:299, 1976.
66. Shillingburg HT, et al: Root dimensions and dowel size. Calif Dent Assoc J 10(10):43, 1982.
67. Abou-Rass M, et al: Preparation of space for posting: effect on thickness of canal walls and incidence of perforation in molars. J Am Dent Assoc 104:834, 1982.
68. Perez Moll JF, et al: Cast gold post and core and pin-retained composite resin bases: a comparative study in strength. J Prosthet Dent 40:642, 1978.
69. Phillips RW: Skinner's science of dental materials, 9th ed, p 550. Philadelphia, Saunders, 1991.
70. Asmussen E, et al: Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 27:275, 1999.
71. Martinez-Insua A, et al: Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. J Prosthet Dent 80:527, 1998.
72. Ahmad I: Zirconium oxide post and core system for the restoration of an endodontically treated incisor. Pract Periodont Aesthet Dent 11:197, 1999.
73. Bittner N, et al: Evaluation of a one-piece milled zirconia post and core with different post-and-core systems: an in vitro study. J Prosthet Dent 103:369, 2010.
74. Sirimai S, et al: An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. J Prosthet Dent 81:262, 1999.
75. Rud J, Omnell KA: Root fractures due to corrosion: diagnostic aspects. Scand J Dent Res 78:397, 1970.
76. Angmar-Manansson B, et al: Root fracture due to corrosion. I. Metallurgical aspects. Odontol Rev 20:245, 1969.
77. Silness J, et al: Distribution of corrosion products in teeth restored with metal crowns retained by stainless steel posts. Acta Odontol Scand 37:317, 1979.
78. Chan RW, Bryant RW: Post-core foundations for endodontically treated posterior teeth. J Prosthet Dent 48:401, 1982.
79. Lovdahl PE, Nicholls JI: Pin-retained amalgam cores vs. cast-gold dowel-cores. J Prosthet Dent 38:507, 1977.
80. Reagan SE, et al: Effects of cyclic loading on selected post-and-core systems. Quintessence Int 30:61, 1999.
81. Foley J, et al: Strength of core build-up materials in endodontically treated teeth. Am J Dent 10:166, 1997.
82. Kovarik RE, et al: Fatigue life of three core materials under simulated chewing conditions. J Prosthet Dent 68:584, 1992.
83. Oliva RA, Lowe JA: Dimensional stability of composite used as a core material. J Prosthet Dent 56:554, 1986.
84. Larson TD, Jensen JR: Microleakage of composite resin and amalgam core material under complete cast crowns. J Prosthet Dent 44:40, 1980.

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85. Rosenstiel SF, et al: Custom-cast post fabrication with a thermoplastic material. J Prosthet Dent 77:209, 1997.
86. Waldmeier MD, Grasso JE: Light-cured resin for post patterns. J Prosthet Dent 68:412, 1992.
87. Zmener O, et al: Coronal microleakage of three temporary restorative materials: an in vitro study. J Endod 30:582, 2004.
88. Lee JH: Accelerated techniques for a post and core and a crown restoration with intraoral digital scanners and CAD/CAM and rapid prototyping. J Prosthet Dent 112(5):1024, 2014.
89. Campagni WV, Majchrowicz M: An accelerated technique for the casting of post and core restorations. J Prosthet Dent 66(2):155, 1991.
90. Wilson PR: Low force cementation. J Dent 24:269, 1996.
91. Yoshida T, et al: An experimental study of the removal of cemented dowel-retained cast cores by ultrasonic vibration. J Endod 23:239, 1997.
92. Altshul JH, et al: Comparison of dentinal crack incidence and of post removal time resulting from post removal by ultrasonic or mechanical force. J Endod 23:683, 1997.
93. Warren SR, Gutmann JL: Simplified method for removing intraradicular posts. J Prosthet Dent 42:353, 1979.
94. Masserann J: The extraction of posts broken deeply in the roots. Actual Odontostomatol 75:329, 1966.
95. Williams VD, Bjorndal AM: The Masserann technique for the removal of fractured posts in endodontically treated teeth. J Prosthet Dent 49:46, 1983.
96. Gettleman BH, et al: Removal of canal obstructions with the Endo Extractor. J Endod 17:608, 1991.
97. Machtou P, et al: Post removal prior to retreatment. J Endod 15:552, 1989.

STUDY QUESTIONS

1. What must be determined to ensure that an endodontically treated tooth is ready for subsequent restorative treatment?

2. What six features must be incorporated in the tooth preparation for a cast post and core restoration?

3. Discuss five variables that have an effect on retention form for cast post and core restorations.

4. Discuss four different post and core restoration systems, their advantages and disadvantages, and typical indications and precautions.

5. Which canal configurations are circular? Which are elliptical?

6. Describe recommended step-by-step procedures for the following: (1) custom-made direct procedure for fabrication of a post and core restoration pattern for a maxillary second premolar and (2) amalgam post and core restoration on a mandibular molar.

7. How is an interim restoration fabricated for a mandibular second premolar that has been prepared for a cast post and core restoration?

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CHAPTER 13

Implant-Supported Fixed Prostheses

Burak Yilmaz • Edwin A. McGlumphy

As a result of the continued high rate of success achieved with osseous integrated dental implants, a greater number of patients can enjoy the benefits of fixed dental prostheses, as opposed to removable prostheses.[1-3] The main indications for implant-supported restorations in partially edentulous patients are the free-end distal extension when no posterior abutment is available (Fig. 13-1) and the long edentulous span. In both these situations, the conventional dental treatment plan would include a partial removable dental prosthesis. However, with the advent of dental implants, the patient can benefit from fixed restorations. In addition, in the short edentulous span, the single dental implant (Fig. 13-2) is a popular option that can preserve tooth structure on either side of the edentulous space.

IMPLANT TYPES

There are three major subgroups of dental implants: subperiosteal, transosteal, and endosteal (Fig. 13-3). Subperiosteal and transosteal implants are designed primarily to anchor dentures in completely edentulous patients, and a discussion of them is thus outside the scope of this chapter. Endosteal dental implants are surgically placed within alveolar or basal bone and are most commonly used for the treatment of partially edentulous patients, either singly or in multiples. They can be further subdivided by shape into blade form (plate form) and root form. Blades are wedge shaped or rectangular in cross section and are generally 2.5 mm wide, 8 to 15 mm deep, and 15 to 30 mm long. Root forms are 3 to 6 mm in diameter and 8 to 20 mm long, often with external threads (Fig. 13-4). Endosteal dental implants are also categorized as one-stage or two-stage. The one-stage dental implant is designed to be placed in the bone and to immediately project through mucosa into the oral cavity. The two-stage dental implant necessitates two surgical procedures. First, the implant is placed in bone to the level of the cortical plate and the oral mucosa is sutured over it; this is left for a prescribed healing period (usually 3 months in the mandible and 6 months in the maxilla), depending on the quality of bone. In the second procedure, the mucosa is reflected from the superior surface of the implant, and an extension collar or abutment that projects into the oral cavity is fastened to the implant. Some authors have suggested shortening the time before implant loading, but the long-term consequences of this are still being investigated.[4,5]

Plate Implants (Blades)

Blades were the first endosteal dental implant to be used with reasonable success in a large number of patients. In all the original studies on blades, the researchers used one-stage systems, but the success rates were considerably lower than those of current root-form implants. It has been suggested[6] that many of the problems of blade implants can be traced to the high temperature at which the bone sites were prepared and the routine immediate loading of this type of implant. Both these practices have been linked to the fibrous encapsulation that occurred with many of the original blade implants. Consequently, submersible titanium blades are now available, and in more recent blade studies,[7] investigators have reported 5-year success rates above 80%. However, the drawbacks to blade implants remain: difficulty of preparing precision slots for blade placement, in comparison with placing holes accurately for root-form implants, and the disastrously large circumferential area of the jaw that can be affected when a blade fails.

Root-Form Implants

Root-form endosteal dental implants are considered state-of-the-art implants. Advantages include adaptability to multiple intraoral locations, uniformly precise implant site preparation, and a comparatively low rate of adverse consequences (similar to those experienced when a tooth is lost). Most root forms are made of titanium or titanium alloy with or without hydroxyapatite coating; these materials are perceived to have the highest biofunctionality. Both threaded and nonthreaded designs are available and are quite popular. Today many of the titanium implants are grit blasted or acid etched to roughen the surface and increase surface area for bone contact. The threaded dental implants can be further subdivided into straight and tapered. A one-piece implant design has been developed that combines the threaded implant body, the transmucosal abutment, and the pillar for crown cementation in a single piece (see Fig. 13-4).

In the National Institutes of Health (NIH) Consensus Conference[1] in 1988, root-form implants were reported to have already constituted 78% of the dental implant market. This trend is credited to the Brånemark system, which set the precedent for surgical techniques and restorative procedures that result in predictably successful implants. Two of the most important additions from the Swedish research team led by P. I. Brånemark were atraumatic implant placement and delayed implant

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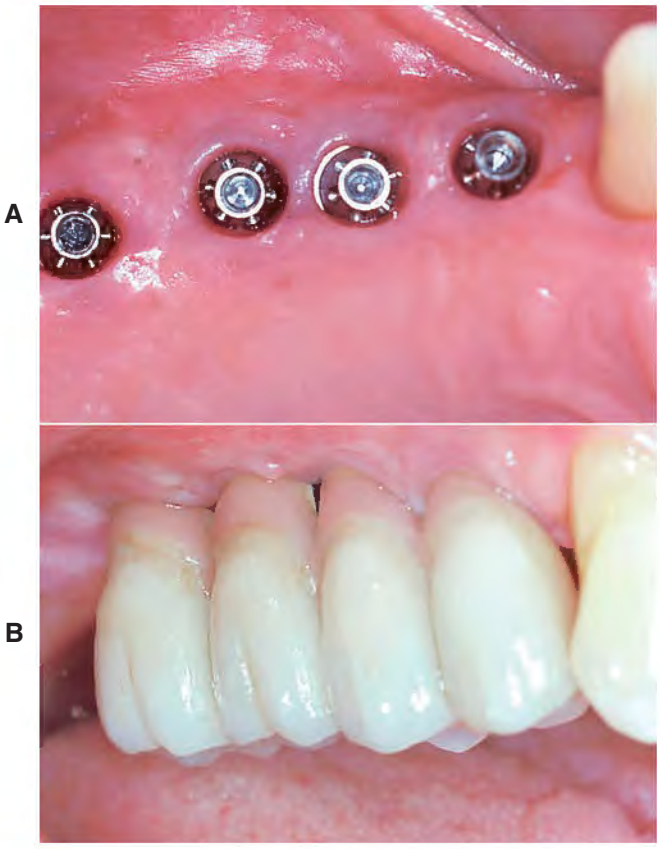

FIGURE 13-1 ■ Implant-supported fixed prosthesis. Four dental implants **(A)** supporting a fixed dental prosthesis **(B).**

loading. These factors contributed to a remarkably increased degree of implant predictability. Brånemark and colleagues' original 15-year success rate of 91% in the mandible[2] has become the standard against which other implant systems are judged.[8] Many of the other root-form implant systems are also believed to have reached or exceeded this high level of long-term success.

TREATMENT PLANNING FOR THE IMPLANT RECIPIENT

The rate of implant success reported from major research institutions is quite high. However, meticulous attention to patient selection, diagnosis, and treatment planning is necessary to duplicate this success. Indications for dental implant treatment in partially edentulous patients are provided in Box 13-1.

A combined surgical and restorative treatment plan must be devised for prospective implant recipients. Feasible alternatives to implants should be included in the overall treatment discussions. Patients need to be evaluated preoperatively, and their ability to tolerate the procedure must be assessed. The predictable risks and expected benefits should be weighed for each patient. Although dental implant placement does entail some risks, they are relatively minor. Absolute contraindications, which are based on immediate surgical and anesthetic risks, are limited to the presence of acute illness, uncontrolled metabolic disease, and pregnancy (these

FIGURE 13-2 ■ **A,** Single-tooth implant with an internal antirotational feature. **B,** Implant crown replacing a single missing tooth (cement retained).

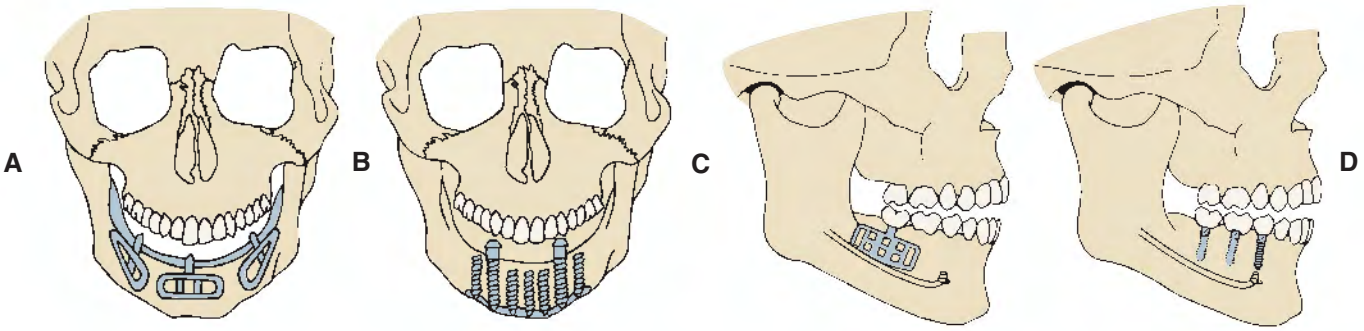

FIGURE 13-3 ■ The three major subgroups of dental implants. **A,** Subperiosteal. **B,** Transosteal. Endosteal implants can be further subdivided into plate form **(C)** and root form **(D).**

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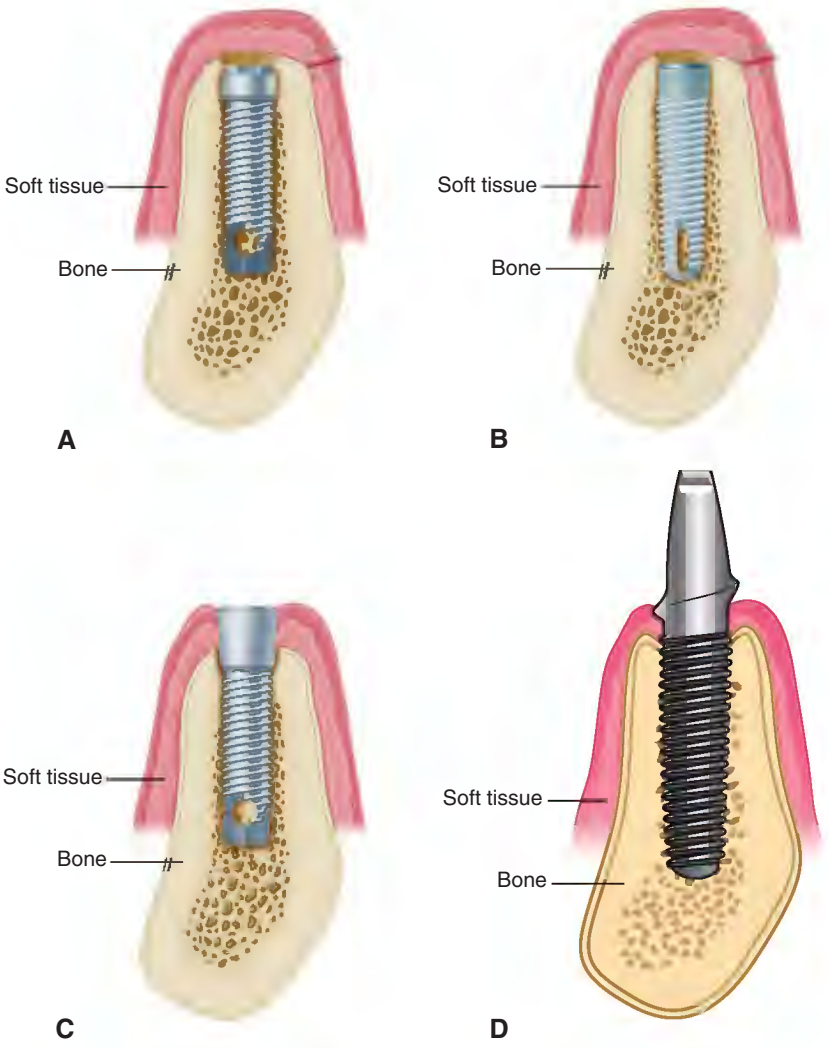

FIGURE 13-4 ■ **A,** Straight-walled two-stage implant. **B,** Tapered two-stage implant. **C,** One-stage implant. **D,** One-piece implant.

BOX 13-1 Indications for Implant Placement in Partially Edentulous Patients

1. Inability to wear a removable partial dental prosthesis or complete denture
2. Need for long-span fixed dental prosthesis and with questionable prognosis
3. Unfavorable number and location of potential natural tooth abutments
4. Single tooth loss that would necessitate preparation of minimally restored teeth for fixed prosthesis

contraindications apply to virtually all elective surgical procedures).

Local and systemic contraindications that threaten long-term implant retention must also be evaluated. Implants may be contraindicated in patients with abnormal bone metabolism, with poor oral hygiene, and who have undergone previous irradiation of the implant site. Most potential implant placement recipients become partially or completely edentulous from caries or periodontal disease as a result of poor oral hygiene. Suspicion that hygiene will continue to be inadequate is a relative contraindication to implant placement. Patients must be motivated and educated in oral hygiene techniques as part of their preparation for implants. Some patients, such as those suffering from paralysis of the arms, debilitating arthritis, cerebral palsy, and severe mental retardation, may not be able to improve their hygiene. Implants are contraindicated in these patients unless caregivers will provide adequate oral hygiene. A summary of contraindications to implant placement is presented in Box 13-2.

Clinical Evaluation

Evaluation of the planned implant site begins with a thorough clinical examination. In this examination, the dentist determines whether bone is adequate and identifies anatomic structures that could interfere with ideal implant placement. Visual inspection and palpation allow the detection of flabby excess tissue, bony ridges, and sharp underlying osseous formations and undercuts that

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BOX 13-2 Contraindications to Implant Placement (National Institutes of Health Consensus Conference)

1. Acute illness
2. Terminal illness
3. Pregnancy
4. Uncontrolled metabolic disease
5. Tumoricidal irradiation of the implant site
6. Unrealistic patient expectation
7. Improper patient motivation
8. Lack of operator experience
9. Inability to restore with a prosthesis

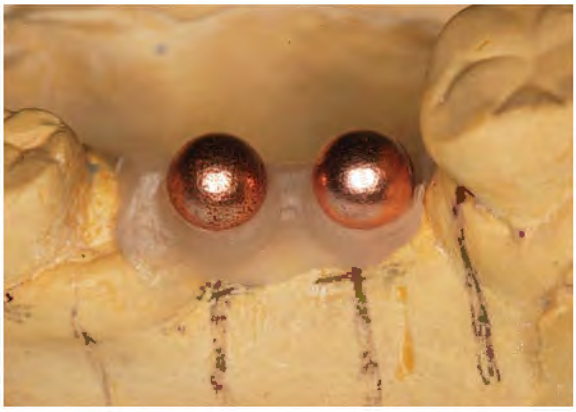

FIGURE 13-5 ■ Ball bearings (5-mm diameter) placed on the diagnostic cast at the proposed implant site.

would limit implant insertion. However, clinical inspection alone may not be adequate if there is thick overlying soft tissue that is dense, immobile, and fibrous.

Radiographic Evaluation

Radiographic evaluation is also necessary. The best initial image is the panoramic view. However, there can be variations in magnification (5% to 35%); a small radiopaque reference object, such as a ball bearing, should therefore be placed near the proposed implant placement site during the exposure (Fig. 13-5). Measurement of this image on the actual radiograph enables the practitioner to correct for any magnification error (Fig. 13-6). Placing the reference object in wax on a denture baseplate or in polyvinyl siloxane impression putty works well. Some new panoramic radiography machines have standardized enlargement ratios; therefore, correction markers are less necessary.

The widths of the posterior parts of the mandible and maxilla are determined primarily by clinical examination. Bone width not revealed on a panoramic view can be evaluated in the anterior parts of the maxilla and mandible with a cephalometric image (Fig. 13-7). The location of the inferior alveolar canal and maxillary sinus can be determined by specialized computed tomography (CT) (Fig. 13-8), although comparatively high radiation exposure and cost may limit its routine use. However,

FIGURE 13-6 ■ A panoramic radiograph showing the ball bearings positioned intraorally with a wax or resin baseplate.

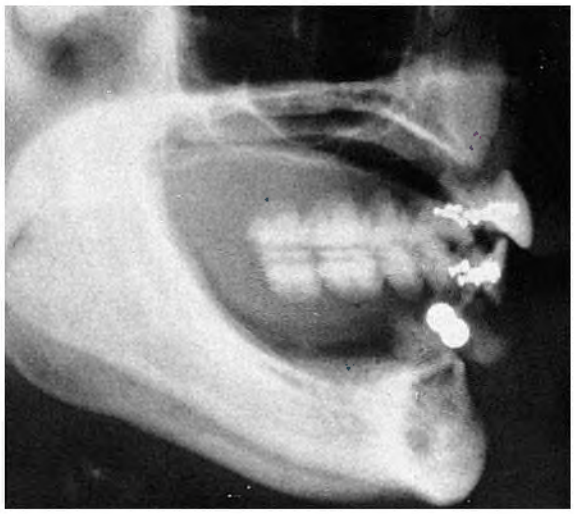

FIGURE 13-7 ■ The lateral cephalometric radiograph can indicate bone width in the anterior midline.

significant advances being made in CT technology may reduce the radiation exposure and cost.

Diagnostic Casts

Accurately mounted diagnostic casts (see Chapter 2) are essential for treatment planning. They help the dentist study the remaining teeth, evaluate the residual bone, and analyze maxillomandibular relationships. They can be helpful to the surgeon for fixture placement. A diagnostic waxing is performed on the cast or on a duplicate. Proposed fixture sites are checked to determine the feasibility of achieving proper alignment, location, and relation to the remaining teeth. The waxing helps determine the most esthetic placement of the teeth to be restored and the potential for functional speech disturbances. After adjustments and the diagnostic waxing are completed, a resin template can be made from the cast to guide the surgeon during implant placement (Fig. 13-9). Diagnostic waxings and surgical templates are essential when

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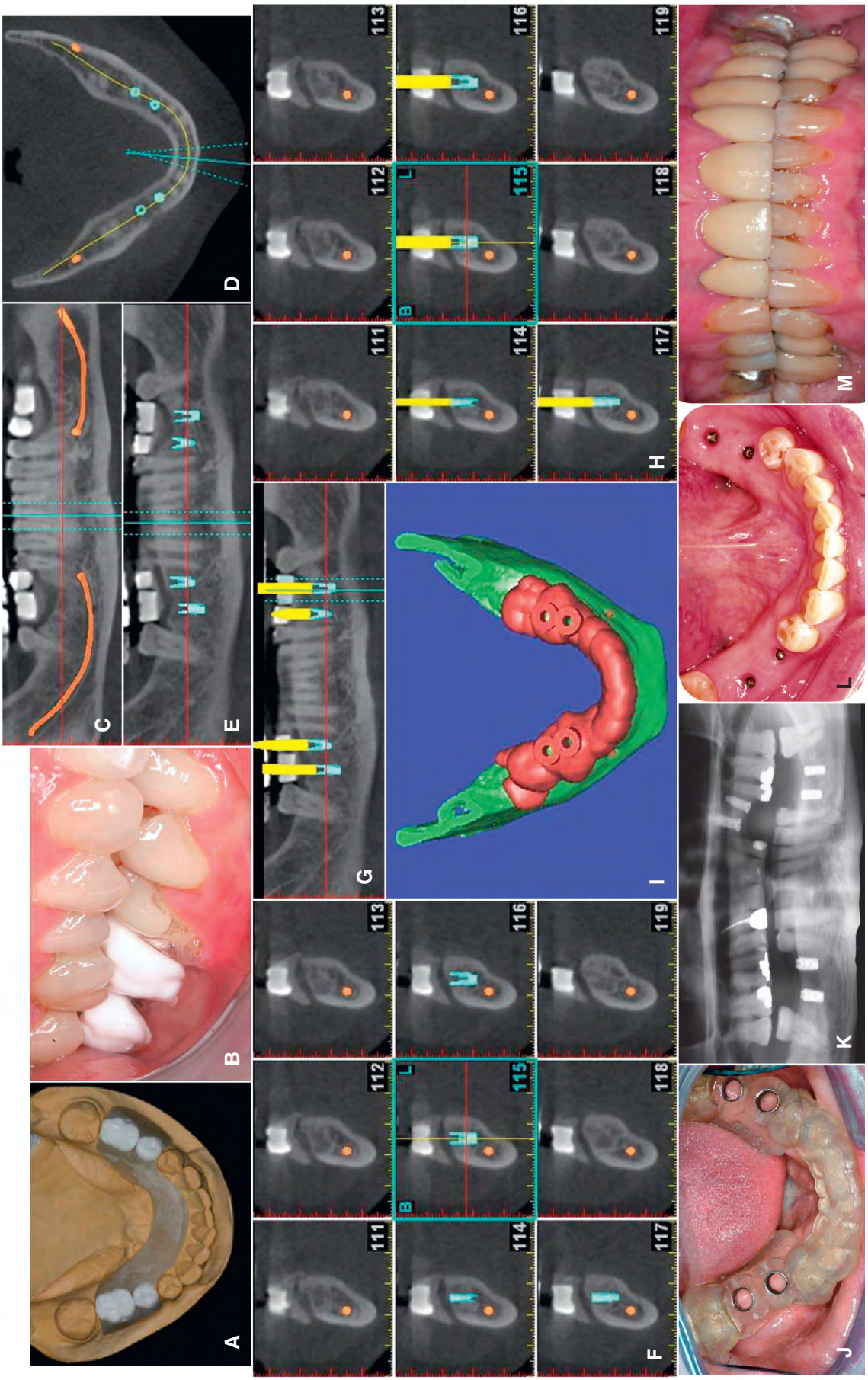

FIGURE 13-8 ■ Computed tomography (CT). **A,** Scan guide with barium-impregnated teeth. **B,** Scan guide positioned in the mouth. **C,** Barium-impregnated teeth in the scan. **D,** Scan with *lines* orienting the position of transverse mandibular cross-sections. **E** and **F,** Reformatted cross section of the posterior part of the mandible. Software allows visualization of prospective implant placement. **G** and **H,** Software allows for placement of abutments for predictable prosthetic positioning. **I** and **J,** CT-generated surgical guide design generated by software **(I)** and the intraoral view **(J). K,** Panoramic radiograph. **L,** Intraoral view of implants. **M,** Intraoral view of definitive restorations.

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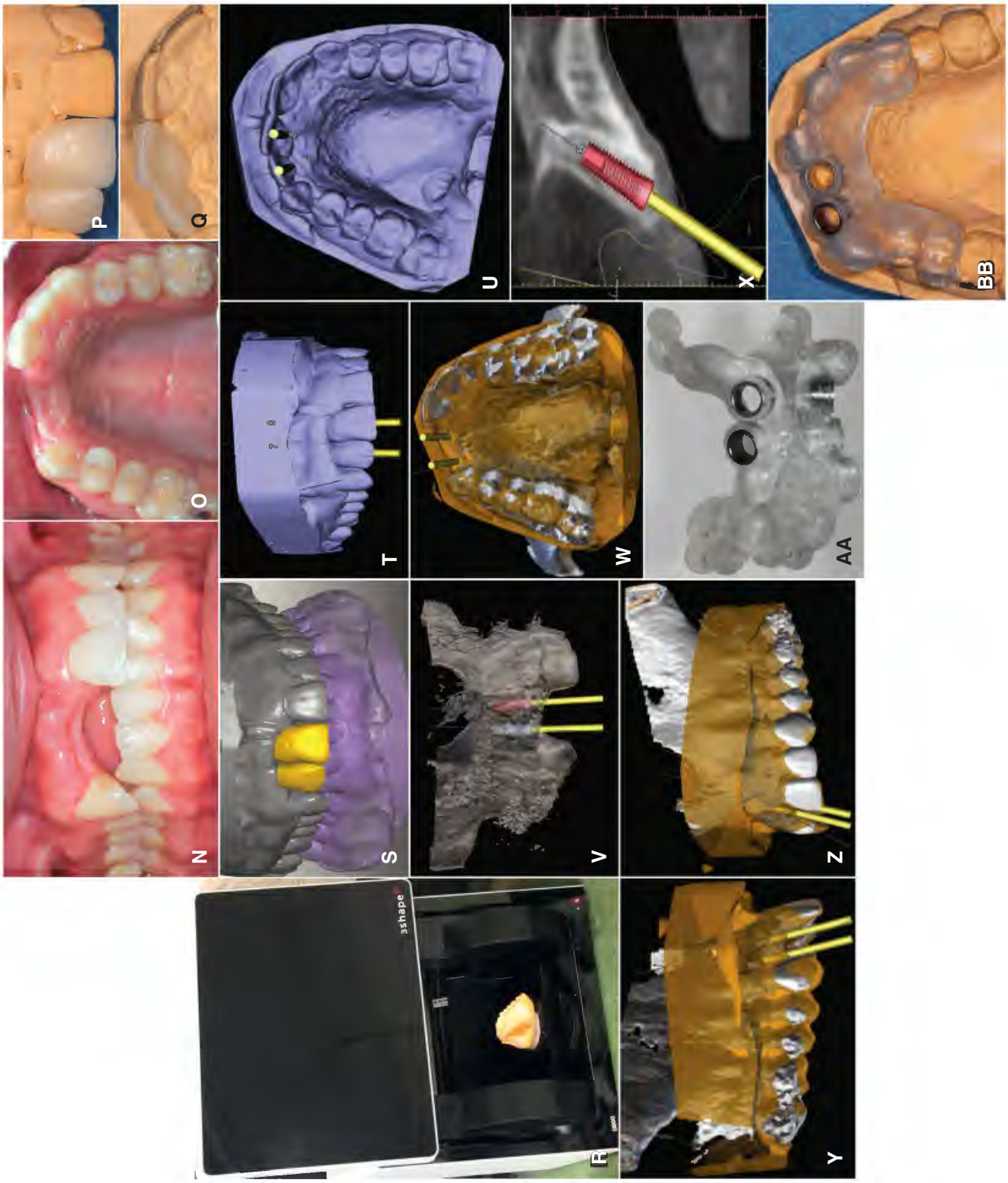

FIGURE 13-8, cont'd ■ **N** and **O**, Missing right lateral and central incisors, to be restored with two implants, **P** and **Q**, Diagnostic waxing. **R**, Laboratory scanner. **S**, Laboratory scan of diagnostically waxed-up cast. **T** to **Z**, Incorporation of software-generated views of waxed-up diagnostic cast into CT for virtual treatment planning. **AA** and **BB**, CT-generated surgical guide.

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FIGURE 13-9 ■ **A,** Bilateral missing posterior teeth, to be replaced with posterior implant-supported restorations. **B,** Diagnostic cast. **C,** Diagnostic denture tooth arrangement to simulate three-unit fixed prostheses on each side of the mandible. **D,** Vacuumed matrix formed over the cast with 1.5-mm (0.060-inch) thermoplastic sheet. **E,** The matrix is marked with the most appropriate implant locations and alignments and then removed from the cast. **F,** The completed surgical guide with holes drilled to guide the surgeon during implant site preparation.

implants are planned as part of a full-mouth reconstruction or when the anterior esthetic zone is restored (Fig. 13-10).

Bone Sounding

When the results of clinical and radiographic examinations are equivocal and additional information is needed, sounding of the bone with a probe may be attempted. The patient is given a local anesthetic, and a needle or sharp caliper is pushed through the tissue until it contacts bone. This can help the examiner judge soft tissue thickness at the planned implant sites.

PRINCIPLES OF IMPLANT LOCATION

Anatomic Limitations

To maximize success, the implant should be placed entirely within bone and away from significant anatomic structures (e.g., the inferior alveolar canal). Ideally, 10 mm of vertical bone dimension and 6 mm of horizontal should be available for implant placement. Placement at these dimensions prevents encroachment on anatomic structures and allows 1.0 mm of bone on both the lingual and facial surfaces of the implant. Adequate space between adjacent implants is also necessary. The minimum recommended distance varies slightly among implant systems but is generally accepted as 3.0 mm (Fig. 13-11). This space is needed to ensure bone viability between the implants and to allow adequate oral hygiene once the restorative procedures are complete. Specific limitations resulting from anatomic variations among different areas of the jaws also must be considered. These include implant length, diameter, proximity to adjacent structures, and time required for integration.

The anterior and posterior parts of the maxilla and mandible each require special considerations in placing implants. Some common guidelines include staying 2.0 mm above the superior aspect of the inferior alveolar canal, 5.0 mm anterior to the mental foramen, and 1.0 mm from the periodontal ligament of adjacent natural teeth.

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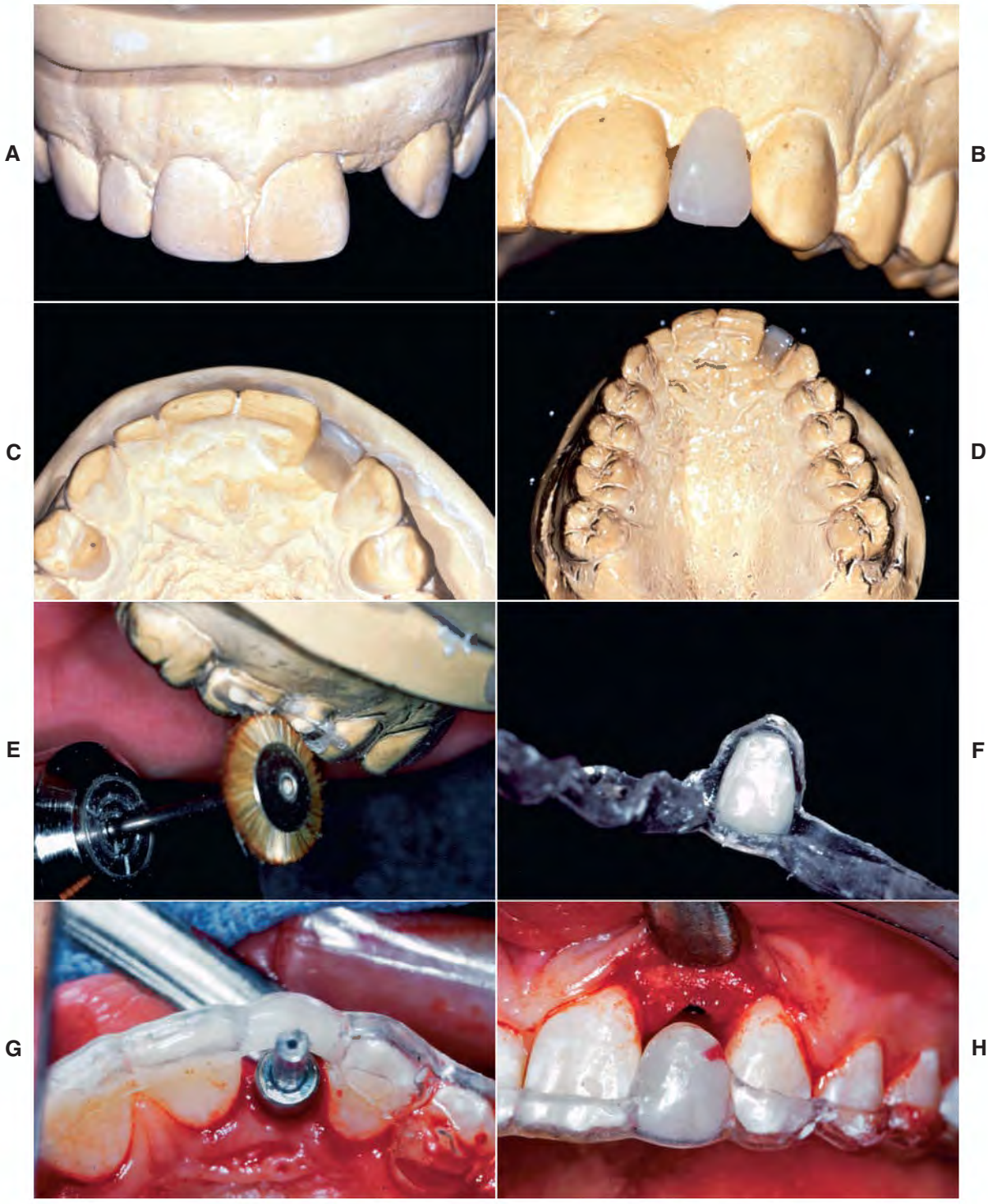

FIGURE 13-10 ■ **A,** Diagnostic cast with missing maxillary left lateral incisor. **B,** The denture tooth is positioned for optimum esthetics. **C,** The denture tooth is trimmed from the lingual side until it is 2 mm thick. **D,** If the denture tooth is held in position with light-cured composite, a vacuum matrix can be performed directly without duplication of the cast. **E,** The matrix can be trimmed to the height of contour with a stiff bristle brush. **F,** The denture tooth can be glued back into the matrix. **G** and **H,** The surgeon can use this template to guide both horizontal and vertical positioning.

After tooth loss, resorption of the ridge follows a pattern that results in crestal bone thinning and a change in angulation of the residual ridge. These sequelae most often cause problems in the anterior parts of the mandible and maxilla. The irregular anatomy of the residual ridge may lead to problems with achieving ideal implant angulation or adequate bone thickness along the labial aspect of the implant. Techniques for the management of these problems during surgery are discussed in this chapter, but they must be anticipated in the preoperative phase.

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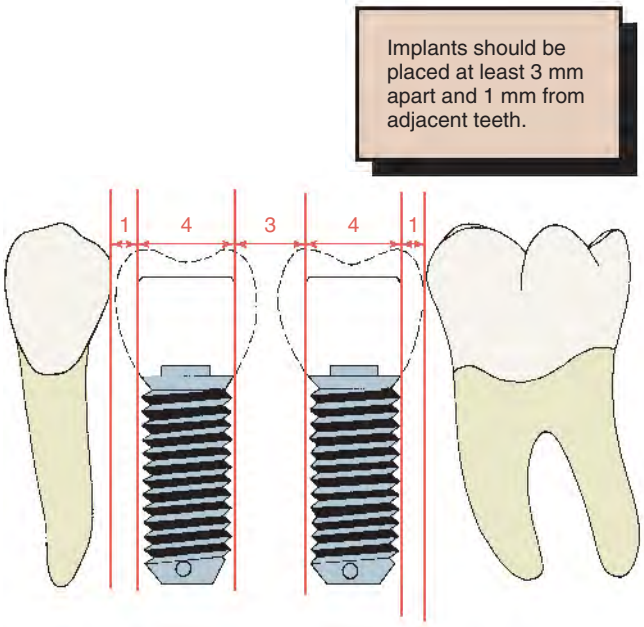

FIGURE 13-11 ■ Recommended minimum distances (in millimeters) between implants and between implants and natural teeth.

Anterior Part of the Maxilla

The anterior part of the maxilla must be evaluated for proximity to the nasal cavity. A minimum of 1.0 mm of bone should remain between the apex of the implant and the nasal vestibule. Because of resorption of the anterior part of the maxilla, the incisive foramen may be located near the residual ridge, especially in patients whose edentulous maxilla has been allowed to function against natural mandibular anterior dentition. Anterior maxillary implants should be located slightly off midline, on either side of the incisive foramen.

Posterior Part of the Maxilla

Implant placement in the posterior part of the maxilla poses two specific concerns. First, the bone of the posterior part of the maxilla is less dense than that of the posterior part of the mandible. It has larger marrow spaces and a thinner cortex, which can affect treatment planning, inasmuch as increased time must be allowed for integration of the implants and additional implants may be needed. A minimum of 6 months is usually needed for adequate integration of implants placed in the maxilla. In addition, one implant for every tooth that is being replaced is normally recommended, especially in the posterior part of the maxilla.

The second concern is that the maxillary sinus is close to the edentulous ridge in the posterior part of the maxilla. Frequently, because of the resorption of bone and increased pneumatization of the sinus, only a few millimeters of bone remain between the ridge and the sinus (Fig. 13-12, *A*). In treatment planning for implants in the posterior part of the maxilla, the surgeon should leave 1.0 mm of bone between the floor of the sinus and the implant so that the implant can be anchored apically into cortical bone of the sinus floor. Bone height between

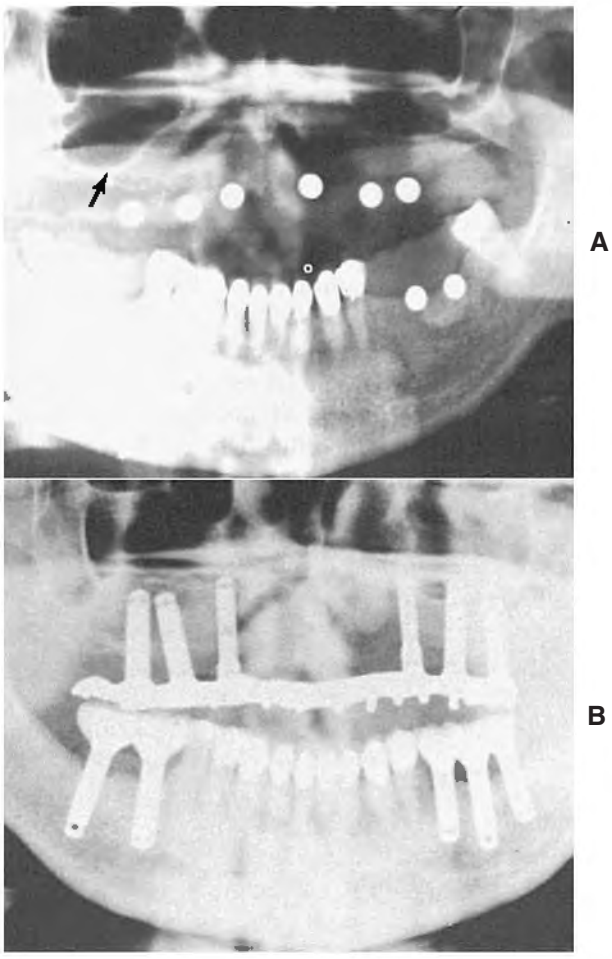

FIGURE 13-12 ■ **A,** Thin maxillary bone inferior to the sinus *(arrow)* would be inadequate for implant placement without additional grafting procedures. **B,** Radiograph showing successful treatment with dental implants after graft placement.

the nasal cavity and the maxillary sinus is usually adequate for implant stability. If bone is not adequate for implant placement and support, bone augmentation through the sinus should be considered (see Fig. 13-12).

Anterior Part of the Mandible

With regard to anatomic limitations, the anterior part of the mandible is usually the most straightforward area for treatment planning. It usually has adequate height and width for implant placement, and the bone quality is normally excellent; therefore, it requires the least amount of time for integration. Success with immediate loading of implants in the anterior part of the mandible has been reported. This seems to be possible because the implants can have good initial stability.

When possible, an implant in the anterior part of the mandible should be placed through the entire cancellous bone so that the apex of the implant engages the cortex of the inferior mandibular border (Fig. 13-13). In the premolar area, care must be taken that the implant does not impinge on the inferior dental nerve. Because this nerve courses as close as 3.0 mm anterior to the mental foramen before turning posteriorly and superiorly to exit

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at the foramen, an implant should be at least 5.0 mm anterior to the foramen.

Posterior Part of the Mandible

The posterior part of the mandible poses some limitations on implant placement. The inferior alveolar nerve traverses the mandibular body in this region, and treatment planning must allow for a 2.0-mm margin from the apex of the implant to the superior aspect of the inferior alveolar canal. This is an important guideline: Disregarding it can cause damage to the nerve and numbness of the lower lip. If adequate length is not present for even the shortest implant, nerve repositioning, onlay grafting, or a conventional non–implant-supported prosthesis must be considered.

Implants placed in the posterior part of the mandible are usually shorter, do not engage cortical bone inferiorly, and must support increased biomechanical occlusal forces once they are loaded because of their location in the posterior area. Consequently, allowing slightly more time for integration may be beneficial. In addition, if short implants (8- to 10-mm) are used, "overengineering" and placing more implants than usual to withstand the occlusal load is recommended. Short implants are often necessary because of bone resorption, which thus increases the crown-to-implant ratio when the normal plane of occlusion is reestablished (Fig. 13-14).

The width of the residual ridge must be carefully evaluated in the posterior part of the mandible. Attachments of the mylohyoid muscle maintain it along the superior aspect of the ridge, and a deep (lingual) depression exists immediately below it. This area should be palpated at the time of evaluation and examined at the time of surgery.

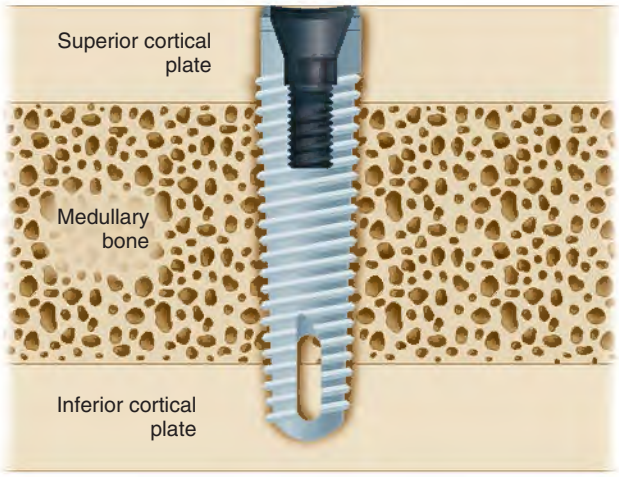

FIGURE 13-13 ■ Whenever possible, implants should engage two cortical plates of bone.

Restorative Considerations

Implant Placement

Implant placement is crucial in the design of the restoration. Thus the treatment-planning aspects of implant placement must begin with a restorative dentistry consultation. Implant location dictates the appearance, contour, and long-term function of the prosthesis. To prevent damage, staying at least 1.0 mm away from the adjacent natural tooth is essential, but staying as close to the natural tooth as possible is also important; therefore, acceptable contours can be created by the restorative dentist. For proper access during oral hygiene procedures, a minimum of 3.0 mm should be left between implants. In addition, implants must not encroach on the embrasure spaces or be angled so that screw access is necessary through the facial surfaces of the completed restoration (Fig. 13-15).

To minimize harmful lateral forces, the long axis of the implant should be positioned in the central fossa of the restoration. This dictates placing the implant accurately in all three planes of space. Superoinferior placement is important to ensure the optimal emergence

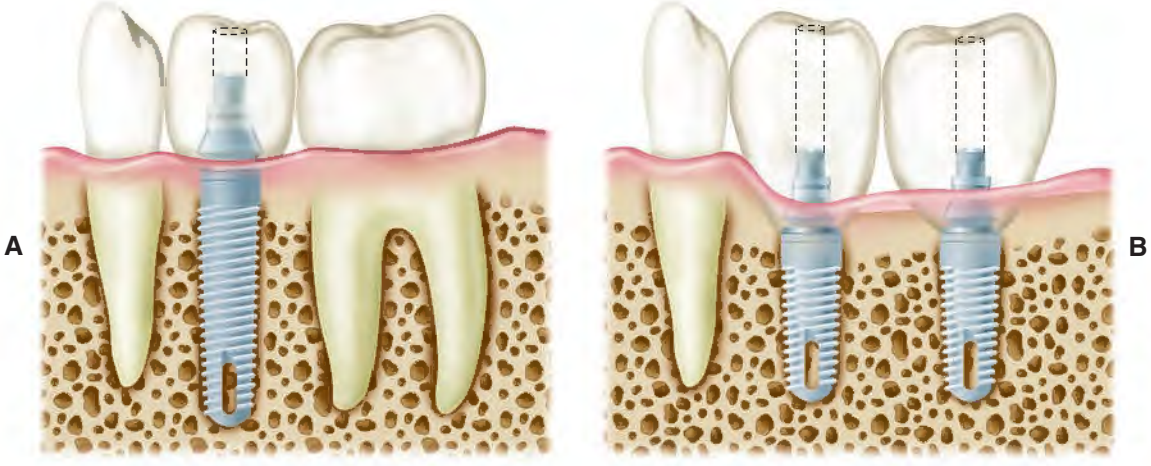

FIGURE 13-14 ■ Shorter implants usually have two problems: (1) less bone contact and (2) longer crowns, which increase the forces acting on the implant. Restorations with more favorable (lower) crown-to-implant ratios **(A)** have a better prognosis than those with less favorable (higher) ratios **(B)**.

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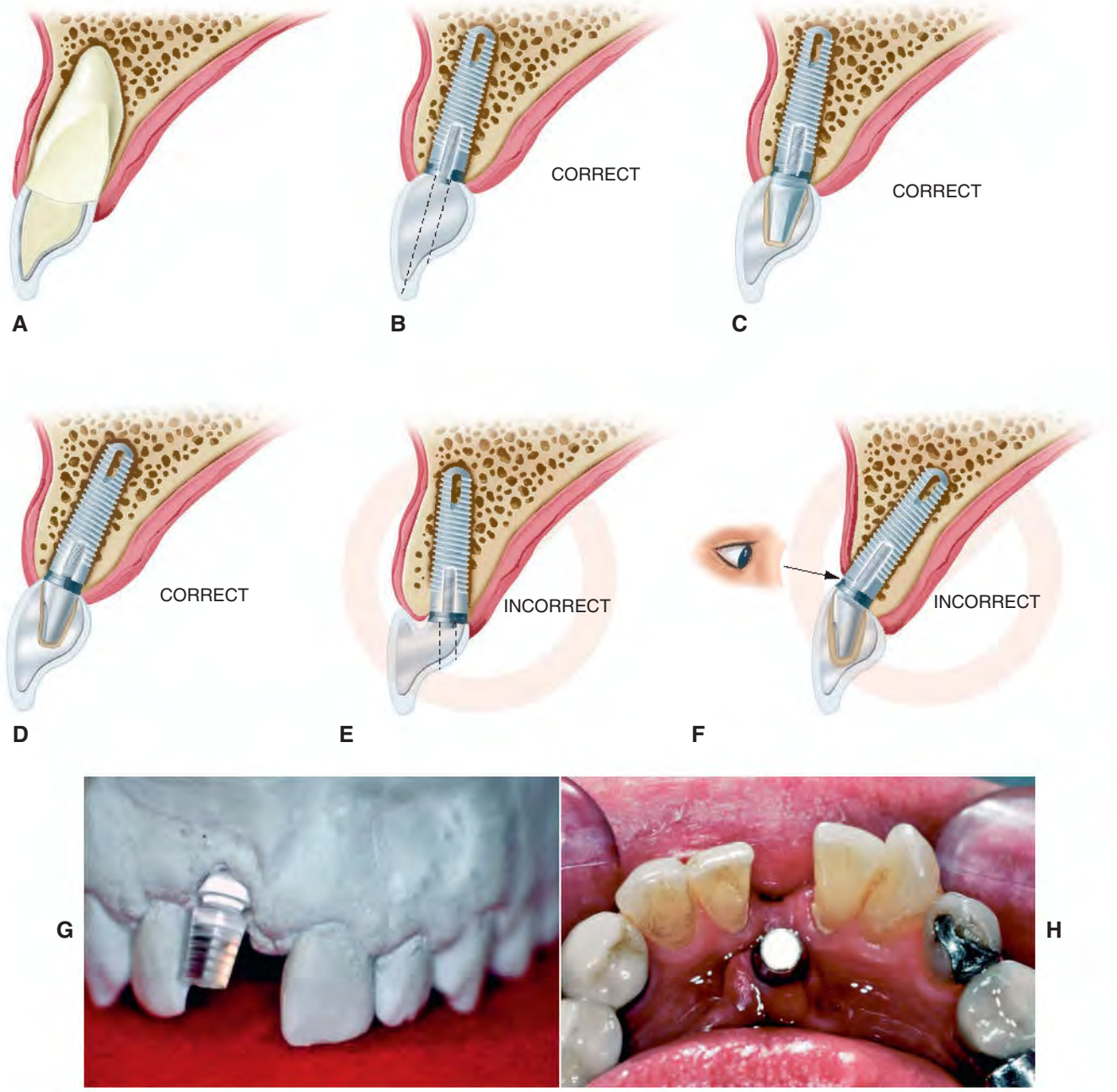

FIGURE 13-15 ■ Implant placement and angulation dictate the screw emergence position and crown contours. Esthetics and access for hygiene can be greatly affected. **A,** A restored tooth. **B,** Ideal implant location with acceptable crown contours and lingual screw emergence. **C,** Acceptable implant location for a cement-retained crown. **D,** If the implant is more facially inclined, an angled abutment for a cement retained crown may be necessary. **E,** If the implant is too lingual and too shallow, crown contours will be inadequate for hygiene. **F,** If the implant is angled too far facially and too shallow, the implant or abutment, or both, may become an esthetic failure. **G,** Implant placed too far labially. **H,** Implant placed too far lingually.

profile of the restoration. Ideally, the superior surface of the implant should be 2.5 to 3.0 mm directly inferior to the emergence position of the planned restoration, particularly when the restoration is to be located in the anterior esthetic zone (Fig. 13-16).

Implant and Restoration Size

The choice of implant and its superoinferior placement location are modified according to the diameter of the intended restoration and can be adjusted for different sizes of teeth. For example, the typical root diameter of a maxillary central incisor is 8.0 mm; the average implant diameter is 4.0 mm. Therefore, a distance of 2.5 to 3.0 mm is needed to make the transition gradually from 4.0 to 8.0 mm. If the lengthening is too short, the restoration will be overcontoured or look unnatural. In contrast, the roots of many mandibular central and lateral incisors are narrower than 4.0 mm at the cementoenamel junction. Therefore, an esthetic restoration on a 4.0-mm

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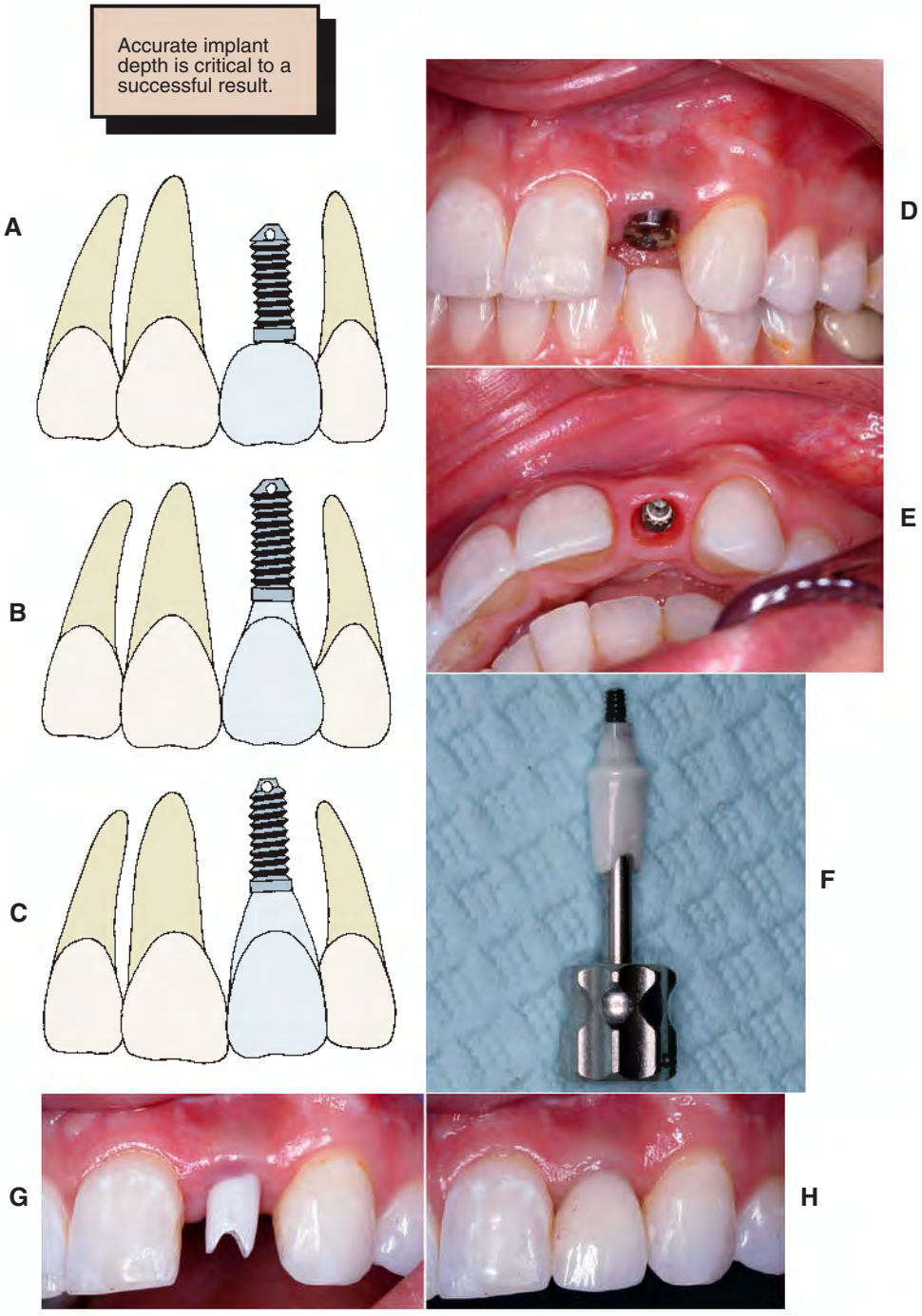

FIGURE 13-16 ■ Superior or inferior positioning may affect crown contours and pocket depth. **A,** The implant is not placed deep enough. As a result, the crown will be short and overcontoured. **B,** Placement 2 to 3 mm apical to the tooth emergence position is ideal. **C,** Placing the implant 4 mm apical to the crown contours may result in an excessively deep gingival sulcus. **D,** Healing abutment in place. **E,** Implant placed to restore missing maxillary lateral incisor. **F,** Custom zirconia abutment. **G,** Abutment in place. **H,** Clinical example of a properly positioned implant, both facially and apically, which results in good esthetics. (Courtesy Dr. Luiz Daroz Diaz.)

implant is impossible. Smaller-diameter implants (about 3.0 mm) are available to allow esthetic restoration in these areas. It is also possible to use a larger implant (5.0 to 6.0 mm) for molar restorations in patients with adequate bone (Fig. 13-17).

Restoration size must always be considered during the treatment planning stage so that a properly sized implant is placed in the ideal location.

Single Tooth Implant

Treatment planning for the single tooth restoration, particularly in the anterior esthetic zone, is one of the most challenging problems in implant restoration. Placement of the implant for both esthetics and biomechanical loading (to minimize screw loosening) is especially crucial. In addition, at the treatment planning stage, the decision to place an implant with an antirotational feature

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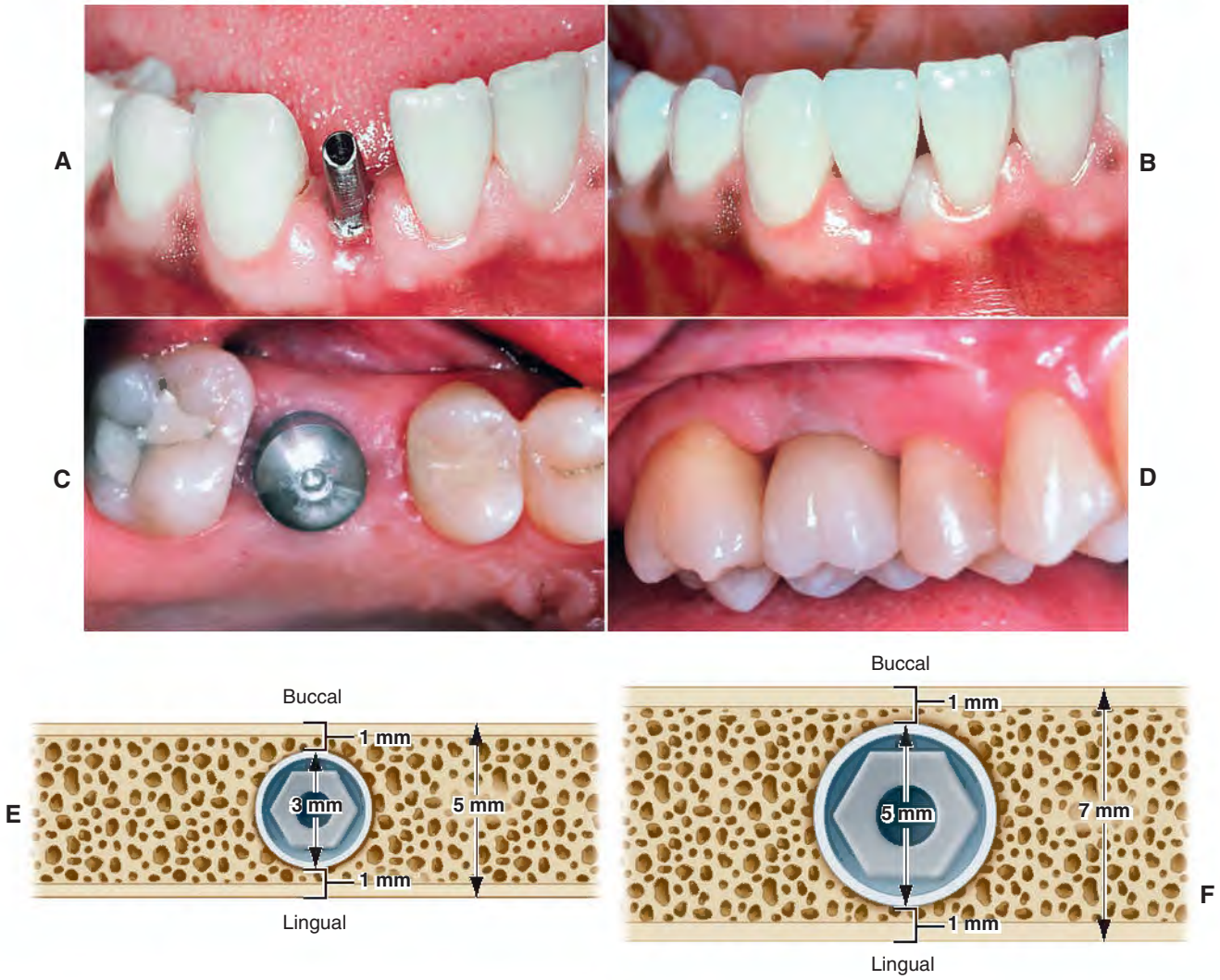

FIGURE 13-17 ■ **A,** Small-diameter implant and abutment positioned to restore a mandibular lateral incisor. The fixed abutment can be custom prepared and narrowed to allow restoration of a tooth with a small root diameter. **B,** Completed implant restoration of the mandibular lateral incisor. **C,** Wide-diameter (5.0 mm) implant in position to replace maxillary first molar. **D,** Completed implant restoration of the maxillary first molar. **E,** The minimum bone dimension for a small diameter implant is 5 mm. Ideally, at least 1 mm of bone is still left on either side of the implant site after the osteotomy has been prepared. **F,** The minimum bone dimension for a wider (5 mm) implant is approximately 7 mm. At least 1 mm of bone should still remain laterally after the site has been prepared.

built into the system (e.g., a spline or a hexagon) is essential (Fig. 13-18).

Soft Tissue Contours

For implant treatment planning in the esthetic zone, it is important to look closely at the soft tissues that will frame the restoration. Achieving a completely formed papilla between the implant restoration and the adjacent teeth in the final outcome can be challenging. If the interdental tissue and underlying bone have already been lost before implant placement, it may not be possible to achieve ideal papillary contours. The literature contains guidelines that help predict whether adequate soft tissue contour can be maintained. As diagrammed (Fig. 13-19), the relationship of interdental bone to the interproximal contact seems correlated with the presence or absence of an interdental

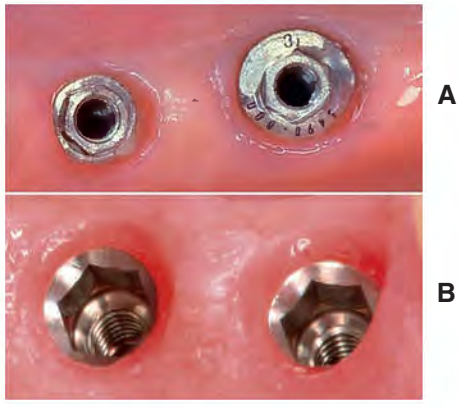

FIGURE 13-18 ■ **A,** Implants with an antirotational feature (standard external hexagon). **B,** Implants with internal hexagon connection.

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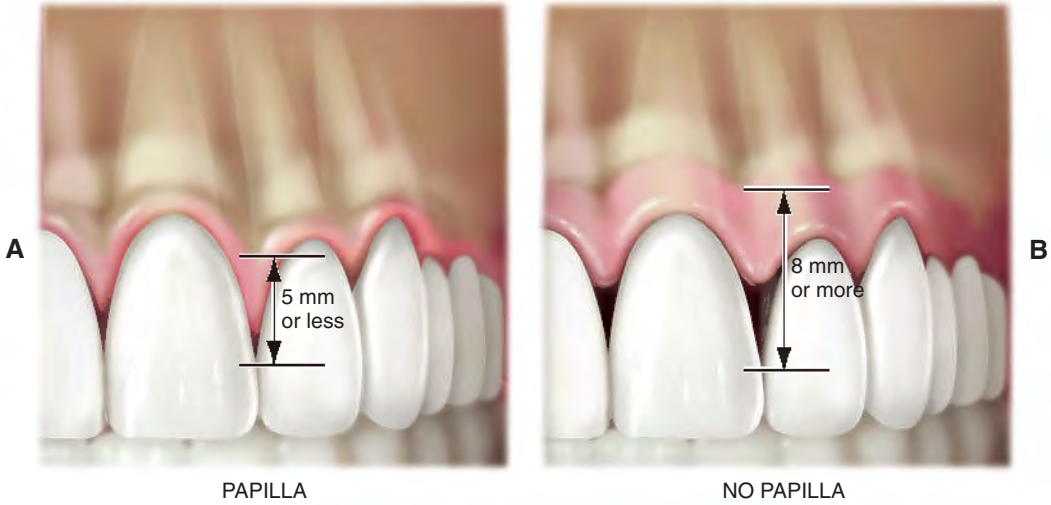

FIGURE 13-19 ■ Relationship of interdental bone to position of interproximal contacts seems to predict whether interdental papilla will be present or not. If the distance between the bone and the contact is less than 5 mm **(A)**, usually a papilla is present; if the distance is more than 8 mm **(B),** usually no interdental papilla is present.

papilla: If the distance between the bone and the contact is short (<5 mm), a papilla is usually present. If the distance is long >8 mm), a papilla would not normally be present without additional soft tissue grafting.[9,10]

SURGICAL GUIDE

The coordination of surgical and prosthetic procedures through proper treatment planning is one of the more crucial factors in obtaining ideal esthetic results for the implant restoration. A surgical guide template is extremely useful for anterior implants because slight variations in angulation can significantly affect the appearance of the final restoration. Fabrication of the surgical guide template has become a requirement for patients in whom it is necessary to optimize fixed replacement and ensure correct emergence profiles. Surgical templates can also be beneficial in areas where esthetics is less important. The objectives for using a surgical template in partially edentulous patients are as follows: (1) Delineate the embrasures, (2) locate the implant within the restoration contour, (3) align implants with the long axis of the completed restoration, and (4) identify the level of the cementoenamel junction or tooth emergence from the soft tissue.

A clear resin facial veneer template is recommended for anterior implant placement to allow the surgeon access to the osseous receptor site and an unimpeded view of the frontal and sagittal angulations as the site is being prepared. This type of template is fabricated from a diagnostic waxing or denture tooth arrangement on a mounted cast. The waxing is duplicated with alginate or polyvinyl siloxane and poured in quick-setting stone. Then 1.5-mm (0.060-inch)–thick vacuum-formed matrix material is adapted to the replicated cast. For accurate orientation, the vacuum-formed matrix should be trimmed to extend over the full facial surface of the teeth being restored and about a third of the facial surface of the remaining dentition. This template is removed from the duplicate cast and returned to the original cast. A 2-mm-thick layer of autopolymerizing resin is added to the lingual surface to compensate for the space occupied by the porcelain on the implant restoration (Fig. 13-20). (The total thickness, including an additional millimeter from the vacuum-formed matrix, is about 3.0 mm.) To make surgical guides appear radiopaque, barium powder is often added to the resin during its fabrication (see Fig. 13-8). The surgeon must stay as close as possible to this guide during implant placement, which allows maximum flexibility in selecting an implant site without violating the facial surface or forcing screw access holes to be located inappropriately in the facial surface of the restoration. By following this guide, the surgeon can place a fixture in the best location with minimum undesirable sagittal angulation. If a cement-retained restoration is desired, the orientation of the implant can be slightly more facial.

Although the use of a guide is most necessary in the maxillary anterior region, where bony dimensions are sometimes surprising and often unfavorable, the guide may also be useful in posterior areas with wide edentulous ridges. However, a different type of guide or template may be fabricated in this area. Holes are drilled through the resin into the underlying cast and are paralleled with a milling machine or dental surveyor. Such templates locate the placement of an implant and direct the inclination of its long axis with maximum accuracy.

Surgical templates also can be fabricated for a maxillary edentulous arch that is to be restored with a fixed prosthesis. Such templates are described later in the chapter, but the same preoperative planning and interspecialty cooperation are as important as just described.

IMPLANT SURGERY

Peter E. Larsen

Implant surgery can be performed in an ambulatory setting with the patient under local anesthesia. However,

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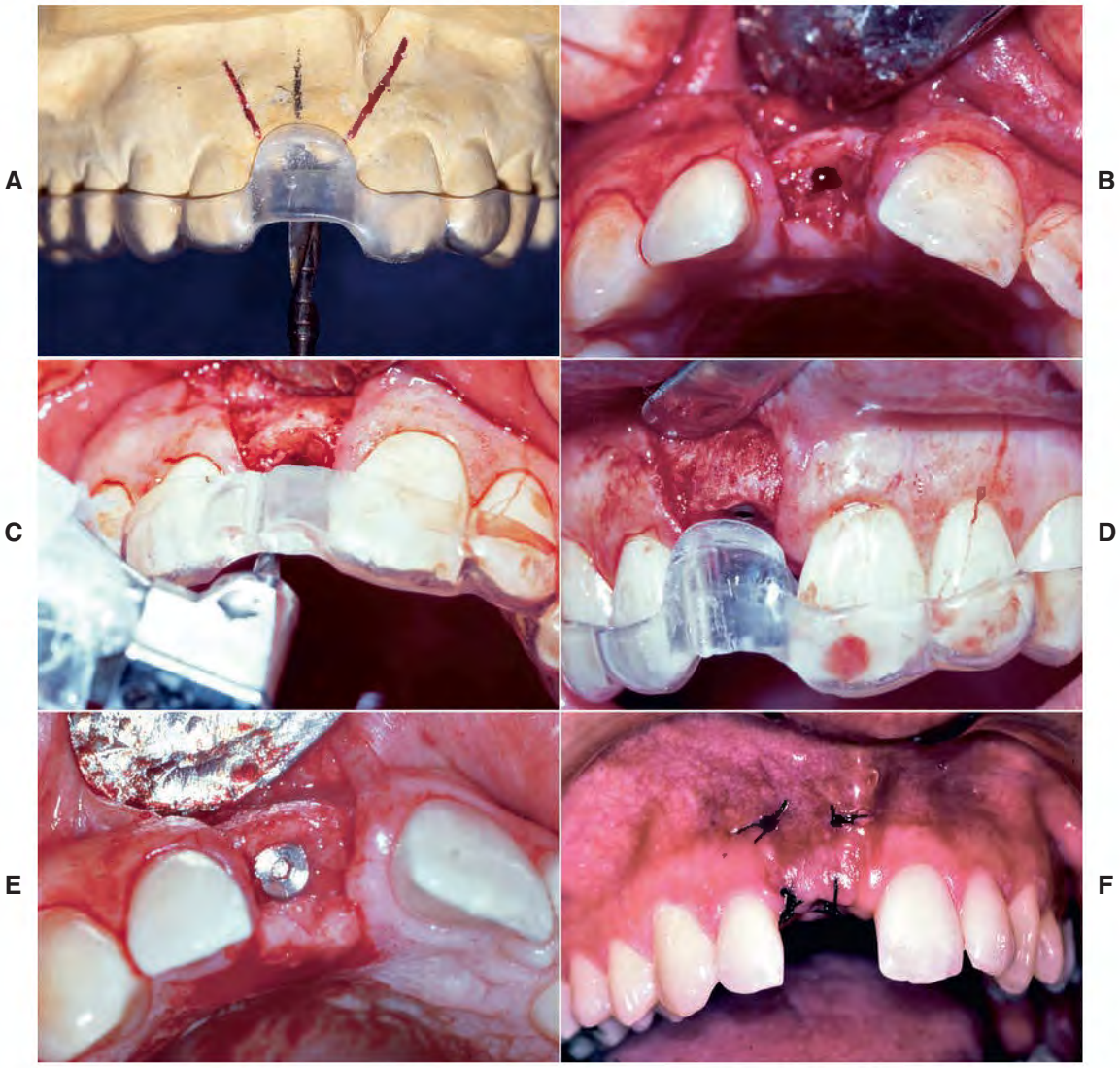

FIGURE 13-20 ■ Anterior implant placement with a surgical guide template. **A,** The apical extent of the template is left in place, which allows the superoinferior orientation of implant placement to be determined. **B,** Full-thickness flap incisions are made, preserving the interdental papilla. The flap is reflected to expose bone for preparation of the implant site. **C,** Resin (2.0 mm) has been added to the lingual aspect of the matrix; the rest of the lingual area is left open so that the surgeon can choose the best available bone. The site should be prepared as close to the template as possible. **D,** The implant is positioned 2.5 to 3.0 mm apical to the desired emergence position of the final restoration. **E,** The implant is positioned at an angle and depth that allows optimum esthetics and access for hygiene. **F,** The surgical site is sutured. Healing takes 4 to 6 months. (Courtesy Dr. J.A. Holloway.)

it requires more time than do other surgical procedures, and so conscious sedation may be preferred. Patients expect implant placement to be more traumatic than extracting a tooth. In fact, it is less traumatic. Preoperative education and conscious sedation should lessen the anxiety.

A complete description of the surgical procedures involved in implant placement can be found in one of the current standard texts.[11,12]

Surgical Access

Several types of incision can be used to obtain access to the residual ridge for implant placement. The incision chosen should allow retraction of the soft tissue for unimpeded implant placement and should preserve attached tissue esthetics and quantity.

When the quantity of attached tissue is adequate and the underlying bone is expected to be of sufficient width, a simple crestal incision is recommended. However, closure must be performed carefully because the implant lies directly beneath. In the posterior part of the mandible, an incision may be placed toward the buccal surface of the ridge to allow the flap to be retracted by a suture. This may be a disadvantage, however, because the incision line is thus immediately over the area where the bone may be thinnest, and a dehiscence can occur during surgery. An incision slightly to the palatal side is particularly effective in the maxillary anterior zone. After the bone is exposed, the surgical template is positioned, and a periodontal probe is used to make a preliminary assessment of the potential implant site. The residual ridge may have areas that are uneven or with sharp edges. These areas should be smoothed before implant placement.

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Implant Placement

Placement procedures for all implant systems require atraumatic preparation of the recipient site. Thermal injury to bone is minimized by the use of a low-speed, high-torque handpiece, along with copious irrigation. The irrigation is applied either externally or internally and is directed through channels in the drill. Manufacturer recommendations relating to the type of irrigation and speed of the drilling equipment should be followed. Threaded implants often require final thread preparation in the bone at very low speeds.

The implant recipient site is prepared with a series of gradually enlarged burs. All implant systems have an initial small-diameter drill used to mark the implant site. The implant site is located through use of the surgical template, which may also assist in directing angulation of the implant. The center of the implant recipient site is marked with the initial drill, and a pilot hole is prepared. A paralleling pin is then placed in the preparation so that the dentist can check alignment and angulation.

At this point, a final determination is made regarding the adequacy of the recipient site for implant placement. Although implant placement is a surgical procedure, it is influenced by critical restorative parameters. The template communicates the range of acceptable implant positions and angulations. At this step, if it is apparent that supporting bone will not allow proper positioning of the implant, further osseous augmentation may be necessary, either simultaneously with implant placement or as a separate procedure with implant placement delayed until proper osseous support is available.

After the desired depth and diameter of the recipient site are achieved, the implant is placed. For titanium implants, an uncontaminated surface oxide layer is required for osseous integration. Hydroxyapatite-coated implants are also sensitive to contamination.

Nonthreaded implants are positioned in the recipient site and gently tapped into place with a mallet and seating instrument. Threaded implants are screwed into place, which also requires cutting the screw threads in the recipient site. Self-tapping implants are available for use in the maxilla, where the bone is soft enough that prethreading is unnecessary. After all implants are placed, tension-free closure prevents wound dehiscence.

Postoperative Evaluation

A radiograph should be obtained postoperatively to evaluate the position of the implant in relation to adjacent structures (i.e., the sinus and the inferior alveolar canal) and other implants. Any significant problems noticed at this time should be corrected.

Patients are given mild analgesics and 0.12% chlorhexidine gluconate rinses for 2 weeks after surgery to keep bacterial populations to a minimum during healing. Weekly evaluations are recommended until soft tissue healing is complete (2 to 3 weeks). If possible, complete or partial removable dental prostheses should not be worn for 1 week after surgery. The resin over the implant can then be reduced by 2.0 or 3.0 mm and replaced with a soft liner, so that the denture can be worn without injuring the healing implant site.

Implant Uncovering

If a two-stage system is used, implant uncovering is performed after complete implant fixture integration has been achieved. The time interval for integration to occur varies and depends on the particular site and patient. Longer times may be required if the bone quality and surgery were less than ideal or if the bone-implant interface was questionable at the time of placement. In general, recommended integration times are 6 months in the maxilla, 3 months in the anterior part of the mandible, and 4 months in the posterior part of the mandible.

The goals of surgical uncovering are to accurately attach the abutment to the implant, to preserve attached tissue, and to recontour tissue as necessary. These goals may be accomplished with any of these three techniques: the tissue punch, crestal incision, or flap repositioning.

After the implant is exposed, the implant abutment is placed. There are two approaches for this procedure. The first approach is to place the same abutment as will be used in the restoration. The second approach is to place an interim healing cap that will remain until the tissue heals and will then be replaced by the abutment during the restorative treatment procedures.

When the abutment is placed, the superstructure must be completely seated on the implant body without gaps or intervening tissue. In systems with antirotational facets in the implant (see Fig. 13-18), these features must be aligned to allow complete seating of the abutment. The superstructure-implant body interface should be evaluated radiographically immediately after the uncovering. If a gap is present, the superstructure must be repositioned.

IMPLANT RESTORATIONS

Osseous integrated implants are generally designed to support screw- or cement-retained dental prostheses. These implant systems offer many advantages over conventional dental restorations and one-stage implants (Box 13-3).

BOX 13-3 Advantages of Osseous Integrated Implants

Surgical

1. Documented success rate
2. In-office procedure
3. Adaptable to multiple intraoral locations
4. Precise implant site preparation
5. Reversibility in the event of implant failure

Prosthetic

1. Multiple restorative options
2. Versatility of second-stage components
   - Angle correction
   - Esthetics
   - Crown contours
   - Screw- or cement-retained options
3. Retrievability in the event of prosthodontic failure

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Fabrication of screw-retained prostheses requires a number of components unique to implant dentistry. For less experienced clinicians, the large number of parts included within one system can be daunting. This section describes in generic terms the component parts typically needed to restore an osseous integrated implant. There are many dental implant systems, and although all the major components are available for each system, many differ slightly in specific design and materials. The basic steps for implant restoration fabrication are described in Figure 13-21.

Clinical Implant Components

Terms used to describe similar implant components vary widely among manufacturing companies. A list of terms used in this book and a partial list of alternative terms are provided in Table 13-1.

Implant Body

The dental implant body is the component placed within the bone during first-stage surgery. It may be a threaded or nonthreaded root form and is ordinarily made of either titanium or titanium alloy of varying surface roughnesses, with or without a hydroxyapatite coating (Fig. 13-22). Although the optimum shape and surface coating for an implant in different parts of the mouth are controversial, the significant factors for success are precise placement, atraumatic surgery, undisturbed healing with minimized micromotion, and passive restoration.

All contemporary dental implants have an internally threaded portion that can accept second-stage screw placements. These implants also may incorporate an antirotational feature within the design of the fixture body. If it is incorporated, the antirotational feature may be either internal or external.

Implant bodies can also be classified as *one-stage* or *two-stage*. One-stage implants project through the soft tissue immediately after first-stage surgery. Two-stage implants are typically covered with soft tissue at this point. Placement of a tall healing screw or cap on a two-stage implant, to project it through the tissue at the time of placement, is referred to as "using a two-stage implant with a one-stage protocol."

Healing Screw

During the healing phase after first-stage surgery, a screw is normally placed in the superior aspect of the fixture. It is usually low in profile to facilitate the suturing of soft tissue in the two-stage implant or to minimize loading in the one-stage implant (Fig. 13-23). At second-stage surgery, it is removed and replaced by subsequent components. In some systems the screw is made slightly larger than the diameter of the implant, which facilitates abutment placement by ensuring that bone does not grow over the edge of the implant. The surgeon should always ensure that the healing screw is completely seated after first-stage surgery to prevent bone from growing between the screw and the implant. If this occurs, removing the bone may damage the superior surface of the implant and affect the fit of subsequent components.

Interim Endosteal Dental Implant Abutment (Interim Abutment)

Interim abutments are dome-shaped screws placed after second-stage surgery and before insertion of the prosthesis. They range in length from 2 to 10 mm and project through the soft tissue into the oral cavity. They may screw directly into the fixture or, in some systems, onto the abutment immediately after second-stage surgery. Those that screw onto the abutment are commonly referred to as *healing caps* (Fig. 13-24). Both interim abutments are most commonly made of titanium or titanium alloy. In areas where esthetics is paramount, healing should be sufficiently completed around an interim abutment to stabilize the gingival margin. At this time, abutments of appropriate length are selected to ensure that the metal-porcelain interface of the restoration will be subgingival. In areas where tissue esthetics is not crucial, adequate healing for impressions usually takes 2 weeks. In esthetic zones, 3 to 5 weeks may be required before abutment selection. In addition, knowing the length of the healing cap can expedite abutment selection.

Abutments

Abutments are the components of the implant system that screw directly into the implant. They eventually support the prosthesis in screw-retained restorations, inasmuch as they accept the retaining screw of the prosthesis. For cement-retained restorations, they may be shaped like a conventional crown preparation. Abutments take many forms (Fig. 13-25). Their walls are usually smooth, polished, and straight-sided titanium or titanium alloy. Their lengths range from 1 to 10 mm. In nonesthetic areas, 1 to 2 mm of titanium should be allowed to penetrate the soft tissue to maximize the patient's ability to clean the prosthesis (Fig. 13-26). In esthetic areas, an abutment can be selected to allow porcelain to extend subgingivally for optimum esthetics (Fig. 13-27).

In implant systems that incorporate an antirotational feature, the abutment must have two components that move independently of each other: One engages the antirotational feature, and the other secures the abutment within the fixture (Fig. 13-28). With angled abutments, a similar technique is used to correct divergently placed implants (Figs. 13-29 and 13-30). Some systems have included tapered or wide-base abutments, which allow teeth with larger cross-sectional diameters to be restored with more physiologic contours. The nonsegmented implant crown (sometimes termed a "UCLA" restoration as it was first described at the University of California, Los Angeles) bypasses the abutment portion by means of a sleeve waxed directly to the implant. Using nonsegmented implant crowns may be necessary when soft tissue thickness is less than 2 mm. All-ceramic components onto which all-ceramic crowns can be cemented are becoming popular for the anterior part of the mouth. The ceramic components are usually made

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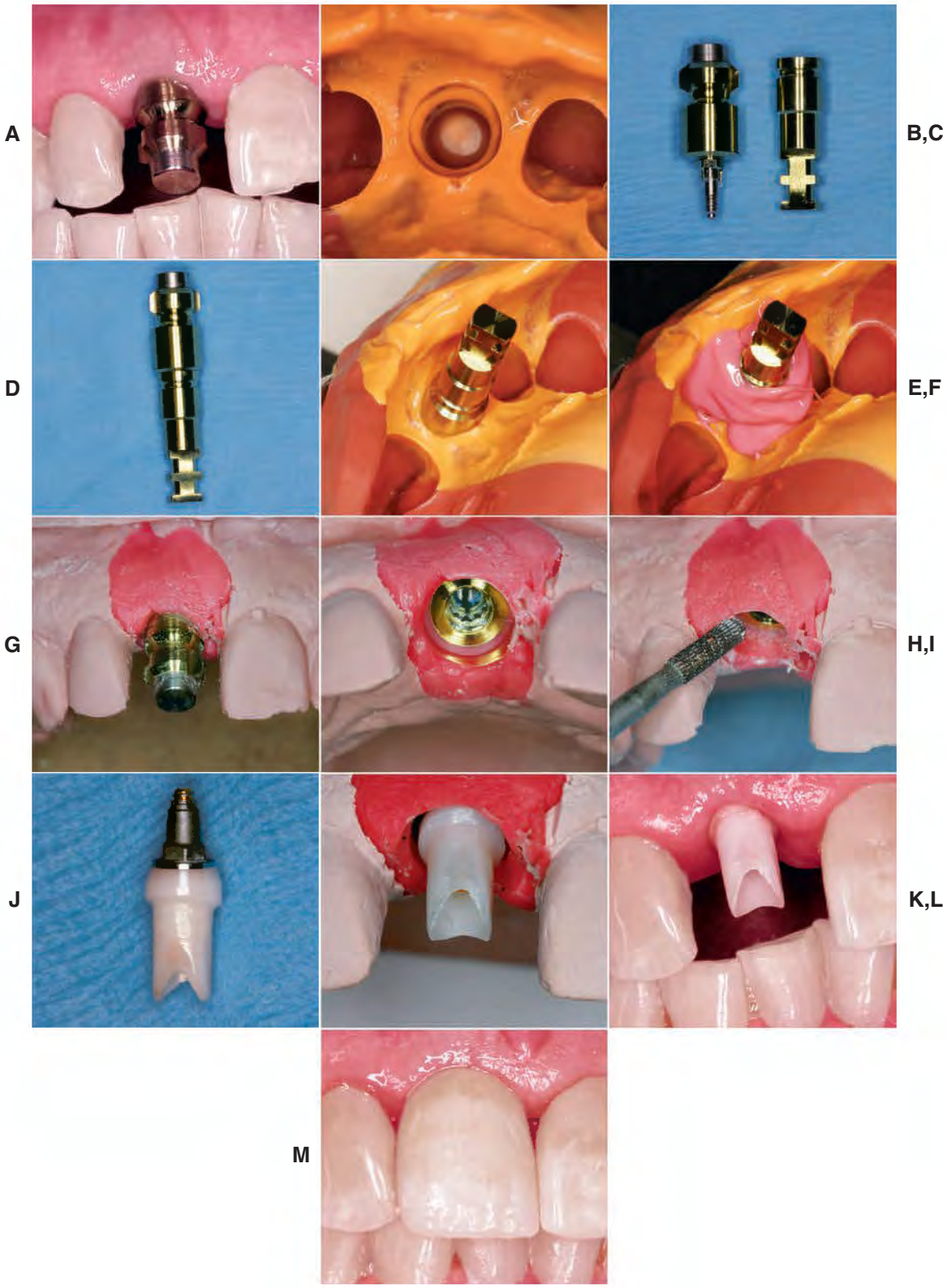

FIGURE 13-21 ■ **A,** A single-unit implant-supported prosthesis will replace the maxillary right central incisor. The impression post is tightened into the implant. **B,** A closed tray impression of the impression coping. **C,** Impression coping removed from the mouth, pictured adjacent to implant analog. The impression coping is attached to the implant analog **(D)** and inserted into the impression **(E)**. **F,** Polyether soft tissue cast material (Permadyne, 3M-ESPE Dental North America) injected around analog before being poured. **G,** Poured cast. After an impression is made, the impression post is removed from the mouth and attached to the implant analog. The impression coping and analog are relocated in the impression before the cast material is poured. **H,** The impression coping locates the analog in the same position on the cast as the implant is in the mouth. **I,** Soft tissue cast material can be contoured to mimic adjacent tooth emergence profile. **J,** Abutment for cement-retained restoration selected. **K,** Zirconia abutment seated on the cast and ready for fabrication of all-ceramic restoration (*see* Chapter 25). **L,** Zirconia abutment seated in the mouth. **M,** Appearance of the all-ceramic restoration.

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TABLE 13-1 **Implant Terminology**

Text Term	Also Known As	Function/Description
Implant body (see Fig. 13-22)	Implant fixture screw or cylinder	Portion of the implant system within the bone
Healing screw (see Fig. 13-23)	Sealing screw Cover screw First-stage cover screw	Seals the occlusal surface of the implant during osseointegration, if a two-stage procedure is used
Interim abutment (see Fig. 13-24)	Temporary gingival cuff Healing collar Implant healing cap Healing abutment	A cover, attached to the implant, that is used to maintain the opening through the tissue until the restoration is completed Placed immediately onto the implant if a one-stage protocol is used
Healing cap (see Fig. 13-24, *B*)	Temporary screw Comfort cap Abutment healing cap	A cover that is attached to the top of a transmucosal abutment, protecting the internal threads and interface surfaces of the abutment while the restoration is being completed
Standard abutment (see Fig. 13-25, *A*)	Transmucosal abutment Tissue extension Permucosal extension	An intermediate component placed between the implant and metal framework/restoration, providing support and retention for a fixed-removable restoration Excellent for bar overdentures
Tapered abutment (see Fig. 13-25, *D*)	Conical abutment Transmucosal abutment Tissue extension Permucosal abutment	An intermediate component placed between the implant and restoration, providing support and retention for a fixed-removable restoration Cone shaped for maximum esthetics Excellent for screw-retained fixed prostheses
Hex driver (see Fig. 13-33, *A*)	Hex tool Screwdriver	Used for placing and removing all hex screws (i.e., abutment fastening screws), impression post-retaining screws, and healing abutments Available in two lengths—short (19 mm, for posterior) and long (24 mm, for anterior)—and three hex sizes (0.048, 0.050, and 0.062 inch)
Abutment driver or seating tool	Name of each driver/tool is specific, based on its use	Used to seat the abutment directly onto the implant
Impression coping (see Fig. 13-33, *A, B,* and *D*)	Impression post Impression pin Transfer pin Transfer post	Component used during the impression procedure to transfer the position of the implant to the cast
Implant analog (see Fig. 13-33, *G*)	Implant fixed analog Laboratory analog Abutment analog Implant body analog Fixture replica	Replicates the implant for use in the cast
Interim abutment sleeve (see Fig. 13-47, *H*)	Temporary cylinder Temporary coping Temporary abutment sleeve Provisional abutment	Provides support and retention for acrylic temporary/interim restorations May also be used for occlusal rim and wax setup try-in procedures for overdentures
Fixed abutment (see Fig. 13-25, *B* and *C*)	Straight abutment Coping abutment Abutment post Crown and bridge abutment (slang)	An abutment used for a cement-retained restoration (also available in 15- and 25-degree angles)
Waxing sleeve (see Fig. 13-37)	Plastic sheath Plastic sleeve Plastic coping Castable abutment Castable coping Gold sleeve Gold coping Gold cylinder	A castable plastic pattern usually attached to a premachined metal base used to form an abutment during the laboratory waxing procedure Placed directly onto the implant or onto the transmucosal abutment
Prosthesis-retaining screw (see Fig. 13-38)	Gold screw Coping screw Implant fixture screw Fastening screw	Screw used to secure a screw-retained metal (bar) framework or restoration to transmucosal abutments (i.e., conical or standard abutments)

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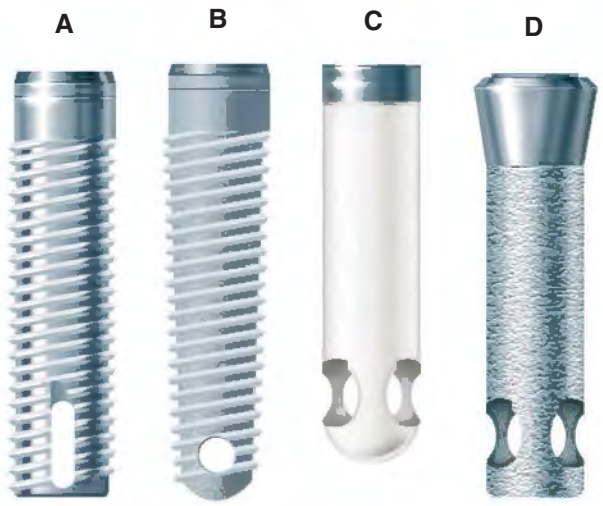

FIGURE 13-22 ■ Four main categories of osseous integrated implants. **A,** Titanium screw. **B,** Ti plasma-sprayed screw. **C,** Hydroxyapatite coated cylinder. **D,** Titanium plasma-sprayed cylinder.

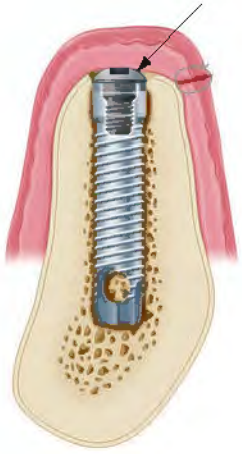

FIGURE 13-23 ■ Healing screw *(arrow)* in place during the initial healing phase of implant placement. Soft tissue is sutured over the implant. A removable prosthesis can be worn over this area during healing.

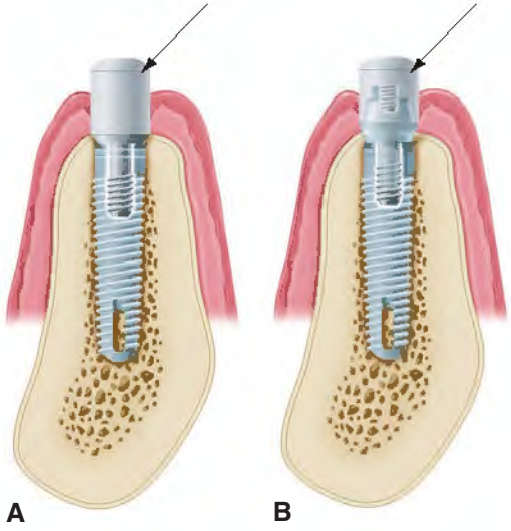

FIGURE 13-24 ■ Components that allow for soft tissue healing after second-stage surgery. **A,** This interim abutment *(arrow)* screws into the implant. **B,** The healing cap *(arrow)* screws into the abutment.

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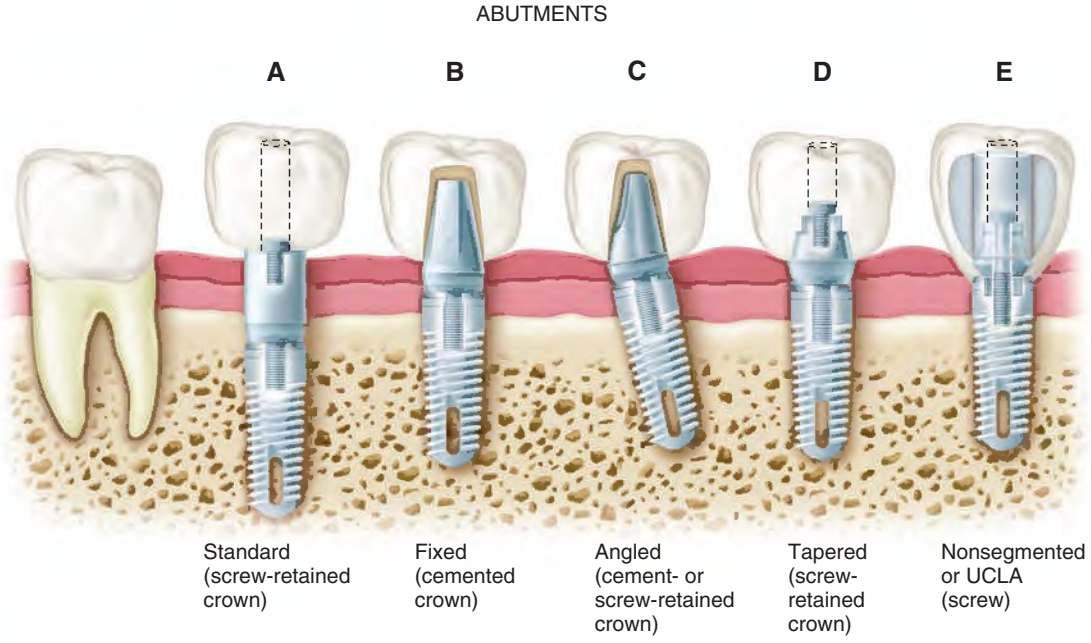

FIGURE 13-25 ■ Types of abutments. **A,** Standard. Length can be selected to make the margin subgingival or supragingival. **B,** Fixed. This abutment is much like a conventional post and core restoration. It is screwed into the implants, has a prepared finish line, and receives a cemented restoration. **C,** Angled (fixed). This type is used when implant angles must be corrected for esthetic or biomechanical reasons. **D,** Tapered. This type can be used to make the transition to restoration more gradual in larger teeth. **E,** Nonsegmented, or direct. This type is used in areas of limited interarch distance or in areas where an esthetic outcome is important. The restoration can be built directly on the implant, so that there is no intervening abutment. This direct restoration technique has been called the *UCLA abutment.* (Modified from Hupp JR, Ellis E, Tucker MR: Contemporary oral and maxillofacial surgery, 5th ed. St. Louis, Mosby, 2008.)

FIGURE 13-26 ■ **A,** Interim abutments projecting through the soft tissue. **B,** Implant restorations supported by standard abutments that allow easy access for oral hygiene.

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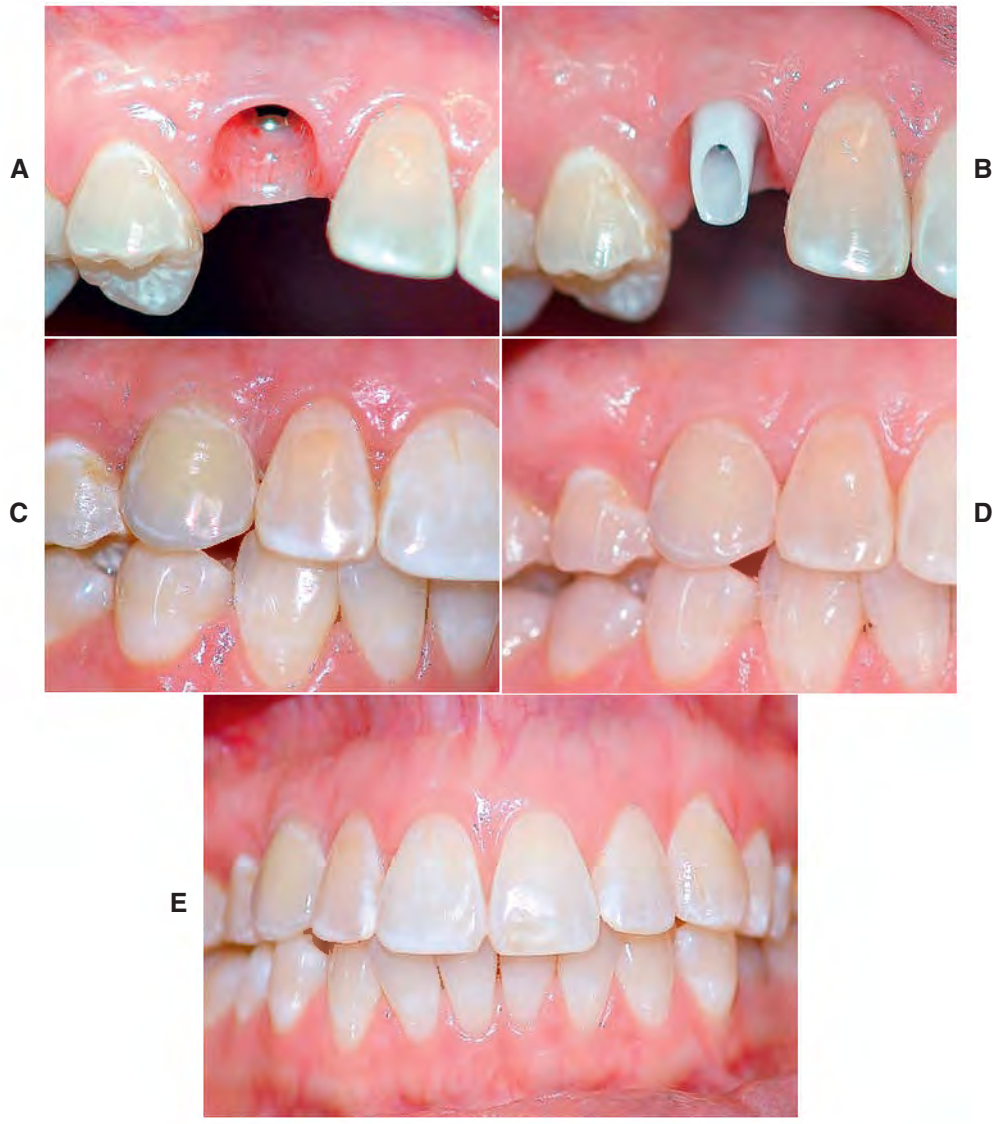

FIGURE 13-27 ■ **A,** Contoured soft tissue for implant restoration of maxillary right canine. **B,** Fixed zirconia abutment selected with margins 1 to 2 mm subgingival. **C,** Completed, cemented restorations. **D,** Five-year restoration result. **E,** Overall 5-year result. Esthetic tissue contours are symmetric with those of the contralateral canine. (Courtesy Dr. Tuncer Burak Ozcelik.)

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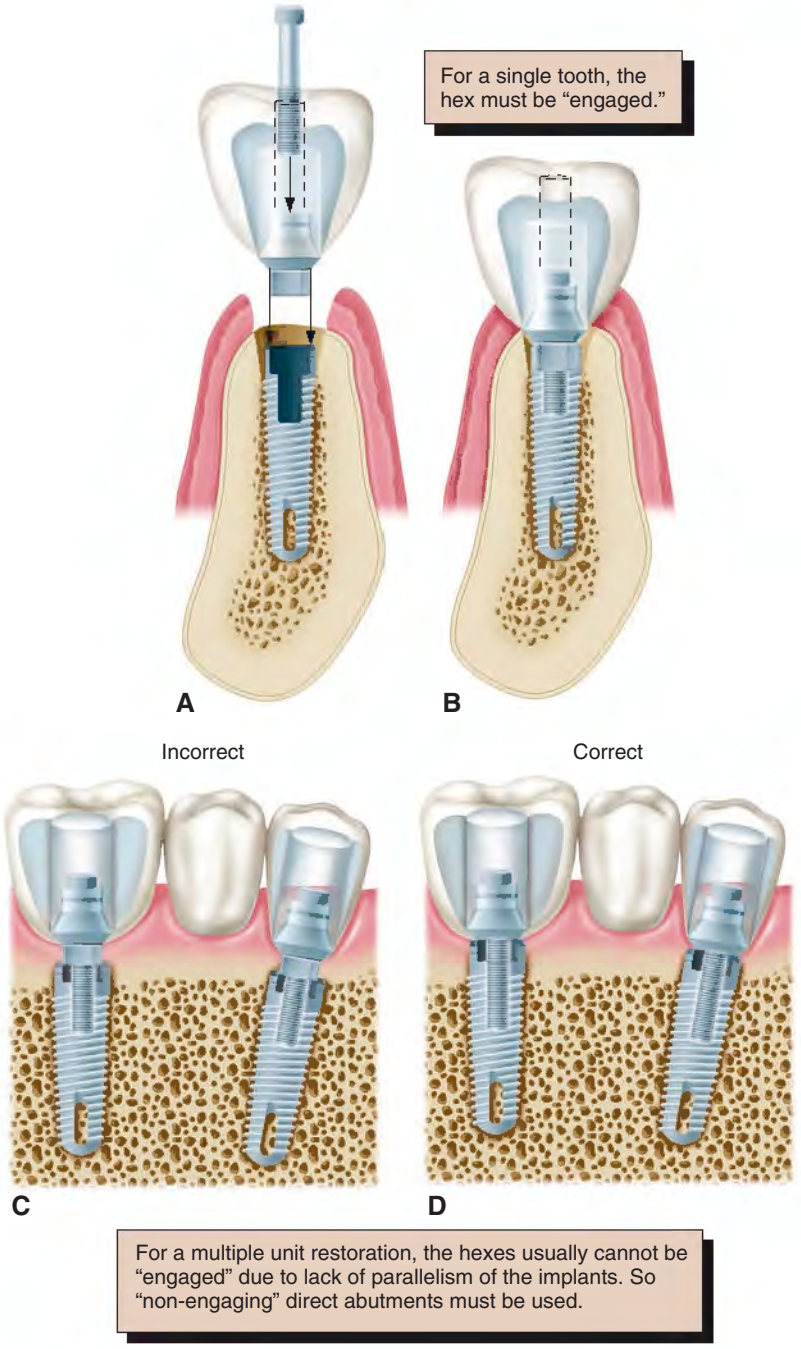

FIGURE 13-28 ■ **A** to **D,** When an antirotational feature is to be engaged by the abutment, one component of the abutment (the sleeve) must fit the hexagon ("hex"), whereas the other (the screw) independently tightens the components together.

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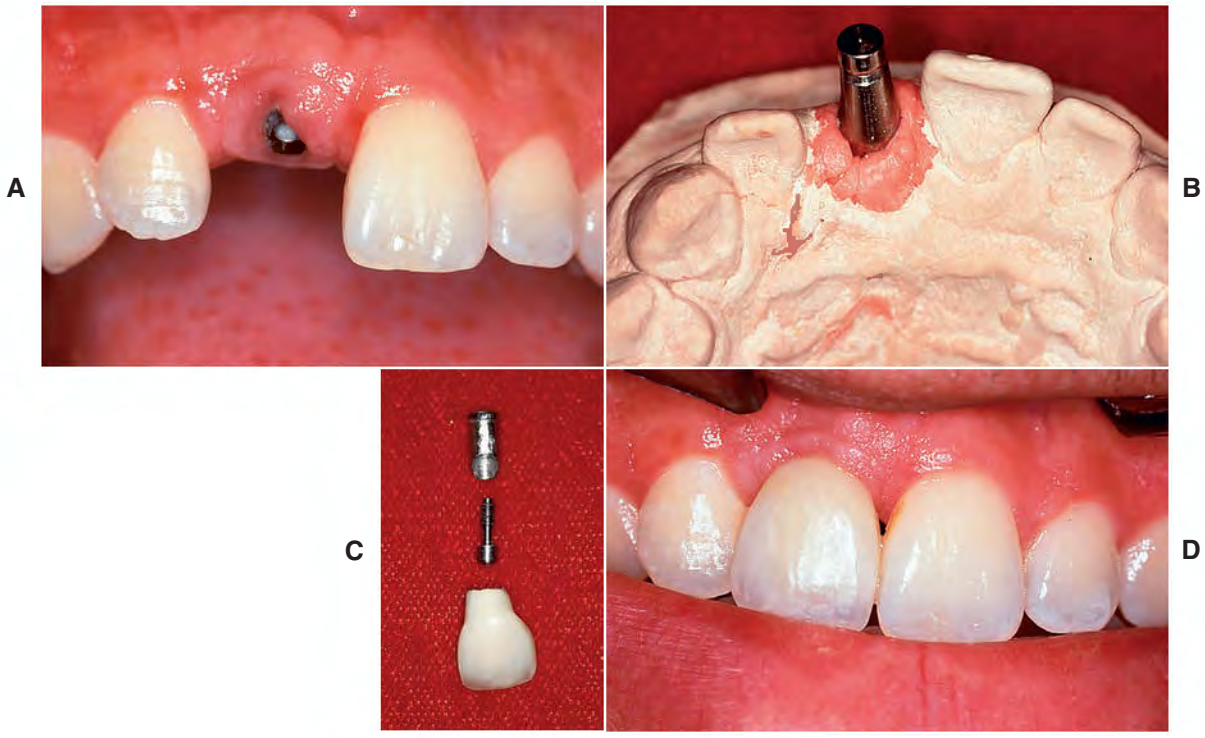

FIGURE 13-29 ■ **A** and **B,** This implant in the maxillary central incisor position is angled too far facially to restore with a straight abutment. **C,** An abutment angled 15 degrees with subgingival margins is chosen to rectify the situation. **D,** The completed crown cemented onto the angled abutment. An interim luting agent can be used to maintain retrievability, although choosing a suitable material that retains the restoration adequately but can still be removed is not always easy.

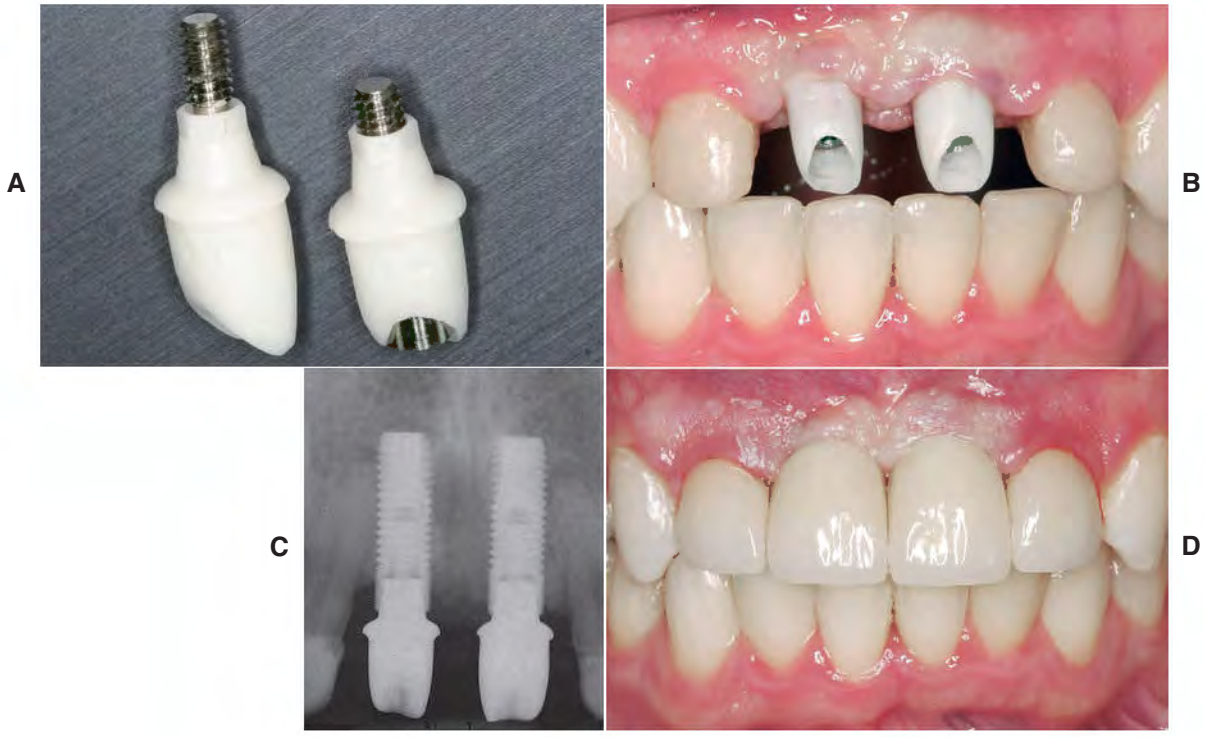

FIGURE 13-30 ■ Zirconia abutments with all-ceramic restorations (**A**) used to replace missing maxillary central incisors (**B** to **D**). (Courtesy Dr. D. Gozalo.)

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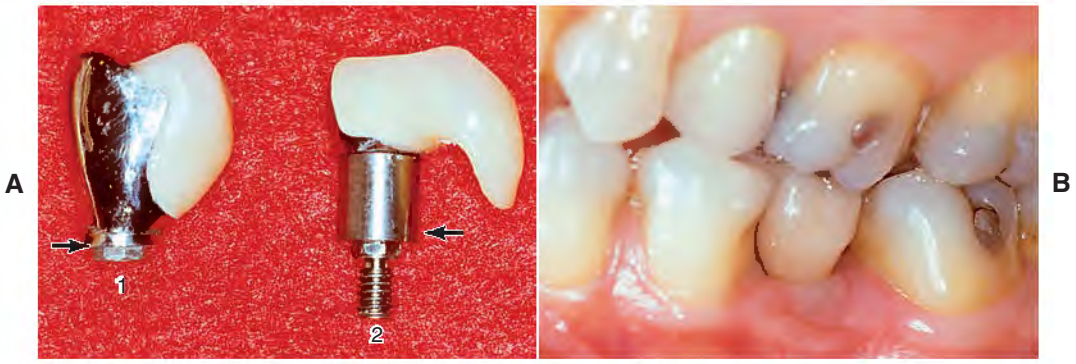

FIGURE 13-31 ■ **A,** Two crowns fabricated for the same lingually tipped mandibular implant. The *arrows* denote the connection to the implant body for both units. Crown 2 is fabricated on a 4-mm abutment. Crown 1 is connected directly to the implant body, allowing the creation of more physiologic contours. **B,** One-year follow-up of crown 1. The soft tissue response is excellent despite poor placement of the implant.

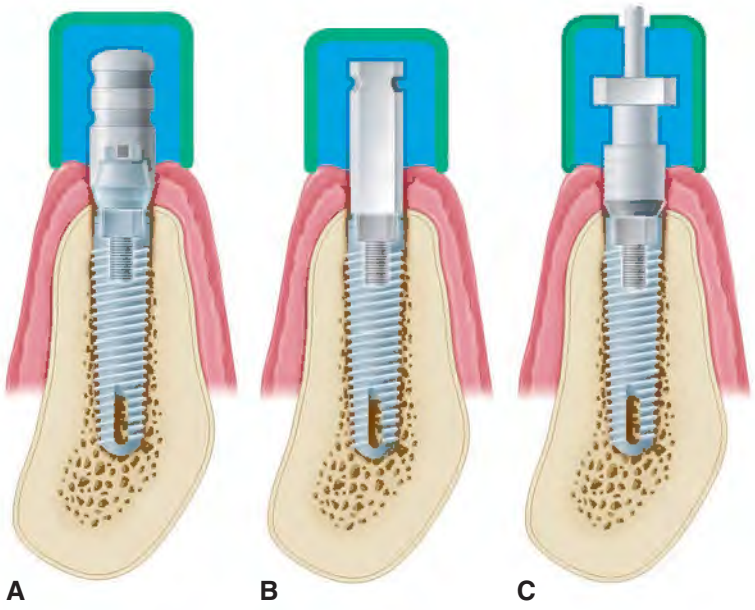

FIGURE 13-32 ■ Types of impression copings. **A,** A one-piece coping (screws onto abutment) is used if the abutment does not need to be changed on the laboratory cast. **B,** A two-piece coping (transfer/closed tray) is attached directly to the fixture if the abutment does need to be changed on the cast (it should have a flat side if angle correction is necessary). **C,** A two-piece coping (pickup/open tray) is used to orient the antirotational feature or to make impressions of very divergent implants.

of sintered alumina, zirconia, or a combination of the two.

The choice of abutment size depends on the vertical distance between the fixture base and opposing dentition, the existing sulcular depth, and the esthetic requirements in the area being restored. For acceptable appearance, fixtures in the posterior part of the maxilla or mandible may require margin termination at or below the gingival crest. For an anterior maxillary crown, 2 to 3 mm of subgingival porcelain at the facial gingival margin may be necessary to create the proper emergence profile and appearance. Framework fit should be checked on multiple-unit restorations if abutment margins are no more than 1 mm subgingival. Periodontal probing of the sulcus after the healing cap is removed reveals the space available for subgingival extension and can be performed at the time of abutment placement or after a period of tissue healing around an interim restoration. When these measurements have been made, the correct abutment is attached to the implant. The abutment length can have a dramatic effect on restoration contours (Fig. 13-31).

Impression Copings

Impression copings facilitate transfer of the intraoral location of the implant or abutment to a similar position on the laboratory cast. They may screw into the implant or onto the abutment and are customarily subdivided into two types: fixture and abutment (Fig. 13-32). Both of these can be further subdivided into transfer (indirect) and pickup (direct) types.

With the transfer impression coping in place, an impression is made intraorally, after radiographs are taken to confirm complete engagement. Heavier body impression

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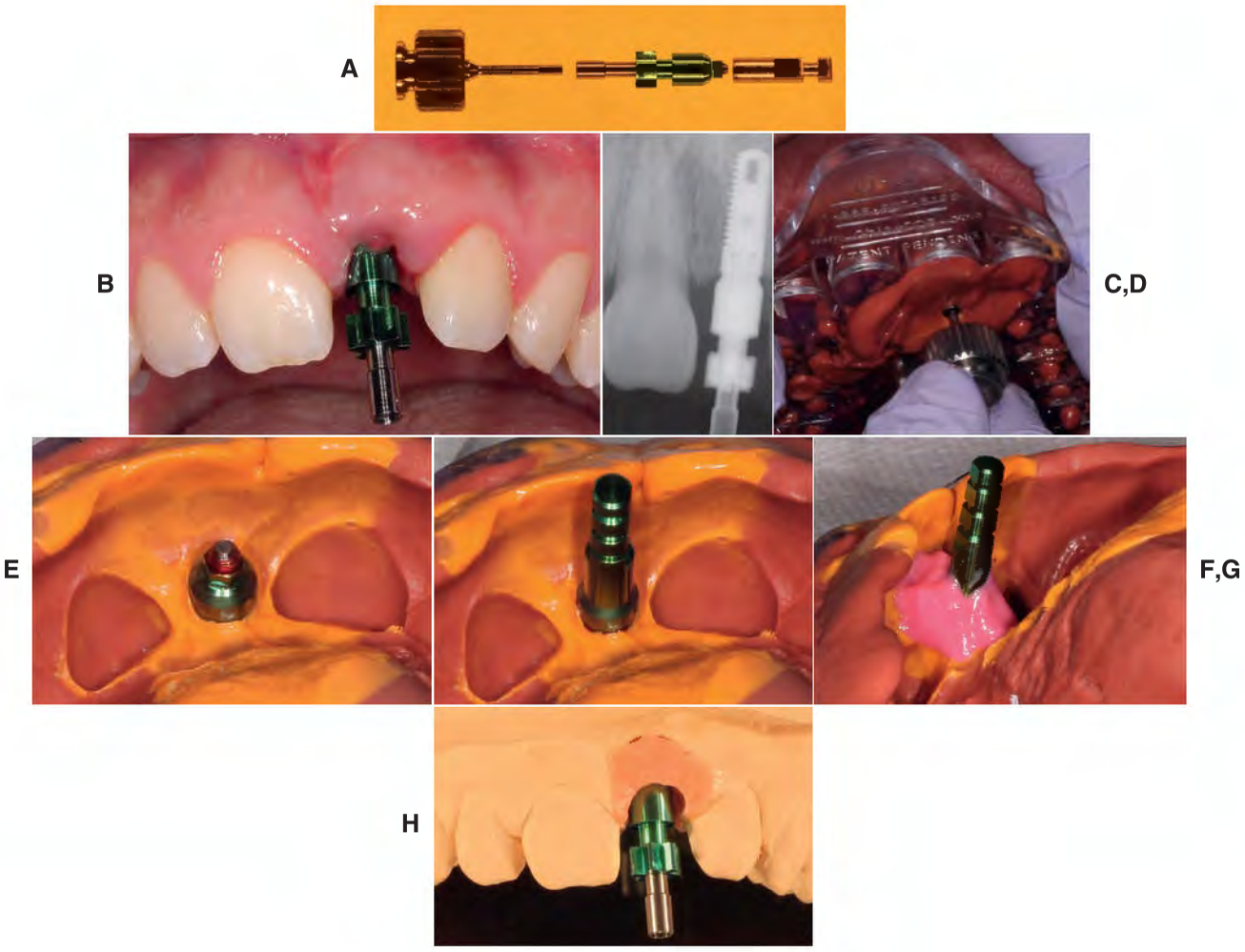

FIGURE 13-33 ■ **A,** A standard open-tray transfer impression coping is a sleeve that matches the implant diameter. A screw penetrates through its center. The screw can be placed through the impression coping sleeve and carried to the mouth with the standard hexagonal driver. **B,** Impression coping seated into the implant. **C,** Radiograph confirming complete seating. **D,** Impression coping being removed from the mouth along with the tray. **E,** Complete impression with the coping secured in place. **F,** Analog screwed into the impression coping. **G,** Polyether impression material injected around the complex before material is poured. **H,** Impression coping orients the implant analog to the cast as the implant body is positioned in the mouth. (Courtesy Dr. V. Mohunta.)

materials (e.g., polyvinyl siloxane and polyether) are usually recommended, although any conventional impression material can be used. When the impression is removed from the mouth, the impression coping remains in place on the implant abutment or on the fixture. It is then removed from the mouth and joined to the implant analog before being transferred to the impression in the proper orientation. If the clinician anticipates that the implant angulation will have to be corrected on the laboratory cast, a flat-sided impression coping that goes directly into the fixture or implant should be used (Fig. 13-33). The flat side of the post helps accurately pinpoint the location of the implant and helps position the threads and the antirotational feature. When an angled abutment is placed or screwed onto the implant, it must be oriented in the same position in which the prosthesis was fabricated in the laboratory.

Completely symmetric impression copings are contraindicated if angle correction may be necessary. If the clinician decides to transfer the orientation of an antirotational feature from the mouth to the laboratory model, the two-piece pickup (direct) impression technique should be used. This technique requires a two-piece impression coping with a removable guide pin that is screwed directly into the abutment or onto the fixture. A square coping with a long guide pin and usually an open-top tray are used. The impression coping is designed with square sidewalls to prevent rotation in the impression material. An open-top impression tray allows access to the guide pin for unscrewing after the material has set so that the copings can be picked up within the impression when it is removed from the mouth (Fig. 13-34). When implants are oriented at significantly divergent angles, the pickup technique is generally considered to be the more accurate of the two procedures. The transfer technique is more convenient and sometimes mandatory when space is limited and screwdriver access would be limited. Before an implant impression is made, a radiograph should be obtained to ensure that the components are properly assembled. This requirement is

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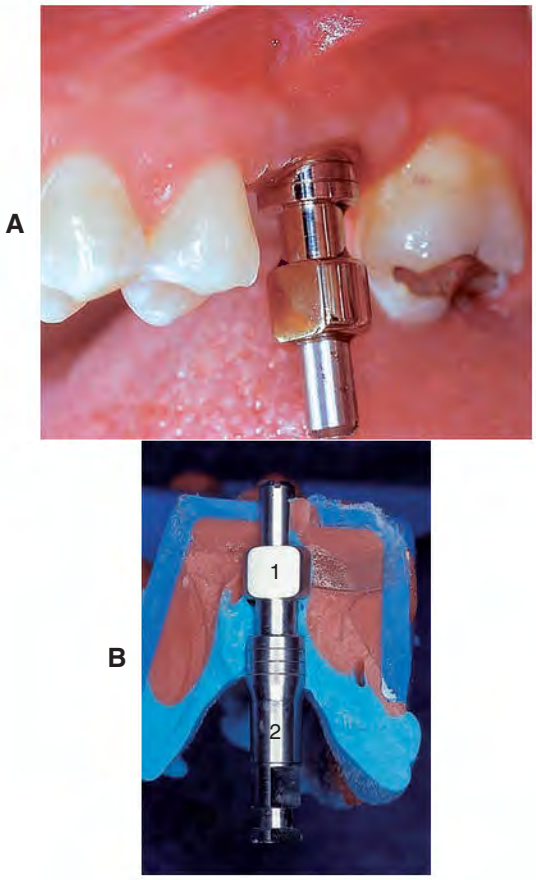

FIGURE 13-34 ■ **A,** Two-piece impression coping and screw seated intraorally. **B,** Cross-sectional view of the impression coping and screw *(1)* with the implant analog *(2)* attached. The impression coping remains within the impression material.

especially important when an antirotational feature is involved.

Implant Analogs

Implant analogs are made to represent exactly the top of the implant fixture or the abutment in the laboratory cast. Therefore, they can be classified as fixture analogs and abutment analogs (Fig. 13-35). Both types screw directly into the impression coping after it has been removed from the mouth, and the joined components are returned to the impression before the final impression material is poured. This material should be poured in either dental stone or die stone. The gingival tissues can be reproduced by injecting an elastomer (e.g., Permadyne [3M-ESPE Dental]) to represent soft tissue around the implant analog before the material is poured. This facilitates removal of the impression coping from the stone cast and the placement of subsequent abutments without the need to break the stone and lose the reference point of the soft tissue (Fig. 13-36).

Abutment analogs are generally attached to an implant impression coping. Implant body impression copings are normally attached to implant body analogs. The advantage of using the implant body analog is that the

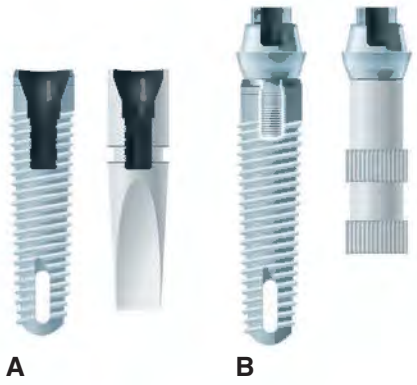

FIGURE 13-35 ■ Implant analogs. These represent either implants (fixture analogs) or abutments (abutment analogs). **A,** Analog that duplicates the top of the implant. **B,** Analog that duplicates the top of the abutment.

abutments can be changed in the laboratory. Also, if a flat-sided impression coping has been used to orient the threads or the hexagon of the implant body analog properly, the decision to correct for less than optimal implant angulation can be deferred until the laboratory stage. If the clinician is confident that the appropriate abutment has been selected, using the abutment impression coping and abutment analog can simplify the procedure. If a supragingival abutment margin has been selected, a soft tissue cast is not necessary.

Waxing Sleeves

Waxing sleeves are attached to the abutment by the relating screw on the laboratory model. They eventually become part of the prosthesis. In nonsegmented implant crowns, they are attached directly to the implant body analog in the cast.

UCLA abutments may be plastic patterns that are burned out and cast as part of the restoration framework, precious metal that is incorporated in the framework when it is cast to the precious alloy cylinder, or a combination of each. Use of a metal waxing sleeve ensures that two machined surfaces are always in contact. The cast surface of the plastic waxing sleeve may be retooled before it is returned to the fixture.

Waxing sleeves are available in several vertical dimensions. Tall ones can be shortened to conform to the requirements of the occlusal plane. Today, most waxing sleeves are a combination of gold alloy and plastic (Fig. 13-37). This combination allows the machined fit of the alloy at the implant, with the cost advantage of plastic at the waxing surface.

Prosthesis-Retaining Screws

Prosthesis-retaining screws penetrate the fixed restoration and secure it to the abutment (Fig. 13-38). They are tightened with a screwdriver and are used to attach nonsegmented crowns to the body of the implant. They generally are made of titanium, titanium alloy, or gold alloy and may be long (which allows them to penetrate

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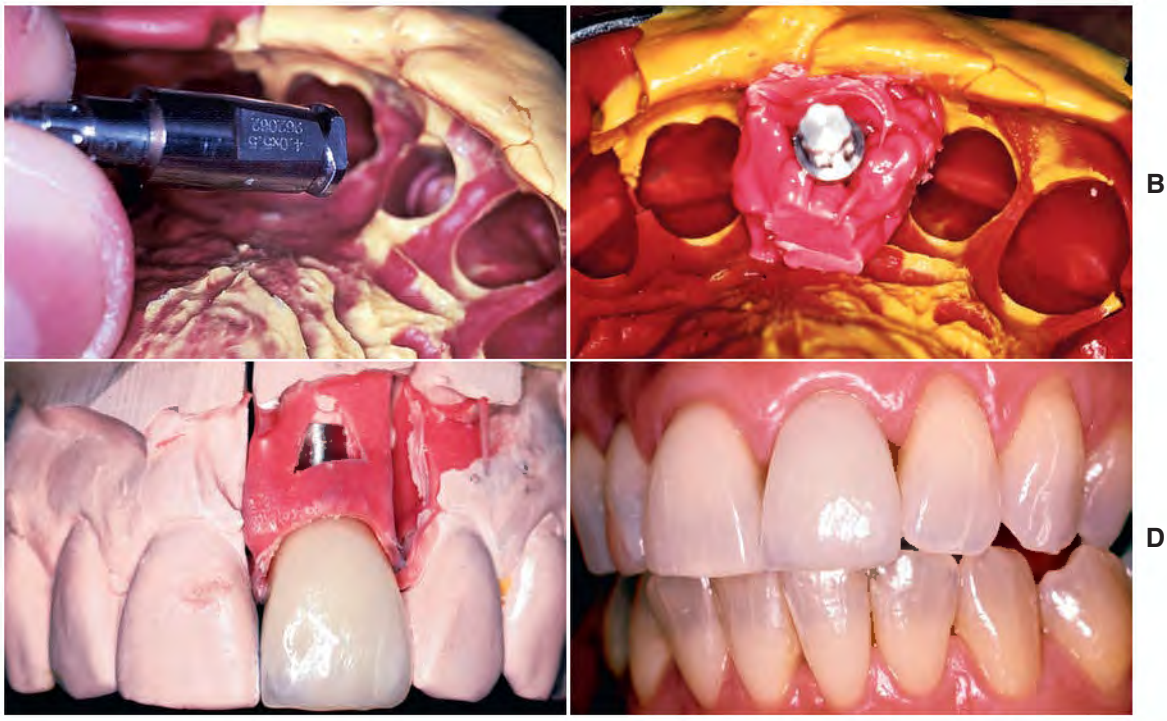

FIGURE 13-36 ■ **A** and **B,** Polyether impression material injected around an implant analog before the impression material is poured. The gingival material should not cover any retention features of the analog. **C,** The impression material reproduces the patient's soft tissue contours adjacent to the implant. The impression coping may be removed and other components inserted without loss of the associated anatomic landmarks. **D,** Completed restoration. (Courtesy Dr. C. Pechous.)

FIGURE 13-37 ■ **A,** Waxing sleeves with gold alloy base and plastic extension. **B,** On the laboratory cast, the technician can wax to the plastic extension. The wax and plastic are burned out, and the new alloy is cast onto the original alloy base.

the total length of the implant crown) or short (which requires countersinking them into the occlusal surface of the restoration). Screws that are countersunk must be covered by an initial layer of resilient material (e.g., gutta-percha, cotton, or silicone). A subsequent seal of composite resin is placed over the resilient plug (Fig. 13-39).

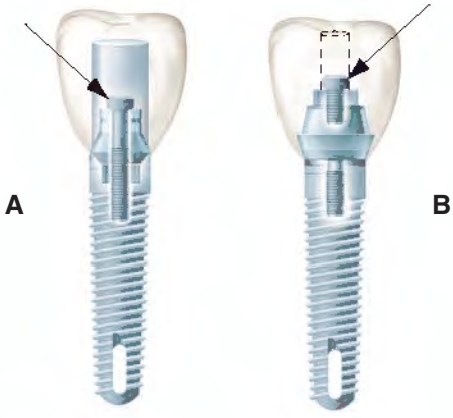

FIGURE 13-38 ■ Two types of prosthesis-retaining screws. **A,** Nonsegmented crown retained to implant. **B,** Crown retained on abutment.

Implant Restorative Options

Distal-Extension Implant-Supported Restoration

Implant support offers major advantages in the treatment of partially edentulous patients in whom no terminal abutment is available. In this situation, the conventional

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dental treatment plan would include a partial removable dental prosthesis. However, with the implant alternative, patients can avoid the discomfort and inconvenience of a removable prosthesis.

There are two distal-extension restorative options. One option is to place an implant distal to the most posterior natural abutment and fabricate a fixed prosthesis connecting the implant with the natural tooth. However, there are problems associated with implants connected to natural teeth (see the section on Connecting Implants to Natural Teeth). The other option is to place two or more implants posterior to the most distal natural tooth and fabricate a completely implant-supported restoration (Fig. 13-40). If the crown-to-implant ratio is favorable, two implants to support a three-unit fixed dental prosthesis may be considered. If implants are short and crowns are long, one implant to replace each missing tooth is highly recommended. If doubt remains, more implants are used when heavier forces are expected (e.g., the posterior part of the mouth in patients with evidence of parafunctional activity). Fewer implants are used when lighter forces are expected (e.g., those opposing a complete denture or those supporting a prosthesis in the anterior part of the mouth).

FIGURE 13-39 ■ Prosthesis-retaining screws countersunk below the occlusal surface of the restoration.

Restoration for a Long Edentulous Span

Similar options can be used to treat a long edentulous span. The clinician may choose to have multiple implants placed between the remaining natural teeth and to fabricate a fully implant-supported restoration. As an alternative, one or two implants can be placed in the long edentulous span and the final restoration connected to natural teeth. When it is necessary to connect implants and the natural teeth, protecting the teeth with telescopic copings is recommended. In this manner, prosthesis retrievability can be maintained. In addition, some long edentulous spans require the reconstruction of soft and hard tissue in addition to teeth. In these instances, resin teeth processed to a metal substructure or zirconia-pink ceramic restorations, rather than a

FIGURE 13-40 ■ **A,** Two implants placed distal to the mandibular premolar. **B** to **D,** The completed restoration is not connected to the crown on the natural tooth. (Courtesy Dr. R.B. Miller.)

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conventional metal-ceramic restoration, are recommended. Soft tissue esthetics can be easily and accurately mimicked with heat-processed resin or pink ceramic in large defects (Fig. 13-41). The metal-resin type of restoration is best described as a complete metal-resin fixed dental prosthesis. It has also been called a *hybrid prosthesis* because it combines the principles of conventional fixed and removable prosthodontics. For smaller defects, pink porcelain can be used to compensate for missing soft tissue (see Fig. 13-26, *B*).

Single-Tooth Implant Restoration

The use of single implants in restoring missing teeth is an attractive option for the patient and the dentist. However, it requires careful implant placement and precise control of all prosthetic components. Single-tooth restorations supported by implants may be indicated in the following situations:

- Otherwise intact dentition
- Dentition with spaces that would be more difficult to treat with conventional fixed prosthodontics
- Distally missing teeth when cantilevers or partial removable dental prostheses are not indicated
- A prosthesis that needs to closely mimic the missing natural tooth

The requirements for single-tooth implant crowns are as follows:

- Esthetics
- Antirotation, to avoid prosthetic component loosening
- Simplicity, to minimize the amount of components used
- Accessibility, to maintain optimum oral health
- Variability, to allow the clinician to control the height, diameter, and angulation of the implant restoration

Several systems have been developed to comply with these demands. Common indications include congenital absence of maxillary lateral incisors (Fig. 13-42) and teeth in which endodontic treatment was unsuccessful (Fig. 13-43). Screw loosening has been associated most commonly with the terminally positioned single molar implant crown (Fig. 13-44).

Matching the soft tissue contours of adjacent natural teeth remains the most difficult challenge for completing the anterior single-tooth restoration. These contours can be reliably created with interim restorations. One technique, which combines soft tissue contouring and interim placement, is shown in Figure 13-45. When the tissue has matured around the interim restoration, a final impression can be made to complete the definitive restoration (Fig. 13-46). Impressions can also be made at the time of first-stage surgery so that an interim restoration can be delivered at second-stage surgery to facilitate more ideal soft tissue contours (Fig. 13-47). The best soft tissue esthetics is still generally achieved when interdental papillae are present before the surgery. If soft tissue contours are deficient before surgery, the patient should expect some compromise in the final soft tissue result.

Text continued on p. 353

FIGURE 13-41 ■ **A,** Large mandibular defect created by a shotgun wound. **B,** Metal substructure of a metal-resin prosthesis tried onto three implants in this defect. **C,** Denture resin can effectively re-create the soft tissue color and contours in the completed restoration, sometimes less expensively than dental porcelain. **D,** Metal-resin restoration over the defect.

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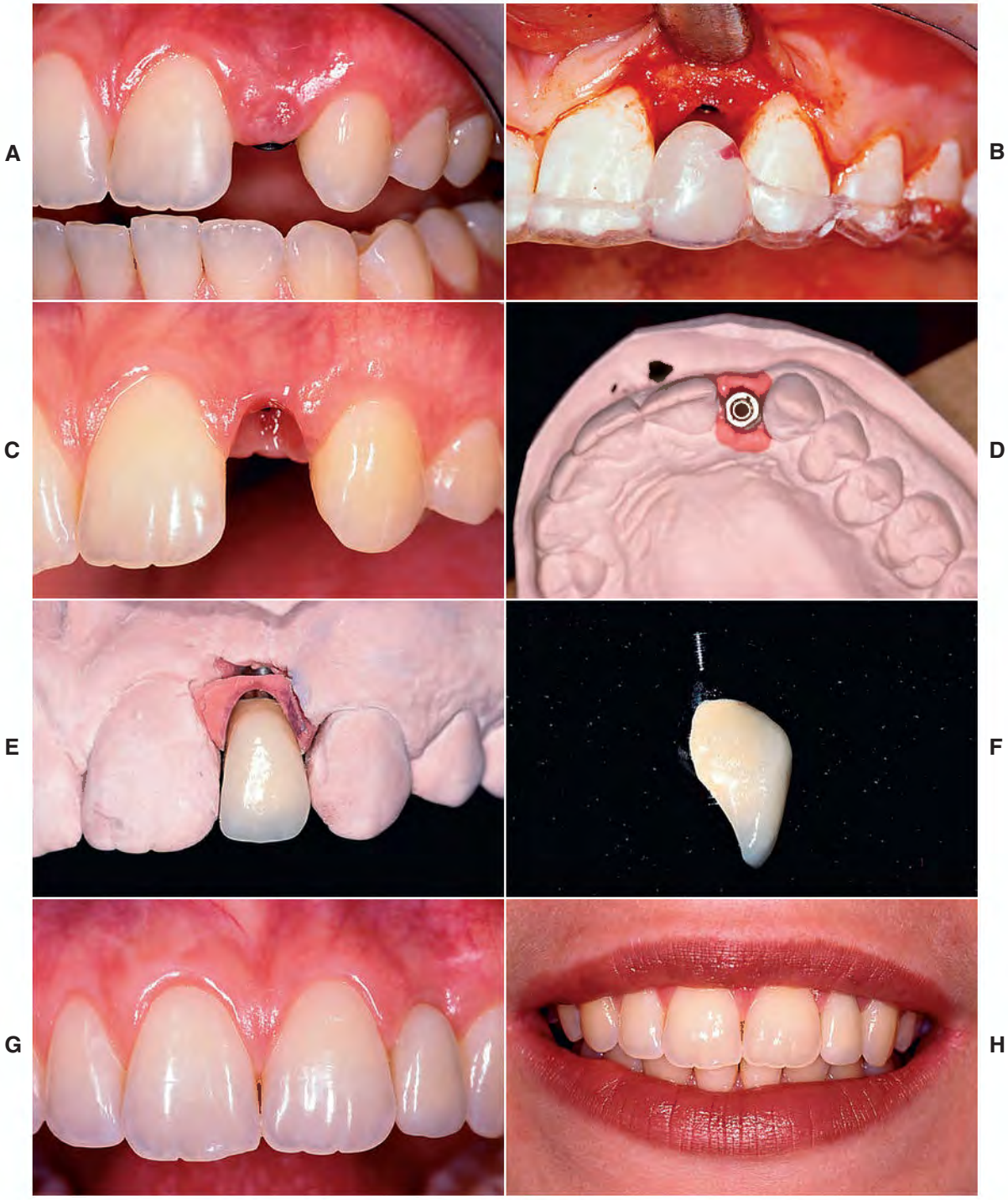

FIGURE 13-42 ■ **A,** Congenital absence of maxillary lateral incisor. **B,** Placement of dental implant through the use of a surgical template. **C,** Final soft tissue contours. **D,** Impression post projecting from definitive cast. **E** and **F,** Final restoration. **G** and **H,** Single-tooth implant crown replacing the maxillary lateral incisor.

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FIGURE 13-43 ■ **A,** Occlusal view of a single-tooth implant crown replacing a fractured mandibular premolar. **B,** Implant crown with screw access restored. **C,** Occlusal view of a screw-retained mandibular second premolar implant crown. **D,** Implant crown with screw access hole restored. (Courtesy Dr. Jairo Sainz.)

FIGURE 13-44 ■ Screw loosening is most commonly associated with single-tooth molar implant crowns.

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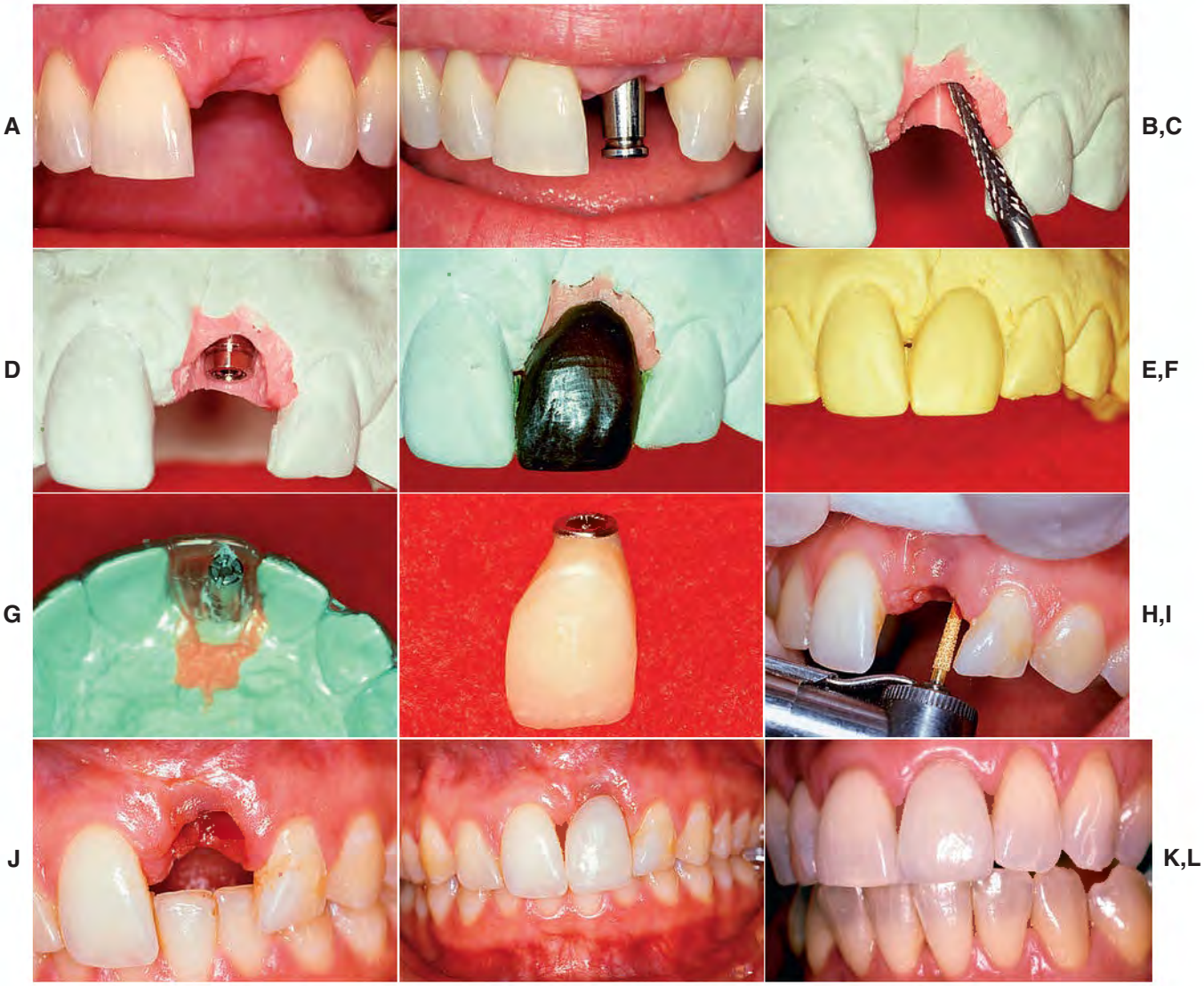

FIGURE 13-45 ■ Soft tissue contouring with interim restoration. **A,** The lost left maxillary central incisor will be replaced with an implant-supported prosthesis. **B,** Soft tissue healing 2 weeks after second-stage surgery and placement of an impression coping. Note that the interdental papilla has been preserved. **C,** Soft tissue cast prepared with a laboratory bur to create the ideal soft tissue architecture. **D,** A waxing sleeve attached to the implant analog retains the interim restoration. **E,** An anatomic-contour wax pattern can be used to fabricate the interim restoration. **F,** Duplicate cast of the anatomic-contour wax pattern. **G,** An acrylic template is adapted to the duplicate cast and returned to the definitive cast. A waxing post is placed in the interim restoration to create a screw access hole. **H,** An interim implant-supported restoration is fabricated by one of the techniques described in Chapter 15. **I,** The soft tissue is contoured to accept the interim restoration. A diamond curettage bur can be used when sufficient attached tissue is present. **J,** Soft tissue contouring improves esthetics, minimizes pocket depths, and allows more physiologic restoration contours. **K,** The interim restoration. Soft tissue is allowed to heal for 4 to 6 weeks before the definitive impression is made. **L,** Definitive implant-supported restoration.

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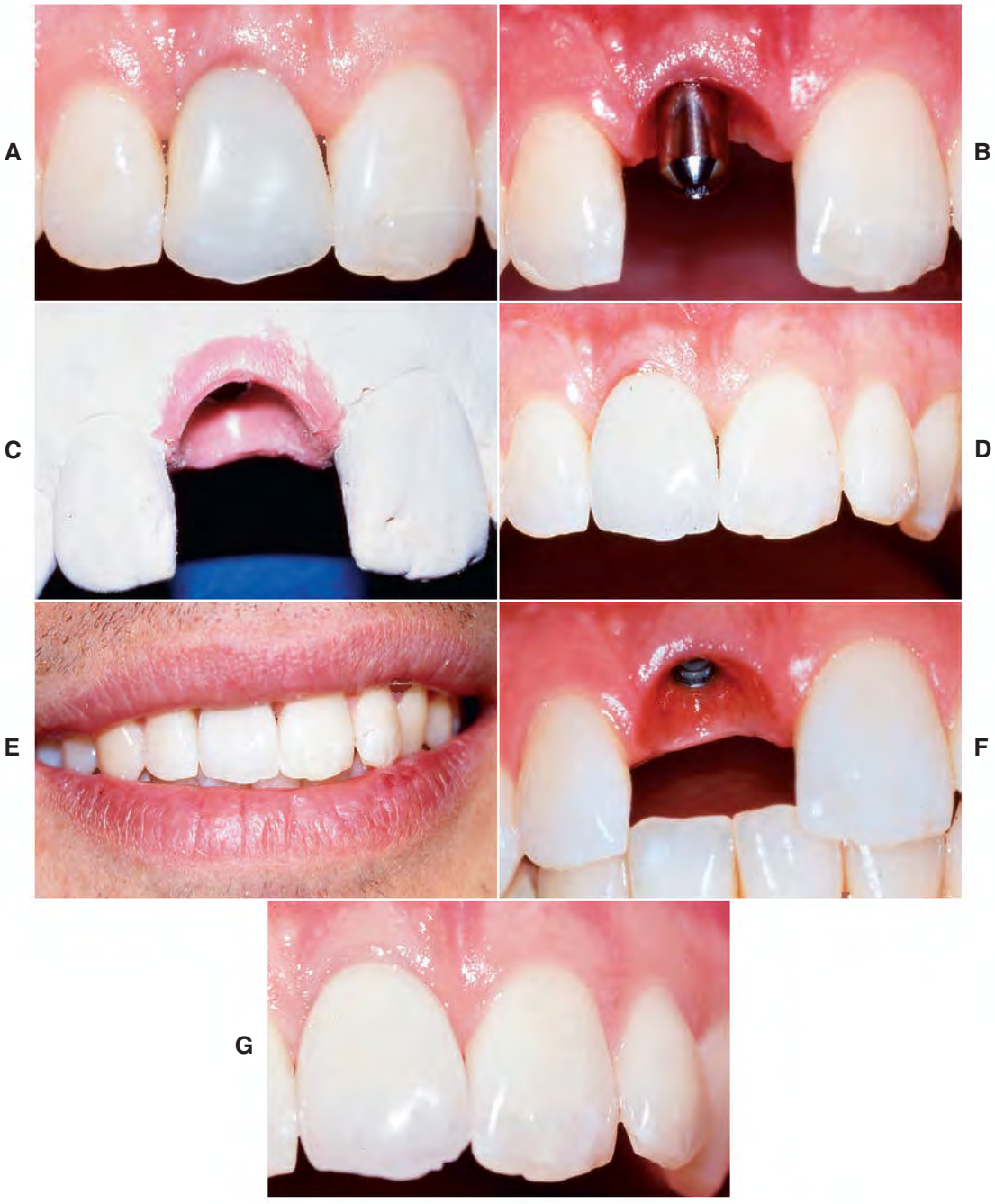

FIGURE 13-46 ■ **A,** Soft tissue around a maxillary implant provisional restoration after 6 weeks of healing. **B,** New soft tissue contours, in comparison to the healing abutment previously in place. **C,** The final impression is made, and a definitive cast is fabricated. The new soft tissue contours are reproduced. **D,** Implant crown placed on the maxillary right central incisor. **E,** Preservation of the interdental papilla is important for patients with medium to high smile lines. **F** and **G,** One- and five-year follow-up photographs show that the patient has maintained healthy soft tissue contours. (Courtesy Dr. J.A. Holloway.)

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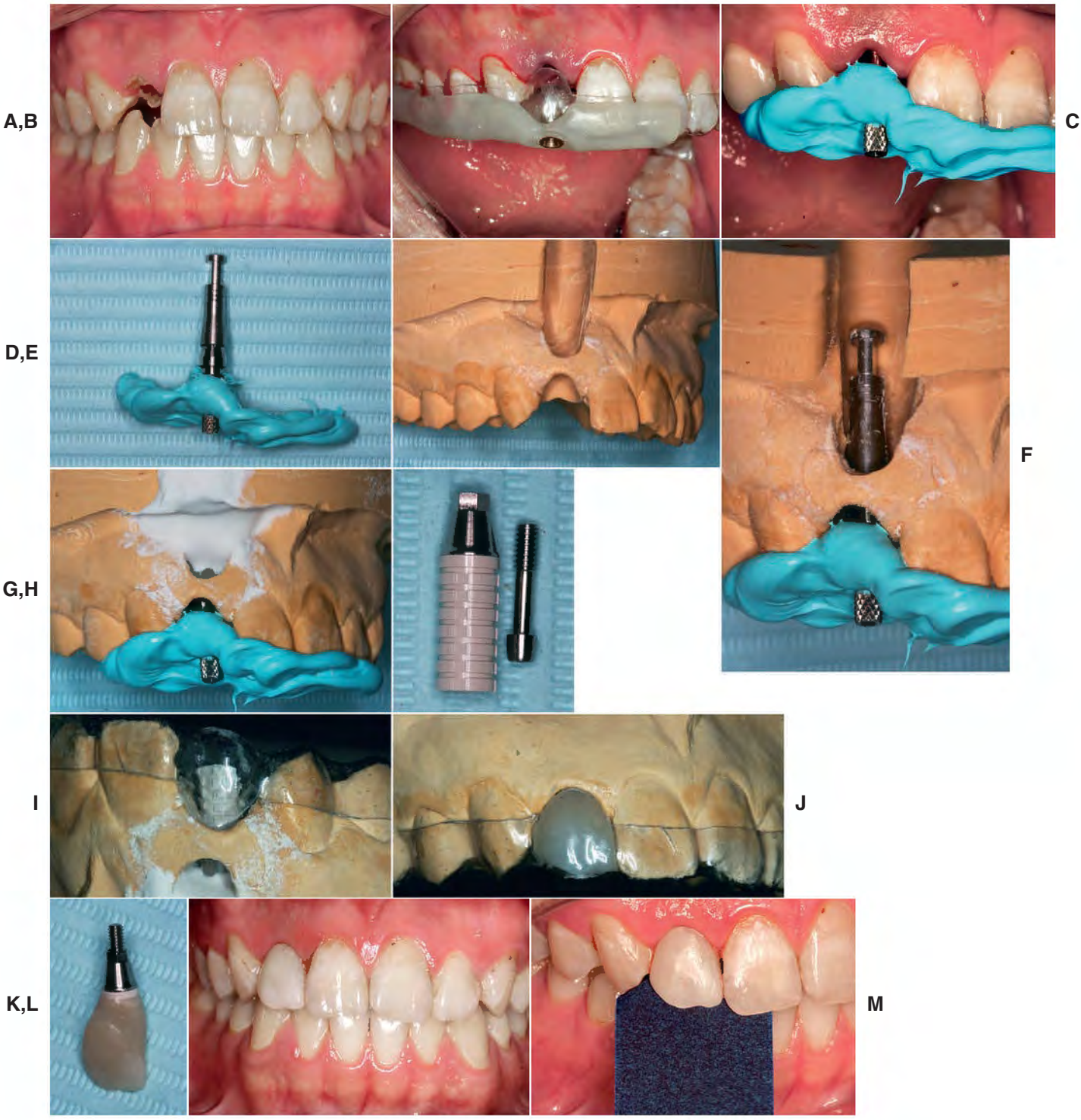

FIGURE 13-47 ■ Stage 1 interim restoration technique. **A,** View of failing maxillary right lateral incisor. **B,** Surgical template in position. **C,** Once the screw-shaped implant is in place, the position of the fixture mount in relation to the adjacent teeth is registered with silicone before it is unscrewed from the mouth. **D,** Analog attached to the fixture mount. **E,** Diagnostic stone cast prepared to position analog. **F,** Template placed back on diagnostic cast. **G,** Dental plaster flowed around the analog. The position of the analog is identical to the position of the implant in the mouth. **H** to **M,** An interim abutment is used for the fabrication of an interim restoration that can be delivered at first or second-stage surgery. (Courtesy Dr. Luiz Daroz Diaz.)

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FIGURE 13-48 ■ **A** to **D,** A metal-ceramic implant restoration may be indicated if adequate bone and soft tissue contours are available.

FIGURE 13-49 ■ Radiograph of patient in Figure 13-48, showing fixed restorations supported by seven implants in the maxilla and six in the mandible.

Fixed Restoration in the Completely Edentulous Arch

For completely edentulous patients who require nonremovable restorations, there are three implant options: a complete metal-resin fixed dental prosthesis, a metal-ceramic fixed dental prosthesis, and a zirconia-ceramic fixed dental prosthesis (Figs. 13-48 to 13-50).

The complete metal-resin fixed dental prosthesis is a cast or milled alloy framework with processed denture resin and teeth. It is typically supported by four to six implants in the mandible and maxilla. One major determining factor for selecting this option is the amount of bone and soft tissue that has been lost. For patients who have had moderate bone loss, the prosthesis restores both bone and soft tissue contours.

The metal-ceramic prosthesis and zirconia-ceramic prosthesis also require four to six implants in the mandible and maxilla. The zirconia prosthesis can be monolithic or layered with feldspathic porcelain. Likewise, zirconia can be milled directly onto the implants or cemented onto titanium abutments that attach to the implants. Another approach is the fabrication of a fixed dental prosthesis as a restoration in which crowns are individually cemented on the metal or zirconia framework. The advantage of this approach over zirconia-ceramic or monolithic zirconia is that in the event of prosthesis failure or need of repair, the design of the prosthesis allows the individual crowns to be more easily removed for corrections to be made. One variation of this approach is to fabricate the simulated gingival portion in composite resin over the metal and use individual all-ceramic crowns on the framework (see Fig. 13-50).

Different framework designs have been proposed for complete fixed dental prostheses (Fig. 13-51).[13] These options can be made esthetically pleasing only if bone loss is minimal and are best suited for patients who have recently (within 5 years) lost their natural teeth. For patients with severe bone loss, there is probably only one option: a removable restoration (Fig. 13-52).

The main advantage of a fixed restoration, whether it is metal-resin, metal-ceramic, or zirconia-ceramic, is that it is attached to the implants at all times. Therefore, patients experience the psychological benefit of having a restoration that closely resembles their original natural teeth. In addition, movement within the system is minimized, and the components tend to wear out less quickly.

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FIGURE 13-50 ■ Metal-resin **(A)** and zirconia-ceramic restorations **(B-D)** are also treatment options for edentulous patients with moderate to severe bone resorption. **E-J,** Metal-resin prostheses with individual all-ceramic crowns. (Courtesy Dr. L. Salaita.)

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Because the prosthesis is screw retained, the dentist can remove it, allowing access for cleaning and repairs. A potential disadvantage is that the implants must be precisely placed, especially in the maxillary anterior esthetic zone. Implants placed in embrasure spaces can lead to disastrous esthetic results and can impede access for hygiene. With a metal-resin or zirconia prosthesis, the clinician must decide between leaving enough space for hygiene access and minimizing space for optimum esthetics. Some patients may be concerned by the amount of metal shown in a metal-resin prosthesis. However, from a conversational distance, a properly made prosthesis is hardly noticeable. Esthetic and phonetic problems in the maxillary arch can often be avoided by placement of implants away from the midline and restoration of the incisor teeth with pontics. This approach to implant placement improves the restorative outcome considerably (Fig. 13-53).

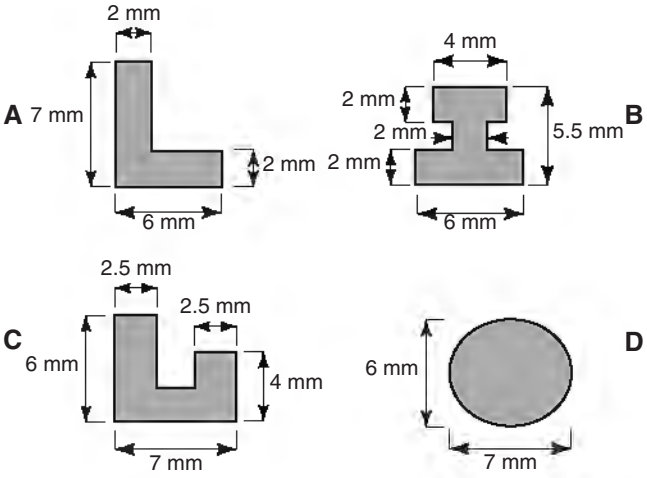

FIGURE 13-51 ■ Complete arch restoration framework designs: L-shaped **(A),** I-shaped **(B),** U-shaped **(C),** and elliptical sections **(D).** (Adapted from Stewart RB, Staab GH: Cross-sectional design and fatigue durability of cantilevered sections of fixed implant-supported prostheses. J Prosthodont Sep;4[3]:188, 1995.)

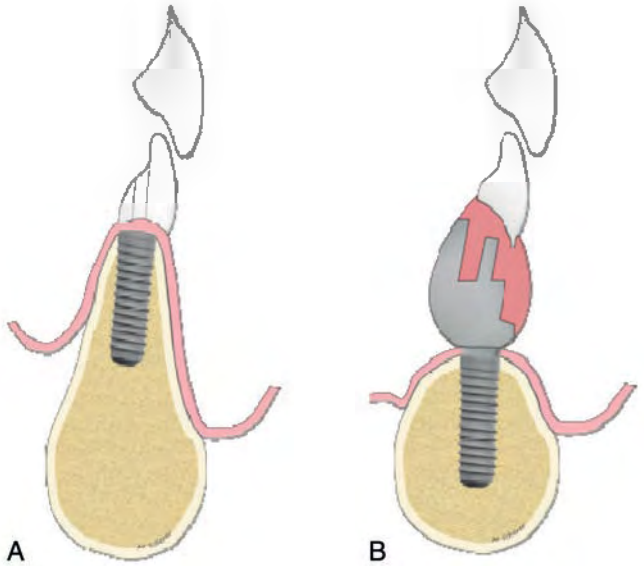

FIGURE 13-52 ■ The amount of bone resorption dictates the treatment options for an edentulous patient. **A,** With minimal resorption, metal-ceramic restorations may be possible. **B,** Moderate to severe resorption may necessitate pink resin-to-metal or pink ceramic-metal/zirconia restorations. (Adapted from drawing by Dr. M. Scherer.)

Because of maxilla and mandible ridge deficiencies, the rehabilitation of edentulous arches is frequently complicated. These challenges are magnified by resorption and angulation of the bone, especially in the posterior region. To compensate for ridge deficiencies and increase the length of implants that can be placed, clinicians may place an implant with an angled trajectory. Several clinical studies have shown that tilting of the implants may represent a feasible treatment option.[14-20]

Angled implants allow for maximum use of the existing bone and placement of posterior fixed restorations in a region where bone height and nerve proximity does not allow for the placement of implants axially.[21] In distal regions of the mandible, posterior implant tilting makes it feasible to use longer implants anchored in the interforaminal region. This allows for good bone anchorage, prevents interference with the mandibular nerve, and moves the prosthetic support more posterior.

This type of implant placement helps increase anterior-posterior (AP) distance between mesial and distal implants and therefore decreases the length of the cantilever extending distally. It has been reported in the literature that increasing the AP distance creates a better situation biomechanically because implants farther in front of the fulcrum line resist biting forces on the cantilever portion of the prosthesis (Fig. 13-54).[22-25] The treatment plan for totally edentulous patients has also changed dramatically with the success of dental implants and immediate-loading protocols. This change was attributable to the success of several different immediate-function prosthetic reconstruction protocols. The general consensus for the success of these techniques is that if implants are stable at insertion and a prosthesis connecting these implants across the arch remains stable during the healing phase, implant success will approach the results achieved with traditional delayed loading protocols. However, most of these publications warn that if implants are not stable at placement or if the prosthesis does not remain stable during initial healing, osseointegration may be jeopardized.

Moreover, the treatment of fully edentulous patients with immediate function has been combined with the four-implant angled protocol and shown to also be a predictable procedure for the long term.[26-29] Clinicians have reported positive clinical outcomes with the placement of implants at an angled trajectory.[15,16,18,30] In these clinical protocols, provisional restorations are most commonly used to load the implants immediately. These "conversion type" all-acrylic temporary restorations necessitate definitive prosthetic rehabilitation and may be prone to fracture.[31] Additional immediate-load surgical and prosthetic protocols have been developed to allow clinicians to deliver a custom, definitive, screw-retained metal-resin prosthesis 2 to 4 days postoperatively, with the use of four to six implants (Fig. 13-55).[32]

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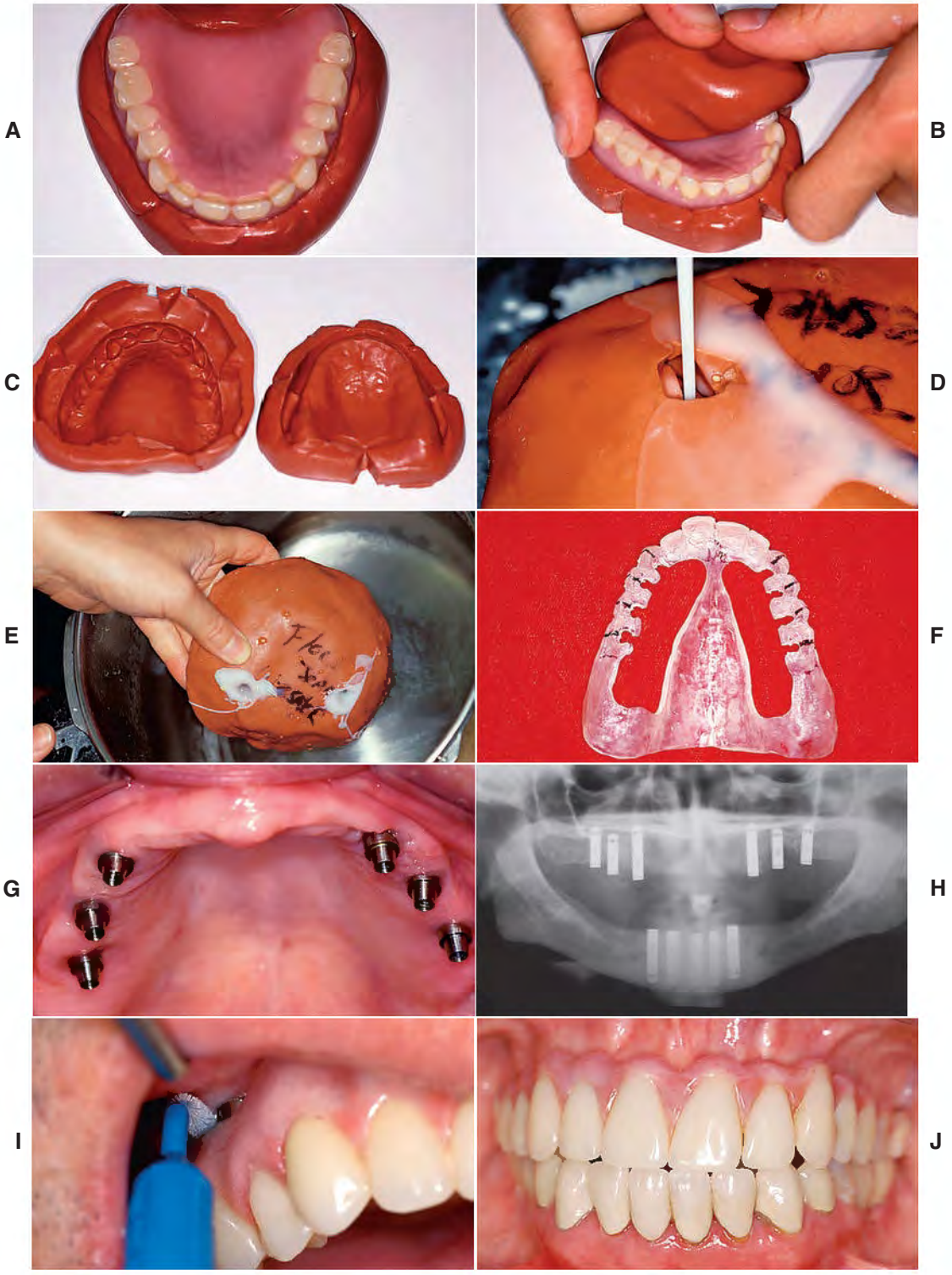

FIGURE 13-53 ■ Posterior implant placement for a maxillary complete arch prosthesis. A surgical template can be fabricated for an edentulous patient by duplicating the existing denture in clear resin. **A** to **C,** Putty impression material is used to form a mold of the fitting and polished surfaces of the denture, which is reassembled to form the mold. Clear autopolymerizing resin is poured into the mold **(D)** and placed in a pressure pot **(E). F,** The lingual aspect of the template is removed, leaving the most facial 2 mm of resin intact. The surgeon will have access to the bone, but it will be confined to the arch form. **G,** The ideal positions for maxillary implants are the canine, second premolar, and second molar areas. **H,** Cross-arch implant parallelism is also important. **I,** Access for hygiene must be allowed around implant abutments. If implants are posterior to the canine, access for hygiene can be created without compromising esthetics or phonetics. **J,** Reasonable esthetics and phonetics can be accomplished with a metal-resin restoration if modified ridge-lap pontics are used in the maxillary central and lateral incisor positions.

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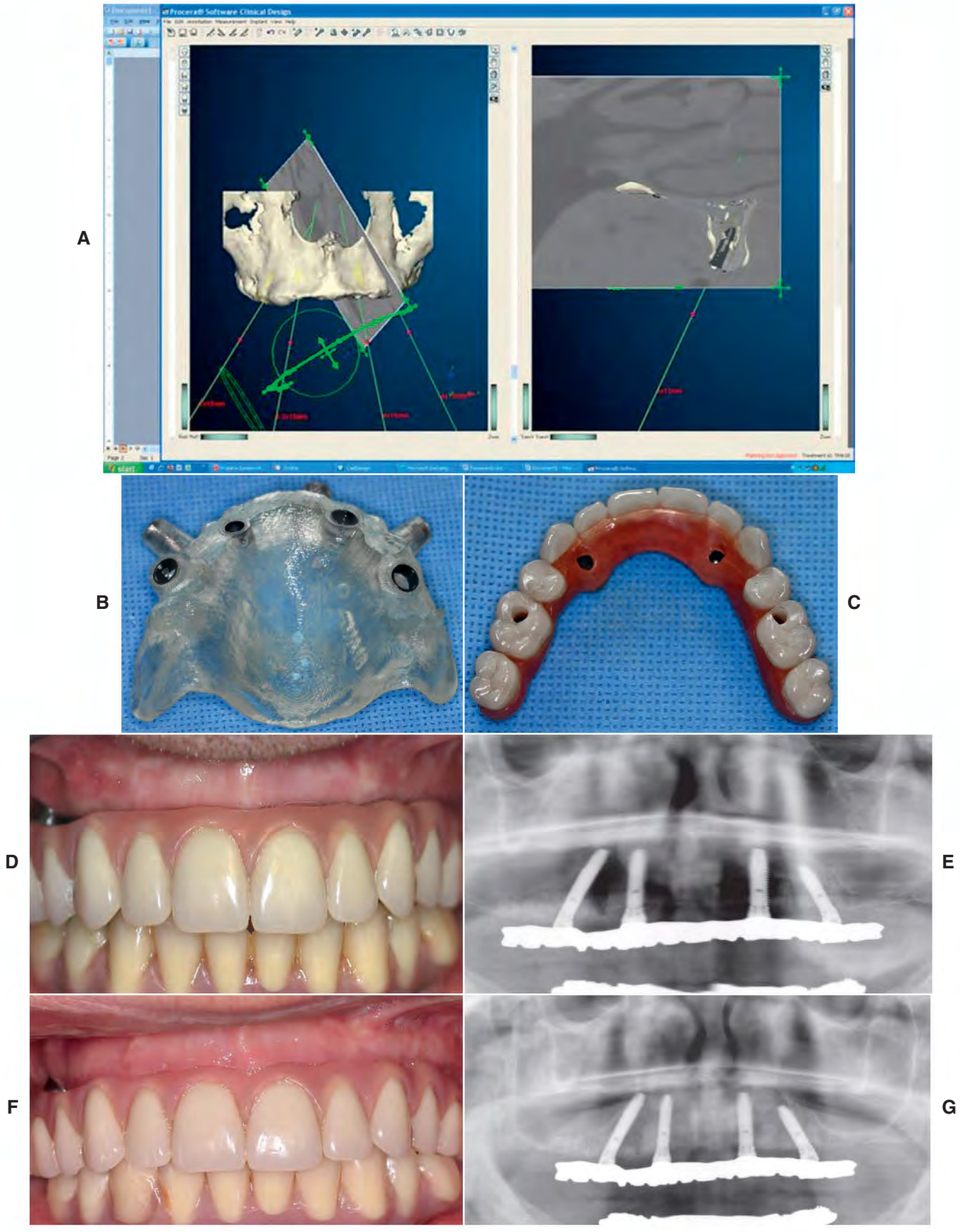

FIGURE 13-54 ■ **A** to **E,** Protocol for angled implant. Fiver-year follow-up intraoral **(F)** and panoramic **(G)** views.

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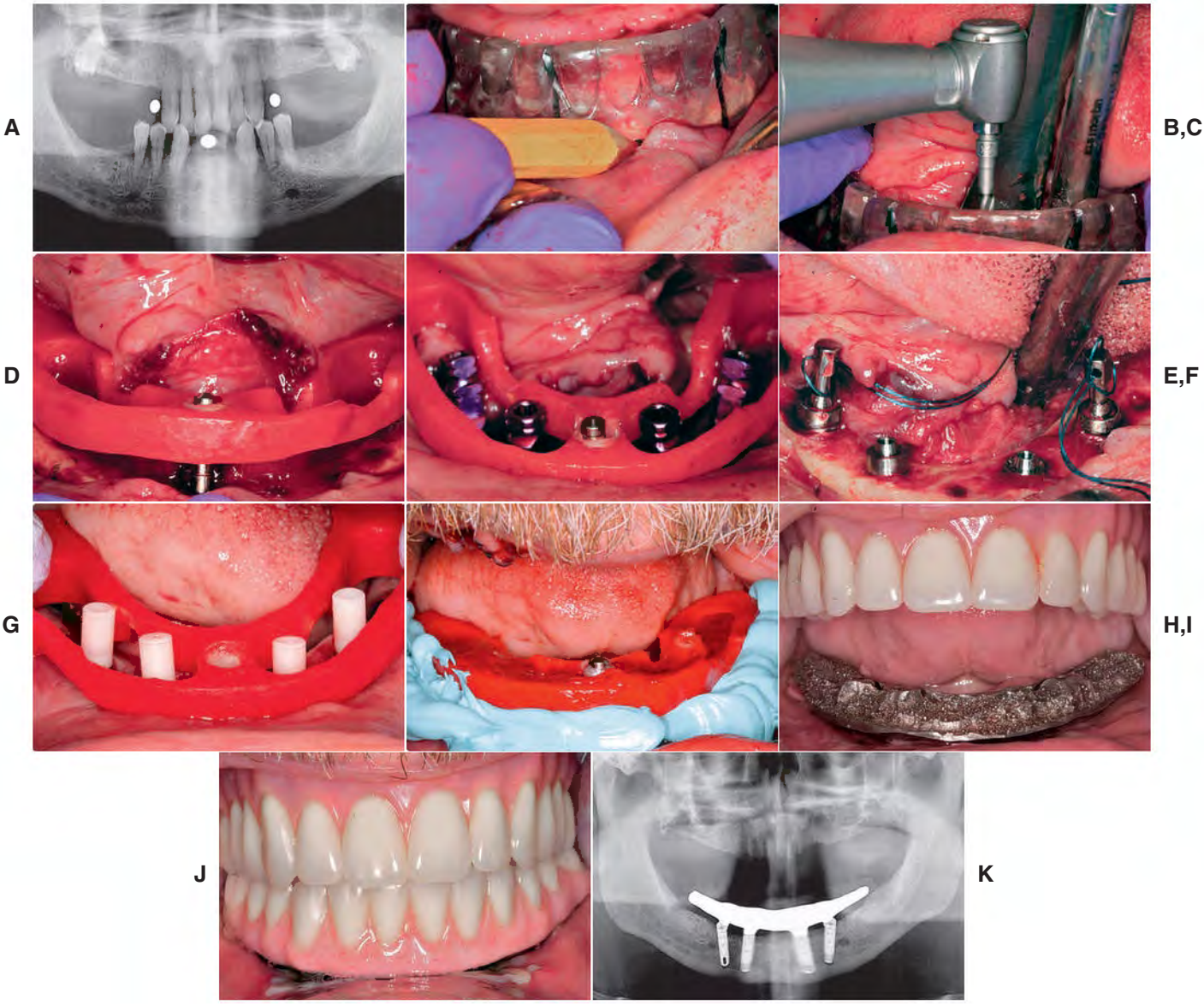

FIGURE 13-55 ■ **A,** Preoperative panoramic radiograph. **B,** Surgical guide in place to determine amount of bone reduction. **C,** Implant site preparation using the surgical guide. **D** and **E,** Acrylic resin framework in place before implant placement to verify implant positions. **F,** Abutments screwed onto implants. **G,** Acrylic resin framework with waxing sleeves. **H,** Acrylic resin framework-waxing sleeves-gingival clearance record complex. **I,** Metal framework try-in. **J,** Intraoral view of maxillary immediate complete and mandibular metal-resin complete dental prosthesis. **K,** Postoperative panoramic radiograph.

Cement-Retained Versus Screw-Retained Implant Crowns

Cemented implant crowns can be luted to a screw-retained abutment. Zinc phosphate, glass ionomer, and composite resin cements have all been suggested for this purpose. However, retrievability of the implant restoration is ordinarily not considered when a permanent cement is used. The interim cements have been recommended because they allow restoration retrieval. Because the interim luting agents are unpredictable, however, retrieval may be difficult or premature displacement may result.[33]

Simplicity and, in some systems, economy are the major advantages of cement-retained restorations. In addition, cementing allows minor angle corrections to compensate for discrepancies between the implant inclination and the facial crown contour (Fig. 13-56). Resistance to rotation is particularly crucial with cemented prosthetics, and the abutment should then incorporate an antirotational feature. Very small teeth are most easily replaced with cement-retained implant crowns.

Two misconceptions about cement-retained crowns are that their restoration is simpler and that they have fewer screw-loosening episodes. They actually may require more chair time and have the same propensity for loosening as does a directly screw-retained restoration. They are, however, more esthetically pleasing and less expensive.

The screw-retained implant crown is fastened either to the abutment or directly to the implant. The main advantage of this restoration is its retrievability. Retrievability allows for crown removal, which can facilitate soft

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FIGURE 13-56 ■ **A,** Implant in facially inclined position to replace the maxillary right central incisor. **B,** A laboratory cast demonstrates facial angulation of the implant. An angled abutment **(C)** improves the esthetic restoration **(D).** A cement-retained restoration would be necessary to avoid a hole through the facial surface.

tissue evaluation, calculus débridement, and any other necessary modifications. In addition, future treatment considerations can be made more easily and are less costly if the implant restoration is retrievable. In screw-retained restorations, however, the access hole must be through the occlusal table of posterior teeth or the lingual surface of anterior teeth. Forces can then be directed in the long axis of the implant, and an optimum esthetic outcome is more easily achieved. This requirement dictates an ideal surgical location, which is not always possible because of anatomic limitations. A possible disadvantage of a screw-retained implant restoration is that the screw may loosen during function. Many techniques for retaining screw connection have been reported.[34] The direct mechanical interlock or antirotational feature appears to be the most effective.

If the screw is sufficiently tightened into the implant crown to seat it, a clamping load or preload is developed between the implant and the crown (Fig. 13-57). If this clamping force is greater than the forces trying to separate the joint between implant and crown, the screw will not loosen. A restoration screw should be tightened with sufficient force to seat the crown but not so much as to affect the bone-implant interface. Torque wrenches are available to achieve such tightening. In addition, lateral forces (which tend to separate the joint) should be eliminated or reduced (Fig. 13-58; Box 13-4).

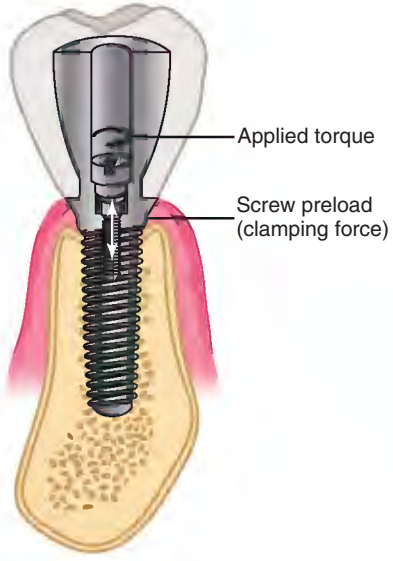

FIGURE 13-57 ■ Torque on the screw develops a preload (clamping force) between the implant and the crown.

BOX 13-4 Loose Restoration-Retaining Screws

Check for the following errors:
1. Excessive occlusal contacts not in the long axis of the implant body
2. Excessive cantilever contacts
3. Excessive lateral contacts
4. Excessive interproximal contacts
5. Inadequately tightened screws

BIOMECHANICAL FACTORS AFFECTING LONG-TERM IMPLANT SUCCESS

Occlusion

Bone resorption around dental implants can be caused by premature loading or repeated overloading. Vertical or

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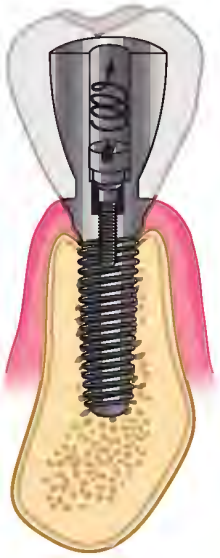

FIGURE 13-58 ■ The screw will loosen only if the joint-separating force is greater than the clamping force.

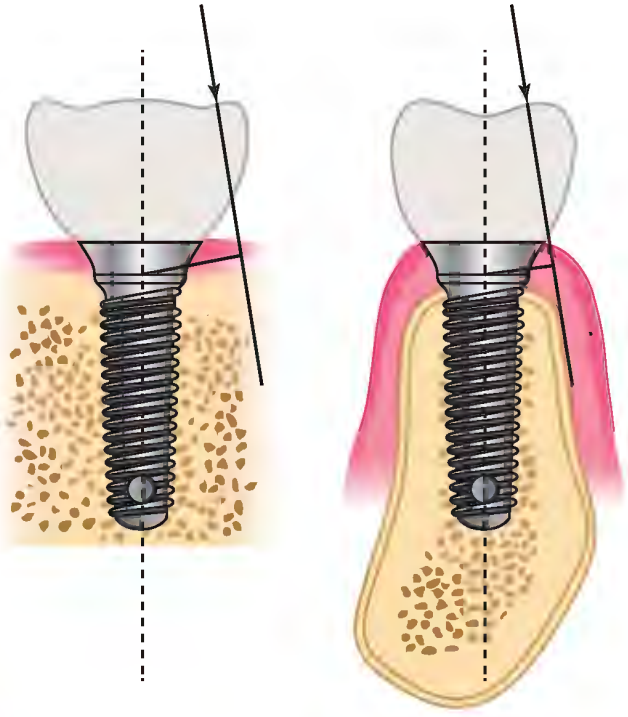

FIGURE 13-59 ■ Sharper cusp inclines and wider occlusal tables increase the resultant force on implant components.

BOX 13-5 Occlusion on Implant-Supported Dental Prostheses

1. Direct forces in the long axis of the implant body.
2. Minimize lateral forces on the implant.
3. Place lateral forces when necessary as far anterior in the arch as possible.
4. When it is impossible to minimize or move lateral forces anteriorly, distribute them over as many teeth and implants as possible.

angular bone loss is usually characteristic of bone resorption caused by occlusal trauma (Box 13-5). When pressure from traumatic occlusion is concentrated, bone resorption occurs by osteoclastic activity. In the natural dentition, bone remodeling typically occurs once the severe stress concentration is reduced or eliminated. In the osseous integrated implant system, however, after bone resorbs, it usually does not re-form. Because dental implants most effectively resist forces directed primarily in their long axis, lateral forces on implants should be minimized.

Lateral forces in the posterior part of the mouth are greater and more destructive than lateral forces in the anterior part of the mouth. When they cannot be completely eliminated from the implant prosthesis, they should be distributed equally over as many teeth as possible.

Implant restorations should be designed to minimize damaging forces at the implant-bone interface, with particular attention to the occlusion.[35] Flatter inclines can be developed on implant-supported cusps, which would create more vertical resultant forces and a shorter moment arm (Fig. 13-59). Whenever possible, a cusp-fossa relationship should be established in maximum intercuspation with no eccentric occlusal contacts (see Chapter 18).

The maxillary single-tooth restoration is vulnerable to screw loosening as a result of occlusal contacts, which usually produce an inclined resultant force with increased torque on the retaining screw. Optimum implant orientation effectively reduces these forces.

In general, the location and inclination of force should be seriously considered in the restorative phase of implant treatment. Divergent implant placement increases the moment arm through which force is transmitted to the bone-implant interface; bone resorption could therefore be inevitable. Interchangeable components to alter implant angles have been produced by implant body manufacturers. However, it has been shown[36] that increasing abutment angles also produces increased stresses at the bone-implant interface. Angled abutments may solve immediate esthetic or contour problems while masking potential long-term consequences created by an implant placement that is poorly planned or dictated by the patient's anatomy.

Inadequate implant distribution may also lead to excessive cantilevers or forces that could potentiate overloading of implant bodies. Whenever possible, dental implants should be joined so that forces may be more equally distributed over multiple implants. Ideally, one implant should be placed for every tooth to be restored. This number is particularly important when shorter implants are placed in bone of poorer quality. When implants longer than 13 mm can be placed in dense bone, two implants for every three teeth being replaced are acceptable. Currently, complete arch restorations are not usually considered for fewer than four implants in the maxilla or mandible. Implant cantilevers should be kept as short as possible. However, cantilevering considerable

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distances off five well-integrated fixtures in the anterior part of the mandible is possible. Cantilevering to the first molar is often possible. Equations based on the distribution and length of fixtures have been proposed.[37]

Connecting Implants to Natural Teeth

It has been suggested[38] that connecting a single osseous integrated implant to one natural tooth with a fixed dental prosthesis can create excessive forces because of the relative immobility of the osseous integrated implant in comparison with the functional mobility of a natural tooth. During function, the tooth moves within the limits of its periodontal ligament, which can create stress at the neck of the implant up to two times the implied load on the prosthesis (Fig. 13-60). Potential problems with this type of restoration include (1) breakdown of the osseous integration, (2) cement failure on the natural abutment, (3) screw or abutment loosening, and (4) failure of the implant prosthetic component. This situation is encountered clinically when the most posterior abutment is lost in the dental arch and a fixed prosthesis is needed to connect a single implant to the natural tooth. If possible, a totally implant-supported fixed dental prosthesis with two or more implants should be provided. However, anatomic limitations of the maxillary sinus or the mandibular canal often limit restorative efforts directed at a single fixture site.

When connecting an implant to a natural tooth is necessary, multiple implant or natural tooth abutments should be used. A semiprecision attachment (keyway) in the prosthesis between the implant and the natural tooth may solve potential problems[38] (Fig. 13-61). In most circumstances, however, when a load is applied to the pontic, the additional movement at the attachment actually increases the cantilever effect on the implant abutment. In practice, the only advantage of a semiprecision attachment may be that it allows a screw-retained implant abutment crown to be removed for periodic evaluation.

When circumstances dictate use of a natural tooth abutment, a telescopic coping should be considered. This is permanently cemented to the natural tooth and can prevent decay if loosening occurs. Interim cement is used to attach the prosthesis to the coping. If it leaches out of the implant crown, the natural tooth is still protected (Fig. 13-62).

Implant and Framework Fit

Pathogenic forces can be placed on an implant if the framework does not fit passively. When all the prosthesis-retaining screws are tightened, gaps between the abutment and a poorly fitting framework close, giving the appearance of an acceptable fit. However, significant compressive forces are placed on the interfacial bone, which can lead to implant failure. The fit of all implant frameworks should be checked with only one screw in place. No amounts of space or any amounts of movement with finger pressure should be discernible on any of the other implant abutments (Fig. 13-63). If a framework does not fit passively, it should be sectioned and soldered and then reassessed for passive fit.

CAD/CAM Abutments and Frameworks

Advances in technology have made it possible to design virtual abutments and frameworks with nearly unlimited design options. By scanning the dental cast of the interim abutment (Fig. 13-64), some manufacturers can fabricate final ceramic or titanium abutments of any shape or angle with computer-assisted design/computer-assisted machining (CAD/CAM) technology. Interimplant titanium frameworks fabricated with this technology have been reported to fit more accurately and passively than those fabricated with standard casting techniques. Intraoral scanners and scannable abutments enable CAD/CAM fabrication of custom abutments and implant restorations without the use of impression materials (see Fig. 13-64).[39]

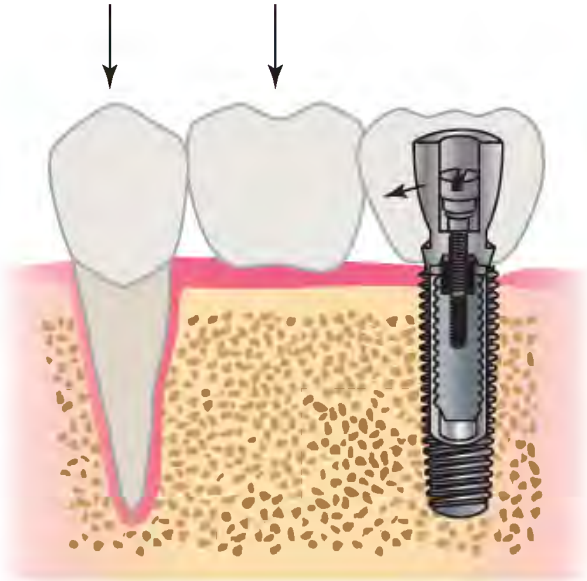

FIGURE 13-60 ■ When a single implant is attached to a natural tooth, biting forces on the natural tooth and pontic cause stress to be concentrated at the superior portion of the implant.

FIGURE 13-61 ■ A semiprecision attachment may compensate for vertical displacement forces in the tooth and an implant-supported fixed prosthesis. It does not compensate for forces in the buccolingual direction. (Courtesy Dr. G. Seal.)

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FIGURE 13-62 ■ **A,** Maxillary abutments positioned to support a fixed prosthesis. **B,** Metal evaluation of maxillary rehabilitation with implant-supported abutments and telescopic copings.

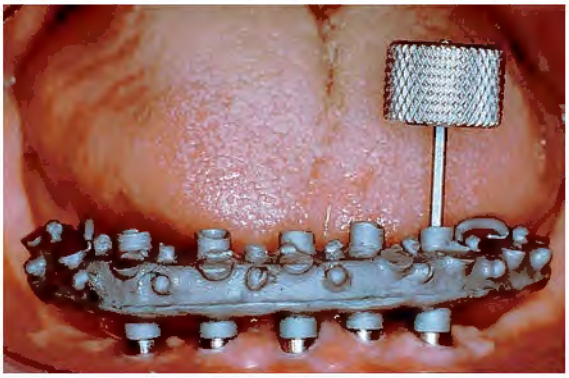

FIGURE 13-63 ■ Metal framework fit should be evaluated with only a single retaining screw tightened in place. Any detectable incomplete seating necessitates framework correction.

MAINTENANCE

The goal of implant maintenance is to eradicate microbes that affect the prosthesis. Although dental implants may be more resistant than natural teeth to the effects of bacterial plaque, this has yet to be definitively proved. Until more research results are available, proper and timely home care measures for prolonging the lifetime of an implant are most effective. The clinician must ensure that the patient receives thorough instruction in maintenance techniques, including an initial session with the clinician. This should be reinforced by a training session with the dental hygienist during a recall visit. Recall visits should be scheduled at least every 3 months during the first year. The patient's oral hygiene should be evaluated and documented at a recall visit; reinstruction should be provided when necessary. Sulcular débridement must be performed with plastic or wooden scalers because conventional instruments scratch the titanium. Implant abutments may be polished by rubber cups with a low-abrasive polishing paste or tin oxide.

At each recall appointment, implant mobility should be evaluated; any bleeding after probing should be examined. Framework fit and occlusion also must be checked. Attention to both biologic and biomechanical factors is important for the long-term success of dental implants.

COMPLICATIONS

Bone Loss

The primary complication with dental implant therapy is bone loss around the implant (Fig. 13-65). Any loss exceeding 0.2 mm per year is cause for concern. Multiple factors are associated with implant bone loss:

- Inappropriate size and shape of the implant
- Inadequate number of implants or inadequate implant positioning
- Poor quality or inadequate amount of available bone
- Initial instability of the implant
- Compromised healing phase
- Inadequate fit of the prosthesis
- Improper design of the prosthesis (e.g., excessive cantilever, poor access for hygiene)
- Excessive occlusal forces
- Deficient fit of abutment components (e.g., gaps that allow bacterial colonization)
- Inadequate oral hygiene
- Systemic influence (e.g., tobacco use, diabetes)

The restorative dentist should pay particular attention to the fit of the prosthesis, the access for hygiene, and the presence of excessive occlusal forces. If bone loss reaches 25% to 30%, revision surgery should be considered.

Prosthetic Failure

Additional implant prosthetic complications include fracture of the implant components or of the prosthesis. Fracture of implant components is usually attributed to fatigue from biomechanical overload. Some instruments are available for removal of broken prosthetic/abutment screw fragments (Fig. 13-66).[40]

Failure of the implant prosthesis is usually traceable to suboptimal laboratory procedures or prosthesis design (Figs. 13-67 and 13-68).

SUMMARY

Implant-supported prostheses, involving cylindrical osseous integrated fixtures placed in a two-stage surgical

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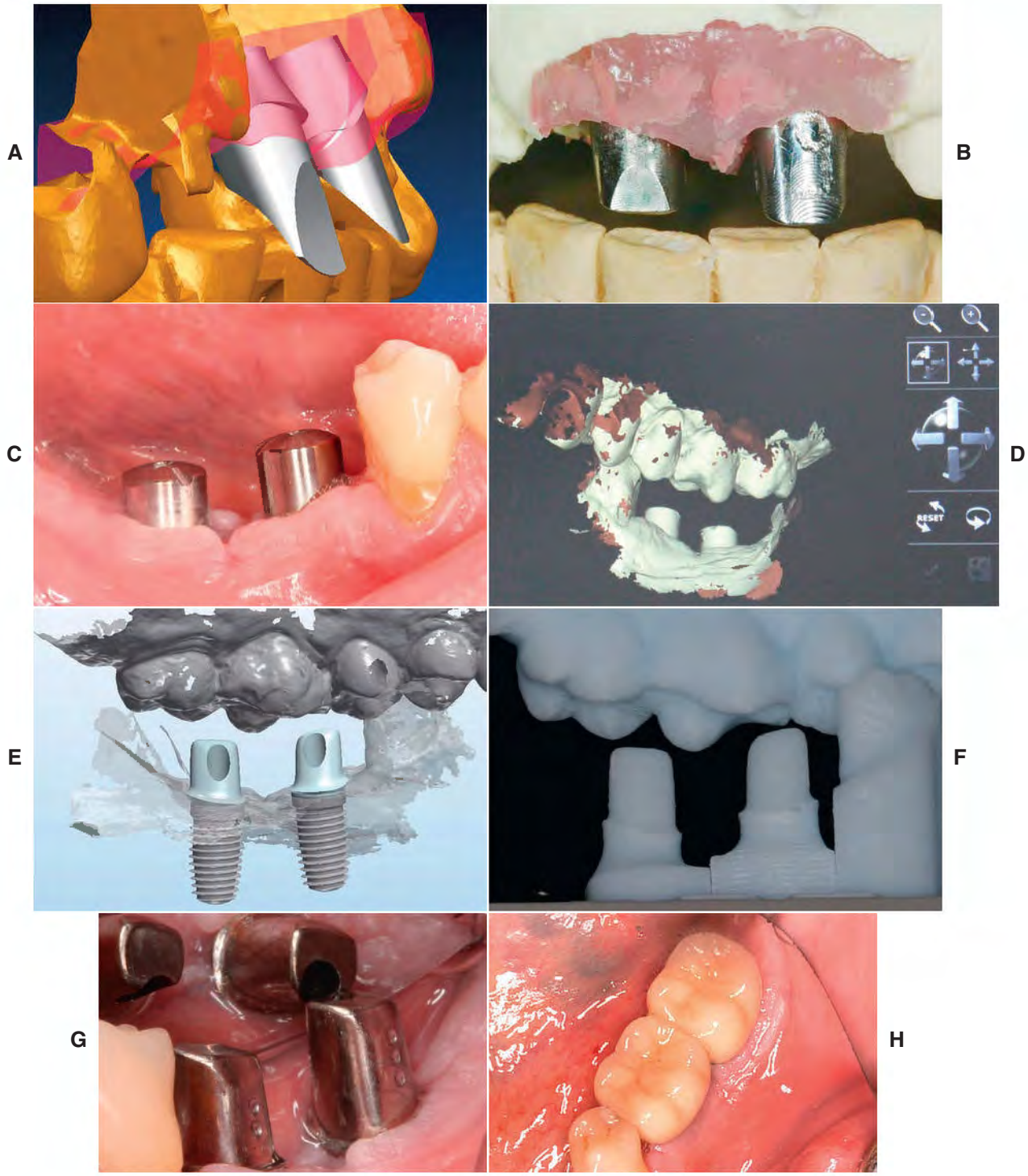

FIGURE 13-64 ■ **A,** Virtual implant-supported abutments designed on the computer screen. **B,** Titanium abutments fabricated through the use of computer-assisted design/computer-assisted machining (CAD/CAM) technology. **C,** Intraoral scannable abutments. **D,** Intraoral scan file. **E,** Virtually designed abutments. **F,** Stereolithographic models of abutments. **G,** CAD/CAM-fabricated custom titanium abutments. **H,** Metal-ceramic crowns.

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technique, should be considered in the treatment of any partially edentulous patient. They are a reliable solution to many situations that are difficult to treat by conventional measures: patients who cannot wear removable appliances, patients with a long edentulous span or other circumstances (e.g., short roots) that diminish the prognosis for a fixed dental prosthesis, and patients with a single missing tooth but sound adjacent teeth.

Success with implant prosthodontic treatment requires the same attention to detail and careful planning as does conventional fixed prosthodontic treatment. Often a team approach is recommended, in which a surgeon places the implant and a restorative dentist designs the prosthesis. The crucial stage is optimum placement of the implant or implants. The surgeon's main concern is that

FIGURE 13-67 ■ Porcelain fracture on an implant prosthesis with inadequate metal support.

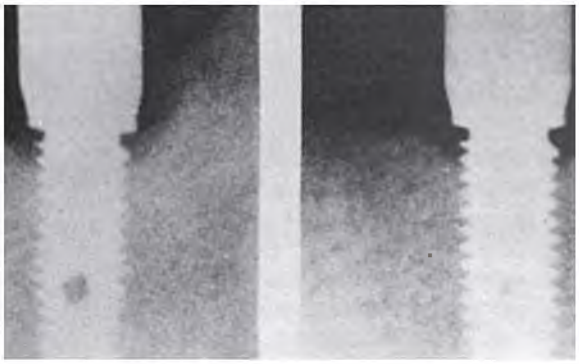

FIGURE 13-65 ■ To monitor implant bone loss, radiographs should be obtained once a year. **A,** At the time of post placement. **B,** At the 1-year follow-up visit.

FIGURE 13-68 ■ Cantilever fracture on a metal-resin prosthesis. The prosthesis can be retrieved easily for a laser-welded repair.

FIGURE 13-66 ■ **A** to **C**, Fractured abutment and retaining screws on a metal-resin implant-supported prosthesis. **D** to **F,** Screw removal tool used to remove screw fragments *(arrow)*.

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it be well within the available bone and away from vital structures (e.g., the inferior dental canal). The restorative dentist's main concern is that the positioning and angulation of each fixture allow optimum occlusion, esthetics, and tissue health, as well as minimum stresses at the implant-bone interface. A clinical examination, radiographs, and a diagnostic waxing on articulated casts supply information crucial for planning. Surgery is guided by a template made from the diagnostic waxing.

Depending on the implant site, 3 to 6 months are required for bone to heal against the implant after two-stage surgery. In a second surgical procedure, the implant is uncovered, and implant abutments are screwed into place. Subsequently, a screw-retained prosthesis is fabricated to restore function and appearance.

Several implant systems are available, each with a variety of components for restorative management (e.g., an antirotational feature incorporated in an implant for single tooth replacement).

Problems unique to implant prosthodontic treatment include screw loosening and bone loss from premature loading or repeated overloading. Occlusal considerations, prosthesis fit, plaque control, and follow-up care are all primary concerns to the professionals who provide implants and conventionally supported prostheses.

REFERENCES

1. National Institutes of Health Consensus Development Conference statement on dental implants June 13-15, 1988. J Dent Educ 52:824, 1988.
2. Adell R, et al: A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 10:387, 1981.
3. Kent J, et al: Biointegrated hydroxlapatite-coated dental implants: 5-year clinical observations. J Am Dent Assoc 121:138, 1990.
4. Lazzara RJ, et al: A prospective multicenter study evaluating loading of osseotite implants two months after placement: one-year results. J Esthet Dent 10:280, 1998.
5. Buser D, et al: Removal torque values of titanium implants in the maxillofacial of miniature pigs. Int J Oral Maxillofac Implant 13:611, 1998.
6. Smithloff M, Fritz ME: Use of blade implants in a selected population of partially edentulous patients. J Periodontol 53:413, 1982.
7. Kapur KK: VA cooperative dental implant study: comparisons between fixed partial dentures supported by blade-vent implants and removable partial dentures. II. Comparisons of success rates and periodontal health between two treatment modalities. J Prosthet Dent 62:685, 1989.
8. Smith D, Zarb GA: Criteria for success for osseointegrated endosseous implants. J Prosthet Dent 62:567, 1989.
9. Tarnow D, et al: Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. J Periodontol 74:1785, 2003.
10. Elian N, et al: Realities and limitations in the management of the interdental papilla between implants: three case reports. Pract Proced Aesthet Dent 15:737, 2003.
11. McGlumphy EA, Larsen PE: Contemporary implant dentistry. In Peterson LJ, et al, eds: Contemporary oral and maxillofacial surgery, 4th ed, p 305. St. Louis, Mosby, 2003.
12. Hobo S, et al, eds: Osseointegration and occlusal rehabilitation. Tokyo, Quintessence Publishing, 1990.
13. Stewart RB, Staab GH: Cross-sectional design and fatigue durability of cantilevered sections of fixed implant-supported prostheses. J Prosthodont 4(3):188, 1995.
14. Agliardi E, et al: Immediate rehabilitation of the edentulous maxilla: preliminary results of a single cohort prospective study. Int J Oral Maxillofac Implants 24:887, 2009.
15. Aparicio C, et al: Tilted implants as an alternative to maxillary sinus grafting: a clinical, radiologic, and periotest study. Clin Implant Dent Relat Res 3:39, 2001.
16. Calandriello R, Tomatis M: Simplified treatment of the atrophic posterior maxilla via immediate/early function and tilted implants: a prospective 1-year clinical study. Clin Implant Dent Relat Res 7:1, 2005.
17. Capelli M, et al: Immediate rehabilitation of the completely edentulous jaws with fixed prostheses supported by upright and tilted implants. A multicenter clinical study. Int J Oral Maxillofac Implants 22:639, 2007.
18. Fortin Y, et al: The Marius implant bridge: surgical and prosthetic rehabilitation for the completely edentulous upper jaw with moderate to severe resorption: a 5-year retrospective clinical study. Clin Implant Dent Relat Res 4:69, 2002.
19. Malo P, et al: "All-on-four" immediate-function concept with Brånemark System implants for completely edentulous mandibles: a retrospective clinical study. Clin Implant Dent Relat Res 5(Suppl. 1):2, 2003.
20. Malo P, et al: All-on-4 immediate-function concept with Brånemark System implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res 7(Suppl. 1):S88, 2005.
21. Esposito M, et al: Interventions for replacing missing teeth: different times for loading dental implants. Cochrane Database Syst Rev (1):CD003878, 2009.
22. Zampelis A, et al: Tilting of splinted implants for improved prosthodontic support: a two-dimensional finite element analysis. J Prosthet Dent 97:35, 2007.
23. Bevilacqua M, et al: The influence of cantilever length and implant inclination on stress distribution in maxillary implant-supported fixed dentures. J Prosthet Dent 105:5, 2011.
24. Kim KS, et al: Biomechanical comparison of axial and tilted implants for mandibular full-arch fixed prostheses. Int J Oral Maxillofac Implants 26:976, 2011.
25. Fazi G, et al: Three-dimensional finite element analysis of different implant configurations for a mandibular fixed prosthesis. Int J Oral Maxillofac Implants 26:752, 2011.
26. Chiapasco M, Gatti C: Implant-retained mandibular overdentures with immediate loading: a 3- to 8-year prospective study on 328 implants. Clin Implant Dent Relat Res 5(1):29, 2003.
27. Degidi M, Piattelli A: 7-year follow-up of 93 immediately loaded titanium dental implants. J Oral Implantol 31(1):25, 2005.
28. Balshi SF, et al: A prospective study of immediate functional loading, following the Teeth in a Day protocol: a case series of 55 consecutive edentulous maxillas. Clin Implant Dent Relat Res 7(1):24, 2005.
29. Yilmaz B, et al: Correction of misfit in a maxillary immediate metal-resin implant-fixed complete prosthesis placed with flapless surgery on four implants. Int J Oral Maxillofac Implants 26(5):e23, 2011.
30. Rocci A, et al: Immediate loading of Brånemark System TiUnite and machined-surface implants in the posterior mandible: a randomized open-ended clinical trial. Clin Implant Dent Relat Res 5(Suppl 1):57, 2003.
31. Malo P, et al: The use of computer-guided flapless implant surgery and four implants placed in immediate function to support a fixed denture: preliminary results after a mean follow-up period of thirteen months. J Prosthet Dent 97(6 Suppl):S26, 2007.
32. Yilmaz B, et al: A technique to deliver immediate metal-resin implant-fixed complete dental prosthesis using "Final-on-Four" concept. J Prosthet Dent. In press.
33. Chiche GI, Pinault A: Considerations for fabrication of implant-supported posterior restorations. Int J Prosthod 4:37, 1991.
34. Hurson S: Laboratory techniques to prevent screw loosening on dental implants. J Dent Technol 13(3):30, 1996.
35. Weinberg LA: The biomechanics of force distribution in implant-supported prostheses. Int J Oral Maxillofac Implants 8:19, 1993.
36. Clelland N, Gilat A: The effect of abutment angulation on the stress transfer for an implant. J Prosthod 1:24, 1992.
37. Takayama H: Biomechanical considerations on osseointegrated implants. In Hobo S, et al, eds: Osseointegrated and occlusal rehabilitation, p 265. Tokyo, Quintessence Publishing, 1990.
38. Sullivan D: Prosthetic considerations for the utilization of osseointegrated fixtures in the partially edentulous arch. Int J Oral Maxillofac Implants 1:39, 1986.
39. Nayyar N, Yilmaz B, McGlumphy E: Using digitally coded healing abutments and an intraoral scanner to fabricate implant-supported, cement-retained restorations. J Prosthet Dent 109(4):210, 2013.
40. Yilmaz B, McGlumphy E: A technique to retrieve fractured implant screws. J Prosthet Dent 105(2):137, 2011.

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STUDY QUESTIONS

1. Discuss the history of and the scientific basis for osseous integration.

2. Discuss the indications and contraindications for implant-supported fixed dental prostheses.

3. For planning treatment with the replacement of a congenitally missing lateral incisor by an implant restoration, describe the necessary minimum bone dimensions vertically, horizontally, and between roots. Also describe the guidelines used to position the implant in the appropriate anteroposterior and superoinferior location.

4. Describe the technique used to replicate the intraoral location of an implant on the laboratory cast.

5. List and describe the various types of abutments used for implant restorations. When is each type recommended? Why?

6. Describe some common problems with implant restorations, and recommend methods to manage them.

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CHAPTER 14

Tissue Management and Impression Making

Because it is neither possible nor desirable to make patterns for fixed prostheses directly in the mouth, an impression, or a negative likeness of the teeth and surrounding structures, provides the necessary information and detail needed to fabricate a restoration. This likeness can be obtained on a solid cast, a three-dimensional replica of the prepared tooth that is fabricated from high-quality dental stone. This cast is then used to make a restoration in the laboratory. Alternatively, after an optical impression (or "capture") of the tooth preparation, the adjacent teeth, and the antagonists, a virtual cast can be generated with special software, which can be manipulated through all phases needed to fabricate a restoration. Both systems have specific advantages and limitations. To obtain a cast made from improved stone, a suitable impression material is mixed and loaded in a tray that is inserted into the patient's mouth. When the material has set as a "negative" impression, it retains sufficient elasticity to be removable; after verification that all necessary information was captured, dental stone is then poured into the impression, and a positive likeness, or definitive cast, is obtained.

To generate a virtual cast, special equipment is needed: a three-dimensional optical scanner that collects distance information for every pixel with the purpose to create a "point cloud." Special measures are needed to ensure uniform surface reflection of a high-intensity light source, and special sensors and software compute a three-dimensional virtual model of the preparation and its surroundings. A single scan is insufficient; multiple scans from many different angles are necessary. This information can then be used to generate a solid cast similar to the stone cast described previously, or the resulting virtual cast can be used in a number of different ways to design a data file that can be used to fabricate the desired restoration (see Chapters 17 and 25).

Regardless of the system used, an acceptable impression must accurately capture all aspects of the prepared tooth. This means it must include sufficient unprepared tooth structure immediately adjacent to the margins so that the dentist and laboratory technician can identify the contour of the tooth and all prepared surfaces. The contour of the unprepared tooth structure cervical to the preparation margin is crucial information that must be available when the restoration is fabricated in the dental laboratory. If the impression does not reproduce this critical area where tooth and future restoration meet, fabricating the restoration with proper contours is not possible (barring some lucky guesswork).

All teeth in the arch and the soft tissues immediately surrounding the tooth preparation must also be reproduced in the impression. They allow the cast to be precisely articulated and contribute to proper contouring of the planned restoration. Particular attention is given to reproducing the lingual surfaces of anterior teeth because they influence anterior guidance, which affects the occlusal form of the posterior teeth (see Chapter 4). Elastic impressions must be free of air bubbles, tears, thin spots, and other imperfections that might produce inaccuracies in subsequent steps. Likewise, optical impressions must be free of artifacts, lest inaccuracies result.

The patient's mouth is a challenging environment in which to make an accurate impression. For either approach to impression making, moisture control is probably one of the most important prerequisites for success. Except for the polyethers, all elastomeric impression materials are hydrophobic[1] (i.e., they do not tolerate or displace moisture). Any moisture results in voids. Consequently, saliva flow into the area must be reduced and diverted to obtain the necessary dry field of operation. Any bleeding must also be controlled in order to obtain a successful impression. Similarly, because dentin and enamel do not reflect light in an identical manner, many optical systems require that the teeth are covered with a thin coating that reflects light more uniformly. These must be applied to dry tissues.

When tooth preparation margins extend subgingivally, as is common on many posterior crown preparations, the adjacent gingival tissues must be displaced laterally to allow visual and physical access and to provide space for adequate impression material thickness. This may require enlarging the gingival sulcus through mechanical, chemical, or surgical means and must not jeopardize periodontal health. Poor tissue displacement technique can lead to permanent soft tissue damage.

PREREQUISITES

Tissue Health

After the teeth are prepared and an interim restoration has been made (see Chapter 15), the health of the surrounding soft tissues is reevaluated. Careful preparation results in minimal tissue damage; however, if a subgingival margin is needed, some tissue trauma in the sulcular area may be unavoidable. The effects of this trauma can be transient as long as the patient receives a properly made interim restoration and maintains adequate oral hygiene. However, if the interim restoration is poorly contoured, is not polished, or has defective margins, plaque retention will lead to a localized inflammatory response. The combination of such tissue trauma in the presence of preexisting periodontal disease can produce

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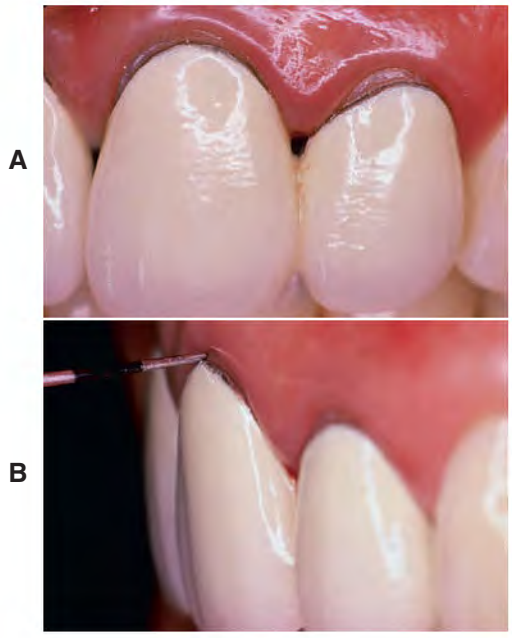

FIGURE 14-1 ■ Compromised embrasure form **(A)** and excessive contours **(B)** have contributed to the inflammatory response and recession of the gingival tissue.

disastrous results. Periodontal disease must be treated and resolved before fixed prosthodontic treatment is initiated.

On occasion, a defective restoration contributes to greater plaque accumulation[2] and an inflammatory sulcular response (Fig. 14-1). If this is the case, a properly adapted and well-contoured polished interim restoration must be fabricated and cemented on the prepared teeth; the focus must then shift from the teeth to the soft tissues, which must be returned to a state of optimum health before impression making is even considered.

Saliva Control

Tissue displacement techniques are rendered useless unless a dry field is achieved and maintained. Depending on the location of the preparations in the dental arch, a number of techniques can create the necessary dry field of operation (Fig. 14-2). When all margins are supragingival, moisture control with a rubber dam is probably the most effective method. In most instances, however, a rubber dam cannot be used, and absorbent cotton rolls must be placed at the source of the saliva: the mucobuccal fold or in the sublingual area. A saliva ejector must be placed where the saliva pools. In the maxillary arch, placing a single cotton roll in the vestibule immediately buccal to the preparation and a saliva evacuator in the opposing lingual sulcus is usually sufficient. When work is being done on a maxillary second or third molar, multiple cotton rolls must sometimes be placed immediately buccal to the preparation and slightly anterior to block off the parotid duct, which opens just anterior to the maxillary first molar. If a maxillary roll does not stay in position but slips down, it can be retained with a finger or the mouth mirror. When a mandibular impression is made, placement of additional cotton rolls to block off the sublingual and submandibular salivary ducts is usually necessary. Cotton rolls on the buccal and lingual sides of the prepared teeth help maintain moisture control, which is prerequisite to successful soft tissue displacement: The cotton roll on the buccal side displaces the cheek laterally, and the one on the lingual side displaces the tongue medially. One or two cotton rolls placed vertically between the horizontally placed cotton rolls in the buccal vestibules help maintain the latter in position.

An alternative to multiple cotton rolls is placement of one long roll in a horseshoe shape in the maxillary and mandibular mucobuccal folds. However, when part of the cotton is saturated, the entire roll must be replaced. The use of moisture-absorbing cards (see Fig. 14-2, *D*) is another method for controlling saliva flow. These cards are pressed-paper wafers that may be covered with a reflective foil on one side. The paper side is placed against the dried buccal tissue and adheres to it. In addition, two cotton rolls should be placed in the maxillary and mandibular vestibules to control saliva and displace the cheek laterally.

The tongue can cause problems when work is being done in the mandibular arch. Saliva evacuators may help eliminate excess flow, but most of these are easily displaced by a "probing" tongue. If lingually placed cotton rolls repeatedly become dislodged (or in conjunction with a conventional saliva evacuator, fail to control moisture adequately), a flange-type evacuator (e.g., the Svedopter [E. C. Moore Company] or the Speejector [Pulpdent Corporation]) should be considered (see Fig. 14-2, *B* and *C*). To avoid the risk of soft tissue trauma, this device must be placed carefully. A cotton roll between the blade and the mylohyoid ridge of the alveolar process minimizes intraoral discomfort for the patient and avoids potential injury of the soft tissues over the mylohyoid ridge from the spring that holds the flanges in place. Simultaneously, if properly positioned, the cotton roll prevents the flange from being displaced farther buccally and thereby allows excellent lingual access to mandibular posterior teeth. Care must be taken not to tighten the chin clamp excessively because considerable discomfort can result from pressure to the floor of the mouth. A disposable saliva ejector designed to displace the tongue may also be effective (see Fig. 14-2, *F*). As an alternative to the rubber dam and cotton rolls a dental isolation device, such as Isolite (see Fig. 14-2, *E*), may be used to achieve the desired oral control of moisture, humidity, and retraction.

In addition to the pain control normally needed during tissue displacement, local anesthesia may help considerably with saliva control during impression making. Nerve impulses from the periodontal ligament form part of the mechanism that regulates saliva flow; when these are blocked by the anesthetic, saliva production is considerably reduced.

When saliva control is especially difficult, a medication with antisialagogic action may be considered (Table 14-1). Dry mouth is a side effect of certain anticholinergics[3,4] (drugs that inhibit parasympathetic innervation and thereby reduce secretions, including saliva). This group of drugs includes atropine, dicyclomine, and propantheline. Anticholinergics should be prescribed with caution in older adults and should not be administered to any patient with heart disease. They are also contraindicated in individuals with glaucoma because

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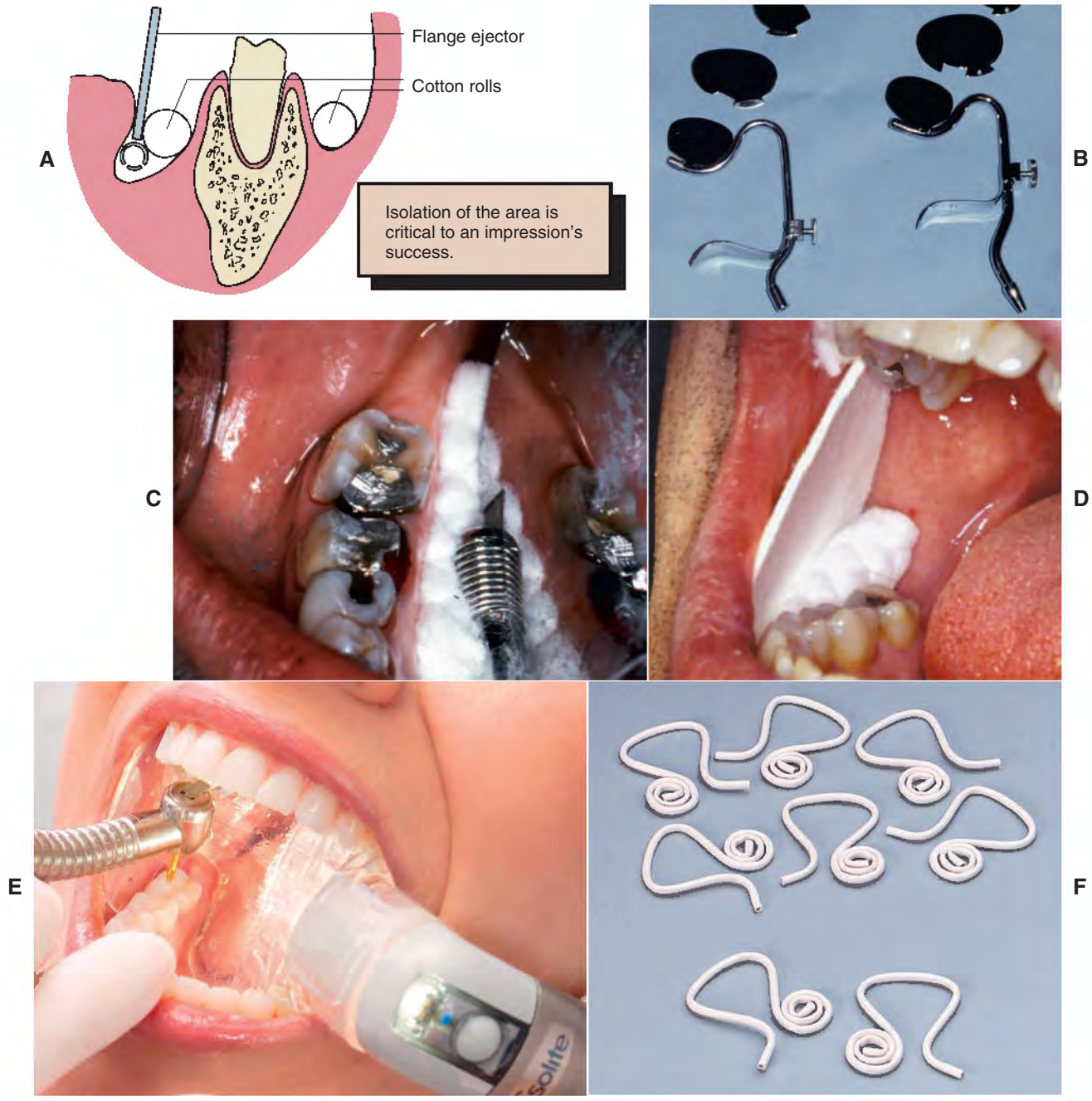

FIGURE 14-2 ■ Saliva control for impression making. **A,** When correctly placed, maxillary cotton rolls block salivary flow from the parotid gland. The evacuator removes saliva from the floor of the mouth, keeping the prepared tooth dry while the flange displaces the tongue medially. **B,** Svedopter *(left)* and Speejector *(right)* saliva evacuators. **C,** Svedopter in place with cotton rolls. **D,** An absorbent card. **E,** Isolite illuminated dental isolation system. **F,** The disposable Hygoformic aspirator system. (**E,** Courtesy Isolite Systems, Santa Barbara, California. **F,** Courtesy Sullivan-Schein Dental, West Allis, Wisconsin.)

they can cause permanent blindness. The incidence of undiagnosed glaucoma in the general population is high, and some physicians recommend that all patients be evaluated ophthalmologically before anticholinergics are used.

Clonidine,[5] an antihypertensive drug, has successfully reduced salivary output. It is considered safer than anticholinergics and has no specified contraindications. However, it should be used cautiously in patients who take hypertension medication. In a clinical trial,[6] 0.2 mg of clonidine reduced salivary flow as effectively as 50 mg of methantheline.

Displacement of Gingival Tissues

Tissue displacement is commonly needed to obtain adequate access to the prepared tooth and to expose all necessary surfaces, both prepared and not prepared. This can be achieved by mechanical, chemical, or surgical means.[7]

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TABLE 14-1 **Medications with Antisialagogic Effect***

Brand Name	Active Ingredient	Dosage
Pro-Banthine	Propantheline bromide	7.5-15 mg
Robinul (Robinul Forte)	Glycopyrrolate	1-2 mg
Bentyl	Dicyclomine HCl	10-20 mg

*Given 30 to 60 minutes before drying effect is required. (Individual dosage should be adjusted in keeping with most recent guidelines.)

FIGURE 14-3 ■ Cord has been placed intrasulcularly as close to the level of the prepared margin as possible to displace tissue laterally.

Mechanical displacement is most effectively achieved by placement of a cord (Fig. 14-3) (generally impregnated with a chemical agent). Alternatively, foam or paste systems can be used, often in conjunction with directed pressure.[8] Chemicals such as aluminum sulfate or epinephrine cause localized soft tissue shrinkage. Surgical tissue removal can be accomplished through curettage, excision with a scalpel, electrosurgery, or laser.

Displacement Cord

If a dry field has been achieved, the sulcus can be enlarged somewhat by placement of a nonimpregnated cord that is left in place for a sufficient length of time. The cord is pushed into the sulcus and mechanically stretches the circumferential periodontal fibers. Placement is often easier if a braided cord (e.g., GingiBraid [Van R Dental Products]) or a knitted cord (e.g., Ultrapak [Ultradent Products]) is used. However, larger sizes of braided cord should be avoided because they have a tendency to double up and can become too thick for atraumatic intrasulcular placement. In areas where extreme narrowness of the sulci precludes placement of the smaller sizes of twisted or braided cord, wool-like cords that can be flattened are preferable for initial displacement of tissue.

Sulci can be enlarged better with a chemically impregnated cord or a cord dipped in an astringent (e.g., Hemodent [Premier Dental Products]).[9] These materials (Fig. 14-4) contain aluminum or iron salts and cause a transient ischemia, shrinking the gingival tissue. Cords with metal filament reinforcement have been developed to help maintain their intrasulcular position.

Even so, on cord removal, the sulcus closes quickly (less than 30 seconds); therefore, the impression must be made immediately.[10] In addition, medicaments help control seepage of gingival fluid. Aluminum chloride ($AlCl_3$) and ferric sulfate ($Fe_2[SO_4]_3$) are suitable because they cause minimal tissue damage. As an alternative, a sympathomimetic amine–containing eye wash (tetrahydrozoline HCl [Visine], 0.05%) or nasal decongestant (oxymetazoline [Afrin], 0.05%) has been shown to be effective.[11]

Many of the chemicals used for their astringent effect are stable only at narrow ranges of low pH levels. Table 14-2 lists the mean pHs of some commonly used materials. The low pH levels have raised concern about the effect of acidic solutions on tooth structure and,

FIGURE 14-4 ■ Hemostatic agents.

perhaps of more importance, on the smear layer.[12,13] Figure 14-5 is a series of scanning electron micrographs of dentin after various durations of exposure to a commonly used $Fe_2(SO_4)_3$ solution. Tissue displacement is time dependent; because several minutes must elapse before adequate displacement has been accomplished, smear layer removal must be assumed in most circumstances. Thus subsequent dentinal tubule sealing may be desirable to minimize the risk of postoperative sensitivity.[14] Several displacement cords preimpregnated with epinephrine are available commercially. Epinephrine should be used with caution because it may cause tachycardia,[15] particularly if it is placed on lacerated tissue. Dosage control is also a potential problem. In one study,[16] clinicians were unable to detect any advantages of using gingival displacement cords that were impregnated with epinephrine.

A 1999 survey revealed that 54% of prosthodontists prefer soaking displacement cord in buffered $AlCl_3$, whereas more than 35% routinely use $Fe_2(SO_4)_3$ or aluminum chloride.[17] The same researchers reported use of a double-cord technique in almost half the clinical situations (Fig. 14-6). In this technique, a thin cord is placed without overlap at the bottom of the gingival crevice. A second cord is placed on top to achieve lateral tissue

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displacement. The latter is removed immediately before impression making, whereas the initial cord is left in place to help minimize seepage.

Step-by-Step Procedure

1. Isolate the prepared teeth with cotton rolls, place saliva evacuators and any other aids as required, and dry the field with air. Do not excessively desiccate the tooth because this may lead to postoperative sensitivity.
2. Cut a length of cord sufficient to encircle the tooth (Fig. 14-7, *A* and *B*).
3. Dip the cord in astringent solution and squeeze out the excess with a gauze square. An impregnated cord can be placed dry but should be slightly moistened in situ immediately before removal from the sulcus, to prevent the thin sulcular epithelium from sticking to it and tearing when it is removed. A convenient way to limit the amount of moisture added is to apply water held between the tips of a dental forceps by opening it.

TABLE 14-2 **Acidity of Commonly Used Hemostatic Agents**

Agent	Manufacturer	Active Ingredient	Vehicle	Mean pH
Astringedent	Ultradent	15.5% $Fe_2(SO_4)_3$	Aqueous	0.7
Gingi-Aid	Gingi-Pak	Buffered 25% $AlCl_3$	Aqueous	1.9
Styptin	Van R	20% $AlCl_3$	Glycol	1.3
Hemodent	Premier	21.3% $AlCl_3$-6-hydrate	Glycol (aqueous)	1.2
Hemogin-L	Van R	$AlCl_3$	Aqueous	0.9
Orostat 8%	Gingi-Pak	8% Racemic epinephrine HCl	Aqueous	2.0
ViscoStat	Ultradent	20% $Fe_2(SO_4)_3$	Aqueous	1.6
Aluminum chloride 25%	USP	25% $AlCl_3$	Aqueous	1.1
Stasis	Gingi-Pak	8% Racemic epinephrine HCl	Aqueous	2.0
For comparison: Ketac Conditioner	3M-ESPE Dental	25% Polyacrylic acid	Aqueous	1.7

$AlCl_3$, Aluminum chloride; *$Fe_2(SO_4)_3$,* ferric sulfate; *HCl,* hydrochloride.

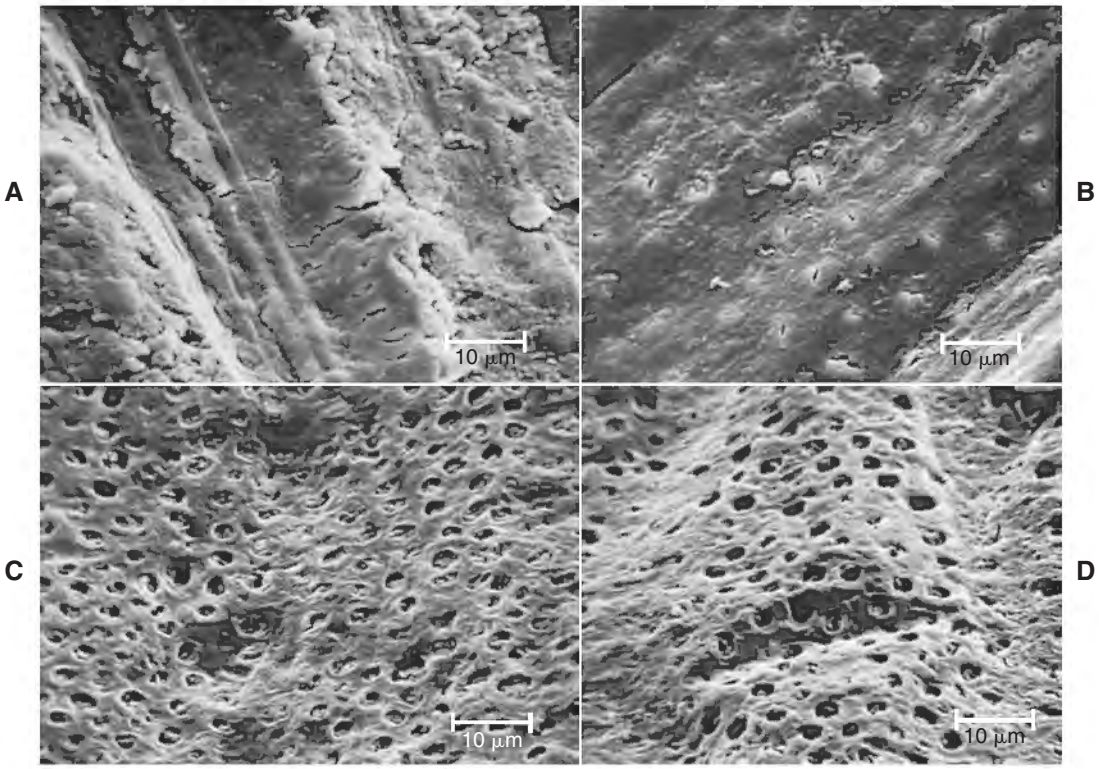

FIGURE 14-5 ■ Disturbance of the dentinal smear layer after contact with hemostatic agents. **A,** Dentin surface prepared with a high-speed, fine-grit diamond. **B,** After exposure to 15.5% ferric sulfate ($Fe_2[SO_4]_3$) solution for 30 seconds. The smear layer is largely removed, but many dentinal tubules are still occluded. **C,** After 2 minutes of exposure. Now the smear layer is totally removed, although the peritubular dentin appears to be largely intact. **D,** After 5 minutes of exposure. Now the dentin is etched, and peritubular dentin has been largely removed. (From Land MF, et al: Disturbance of the dentinal smear layer by acidic hemostatic agents. J Prosthet Dent 72:4, 1994.)

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4. Twist nonbraided cords tightly for easier placement.
5. Loop the cord around the tooth, and gently push it into the sulcus with a suitable instrument (see Fig. 14-7, *C*).

It is often easiest to start interproximally (see Fig. 14-7, *D*), because more sulcular depth is available, than facially or lingually. The instrument should be angled slightly toward the tooth so that the cord is pushed directly into the sulcus. It should also be angled slightly toward any cord previously packed; otherwise, the latter might be displaced. A second instrument holding the cord (see Fig. 14-7, *E*) may aid in subsequent placement.

Tissue must be displaced gently but with sufficient firmness to place the cord just apical to the margin. Overpacking must be avoided because it could cause tearing of the gingival attachment, which leads to irreversible recession. Repeated use of displacement cord in the sulcus also should be avoided because this can cause gingival recession (Fig. 14-8).

Evaluation

Complications in achieving proper tissue displacement are often the result of gingival inflammation. Inflamed and swollen tissues bleed easily, and the resulting moisture prevents proper wetting of the prepared surfaces by the impression material.

Evaluation of initial cord placement after a few minutes is a useful indicator of the amount of lateral displacement

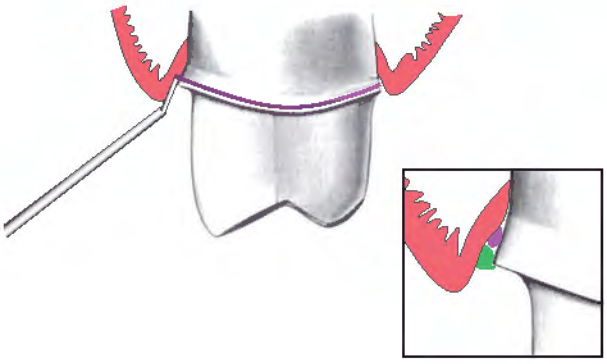

FIGURE 14-6 ■ Dual cord technique. The smaller displacement cord is left in place during impression making, whereas the larger cord at the level of the margin is removed immediately before the impression material is gathered by syringe.

FIGURE 14-8 ■ Excessively aggressive tissue displacement has resulted in gingival recession and trauma. The tissue must be returned to a state of health, and the clinical condition reevaluated, before treatment can proceed. (Courtesy Dr. R.D. Douglas.)

FIGURE 14-7 ■ **A,** Various examples of displacement cord. **B,** Cutting a section of cord of adequate length to surround the tooth. **C,** Most cord-packing instruments have a slightly rounded tip with serrations to hold the cord while it is positioned intrasulcularly. **D,** Initial proximal cord placement. **E,** An additional cord-packing instrument prevents the cord from dislodging. (**D** and **E,** Courtesy Dr. R.D. Douglas.)

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actually accomplished. When evaluating the adequacy of tissue displacement, the clinician should view the tooth preparation from the occlusal aspect: The clinician should be able to see the preparation margin circumferentially and a width of the uninterrupted cord, with no free gingival tissue folded over it or in contact with the tooth. A suitable analogy is a moat around the castle. Visible cord width should rarely exceed half the width of the cord before packing. If there is any doubt, the clinician can assess displacement by removing the cord. The entire preparation margin should be clearly visible and remain directly accessible for between 30 and 60 seconds. If any tissue folds back into contact with the preparation sooner, additional attention must be given to that area because a second cord is inserted immediately after this evaluation. The second placement of displacement cord is usually fairly straightforward because the periodontal fibers have been stretched by the initial displacement effort.

If the result is acceptable, a second cord is typically inserted quickly to maintain the displacement while the impression material is mixed. If the sulcular enlargement is not favorable, the tissue health should be reassessed, particularly if adequate displacement cannot be obtained in repeating the previous steps.

Sometimes use of the double-cord technique is helpful. An initial (thin) cord is trimmed and placed so that its ends do not overlap. A second (thicker) cord is then saturated with astringent, placed in the normal manner, and removed after several minutes. The thin first cord remains during impression making. To be successful, this technique requires that about 1 mm of intact tooth structure remains between the top of the initial cord and the preparation margin. When using this technique, the clinician should be careful not to exert excessive pressure on the tissues, which can damage the epithelial attachment.

Hemorrhage Control with an Infuser Syringe

Step-by-Step Procedure

1. Fill the syringe with $Fe_2(SO_4)_3$ solution (Fig. 14-9, *A*) and attach the infuser tip (see Fig. 14-9, *B*). This hollow metal tip contains a cotton filament to help control flow of the medicament.
2. Rub the tip back and forth for approximately 30 seconds over the hemorrhaging area while slowly replenishing the solution by continuous injection (see Fig. 14-9, *C*).

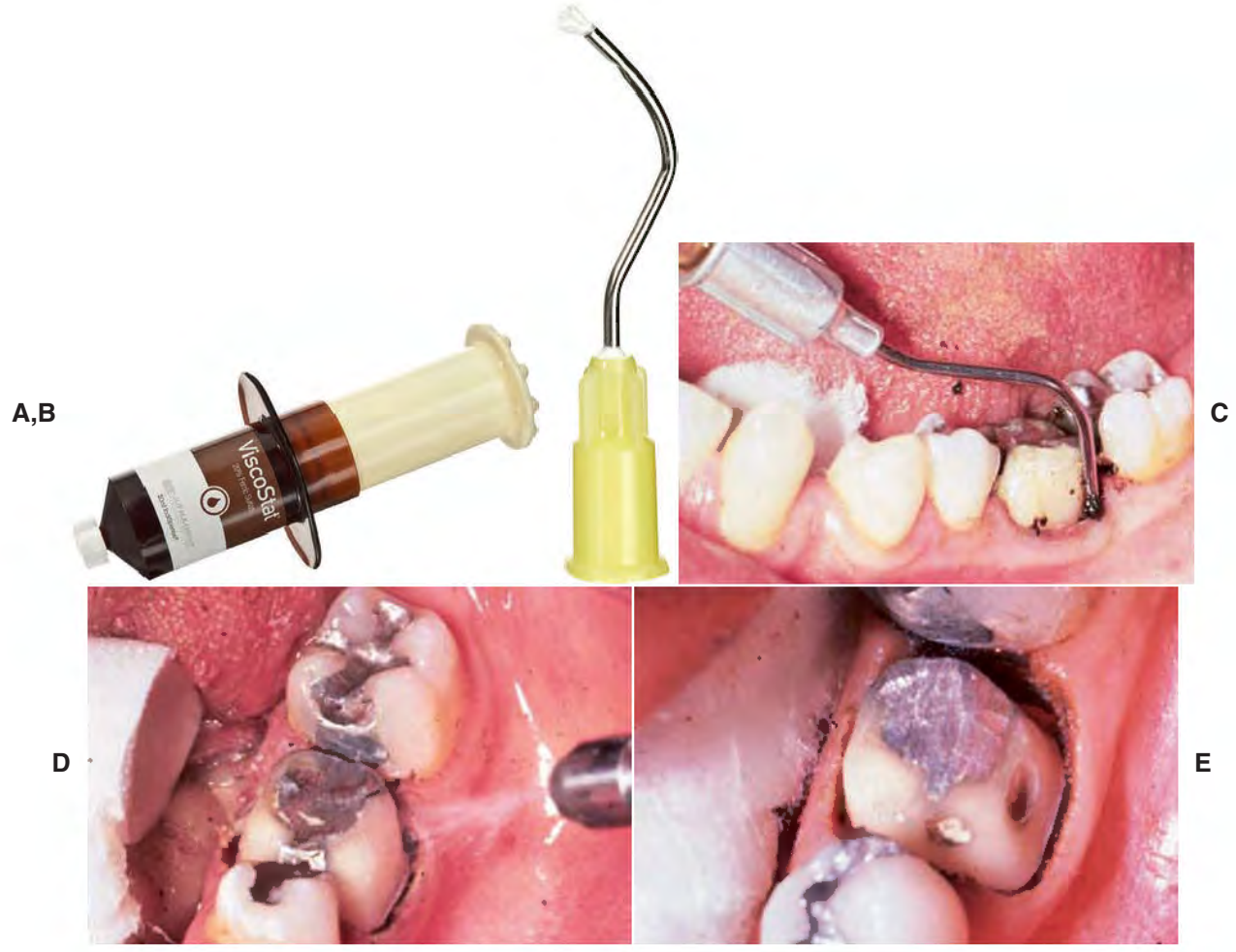

FIGURE 14-9 ■ Hemorrhage control with ferric sulfate ($Fe_2[SO_4]_3$) delivered with an infuser syringe. **A** and **B,** $Fe_2(SO_4)_3$ coagulative hemostatic gel and tip of infuser syringe. **C,** $Fe_2(SO_4)_3$ is released as the tip is moved back and forth in contact with the bleeding area. **D,** The area is cleaned with water spray. **E,** Once bleeding is controlled, the cord is placed in the conventional manner before impression making. (**A** through **B,** Courtesy Ultradent Products Inc., Salt Lake City, Utah.)

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3. Irrigate the area with an air-water syringe (see Fig. 14-9, *D*) and gently dry the tissues with air. Inspect to determine the degree to which bleeding has diminished (see Fig. 14-9, *E*). Repeat several times if necessary, and place a displacement cord.
4. Before cord removal, slightly moisten the cord with water to minimize the risk of dislodgment of blood clots and renewed hemorrhage. Gently dry the tissues, and proceed with impression making.

Evaluation. On many occasions, the correct decision is to delay impression making and concentrate on improving tissue health (e.g., by reassessing the quality of the interim restoration and reinforcing oral hygiene instructions and by prescribing a chlorhexidine rinse) rather than to attempt impression making under adverse conditions. Minor hemorrhaging can sometimes be controlled with an astringent (ViscoStat or Astringedent [15.5% $Fe_2(SO_4)_3$] used with the Dento-Infusor Tips according to the recommendations of Ultradent Products has been effective) or by infiltrating a local anesthetic directly into the adjacent gingival papillae.

Displacement Pastes

Some dentists advocate displacement paste (Expa-syl, Kerr Corp.) (Fig. 14-10) as an alternative to cord.[18] An $AlCl_3$-containing paste is injected into the dried sulcus with a special delivery gun. Advantages of this system include good hemostasis with less discomfort than with traditional cord.[19] However, less tissue displacement is achieved than with cord, which may make subsequent laboratory steps such as die trimming more problematic. Improved displacement may be achieved if the paste is directed into the sulcus by applying pressure with a hollow cotton roll (Roeko Comprecap, Coltène/Whaledent).

Other displacement pastes rely on volumetric expansion as initially described by Feinmann and Martignoni,[20] who combined a polydimethylsiloxane with a tin catalyst. The resulting release of gas resulted in a fourfold volumetric expansion. When the paste was applied into the sulcus, followed by quick seating of a prefabricated interim crown, the volumetric expansion resulted in an apically directed flow that enlarged the gingival sulcus and allowed impression making. A contemporary material (Magic FormCord, Coltène/Whaledent) is based on the identical principle, but a hollow cotton roll (Roeko Comprecap, Coltène/Whaledent) is used to apply pressure to the expanding foam (Fig. 14-11).

Occlusal Matrix Impression Technique

The volumetric expansion pastes are effective because resistance in an occlusal direction exerted by either an

FIGURE 14-10 ■ **A,** Expasyl is an aluminum chloride–containing paste used for gingival displacement. The material is dispensed from a syringe directly into the sulcus. **B,** Fractured ceramic crown had defective margins, which led to significant tissue inflammation and hemorrhage. **C,** Crown is removed. **D** to **F,** Paste is directed into the gingival tissues around the prepared margin. **G,** After 1 to 2 minutes, the paste is removed with copious amounts of water. **H,** Prepared tooth before impression material is injected **(I).** (**A,** Courtesy Kerr Corp., Orange, California. **B** to **I,** Courtesy Dr. Tony Soileau.)

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FIGURE 14-11 ■ Expanding polymeric foam provides tissue displacement with minimal discomfort or gingival trauma. **A,** Magic FoamCord polyvinyl siloxane tissue displacement system. **B,** Maxillary incisor prepared for an all-ceramic crown. Hemorrhage control with ferric sulfate can be used if bleeding is noted (see Fig. 14-9). **C,** The expanding polymeric foam is injected around the preparation and condensed with a special hollow cotton roll (Roeko Comprecap Compression Caps). **D,** The patient closes on the cotton roll, maintaining pressure for 5 minutes. **E,** Tissue has been displaced from the preparation margins before the impression material is injected. (**A,** Courtesy Coltène Whaledent, Cuyahoga Falls, Ohio.)

interim restoration or hollowed-out cotton roll results in an apically directed flow of the impression material. By using an occlusal matrix, the clinician takes advantage of the identical principle. As first reported by LaForgia,[21] and subsequently with more contemporary materials by Livaditis,[22] an index is fabricated from a rigid material, such as polyether, directly over the prepared teeth. This index is trimmed short of the margin by approximately 1 mm with a scalpel. On intraoral verification, the index is filled with medium-bodied impression material and seated over the tooth preparations, which ensures an apically directed flow of the impression material. A regular-bodied impression material is then seated in a suitable impression tray over the index (Fig. 14-12).

Electrosurgery

An electrosurgery unit[23-26] (Fig. 14-13, *A*) may be used for minor tissue removal before impression making. In one technique,[27] the inner epithelial lining of the gingival sulcus is removed, which thus improves access for a subgingival crown margin (see Fig. 14-13, *B* to *F*) and helps effectively control postsurgical hemorrhage[28] (provided that the tissues are not inflamed). Unfortunately, there is the potential for gingival tissue recession after treatment.[29]

An electrosurgery unit works by passage of a high-frequency current (1 to 4 million Hz [1 Hz = 1 cycle/second) through the tissue from a large electrode to a small one. At the small electrode, the current

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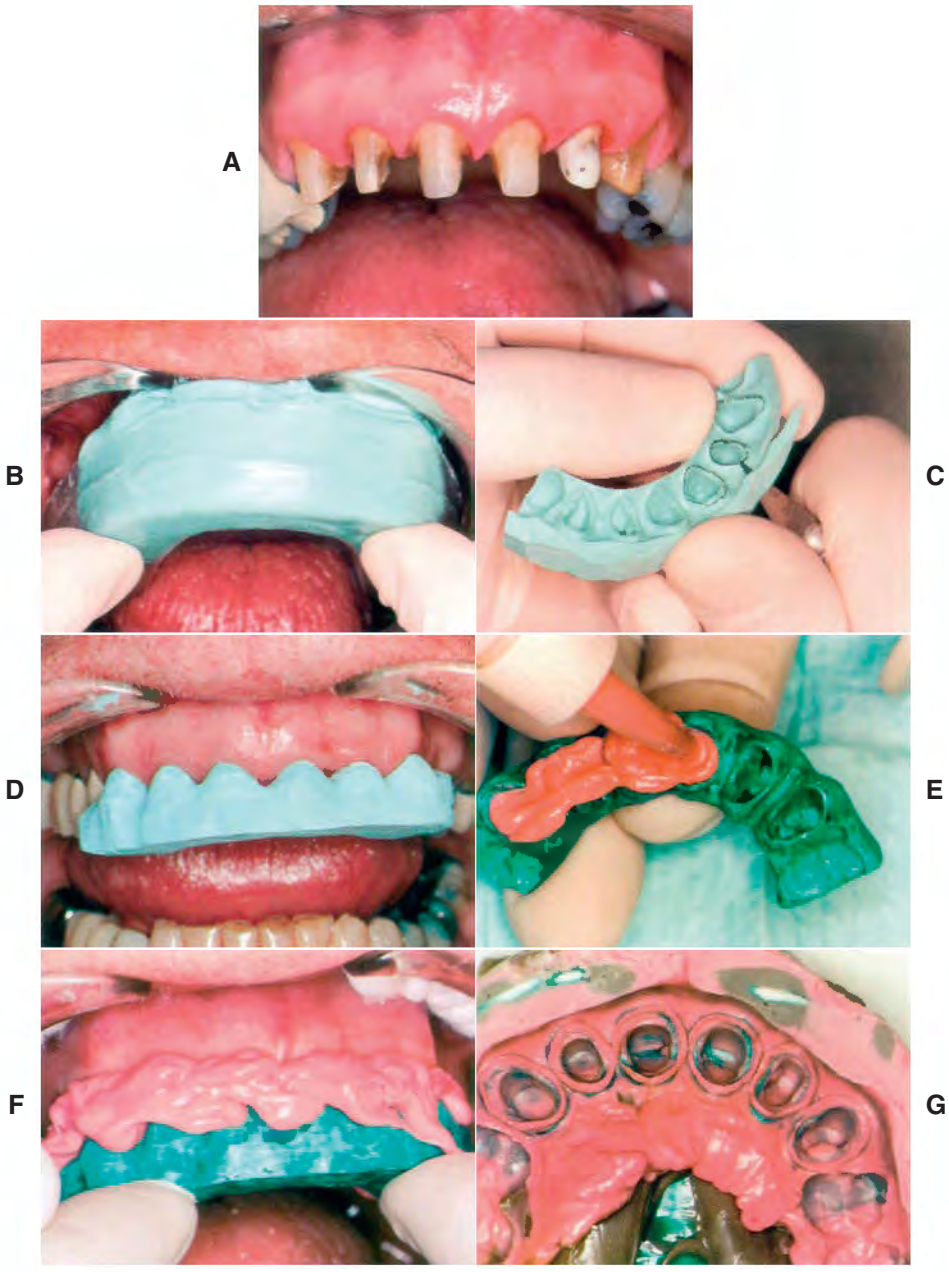

FIGURE 14-12 ■ Occlusal matrix impression system. **A,** Maxillary anterior teeth are prepared for complete crowns. **B,** Matrix is made in the carrier with elastomeric impression material putty before soft tissue is displaced. Registration of the gingival crest is the primary objective. **C,** Facial and palatal sides of matrix are trimmed with a scalpel. Matrix should extend one half to two thirds of the tooth beyond prepared teeth and close to the gingival crest. Black lines indicate sulcular extension. **D,** Matrix in place in the mouth. A stock tray is selected to fit over matrix and any remaining teeth not covered with matrix. **E,** Matrix is painted with adhesive and filled with medium-viscosity impression material. **F,** Matrix impression is seated with light pressure. The stock tray filled with medium-viscosity impression material is seated over the matrix impression before the matrix material polymerizes. **G,** Completed impression. (From Livaditis GJ: The matrix impression system for fixed prosthodontics. J Prosthet Dent 79:208, 1998.)

induces rapid localized polarity changes that cause cell breakdown ("cutting"). For restorative procedures, an unmodulated alternating current is recommended because it minimizes damage to deeper tissues.[24]

The following facts should be considered before electrosurgery is attempted:

- It is contraindicated in or near patients with any electronic medical device (e.g., a cardiac pacemaker, transcutaneous electrical nerve stimulation [TENS] unit, insulin pump),[30] even though newer devices are designed to deflect unwanted current flow,[31] or in patients with delayed healing as a result of debilitating disease or radiation therapy.
- It is not suitable on thin attached gingivae (e.g., the labial tissue of maxillary canines).
- It should not be used with metal instruments because contact could cause electric shock. (Plastic mirrors and evacuation tubes are available.)
- Profound soft tissue anesthesia is mandatory.
- A thin wire or slightly tapered electrode is best for sulcular enlargement. Gingival contouring is usually performed with a loop electrode.

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FIGURE 14-13 ■ **A,** An electrosurgery unit. **B,** The tip of the electrode is used to probe the area where the incisions will be made. **C,** The tip of the electrode is passed through the hyperplastic tissue. The area is irrigated **(D)** and dried for inspection **(E). F,** After tissue removal, cord placement precedes impression making. (**A,** Courtesy Macan Engineering Co., Chicago, Illinois.)

- The instrument should be set to unmodulated alternating current mode.
- The electrode should be passed rapidly through the tissue with a single light stroke and kept moving at all times.
- If the tip drags, the instrument is at too low a setting, and the current should be increased.
- If sparking is visible in the tissue, the instrument is at too high a setting, and the current should be decreased.
- A cutting stroke should not be repeated within 5 seconds.
- The electrode must remain free of tissue fragments.
- The electrode must not touch any metallic restoration. Contact lasting just 0.4 second has been shown to lead to irreversible pulpal damage in dogs.[32]
- The sulcus should be irrigated with hydrogen peroxide before the displacement cord is placed.

Soft Tissue Laser

Soft tissue lasers have been introduced into dentistry and can provide an excellent adjunct for tissue management before impression making (Figs. 14-14 and 14-15).[33,34] They are also useful for tissue contouring procedures. They enable predictable removal of tissue by creating a trough around the prepared tooth. The diode laser, which operates at a low wavelength near infrared, has been claimed[35] to result in minimal or no discomfort for the patient and no tissue recession, and it has been found to be more effective than conventional displacement at establishing hemostasis.

Radiosurgery

Radiosurgery is a technique that provides cutting and/or coagulation from radio waves. An advantage over electrosurgery is that minimal lateral heat is generated.[35a] Different wafeforms are used for tissue removal or coagulation.

MATERIALS SCIENCE

James L. Sandrik

Elastic Impression Materials

Various materials are available for making a precision negative mold of soft and hard tissues. In order of their historical development, they are the following:

1. Reversible hydrocolloid
2. Polysulfide polymer
3. Condensation silicone
4. Polyether
5. Addition silicone

Each material has advantages and disadvantages, and none is entirely free of shortcomings. However, they all share one important characteristic: When handled correctly, they can produce casts of sufficient accuracy[36] and surface detail[37] for the fabrication of clinically acceptable fixed prostheses. In comparison, Irreversible hydrocolloid is not sufficiently accurate for fabrication of precisely fitting restorations.

Nevertheless, there are reasons for selecting one material over another: If it becomes necessary to store the impression before a cast is made, the polyethers and addition silicones are preferable because they exhibit sufficient long-term dimensional stability; the other materials, particularly the reversible hydrocolloids, must be poured immediately or soon after the impression is made. If the impression is to be poured in epoxy or electroplated (see Chapter 17), reversible hydrocolloid cannot be selected because it is compatible only with die stone.

The advantages and disadvantages of the elastic impression materials are summarized in Table 14-3.

Reversible Hydrocolloid

Reversible hydrocolloid (also called *agar hydrocolloid* or simply *hydrocolloid*) (Fig. 14-16) was originally derived as

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FIGURE 14-14 ■ **A,** Erbium, chromium:yttrium-scandium-gallium-garnet (WaterLase YSGG) pulsed laser. **B,** Trough made with the laser before impression making. **C,** Impression. (**A,** Courtesy BIOLASE, Inc., Irvine, California. **B** and **C,** Courtesy Dr. A. Scott.)

FIGURE 14-15 ■ **A,** Radiosurgery unit. **B,** The gingival sulcus enlarged before impression making. (Courtesy Ellman, A Cynosure Company, Hicksville, NY.)

a natural product of kelp. However, the material currently available is considerably different.

If poured immediately, reversible hydrocolloid produces casts of excellent dimensional accuracy and acceptable surface detail. At elevated temperatures, it changes from a gel to a sol. This change is reversible; that is, as the material cools, the viscous fluid sol is converted to an elastic gel. Agar changes from gel to sol at 99°C (210°F) but remains a sol as low as 50°C (122°F), forming a gel only slightly above body temperature. These unique characteristics are very favorable for its use as an impression material.

Reversible hydrocolloid is supplied in various degrees of viscosity. In general, a heavy-bodied tray material is used with a less viscous syringe material. The required temperature changes are effected with a special conditioning unit (see Figs. 14-36 and 14-37) and water-cooled impression trays.

The lack of dimensional stability of reversible hydrocolloid results primarily from the ease with which water can be released from or absorbed by the material (syneresis and imbibition). The accuracy of a reversible hydrocolloid impression is improved if the material has as much bulk as possible (low ratio of surface area to volume). In contrast, the accuracy of elastomeric impression materials is improved by minimizing bulk (e.g., polysulfide and condensation silicone) because stresses produced during removal are reduced.[38] Therefore, an additional advantage of reversible hydrocolloid is that a custom impression tray is not required.

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TABLE 14-3 **Available Elastic Impression Materials**

Material	Advantages	Disadvantages	Recommended Uses	Precautions
Irreversible hydrocolloid	Rapid setting Straightforward technique	Poor accuracy and surface detail	Diagnostic casts Not suitable for definitive casts	Must be poured immediately
Reversible hydrocolloid	Low cost Hydrophilic Long working time Low material cost No custom tray required	Low tear resistance Low stability Equipment needed	Multiple preparations Problems with moisture	Must be poured immediately For use only with stone
Polysulfide polymer	High tear resistance Easier to pour than other elastomers	Messy Unpleasant odor Long setting time Stability: only fair	Most impressions	Must be poured within 1 hr; takes 10 min to set
Condensation silicone	Pleasant to use Short setting time	Stability: only fair Hydrophobic Poor wetting	Most impressions	Must be poured immediately Care is needed to avoid bubbles during pouring
Addition silicone	Dimensional stability Pleasant to use Short setting time Automixing available	Hydrophobic Poor wetting Some materials release H_2 Hydrophilic formulations imbibe moisture	Most impressions	Pouring of some materials must be delayed Care is needed to avoid bubbles during pouring
Polyether	Dimensional stability Accuracy Short setting time Automixing available	Set material: very stiff Imbibition Short working time	Most impressions	Care is needed not to break teeth when separating cast

FIGURE 14-16 ■ Reversible hydrocolloid impression material. Tray **(A)** and wash material **(B). C,** Syringe material. (Courtesy Dux Dental, Oxnard, California.)

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FIGURE 14-17 ■ **Polysulfide polymers.** (Courtesy GC America Inc., Alsip, Illinois.)

FIGURE 14-18 ■ **Condensation silicone.** (Courtesy Coltène Whaledent, Cuyahoga Falls, Ohio.)

Polysulfide Polymer

The polysulfides (Fig. 14-17), commonly (although erroneously) known as *rubber bases*, were introduced in the early to middle 1950s. (Note that all elastomeric materials, not just polysulfides, can be called *rubber bases.*) They were received enthusiastically by dentists because they had better dimensional stability and tear strength than did hydrocolloid. Nevertheless, they should be poured as soon as possible after impression making; delays of more than an hour result in clinically significant dimensional change.[30]

Polysulfide contracts slightly during polymerization, but the effects can be minimized with a custom impression tray to reduce the bulk of the material.[39] In general, a double-mix technique is used with a heavy-bodied tray material and a less viscous syringe material. These polymerize simultaneously, forming a chemical bond of adequate strength.[40]

The high tear resistance[41,42] and enhanced elastic properties of polysulfide facilitate impression making in sulcular areas and pinholes, and it has improved dimensional stability over hydrocolloid (inferior to that of polyether and addition silicone). Although it is the least expensive elastomer, it is not well liked by patients because of its unpleasant sulfide odor and long setting time in the mouth (about 10 minutes). Furthermore, high humidity and temperature dramatically reduce its working time,[43] which may be so short that polymerization begins before it is inserted in the mouth, which results in severe distortion. Although air conditioning is common in dental operating rooms, temperatures near 25°C (77°F) with humidity exceeding 60% can create problems.

In the past, polysulfide materials were polymerized with the aid of lead peroxides, which explains this material's typical brown color. The unpolymerized product is sticky and should be handled carefully because it stains clothing permanently. Contemporary materials are generally polymerized by copper hydroxide. Copper hydroxide–polymerized polysulfide is light green and shares many of the characteristics of the lead peroxide–polymerized material (except for a reduced setting time).

Condensation Silicone

Some of the disadvantages of polysulfide have been overcome by condensation silicone (Fig. 14-18), which is essentially odorless and can be pigmented to virtually any shade. Unfortunately, its dimensional stability is less than that of polysulfide, but it is greater than that of reversible hydrocolloid. An advantage of this silicone is its relatively short setting time in the mouth (about 6 to 8 minutes). As a result, patients tend to prefer condensation silicone over polysulfide. In addition, condensation silicone is also less affected by high temperatures and humidity in the operating room.[38]

The main disadvantage of silicone is its poor wetting characteristics, which stems from its being extremely hydrophobic (for this reason, it is used in commercial sprays that protect automobile electrical systems from moisture). In this context, the prepared teeth and gingival sulci must be completely dried so that the impression can be free of defects. Pouring without trapping air bubbles is also more difficult than with other impression materials, and a surfactant may be needed. Silicone impression material is available in various degrees of viscosity. One technique involves using a heavily filled putty material to customize a stock impression tray in the mouth, generally with a polyethylene spacer. The spacer allows room for a thin wash of light-bodied material, which makes the impression. This technique requires considerable care in seating, however, to prevent strain in the set putty. If strain happens, the impression rebounds when removed from the mouth, which results in dies that are too small.[44] Care is also needed to avoid contaminating the putty surface with saliva, which prevents the wash impression from adhering properly.[45]

Silicone and polysulfide have a dimensional instability that results from their mode of polymerization. Both are condensation polymers, which, as a byproduct of their polymerization reactions, give off alcohol and water, respectively. As a result, evaporation from the set material causes dimensional contraction in both.

Polyether

Polyether impression material (Fig. 14-19), developed in Germany in the mid-1960s, has a polymerization mechanism unlike those of the other elastomers. No volatile byproduct is formed, and thus the resulting dimensional stability is excellent. In addition, its polymerization shrinkage[46] is unusually low in comparison with most room temperature–cured polymer systems. However, its thermal expansion[47] is greater than that of polysulfide.

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FIGURE 14-19 ■ Polyether impression material. (Courtesy 3M ESPE Dental, St. Paul, Minnesota.)

With the high dimensional stability of polyether, accurate casts can be produced when the material is poured more than a day after the impression has been made. This is especially useful when pouring the impression immediately is impossible or inconvenient. Another advantage of polyether is its short setting time in the mouth (about 5 minutes, which is less than half the time required for polysulfide). For these reasons, polyether is used by many practitioners.

However, polyether has certain disadvantages. The stiffness of the set material causes problems when a stone cast is separated from the impression. Thin and single teeth, in particular, are liable to break unless the practitioner uses great care. Softer formulations that avoid this disadvantage are available. Polyether is stable only if stored dry because it absorbs moisture and undergoes significant dimensional change. The relatively short working time of polyether may limit the number of prepared teeth that can be reliably captured in a single impression. Isolated cases of allergic hypersensitivity[48] to polyether elastomer have been reported (manifested as sudden onset of burning, itching, and general oral discomfort). Therefore, the allergic patient's record should carry a warning against future use of polyether, and an alternative elastomer should be chosen. Improvements in these materials have reportedly reduced, though not eliminated, this problem.[48a]

Addition Silicone

Addition silicone (Fig. 14-20) was introduced as a dental impression material in the 1970s. Also known as *polyvinyl siloxane* (*polysiloxane* is the generic chemical expression for silicone resins), it is similar in many ways to condensation silicone except that it has much greater dimensional stability[49] (equivalent to that of polyether polymer), and its working time is more affected by temperature.[37] The set material is less rigid than polyether but stiffer than polysulfide. As with the other materials previously described, adverse soft tissue responses have been reported.[50] One disadvantage of some of these materials is that setting can be inhibited by selected latex gloves[51] or by interim resin materials.[52] Dithiocarbamates, which are used in glove manufacturing as either vulcanizing agents or accelerators, have been implicated as causative agents.[53] Glove exposure to alcohol has been shown to

FIGURE 14-20 ■ Addition silicone. (Courtesy GC America Inc, Alsip, Illinois.)

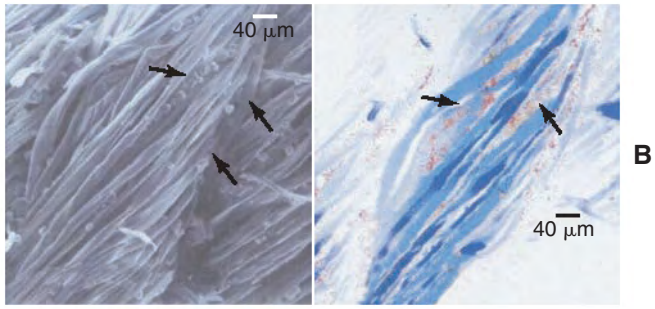

FIGURE 14-21 ■ **A,** Scanning electron microscope finding of gingival displacement cord contaminated by latex glove contact. *Arrows* indicate particles on surfaces and within fibers of gingival displacement cord. **B,** Electron probe microanalysis of gingival displacement cord contaminated by latex glove contact. The red patches are areas of sulfur element *(arrows).* (From Kimoto K, et al: Indirect latex glove contamination and its inhibitory effect on vinyl polysiloxane polymerization. J Prosthet Dent 93:433, 2005.)

exacerbate setting inhibition for selected combinations of impression material and latex gloves.[51] The problem is most apparent if a hand-mixed putty is used, but problems can occur if the tissues are touched with gloved hands immediately before impression placement. It has also been shown that sulfide and sulfide-chloride can be transferred from latex gloves to displacement cord,[54] which enables the transfer of these known inhibiting agents to sulcular tissues (Fig. 14-21). When addition silicones are used, gloves that do not interfere with setting should be used.[55]

Like condensation silicone, addition silicones are hydrophobic. Some formulations contain surfactants, which give them hydrophilic properties,[56] imparting wettability similar to that of the polyethers.[57] However, these products also expand like polyether when in contact with moisture.[58] Addition silicone is generally used by combining a low-viscocity syringe material with a higher-viscocity tray material, although monophase formulations are also available. It is easier to trap bubbles with the monophase formulation.[59]

Manufacturer recommendations should be followed when a cast is being poured, and pouring should be delayed with some of the earlier products; otherwise, a generalized porosity of the cast surface will be caused by gas from the impression material. Newer products contain "scavengers", chemicals that prevent the escape of gas at the polymer-cast interface. Addition silicone that contains scavenger material can be poured immediately.

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Vinyl Polyether Silicone

Vinyl polyether silicone (Fig. 14-22) is a formulation that combines properties of the addition silicones and the polyethers. It was commercially introduced in 2009. The material has dimensional properties similar to those of the addition silicones and polyethers.[60]

• • •

IMPRESSION TRAYS

The choice of impression material influences tray selection. Reversible hydrocolloids require special water-cooled trays, whereas irreversible hydrocolloid and many elastomeric impressions for uncomplicated fixed prosthodontic procedures are made with prefabricated impression trays. To reduce associated distortion invariably associated with the use of such trays, they must have adequate rigidity, and tray design should provide for control of impression material thickness. Retention is provided by perforations, rim locks, adhesives, or a combination of these (Fig. 14-23). Custom trays are fabricated for each patient individually through the use of diagnostic casts (see Chapter 2) and offer a number of advantages over prefabricated stock trays.

Adhesives should be applied sufficiently in advance to allow thorough drying, although they may remain slightly tacky to touch. Because evaporation of the volatile solvent is time dependent, it is preferable to apply the adhesive in a thin layer. Spray-on adhesives have been shown to result in significantly less retention of polyvinyl siloxane impression materials to both autopolymerizing and photopolymerizing tray materials than do paint-on adhesives.[61]

FIGURE 14-22 ■ Vinyl polyether silicone. (Courtesy GC America Inc, Alsip, Illinois.)

CUSTOM TRAY FABRICATION

A custom tray improves the accuracy[62] of an elastomeric impression by limiting the volume of the material, thus reducing two sources of error: stresses during removal and thermal contraction. Although reducing the bulk of an elastomeric impression material increases its accuracy, the opposite is true for reversible hydrocolloid impressions. In hydrocolloid impressions, dimensional change is caused by water loss (or gain) from the surface of the impression. A bulky hydrocolloid impression has a lower ratio of surface area to volume and is therefore less subject to dimensional change.

Custom trays can be made from autopolymerizing acrylic resin, thermoplastic resin, or photopolymerized resins. Thermoplastic materials can be softened in a water bath and adapted either manually or with a vacuum former with a heating element (Figs. 14-24 and 14-25). The accuracy of impressions made with a thermoplastic tray material or light-polymerized materials is

FIGURE 14-23 ■ **A,** This prefabricated segmented tray relies on internal modification to ensure material thickness. **B,** This system allows the dentist to match tray size to patient arch width. (**B,** Courtesy Clan Dental Products, Maarheeze, The Netherlands.)

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FIGURE 14-24 ■ Thermoplastic custom tray material. **A** and **B,** The material is softened in hot water. **C** and **D,** The material has been adapted to the spaced cast.

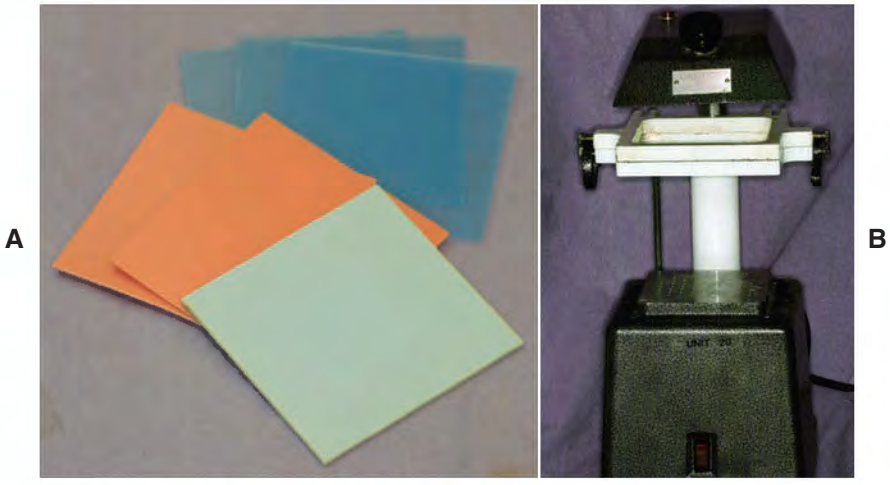

FIGURE 14-25 ■ Vacuum-formed custom tray material. The thermoplastic sheets **(A)** are much thicker and more rigid than those used for making interim restorations (see Chapter 15), but the same equipment is used **(B).**

comparable with that of impressions made with an autopolymerized resin.[63,64] Light-polymerized materials are convenient because a storage period is not needed for the completion of polymerization[65] (Fig. 14-26). In addition, the resin is less susceptible to distortion in moisture, and the impression is thus suitable for the electroformed die technique (see Chapter 17). With the appropriate adhesive, it produces a strong bond to the impression material.[66]

With any system, tray rigidity is important because even slight flexing of the tray causes distortion of the impression. This is particularly frustrating because the errors are usually undetectable until the practitioner attempts to seat the restoration. For this reason, thin,

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FIGURE 14-26 ■ Visible light-polymerized custom tray material. The material is removed from the packet **(A)** and adapted to the spaced cast **(B)**. **C,** The assembly is placed on the turntable of a special polymerization unit and exposed to intense light.

disposable plastic trays are unacceptable.[67] Resin must be 2 to 3 mm thick for adequate rigidity. Clearance between the tray and the teeth should also be 2 to 3 mm; however, greater clearance is necessary for the more rigid polyether materials.

Armamentarium

- Baseplate wax
- 0.025-mm (0.001-inch) tin or aluminum foil
- Scalpel
- Scissors
- Waxing instrument

Step-by-Step Procedure: Autopolymerizing Resin

1. Using a pencil, mark the border of the tray on the diagnostic cast approximately 5 mm apically from the crest of the free gingiva (less for the more rigid impression materials). Allow for muscle and frenulum attachments. Maxillary trays do not always necessitate covering the entire palate, although this may be desirable if a removable appliance is planned after completion of the fixed prostheses. Under no circumstances should the posterior border extend farther than the demarcation between hard and soft palates.
2. Adapt a wax or other suitable spacer to the diagnostic cast. Two layers of baseplate wax result in a combined thickness of approximately 2.5 mm (the sheets should be measured with a thickness gauge because wax thicknesses vary).
3. Soften the wax by carefully heating it over a Bunsen burner or in hot water. Overheating may melt it and produce an undesirable thin spot. Only light pressure should be applied.
4. After the second sheet of wax has been applied, trim it back until the pencil line is just visible. An alternative technique involves repeated dipping of the cast in molten wax. The cast is thoroughly wetted and then dipped three or four times to obtain a sufficient and uniform wax thickness (about 2 or 3 mm). This creates the space needed for the impression material. Three stops are needed in the tray to maintain even space for the impression material in the oral cavity. These are placed on nonfunctional cusps of teeth that are not to be prepared (buccal cusps of the maxillary teeth, lingual cusps of the mandibular teeth). If all teeth are involved, a larger soft tissue stop (Fig. 14-27) can be placed on the crest of the alveolar ridge or in the center of the hard palate. To make stops (Fig. 14-28), remove wax at an angle of 45 degrees to the occlusal surfaces of three teeth that have a tripodal arrangement in the arch. This

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FIGURE 14-27 ■ If necessary, a tray stop can be placed on the hard palate.

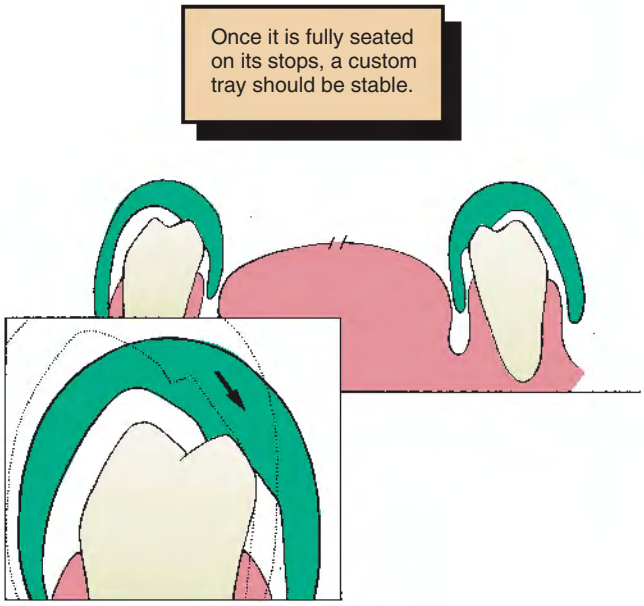

FIGURE 14-28 ■ Drawing of a cross section through a mandibular custom tray. Stops have been placed on the nonfunctional cusps so that distortion does not interfere with the intercuspal relationship. The 45-degree slope helps to center the tray during seating *(arrow)*. Space for the impression material is present.

lends stability to the tray, and the 45-degree slope helps center the tray during insertion.

5. Because the wax may melt from the polymerization heat of the material, apply a layer of tin or aluminum foil over the wax to prevent it from contaminating the inside of the tray.
6. Mix autopolymerizing acrylic resin according to the manufacturer's recommendations. The use of vinyl gloves is recommended to prevent the development of sensitivity to the monomer.
7. After the resin is mixed, set it aside until it is doughy (with the consistency of putty). A template or a wooden slab and roller may help obtain a consistent thickness, although with practice, the resin can be thinned out accurately by hand. Care must be taken not to stretch the material when it is manipulated; thin areas in the resin may cause the tray to become flexible and produce distortions.

FIGURE 14-29 ■ Buccal ridges can be provided to facilitate removal of the impression. (Courtesy Dr. H. Lin.)

8. Gently adapt the resin to the cast. A handle made from the excess resin can be attached at this time. If working time is unavailable, it can also be attached later with a separate second mix of acrylic resin. Buccal ridges, which are helpful with impression removal, can also be added (Fig. 14-29).
9. After the material has polymerized, remove it from the cast and trim it with an acrylic-trimming bur (see Fig. 14-30, *R*) where the indentation made by the wax ledge is visible. All rough edges should be rounded to prevent soft tissue trauma.
10. If necessary, fill defects in the stops with additional resin, wetting the set tray material with monomer to ensure a good bond. To prevent the material from lifting up, maintain some pressure during this phase.

Step-by-Step Procedure: Photopolymerized Resin

Follow steps 1 to 5 as for the autopolymerizing technique (Fig. 14-30, *A* to *H*).

6. Remove photopolymerized tray material sheets from their lightproof packaging (see Fig. 14-30, *H*) and adapt them to the relieved cast. Adapt small pieces in the areas of the stops first, to make sure they are filled completely (see Fig. 14-30, *I*). Two sheets are needed to make each tray and should be cut as shown in Figure 14-30, *J*. Carefully adapt the large piece of material to the cast, being careful not to extend the material beyond the scribed borders (see Fig. 14-30, *K* to *M*). Use a blade to trim the excess material away from the cast. It may help to roll the edge of material back onto itself at the borders, so that it is not too thin in these areas for trimming. Adapt the material with gloved fingers until the pieces blend together and no seams are visible. Do not press hard; otherwise, the material will be deformed and thinned. This weakens the tray.
7. Shape and attach a handle by molding excess material. Blend it into the tray material (see Fig. 14-30, *N*). Use a paper clip to support the handle material by adapting the material around it.
8. Position the cast in the polymerization unit for approximately 2 minutes (see Fig. 14-30, *O*).

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FIGURE 14-30 ■ Custom tray fabrication with photopolymerized resin. **A,** Baseplate wax and foil are used to create a spacer on the cast. **B,** Outline and locations of occlusal stops are drawn on the cast. **C,** Softened baseplate wax is applied as a spacer. The wax is trimmed to the pencil line. **D,** After application of a second layer, wax is removed to create an incisal stop. **E,** Posterior stops are placed on the nonfunctional cusps. Foil is applied to the cast **(F)** and burnished **(G)** to prevent resin contamination. **H,** Photopolymerized tray material sheets are supplied in lightproof packaging.

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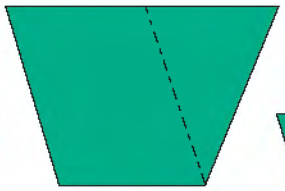
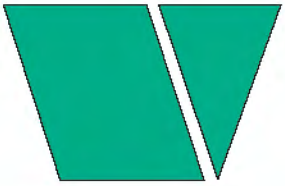
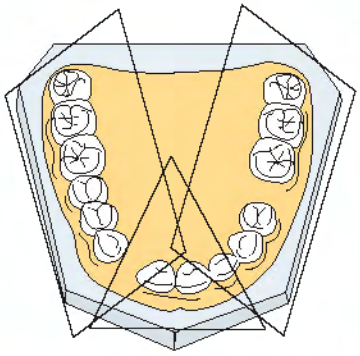

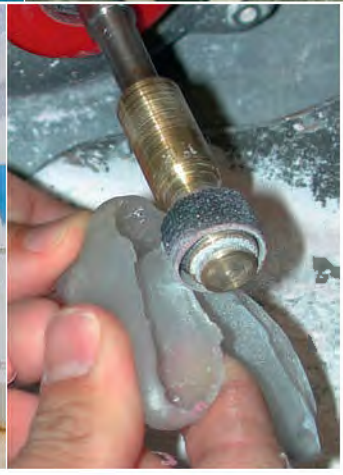

I J K L,M N O,P Q R

FIGURE 14-30, cont'd ■ **I,** Some resin is applied into the areas for the stops and small edentulous spaces. **J,** Sheets should be cut as shown. A sheet of resin is then adapted **(K),** with care to not thin the material excessively **(L). M,** Note that the adapted resin seals the posterior aspect of the tray to help retain impression material. **N,** Additional resin is added to shape a handle of the desired configuration. **O,** The resin is then polymerized. **P,** On removal from the cast, the foils facilitate removal of the wax spacer. **Q,** An air-barrier coating is then applied to prevent a sticky oxygen-inhibited layer. **R,** The tray is trimmed. (Fabrication sequence courtesy Dr. R. Froemling.)

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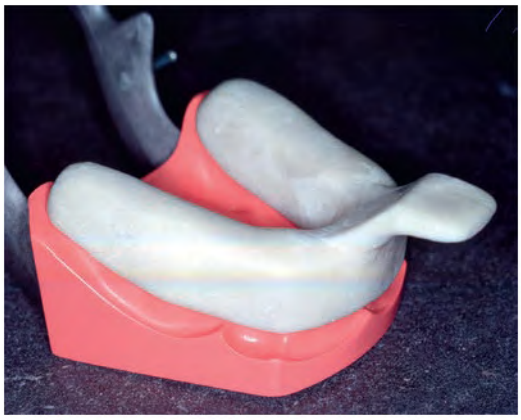

FIGURE 14-31 ■ A custom tray should be smooth and well finished. This will enhance its acceptability to the patient.

Remove the cast from the polymerization unit, separate the tray from the cast, and remove the softened wax spacer and the foil barrier (see Fig. 14-30, *P*). Paint the tray with the air-barrier coating provided by the manufacturer (see Fig. 14-30, *Q*).

9. Return the cast to the polymerization unit and polymerize in accordance with the time recommended by the manufacturer. Remove the tray, and scrub it clean under warm running water.
10. Clean the tray, and trim as for the autopolymerizing resin tray (see Fig. 14-30, *R*). Add additional resin as needed.

Evaluation

The completed custom tray needs to be rigid, with a consistent thickness of 2 to 3 mm. It should extend about 3 to 5 mm cervical to the gingival margins and should be shaped to allow muscle attachments. It should be stable on the cast with stops that can maintain an impression thickness of 2 or 3 mm. The tray must be smooth, with no sharp edges. Finally, the handle should be sturdy and shaped to fit between the patient's lips (Fig. 14-31).

To avoid distortion from continued polymerization of the resin,[68] the tray should be made at least 9 hours before its use. When a tray is needed more urgently, it can be placed in boiling water for 5 minutes and allowed to cool to room temperature. A light-polymerized tray can also be made (see Fig. 14-26).

IMPRESSION MAKING

Elastomeric Materials

When elastomeric impressions are made, an assistant is essential, unless an automixing dispenser is used.

Step-by-Step Procedure

Heavy-bodied–Light-bodied Combination

1. Evaluate the custom tray in the patient's mouth to verify its fit. Correct the tray as needed.

   If existing partial fixed dental prostheses are present in the arch to be impressed, apply soft wax (rope wax works well) or an alternative suitable block-out material in the cervical aspect of all pontics to prevent the set impression material from "locking" in the patient's mouth. The only remedy, should this accidentally occur, is to literally cut the impression tray from the mouth, which would seriously undermine the patient's confidence in this method.
2. Apply tray adhesive to extend a few millimeters onto the external surface of the tray (Fig. 14-32, *A*). Allow the adhesive to dry in accordance with manufacturer's recommendations.
3. Ensure that the disposable syringe tip has an opening of adequate size in relation to the viscosity of the impression material that has been selected. For most light-bodied materials, a cross-sectional opening of approximately 0.8 to 1.0 mm is adequate.
4. Isolate the abutment teeth, and place gingival displacement cord in the sulcus.
5. On separate pads (one for the tray and one for the syringe material), disperse equal amounts of base and accelerator (see Fig. 14-32, *B* and *C*).

   When mixing polysulfide polymers, pick up the brown catalyst first (see Fig. 14-32, *D*), rather than the white base material, because the base sticks to the spatula and makes it virtually impossible to incorporate all the catalyst.
6. Blend the two pastes thoroughly (see Fig. 14-32, *E*). Initially, the spatula is kept somewhat vertical during mixing; this position is changed gradually to be more horizontal as the two pastes become better incorporated. At this time, the spatula is wiped on a clean paper towel. Mixing continues for another 10 seconds to ensure that the material is homogeneous.
7. Load the syringe. This can be done by holding the barrel vertically, pushing it through the mix, and then angling and sliding it sideways over the mixing pad. The syringe can also be loaded from the other end (see Fig. 14-32, *F*) by picking up the mixing sheet, forming a funnel, and expressing the material into the breech of the syringe.

   Concurrently with steps 5 through 10, have the assistant mix the heavy-bodied material in a similar manner as the light-bodied material (see Fig. 14-32, *G* to *I*) and load the tray.
8. Remove the displacement cord, and gently dry the preparation with compressed air.

   When removing cord, hold the cord in tweezers and pull the cord in an occlusal direction, angled slightly toward the tooth preparation. The objective is to minimize dragging the cord across the internal aspect of the free gingiva, which can increase the risk of renewed hemorrhage. Prewetting the cord with a few drops of water held in cotton forceps will also reduce the risk of renewed bleeding. Before proceeding, dry the preparation and adjacent surfaces with the multifunction syringe. It is prudent to "bleed" the air water

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syringe tip to ensure that no residual water is inadvertently blown onto the preparation.

9. Place the tip of the impression syringe nozzle so that it touches the margin, and inject the material slowly (see Fig. 14-32, *J* and *K*). The tip should be inserted into the most distal embrasure first. This prevents the material from flowing down over the preparation and trapping air bubbles. The tip is moved so that it follows the material rather than traveling ahead of it. When all the margins and axial surfaces have been covered, the material is air-blown into a thin layer.
10. Express additional light-bodied material to cover any edentulous spaces, the lingual concavities of the anterior teeth (which are important for guidance), and occlusal surfaces of the posterior teeth (which are important for achieving an accurate articulation) (see Fig. 14-32, *J* and *K*).
11. Seat the tray (see Fig. 14-32, *L*). It must remain immobile while the material undergoes polymerization (6 to 12 minutes, depending on the material). Otherwise, strains form in the elastomer, which can cause distortion of the impression when it is removed. The manufacturer's recommendations for maximum working time and minimum setting time should be followed. It is difficult to judge clinically when elastomers start to develop elasticity.[69] Any delay in seating the tray results in distortion of the impression. It is tempting to remove the impression too soon because the patient may find it uncomfortable. However, premature impression removal is a common cause of impression distortions.

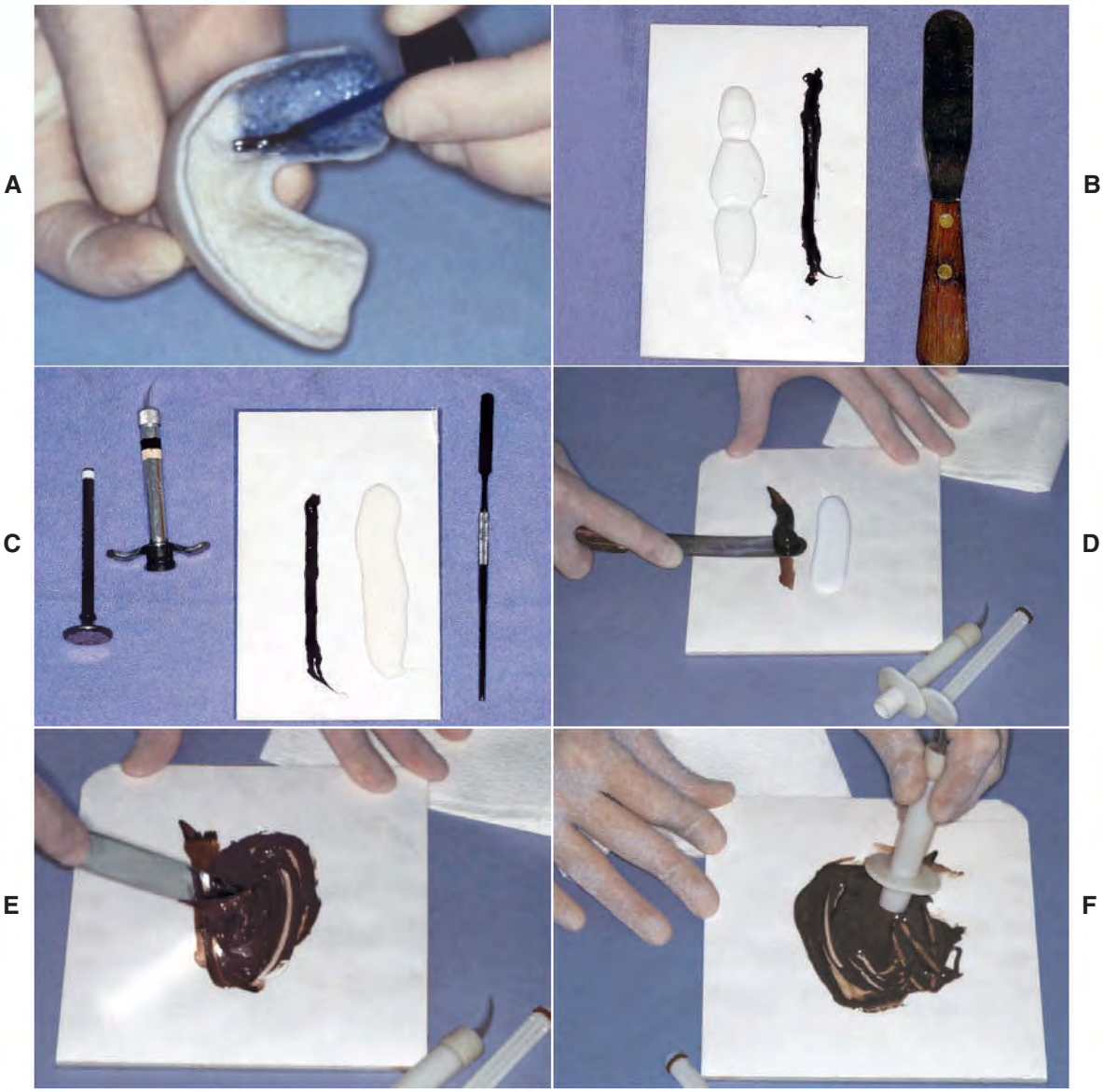

FIGURE 14-32 ■ Elastomeric impression making (polysulfide polymer). **A,** Adhesive is applied to the tray. Sufficient time is allowed for drying. **B,** Heavy-bodied tray material. **C,** Light-bodied syringe material. **D,** The brown catalyst is picked up first. **E,** The brown catalyst is thoroughly mixed with the white base material. **F,** Impression syringe is loaded. *Continued*

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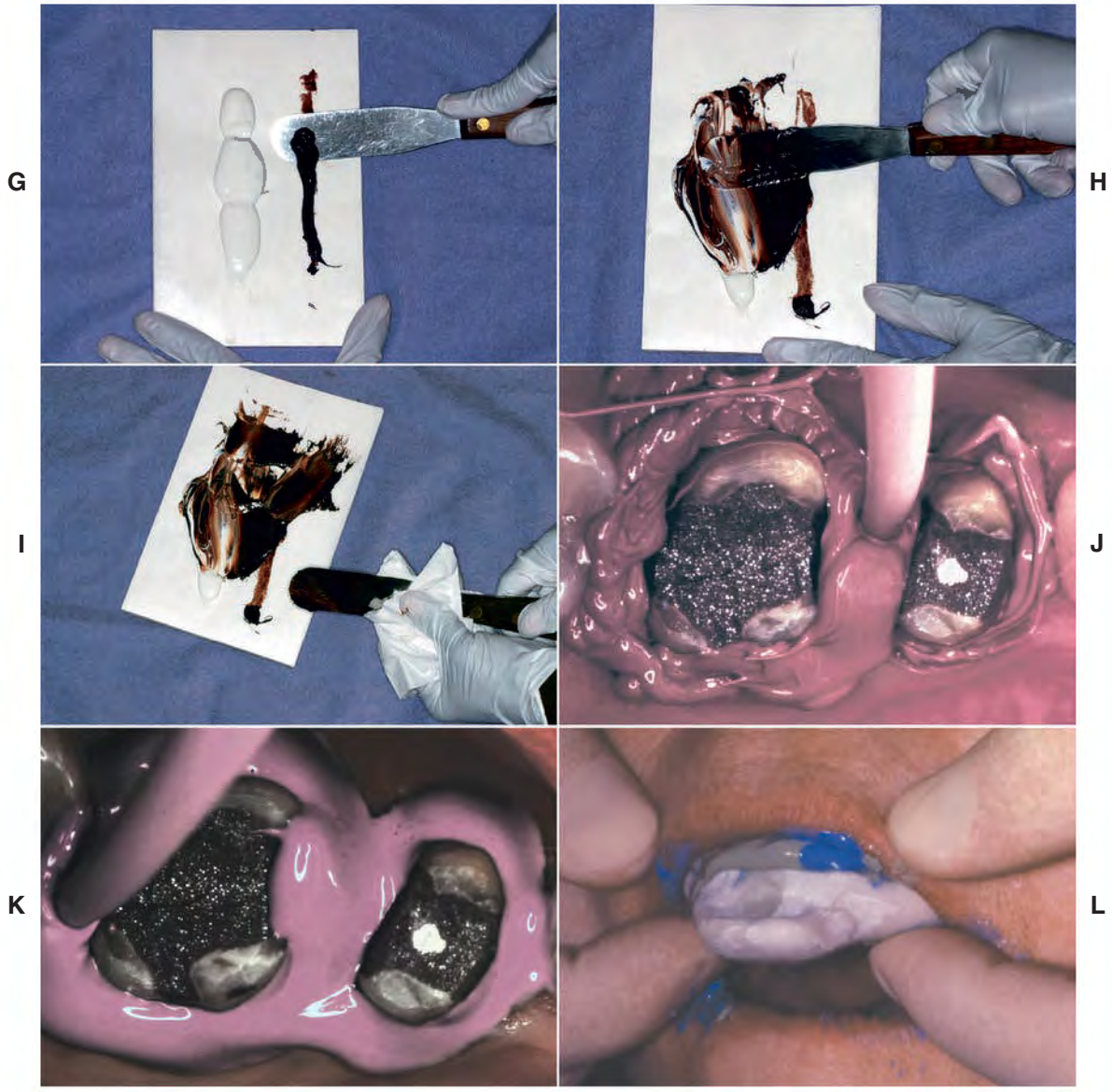

FIGURE 14-32, cont'd ■ **G** and **H,** Meanwhile, an assistant mixes the heavy-bodied material. **I,** The spatula is wiped to prevent unmixed material from being incorporated into the impression. **J** and **K,** Displacement cord is removed, and the impression material is applied by syringe into the sulcus, around the prepared teeth, and into the grooves of the occlusal surfaces. The material is air-blown into a thin layer at this time. **L,** The impression tray is filled with heavy-bodied material and seated.

Many patients experience impression making as somewhat uncomfortable. The clinician can enhance the patient's comfort by providing a saliva ejector to reduce pooling; by adjusting the chair so that the patient is seated in a more upright position, which, particularly with maxillary impressions, reduces the quantity of material flowing to the back of the mouth and thus reduces the potential for gagging or coughing; and by remaining at chairside throughout the setting of the material.

Single-mix Technique. The same steps are performed for the single-mix technique as for the heavy-bodied–light-bodied systems; however, as the name indicates, a single medium-viscosity mix is used both to load the syringe and to fill the tray. Most single-mix materials tend to produce a mix of slightly higher viscosity in a slightly shorter working time.

Automix Technique. Most manufacturers offer impression material in prepackaged cartridges with a disposable mixing tip attached (Fig. 14-33) to the mixing tube. The cartridge is inserted in a caulking gun–like device, and the base and catalyst are extruded into the mixing tip, in which mixing occurs as they progress to the end of the tube. The homogeneously incorporated material can be placed directly on the prepared tooth and impression tray. One of the advantages of this system is the elimination of hand mixing on pads; as a result, the impression has fewer voids.[70] A disadvantage, especially for novices, is that the comparatively larger gun systems require a steadier hand to precisely track the preparation margin than do the shorter syringe systems described previously. Even minor movement of the hand that holds the impression gun will be magnified at the tooth preparation because of the longer lever arm; thus air, and

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FIGURE 14-33 ■ **A,** Automix addition silicone impression materials are available in various degrees of viscosity. **B,** The barrels should be "bled" to ensure that any partially set material is removed and that the flow is even from each component. To prevent cross contamination of the catalyst and base, a mixing tip should remain attached to the cartridge after each use. The light-bodied material can be dispensed into an impression syringe **(C)** or directly onto the prepared tooth with a special tip **(D)**. The heavy-bodied material is dispensed into the adhesive-coated tray **(E)**.

consequently bubbles and voids in the impression, are more likely to be included. As described previously, the syringe tip must follow the impression material as it flows onto the prepared tooth surfaces. Following the manufacturer's directions and bleeding the cartridge before inserting the tip are crucial to ensure that possible residue of partially polymerized material is removed from the cartridge openings, which might prevent equal amounts of base and catalyst from being dispensed. Automix material is not available for the polysulfide polymers because these materials are too sticky for proper mixing with existing cartridge tips.

Machine Mixing Technique. An alternative method for improving impression mixing is to use a machine mixer (Pentamix Automatic Mixing Unit, 3M ESPE Dental) (Fig. 14-34). These systems are convenient and produce void-free mixes. Typically, a single degree of viscosity is used for the syringe and the tray material. Mixing machines offer the advantage of bulk loading larger quantities of material, which may be advantageous in certain practice settings. This equipment should be located close to the dental chair to reduce time loss between mixing and the actual making of the impression.

Evaluation

The impression must be inspected for accuracy when it is removed (Fig. 14-35). (Viewing with magnification is helpful.) If bubbles or voids appear in the margin, the impression must be discarded. An intact, uninterrupted cuff of impression material should be present beyond the margin circumferentially. Streaks of base or catalyst material indicate improper mixing and may render an

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FIGURE 14-34 ■ Machine mixing system. **A,** Pentamix machine. **B,** Polyether impression material. **C,** Loading an impression tray. (Courtesy 3M ESPE Dental, St. Paul, Minnesota.)

FIGURE 14-35 ■ Impression evaluation. **A,** Low magnification of elastomeric impression. On the left, an adequate cuff is formed by material extending beyond the preparation margin. On the right side *(arrow),* the impression does not extend adequately. **B,** This impression reproduces an adequate amount of the unprepared tooth structure cervical to the preparation margin.

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impression useless. If the impression passes all these tests, it can then be disinfected (see the section "Disinfection" later in this chapter) and poured to obtain a die and definitive cast (see Chapter 17).

Reversible Hydrocolloid

Reversible hydrocolloid impression material requires a special conditioning unit (Fig. 14-36) that is made up of three thermostatically controlled water baths:

- A liquefaction (boiling) bath (100°C [212°F]) for the heavy-bodied tray material and the light-bodied syringe material
- A storage bath (≅65°C [150°F]) for maintaining liquefied materials until they are needed
- A tempering bath (≅40°C [105°F]) for reducing the temperature of the heavy-bodied tray material enough to avoid tissue damage

Step-by-Step Procedure

1. Select the correct size of water-cooled impression tray. For maximum accuracy, use the largest size that can be comfortably accommodated by the patient.
2. Place prefabricated stops across the posterior of the tray to prevent overseating and to provide additional retention.
3. For adequate access, displace the gingival tissues as previously described.
4. Fill the impression tray with heavy-bodied material from the storage bath. Add wash material to the surface of the hydrocolloid tray material in the area of the preparation and one adjacent tooth (Fig. 14-37, *A* and *B*). Submerge the tray in a tempering bath (see Fig. 14-37, *C*).
5. Carefully remove the cord from the sulcus, and flood the sulcus with warm water (see Fig. 14-37, *D*).
6. Remove the impression tray from the tempering bath and seat the tray in the patient's mouth. After seating, initiate and maintain the flow of room-temperature water through the tray (see Fig. 14-37, *E*).
7. Hold the tray firmly in the patient's mouth while the impression material is gelling.
8. Remove the tray with a rapid motion, wash it with room-temperature water, disinfect it (see Table 14-3), and evaluate it for accuracy. Potassium sulfate can be used as a dipping solution for improved stone characteristics.
9. After the impression is judged to be acceptable, pour immediately in Type IV or V stone. If delay is inevitable, the impression can be immersed in a special oil-based solution (Extend-A-Pour, Dux Dental).

FIGURE 14-36 ■ Hydrocolloid conditioning equipment consists of three thermostatically controlled water baths: boiling or liquifaction, storage, and tempering. (Courtesy Dux Dental, Oxnard, California.)

Evaluation

A reversible hydrocolloid impression is evaluated in the same manner as polysulfide polymer (see Fig. 14-37, *F*). However, the translucency of the material may make small imperfections difficult to detect. If doubt exists, it may be expedient to make a new impression because this does not require additional tissue displacement and can be easily accomplished.

Closed-mouth Impression Technique

The closed-mouth impression technique, also called the *dual-arch* or *triple-tray technique*, is popular for making impressions for single units and less expensive restorations made to conform to the existing occlusion.[71,72] The impression is made in maximum intercuspation with a high-viscosity polyvinyl siloxane or polyether impression material supported by a thin mesh in a frame. Similar success rates have been reported with these impression material types.[73] The impression includes the prepared tooth, the adjacent teeth, and the opposing teeth and records their maximum intercuspation relationship (hence the name "triple tray"). Because the impression is made at the occlusal vertical dimension, the technique facilitates making an accurate impression[74,75] and occlusal record. However, the laboratory stages must be performed very carefully and, as no eccentric relationships are recorded, after the restoration has been fabricated, these need to be evaluated and adjusted at the delivery appointment.

Step-by-Step Procedure

1. Select and evaluate a closed-mouth tray. Make sure the patient can close easily into maximal intercuspation without interference with the tray. If the preliminary impression (external mold) for the interim restoration (see Chapter 15) is made with

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FIGURE 14-37 ■ Hydrocolloid impression technique. **A,** The water-cooled impression tray is loaded with heavy-bodied material. **B,** The wash hydrocolloid is squeezed onto the tray material in the area of the preparations. **C,** The filled tray is placed in a tempering bath for the recommended 3 minutes. **D,** The sulcus is flooded with water or a surfactant. Alternatively, some dentists prefer a syringe technique. **E,** Water-cooling tubes are connected and then the tray is seated. **F,** The completed impression. Light-bodied material should have been displaced by the tray material. (Courtesy Dux Dental, Oxnard, California.)

a closed-mouth tray, this will serve as a useful rehearsal of the procedure for the patient (Fig. 14-38, *A*).

2. Load both sides of the closed-mouth tray with a high-viscosity elastomeric impression material. Many closed-mouth trays do not require an adhesive because they have mechanical locks in their design, but if necessary, apply adhesive to the tray walls. The adhesive should not be painted on the mesh.
3. Concurrently, remove cord and, using a syringe, apply impression material onto critical areas.
4. Place the loaded closed-mouth tray into position and have the patient close properly. Check the contralateral side to verify that maximum intercuspation was achieved and remains sustained throughout the setting of the impression material.
5. Remove the polymerized impression; help the patient open the mouth by applying pressure to the set material or tray border.

Evaluation

The impression is evaluated for accuracy and detail (see Fig. 14-38, *E*). Ensure that the patient has not closed into the sides or distal bar of the tray. Check the centric contact of the unprepared teeth. Light should shine

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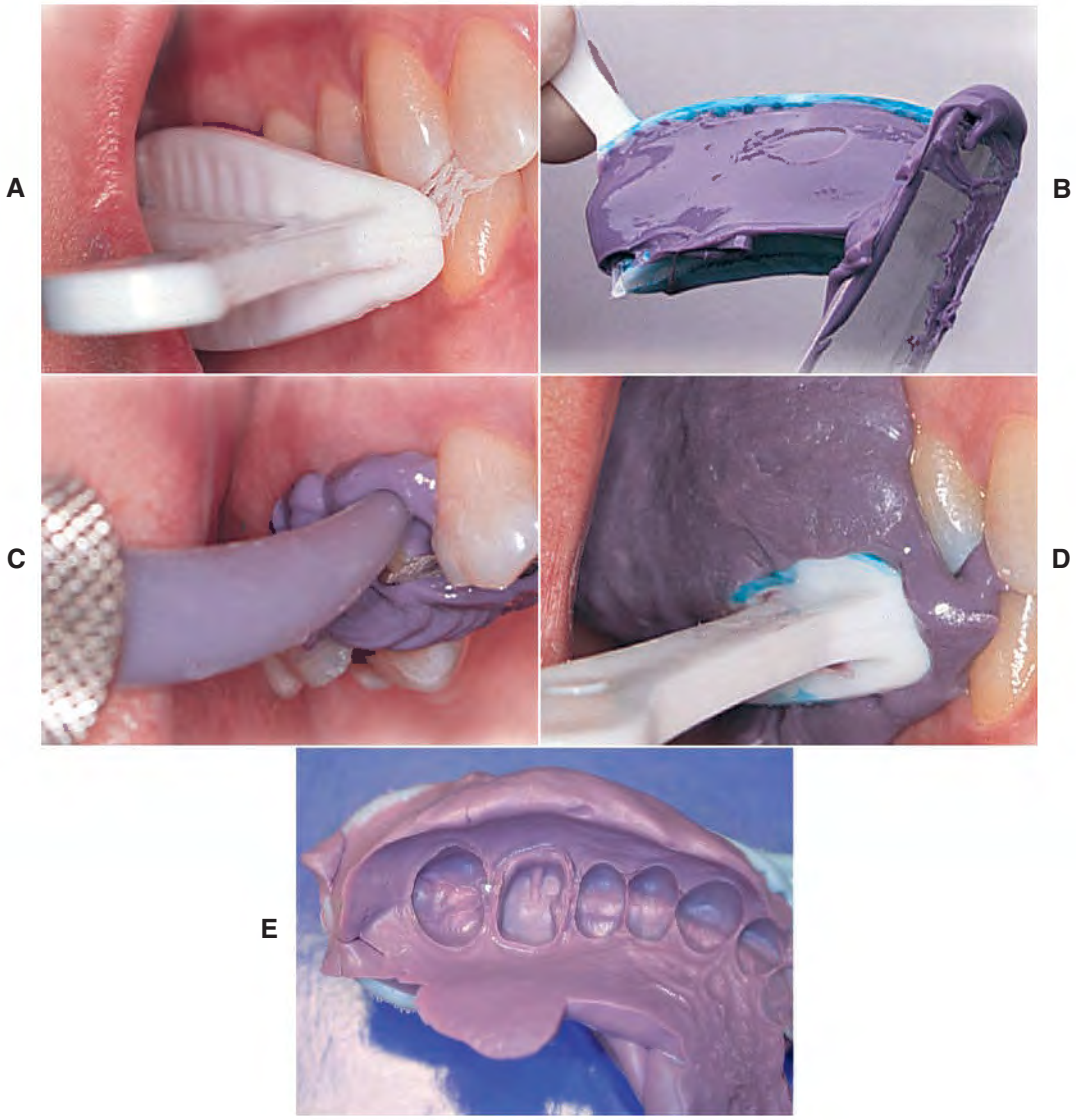

FIGURE 14-38 ■ Closed-mouth impression technique. **A,** The tray is selected and evaluated. **B,** The tray is loaded. **C,** Impression material is delivered by syringe. **D,** Patient closes into maximum intercuspation. **E,** Completed impression. (**A** to **D,** Courtesy Premier Dental Products Co., Plymouth Meeting, Pennsylvania.)

through in these areas, demonstrating proper centric closure by the patient.

Special Considerations

Certain modifications of the basic impression technique are sometimes needed, particularly for making impressions with additional retention features, such as for the post space of endodontically treated teeth.

Elastomeric materials can be successfully used to make impressions of the post space when endodontically treated teeth are being restored. The procedure involves reinforcing the impression with a plastic pin or suitable wire (e.g., orthodontic wire), as described in Chapter 12.

Disinfection

When they are removed from the patient's mouth, it must be assumed that all impression materials have been in contact with body fluids. The materials should be disinfected according to the recommended procedures for the material being used. After being removed from the patient's mouth, the impression is immediately rinsed with tap water and dried with an air syringe. Suitable chemicals should be used for disinfection, such as glutaraldehyde solutions or iodophor sprays. Table 14-4 shows the most commonly recommended techniques for the materials discussed in this section. Some are perfectly acceptable for one material but unsuitable for others. Because of its tendency to distort and absorb moisture, polyether or "hydrophilic" addition silicone impression materials should be sprayed and stored in a plastic bag rather than submerged and soaked in a glutaraldehyde solution. Disinfection is an essential step for preventing cross infection and exposure of laboratory personnel. If it is performed properly, disinfection does not affect the accuracy or surface reproduction of the elastomer.[76-79]

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Evaluation

After disinfection, the completed impression (Fig. 14-39) is inspected carefully before the definitive cast is made. An elastomeric impression should be dried before it is evaluated. The following points are then considered:

1. Has the material been properly mixed? An impression that contains visible streaks of base or catalyst material should be rejected.
2. Is there an area where the custom tray shows through? This must be identified and its potential effect on the quality of the impression assessed. A common error is rotation and the resulting inaccurate seating of the tray. This can result in the tray's contacting several teeth and an uneven thickness of impression material. Normally this occurs only at the tray stops, but when it touches a critical area, the impression must be discarded and a new one made. However, if a thin spot is not near the prepared teeth, it can sometimes be allowed to remain.
3. Are there any voids, folds, or creases? These should have been avoided by careful technique; however, the impression may still be acceptable when a small defect is present in a noncritical area (e.g., away from the margin of a prepared tooth). Careful judgment must be exercised.
4. Is there an even, uninterrupted extension of impression material beyond the margins of the prepared teeth? This is essential if restorations with well-fitting margins and correct contours are to be made.
5. Has the impression material separated from the tray? This is a common cause of distorted impressions and results from improper application and/or inadequate drying of the adhesive.

DIGITAL IMPRESSION TECHNIQUES

Dental digital impression systems were initially envisioned by Duret in the 1970s for digital impression making directly in the patient's mouth or on a cast.[80] Mörmann et al developed the first in-office optical capture and ceramic machining system which allowed chairside milling of inlays from prefired ceramic blocks after optical data acquisition directly in the patient's mouth.[81] Initial scanning relied on stripe scanning and

TABLE 14-4 **Recommended Disinfection Method by Impression Material**

Disinfection	Irreversible* Hydrocolloid	Reversible* Hydrocolloid	Polysulfide	Silicones	Polyether†
Glutaraldehyde 2% (10-minute soak time)	Not recommended	Not recommended	Yes	Yes	No
Iodophors (1:213 dilution)	Yes	Yes	Yes	Yes	No
Chlorine compounds (1:10 dilution of commercial bleach)	Yes	Yes	Yes	Yes	Yes
Complex phenolics	Not recommended	Limited date	Yes	Yes	No
Phenolic glutaraldehydes	Not recommended	Yes	Yes	Yes	No

*Immersion time should be minimized. Dip in glutaraldehyde, rinse in sterile water, dip again, and delay pouring for 10 minutes while maintaining a humid environment. Alternatively, spray with sodium hypochlorite, rinse, and respray with a similar 10-minute delay before pouring.

†Imbibition distortion results from prolonged immersion. For 1:10 hypochlorite or chlorine dioxide: spray, rinse, repeat, spray again, and delay pouring for approximately 10 minutes.

Modified from Merchant VA: Update on disinfection of impressions, prostheses, and casts. ADA 1991 guidelines, J Calif Dent Assoc *20:10, 31, 1992.*

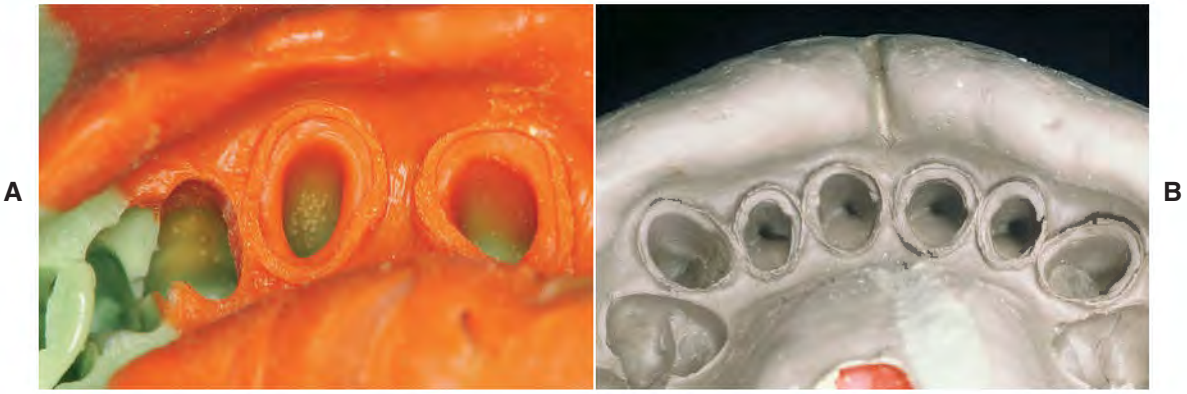

FIGURE 14-39 ■ The completed impression. **A** and **B,** Careful technique ensures a complete cuff of impression material beyond the margin and greatly facilitates trimming of the die and contouring of the wax pattern.

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video chips of crude design by today's standards, and the first optical impression of a cavity was obtained in 1982.

The resulting restorations had less than optimal adaptation and required substantial intraoral adjustment. Scanning technologies evolved in the subsequent decades, and the dimensional accuracy of optical scanning of tooth preparations is now comparable to or even better than conventional impression techniques.[82,83]

Subsequent improvements gradually led to wider application expanding from the initial optical capture of inlay preparations to onlays and veneers, and eventually to crowns and short-span partial fixed dental prostheses.

Although market penetration of digital impression technologies remains relatively modest, it has the potential to accelerate certain steps of the laboratory fabrication process. Digital impressions can be sent electronically to fabrication units in the dental office for chair-side fabrication of restorations for same-day delivery, or alternatively to off-site dental laboratories for fabrication of definitive fixed prostheses through conventional or digital means (see Chapter 25).

Types of Scanning Systems

Three dimensional scanning systems developed fairly wide acceptance well before becoming popular in dentistry. This technology found application in rapid prototyping for purposes of industrial design and is in use in the entertainment industries.

Scanners can be divided into contact and non-contact scanners. Contact scanning relies on physical contact of a probe with the object being copied. A simple example would be the mechanical device used to generate duplicates of keys. However, contact between the scanner's sensor and the object being scanned may cause damage to a fragile substrate. This renders contact scanners less useful for scanning of unique or costly items that are not readily replaceable, such as museum quality artifacts. Such concerns helped shift the focus to optical scanning, paving the path for optical scanning as we know it today in dentistry.

Non-contact scanners include radiation, ultrasound, and light. Dental scanners are three-dimensional light scanners that collect distance information for every pixel being captured. The purpose is to create a three-dimensional "point-cloud" that is refined into a virtual record of the three-dimensional structure that is recorded for further manipulation. Although early dental systems relied on single static scans, as the three-dimensional complexity of the object being scanned increases, multiple scans taken from many different directions are necessary to enable accurate computer renderings of the original object. Structured light scanners project a specific light pattern onto an object, and its sensors focus on distortions or deviations from that known pattern, using them to compute distance information.

Most dental scanners are triangulation scanners based on the same principles underlying the original technology developed in the 1970s.[84] A light source, typically a laser, shines onto an object and its reflection is captured by a sensor that is positioned slightly off-angle to the angle of the incident light. As the next laser beam is reflected by an adjacent location at a different distance to the light source, it is recorded in a different location on the sensor array (Fig. 14-40). It is this difference that is used to compute the difference in distance to the original source, and by inference the topography of the surface being scanned.

As scanner resolution evolved, it became possible to move the scanner head while capturing the data, as opposed to static scans that are "stitched together." This led to the development of contemporary intraoral scanners that can be moved around the tooth preparation and arch while gathering information. Trackers can be built into the scanner, or multiple cameras can be used to record ambient light from infrared LEDs to keep spatial records of the path traveled by such scanning heads. A record of the path traveled is needed to permit computation of the actual geometry of the substrate. Similarly, those data are used to compensate for inadvertent operator movement during the acquisition. Current scanning accuracy is in the range of 10 to 20 μm.

Light Reflection

Scanning accuracy depends in part on achieving a uniform surface reflection of the incident light. If the surface reflects unevenly or incompletely, accuracy will be affected.

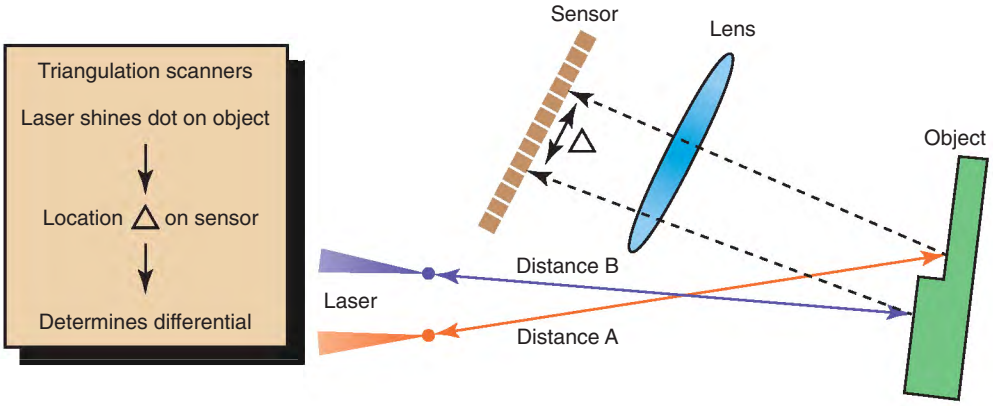

FIGURE 14-40 ■ How a triangulation scanner works.

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Optical scanners encounter some difficulty when scanning transparent or shiny objects such as teeth. Teeth scatter the incident light, some of the dispersed light travels laterally before re-emerging, and as a result, the reflected return to the sensor array is affected. Use of a thin layer of highly reflective powder (such as titanium oxide) is a means of compensating for this problem, but care is needed to prevent an unnecessary build-up of material, as accuracy of the scan can be affected. Powdering requires a dry field. One system (Planmeca PlanScan System, E4D Technologies) advocates the use of an accent liquid if difficulty in acquisition is encountered, typically on thin (translucent) enamel, or on reflective surfaces such as metallic restorations.

Active Wave-front Sampling

Dental scanning systems that use active wave-front sampling include the True Definition Scanner (Figure 14-41, 3M ESPE Dental).[85] The system uses a single lens to obtain the necessary information through complex proprietary algorithms.[84,86] The system has a small lightweight wand that allows one-handed scanning from multiple positions. Once the field is prepared, an experienced user can scan an arch in as little as 60 seconds.

Parallel Confocal Scanning

iTero Principle

In contrast with the laser scanners, one system uses a multitude (100,000) concurrent beams of red light. Its scanner head has sensors that force reflected light to pass through sensors preprogrammed to be reflected from specific distances. Only light reflected at a known distance will pass through the filtering device and be used to compute the geometry of the substrate. The illustrated system captured 1,000,000 points at 200 focal depths 50 µm apart. Its telecentric system is said not to require powdering.

FIGURE 14-41 ■ The 3M True Definition Scanner uses active wavefront sampling to obtain an accurate scan of the prepared tooth. (Courtesy 3M ESPE Dental, St. Paul, Minnesota).

Architecture of Captured Data

The computer files generated on completion of the scan have either an open or closed format. Open systems present the data in an industry standardized format that permits the data to be interpreted independent of a given manufacturer, although the dental laboratory may require information technology support to initially develop its software interface.

Closed architecture files are manufacturer linked and proprietary data files, requiring that subsequent fabrication steps of prostheses are performed solely with compatible software and equipment from the same manufacturer.

Optical Impression Units

Chairside optical impression units typically consist of a computer with screen attached to a mobile base. The optical scanning wand is used for the intraoral capture, and some systems (Figure 14-42) permit direct visualization of the intraoral target that is to be acquired as the three dimensional rendering is in progress.

SUMMARY

An impression or negative likeness of the teeth and surrounding structures is used to obtain a cast, on which the planned restoration is fabricated. A good impression is an exact negative replica of each prepared tooth and must include all of the prepared surfaces and an adequate amount of unprepared tooth structure adjacent to the margin.

Healthy soft tissues and the control of saliva flow are essential for a successful impression. However, caution must be exercised to prevent injury to the gingiva. Cotton rolls, cards, and saliva evacuators are needed for adequate moisture control. Use of a local anesthetic to minimize discomfort and to reduce saliva flow during the impression procedure is recommended.

FIGURE 14-42 ■ Optical impression being generated.

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Mechanical, chemical, and surgical methods for enlargement of the gingival sulcus can be used to obtain access to subgingival margins of prepared teeth. However, a narrow cord impregnated with a mild astringent (e.g., $AlCl_3$) is recommended. To protect the smear layer, excessive contact between hemostatic agents and cut tooth structure should be avoided.

A custom acrylic resin tray should be used when making an impression with any of the elastomeric materials. All impression materials should be rinsed, dried, and disinfected when removed from the mouth. Impressions made with polysulfide polymer should be poured within 1 hour. Impressions made with polyether or addition silicone have high dimensional stability and can be stored considerably longer before pouring. When making pin-retained restorations, a cement tube, lentulo, or nylon bristle is needed for an accurate impression of the pinholes or post spaces. In this technique and others, a good impression is crucial for an accurately fitting restoration.

REFERENCES

1. McCormick JT, et al: Wettability of elastomeric impression materials: effect of selected surfactants. Int J Prosthod 2:413, 1989.
2. Kissov HK, Chalashkanova MI: The impression as a means for analysis of clinical mistakes in fixed prosthodontics. Folia Med (Plovdiv) 43(1-2):84, 2001.
3. Council on Dental Therapeutics, American Dental Association: Accepted dental therapeutics, 38th ed, p 247. Chicago, American Dental Association, 1979.
4. Sherman CR, Sherman BR: Atropine sulfate: a current review of a useful agent for controlling salivation during dental procedures. Gen Dent 47:56, 1999.
5. Findlay D, Lawrence JR: An alternative method of assessing changes in salivary flow: comparison of the effects of clonidine and tiamenidine (HOE 440). Eur J Clin Pharmacol 14:231, 1978.
6. Wilson EL, et al: Effects of methantheline bromide and clonidine hydrochloride on salivary secretion. J Prosthet Dent 52:663, 1984.
7. Baba NZ, et al: Gingival displacement for impression making in fixed prosthodontics: contemporary principles, materials, and techniques. Dent Clin North Am 58:45, 2014.
8. Bennani V, et al: Comparison of pressure generated by cordless gingival displacement materials. J Prosthet Dent 112(2):163, 2014.
9. Acar O, et al: A clinical comparison of cordless and conventional displacement systems regarding clinical performance and impression quality. J Prosthet Dent 111:388, 2014.
10. Laufer BZ, et al: The closure of the gingival crevice following gingival retraction for impression making. J Oral Rehabil 24:629, 1997.
11. Bowles WH, et al: Evaluation of new gingival retraction agents. J Dent Res 70:1447, 1991.
12. Land MF, et al: Disturbance of the dentinal smear layer by acidic hemostatic agents. J Prosthet Dent 72:4, 1994.
13. Land MF, et al: Smear layer instability caused by hemostatic agents. J Prosthet Dent 76:477, 1996.
14. Rosenstiel SF, Rashid RG: Postcementation hypersensitivity: scientific data versus dentists' perceptions. J Prosthodont 12:73, 2003.
15. Pelzner RB, et al: Human blood pressure and pulse rate response to racemic epinephrine retraction cord. J Prosthet Dent 39:287, 1978.
16. Jokstad A: Clinical trial of gingival retraction cords. J Prosthet Dent 81:258, 1999.
17. Hansen PA, et al: Current methods of finish-line exposure by practicing prosthodontists. J Prosthodont 8:163, 1999.
18. Cranham JC: Tips from the lab: predictable impressioning. Dent Equip Mater (May-June):46, 2003.
19. Sarmento HR, et al: A double-blind randomised clinical trial of two techniques for gingival displacement. J Oral Rehabil 41:306, 2014.
20. Feinmann BPP, Martignoni M: Material and method for dentistry. Washington, D.C., U.S. Patent Office, Publication No. US4677139A, June 30, 1987.
21. LaForgia A: Cordless tissue retraction for impressions for fixed prosthesis. J Prosthet Dent 17(4):379, 1967.
22. Livaditis GJ: The matrix impression system for fixed prosthodontics. J Prosthet Dent 79:208, 1998.
23. Harris HS: Electrosurgery in dental practice. Philadelphia, JB Lippincott, 1976.
24. Gnanasekhar JD, al-Duwairi YS: Electrosurgery in dentistry. Quintessence Int 29:649, 1998.
25. Louca C, Davies B: Electrosurgery in restorative dentistry. I. Theory. Dent Update 19:319, 1992.
26. Louca C, Davies B: Electrosurgery in restorative dentistry. II. Clinical applications. Dent Update 19:364, 1992.
27. Podshadley AG, Lundeen HC: Electrosurgical procedures in crown and bridge restorations. J Am Dent Assoc 77:1321, 1968.
28. Maness WL, et al: Histologic evaluation of electrosurgery with varying frequency and waveform. J Prosthet Dent 40:304, 1978.
29. DeVitre R, et al: Biometric comparison of bur and electrosurgical retraction methods. J Prosthet Dent 53:179, 1985.
30. Walter C: Dental treatment of patients with cardiac pacemaker implants. Quintessence Int 8:57, 1975.
31. Dawes JC, et al. Electrosurgery in patients with pacemakers/implanted cardioverter defibrillators. Ann Plast Surg 57:33, 2006.
32. Krejci RF, et al: Effects of electrosurgery on dog pulps under cervical metallic restorations. Oral Surg 54:575, 1982.
33. Parker S: The use of lasers in fixed prosthodontics. Dent Clin North Am 48:971, 2004.
34. Scott A. Use of an erbium laser in lieu of retraction cord: a modern technique. Gen Dent 53:116, 2005.
35. Gherlone EF, et al: The use of 980-nm diode and 1064-nm Nd:YAG laser for gingival retraction in fixed prostheses. J Oral Laser Appl 4:183, 2004.

35a. Schoinohoriti OK, Chrysomali E, Iatrou I, et al: Evaluation of lateral thermal damage and reepithelialization of incisional wounds created by CO2-laser, monopolar electrosurgery, and radiosurgery: a pilot study on porcine oral mucosa. Oral Surg Oral Med Oral Pathol Oral Radiol 113:741-747, 2012.

36. Tjan AH, et al: Clinically oriented evaluation of the accuracy of commonly used impression materials. J Prosthet Dent 56:4, 1986.
37. Setz J, et al: Profilometric studies on the surface reproduction of dental impression materials. Dtsch Zahnarztl Z 44:587, 1989.
38. Luebke RJ, et al: The effect of delayed and second pours on elastomeric impression material accuracy. J Prosthet Dent 41:517, 1979.
39. Eames WB, et al: Elastomeric impression materials: effect of bulk on accuracy. J Prosthet Dent 41:304, 1979.
40. Cullen DR, Sandrik JL: Tensile strength of elastomeric impression materials, adhesive and cohesive bonding. J Prosthet Dent 62:142, 1989.
41. Herfort TW, et al: Tear strength of elastomeric impression materials. J Prosthet Dent 39:59, 1978.
42. Hondrum SO: Tear and energy properties of three impression materials. Int J Prosthodont 7:517, 1994.
43. Harcourt JK: A review of modern impression materials. Aust Dent J 23:178, 1978.
44. Fusayama T, et al: Accuracy of the laminated single impression technique with silicone materials. J Prosthet Dent 32:270, 1974.
45. Tjan AH: Effect of contaminants on the adhesion of light-bodied silicones to putty silicones in putty-wash impression technique. J Prosthet Dent 59:562, 1988.
46. Henry PJ, Harnist DJR: Dimensional stability and accuracy of rubber impression materials. Aust Dent J 19:162, 1974.
47. Mansfield MA, Wilson HJ: Elastomeric impression materials: a method of measuring dimensional stability. Br Dent J 139:267, 1975.
48. Nally FF, Storrs J: Hypersensitivity to a dental impression material: a case report. Br Dent J 134:244, 1973.

48a. Mittermüller P, Szeimies RM, Landthaler M, et al: A rare allergy to a polyether dental impression material. Clin Oral Investig 16:1111-1116, 2012.

49. Lacy AM, et al: Time-dependent accuracy of elastomer impression materials. II. Polyether, polysulfides, and polyvinylsiloxane. J Prosthet Dent 45:329, 1981.
50. Sivers JE, Johnson GK: Adverse soft tissue response to impression procedures: report of a case. J Am Dent Assoc 116:58, 1988.
51. Peregrina A, et al: Effect of two types of latex gloves and surfactants on polymerization inhibition of three polyvinylsiloxane impression materials. J Prosthet Dent 90:289, 2003.

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52. Al-Sowygh ZH: The effect of various interim fixed prosthodontic materials on the polymerization of elastomeric impression materials. J Prosthet Dent 112(2):176, 2014.
53. Tseng KC, et al: Effect of dithiocarbamate on polymerization of polyvinylsiloxane impression materials [Abstract 1645]. Presented at American Association of Dental Research/International Association of Dental Research Annual Session, Baltimore, March 9-12, 2005.
54. Kimoto K, et al: Indirect latex glove contamination and its inhibitory effect on vinyl polysiloxane polymerization. J Prosthet Dent 93:433, 2005.
55. Matis BA, et al: The effect of the use of dental gloves on mixing vinyl polysiloxane putties. J Prosthodont 6:189, 1997.
56. Boening KW, et al: Clinical significance of surface activation of silicone impression materials. J Dent 26:447, 1998.
57. Pratten DH, Craig RG: Wettability of a hydrophilic addition silicone impression material. J Prosthet Dent 61:197, 1989.
58. Oda Y, et al: Evaluation of dimensional stability of elastomeric impression materials during disinfection. Bull Tokyo Dent Coll 36:1, 1995.
59. Millar BJ, et al: In vitro study of the number of surface defects in monophase and two-phase addition silicone impressions. J Prosthet Dent 80:32, 1998.
60. Nassar U, et al: An in vitro study on the dimensional stability of a vinyl polyether silicone impression material over a prolonged storage period. J Prosthet Dent 109:172, 2013.
61. Peregrina A, et al: The effect of different adhesives on vinyl polysiloxane bond strength to two tray materials. J Prosthet Dent 94:209, 2005.
62. Millstein P, et al: Determining the accuracy of stock and custom tray impression/casts. J Oral Rehabil 25:645, 1998.
63. Gordon GE, et al: The effect of tray selection on the accuracy of elastomeric impression materials. J Prosthet Dent 63:12, 1990.
64. Martinez LJ, von Fraunhofer JA: The effects of custom tray material on the accuracy of master casts. J Prosthodont 7:106, 1998.
65. Wirz J, et al: Light-polymerized materials for custom impression trays. Int J Prosthod 3:64, 1990.
66. Bindra B, Heath JR: Adhesion of elastomeric impression materials to trays. J Oral Rehabil 24:63, 1997.
67. Burton JF, et al: The effects of disposable and custom-made impression trays on the accuracy of impressions. J Dent 17:121, 1989.
68. Pagniano RP, et al: Linear dimensional change of acrylic resins used in the fabrication of custom trays. J Prosthet Dent 47:279, 1982.
69. McCabe JF, Carrick TE: Rheological properties of elastomers during setting. J Dent Res 68:1218, 1989.
70. Chong YH, et al: The effect of mixing method on void formation in elastomeric impression materials. Int J Prosthod 2:323, 1989.
71. Wilson EG, Werrin SR: Double arch impressions for simplified restorative dentistry. J Prosthet Dent 49:198, 1983.
72. Donovan TE, Chee WWL: A review of contemporary impression materials and techniques. Dent Clin North Am 48:445, 2004.
73. Johnson GH, et al: Clinical trial investigating success rates for polyether and vinyl polysiloxane impressions made with full-arch and dual-arch plastic trays. J Prosthet Dent 103:13, 2010.
74. Ceyhan JA, et al: The effect of tray selection, viscosity of impression material, and sequence of pour on the accuracy of dies made from dual-arch impressions. J Prosthet Dent 90:143, 2003.
75. Wöstmann B, et al: Accuracy of impressions obtained with dual-arch trays. Int J Prosthodont 22:158, 2009.
76. Drennon DG, et al: The accuracy and efficacy of disinfection by spray atomization on elastomeric impressions. J Prosthet Dent 62:468, 1989.
77. Drennon DG, Johnson GH: The effect of immersion disinfection of elastomeric impressions on the surface detail reproduction of improved gypsum casts. J Prosthet Dent 63:233, 1990.
78. Estafanous EW, et al: Disinfection of bacterially contaminated hydrophilic PVS impression materials. J Prosthodont 21:16, 2012.
79. Carvalhal CI, et al: Dimensional change of elastomeric materials after immersion in disinfectant solutions for different times. J Contemp Dent Pract 12:252, 2011.
80. McLaren E. CAD/CAM dental technology. Compend Contin Educ Dent 32:73, 2011.
81. Mörmann WH. The evolution of the CEREC system. J Am Dent Assoc 137(Suppl):7S, 2006.
82. Tidehag P, et al: Accuracy of ceramic restorations made using an in-office optical scanning technique: an in vitro study. Oper Dent 39:308, 2014.
83. Ng J, et al: A comparison of the marginal fit of crowns fabricated with digital and conventional methods. J Prosthet Dent 112:555, 2014.
84. Mayer R: Scientific Canadian: invention and innovation from Canada's National Research Council. Vancouver, B.C., Raincoast Books, 1999.
85. Rohaly J, et al: Three-channel camera systems with non-collinear apertures. Washington, D.C., U.S. Patent Office, Publication No. US7372642 B2, May 13, 2008.
86. Kachalia PR, Geissberger MJ: Dentistry a la carte: in-office CAD/CAM technology. J Calif Dent Assoc 38:323, 2010.

STUDY QUESTIONS

1. Discuss the prerequisites to successful and predictable impression making with elastomeric impression materials.

2. Discuss three ways to ensure access to prepared tooth structure for impression making. What are the respective indications and contraindications?

3. Name three classes of impression materials for fixed prosthodontics, and discuss their advantages and disadvantages. Illustrate their indicated use with three clinical scenarios.

4. Describe 10 issues to consider before electrosurgery is implemented.

5. What are the requirements for a successful custom impression tray?

6. Disinfection techniques vary among materials. Select three classes of impression material and illustrate how the respective disinfection techniques change for each.

7. Explain the principle underlying triangulation scanning.

8. What is the difference between open and closed architecture of optically scanned impression data?

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CHAPTER 15

Interim Fixed Restorations

Anthony G. Gegauff • Julie A. Holloway

Interim crowns or interim partial fixed dental prostheses (FDPs) are essential in prosthodontic therapy. The word *interim* means established for the time being, pending a permanent arrangement. Even though a definitive restoration may be placed as quickly as a few weeks after tooth preparation, the interim restoration must satisfy important needs of the patient and dentist. Unfortunately, *temporary* usually connotes laxity. If this becomes a philosophy governing the interim phase of treatment, clinical efficiency and treatment quality will be adversely affected. Experience has repeatedly shown that time and efforts expended in fulfilling the requirements of interim fixed restorations are well spent.

Because of unforeseen events (e.g., laboratory delays or patient unavailability), an interim restoration may have to function for an extended period. For other patients, a delay in placing the definitive restoration may be intentional (e.g., because the etiologic factors of a temporomandibular disorder or periodontal disease must be corrected). Whatever the intended length of treatment time, an interim restoration must be adequate to maintain patient health. Thus it should not be casually fabricated on the basis of an expected short term of use.

Interim procedures also must be performed efficiently because they are made during the same appointment that the teeth are prepared. Costly chairside time must not be wasted, and yet the dentist must produce an acceptable restoration. Failure to do so results in the eventual loss of more time than was initially thought saved. For example, an inadequate restoration may necessitate repairs that were previously unnecessary or result in the need to treat gingival inflammation and remake an elastomeric impression. Such problems can be avoided if the dentist thoroughly understands what is required of the interim restoration and makes the effort to meet these requirements.

REQUIREMENTS

An optimum interim fixed restoration must satisfy many interrelated factors, which can be classified as biologic, mechanical, and esthetic (Fig. 15-1).

Biologic Requirements

Pulpal Protection

An interim fixed restoration must seal and insulate the prepared tooth surface from the oral environment to prevent sensitivity and further irritation of the pulp. A certain degree of pulp trauma is inevitable during tooth preparation because of the sectioning of dentinal tubules (Fig. 15-2). In health, each tubule contains the cytoplasmic process of a cell body (the odontoblast), whose nucleus is in the pulp cavity. Unless the environment around the exposed dentin is carefully controlled, adverse pulp effects can be expected.[1] In addition, pulpal health of a tooth requiring a cast restoration is likely to be compromised before and after preparation (Table 15-1). In severe situations, leakage can cause irreversible pulpitis, with the consequent need for root canal treatment.[2]

Periodontal Health

To facilitate plaque removal, an interim restoration must have good marginal fit, proper contours, and smooth surfaces. This is particularly important when the crown margin is placed intrasulcularly.[3] If the interim fixed restoration is inadequate and plaque control is impaired, gingival health deteriorates.[4]

The maintenance of good gingival health is always desirable, but it has special practical significance when fixed prosthodontic treatment is undertaken. Inflamed or hemorrhagic gingival tissues during treatment make subsequent procedures (e.g., impression making and cementation) very difficult. The longer the interim fixed restoration must serve, the more significant any deficiencies in its fit and contour become (Fig. 15-3). When gingival tissue is impinged on, ischemia is likely to develop, detected initially as tissue blanching. If it is not corrected, a localized inflammation or necrosis can develop.

Occlusal Compatibility and Tooth Position

The interim restoration should establish or maintain proper contacts with adjacent and opposing teeth (Fig. 15-4). Inadequate contacts allow supraeruption and horizontal movement. Such supraeruption is detected at the evaluation appointment, when the definitive restoration makes premature contact. It is sometimes possible to correct this in the operating room, but the effort is time consuming and the resulting restoration often has poor occlusal form and function. If supraeruption is severe, it may be necessary to reprepare the tooth and make a new impression. Horizontal movement results in excessive or deficient proximal contacts. The former necessitate tedious chairside adjustment; the latter involve a laboratory procedure to add metal or ceramic to the deficient site. In spite of these efforts, proximal crown contours are distorted. This distortion, along with resulting root proximity (Fig. 15-5), can impair oral hygiene measures.

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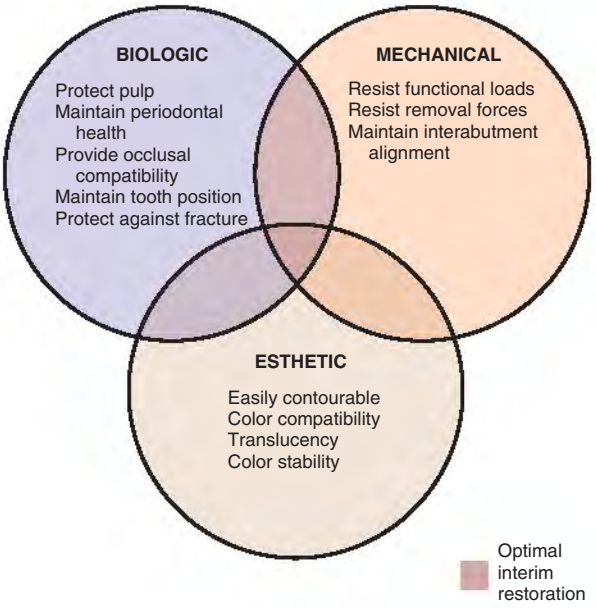

FIGURE 15-1 ■ Factors to be considered in making an interim restoration. The *central area* represents the optimum, in which biologic, mechanical, and esthetic requirements are adequately met.

FIGURE 15-2 ■ Pulp trauma and exposure of the dentinal tubules from tooth preparation.

Rough margins around interim restorations will jeopardize subsequent procedures.

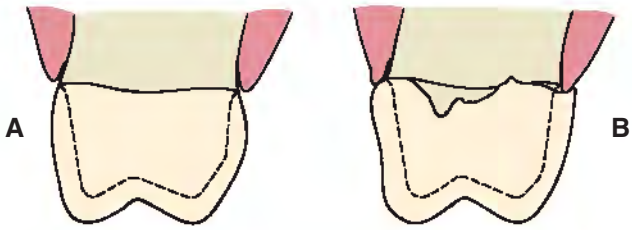

FIGURE 15-3 ■ An interim restoration should have good marginal fit, proper contour, and a smooth surface finish. **A,** A properly contoured interim restoration. It is smoothly continuous with the external surface of the tooth. **B,** Overcontouring. The transition from the restoration to the root surface is irregular, and marginal adaptation is inadequate. These contribute to plaque accumulation and an unhealthy periodontium.

If an interim restoration does not ensure positional stability, tooth movement can occur, and additional treatment will be necessary.

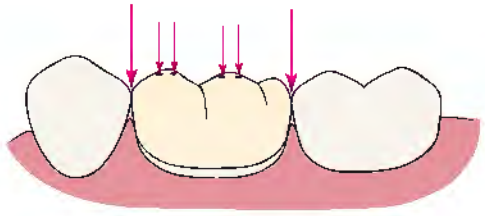

FIGURE 15-4 ■ Proper occlusal and proximal contacts promote patient comfort and maintain tooth position.

TABLE 15-1 **Factors Contributing to Pulp Death**

Past	Present (during Fixed Prosthodontic Therapy)
Caries	Preparation trauma
Operative dentistry	Microbial exposure
Bruxism	Desiccation
Periodontal surgery	Chemical exposure
Prosthodontic therapy	Thermal exposure

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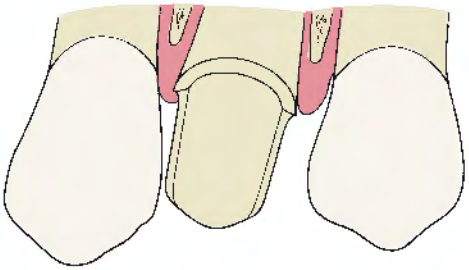

FIGURE 15-5 ■ A missing proximal contact allows tooth migration. The resulting root proximity may necessitate surgical or orthodontic correction to allow impression making.

FIGURE 15-6 ■ The interim restoration must protect the tooth. Fracture of a tooth after the impression phase delays treatment and jeopardizes restorability.

Prevention of Enamel Fracture

The interim fixed restoration should protect teeth weakened by crown preparation (Fig. 15-6). This is particularly true with partial coverage designs, in which the margin of the preparation is close to the occlusal surface of the tooth and could be damaged during chewing. Even a small chip of enamel will render the definitive restoration unsatisfactory and necessitate a time-consuming remake.

Mechanical Requirements

Function

The greatest stresses in an interim fixed restoration occur during mastication. Unless the patient avoids contacting the prosthesis when eating, internal stresses are similar to those occurring in the definitive restoration. However, the strength of polymethyl methacrylate (PMMA) resin is about one-twentieth that of metal-ceramic alloys,[5] and thus the interim fixed restoration is much more likely to fracture. Fracture is not usually a problem with a complete crown interim restoration, as long as the tooth has been adequately reduced (Fig. 15-7). More frequently, breakage occurs with partial-coverage interim restorations and partial FDPs. Partial-coverage restorations are inherently weaker because they do not completely encircle the tooth.

A partial FDP must function as a beam in which substantial occlusal forces are transmitted to the abutments. This creates high stresses in the connectors,[6] which are commonly the sites of failure. To reduce the risk of failure, connector size is increased in the interim restoration in comparison with the definitive restoration (Fig. 15-8). Greater strength is achieved by reductions in the depth and sharpness of the embrasures. These reductions increase the cross-sectional area of the connector while reducing the stress concentration associated with sharp internal line angles. The biologic and sometimes the esthetic requirements place limits on just how much larger connectors can be made. To avoid jeopardizing periodontal health, they should not be overcontoured near the gingiva (Fig. 15-9). Good access for plaque control must be a high priority.

FIGURE 15-7 ■ This acrylic interim crown fractured. The interocclusal record between the preparation and its antagonist shows that the preparation was underreduced.

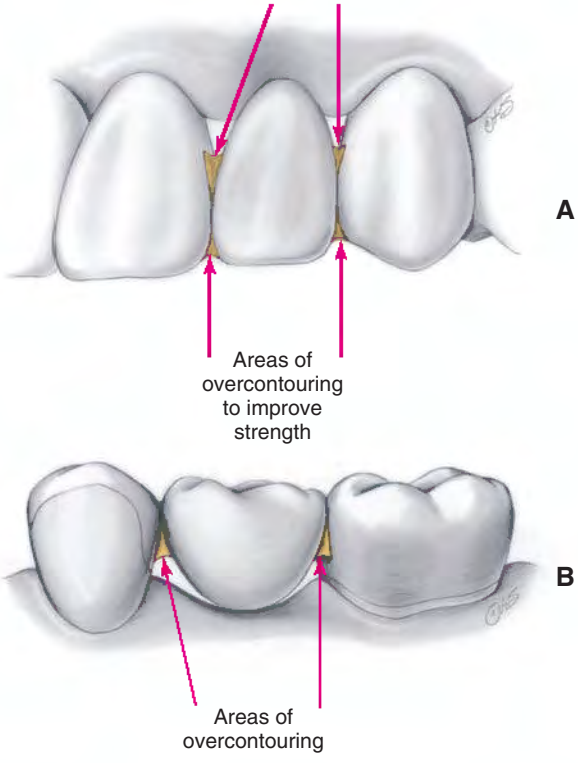

FIGURE 15-8 ■ The connectors of an interim fixed dental prosthesis are often purposely overcontoured. **A,** In the anterior region, the degree of overcontouring is substantially limited by esthetic requirements. **B,** In the posterior region, esthetics is less restrictive, but overcontouring still must not jeopardize the maintenance of periodontal health.

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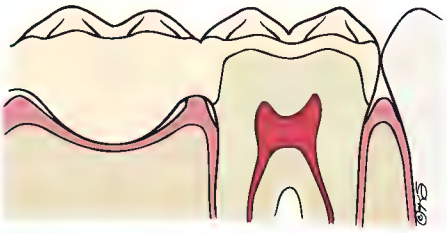

FIGURE 15-9 ■ In this mesiodistal section, an overcontoured connector impinges on the gingiva. Pressure ischemia and poor access for plaque removal promote gingivitis.

BOX 15-1 Indications for Fiber-reinforced Interim Restorations

A long-span posterior partial fixed dental prosthesis
Prolonged treatment time
Patient's inability to avoid excessive forces on the prosthesis
Above-average masticatory muscle strength
History of frequent breakage

In some instances, fiber-reinforced, heat-processed resin or cast metal interim restorations can spare the practitioner and the patient inconvenience, lost time, and the expense of remaking a restoration (Box 15-1).

Displacement

If pulp irritation and tooth movement are to be avoided, a displaced interim restoration must be recemented promptly. An additional office visit is usually required, which results in considerable inconvenience for both patient and dentist. Displacement is best prevented through proper tooth preparation and an interim restoration with a closely adapted internal surface. Excessive space between the restoration and the tooth places greater demands on the luting agent, which has lower strength than regular cement and thus cannot withstand the added force. For this and for biologic reasons, unlined preformed crowns should be avoided.

Removal for Reuse

Interim restorations often need to be reused and so should not be damaged when removed from the teeth at the subsequent appointment. In most instances, if the cement is sufficiently weak and the interim restoration has been well fabricated, it does not break upon removal.

Esthetic Requirements

The appearance of an interim fixed restoration is particularly important for incisors, canines, and sometimes premolars. Although it may not be possible to duplicate the appearance of an unrestored natural tooth exactly, the tooth contour, color, translucency, and texture are essential attributes. When necessary, esthetic enhancement procedures are available to create personalized details; however, because these are not routinely called for, they are addressed in "Esthetic Enhancement," after the discussion of cementation and repair.

An essential requirement of prosthodontic treatment is that a material matches the color of adjacent teeth initially. However, some resins discolor with time intraorally,[7] and thus color stability (along with the propensity for stain accumulation) governs the selection of materials when a long period of service is anticipated.

The interim restoration is often used as a guide to achieve optimum esthetics in the definitive restoration. In complete denture prosthodontic treatment, it is customary to have a wax evaluation so that the patient can respond to the dentist's esthetic interpretation before the denture is processed. Many dentists consider this essential because of the frequency of patients' requests for changes and the ease with which such changes can be made. Fixed prosthodontic treatment in the anterior oral cavity greatly influences appearance, and the patient should be given an opportunity to voice an opinion. Beauty and personal appearance are highly subjective and difficult to communicate verbally, and a facsimile prosthesis can play a vital role in the patient's consideration of esthetics and the effect that the prosthesis has on his or her self-image. Obtaining the opinions of others whose judgment is valued is also important. An accurate interim restoration is a practical way of obtaining specific feedback for the design of a definitive restoration. Word descriptions alone are often too vague and frequently lead to overcorrections, which are difficult or impossible to reverse in the definitive restoration. The interim restoration is shaped and modified until its appearance is mutually acceptable to dentist and patient. When this is achieved, an impression is made of the interim restoration (Fig. 15-10), and a cast is poured. This cast accompanies the fixed prosthodontic work order to the laboratory, where the contours are then replicated in the definitive restoration. This process is most efficient when it begins with diagnostic waxing procedures. Involving the patient in decision making increases the patient's satisfaction.

MATERIALS AND PROCEDURES

Many procedures involving a wide variety of materials are available to make satisfactory interim restorations (Fig. 15-11). As new materials are introduced, associated techniques are reported, and thus there is even more variety. In all the procedures, a mold cavity is formed, into which a plastic material is poured or packed. Furthermore, the mold cavity is created by two correlated parts: one forming the external contour of the crown or FDP, the other forming the prepared tooth surfaces and (when present) the edentulous ridge contact area. The terms *external surface form* (ESF) and *tissue surface form* (TSF) are suggested for these mold parts. These terms are used in the ensuing discussions.

External Surface Form

There are two general categories of ESFs: custom and preformed.

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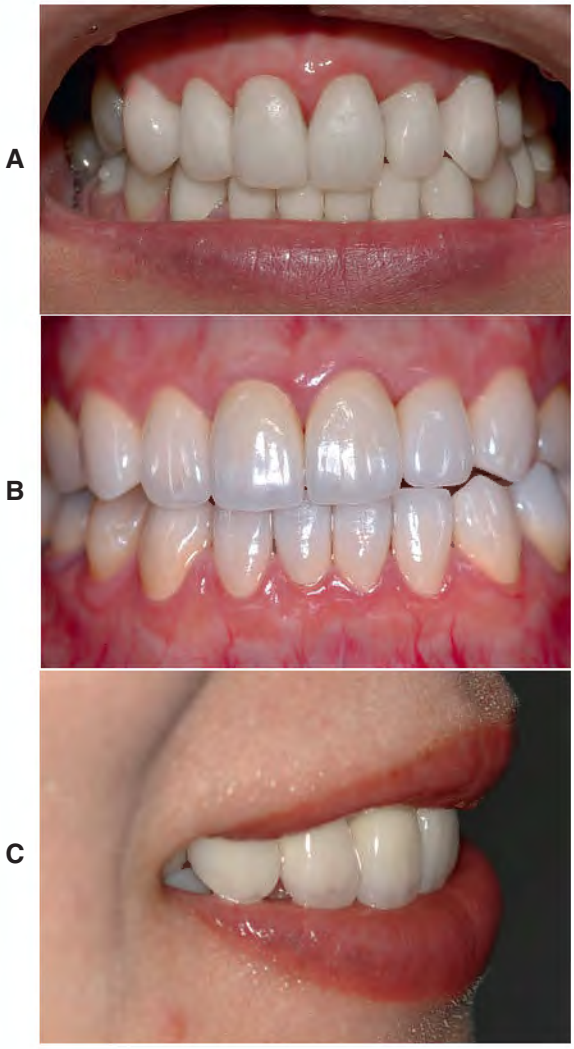

FIGURE 15-10 ■ **A,** This interim dental prosthesis was used to establish anterior guidance, incisal edge position, proper phonetics, and function before work on the definitive prostheses began. **B** and **C,** The definitive restorations closely match their interim predecessors in form and function.

Custom

A custom ESF is a negative reproduction of either the patient's teeth before preparation or a modified diagnostic cast. It may be obtained directly with any impression material. Impressions made in a quadrant tray with irreversible hydrocolloid or silicone are convenient. The higher cost of addition silicone may be offset by its ability to be retained for possible reuse at any future appointment. Accurate reseating of the ESF is easier, and the mold cavity produces better results, if thin areas of impression material (as may be found interproximally or around the gingival margin) are trimmed away (Fig. 15-12). The moldable putty materials are popular because they can be used without a tray and are easily trimmed to minimum size with a sharp knife. Also, their flexibility facilitates subsequent removal of the polymerized resin (Fig. 15-13).

A custom ESF can be produced from thermoplastic sheets, which are heated and adapted to a stone cast with vacuum or air pressure while the material is still pliable (Fig. 15-14). This produces a transparent form with thin walls, which makes it advantageous in the direct technique because of its minimum interference with the occlusion. It is filled with resin, placed in the mouth, and fully seated as the patient closes the jaws into maximum intercuspation. Little additional effort is then required to adjust the occlusal contacts. The thinness of the material, however, may also be a disadvantage in the direct technique. The material is a poor dissipater of the heat released during resin polymerization, and so care must be taken to remove it from the mouth before potential thermal injury can occur. A thermoplastic ESF has other uses in fixed prosthodontic treatment, in both the clinical and the laboratory phase; for example, it can be helpful in evaluating the adequacy of tooth reduction[8,9] (Fig. 15-15).

Transparent sheets are available in cellulose acetate or polypropylene of various sizes and thicknesses; a 125 × 125 mm sheet of 0.5-mm (0.020-inch) thickness is recommended for making interim restorations. Polypropylene is preferred because it produces better surface detail and is more tear resistant. Better tear resistance makes initial removal from the forming cast less tedious and enables the ESF to be used more than once.

Although thermoplastic sheets have a number of advantages, a wide variety of other materials and methods can be used successfully. For example, some practitioners favor baseplate wax because it is convenient and economical (see Fig. 15-11, *B*), although it is usually not adapted easily with a high degree of precision; additional adjustment time is required.

Preformed

Various preformed crowns are available commercially. On their own, they rarely satisfy the requirements of an interim restoration, but they can be thought of as ESFs rather than as finished restorations and thus must be lined with autopolymerizing resin. Most crown forms need some modification (internal relief, axial recontouring, occlusal adjustment) in addition to the lining procedure (Fig. 15-16). When extensive modification is required, a custom ESF is superior because it is less time consuming. Preformed crowns are generally limited to use as single restorations because it is not feasible to use them as pontics for partial FDPs.

Materials from which preformed ESFs are made (Fig. 15-17) include polycarbonate, cellulose acetate, aluminum, tin-silver, and nickel-chromium. These are available in a variety of tooth types and sizes (Table 15-2).

Polycarbonate. Polycarbonate (Fig. 15-18) has the most natural appearance of all the preformed materials. When properly selected and modified, it rivals a well-executed porcelain restoration in appearance. Although it is available in only a single shade, this can be modified to a limited extent by the shade of the lining resin. Polycarbonate ESFs are supplied in incisor, canine, and premolar tooth types.

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FIGURE 15-11 ■ Although there are many variations, molds used in making interim restorations consist of an external surface form (ESF) and a tissue surface form (TSF). Direct techniques entail use of the patient's mouth directly as the TSF. **A,** Indirect technique: ESF is an alginate impression; TSF, a quick-set plaster cast. **B,** Direct technique: ESF is a baseplate wax impression; TSF, the patient. **C,** Direct technique: ESF is a vacuum-formed acetate sheet; TSF, the patient. **D,** Direct technique: ESF is a polycarbonate preformed shell; TSF, the patient. **E,** Indirect-direct technique: ESF is a custom preformed three-unit fixed dental prosthesis shell (maxillary right central incisor to canine) made indirectly; TSF, the patient. **F,** Indirect technique: ESF is a silicone putty impression; TSF, a quick-set plaster cast of the preparations.

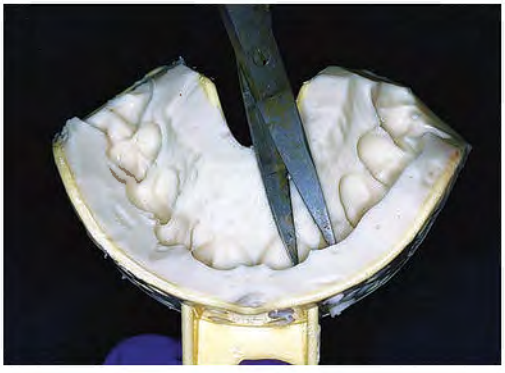

FIGURE 15-12 ■ Shortening proximal projections of the impression material facilitates complete reseating of the ESF. Note that excess impression material palatally and facially has been trimmed away with a sharp knife for this reason. The anterior sextant tray shown was selected because it adequately captures the teeth adjacent to the proposed interim restoration.

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FIGURE 15-13 ■ **A,** One of the flexible silicone putties suitable for making external surface forms. **B,** The putty form has been spread apart. Note the completed resin interim restoration in place, to demonstrate the degree of putty flexibility.

FIGURE 15-14 ■ **A,** Inexpensive system for producing external surface forms from thermoplastic sheets. **B,** After heating, the sheet is formed with reusable putty and finger pressure applied over a stone cast. **C,** More expensive system incorporating an electric heating element and a vacuum source. **D,** Trimmed polypropylene external surface form. Note the detail that can be captured with this material.

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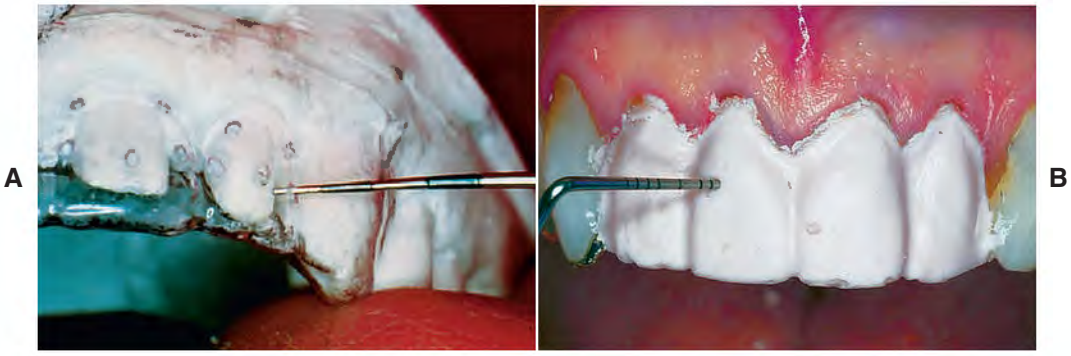

FIGURE 15-15 ■ **A,** The thinness and transparency of these external surface forms (ESFs) allow their use directly as tooth-reduction guides both in and out of the mouth. **B,** The dentist may assess tooth reduction by using the ESF to mold alginate over the prepared tooth. When the alginate is set, the ESF is removed, and a periodontal probe is pushed through the alginate for measurements at desired locations. (**B,** Courtesy Dr. T. Roongruangphol.)

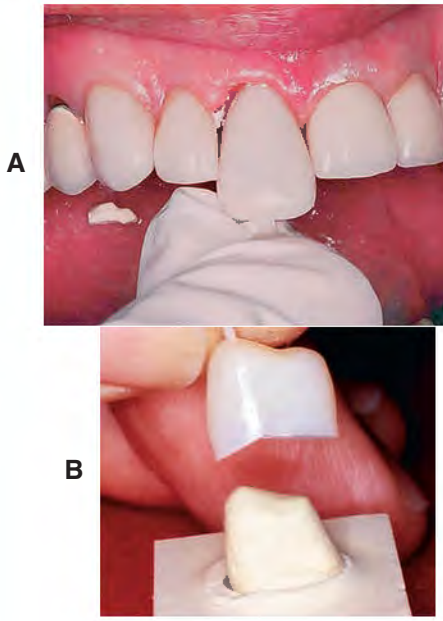

FIGURE 15-16 ■ **A,** The time necessary to modify this particular preformed crown outweighs the advantages it might provide. A custom external surface form, if available, would be more efficient and more economical. **B,** The internal lingual wall of this preformed crown is tapered excessively, which necessitates grinding in order to accommodate a properly prepared tooth. The stone cast in the lower portion of the illustration duplicates the internal surface of the preformed crown.

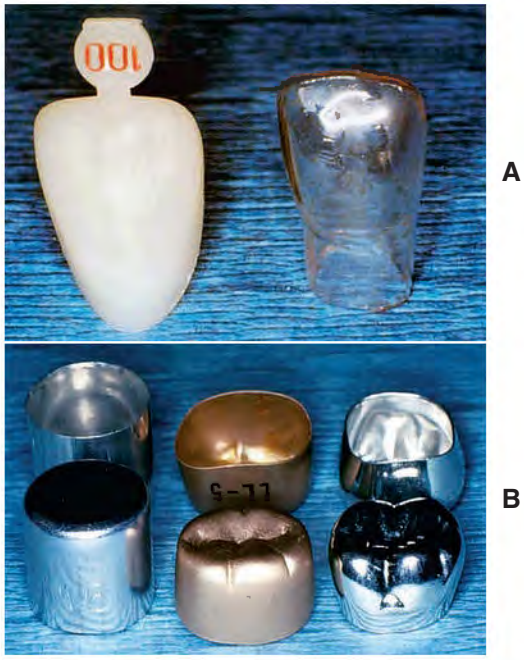

FIGURE 15-17 ■ **A,** Preformed anterior crown forms: polycarbonate (left) and cellulose acetate (right). **B,** Preformed posterior crown forms: aluminum shell (left), aluminum anatomic (center), and tin-silver anatomic (right).

TABLE 15-2 **Preformed Crowns**

Material	Area of Use				SIZES IN EACH MOLD	APPROXIMATE COST ($/UNIT)
	INCISOR	CANINE	PREMOLAR	MOLAR		
Resin						
Cellulose acetate	X	X	X	X	6	1.83
Photopolymerized composite resin		X	X	X	2	11.52
Polycarbonate	X	X	X		7	1.11
Metal						
Aluminum			X	X	20	0.24
Aluminum (anatomic)			X	X	6	5.45
Aluminum (tooth colored)			X	X	6	4.60
Tin-silver (anatomic)			X	X	7	5.20
Stainless steel (anatomic)	X*	X*	X	X	5	7.17

*Primary teeth.

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FIGURE 15-18 ■ Polycarbonate crowns. They are available in maxillary and mandibular incisor, canine, and premolar shapes.

FIGURE 15-19 ■ Aluminum anatomic crowns. They are available in a variety of sizes and shapes. The manufacturer has produced two maxillary and four mandibular shapes for the left and right side of the mouth, each in six sizes.

Cellulose Acetate. Cellulose acetate is a thin (0.2- to 0.3-mm), transparent material available in all tooth types and a range of sizes (see Fig. 15-17, *A*). Shades are entirely dependent on the autopolymerizing resin. The resin does not chemically or mechanically bond to the inside surface of the shell; therefore, after polymerization, the shell is peeled off and discarded to prevent staining at the interface. The disadvantage of removing the shell is the necessity to add resin to reestablish proximal contacts.

Aluminum and Tin-Silver. Aluminum (Fig. 15-19) and tin-silver are suitable for posterior teeth. The most elaborate crown forms have anatomically shaped occlusal and axial surfaces. The most basic and least expensive forms are merely cylindrical shells resembling a tin can (see Fig. 15-17, *B*).

The nonanatomic cylindrical shells are inexpensive but must be modified to achieve acceptable occlusal and axial surfaces. It is more efficient to use crowns that have been preformed as individual maxillary and mandibular posterior teeth. Care must also be taken to avoid fracturing the delicate cavosurface margin of the tooth preparation when a metal crown form is fitted. This is a greater risk if adaptation entails having the patient occlude forcefully on the crown shell. The edge of the shell can engage the margin and fracture it under biting pressure. An even greater risk occurs when the crown has a constricted cervical contour. Tin-silver crowns are deliberately so designed (see Fig. 15-17, *B*). This highly ductile alloy allows the crown cervix to be stretched to fit the tooth closely. Direct stretching on the tooth is practical only where feather-edge margins are used. For other margin designs, cervical enlargement should be performed indirectly on a swaging block, which should be supplied with the crown kit.

FIGURE 15-20 ■ Stainless steel anatomic crowns. They are available in a variety of sizes and shapes, including ones for the primary teeth, with straight and contoured axial surfaces.

Stainless Steel. Stainless steel shells (Fig. 15-20) are used primarily for children with extensively damaged primary teeth. In that application, they are not lined with resin but are trimmed, adapted with contouring pliers, and luted with a high-strength cement. They may be applied to secondary teeth but are more suitable for deciduous teeth, for which longevity is less critical. Stainless steel is very hard and thus can be used for longer term interim restorations.

Tissue Surface Form

There are two primary categories of TSFs: indirect and direct. A third category, indirect-direct, is the sequential application of these.

Indirect Procedure

An impression is made of the prepared teeth and ridge tissue and is poured in quick-setting gypsum or polyvinyl siloxane.[10] The interim restorations are fabricated outside the mouth. This technique (Table 15-3) has several advantages over the direct procedure:

1. There is no contact of free monomer with the prepared tooth or gingiva, which might cause tissue damage[11] and an allergic reaction or sensitization.[12-15]

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TABLE 15-3 **Summary of Techniques Used to Fabricate Interim Crowns**

Technique	Tissue Surface Form	External Surface Form	Advantages	Disadvantages
Direct	Tooth preparation itself	Custom or preformed	1. Quick 2. Easy 3. No laboratory work needed	1. Free mononer 2. Heat production 3. Margin inaccuracy
Indirect	Analog of tooth preparation	Custom	1. Easy on tissues 2. No polymerization shrinkage 3. Marginal accuracy	1. Time consuming
Indirect/direct combination	Diagnostic preparation	Custom	1. Easy on tissues 2. Efficient	1. Prior preparation is estimate; internal adjustment may be needed before relining
Digital	Scan of tooth preparation	Custom digital form	1. Efficient 2. No laboratory work needed 3. Easy on tissues 4. Lowest residual monomer 5. Generally more wear resistant 6. No air-inhibited layer 7. No polymerization shrinkage; some can be bonded to tooth structure 8. Definitive restoration can be milled as an exact duplicate of interim	1. Digital impression and in-office mill needed 2. Some blanks are monocolor

FIGURE 15-21 ■ Allergic reactions after brief exposure to polymethyl methacrylate monomer. **A,** Labial ulcerations. **B,** Gingival ulcerations. **C,** Adverse tissue reaction to contact with PMMA interim pontics 6 days after placement.

One group of investigators[16] reported a 20% incidence of allergic sensitivity in patients previously exposed to a monomer patch test. The risk of sensitization in patients who are not allergic to monomer increases with the frequency of exposure. In allergic patients, exposure to even small amounts of monomer usually causes painful ulceration and stomatitis (Fig. 15-21).

2. Prepared teeth are not subjected to the heat evolved from polymerizing resin. The exotherms charted in Figure 15-22 give an indication of temperature increases with time for several materials under similar experimental conditions. Clinical simulation experiments[17,18] have shown peak temperature increases of approximately 10° C in the pulp chambers of prepared teeth upon which direct interim restorations were made. That amount of temperature elevation is capable of causing irreversible damage to the pulp.[19] The simulation experiments also indicate that temperature rise depends directly on the type and volume of resin present. Therefore, a directly made restoration with a large pontic is more likely to cause injury than one for a single crown (especially if the tooth is prepared conservatively). These studies also demonstrate that the heat-conducting properties of the ESFs significantly influence how high the temperature can reach. However, of importance is that peak temperatures were not reached until 7 to 9 minutes had elapsed[18] (Fig. 15-23). For this and the practical reason that it must be drawn through the undercuts of adjacent proximal tooth surfaces, the resin should be removed at the rubbery stage of polymerization, which typically occurs 2 to 3 minutes after insertion in the mouth. In Figure 15-23, the temperature rise is negligible at 3 minutes, which suggests that thermal injury is easily avoidable.
3. The marginal fit of interim restorations that have been polymerized undisturbed on stone casts is significantly better than that of interim restorations that have been removed from the mouth before becoming rigid.[20,21] This is because (1) the stone

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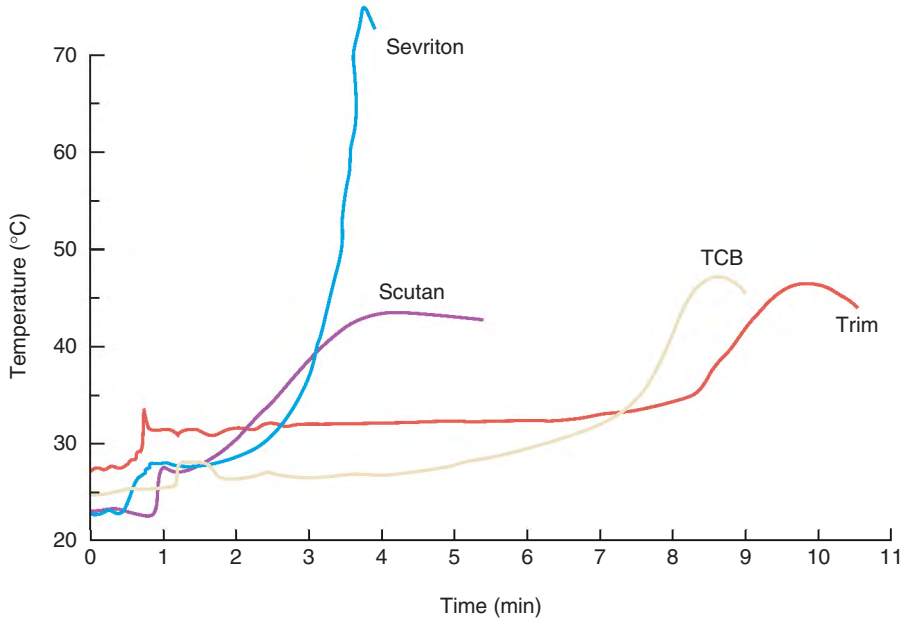

FIGURE 15-22 ■ Heat generated during resin polymerization. Under nonclinical experimental conditions, the temperature rises are severe. Sevriton (a polymethyl methacrylate resin) produced significantly higher temperatures than did the others represented. This is useful information for selecting resins to be used intraorally, although under clinical conditions the differences may be insignificant. *TCB,* Temporary crown and bridge. (Redrawn from Braden M, et al: A new temporary crown and bridge resin. Br Dent J 141:269, 1976.)

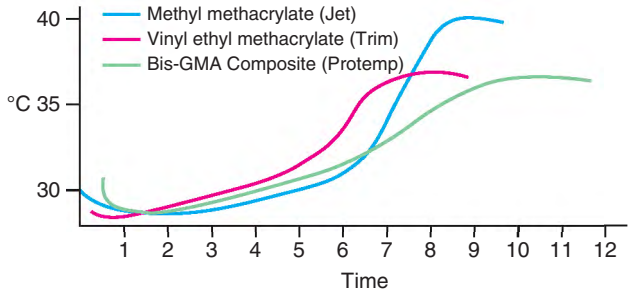

FIGURE 15-23 ■ These exotherms (time in minutes) are derived from a simulated clinical procedure for making a single crown with silicone putty as the external surface form (ESF). A thermocouple probe in the pulp chamber of an extracted tooth was used to measure temperature changes. Initial readings reflect the cooling effect of room-temperature resin mixtures. For all three classes of resins tested, the temperatures did not exceed 35° C until more than 6 minutes had elapsed. *Bis-GMA,* Bisphenol A-glycidylether methacrylate. (Redrawn from Tjan AHL, et al: Temperature rise in the pulp chamber during fabrication of provisional crowns. J Prosthet Dent 62:622, 1989.)

restricts resin shrinkage during polymerization and (2) separating the resin from the tooth in the rubbery phase causes distortion. Directly made long-span or multiple-abutment partial FDPs are likely to have unacceptable marginal discrepancies caused by shrinkage and distortion.

4. When a dimensionally stable elastomer impression is made to form the TSF,[10] it can be retained for possible reuse with the ESF. This allows the dentist to make replacement restorations without having the patient present. For example, if a patient calls to report a lost interim partial FDP, a replacement can be made at the dentist's convenience before the patient arrives. This minimizes disruption of the office schedule and earns the appreciation of the patient. Whether using an elastomer TSF results in margins that fit as well as those obtained with a gypsum TSF is not known. The elastomer may not resist polymerization shrinkage as effectively as does the gypsum.
5. The technique gives the patient a chance to rest, and it frees the dentist to perform other tasks, provided that auxiliary staff are trained to carry out the laboratory procedures.

Direct Procedure

The patient's prepared teeth and gingival tissues (in the case of a partial FDP) directly provide the TSF, and so the intermediate steps of the indirect technique are eliminated (see Table 15-3). This is convenient when assistant training and office laboratory facilities are inadequate for efficiently producing an indirect restoration. However, the direct technique has significant disadvantages: potential tissue trauma from the polymerizing resin and inherently poorer marginal fit. Therefore, the routine use of directly formed interim restorations is not recommended when indirect techniques are feasible.

Indirect-Direct Procedure

In this technique (see Table 15-3), the indirect component produces a "custom-made preformed ESF" similar to a preformed polycarbonate crown. In most cases, the practitioner uses a custom ESF and a diagnostic cast with intentionally underprepared diagnostic preparations as the TSF.

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The resulting mold forms a shell that, after tooth preparation, is lined with additional resin (the patient's mouth serving as the TSF). This last step is the direct component of the procedure. Another method of creating the shell, which eliminates the need for an indirect TSF, is to paint monomer liquid into the ESF and carefully sprinkle or blow resin powder on it. Shell thickness is difficult to control with this technique, however, and may result in the need for time-consuming corrective grinding.

The indirect-direct approach has these advantages:

- Chairside time is reduced. Most of the procedures have been completed before the patient's visit.
- Less heat is generated in the mouth. The volume of resin used during lining is comparatively small.
- Contact between the resin monomer and soft tissues is minimized in comparison with the direct procedure. Because pontic ridge areas do not normally require lining, the risk of allergic reaction is reduced.

However, even with the diagnostic cast method, adjustments are frequently needed to seat the shell completely on the prepared tooth. This is the chief disadvantage of the indirect-direct procedure.

Materials for Interim Fixed Restorations

While in a fluid state, the interim restorative materials fill the cavity formed by the ESF and TSF; they then solidify, producing a rigid restoration.

Ideal Properties

The characteristics of an ideal interim material are as follows:

- Convenient handling: adequate working time, easy molding, rapid setting time
- Biocompatibility: nontoxic, nonallergenic, nonexothermic
- Dimensional stability during solidification
- Ease of contouring and polishing
- Adequate strength and abrasion resistance
- Good appearance: translucent, color controllable, color stable
- Good acceptability to patient: nonirritating, odorless
- Ease of adding to or repairing
- Chemical compatibility with interim luting agents

Currently Available Materials

As yet, an ideal interim material has not been developed. A major problem still to be solved is dimensional change during solidification. These materials (Fig. 15-24) shrink and cause marginal discrepancy,[20-22] especially when the direct technique is used (Fig. 15-25). Also, the resins currently employed are exothermic and not entirely biocompatible.

The materials can be divided into four resin groups:

- PMMA
- Poly-R′ methacrylate*
- Microfilled composite
- Light-polymerized

The properties of these resins are compared in Table 15-4. The overall performances of the groups are similar; no material is superior in all categories. The choice of material should be based on optimally satisfying the requirements or conditions crucial for the success of the treatment. For example, materials with the least toxicity and least polymerization shrinkage should be chosen for a direct technique. Alternatively, when a long-span prosthesis is being fabricated, high strength is an important selection criterion. The residue from some interim materials may interfere with the polymerizing of polyvinyl siloxane elastomeric impression materials.[23] Although the resin can be cleaned in hydrogen peroxide to prevent this interaction, the problem can be avoided if the interim restoration is made indirectly or the impression is made before a direct interim restoration is made.

*The *R′* represents an alkyl group larger than methyl (e.g., ethyl or isobutyl).

MATERIALS SCIENCE

William M. Johnston

The material used for fabrication of an interim restoration consists of pigments, monomers, filler, and an initiator, all combining to form an esthetic restorative substance. The pigments are incorporated by the manufacturer so that the set material appears as much like natural tooth structure as possible; a variety of shades are available. Although each of the other ingredients plays a role in the handling, setting, and final properties of the interim restoration, many important characteristics of the material are determined by the primary monomer. The ability of this monomer to convert to a polymer allows the material, after it has been formed as desired, to set into a solid that is durable enough to withstand the oral environment for the necessary interim period.

Depending on the brand, the most commonly used monomers are methyl methacrylate, ethyl methacrylate, isobutyl methacrylate, bisphenol A-diglycidylether methacrylate (bis-GMA), and urethane dimethacrylate. Each of these, or combinations thereof, may be converted to a polymer by free radical polymerization, although the conversion process is never perfectly complete.

Free Radical Polymerization

The polymerization process invokes chemical, mechanical, dimensional, and thermal changes that affect the successful use of these materials in dentistry. Because monomers may be unpleasant or even harmful biologically, the chemical conversion of monomer to a biologically inert polymer is desirable. Also, if the polymerization process is not properly initiated or if it is prematurely terminated, the resultant restoration may not have adequate mechanical properties and may fail easily or quickly. However, because the density of the polymer is inherently and often substantially greater than that of the monomer, a dimensional contraction occurs during polymerization. The polymerization reaction is exothermic, which causes the material to become hot before it

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FIGURE 15-24 ■ Currently available interim materials. **A** and **B,** Polymethyl methacrylate resins. **C,** A poly-R′ methacrylate resin. **D,** Microfilled composite resins with automix delivery system. **E,** Photopolymerized polymethyl methacrylate. (**A,** Courtesy Lang Dental Manufacturing Co., Inc, Wheeling, Illinois. **B** and **E,** Courtesy GC America Inc., Alsip, Illinois.)

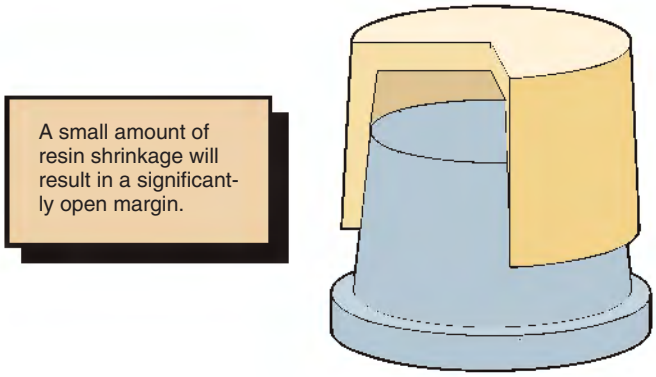

FIGURE 15-25 ■ With ideal axial wall convergence, a 2% reduction in crown diameter results in a comparatively high marginal discrepancy.

loses its fluidity, and so when it cools, the restoration contracts further. If a direct technique is being used, the heat of reaction can cause irreversible damage to nearby pulpal tissues, which may already have been thermally insulted during cavity preparation.

Initiation

Free radical polymerization begins with the formation of a free radical, a process called *activation*, and the subsequent combination of this free radical with a monomer. Free radicals are formed by the decomposition of a chemical (the initiator); the method of decomposition is dependent on the nature of the initiator. Possible initiators include benzoyl peroxide and camphorquinone.

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TABLE 15-4 **Ranked Characteristics of Representative Provisional Restoration Resins**

	Characteristic													
Material	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Jet (PMMA)	2*	2†	3	1‡	1†	3†	1§	2	1	1	2‖	1	3	1
Duralay (PMMA)	1†	—	3	—	—	—	1	2	1	1	—	1	3	1
Trim (PR′MA)	2†	1†	2	3‡	—	3†	2†	3	1	1	3‖	1	2	1
Snap (PR′MA)	2†	2†	2	—	—	2†	2	3	1	1	—	1	2	1
Temphase Fast-set (bis-acryl composition)	1	1	1	2	—	1	2	3	1	2	1	2	2	2
Protemp Garant (bis-GMA composition)	1*	1	1	2	2	1	2†	3	2	2	1‖	2	1	2
Tuff-Temp (dual-polymerized, urethane)	1	1	1	3**	—	1	2	3	1	2	1	2	2	2
Unifast LC (light-polymerized, PR′MA)	2*	2¶	3	—	—	2#	2	1	3	1	—	2	3	2
Triad (light-polymerized, urethane DMA composition)	2§	3†	1	1	1†	1†	3†	1	3	3	—	3	1	3

A, Marginal adaptation (indirect); *B,* temperature release during reaction; *C,* toxicity/allergenicity; *D,* strength (fracture toughness); *E,* repair strength (percentage of original); *F,* color stability (ultraviolet light); *G,* ease of trimming and contouring; *H,* working time; *I,* setting time; *J,* flowability for mold filling; *K,* contaminated by free eugenol; *L,* special equipment needed; *M,* odor; *N,* unit volume cost.
Bis-GMA, Bisphenol A-diglycidylether methacrylate; *DMA,* dimethacrylate; *PMMA,* polymethyl methacrylate; *PR′MA,* poly-R′ methacrylate.
1, Most desirable; *2,* less desirable; *3,* least desirable; -- data unavailable.
*Source of data: Tjan AHL, et al: Marginal fidelity of crowns fabricated from six proprietary provisional materials. J Prosthet Dent 77:482, 1997.
†Source of data: Wang RL, et al: A comparison of resins for fabricating provisional fixed restorations. Int J Prosthodont 2:173, 1989.
‡Source of data: Gegauff AG, Pryor HG: Fracture toughness of provisional resins for fixed prosthodontics. J Prosthet Dent 58:23, 1987.
§Source of data: Koumjian JH, Holmes JB: Marginal accuracy of provisional restorative materials. J Prosthet Dent 63:639, 1990.
‖Source of data: Gegauff AG, Rosenstiel SF: Effect of provisional luting agents on provisional resin additions. Quintessence Int 18:841, 1987.
¶Source of data: Castelnuovo J, Tjan AH: Temperature rise in pulpal chamber during fabrication of provisional resinous crowns. J Prosthet Dent 78:441, 1997.
#Source of data: Doray PG, et al: Accelerated aging affects color stability of provisional restorative materials. J Prosthodont 6:183, 1997.
**Source of data: Kerby RE, et al: Mechanical properties of urethane and bis-acryl interim resin materials. J Prosthet Dent 110:21, 2013.

Benzoyl peroxide decomposes to free radicals at approximately 50° C or higher in a process called *thermal activation*. Because the heating of some monomers to temperatures near 100° C can cause them to vaporize, with subsequent formation of porosity in the resultant polymer, excessive temperatures should be avoided during the early stages of thermal activation. Thermal activation results in greater contraction on cooling than is obtained with other activation methods and therefore is usually avoided for interim restorations.

Benzoyl peroxide also decomposes to free radicals when catalyzed by a tertiary amine, and this process is called *chemical activation*. Chemical activation occurs when the activator, initiator, and monomer are mixed together, and so these materials are usually supplied separately, the monomer and activator in one container and the initiator and filler in another. Proper mixing is necessary to prevent voids. Because chemical activation requires intimate contact of the chemical activator with the initiator, this activation method is not as efficient as thermal activation. Inefficient activation of the initiator results in more residual monomer and less color stability of the restoration, inasmuch as unreacted benzoyl peroxide can cause color changes. However, because benzoyl peroxide is decomposed by both thermal and chemical activation, increased temperature can enhance its decomposition in a chemically polymerized system and does not increase contraction if the restoration initially undergoes chemical setting. Heating a recently set restoration in 100° C water promotes greater polymerization efficiency and removes any unconverted monomer, which might cause a sensitivity reaction in a patient susceptible to monomer irritation.

Camphorquinone decomposes to free radicals in the presence of both an aliphatic amine and blue light energy, and this process is called *visible-light activation*. Light-activated materials have two advantages: (1) The ingredients can be mixed by the manufacturer with little porosity, and (2) working time is infinite because no setting occurs if the material is kept in a dark environment. The limitation of this method is the depth to which visible light can penetrate (less for darker materials). Whenever possible, the activation illumination should be directed toward the center of the restoration from all surfaces. Also, for darker materials, the exposure time should be longer.

Propagation

After its onset, the polymerization process continues by including more monomer molecules in the growing molecular chain. It is important that the material be allowed to set undisturbed because, during this phase, defects can easily result if the material is jostled. During propagation, (1) the setting material undergoes an increase in density, which causes contraction; (2) the exothermic reaction heat may cause a substantial increase in temperature, with subsequent increased contraction; and (3) other physical properties (e.g., rigidity, strength, and resistance to dissolution) increase.

Termination

Because of the randomness of position of the growing chains, it is possible that some of them might combine

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and thereby terminate the growth process. This type of termination cannot be avoided, although termination is desirable only after polymerization of all the monomer. Termination may also result from the reaction with eugenol, hydroquinone, or oxygen; therefore, contact with these substances must be avoided or at least minimized when possible.

Properties Associated with the Monomer

The various monomers exhibit different initial and setting characteristics, and the resulting polymers have significantly different properties (e.g., viscosity before setting, exothermic heat of reaction, dimensional change on setting, and strength). In general, the greater the size of the monomer molecule, the less the exothermic heat of reaction on setting and the lower the physical strength of the set mass. Properties of available materials are presented in Table 15-4.

Filler

Although the primary properties of an interim restorative material are determined by the monomer or monomers involved, a decrease in the less desirable setting and mechanical properties is accomplished mainly through the filler. An increase in filler content reduces the relative amounts of exothermic heat and contraction while increasing the strength of the set material. However, too much filler can lead to insufficient handling characteristics before setting; this impedes mixing and shaping and introduces porosity in the set restoration. For light-activated systems, the amount of filler is determined by the manufacturer; for the other systems, it is desirable to incorporate as much filler as possible without interfering in the handling or manipulation characteristics of the material.

• • •

PROCEDURES

The basic clinical armamentarium (Fig. 15-26) and the basic laboratory armamentarium (Fig. 15-27) are listed only once; they may be referred to as needed. As each procedure is discussed, only items necessary to augment the basic armamentarium are listed.

Basic Clinical Armamentarium

- Gloves
- Face mask
- Protective eyewear
- Mouth mirror
- Explorer
- Periodontal probe
- Saliva evacuator
- Cotton rolls
- Gauze squares
- Gingival displacement cord
- Astringent solution

FIGURE 15-26 ■ **A** and **B,** Basic clinical armamentarium for interim fixed dental prostheses.

- Cotton-roll pliers
- Plastic filling instrument
- Cotton pellets
- Petrolatum
- Autopolymerizing resin
- Dropper
- Three dappen dishes
- Cement spatula
- Backhaus towel clamp forceps
- Straight slow-speed handpiece
- Carborundum disks with mandrels, straight handpiece
- Fine garnet paper disks (7/8-inch diameter) with mandrels, straight handpiece
- Tungsten carbide burs, straight handpiece
- High-speed handpiece with air-water supply
- Round bur (No. 4), friction-grip
- Tungsten carbide 12-fluted finishing bur, friction-grip (e.g., 7803)
- High-volume evacuation
- Articulating ribbon and holder
- Disposable brush
- Cup of warm water

Basic Laboratory Armamentarium

- Protective eyewear
- Face mask (for respiratory protection)
- Disposable brush

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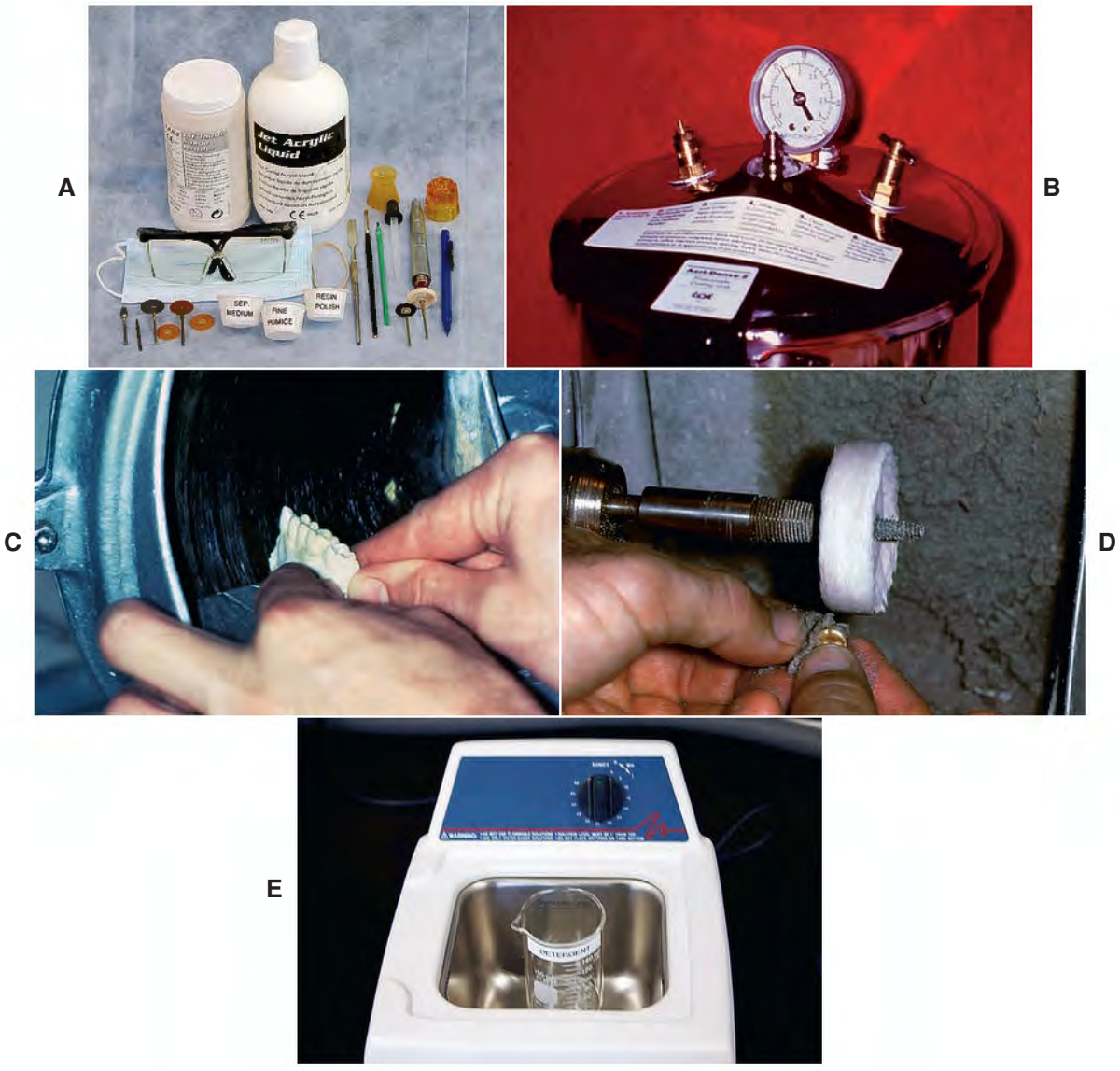

FIGURE 15-27 ■ Basic laboratory armamentarium for interim fixed dental prostheses. **A,** Assorted small items appearing on the accompanying list (see text). **B,** Pressure-polymerization vessel. **C,** Cast trimmer. **D,** Dental lathe and dust collector. **E,** Ultrasonic cleaner and liquid detergent.

- Gypsum-resin separating medium
- Autopolymerizing resin
- Dropper
- Two dappen dishes
- Cement spatula
- Polypropylene syringe
- Rubber bands
- Pressure vessel
- Cast trimmer
- Straight slow-speed handpiece
- Carborundum disks with mandrels, straight handpiece
- Fine garnet paper disks (7/8-inch diameter) with mandrels, straight handpiece
- Tungsten carbide burs, straight handpiece
- Dental lathe
- Muslin wheels
- Robinson bristle brushes
- Felt wheels (1-inch diameter) with mandrels
- Fine pumice
- Resin-polishing compound
- Ultrasonic cleaner with detergent solution

Interim Partial Fixed Dental Prostheses: Custom Indirect Method

The custom indirect procedure is probably the best overall technique for partial FDPs and should provide the most predictable results with the least risk to the patient's health.

Additions to Clinical Armamentarium

- Shade guide
- Irreversible hydrocolloid impression material
- Rubber bowl

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FIGURE 15-28 ■ For subgingival margins, tissues often must be displaced before an adequate impression can be made. Alginate in a disposable tray produces an economical and satisfactory impression. After treatment for infection control, the impression is poured in quick-set plaster to create the tissue surface form (TSF).

- Impression tray
- Mixing spatula

Step-by-Step Procedure

1. After shade selection and tooth preparation, obtain an impression tray for an irreversible hydrocolloid impression. A sextant impression is adequate only if it extends one tooth beyond the abutments, and so the ESF will correspond accurately to the cast (TSF).
2. Displace the gingiva if necessary to expose the cavosurface margins (Fig. 15-28).
3. Make an irreversible hydrocolloid impression. Other clinical procedures (e.g., making the definitive impression) can take place while the assistant is pouring the cast.

Additions to Laboratory Armamentarium

- Accelerated-setting plaster
- Rubber bowl
- Spatula
- Vibrator
- ESF

Step-by-Step Procedure

The clinician can accelerate the setting of plaster by shaking dry powder with the water before mixing (1 tsp of powder in 30 mL of water).[24] Alternative methods include adding salt, mixing with lukewarm water, or using a commercially available quick-setting plaster.

1. Pour the quick-setting stone or plaster into the irreversible hydrocolloid impression, and allow it to set for 8 minutes.
2. Remove the cast and trim it to provide proper indexing with the ESF. The ESF is normally made from a diagnostic waxing of the proposed restoration. Check that the two forms fit together passively and completely.

FIGURE 15-29 ■ **A,** After trimming, the indirect tissue surface form (TSF) is fitted with the external surface form (ESF) to verify accurate passive indexing. **B,** With this accomplished, the forms are separated, and the TSF is completely coated with a resin-gypsum separating medium (brushed on).

3. Paint the cast uniformly with separating medium (Fig. 15-29). Avoid leaving unpainted "islands" on the cast, especially at the cavosurface margin areas. Drying can be accelerated by a gentle stream of air. Do not forcefully blow the medium from the surface of the cast. When the cast is thoroughly dry, it is optional to mark the cavosurface margins of the preparations with a soft lead pencil to serve as a guide for trimming later. This should not be done where the margins are visible because the pencil marks are difficult to remove from the resin.
4. Mix autopolymerizing resin (e.g., methyl methacrylate), and load it into a polypropylene syringe. The orifice of the syringe tip should be about 2 to 3 mm in diameter.
5. Fill the ESF methodically with the syringe, starting at one end of the restoration space and working to the other. To avoid trapping air, keep the syringe tip in constant contact with the resin. The mold should not be overfilled; the resin should just reach the level of the gingiva (Fig. 15-30).
6. Seat the TSF into the filled ESF (Fig. 15-31). They can be lightly held together by rubber bands. The assembly is then placed in warm water (40° C [100° F]) in a pressure vessel, after which air is applied at about 0.15 MPa (20 pounds/square inch). Postpolymerizing heat treatment has been shown to improve physical properties,[25] and pressure polymerization reduces resin porosity.

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7. Remove the assembly after 5 minutes.
8. Separate the ESF from the polymerized resin restoration, which usually remains in contact with the TSF (Fig. 15-32). The bulk of the stone can be removed on a cast trimmer and with a carborundum disk (Fig. 15-33). If the margins were marked with lead, dielike remnants of the TSF should be retained for use as a guide to correct trimming. However, the TSF often separates completely from the resin during handling. This is an advantage because it eliminates any further effort needed to remove the stone. This should not be postponed because the margins are more difficult to identify accurately after trimming is begun.
9. Eliminate resin flash with an acrylic-trimming bur and a fine-grit garnet paper disk.
10. Contour the pontic areas according to proper pontic design (Fig. 15-34) (see Chapter 20).
11. Finish the restoration with wet pumice. Include the gingival surface of the pontic. If this area is not otherwise accessible, a Robinson brush on a straight handpiece should be used.
12. Check for and remove any resin blebs or remnants of stone on the internal surfaces of the restoration.
13. Clean the restoration, using appropriate infection control procedures in preparation for clinical try-in.

Evaluation

The interim partial FDP should be evaluated in the patient's mouth for proximal contacts, contour, surface defects, marginal fit, and occlusion. Deficient proximal contacts, imperfections in contour, or surface defects can

FIGURE 15-30 ■ A polymer syringe with a widened orifice (2 mm in diameter) is useful for filling the external surface form (ESF). To avoid entrapping air, it is best to begin at one end and progress slowly to the other, keeping the syringe tip in contact with the expressed resin.

FIGURE 15-32 ■ External surface form removed.

FIGURE 15-31 ■ **A,** The resin-filled external surface form is seated on the tissue surface form. **B,** Rubber bands are placed around the mold assembly and located over adjacent unprepared teeth. This avoids distorting the external surface form. **C,** The assembly is placed into a pressure vessel filled with warm water. **D,** The resin polymerizes for 5 minutes under 0.15-MPa (20 pounds/square inch) pressure.

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FIGURE 15-33 ■ The tissue surface form is reduced to attain the final shape of the restoration. **A,** Bulk reduction on a cast trimmer. **B,** Sectioning and removal of pontic-contact areas with a carborundum disk. **C,** Linguogingival surface of the pontic shaped with a tapered bur. **D,** An abrasive disk (⅛-inch diameter, garnet) is excellent for creating proper embrasure form. It must be carefully oriented parallel to the desired contour so that overtrimming at the margins is avoided. **E,** The contoured restoration.

FIGURE 15-34 ■ The restoration before try-in.

FIGURE 15-35 ■ Proximal contact added by the brush-bead technique. When the resin reaches the doughy stage, the restoration is set on the prepared tooth to form the contact.

be corrected by the addition of resin through the brush-bead technique (Fig. 15-35; see Fig. 15-73).

Unacceptable marginal fit can be corrected as for custom indirect-direct partial FDPs (see "Interim Partial Fixed Dental Prostheses: Custom Indirect-Direct Method," steps 3 to 8 of "Step-by-Step Procedure") if the patient has no history of allergy to monomer. If occlusal correction is needed, the restoration is marked with articulating ribbon and adjusted with a 12-fluted tungsten carbide finishing bur rotating at high speed with copious air-water spray to prevent the resin from melting (Fig. 15-36). Adequate intraoral evacuation and eye protection are essential.

After practicing appropriate infection control procedures, return to the laboratory for wet pumice finishing and dry polishing with resin-polishing compound. If

FIGURE 15-36 ■ Intraoral adjustment of occlusal contacts.

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FIGURE 15-37 ■ Additions to the basic laboratory armamentarium for the indirect-direct procedure: the diagnostic tissue surface form (TSF) and the polypropylene external surface form (ESF).

access to the gingival surfaces of the pontics is restricted, a ¼-inch diameter felt wheel can be used for polishing.

Interim Partial Fixed Dental Prostheses: Custom Indirect-Direct Method

The custom indirect-direct procedure may be a good compromise when laboratory support is not immediately available and chair time must be minimized.

Additions to Laboratory Armamentarium

The following equipment is also needed (Fig. 15-37):

- Diagnostic TSF (duplicate of conservatively prepared diagnostic cast)
- ESF (vacuum-formed polypropylene sheet)
- Original diagnostically prepared cast mounted on an articulator
- Articulating ribbon

Step-by-Step Procedure

1. Prepare the abutment teeth on articulator-mounted diagnostic casts (Fig. 15-38). The diagnostic preparation should be more conservative than the eventual tooth preparation and should have supragingival margins. These preparations are often helpful for treatment planning (see Chapter 2), and make actual clinical preparation much easier.
2. Make an irreversible hydrocolloid impression of the diagnostic preparations to duplicate them in stone (Fig. 15-39).
3. Coat the stone TSF with separating medium.
4. Perform a diagnostic waxing procedure on the articulated casts. This step is often recommended in the treatment planning phase as well. The ESF is made from the diagnostically waxed cast. If a thermoplastic sheet is used, it should be molded over a stone duplicate of the cast rather than directly on the wax (which melts if contacted by the heated sheet) (Fig. 15-40).

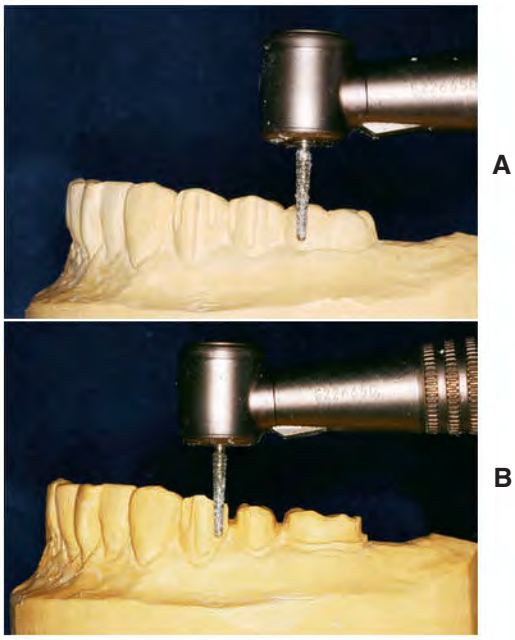

FIGURE 15-38 ■ Preparations involved in making the articulator-mounted diagnostic cast. **A,** Conservative depth-orientation grooves. **B,** Placement of supragingival cavosurface margins.

FIGURE 15-39 ■ The prepared cast is duplicated by means of an alginate impression. This creates the indirect tissue surface form. Quick-set plaster is used.

5. Check that the ESFs and TSFs fit together accurately (Fig. 15-41).
6. Using a syringe, apply the resin into the ESF, and complete the interim restoration as described in the preceding section (see Figs. 15-30 to 15-34).
7. If the wax has been removed from the diagnostic cast (after duplication), seat the completed interim restoration (custom-preformed ESF) on it and refine the occlusion by using the articulator. If this cannot be done, more clinic time is required for adjustment.
8. Finish and clean the preformed ESF for try-in, which follows tooth preparation (Fig. 15-42).

Addition to Clinical Armamentarium

- Custom-preformed ESF

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FIGURE 15-40 ■ Creating a custom external surface form (ESF) from a diagnostic waxing. **A,** The diagnostically waxed articulated casts. Patterns should satisfy biologic, mechanical, and esthetic requirements. **B,** If a thermoplastic ESF is desired, the completed waxing must be duplicated in stone.

FIGURE 15-43 ■ The custom-preformed external surface form (ESF) fully seated over the prepared teeth. Note the marginal discrepancy on each abutment. The tip of the periodontal probe easily fits into the space, which will be filled by a direct lining procedure.

FIGURE 15-41 ■ Proper relationship between the external surface form (ESF) and the tissue surface form (TSF). If it is necessary to remove any cast artifacts to correct the relationship, this should be done before the separating medium is applied.

FIGURE 15-42 ■ The completed custom-preformed external surface form (ESF). This is the end product of the indirect component of the indirect-direct technique.

Step-by-Step Procedure

1. Prepare the patient's teeth in the usual manner.
2. Try in the preformed ESF (Fig. 15-43). If it is not compatible with the occlusion (does not seat completely) and the teeth have been reduced adequately, the internal surface of the ESF should be reduced until the occlusion is acceptable. If the teeth require more reduction, this should be done and the ESF then reevaluated and adjusted. This is a distinct disadvantage of the indirect-direct procedure. The adjustment process can be tedious, particularly if the preliminary steps were not performed with attention to detail. The remaining steps outline the (direct) procedure for lining, which is necessary to produce internal and marginal adaptation (Fig. 15-44). Because of their relatively low potential for tissue trauma, resins in the poly-R′ methacrylate group are recommended for direct procedures.
3. Apply a uniform coat of petrolatum on the prepared abutment teeth, gingival tissues, and outside of the ESF.
4. Make a vent hole with a round bur through the occlusal (or lingual) surface of each retainer.
5. Fill the retainers with resin, and after it loses its surface sheen, seat the restoration. Placing fingertips over the vent holes in a manner similar to playing a flute can control the quantity of excess resin expressed around the margin. When a small amount of excess resin appears around the entire periphery of the margin, lift the fingertip to allow trapped air and remaining excess resin to escape. Resin on the occlusal surface can be wiped away immediately, which eliminates the need to grind it off after it sets.
6. When the rubbery stage of polymerization is reached (about 2 minutes in the mouth), engage the facial and lingual surfaces of an abutment retainer with the Backhaus forceps, and rock the interim restoration buccolingually to loosen it. Move to the other retainer and rock it in a similar manner. When the partial FDP is loosened at both ends, remove it from the patient's mouth. The forceps tines may make small indentations in the resin, but this is not usually a concern for posterior units. The defects can be smoothed later during the finishing procedures.
7. Place the interim restoration in warm water (37° C) to hasten polymerization.

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FIGURE 15-44 ■ Lining the custom-preformed external surface form (ESF). This is the direct component of the indirect-direct technique. **A,** Oral tissues are protected with petrolatum. **B,** Vent holes help eliminate trapped air. **C,** Abutment retainers are filled with lining resin. **D,** The restoration is completely seated. (The amount of resin at the margins is controlled by covering or uncovering the vent holes.)

8. After 3 to 5 minutes, eliminate the excess resin. The bulk of it can be removed with an acrylic resin-trimming bur or carborundum disk (Fig. 15-45). Use a fine-grit garnet paper disk to complete axial shaping.

To simplify accurate trimming to the margins, the disk can be held virtually parallel to the desired final contour. A paper-thin extension remaining beyond the marked margin is an indication that the contour is correct and the cavosurface margin fully covered. Often this flash can be easily peeled away from the margin with the fingers (Fig. 15-46).

The clinician then confirms the marginal fit and occlusion, refinishes and polishes where necessary, and cements the restoration (Fig. 15-47).

Custom Single-Unit Interim Restorations

Complete Crowns

Single-unit complete crowns or splinted crowns may be made directly or indirectly in accordance with the basic procedures described for partial FPDs. Because pontics are not involved, creating an ESF is simpler. Diagnostic procedures are not required unless extensive coronal changes are planned. For example, extensive changes are usually required when the occlusal vertical dimension is increased. If diagnostic procedures are not needed, an alginate impression of the crown or crowns before tooth preparation should be adequate to serve directly as the ESF or indirectly when a cast has been poured in another impression material.

Onlays and Partial Veneer Crowns

The technique for making onlay and partial veneer interim restorations is similar to that for making custom single

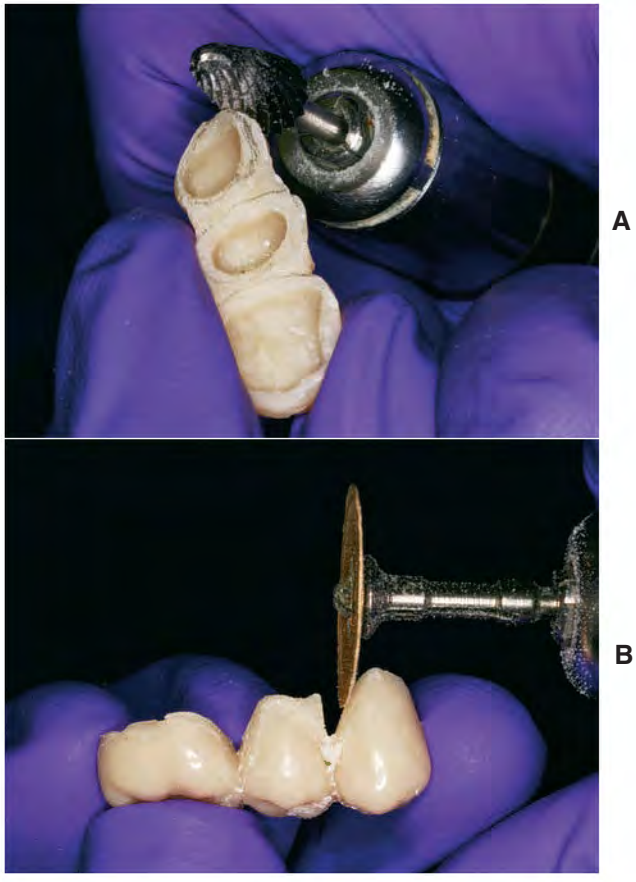

FIGURE 15-45 ■ Removal of excess after the lining resin hardens. **A,** Gross resin excess is quickly removed. (Margins must be avoided.) **B,** The final axial contours, connectors, and marginal fit are perfected with an abrasive disk rotating toward the margin to prevent debris from obscuring the margin. Note the orientation of the disk, parallel to the desired final contour.

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FIGURE 15-46 ■ Flash at the margin of a restoration whose axial surface was contoured with proper disk orientation. (Courtesy Dr. R.E. Kerby.)

FIGURE 15-47 ■ Occlusal contacts of the completed restoration are checked and adjusted before polishing. Note that the units are splinted together for increased resistance to dislodgment during an anticipated lengthy treatment period. (Courtesy Dr. R. Liu.)

crowns. However, the interim restorations are more easily distorted during handling because of the conservative tooth preparations that interrupt the continuity of the axial walls. Thus the direct method mandates extra care in separating the resin from the tooth. Significantly better results can be expected with the indirect procedure.

When the polymerized resin is trimmed to the margin, it is advisable to leave an excess of resin at the occlusal cavosurface margin. This helps prevent enamel fracture, which is likely to result from the lesser strength of resin in comparison with metal. Second, if lining is needed, an occlusal vent hole is not necessary because the high location of the margin and its configuration provides an adequate escape way for trapped air and excess resin.

Inlays

Inlays present the challenge of being small and difficult to handle, especially during trimming. Making interim inlay restorations requires a number of modifications.

Additions to Clinical Armamentarium

- Tofflemire retainer/matrix band
- Wedges
- Amalgam condenser
- Spoon excavator
- Scalpel handle and blade (No. 15)

FIGURE 15-48 ■ A floss handle facilitates removal of an inlay resin interim restoration during late rubbery stage.

Step-by-Step Procedure

1. For a two- or three-surface inlay, apply the matrix band and wedges as in preparation for condensing a class II amalgam restoration. The wedges should be placed with firm pressure so that when the band is removed, proximal contact is reestablished. The band must seal all aspects of the proximal cavosurface margins.
2. Using petrolatum on a small cotton pellet, lightly coat all sides of the cavity preparation and the matrix band.
3. Make a handle to remove the resin by placing one end of a 2- to 3-cm length of unwaxed dental floss in the preparation cavity.
4. Mix a small amount of poly-R′ methacrylate, and when it can be kneaded like bread dough, mold a small cone of it on the end of an amalgam condenser.
5. Lightly condense the resin into the cavity, being careful not to force it past the matrix into an undercut. Immediately remove as much occlusal excess as possible with a sharp spoon excavator.
6. Monitor the polymerization by light probing with a hand instrument. When the resin reaches the late rubbery stage, remove it by tugging the floss handle with a cotton roll forceps along the path of withdrawal (Fig. 15-48).
7. Place the resin in a cup of warm water (37° C) for 5 minutes.
8. Trim away whatever flash may be present.
9. Return the polymerized resin to the cavity preparation and adjust the occlusion, using marking film and a slow-speed handpiece. (Take extreme care to avoid removing tooth structure.) Leave the floss handle in place as long as it does not interfere with adjustments of the occlusion.
10. Remove the adjusted interim restoration with the floss handle, and put it aside where it may be found easily after impression making for the definitive inlay.
11. Clean and dry the cavity preparation, and place a thin coat of interim cement on the cavity walls. Immediately insert the interim restoration.

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12. When the cement is set, remove the excess with an explorer and a spoon excavator. Carefully cut off the floss handle with the scalpel blade.

Digital Interim Fixed Restorations

With the advent of digital impression technology and computer-aided design and computer-aided manufacturing (CAD/CAM) production of restorations, definitive restorations can be fabricated the same day as tooth preparation, and interim crowns are not necessary. However, not all clinical situations are amenable to treatment with same-day CAD/CAM restorations, necessitating the use of interim restorations. Such situations include the need for large reconstructions, evaluating the effects of changes in occlusion in the presence of a temporomandibular disorder, a planned change in occlusal vertical dimension, and the period of healing of pontic or implant sites. In these situations, interim restorations can be extremely helpful. The patient can now evaluate comfort, function, and appearance before the fabrication of the definitive restorations.

Interim restorations can be fabricated by means of a digital workflow. The TSF consists of a three-dimensional virtual image of the prepared tooth. The ESF consists of one of the following: a three-dimensional virtual image of the intended tooth before preparation, a scan of a preoperative diagnostic waxing, or a virtual shape proposal generated by computer. The digital information is sent to a milling machine at the time of tooth preparation and the TSF and ESF are milled from solid blocks/disks of resin. Thus there is no need to have analog representations of the TSF and ESF or to then fill a mold cavity with material. Resins available for milling interim restorations include PMMA and composite.

The CAD/CAM process reduces the patient's exposure to chemicals dramatically, inasmuch as the commercially produced blanks from which interim restorations are milled contain only approximately 1% residual-free monomer.[25] Therefore, the digital method of fabricating an interim crown is an entirely indirect method. The CAD/CAM interim restorations have been shown to be stronger and more accurate than traditional bis-acryl composite prostheses.[26] Another advantage of the digital production of interim restorations is that the data file can be used to mill the definitive restoration, if the tooth preparations (and tissue contours) have not been altered (Fig. 15-49).

Interim restorations must be formed efficiently at the time of tooth preparation, and digital technologies also allow fabrication of large multiple-unit composite or PMMA ESFs in advance for use with the indirect-direct technique. A preoperative diagnostic wax-up or diagnostic tooth preparations are provided to the dental laboratory, where digital design software is used to virtually "prepare" the tooth with a margin near the gingival margin or to design the external contours, or both. An interim shell is milled, which will be later relined in the mouth at the time of tooth preparation. When large multiple-unit restorations are planned, the dentist probably needs to recruit the assistance of a dental laboratory possessing a large commercial mill, because the blanks for in-office mills are generally too small for restorations larger than five units. The practitioner also must inquire about the appropriate materials for relining a milled provisional, so that delamination, separation, or leakage does not occur between the milled material and the relining material.

Interim restorations can be milled from a blank of resin of one color or layered colors. When a single-color blank is used, the crown or all the units of an FDP will be the same shade (Fig. 15-50). All milled materials need to be highly polished before cementation in the mouth because roughness from the milling burs remains. Depending on the composition of the milled blank, adjustment of color and characterization may be possible with matching materials.[26]

It is important to use matching materials for long-term color stability and adhesion. In-office mills often require additional software or a modified tank or coolant filler system, or both, to avoid clogging of the cooling and lubricating circulation system caused by ground polymer particles.

Because not all clinical situations can be restored the same day as tooth preparation, CAD/CAM interim restorations have many advantages. The composite-based materials in particular are sufficient in their mechanical properties, wear resistance, color stability, and bonding ability to warrant their use as long-term interim restorations.

Laminate Veneers

Additions to Clinical Armamentarium

- Composite resin shade guide
- Photopolymerized composite resin
- Hand-held polymerization light
- Phosphoric acid etchant gel
- Autopolymerizing unfilled resin

Step-by-Step Procedure

1. Select the most appropriate resin shade or combination of shades before preparing the tooth.
2. When tooth preparation is complete, apply a thin coat of petrolatum to the prepared tooth surface.
3. Using a plastic instrument wetted with alcohol, form the preselected photopolymerized resin. If the material is difficult to control, placement and polymerization may be accomplished in stages. It is also possible to form the veneers indirectly by creating a TSF and an ESF, as was recommended for the partial FDP interim restoration. The indirect method may be more efficient if multiple veneers are being made.
4. Photopolymerize the resin, and remove it from the tooth surface.
5. Thoroughly clean the petrolatum from the prepared tooth enamel, and apply the etchant gel to three 1-mm-diameter areas to form an equilateral triangle, with two of the corners at the mesioincisal and distoincisal line angles and the third centered

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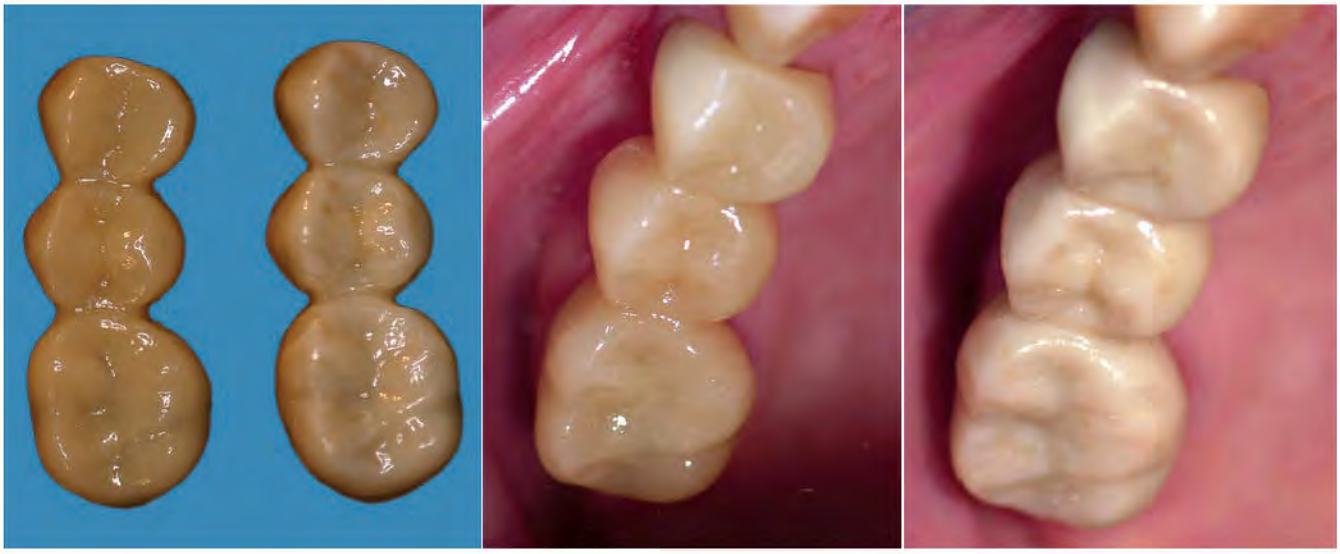

FIGURE 15-49 ■ **A,** Maxillary three-unit fixed dental prosthesis (FDP) milled from polymethyl methacrylate (PMMA) as an interim *(left)* and the definitive restoration fabricated from monolithic zirconia *(right).* **B,** The interim restoration used during the healing of a dental implant in the opposing arch. **C,** The definitive zirconia FDP restoration.

FIGURE 15-50 ■ CAD/CAM interim restorations milled from resin disk.

more cervically. Allow the etchant to remain for 20 seconds; then rinse completely with water, and dry.

6. Mix the autopolymerizing unfilled resin, and place a small amount on the three etched areas. Immediately place the veneer on the tooth, and hold it in place until the resin is set.
7. At the patient's return visit, remove the veneers with a spoon excavator.

Interim Crowns Mass Produced from External Surface Forms

Under most circumstances, a custom ESF yields the best results in the shortest time. However, there are instances when a custom ESF is not readily available: for example, a first-visit emergency in which a crown is missing and must be replaced. If by coincidence a crown form closely matches the size and shape of the desired interim restoration, the mass-produced form is more convenient than initiating custom procedures (generating a diagnostic cast and waxing the missing crown contours). Such coincidences, however, are not routine and should not be relied upon. Whatever the situation, the dentist should think of mass-produced interim crowns as ESFs; they need to be lined with resin to meet the basic requirements of an interim restoration.

Polycarbonate Crown Forms

Polycarbonate crown forms are useful for making interim restorations on single anterior teeth and premolars.

Additions to Clinical Armamentarium

- Assorted polycarbonate crowns
- Boley gauge or dividers
- Green stone, straight handpiece

Step-by-Step Procedure

1. Measure the mesiodistal width of the crown space with dividers (some crown kits provide a selection guide), and select a shell that is of the same or slightly larger width (Fig. 15-51).
2. Mark the crown height (from the incisal edge) with the dividers (Fig. 15-52), and use this

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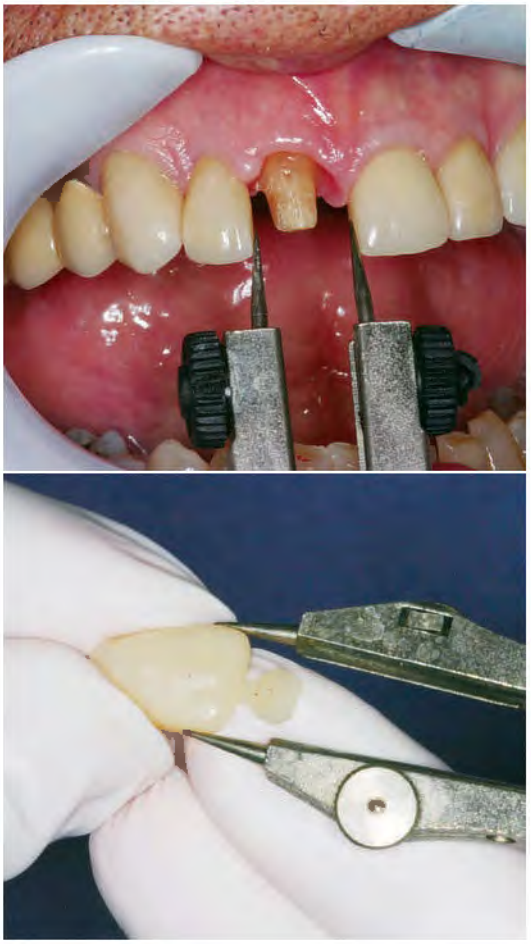

FIGURE 15-51 ■ Crown selection. **A,** Measuring the mesiodistal width of the space with dividers. **B,** Selecting the appropriate crown size for the measured space.

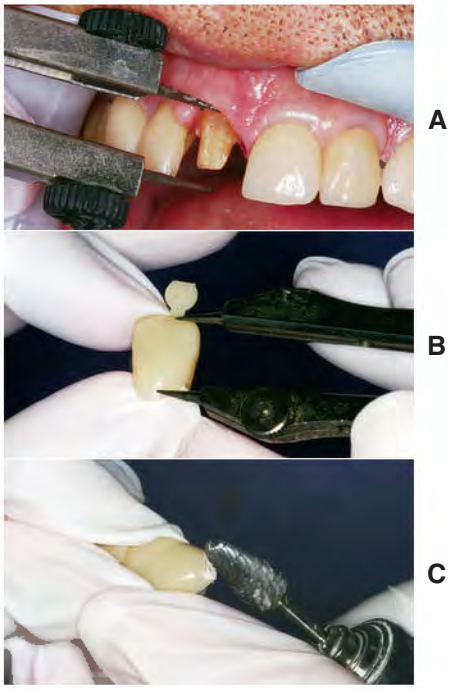

FIGURE 15-52 ■ Crown length adjustment. **A,** Incisocervical height required for the completed restoration. **B,** Measurement transferred to the crown. **C,** Cervical portion of the crown adjusted to duplicate the curvature of the cavosurface margin.

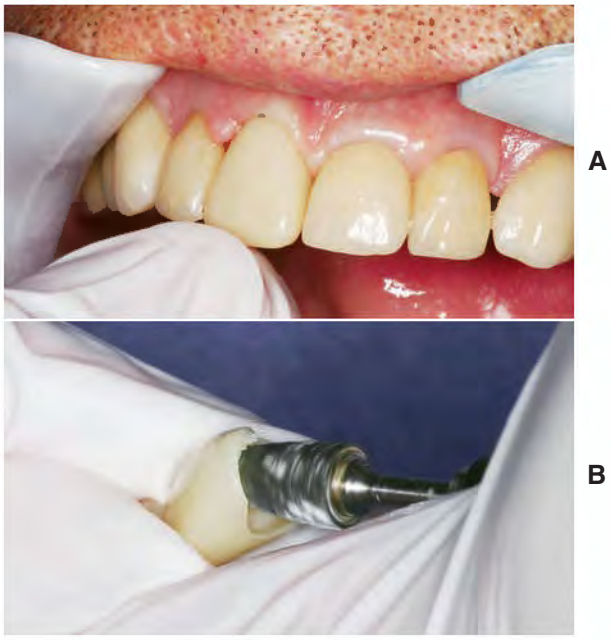

FIGURE 15-53 ■ **A,** Cervical portion of the crown trimmed until the length and axial inclination are correct. **B,** If necessary, internal surfaces are adjusted for proper orientation of the crown.

measurement as a guide to trimming the shell so that it matches the approximate curvature of the prepared cavosurface margin. For this trimming, it is recommended that a green stone or small-diameter tungsten carbide bur be used.

3. Try the shell on the prepared tooth (Fig. 15-53), being especially careful that the incisal edge and labial surface of the shell align properly with those of the adjacent teeth. The internal surface of the shell often needs reduction to achieve this match. For now, the occlusion should be ignored, inasmuch as it is usually better to adjust it after lining. When the shell can be properly positioned without forceful gingival contact, it is ready to be lined with resin.
4. Apply a uniformly thin coat of petrolatum to the prepared teeth and adjacent gingiva (Fig. 15-54). This prevents direct contact of the monomer with these tissues and the possibility of injury.
5. Mix the autopolymerizing resin and fill the shell (poly-R′ methacrylate is recommended). When the surface just loses its gloss or the resin forms a peak without slumping, place the shell over the tooth, and align the incisal and labial surfaces with those of the adjacent teeth.
6. Immediately eliminate any marginal excess. If polymerization is too far advanced, the doughy resin will pull away from the margin, and a later repair will be necessary.

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7. When the rubbery stage of polymerization is reached (after about 2 minutes), rock the crown faciolingually to loosen and remove it. The Backhaus forceps should be kept within easy reach in case there is difficulty separating the crown from the tooth. However, because it makes small indentations in the crown surface, the forceps should be used only when needed on anterior units.

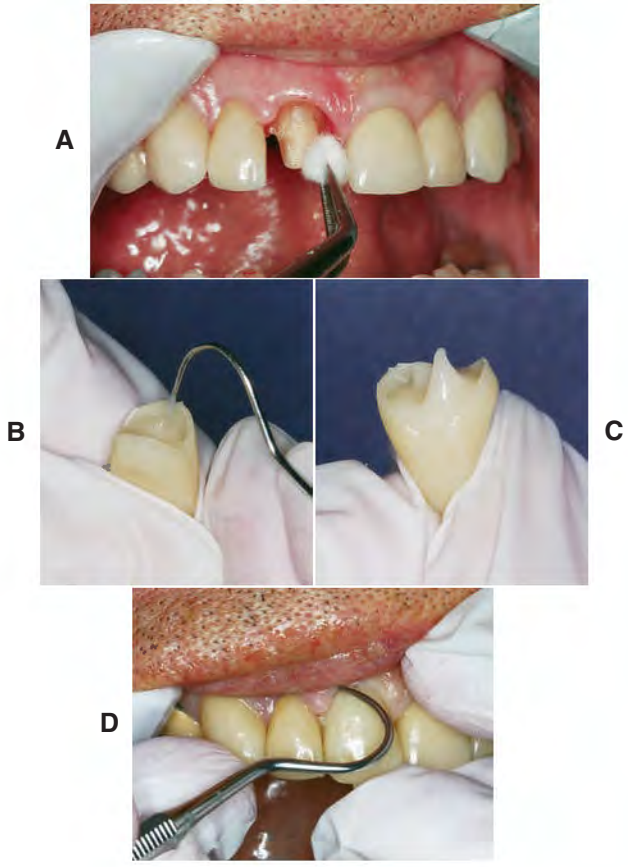

FIGURE 15-54 ■ Lining the adjusted shell. **A,** Protection with petrolatum. The shell is filled with resin **(B)** and is seated **(C)** when the resin does not slump after a peak is formed with the tip of an explorer. **D,** Excess resin is immediately removed after the crown has been positioned.

8. Place the crown in warm water (40°C) (Fig. 15-55).
9. When the resin has fully set (after approximately 5 minutes), the axial surfaces can be shaped, and the flash eliminated, with straight-handpiece tungsten carbide burs or abrasive disks.
10. Try on the newly lined crown, and adjust the lingual surface to the desired occlusion and contour (Fig. 15-56).
11. Polish and cement the restoration (Fig. 15-57).

Aluminum Crown Forms

Aluminum shells are useful for restoring single posterior teeth, where their unnatural appearance is not a disadvantage.

Additions to Clinical Armamentarium

The following equipment is needed (Fig. 15-58)

- Assorted aluminum crowns
- Dividers
- Crown-and-collar scissors
- Contouring pliers
- Cylindrical green stone, straight handpiece
- Coarse garnet paper disk (7/8-inch diameter)

Step-by-Step Procedure

1. Measure the mesiodistal width of the crown space, using dividers, and select an appropriate shell type with a width as close as possible to that measured. A slightly larger or smaller shell can be deformed with contouring pliers to attain the proper fit (Fig. 15-59).
2. Measure the occlusocervical height, and trim the shell with crown-and-collar scissors so that it extends about 1 mm apical to the cavosurface margin (Fig. 15-60). Sharp edges left by the scissors can be smoothed or rounded with the green stone.
3. Place the trimmed shell over the prepared tooth, and apply seating pressure gradually while observing the gingiva. Trim the margins farther at any location where the gingiva blanches. The shell margin should not engage the prepared tooth margin.

FIGURE 15-55 ■ **A,** When the resin has reached the rubbery stage, the crown is removed and placed in warm water (40°C). Hot water must not be used because it increases resin shrinkage. However, warm water is not recommended for polymethyl methacrylate resin because excessive shrinkage makes the marginal fit unacceptable. **B,** After about 5 minutes in warm water, the resin should be rigid enough for removal of the excess lining resin starting with a coarse garnet disk.

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FIGURE 15-56 ■ **A,** A considerable amount of lingual reduction may be needed. If only minor reduction is necessary, it can be accomplished intraorally. **B,** To increase efficiency and ensure the patient's comfort, any bulk reduction should be accomplished extraorally. **C,** Finalized lingual contour promotes gingival health and allows access for oral hygiene. Note the more natural contour of the left central incisor than that of the interim crown on the right central incisor.

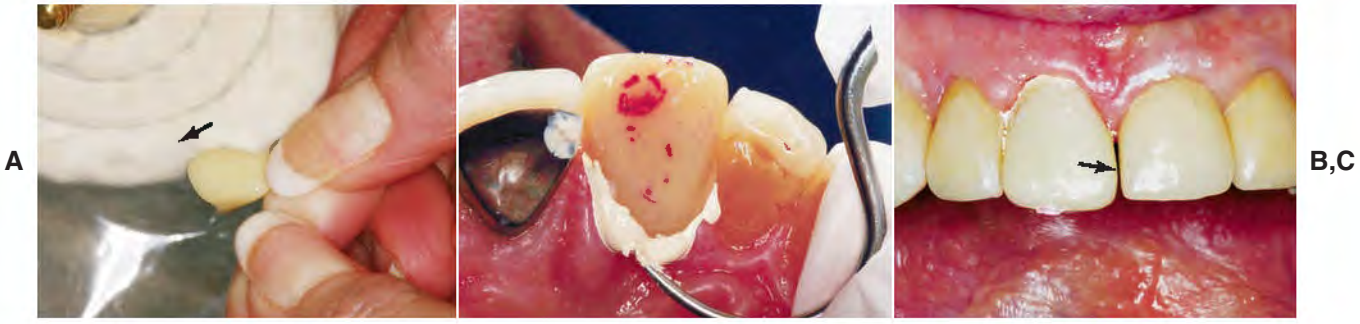

FIGURE 15-57 ■ **A,** A rag wheel and pumice are used before polishing with compound. Note the parallel orientation of the wheel to the crown's axial surface at the point of contact *(arrow).* The crown should be positioned so that the wheel rotates from the surface toward the margin. **B,** An explorer and dental floss are used to carefully remove all excess luting agent. **C,** Overpolishing results in a deficient mesial contact *(arrow).* The brush-bead technique is recommended for correcting a small inadequacy.

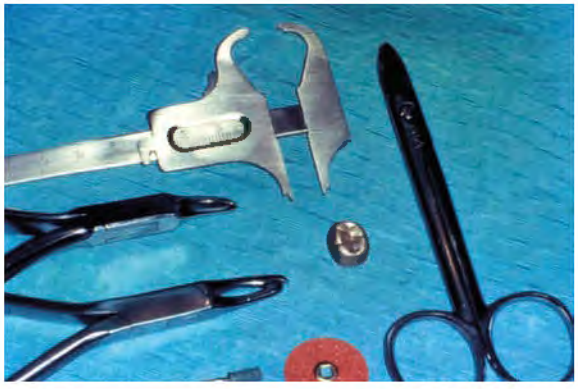

FIGURE 15-58 ■ Additions to the basic clinical armamentarium for aluminum crown forms.

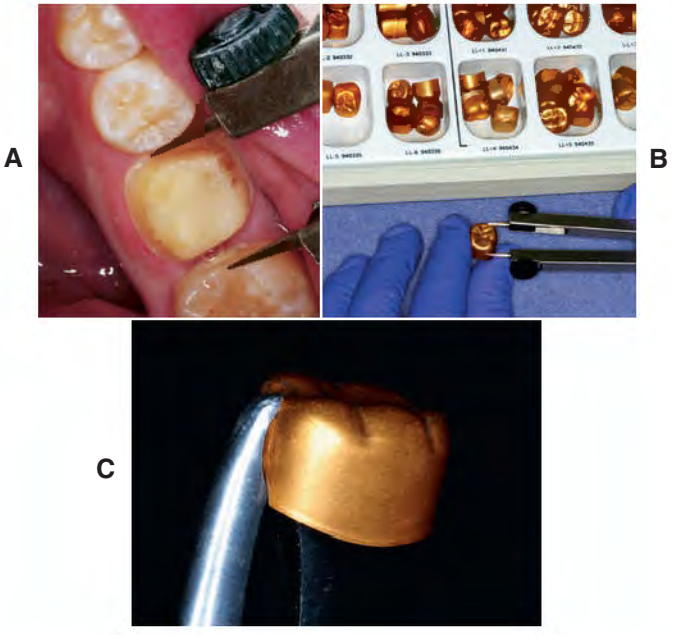

FIGURE 15-59 ■ Aluminum crown selection and modification. **A,** Mesiodistal dimension of the space. **B,** Appropriate crown size, nearest this measurement. **C,** Contouring pliers modifying axial wall form.

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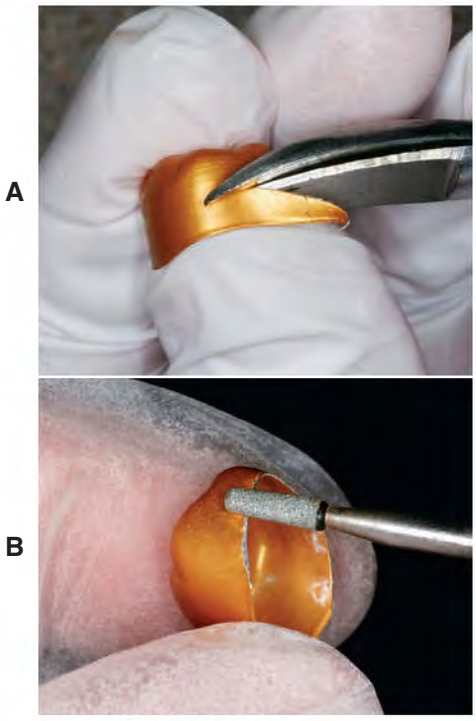

FIGURE 15-60 ■ **A,** Cervical portion of the crown trimmed to proper length. **B,** Smoothing the cut edge to prevent gingival injury.

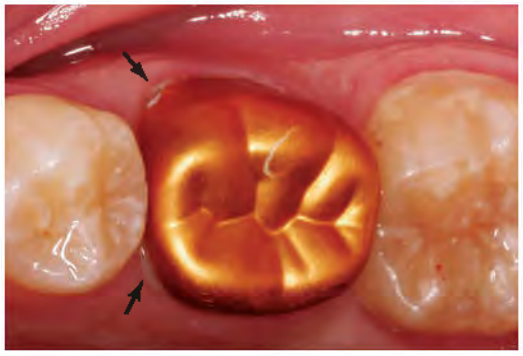

FIGURE 15-61 ■ The patient is instructed to bite on the shell after the length has been adjusted. Note the occlusal indentation and gingival blanching *(arrows)*. Where the shell causes blanching, additional shortening is needed.

4. Repeat the evaluation, and trim as necessary.
5. Instruct the patient to close the jaws with moderate force. The soft aluminum should deform until normal intercuspation is reached (Fig. 15-61).
6. Apply petrolatum to the prepared tooth and adjacent gingival tissues; mix poly-R′ methacrylate resin, and fill the shell.
7. When the resin surface becomes matte, place the shell over the tooth and guide it to a slightly supraclusal position (Fig. 15-62). Have the patient close the jaws.
8. To avoid pulling the resin away from the cavosurface margin, immediately remove the marginal excess.

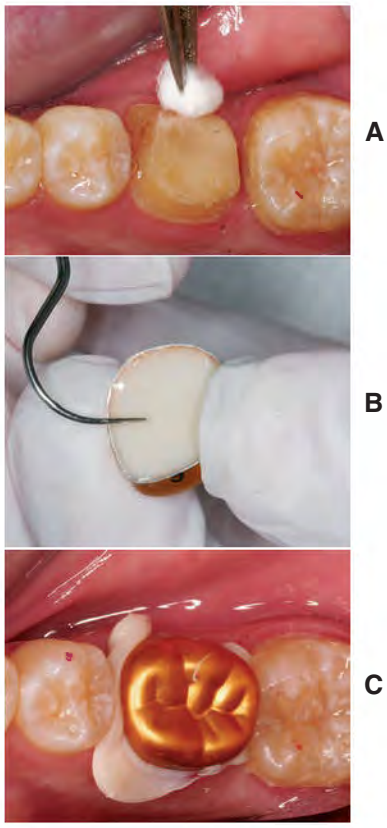

FIGURE 15-62 ■ **A,** The prepared tooth is protected with petrolatum. **B,** The adjusted shell is filled with lining resin and seated to just short of its final position after the resin has lost its sheen. **C,** The final position is determined by the patient's closing into maximum intercuspation. Excess resin is immediately removed.

9. When the rubbery stage of polymerization is reached (after approximately 2 minutes in the mouth), engage the crown with the Backhaus forceps to just penetrate the aluminum shell (Fig. 15-63). Loosen and remove the crown by rocking it buccolingually or by using the thumb and index finger of the other hand to apply occlusally directed force under the tines. The small buccal and lingual holes created in the surface of the aluminum are not usually a problem and can be ignored until the patient returns, whereupon they may be used to remove the crown again.
10. Place the shell in a cup of warm water (40°C).
11. After about 5 minutes, mark the margins and trim away any excess. To establish periodontally healthy axial contours, the aluminum shell frequently is ground away in certain areas (Fig. 15-64).
12. Replace the crown, and adjust the occlusion as deemed necessary. If either proximal surface lacks contact, resin can be added to correct the deficiency. Metal must be ground away in the contact area to provide a resin-to-resin bond (Fig. 15-65).
13. Polish, clean, and cement the restoration.

Post and Core Interim Restorations

Intraradicular retention and support are often obtained from a cast metal post and core restoration (see Chapter

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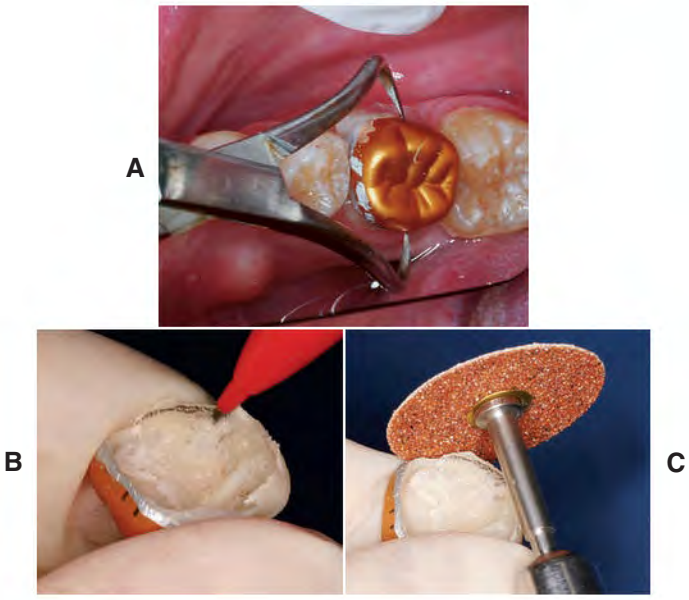

FIGURE 15-63 ■ **A,** Backhaus forceps provides definite purchase of the shell for controlled removal. **B,** After 5 minutes in warm water, the margin is marked with a pencil. **C,** A coarse garnet disk is recommended for initial contouring of the axial surfaces. This usually necessitates partial removal of the aluminum. After the overcontoured aluminum has been ground away, a fine garnet disk is used to finalize the axial contours (including the marginal areas). Again, disk orientation is important for establishing a straight emergence profile and well-adapted margins.

12). An interim restoration is needed while the casting is being made.

Additions to Clinical Armamentarium

- Wire
- Wire-cutting pliers
- Cylindrical green stone, straight handpiece
- Wire-bending pliers
- Paper points

Step-by-Step Procedure

1. Place a piece of wire (e.g., a straightened paper clip) in the post space. To avoid root fracture, it must extend passively to the end of the post space. A mounted stone can be used to taper the wire if binding occurs.
2. Mark the wire with a pencil at the mouth of the post space. Then, at a point slightly occlusal to this mark, use the pliers to make a 180-degree bend in the wire (Fig. 15-66).
3. Lubricate the tooth and surrounding soft tissues with petrolatum. Paper points are convenient for lubricating the post space.
4. Fill the ESF with interim resin (poly-R′ methacrylate is recommended).

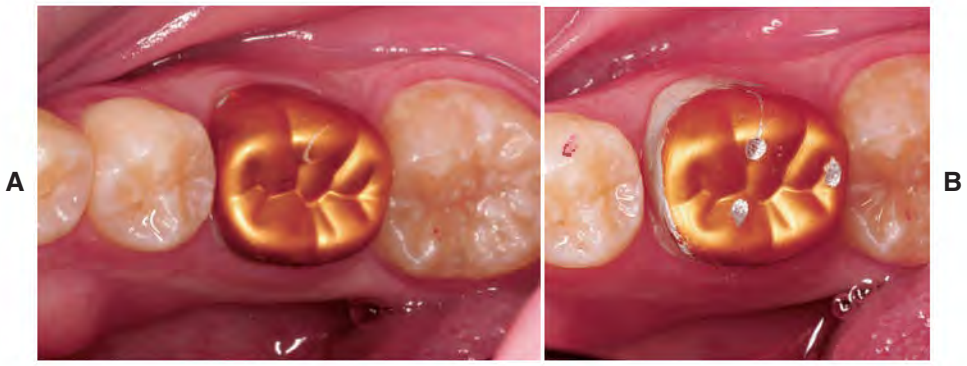

FIGURE 15-64 ■ **A,** Proper contouring of the axial walls exposes lining resin in the cervical area. Note the indentations in the shell from the Backhaus forceps. **B,** Final occlusal adjustment removes the anodized gold finish, but this is of no concern.

FIGURE 15-65 ■ Adding proximal contacts to aluminum crowns. **A,** Contacts are absent in this lined crown *(arrows).* **B,** The metal in the contact area is ground away to expose the underlying resin. The brush-bead technique is then used for correcting the deficiency. **C,** Appearance of the crown after resin addition to the mesial surface. Further contouring with a disk is recommended to improve the gingival embrasure form.

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FIGURE 15-66 ■ Interim post preparation. **A,** Wire is marked so that the bend is made at the correct level. When in position, the wire must not interfere with the external surface form. **B,** A 180-degree or greater bend in the wire is made to resist displacement in the lining resin.

FIGURE 15-67 ■ **A,** Wire is inserted in the post space just before placement of the filled external surface form (ESF). A gauze throat pack is recommended to protect the patient from aspirating or swallowing the wire. The patient should not be placed in the supine position. **B,** Filled ESF is seated.

5. When the resin loses its surface gloss, place the wire in the post space, and seat the ESF over it (Fig. 15-67). Precautions, including using a gauze throat pack and not placing the patient supine, must be taken to protect the patient from swallowing or aspirating the wire.
6. Remove the ESF while the resin is still rubbery (after 2 to 2½ minutes). The stage of polymerization should be monitored. If the resin is allowed to become rigid and lock into the undercut surfaces within the post preparation, removing it and the wire will be time consuming and risk the restorability of the tooth. The interim usually remains in the ESF, which can be placed in warm water to hasten polymerization. The wire must not be disturbed while the resin is soft. If the interim remains on the tooth, it should be loosened and reseated several times and then removed before the resin has fully polymerized.
7. Trim and contour the restoration with disks or straight-handpiece tungsten carbide burs.
8. Evaluate the restoration in the mouth, and adjust as necessary.
9. Polish, clean, and cement the restoration (Fig. 15-68).

FIGURE 15-68 ■ The completed interim post and crown restoration. (The unusual mesial contour is the result of a mesiobuccal root amputation.)

Cementation

The primary function of the interim luting agent is to provide a seal, preventing marginal leakage and hence pulp irritation. The luting agent should not be relied upon to resist occlusal forces, inasmuch as it is purposely formulated to have low strength. Unintentional displacement of an interim restoration is frequently caused by a nonretentive tooth preparation or excessive cement space rather than the choice of luting agent.

Ideal Properties

Desirable characteristics of an interim luting agent are as follows:

- Seal against leakage of oral fluid
- Strength consistent with intentional removal

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FIGURE 15-69 ■ Interim luting agents are available in various formulations. A non–eugenol-containing product is recommended for bonded restorations; the clear luting agent is used for improved esthetics. (Courtesy Kerr Corp., Orange, California.)

- Low solubility
- Blandness or obtundent quality
- Chemical compatibility with the interim polymer
- Convenience of dispensing and mixing
- Ease of eliminating excess
- Adequate working time and short setting time

Available Materials

Of the currently available materials (Fig. 15-69), zinc oxide–eugenol (ZOE) cements appear to be the most satisfactory. Zinc phosphate, zinc polycarboxylate, and glass ionomer cements are not recommended because their comparatively high strength makes intentional removal difficult. Using high-strength cements frequently damages the restoration or even the tooth when removal is attempted and can make seating of the definitive restoration difficult. Weaker ZOE cements provide for easy removal, allowing the restoration to be reused when additional service is needed. ZOE has an obtundent effect on the pulp, in addition to its acceptable sealing properties.[27] Unfortunately, however, free eugenol acts as a plasticizer of methacrylate resins. It has been shown to reduce surface hardness[28] and presumably strength. New resin applied over polymerized resin previously in contact with free eugenol results in softening[29] of the added resin, which precludes successful linings or repairs. The poly-R′ methacrylate resins are severely affected by free eugenol. Methyl methacrylate resins are affected moderately, and the composites are only slightly softened. These adverse effects have stimulated the marketing of interim luting agents without eugenol, but in the studies cited, the mere presence of eugenol in a cement was not enough to cause adverse effects. It appears that unreacted or free eugenol must be present to cause problems. Therefore, when using products that contain eugenol, the dentist must be sure that the correct proportions are blended. Whether free eugenol is necessary to provide an obtundent effect on the pulp remains a question.

In situations in which the tooth preparation lacks retention, a span is long or long-term use is anticipated, or parafunction exists, it may be desirable to use a cement of higher strength. A good compromise would be reinforced ZOE; another might be eugenol-free zinc oxide, which has slightly greater strength than cements containing eugenol.[30] Conversely, sometimes minimum strength is desired, as with temporary placement of the definitive restoration. (Its removal may be needed to refire the porcelain.) Petrolatum can be mixed with equal parts of the interim cement base and catalyst to reduce the cement's strength by more than half. When the definitive cement planned is a resin luting agent, non-eugenol cements are recommended for the interim restoration because of the adverse effect of eugenol on bond strength.

Armamentarium

The following equipment is needed (Fig. 15-70):

- Interim luting agent
- Mixing pad
- Cement spatula
- Plastic filling instrument
- Petrolatum
- Mirror and explorer
- Dental floss
- Gauge

Step-by-Step Procedure

Most interim luting agents are supplied as a two-part system (Fig. 15-71).

1. To facilitate removal of excess cement, lubricate the polished external surfaces of the restoration with petrolatum (see Fig. 15-71, *A*).
2. Mix the two pastes together rapidly, and apply a small quantity just occlusal to the cavosurface margin (see Fig. 15-71, *B*). A marginal bead of cement forms the required seal against oral fluids.

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Filling the crown or abutment retainers should be avoided, because it prolongs cleanup and increases the risk of leaving debris in the sulcus.

3. Seat the restoration, and allow the cement to set (see Fig. 15-71, *C*).
4. Carefully remove excess with an explorer and dental floss (see Fig. 15-71, *D* to *F*).

Cement remnants left in the sulcus have an irritating effect on the gingiva and may cause severe periodontal inflammation with possible bone loss. Therefore, the sulcus must be carefully checked and irrigated with the air-water syringe.

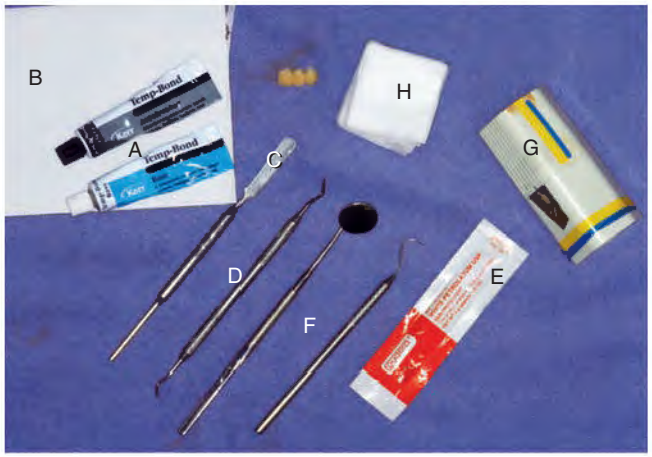

FIGURE 15-70 ■ Interim restoration luting armamentarium. *A,* Interim luting agent; *B,* mixing pad; *C,* cement spatula; *D,* plastic filling instrument; *E,* petrolatum; *F,* mirror and explorer; *G,* dental floss; *H,* gauze.

Removal, Recementation, and Repair

Armamentarium

- Backhaus towel clamp forceps or hemostatic forceps
- Spoon excavator
- Ultrasonic cleaner with cement-remover solution

The interim restoration is removed when the patient returns for placement of the definitive restoration or for continued preparation. Fracture of the prepared tooth or foundation must be avoided. Risk of this can be minimized if removal forces are directed parallel to the long axis of the preparation. The Backhaus towel clamp forceps or a hemostatic forceps is effective for obtaining sound purchase on a single unit (Fig. 15-72). A slight buccolingual rocking motion helps break the cement seal.

Damage can occur when an FDP is being removed. If one abutment retainer suddenly breaks loose, the other can be subjected to severe flexure stresses when the FDP acts as a lever arm. Care must be exercised to remove the prosthesis along the path of placement. Sometimes it is helpful to loop dental floss under the connector at each end of the FDP.

Step-by-Step Procedure

1. If the interim restoration is going to be recemented, clean out the bulk of existing cement with a spoon excavator.
2. Place the restoration in a cement-dissolving solution, and set this in the ultrasonic cleaner.
3. Line the restoration with a fresh mix of resin if necessary (e.g., if the tooth preparation has been modified). The internal surface is relieved slightly

FIGURE 15-71 ■ Luting procedure. **A,** The external surface is lightly coated with petrolatum to aid removal of the set luting agent. **B,** Careful placement of the luting agent seals the margins and reduces the clean-up effort. **C,** The restoration is seated with firm finger pressure, or (for posterior restorations) the patient may bite on a cotton roll. **D** and **E,** An explorer is used to remove excess and to probe the sulcus gently for remnants. **F,** The proximal contact areas and sulcus are cleaned with dental floss (a knot will help remove excess cement), followed by copious irrigation with the air-water syringe.

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and painted with monomer to ensure good bonding of the new material.

A fractured or damaged interim restoration can be repaired easily with resin, added directly by means of the brush-bead technique (Fig. 15-73).

Esthetic Enhancement

Contour, color, translucency, and texture are the key elements of coronal appearance. Contour and color are esthetically fundamental and more important than the other two elements. The indirect partial FDP procedure just described includes methods for controlling contour and color.

Contour

Diagnostic waxing provides the ultimate control of contour, and shade selection before tooth preparation gives the operator some control of color. If contour and color are well controlled, most interim restorations are very acceptable or even excellent in appearance. Routinely achieving this outcome requires attention to detail and skill. Also, achieving translucency in an interim crown can be a significant challenge for patients with unabraded teeth.

FIGURE 15-72 ■ Backhaus towel clamp forceps provides positive purchase on interim restorations. For maximum control, occlusal finger pressure is applied directly to the tines.

Color

Whereas some resin manufacturers use only general color descriptors *(light*, *medium*, *dark)* for their products, most cross-reference their colors to popular shade guides for porcelain or denture teeth. However, even when colors are cross-referenced, shade matching can be inaccurate because of manufacturer and material differences. Better control of color is obtained through the use of a custom shade guide. The dentist can make this easily by casting the resins into an elastomeric putty mold of an extracted incisor crown. Combining two or more existing hues in known proportions can create a wider selection of shades; resin-coloring tints are another option.

Custom color effects that simulate intrinsic and extrinsic stains, cracks, or hypocalcification of adjacent teeth may be added to interim restorations with the help of paint-on stain kits (Fig. 15-74). These are best applied

FIGURE 15-74 ■ This interim stain kit contains violet, blue, yellow, orange, brown, white, and gray paint-on colorants to create custom effects and a clear material used to form a glazed translucent surface. The liquids are formulated to dry quickly, which requires that they be kept covered until immediately before use. A thinner and a brush cleaner are provided.

A

B,C

FIGURE 15-73 ■ Brush-bead technique for repairs. **A,** Monomer liquid is painted on the surface of the thoroughly cleaned restoration to which resin will be added. **B,** The brush is dipped in monomer and briefly touched to the powder, which causes a small bead to form on the tip. **C,** The bead is touched to the repair site, and the brush handle is rolled to deposit it. Bead placement continues in this manner until the desired contour is achieved. To prevent excessive porosity, the unset resin should be painted lightly with monomer until hard.

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quickly, and overmanipulation should be avoided because it causes streaking and surface roughness. Under optimum conditions, the surface should have a glazed appearance similar to that of porcelain. Thickening of stains as a result of the evaporation of solvent is a common problem that hampers manipulation. Another problem with the paint-on colorants is their poor resistance to abrasion. Loss of the pigments in high-abrasion areas produces an unattractive mottled effect.

Translucency

Coronal translucency is determined by the type and amount of enamel present. In an unworn anterior tooth where there is no dentin in the light path, the incisal edge often takes on a blue or gray hue, which comes about from the dark oral cavity. This effect is most pronounced with enamel that scatters very little light as a result of the absence of pigments or opacifying mineralization (e.g., fluorosis). Although less obvious, the translucent appearance of enamel is observable over the entire incisal or occlusal third of the crown. Thus when it is readily visible in adjacent teeth or when a more realistic appearance is desired, translucency can be simulated in the interim. The procedure requires two resins: one colored to match the body of the tooth and one to match the enamel of the tooth. Some manufacturers produce enamel or incisal shades that may be used without modification. When these are not available or when variation is needed, clear resin powder may be mixed with a smaller fraction of the "body" powder to produce the desired translucency.

Two procedures can be followed to create a translucent effect. In the first, which is more difficult to control, the enamel color resin is carefully brush-beaded onto the occlusal or incisal surface of the ESF and tapered to end at the middle or cervical third. The tendency to flow where it is not wanted is controlled in part by the orientation of the ESF with regard to gravity and in part by manipulation with the brush tip. When the desired distribution of enamel color resin is achieved, a disposable syringe is loaded with body color resin, and the ESF is immediately filled to avoid disruption of the enamel color resin. The TSF is then positioned in the ESF, and normal procedures are followed (Fig. 15-75).

In the second procedure, the enamel color resin is allowed to polymerize on the ESF without the addition of body color resin on the TSF. The rigid enamel veneer is removed from the ESF and trimmed to occupy only the space intended for enamel. It is important to check that the ESF and TSF can be fitted without interference from the in-place veneer. With the veneer in place, monomer liquid is painted on it and the body color resin is added. The TSF is then inserted, and standard procedures are followed for the remainder of the restoration. The timing for this procedure is less crucial than for the first one described and may be better suited to practitioners with less experience. A disadvantage is that sometimes this approach results in a more obvious demarcation between the enamel and the body resins.

FIGURE 15-75 ■ The layering of translucent resin and dentin-shaded resin allows a more realistic appearance of the premolar and canine interim restorations. They serve as removable dental prosthesis (RDP) abutments and are splinted together to help resist dislodgment.

Texture

With practice, texture effects require only a small amount of time, but they may contribute significantly to the overall appearance of the interim restoration. These effects are most important for maxillary anterior teeth adjacent to teeth with well-defined lobes, imbrication lines, or developmental defects.

Developmental lobes are best simulated in wax during the final stage of the diagnostic waxing. To produce a natural effect, it is crucial to avoid making grooves that are straight, have sharp edges, or have uniform cross sections. Rather, the simulation should have a gentle crescent shape, the edges should be softened, and the cross section slightly varied by burnishing with the largest diameter waxing wire. If a polypropylene sheet is used to form the ESF, these subtle details can be reproduced in the resin.

Placement of developmental defects is best accomplished in the resin just before pumice and rag wheel finishing. Depending on their size and definition, these features may be made with a sharp-edged, inverted-cone green stone rotating parallel to the occlusal plane and touched briefly to the resin. Often the defects are most noticeable in the cervical third of the tooth, but an adjacent tooth is the best guide for determining their distribution.

Imbrication lines may be simulated with a coarse diamond rotary instrument rotating slowly and moved across the facial surface from proximal to proximal. This reduces the surface reflectance of the resin after it is finished and polished. However, as with all texture effects, overfinishing obliterates these lines. Care must be taken to monitor the finishing by rinsing pumice from the surface and drying it. A completely smooth and highly polished interim restoration may be excellent for plaque control but not esthetically compatible with the adjacent teeth. The debate as to which is more important can probably best be settled by consultation with the patient to determine his or her needs.

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FIBER-REINFORCED COMPOSITE FIXED PROSTHESES

Martin A. Freilich • Jonathan C. Meiers • A. Jon Goldberg

Fiber-reinforced fixed prostheses consist of a fiber-reinforced composite (FRC) substructure veneered with a particulate composite material. The substructure provides strength, and the veneer, because it is laboratory processed, exhibits better physical properties and esthetics than do direct placement composite restoratives (Fig. 15-76). They are ideal prostheses when a longer term interim restoration is needed.

Because of their good flexure strength and other physical characteristics, FRCs are suitable substructure materials for FDPs.[31-33] In addition, the FRC substructure is translucent, and no opaque masking is required. This allows a relatively thin layer of particulate covering composite and excellent esthetics. FRCs have been used to make two-phase all-polymer prostheses composed of an internal glass fiber–reinforced composite substructure covered by a particulate composite (Fig. 15-77).

FIGURE 15-76 ■ **A,** All-ceramic crown restoring the right maxillary central incisors. **B** and **C,** Maxillary anterior teeth restored with facial veneers and an all-ceramic fixed dental prosthesis. (**B** and **C,** Courtesy Dr. D.H. Ward.)

Available Materials

FRC materials are categorized according to the following characteristics:

- Type of fiber
- Fiber orientation
- Whether the resin impregnation of the fiber is performed by the dentist/laboratory technician or by the manufacturer

The most commonly used fibers in dental applications are glass, polyethylene, and carbon. Fiber architectures in dentistry include unidirectional patterns, in which all fibers are parallel, and braided and woven patterns. Commercially available non–resin-impregnated materials include polyethylene weaves (e.g., Ribbond, Ribbond, Inc., and Construct, Kerr Corp.) and glass weaves (e.g., GlasSpan, GlasSpan, Inc.). For these products, the resin must be added to the fibers by hand. Resin-preimpregnated materials include everStick and StickNET (GC America Inc.), which are hand formed and available in both unidirectional and woven-glass forms; FibreKor (Pentron Clinical), which is hand formed and available as a unidirectional glass material; and Splint-It (Pentron Clinical), which is also hand formed and available in both unidirectional and woven glass forms (Fig. 15-78).

Different FRC materials exhibit different handling and mechanical properties. Fiber type, fiber orientation, and the quality of fiber impregnation with the resin matrix have a substantial effect on handling characteristics and physical properties. Glass materials with a unidirectional architecture exhibit flexural properties that are superior to the polyethylene materials with a woven or braided architecture (Table 15-5). These glass materials have a flexural strength that is more than twice the strength of polyethylene materials and a flexural modulus almost eight times as great.[16] Because of their good handling characteristics, the braided and woven polyethylene products may be useful for other dental applications (e.g., operatory fabrication of periodontal splints).

Currently available materials demonstrate excellent esthetics, good handling characteristics, and good flexure properties.[32,34-37] Commercial products have been based on these formulations. The fabrication of a complete-coverage prosthesis with a commercially available, preimpregnated unidirectional FRC (FibreKor, Pentron Clinical) and a hand-fabricated technique is shown in Figure 15-79.

SUMMARY

Although interim restorations are usually intended for short-term use and then discarded, they can be made to provide pleasing esthetics, adequate support, and good protection for teeth while maintaining periodontal health. They may be fabricated in the dental office from any of several commercially available materials and by a number of practical methods. The success of fixed prosthodontic treatment often depends on the care with which the interim restoration is designed and fabricated.

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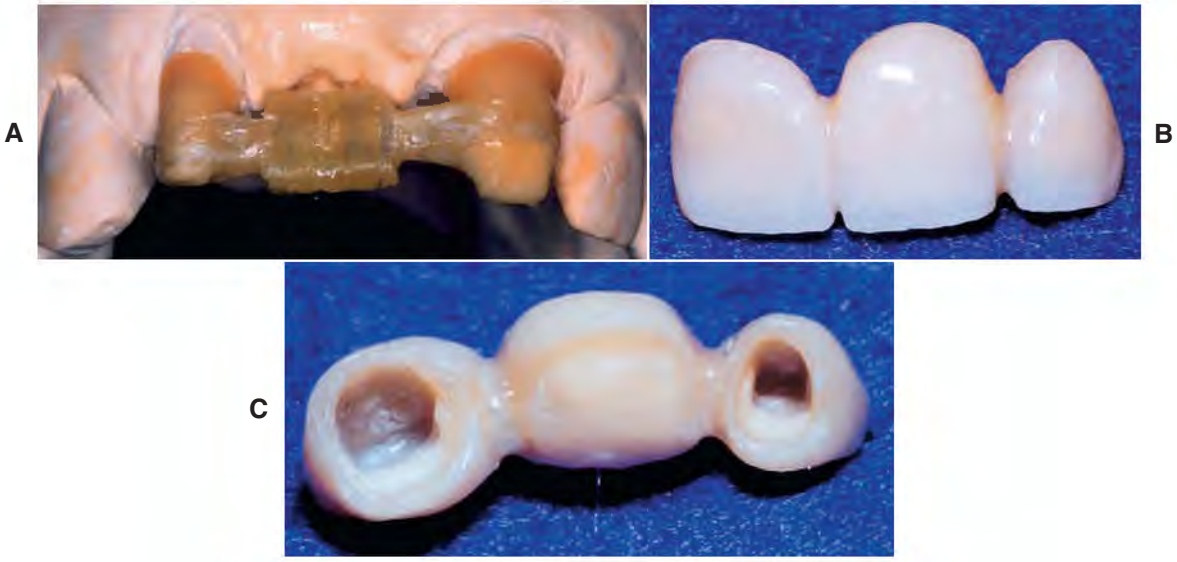

FIGURE 15-77 ■ **A,** Fiber-reinforced composite (FRC) substructure for a three-unit polymer fixed dental prosthesis (FDP). **B,** Particulate composite veneers completed over FRC substructure. **C,** Internal surface of FRC-reinforced polymer FDP.

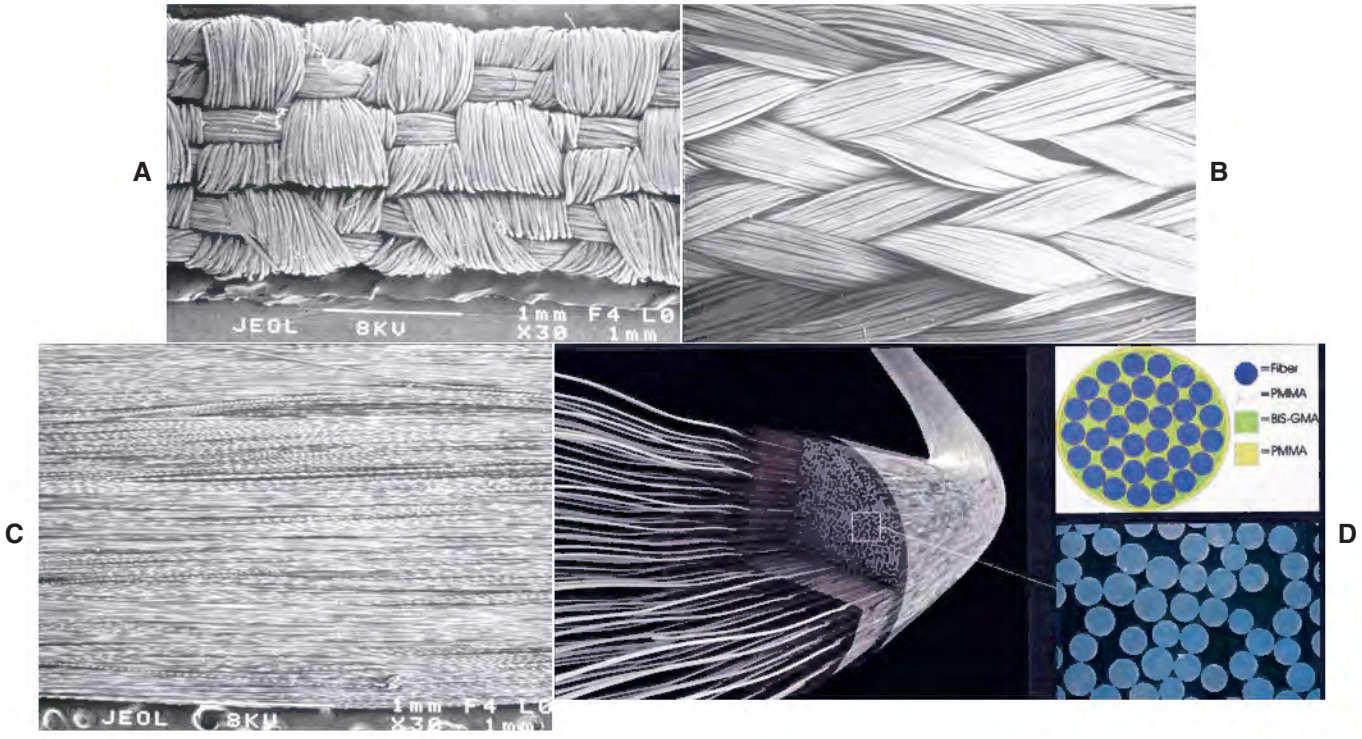

FIGURE 15-78 ■ Scanning electron micrographs of fiber-reinforced composite (FRC) materials. **A,** Woven polyethylene FRC (Construct, Kerr Corporation). **B,** Braided polyethylene FRC (Ribbond, Ribbond, Inc.). **C,** Unidirectional long glass fiber FRC (FibreKor, Pentron Clinical Technologies, LLC). **D,** Unidirectional long glass fibers with a polymethyl methacrylate (PMMA) outer membrane (everStick, GC America Inc.).

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TABLE 15-5 **Flexure Properties of Commercial Fiber-Reinforced Composite Materials***

Material	Fiber Type	Fiber Architecture	Flexural Strength (MPa)		Flexural Modulus (GPa)	
			M	*SD*	*M*	*SD*
FibreKor 2K	Glass	Unidirectional	541	32	25.0	2.0
FibreKor 16K	Glass	Unidirectional	639-919†	35-42	28.0	3.0
everStick	Glass	Unidirectional	739	47	24.3	1.5
GlasSpan	Glass	Braid	321	28	13.9	1.1
Construct	Polyethylene	Braid	222	23	8.3	0.5
Ribbond	Polyethylene	Leno weave	206	15	3.9	0.7

*Data generated in the authors' laboratory.
†Manufacturer's data.
M, Mean; *SD*, standard deviation.

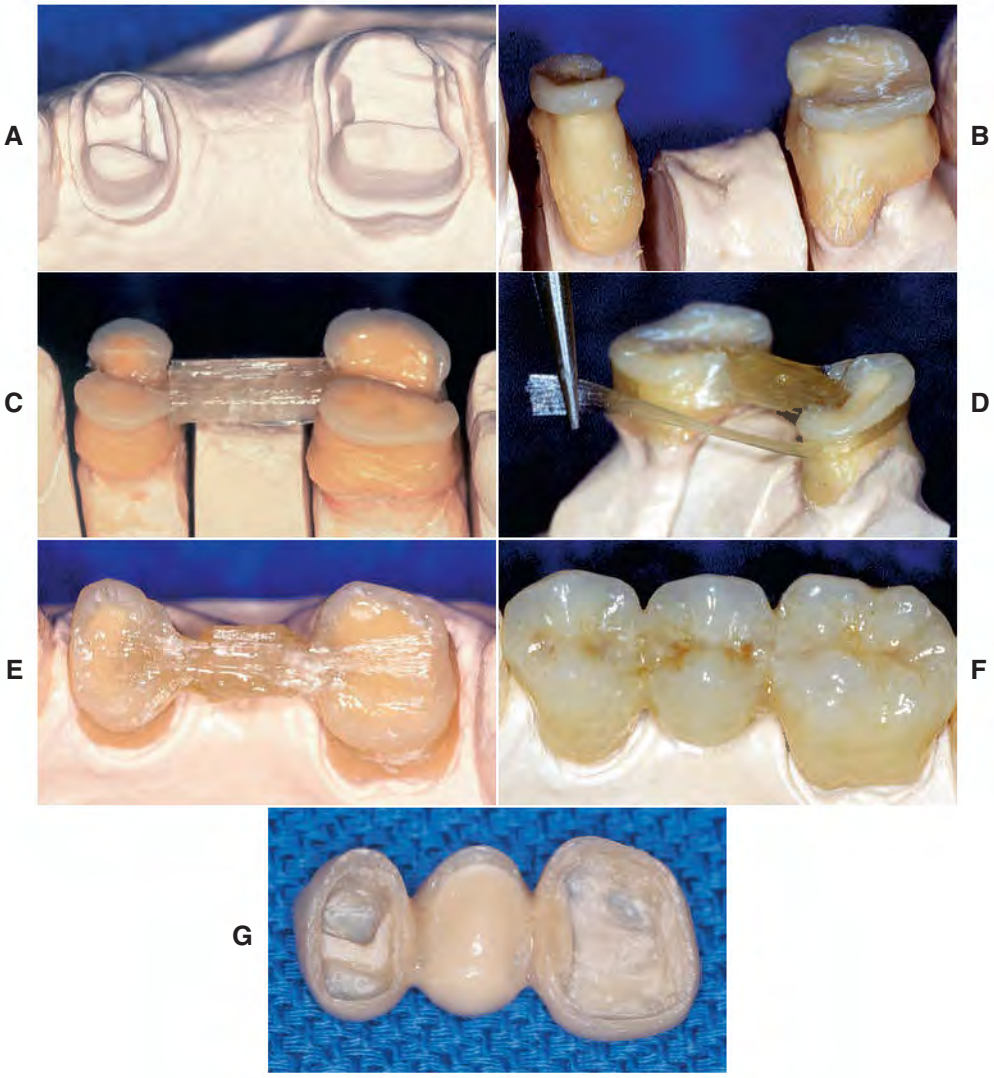

FIGURE 15-79 ■ The step-by-step fabrication of a complete-coverage fiber-reinforced composite (FRC) prosthesis with a unidirectional glass material (FibreKor, Pentron Clinical Technologies, LLC), accomplished with a hand-fabricated technique. **A,** Dies showing posterior abutment preparations for an FRC polymer fixed prosthesis. **B,** Thin coping of opacious body particulate composite adapted to the die. **C,** Bar of multiple layers of FRC spanning the pontic region, bonding the copings together. **D,** Continuous strip of FRC bonded to one end of the pontic bar and then wrapped around the axial surfaces of the copings while being polymerized. **E,** Occlusal view of the completed FRC substructure. **F,** Completed prosthesis with particulate resin veneers on model. **G,** Tissue side view of completed prosthesis, showing the internal adaptation to preparation design of the abutment teeth.

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REFERENCES

1. Seltzer S, Bender IB: The dental pulp; biologic considerations in dental procedures, 3rd ed, p 191. Philadelphia, Lippincott, 1984.
2. Seltzer S, Bender IB: The dental pulp; biologic considerations in dental procedures, 3rd ed, pp 267-272. Philadelphia, Lippincott, 1984.
3. Larato DC: The effect of crown margin extension on gingival inflammation. J South Calif Dent Assoc 37:476, 1969.
4. Waerhaug J: Tissue reactions around artificial crowns. J Periodontol 24:172, 1953.
5. Phillips RW: Skinner's science of dental materials, 8th ed, pp 221, 376. Philadelphia, WB Saunders, 1982.
6. El-Ebrashi MK, et al: Experimental stress analysis of dental restorations. VII. Structural design and stress analysis of fixed partial dentures. J Prosthet Dent 23:177, 1970.
7. Koumjian JH, et al: Color stability of provisional materials in vivo. J Prosthet Dent 65:740, 1991.
8. Preston JD: A systematic approach to the control of esthetic form. J Prosthet Dent 35:393, 1976.
9. Moskowitz ME, et al: Using irreversible hydrocolloid to evaluate preparations and fabricate temporary immediate provisional restorations. J Prosthet Dent 51:330, 1984.
10. Roberts DB: Flexible casts used in making indirect interim restorations. J Prosthet Dent 68:372, 1992.
11. Hensten-Pettersen A, Helgeland K: Sensitivity of different human cell lines in the biologic evaluation of dental resin-based restorative materials. Scand J Dent Res 89:102, 1981.
12. Munksgaard EC: Toxicology versus allergy in restorative dentistry. Adv Dent Res 6:17, 1992.
13. Dahl BL: Tissue hypersensitivity to dental materials. J Oral Rehabil 5:117, 1978.
14. Weaver RE, Goebel WM: Reactions to acrylic resin dental prostheses. J Prosthet Dent 43:138, 1980.
15. Giunta J, Zablotsky N: Allergic stomatitis caused by self-polymerizing resin. Oral Surg 41:631, 1976.
16. Spealman CR, et al: Monomeric methyl methacrylate: studies on toxicity. Industrial Med 14:292, 1945.
17. Moulding MB, Teplitsky PE: Intrapulpal temperature during direct fabrication of provisional restorations. Int J Prosthodont 3:299, 1990.
18. Tjan AHL, et al: Temperature rise in the pulp chamber during fabrication of provisional crowns. J Prosthet Dent 62:622, 1989.
19. Zach L, Cohen G: Pulpal response to externally applied heat. Oral Surg 19:515, 1965.
20. Crispin BJ, et al: The marginal accuracy of treatment restorations: a comparative analysis. J Prosthet Dent 44:283, 1980.
21. Monday JJL, Blais D: Marginal adaptation of provisional acrylic resin crowns. J Prosthet Dent 54:194, 1985.
22. Robinson FB, Hovijitra S: Marginal fit of direct temporary crowns. J Prosthet Dent 47:390, 1982.
23. Al-Sowygh ZH: The effect of various interim fixed prosthodontic materials on the polymerization of elastomeric impression materials. J Prosthet Dent 112:176, 2014.
24. Von Fraunhofer JA, Spiers RR: Accelerated setting of dental stone. J Prosthet Dent 49:859, 1983.
25. Thompson GA, Luo Q: Contribution of postpolymerization conditioning and storage environments to the mechanical properties of three interim restorative materials. J Prosthet Dent 112:638, 2014.
26. Yao J, et al: Comparison of the flexural strength and marginal accuracy of traditional and CAD/CAM interim materials before and after thermal cycling. J Prosthet Dent 112:649, 2014.
27. Pashley EL, et al: The sealing properties of temporary filling materials. J Prosthet Dent 60:292, 1988.
28. Rosenstiel SF, Gegauff AG: Effect of provisional cementing agents on provisional resins. J Prosthet Dent 59:29, 1988.
29. Gegauff AG, Rosenstiel SF: Effect of provisional luting agents on provisional resin additions. Quintessence Int 18:841, 1987.
30. Olin PS, et al: Retentive strength of six temporary dental cements. Quintessence Int 21:197, 1990.
31. Karmaker AC, et al: Fiber reinforced composite materials for dental appliances. In ANTEC 1996 Plastics: Plastics—Racing into the Future, Volume 3: Special Areas, pp 2777–2781. Indianapolis, Society of Plastic Engineers, 1996.
32. Freilich MA, et al: Flexure strength of fiber-reinforced composites designed for prosthodontic application [Abstract no. 999]. J Dent Res 76:138, 1997.
33. Freilich MA, et al: Flexure strength and handling characteristics of fiber-reinforced composites used in prosthodontics [Abstract no. 1561]. J Dent Res 76:184, 1997.
34. Goldberg AJ, Burstone CJ: The use of continuous fiber reinforcement in dentistry. Dent Mater 8:197, 1992.
35. Karmaker AC, et al: Extent of conversion and its effect on the mechanical performance of Bis-GMA/PEGDMA-based resins and their composites with continuous glass fibers. J Mater Sci 8:369, 1997.
36. Freilich MA, et al: Preimpregnated, fiber-reinforced prostheses. I. Basic rationale and complete-coverage and intracoronal fixed partial denture designs. Quintessence Int 29:689, 1998.
37. Freilich MA, et al: Development and clinical applications of a light-polymerized fiber-reinforced composite. J Prosthet Dent 80:311, 1998.

STUDY QUESTIONS

1. What are the ideal properties of an interim restorative material? What are the ideal properties of the optimum interim luting agent?
2. List at least five requirements for the success of an interim restoration.
3. Explain why these factors are crucial for clinical success. What would occur if they were not appropriately performed or obtained?
4. Select three techniques for fabricating an interim restoration for a single tooth. Identify the factors involved when a certain technique is selected for an indication or tooth.
5. What are the currently available materials for fabrication of interim restorations? What are their respective material properties, advantages, and disadvantages?
6. Explain the basic chemical events involved in resin polymerization.
7. What factors should be considered in the decision of whether to use a direct, indirect, or indirect-direct fabrication technique for interim fixed dental prostheses?

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PART III

LABORATORY PROCEDURES

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CHAPTER 16

Communicating with the Dental Laboratory

To make a high-quality fixed prosthesis, all members of the dental team must understand what they can reasonably expect from each other. A mutual knowledge of individual limitations is crucial. The dentist who does not understand and appreciate the challenges faced by the technician is at a serious disadvantage when prescribing and delegating laboratory procedures (Fig. 16-1). Crucial to the development of sound clinical judgment is a thorough understanding of technical procedures and their rationale, which are described in the chapters of this section.

DENTAL TECHNOLOGY TRAINING AND CERTIFICATION

The National Association of Dental Laboratories (NADL) is committed to upholding and advancing the commercial dental laboratory industry. This organization emphasizes the following information[1]:

In 46 states, there are no laws to set minimum qualifications for performance of dental technology or the operation of a dental laboratory. However, several states are moving forward with legislative proposals on "mandated technician certification." At the 2013 American Dental Association (ADA) House of Delegates, the ADA passed a resolution that came from cooperative work from the ADA Council on Dental Practice and the NADL that "strongly encourages all state dental boards to register dental laboratories."

Certification of technicians and laboratories is evidence of their commitment to maintaining professional standards in dental technology. There were approximately 44,000 individual dental laboratory technicians in the United States, as of June 2013, according to the U.S. Department of Labor. Because technicians are not required to be registered or licensed in most states, tracking has to come from various government and private sources.

In 2002, 25 programs in dental laboratory technology were approved (accredited) by the Commission on Dental Accreditation in conjunction with the ADA. Today, there are only 18.

The National Board for Certification in Dental Laboratory Technology, an independent board established by the NADL, offers voluntary certification in dental laboratory technology. Certification can be obtained in six specialty areas: crowns and bridges, ceramics, partial dentures, complete dentures, implants, and orthodontic appliances. Certification is required in Kentucky, Texas, and South Carolina. The standards and requirements for certification do not vary across state lines. A certified dental technician (CDT) tested in New England must demonstrate the same competencies as a CDT tested on the Pacific coast.

To qualify for certification, technicians must have a 2-year dental technology degree or at least 5 years' experience in dental technology and must pass written and practical examinations. To maintain certification, they must document at least 12 hours of continuing education annually, including 1 hour in regulatory standards that includes study on the Occupational Safety and Health Administration's (OSHA's) standards about bloodborne pathogens, infection control, and the U.S. Food and Drug Administration's (FDA's) quality systems. The requirements for a certified dental laboratory include having a CDT present to supervise each department in the specialty, in which they and the laboratory are certified, to ensure that proper safety and production practices are followed. Certification must be renewed annually.*

Technicians who maintain their certification must take 12 hours of continuing education each year, including a required hour in regulatory standards.

The first CDTs were tested in 1958. Today the National Board for Certification tests more than 1200 technicians annually. In 1978, the current standards for laboratory certification were adopted; today there are more than 300 certified dental laboratories (C.A.E. Bennett Napier, personal communication, November 19, 2013).

In 2012, the U.S. dental laboratory industry produced approximately $7 billion in sales. The number of dental laboratories in the United States is just over 9000.

MUTUAL RESPONSIBILITIES

Good communication—the key to the technical success of the dental team[2-4]—requires a close working relationship between the dentist and laboratory technician. Anticipating satisfactory results is unrealistic if the dentist does not have a reasonable amount of experience with, and a thorough understanding of, dental laboratory procedures. Active participation in the technical procedures by the dentist is paramount, and clinicians who take the time to develop an in-depth understanding of laboratory work make better clinical decisions because of their understanding of applicable technical and material science limitations. Only then can a dentist select the best compromise between (1) technical restrictions, (2) biologic factors, and (3) esthetic needs. Similarly, if the technician

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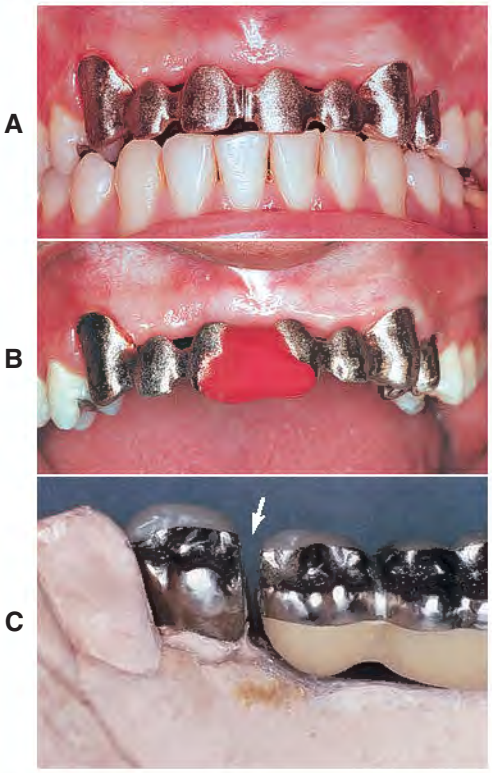

FIGURE 16-1 ■ **A,** This six-unit anterior metal-ceramic framework did not seat. After it was sectioned between the incisors, the adaptation of the individual components was satisfactory. Note the (correct) narrow width of the soldering gap. **B,** Appearance of the two segments indexed with autopolymerizing resin for subsequent soldering. **C,** The dentist sectioned this fixed dental prosthesis (FDP) incorrectly: The soldering gap is much too wide *(arrow),* and distortion during soldering will almost certainly result.

FIGURE 16-2 ■ Soft tissue contours and embrasure forms present a challenge for technicians. In this case, these substructures were not fabricated properly: The metal-porcelain junction was placed too far facially *(arrows).* Unless corrected during clinical evaluation, metal would be visible and detract from the appearance of the prosthesis.

does not appreciate and respect the clinical demands or the treatment rationale of the dentist, the results will be unsatisfactory (Fig. 16-2). The dentist can earn this respect by being prepared to meet personal responsibilities, by listening carefully to technical advice rendered, and by actively participating in the technical decision-making process.

Surveys[5-7] of fixed prosthodontic laboratories have revealed that dentists delegate a significant proportion of their responsibilities. The technicians surveyed were often dissatisfied with the quality of assignments received; complaints included insufficient information being included in the work authorization, the submission of deficient impressions, and inadequate occlusal records. Such surveys highlight significant problems in dentist-technician communication. In other studies and opinions concerning dentist-technician interaction, whether written by dentists or technicians, the authors emphasized that better patient care is achievable only by better communication about patient care.[8]

The ADA issued guidelines to improve the relationship between dentist and technician.[9] The introduction is reprinted as follows:

> *Working relationships between dentists and dental laboratories: The current high standard of prosthetic dental care is directly related to, and remains dependent upon, mutual respect within the dental team for the abilities and contributions of each member. The following guidelines are designed to foster good relations between dental laboratories, dental laboratory technicians and the dental profession. Applicable laws shall take precedence if they are inconsistent with any of the following guidelines.*

The guidelines themselves are reprinted in the following two sections.[9]

The Dentist

1. The dentist should provide written instructions to the laboratory or dental technician. The written instructions should detail the work which is to be performed, describe the materials which are to be used, and be written in a clear and understandable fashion. A duplicate copy of the written instructions should be retained for an appropriate time as may be required by law.
2. The dentist should provide the laboratory technician with accurate impressions, casts, occlusal registrations and/or mounted casts. Materials submitted should be identified.
3. The dentist should identify, as appropriate, the crown margins, postpalatal seal, denture borders, any areas to be relieved, and design of the removable partial dentures on all cases.
4. The dentist should furnish instruction regarding preferred materials, coloration, [and] description of prosthetic tooth/teeth to be utilized for fixed or removable prostheses, which may include, but [is] not limited to, a written description, photograph, drawing, or shade button.
5. The dentist should provide verbal or written approval to proceed with a laboratory procedure, or make any appropriate change(s) to the written instructions as the dentist deems necessary, when notified by a laboratory/dental technician that a case may have a questionable area with respect to paragraphs 2-4.

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6. The dentist should clean and disinfect all items according to current infection control standards prior to sending them to the laboratory technician. All prostheses and other materials that are forwarded to the laboratory/technician should be prepared for transport, utilizing an appropriate container and packaged adequately to prevent damage and maintain accuracy.
7. The dentist should return all casts, registration, and prostheses/appliances to the laboratory/technician if a prosthesis/appliance does not fit properly or if a shade selection is incorrect.

The Laboratory Technician

1. The laboratory technician should custom manufacture dental prostheses/appliances which follow the guidelines set forth in the written instructions provided by the dentist and should fit properly on the casts and mounting provided by the dentist. Original written instructions should be retained for a period of time as may be required by law. When a laboratory provides custom-printed written instruction forms to a dentist, the laboratory document should include the name of the laboratory and its address, provide ample space for the doctor's written instruction, areas to indicate the desired delivery date, the patient's name, a location for the doctor to provide his/her name and address, as well as to designate a site for the doctor to provide a signature. The form should also allow for other information which the laboratory may deem pertinent or which may be mandated by law.
2. The laboratory should return the case to the dentist to check the mounting if there is any question of its accuracy or of the bite registration furnished by the dentist.
3. The laboratory/technician should match the shade which was described in the original written instructions.
4. The laboratory/technician should notify the dentist within two (2) working days after receipt of the case, if there is a reason for not proceeding with the work. Any changes or additions to the written instructions must be agreed to by the dentist and must be initialed by authorized laboratory personnel. A record of any changes shall be sent to the dentist upon completion of the case.
5. After acceptance of the written instructions, the laboratory/technician should custom manufacture and return the prostheses/appliances in a timely manner in accordance with the customary manner and with consideration of the doctor's request. If written instructions are not accepted, the laboratory/technician should return the work in a timely manner and include a reason for the denial.
6. The laboratory should follow current infection control standards with respect to the personal protective equipment and disinfection of prostheses/appliances and materials. All materials should be checked for breakage and [such breakage] immediately reported if found.
7. The laboratory/technician should inform the dentist of the materials present in the case and may suggest methods on how to properly handle and adjust these materials.
8. The laboratory/technician should clean and disinfect all incoming items from the dentist's office; e.g., impressions, occlusal registrations, prostheses, etc., according to current infection control standards, placed in an appropriate container, packed properly to prevent damage, and transported.
9. The laboratory/technician should inform the dentist of any subcontracting laboratory/technician employed for preparation of the case. The laboratory/technician should furnish a written order to the dental laboratory which has been engaged to perform some or all of the services on the original written instructions.
10. The laboratory/technician should not bill the patient directly unless permitted by the applicable law. The laboratory should not discuss or divulge any business arrangements between the dentist and the laboratory with the patient.

RESPONSIBILITIES OF THE DENTIST

The dentist has the overall responsibility for the treatment rendered. Delegating many procedures to auxiliary personnel is possible if all the necessary information is provided to enable them to deliver high-quality service. However, errors such as insufficient tooth reduction, uncertainty about the location of tooth preparation margins, improper interocclusal records and articulations, and ambiguity in communicating the desired shades for esthetic restorations to the technician hamper this responsibility.

Infection Control

The U.S. Department of Health and Human Services[10] and the ADA[11] issued guidelines about the disinfection and handling of impressions and other material transferred from the dental office to the dental laboratory. Applicable guidelines are detailed in Chapter 14. Adherence to infection control guidelines must be strict because of the potential for infection of dental laboratory personnel. In a 1990 sample,[12] of all materials sent from dental offices to dental laboratories, 67% were contaminated. Results from a more recent questionnaire submitted to dental laboratories suggest that in less than 60% of the cases, technicians believed that materials had been appropriately disinfected before being submitted to the laboratory.[7]

Tooth Preparation

An organized approach to tooth preparation is discussed in Chapters 7 to 11, which provide the criteria for minimally necessary clearances for the various restorations.

Inadequate tooth reduction in the cervical third for a metal-ceramic restoration is a common error. Obviously, on long clinical crowns of vital teeth (e.g., after

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FIGURE 16-3 ■ Unrealistic expectations. Restoration failure resulting from excessive axial contours. **A,** Recently placed metal-ceramic crowns have contributed to gingival inflammation. **B,** After removal of the restorations, shoulder margin width is seen to be insufficient when the crowns are removed. **C** and **D,** Excessive contours. Note the cervical bulge on the facial aspect of this restoration **(D). E,** A significant amount of axial wall is visible from a gingival view. **F** to **H,** The restorations are recontoured and polished. Compare the view in **G** with that in **D** and the view in **H** with that in **E. I,** Tissue health quickly improves when the recontoured restorations are temporarily recemented. After correction of the underreduced tooth preparations, replacement crowns were made for esthetic reasons.

periodontal surgery), it is not always possible to reduce the desired 1.2 to 1.5 mm without pulp exposure. Nevertheless, it is generally impossible, even for an experienced ceramist, to achieve superior esthetic results if the tooth is underprepared.[13] Inexperienced technicians tend to resolve the problem by overcontouring (Fig. 16-3), but this usually leads to the initiation or recurrence of periodontal disease. Esthetic difficulties and treatment limitations such as these should be discussed with the patient during the treatment planning phase. Communication

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FIGURE 16-4 ■ Marking the preparation margin with a colored pencil. The line must be clearly visible but of minimal thickness.

regarding any deviation from "ideal" criteria is essential ahead of time and can prevent misunderstanding, frustration, and ultimate failure.

Preparation Margins

Margins should be easily discernible and accessible on the casts submitted to the technician. The saying "If you can't see it, you can't wax it" describes the situation well. (The requirements for dies are listed in Chapter 17.)

The dentist should outline the margins on the dies[14] (Fig. 16-4). However, in practice, few dentists do this.[15] If the teeth are properly prepared and the impression is accurate, the margins should be obvious, which makes this step unnecessary. When doubt exists, the dentist's knowledge of the extent of the preparation should resolve any uncertainty.

Dentists must understand the importance of margin design and geometry. For instance, it is unrealistic to request a collarless restoration on a shoulder-bevel type of margin or a lithium disilicate ceramic crown restoration on a tooth with a narrow chamfer finish line (Figs. 16-5 and 16-6).

Although an experienced technician will probably bring any unrealistic demands to the attention of the dentist, some well-meaning technicians may attempt to meet a request that is doomed to failure from the beginning. To quote one excellent dentist, "When you discover an error has occurred—STOP! Don't proceed. Return to the step where the error occurred and correct it. Attempting to blunder on without correcting it properly will only compound and complicate the error."

Articulation

Proper articulation of opposing casts is the responsibility of the dentist. Often it is advisable to schedule a separate appointment with the patient for verification of the articulation. This is particularly crucial as the complexity of treatment increases (Fig. 16-7). An apparently slight discrepancy may necessitate a remake or hours of corrective grinding and a compromised result. With careful planning, the articulation can be verified efficiently. The dentist should trim the interocclusal records appropriately. Only after trimming is it possible to verify the positional stability of the record on the cast (Fig. 16-8).

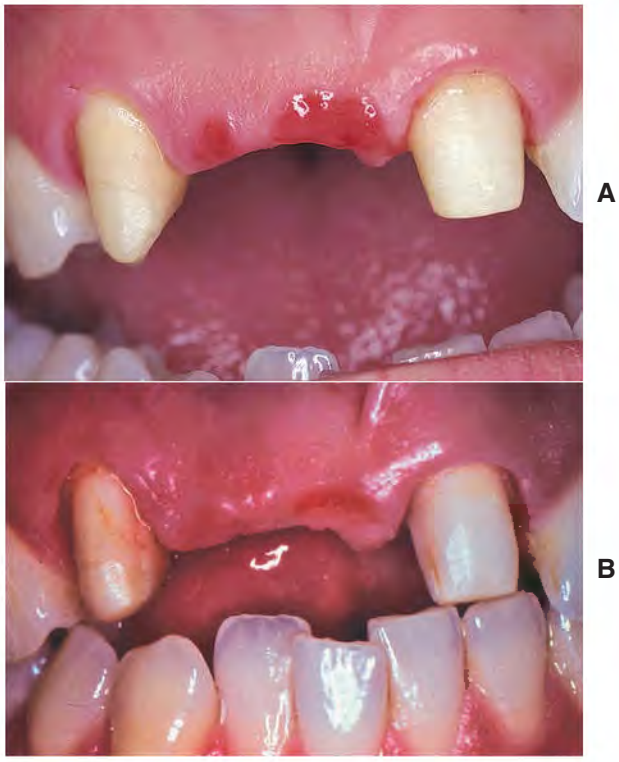

FIGURE 16-5 ■ **A,** The expectations of the dentist in this treatment are not realistic. These preparations are unsuitable for the metal-ceramic restorations requested because the gingival third of the tooth was inadequately reduced. **B,** After correction, proper retainer contour is achievable.

FIGURE 16-6 ■ Three types of esthetic restorations. The restoration with the metal collar can be fabricated on a shoulder or shoulder-bevel margin; the porcelain labial margin metal-ceramic crown can be fabricated on a shoulder margin; and the all-ceramic crown requires a slightly rounded internal angle. The latter two require margins that are glasslike in smoothness.

Work Authorization

In some jurisdictions, the written instructions are referred to as a *work authorization;* elsewhere, it may be referred to as a *laboratory work order* or *prescription.* In addition to certain general information that is required by law, a

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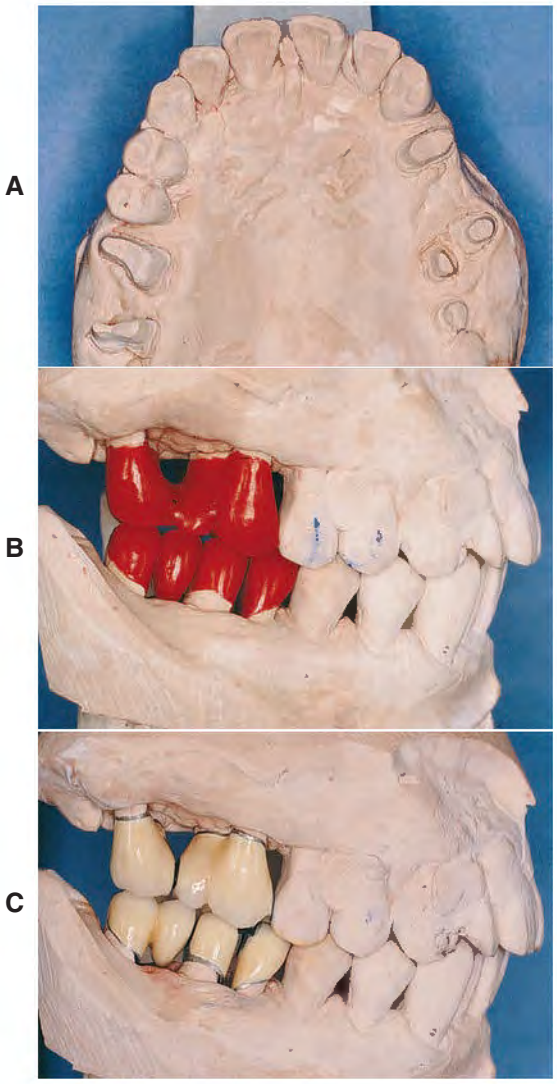

FIGURE 16-7 ■ A common error is for the dentist and technician to try to achieve normal anatomic contours on a compromised preparation outline form. Periodontal complications invariably result. **A,** Atypical coronal form after root resection. **B,** Note that every effort was made to achieve axial contours with optimal emergence profile resulting in modified axial contours. **C,** The definitive restoration permits optimal access for oral hygiene measures.

FIGURE 16-8 ■ It is important that interocclusal records are trimmed through the buccal cusp tips to enable easy verification that both casts are properly positioned in the record and stable.

work authorization form (Fig. 16-9) should include the following:

- General description of the restoration to be made
- Material specification (e.g., anatomic contour zirconia)
- Desired occlusal scheme
- Connector design for fixed dental prostheses
- Pontic design, including the material specification for tissue contact
- Substructure design for metal-ceramic restorations
- Information regarding the shade selection for esthetic restorations
- Proposed partial removable dental prosthesis design (if applicable)
- Date of the patient's next scheduled appointment and the stage of completion required by then

The dentist must be familiar with the materials that the technician prefers to use for certain procedures. Specifying those materials can save both time and effort. The technician should also respect the selection when the dentist requests a specific material. Written instructions should be explicit.[16]

Communication improves if the technician and dentist discuss a particular choice, rather than if the dentist merely writes a statement on the work authorization form. It may be inconvenient for the technician to comply with a request, and so its importance should be discussed.

Occlusion

The work authorization form should designate the location of the occlusal contacts. It must be specified whether they are to be on metal or ceramic. In theory, the two most desirable occlusal schemes are cusp-fossa and cusp–marginal ridge. Assuming that these will be attained in every restoration is unrealistic, however, because they can be accomplished consistently only when the opposing teeth are reasonably close to ideal relative positions (Angle class I occlusion; see Chapter 1). Compromises often must be made, especially when teeth are being restored to conform to an existing dentition. For example, when a mandibular molar is in a buccolingual edge-to-edge posterior relationship with its antagonist, a decision must be made whether to restore the tooth in a reverse articulation or whether the tooth preparation should be modified (additional reduction of the buccal functional cusp bevel) to accommodate a more conventional occlusal relationship. As an alternative, restoring the opposing tooth may need to be considered.

If the dentist has performed a diagnostic tooth preparation and waxing (see Chapter 2), it is possible to communicate the desired occlusal relationship or tooth form very specifically (Fig. 16-10). A wax record rim that has been adjusted intraorally can convey a general idea of the desired position of the occlusal plane (Fig. 16-11). Similarly, a custom anterior guide table made by the dentist from anterior interim restorations that have proved comfortable for the patient is most helpful to the technician in reproducing the same anterior guidance in the definitive fixed prostheses (Fig. 16-12). An impression of an interim crown poured in fast-setting dental stone is an excellent means of communicating the desired size and

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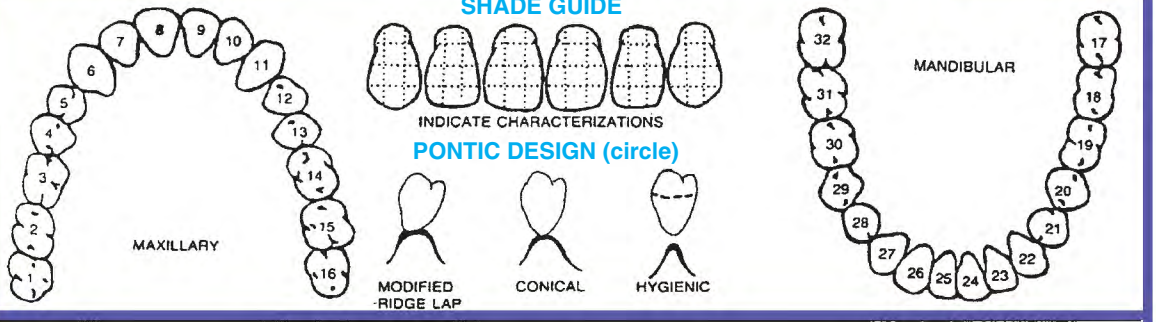
SIU
SCHOOL OF DENTAL MEDICINE

DENTAL LABORATORY
WORK AUTHORIZATION

School of Dental Medicine, 2800 College Avenue, Alton, IL 62002-4700

Student _____ Rec. by SDM Lab _____ Units Rec. _____
Patient _____ F. P. Sec. Head Begin _____
Patient # _____ Technician _____
Lab _____ F.P. Sec. Head Complete _____
Received by Student _____
Date Due _____ (Name & Date for each of the above)

SHADE GUIDE



Porcelain Shades										Articulator Number
				Shade		Margin		Contacts		Articulator Settings
Tooth #	Rest. Type	Metal	Guide	Incisal	Gingival	0.3 mm metal	Porc. Shoulder	Metal	Porcelain	R L
										Cond. Guid.
										Inc. Guid.
										ISS
										PSS

℞

Dental License No. _____ Signature _____ D.M.D. D.D.S.

Office Use Only			Business Office Paid
Wax		Bridge Units	
Cast			
Porc.		Crown Units	
Sold.			

EML 11/89 White–Lab. Credit Voucher / Yellow–Lab. Record Copy / Pink–File Copy 1810-23 rev. 4/99

FIGURE 16-9 ■ Work authorization form. *Cond. Guid.,* Condylar guidance angle; *Inc. Guid.,* incisal guidance; *ISS,* immediate side shift; *Porc.,* porcelain; *PSS,* progressive side shift; *SDM,* School of Dental Medicine.

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FIGURE 16-10 ■ Diagnostic waxing used to communicate desired occlusal form **(A),** the mandibular incisal edge position **(B),** and the shape of maxillary incisors **(C).** (Courtesy Dr. M. Chen.)

FIGURE 16-11 ■ A wax record rim that has been adjusted intraorally with a Fox plane can provide helpful information to the technician. Note that the desired position of the midline has been marked.

contours (Fig. 16-13). On occasion, when a single crown is to be made, an existing malocclusion may be accepted. This can limit the need for more extensive treatment, although it makes sense only if the opposing teeth will not need a restoration in the near future.

FIGURE 16-12 ■ A custom anterior guide table made from anterior interim restorations that have proved comfortable for the patient. The guide table helps the technician replicate lingual contours in the fixed prostheses.

FIGURE 16-13 ■ A putty impression of the interim restorations has been poured. The resulting cast conveys desired tooth size and form and can be used as a starting point for contour waxing (see Chapter 19). (Courtesy Dr. M. Chen.)

Connectors

The work authorization form should specify which connectors are to be cast, which are to be soldered before ceramic application, and which are to be soldered after ceramic application. The sequence of the planned procedures should be indicated and discussed when necessary or when clarity can be enhanced. If nonrigid connectors are requested, the desired type of connector and path of placement should be specified.

Pontic and Substructure Design

Pontic design is discussed in Chapter 20. A simple checklist on the work authorization form should suffice if the dentist and technician have agreed on applicable expectations and requirements.[16,17]

The design of metal substructures for metal-ceramic restorations is somewhat controversial. Many technicians believe that it is not necessary to create the contours of the completed restoration in wax first and then cut back

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FIGURE 16-14 ■ **A,** Anatomic contour waxing with the use of incisal polyvinyl siloxane index. **B,** Cutback with the use of facial polyvinyl siloxane index. **C,** The same indexes are used during porcelain application. **D,** The desired form is accurately replicated. **E,** This leads to predictable success when esthetic appearance is paramount. (Courtesy Dr. M. Chen.)

the veneering area. The reasoning behind disagreement with that belief is discussed in Chapter 19 (Fig. 16-14). The authorization should specify whether the anatomic contour wax patterns are to be returned for evaluation and possible modification. The more complex the restorative effort is, the more crucial a careful evaluation is at this stage. Long-term success is the goal, and inadequate framework design is a relatively common cause of failure for which the dentist bears the responsibility (although the dentist often blames the ceramist).

Shade Selection

With the variety of tooth-colored restorations, dentists and technicians have become acutely aware of the difficulty involved in communicating shade selection. A thorough understanding of the principles of color science (presented in Chapter 23) and of the use of internal and surface colorants (discussed in Chapters 24 and 29) is essential to both parties.

A diagram of the tooth that allows specifications of multiple shades is often helpful (Fig. 16-15).[18] The

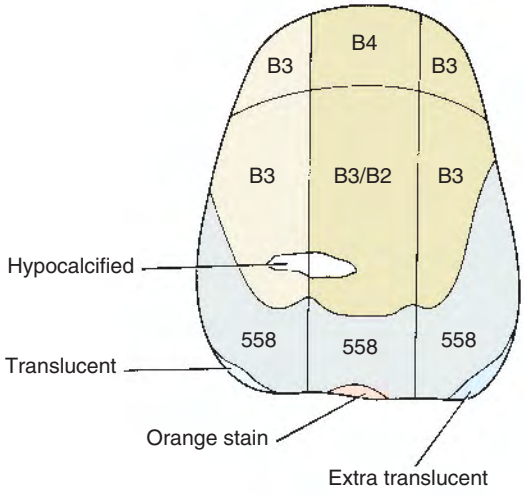

FIGURE 16-15 ■ A shade distribution chart must be adequate in size to allow inclusion of enough detail. Subtle differences observed in cervical shades are identified, as are surface details such as hypocalcification, incisal translucency, and stains.

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diagram should be large enough to designate a cervical shade, an incisal shade, and any applicable individual characterization. Diagrams on most preprinted laboratory work authorization forms do not provide adequate space (see Fig. 16-9), and so other space must be available. A separate entry regarding the value or brightness can be helpful. When selecting a shade, the dentist should use a guide that corresponds to the ceramic system used by the technician. On occasion, it may not be possible to obtain a match with a simple shade guide (e.g., the Vita Lumin vacuum system). In those cases, an alternative guide or a shade distribution chart (outlined in Chapter 23) should be used. The dentist must have excellent color perception skills and should be able to transfer those precisely onto a written prescription that includes a large, detailed diagram that enables the ceramist to accurately reproduce the shade observed and described by the clinician. Close communication and cooperation are obviously necessary, and a trial porcelain firing may be needed.

A practical alternative to written color communication is the use of light-polymerized, resin-based staining kits to custom-stain a shade tab. The closest matching shade tab is selected and modified by stains mixed with liquid resin. Once the desired match has been obtained, the resin is light-polymerized, and the customized tab is sent to the dental laboratory. The ceramist then has an actual reference and can compare the work and make the required modifications, thus ensuring predictable success. A number of tooth shade–recording devices have been developed: colorimeters, spectrophotometers, and digital camera systems (Fig. 16-16). (See also Chapter 23.) These techniques hold promise, although research on their reliability and reproducibility has revealed varying results with different shade guides. In general, color measurement reproducibility is better in a controlled research laboratory setting than intraorally. Several of these systems provide a detailed color analysis in printed or electronic format, which can be used to help communicate the specific shade or shades to the dental ceramist.

If esthetic requirements are extensive or difficult to communicate through the means just described, involving dental laboratory personnel in the shade selection process may be helpful. The ADA takes the position that when a dentist requests the assistance of a dental laboratory technician in the shade selection process, this does not constitute the practice of dentistry by the technician, provided the activity is undertaken in consultation with the dentist and that it complies with the dentist's written instructions. Specifically, the shade selection site, whether dental office or laboratory (where lawful), should be determined by the professional judgment of the dentist in the best interest of the patient and where communication between dentist, patient, and technician is enhanced.[9]

Additional Information

Additional information often helps the technician considerably. Reference to diagnostic waxing can communicate specific information about desired tooth length and form or a desired occlusal arrangement. A custom anterior guide table (see Chapter 2) provides specific information to follow as anterior guidance is established in maxillary and/or mandibular anterior crowns. Casts of interim restorations are invaluable to the technician when he or she is asked to fabricate fixed dental prostheses with a high esthetic requirement. They provide information about midlines, incisal edge position, and coronal

FIGURE 16-16 ■ **A,** The VITA Easyshade Advance 4.0 shade measuring system. **B,** VITA Easyshade Compact system. The probe tip is placed on the tooth and the tooth shade is recorded in VITA Classical or VITA System 3D-Master shade units. (**A,** Courtesy of Vident, Brea, California.)

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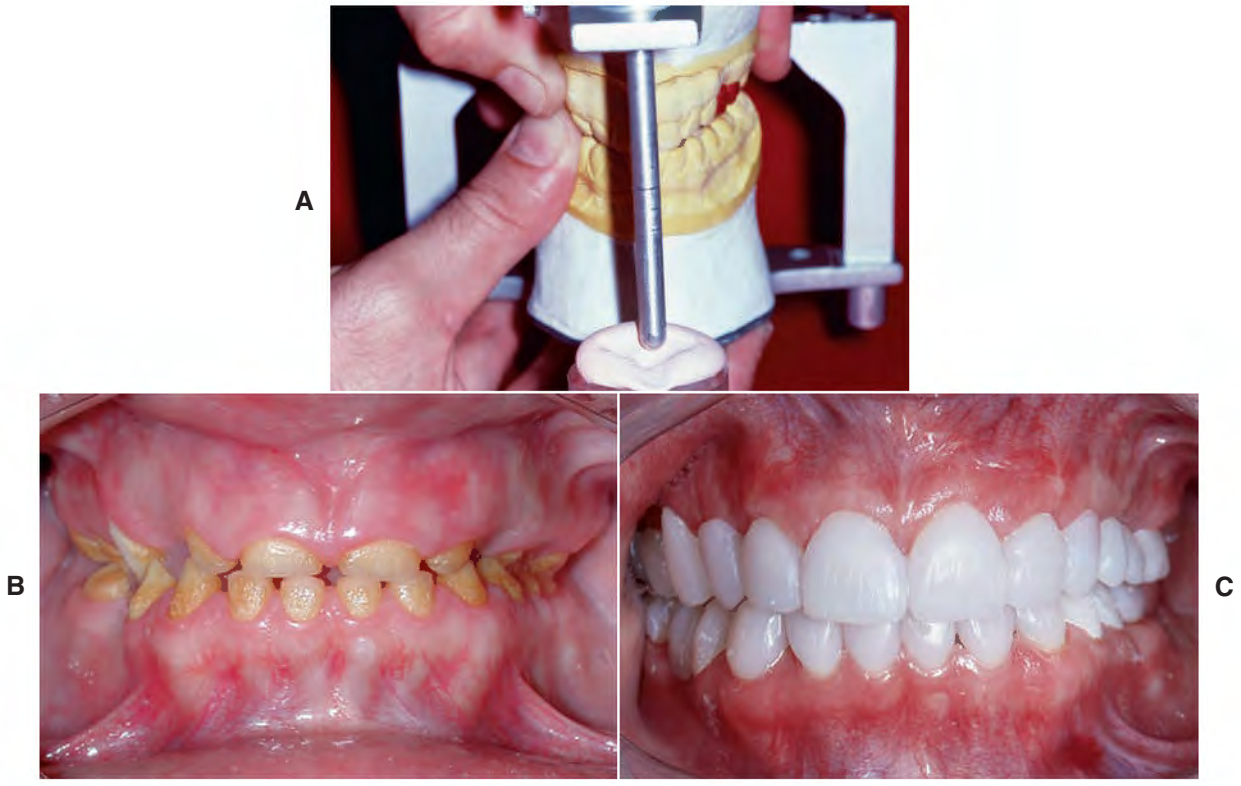

FIGURE 16-17 ■ **A,** Diagnostic casts, anterior guide table, and waxing provide additional information for the technician. **B** and **C,** Carefully adjusted interim restorations are an essential part of complex rehabilitation. This 19-year-old patient had generalized hypoplastic amelogenesis imperfecta, rough pattern (type I F). Her interim restorations were duplicated and replicated in the definitive prosthesis. (**B** and **C,** Courtesy Dr. A. Hernandez.)

form and are the most practical way of accurately conveying information to the laboratory (Fig. 16-17). The diagnostic waxing enables the dentist to explore all the treatment alternatives before choosing a course of therapy. A resin interim restoration can be fabricated and adjusted intraorally as necessary for optimum appearance and function. Standardized digital images can be especially helpful in conveying essential additional information.

APPROPRIATE CHECKS

In any new working relationship between a dentist and a technician, every laboratory step should be reviewed in detail for the initial patients. Only then can teamwork develop over time. As the dentist and technician become familiar with each other's preferences, several steps may then be combined.

The initial review may include the wax patterns for corrective shaping of occlusal and axial contours of retainers and pontics. When treating patients with fixed dental prostheses and metal-ceramic crowns, the dentist must decide whether the restorations should be completed through porcelain application in the laboratory or whether a preliminary appointment for metal substructure evaluation is needed. Routine evaluations of the metal substructure are recommended for metal-ceramic restorations (Fig. 16-18). As an example, the technician may not have adequate information to

FIGURE 16-18 ■ Unrealistic expectations by the dental technician. **A,** Inappropriate substructure design provides insufficient support for the porcelain veneer. This fixed dental prosthesis must be remade. **B,** An appropriately designed superstructure.

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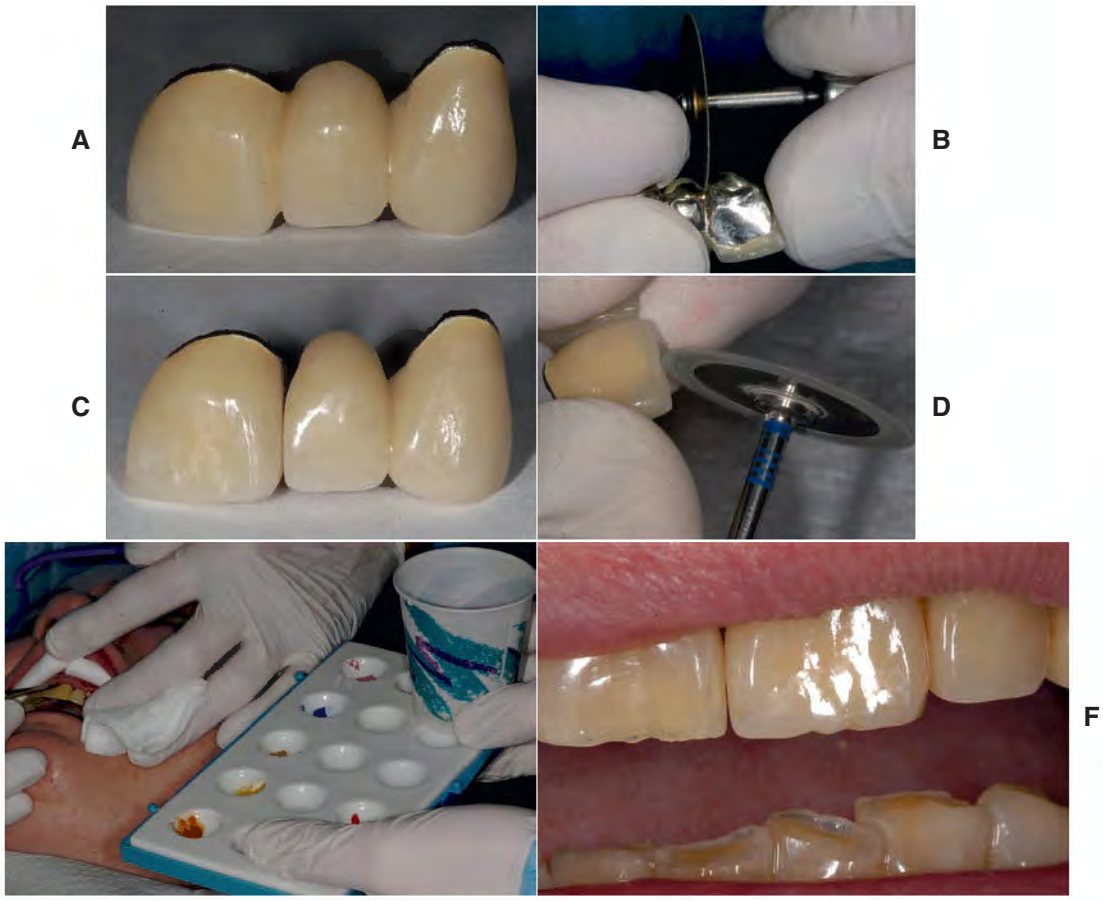

FIGURE 16-19 ■ Chairside correction. **A,** Note that excess porcelain obliterates the cervical embrasure. **B,** An ultrathin separating disk is used to reestablish normal emergence profile. **C,** Note the difference between the facial embrasure between the lateral and central incisors, which was opened by separating the two units with a thin diamond disk. The distal embrasure has not yet been modified. **D,** Incisal edge modification to mimic the adjacent tooth. **E,** Surface stain being applied. **F,** Appearance after modification.

evaluate how far the veneering area should be extended into the cervical embrasures, and this can be readily determined by the dentist during evaluation (Fig. 16-19). When fixed dental prostheses are soldered, often it is best to index the component parts directly in the mouth rather than rely on the accuracy of the definitive cast (Fig. 16-20). An evaluation appointment can facilitate making small corrections of discrepancies that could later become significant errors. Similarly, it may be advantageous to plan an evaluation appointment for final contouring, texturing, and characterization of a metal-ceramic restoration in the bisque bake stage, before glazing. It takes time and effort to perform these clinical procedures (see Chapter 29), but patients will recognize and appreciate the improved results.

The use of checklists by both clinician and technician can be helpful.[17,19] For instance, before an impression leaves the dental office, the dentist and auxiliary personnel can use a standard protocol to confirm that finish lines are distinct; that no blood or saliva is present in impressions; that disinfection protocols were followed; that no voids, tears, defects, or areas where the tray was seated are present; and that contact has not occurred between occlusal surfaces and the tray, which would create thin spots that can lead to articulation errors. For casts, the dentist must confirm die trimming, the absence of undercuts, the retention form, the adequacy of reduction for facial porcelain and porcelain margins, and the occlusal clearance.

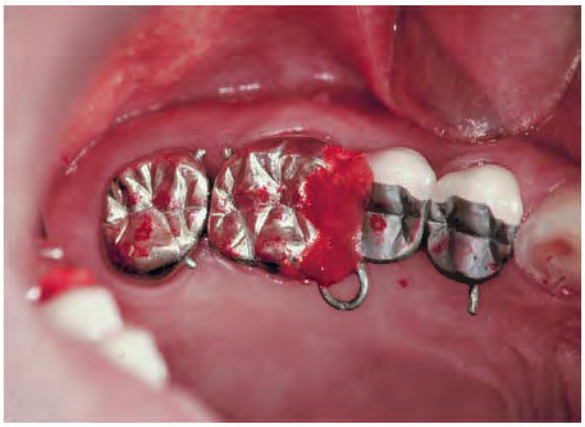

FIGURE 16-20 ■ Intraoral fabrication of a soldering index with autopolymerizing resin. This index relates two components of a fixed dental prosthesis.

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FIGURE 16-21 ■ Tripod marks provide accurate information to the technician about the planned path of placement of the partial removable dental prosthesis.

FIGURE 16-22 ■ High quality fixed prosthodontic care is facilitated by excellent communication between dentist and dental technician and the use of magnification.

Where retainers for partial removable dental prostheses are involved, the work authorization and cast are checked to ensure availability of all pertinent information in relation to the path of insertion of the partial removable dental prosthesis, the guide planes, the rest seats, and the desired heights of contour (Fig. 16-21).

SUMMARY

The key to high-quality fixed prosthodontics is good communication between the dentist and the technician (Fig. 16-22). All too often, each operates in a vacuum: The dentist forgets how a straightforward step such as rounding line angles can expedite the fabrication of a restoration, or the technician is unaware of the difficulties of a particular clinical phase (e.g., impression making or a remount procedure).

Through mutual respect and a coordinated effort, each can contribute to the delivery of patient care and, at the same time, keep failures to a minimum.

The most common problems seen by the dentist at evaluation are poor marginal adaptation, poor occlusion, poor axial contour (specifically, overcontouring of the cervical third of the tooth), and haphazard pontic and substructure design. The most common problems encountered by the technician are inadequate tooth reduction, "mystery (indistinct) margins," improper articulation, and vagueness in color communication.

The use of certain ancillary devices (e.g., diagnostic waxing and casts of interim restorations) helps both dentist and technician deliver more effective treatment to the prosthodontic patient.

The student and practitioner involved in fixed prosthodontic treatment must acquire an in-depth understanding of the laboratory procedures described in the following chapters in this section. Often such understanding is most rapidly developed by personal involvement in the technical aspects of clinical dentistry. Over time, this leads to significantly improved interaction with dental technicians, which results in improved clinical decision making and more predictable and successful fixed prostheses.

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REFERENCES

1. National Association of Dental Laboratories: NADL news. Available at http://www.nadl.org/news/index.cfm (accessed March 13, 2015).
2. Small BW: Laboratory communication for esthetic success. Gen Dent 46:566, 1998.
3. Gleghorn T: Improving communication with the laboratory when fabricating porcelain veneers. J Am Dent Assoc 128:1571, 1997.
4. Warden D: The dentist-laboratory relationship: a system for success. J Am Coll Dent 69:12, 2002.
5. Aquilino SA, Taylor TD: Prosthodontic laboratory and curriculum survey. III. Fixed prosthodontic laboratory survey. J Prosthet Dent 52:879, 1984.
6. Leith R, et al: Communication between dentists and laboratory technicians. J Ir Dent Assoc 46:5, 2000.
7. Lynch CD, Allen PF: Quality of written prescriptions and master impressions for fixed and removable prosthodontics: a comparative study. Br Dent J 198:17, 2005.
8. Landesman HM: Prosthodontics. Clinical practice—professional affairs. Review of the literature. J Prosthet Dent 64:252, 1990.
9. American Dental Association: Current policies, adopted 1954-2003, pp 141-142. Chicago: American Dental Association.
10. Centers for Disease Control: Recommended infection control practices for dentistry. MMWR Morb Mort Wkly Rep 35(15):237, 1986.
11. Infection control recommendations for the dental office and the dental laboratory. Council on Dental Materials, Instruments, and Equipment. Council on Dental Practice. Council on Dental Therapeutics. J Am Dent Assoc 116:241, 1988.
12. Powell GL, et al: The presence and identification of organisms transmitted to dental laboratories. J Prosthet Dent 64:235, 1990.
13. Jorgenson MW, Goodkind RJ: Spectrophotometric study of five porcelain shades relative to dimensions of color, porcelain thickness, and repeated firings. J Prosthet Dent 42:96, 1979.
14. Leeper SH: Dentist and laboratory: a "love-hate" relationship. Dent Clin North Am 23:87, 1979.
15. Olin PS, et al: Current prosthodontic practice: a dental laboratory survey. J Prosthet Dent 61:742, 1989.
16. Drago CJ: Clinical and laboratory parameters in fixed prosthodontic treatment. J Prosthet Dent 76:233, 1996.
17. Deyton G: Communications checksheet will ease relations with laboratories. Mo Dent J 74(5):32, 1994.
18. Pensler AV: Shade selection: problems and solutions. Compendium Contin Educ Dent 19:387, 1998.
19. Maxson BB: Quality assurance for the laboratory aspects of prosthodontic treatment. J Prosthodont 6:204, 1997.

STUDY QUESTIONS

1. Discuss the guidelines issued by the American Dental Association in relation to working relationships between dentists and dental laboratories. What are specific responsibilities of the dentist? What are the responsibilities of the dental technician?

2. What is a certified dental technician (CDT)? What are requirements for certification?

3. Write a series of complete and comprehensive prescriptions for the various stages of laboratory fabrication of an anterior metal-ceramic fixed dental prosthesis from tooth #8 to tooth #11 (two pontics), to be fabricated in two segments and soldered after clinical evaluation and before porcelain application. List the various materials and models to be submitted with each prescription.

4. What is the purpose of submitting a custom anterior guide table to the dental laboratory? When would this be advisable?

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CHAPTER 17

Definitive Casts and Dies

Because direct fabrication of patterns for extracoronal restorations in the mouth is inconvenient, difficult, time consuming, and next to impossible, practically all wax patterns are made in the dental laboratory. This technique requires an accurate reproduction of the prepared tooth, the surrounding soft tissues, and the adjacent and opposing teeth. A solid cast-and-die system captures the necessary information so the laboratory has all necessary information to fabricate the prescribed restoration. Most commonly, solid definitive casts are fabricated from improved stone (see Chapter 2), although some other materials may be used as well. For an increasing number of dental procedures, virtual casts can also be used.

To learn to properly use virtual casts, the underlying principles of conventional definitive cast-and-die systems must be understood. Virtual systems model the same information in three-dimensional formats that enable the technician to use virtual tools for certain phases of the restoration fabrication process. The virtual systems continue to improve and are rapidly gaining widespread acceptance in the dental laboratory industry; even at their current level of development, they already offer the potential of significantly improved efficiency. Throughout this chapter, the terms *solid* and *virtual* are used to identify the type of specific system that is referred to.

A solid *definitive cast* (or master or working cast) is a replica of the prepared teeth, ridge areas, and other parts of the dental arch. The *die* is the positive reproduction of the prepared tooth and consists of a suitable hard substance of sufficient accuracy (usually an improved stone, resin, or metal plating; Fig. 17-1).

The accuracy of a cast-and-die system is a function of the completeness and accuracy of the impression, or optical capture. The cast cannot contain more information than the impression from which it was made.

In this chapter, the requirements of a cast-and-die system are described first, and these are correlated with the available materials. A later section describes virtual cast-and-die systems. The procedures are generally straightforward, but the steps must be followed carefully if the intended prosthesis is to be successful.

PREREQUISITES

A solid cast that will be used to make a fixed restoration must meet certain requirements. It must reproduce all details captured in the impression and should be free of defects (Fig. 17-2). Minor imperfections, however, may be acceptable, depending on their location. The cast must meet certain requirements:

- It must be an exact reproduction of both prepared and unprepared tooth surfaces.
- The unprepared teeth immediately adjacent to the prepared tooth or teeth must be free of voids.
- All surfaces of any teeth involved in anterior guidance and the occlusal surfaces of all unprepared teeth must allow for precise articulation of the opposing casts (Fig. 17-3).
- All relevant soft tissues should be reproduced in the definitive cast, including all edentulous spaces and residual ridge contours that will be involved in the fixed prosthesis.

The die for the fixed restoration also must meet certain requirements:

- It must be an exact reproduction of the prepared tooth.
- All surfaces must be accurately duplicated, and no bubbles or voids can be accepted.
- The remaining unprepared tooth structure immediately cervical to the finish line should be easily discernible on the die, ideally with 0.5 to 1 mm visible (enough must be present to help the technician establish the correct cervical contour of the restoration; Fig. 17-4).
- Adequate access to the margin is imperative.

MATERIALS SCIENCE

James L. Sandrik

Gypsum

The two crucial characteristics of cast-and-die materials, dimensional accuracy and resistance to abrasion while the wax pattern is being formed, are adequately achieved with *gypsum*. This material is inexpensive, is easy to use, and produces consistent results. Manufactured in enormous quantities for industrial use, it can easily be modified for dental use.

Dental gypsum products are available in five forms (American Dental Association [ADA] types I to V), defined as impression plaster; model plaster; dental stone; high-strength dental stone; and high-strength, high-expansion stone. The gypsum components are identical chemically. The setting reaction results from the hydration of calcium sulfate hemihydrate:

$$CaSO_4 \cdot \tfrac{1}{2}H_2O + 1\tfrac{1}{2}H_2O \rightarrow CaSO_4 \cdot 2H_2O$$

The hemihydrate is manufactured by heating of the dihydrate under controlled conditions to drive off some of the water of crystallization (a process called *calcination*). The differences between the various types of dental gypsum are attributable to calcination. The physical

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properties of die stone are improved over those of dental stone and plaster because less water is needed to obtain a sufficiently fluid mix. Thus 100 g of plaster requires 45 to 50 mL of water, 100 g of dental stone requires 30 to 35 mL of water, and 100 g of die stone requires 20 to 25 mL of water, depending on the particular brand. Theoretically, the stoichiometric amount of water needed for the setting reaction is 18.6 mL. Only die stone has suitable physical properties for making cast restorations. However, its properties are totally dependent on accurate measurement of the water-to-powder ratio.

Hand mixing of gypsum products is easy, but results are better when the mixing is done mechanically in a vacuum; porosity is reduced, with a concomitant increase in strength, after only 15 seconds of mechanical vacuum mixing. Newly poured casts should be left undisturbed for at least 30 minutes; superior results are achieved at 1 hour, although setting times may vary among brands.

Surface detail reproduction with type IV and type V gypsum products is acceptable for fixed prosthodontics. These materials are capable of reproducing a 20-μm-wide line as prescribed by ADA specification No. 19.[1] However, not all brands of die stone are compatible with all brands of impression material,[2,3] and if surface detail reproduction is poor, use of an alternative product may resolve the problem.

With some techniques (e.g., when a cast is prepared for duplication), it is necessary to soak a set gypsum cast in water to prevent the duplicating material from sticking

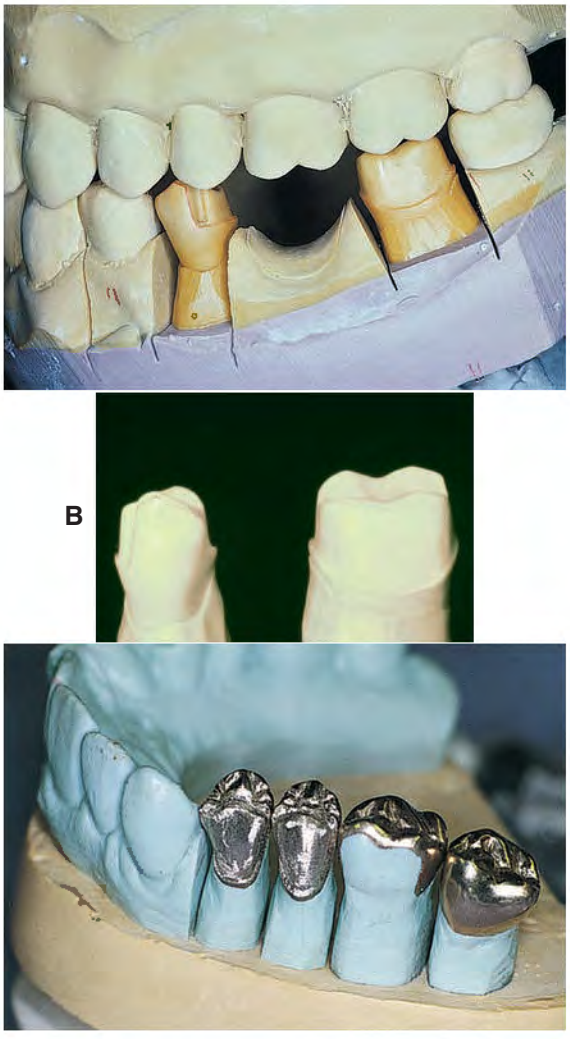

FIGURE 17-1 ■ Removable die system. **A,** Definitive cast. The dies of the prepared teeth are retained by the dowel pins in the pink base pour. **B,** The individual stone dies removed from the cast. **C,** Epoxy dies with metal castings. (**B,** Courtesy Dr. J.H. Bailey.)

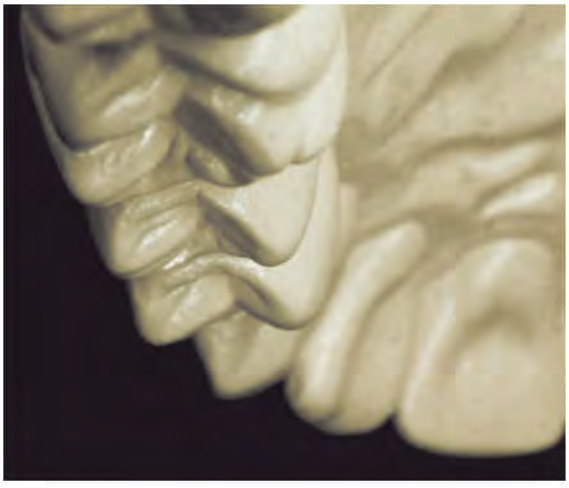

FIGURE 17-3 ■ Defect-free occlusal surfaces are essential for precise articulation.

FIGURE 17-2 ■ Examples of individual dies. These are sectioned from a solid pour.

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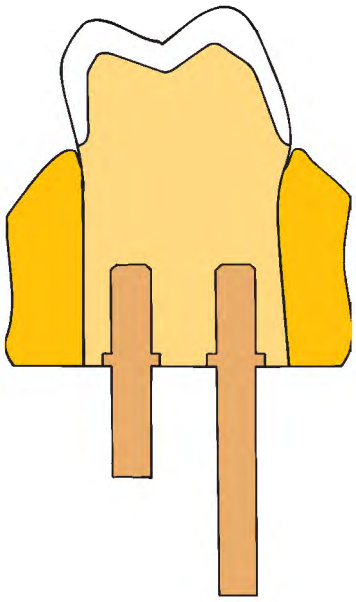

FIGURE 17-4 ■ To facilitate trimming, the impression should extend beyond the preparation margin. A properly trimmed die must have the same cervical contour as the tooth *(light yellow).* The *gold areas* on the side indicate the parts of the die to be removed during trimming.

to the cast. However, although the cast appears to be insoluble, when immersed, the gypsum slowly dissolves, which ruins the surface detail of the original cast. If soaking is required, it should be done in water saturated with plaster slurry and only long enough to achieve the desired degree of wetting that will enable easy separation of the original cast from the duplicating material used.

Gypsum's greatest disadvantage is its relatively poor resistance to abrasion. This may be partly overcome through the use of "gypsum hardeners." Although these materials (e.g., colloidal silica) actually have relatively little effect on the hardness of the stone, they improve abrasion resistance (some by as much as 100%).[4] Their use is accompanied by a slight increase in setting expansion, but this increase is not necessarily clinically significant. An alternative approach[5] is to impregnate the surface of the relatively porous die with a low-viscosity resin such as cyanoacrylate, which also results in improved abrasion resistance. Care is needed to select a low-viscosity resin to ensure that after application, resin film will have no significant thickness.[6] Experts continue their efforts to improve the properties of die stone. One approach is to apply additives used in industrial applications (e.g., concrete manufacture) to dental gypsum products.[7] Another is the use of a gum arabic, calcium hydroxide mixture.[8] Resin-strengthened gypsum products with high strength and low expansion,[9] such as ResinRock (Whip Mix Corp.), are also popular and are particularly suitable for casts for implant restorations (see Chapter 13). Highly reflective stones are available to fabricate solid casts that may be scanned in the dental laboratory to generate subsequent virtual cast-and-die systems.

Additional die materials that are even stronger are also available. These include resin and electroplated dies.

Resin

Resins may be used as a die material to overcome the low strength and abrasion resistance of die stone. Most available resin die materials are epoxy resins, but polyurethane is also used. Epoxy resin is well known as a household and industrial adhesive. It can be polymerized at room temperature without expensive or complicated equipment, and the result is a form that is reasonably stable dimensionally. Its abrasion resistance is many times greater than that of gypsum products. However, it is more expensive than gypsum and undergoes some shrinkage during polymerization, which can be compensated for by slight adjustments in other steps of the fabrication of the restoration.

Epoxy resins suitable for fabrication of precision dies are available, but there is great variability among brands.[10] The amount of shrinkage upon polymerization is quantitatively about equal to the expansion that occurs in fabricating a model with gypsum. Polymerization shrinkage is less of a problem with newer formulations[11] and polyurethane resin.[12] When used with polyvinyl siloxane, contemporary resin systems produce complete arch casts with dimensional accuracy similar to that of traditional die stone.[13] In general, detail reproduction is better[14]; however, prostheses fabricated on resin dies tend to fit more tightly than those made on gypsum.[15]

Certain impression materials (e.g., polysulfide and hydrocolloid) are not compatible with resin. However, good results may routinely be achieved with silicone and polyether.

Flexible Die Materials

Chemically, flexible die materials are similar to heavy-bodied silicone or polyether impression materials (see Chapter 14), and they have been used to make interim restorations,[16,17] indirect composite resin inlays, and onlays[18,19] at chairside. The advantages of the flexible material over a stone die include more rapid setting and the ease of removal of the interim restoration or inlay. When choosing materials for flexible dies, the dentist must be sure to select impression and die materials that are compatible and whose combination provides good surface details. One study[20] revealed that the best detail reproduction was obtained when Impregum F die material (3M ESPE Dental) was combined with Extrude Light impression material (Kerr Corp).

• • •

SELECTION CRITERIA

Choosing one cast-and-die system over another depends on several factors:

- The material must allow fabrication of a dimensionally accurate cast that should be strong and resistant to abrasion.

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TABLE 17-1 **Die Materials**

Material	Advantages	Disadvantages	Recommended Use	Precautions
ADA type IV stone	Dimensional accuracy Straightforward in-office procedure	Will be damaged if not handled carefully	Most situations	Accurate proportioning essential
ADA type V stone	Straightforward technique Low cost Straightforward in-office procedure Harder than type IV stone	Increased expansion	Most situations	Accurate proportioning essential Vacuum mixing recommended
Epoxy resin	High strength Good abrasion resistance	Polymerization shrinkage Time-consuming, complex procedure	Complete ceramic crowns	Not compatible with polysulfide or hydrocolloid
Electroplating	High strength Good abrasion resistance	Time-consuming Special equipment needed	Complete ceramic crowns	Silver entails use of cyanide, which is toxic Incompatible with many impression materials

ADA, American Dental Association.

- It should be easy to section and trim with routinely available equipment.
- It should be compatible with the separating agent that will be used so that wax patterns do not stick to the die.
- It should reproduce surface detail accurately.
- It should be available in a color that contrasts with the wax used so that the preparation margin can be seen and even very small amounts of excess material are readily discernible
- It should be easily wettable by the wax. In addition, it must be compatible with the impression material.

The advantages and disadvantages of the available materials are summarized in Table 17-1.

FIGURE 17-5 ■ Dowel pins.

Available Methods

Removable Dies

In a removable die system (see Fig. 17-1), the die is an integral component of the definitive cast and can be lifted from the cast to facilitate access. Precise relocation of the die in the definitive cast is crucial to the success of this system and is usually accomplished with brass pins or dowels (Fig. 17-5). When a single dowel is used, it should have at least one flat surface to provide resistance against rotation. In alternative methods, such as the popular Pindex system (Coltène/Whaledent, Inc; Fig. 17-6), multiple or interlocking dowels are used to ensure such resistance.

The cast is made in two pours of type IV or V stone of contrasting colors: the first forms the teeth, and the second forms the base of the cast (type V stone, with greater expansion, requires less die spacing [see Chapter 18] to achieve the appropriate space for luting agent). The area to be removed is shaped, and then coated with a separating agent before the second layer is poured. In other areas, undercuts are provided to prevent unwanted separation. The location and orientation of the dowels are critical; if they are improperly placed, the dowels do not allow the die of the prepared teeth to be withdrawn from the cast (Fig. 17-7).

FIGURE 17-6 ■ Removable dies made with the Pindex dowel system (see Fig. 17-21). (Courtesy Coltène/Whaledent AG, Altstatten, Switzerland.)

Dowels may be positioned in the stone of the initial pour before it is set. An alternative method is to drill controlled holes into the set stone cast and then cement the pins into the stone base.[21]

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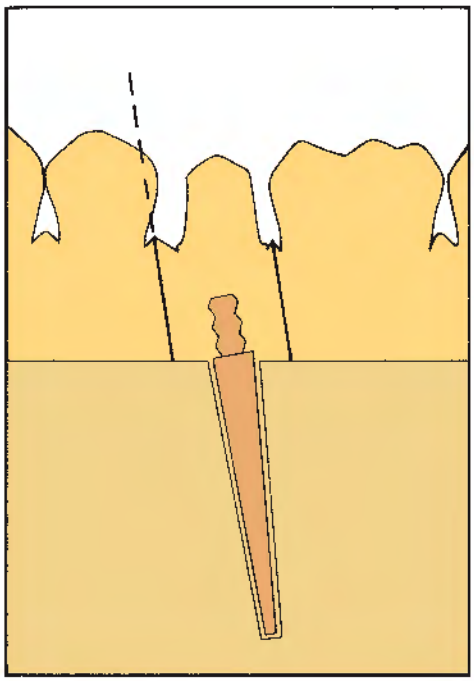

FIGURE 17-7 ■ Incorrect alignment of the dowel pin prevents removal of the die. The proximal surface of the adjacent tooth blocks die removal *(dashed line).*

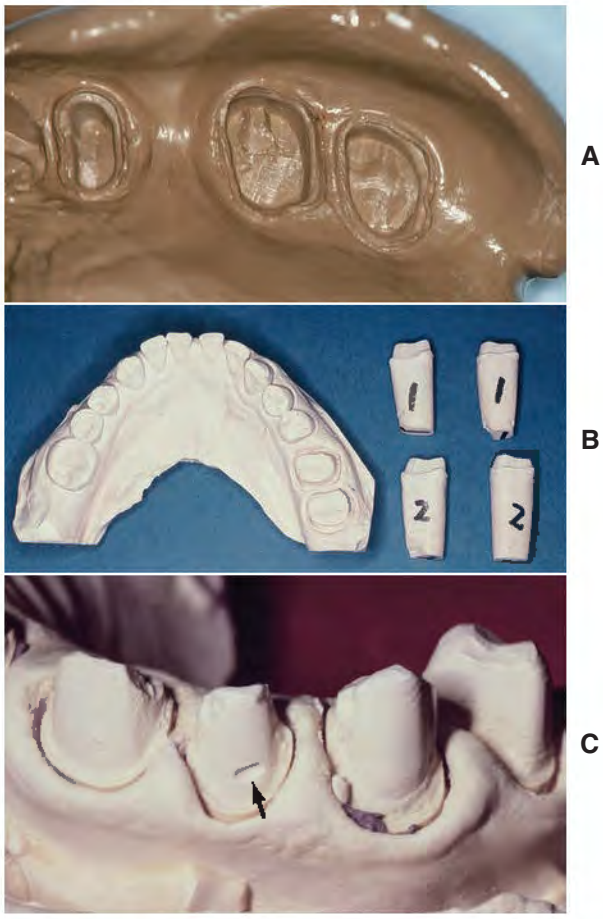

FIGURE 17-8 ■ **A,** An accurate impression is essential for successful fixed prostheses. **B,** The first and second pours have been sectioned into individual dies. The third pour will be the definitive cast. **C,** Small defects *(arrow)* can sometimes be overcome, but any voids make the laboratory phase much more difficult.

The Pindex system is designed to facilitate this latter technique. All removable die systems depend on careful execution so that the die will separate cleanly and return to place accurately. In one study, investigators found similar accuracy with four removable die systems, although the Pindex system showed the least horizontal movement, and the brass dowel pins produced the least occlusogingival reseating discrepancy.[22]

Solid Cast with Individual Die

The solid cast–individual die system, also referred to as the *multiple-pour technique*, has certain advantages over the removable die system; its primary advantage is its simplicity. It may also be slightly more accurate.[23] In this technique, once the impression is judged to be satisfactory, type IV or V stone is poured only in the area of the preparations. When set, it is separated. A second pour is then made of the entire arch.

The first pour, which is the most accurate, is trimmed into a die with a handle of sufficient length (similar to a tooth root; Fig. 17-8). The complete arch cast (second pour) is mounted on an articulator. (Sometimes the second pour is used for an additional set of individual dies for polishing, and the solid cast is obtained from a third pour.) The wax pattern is started on the initial pour (the die) and is then transferred to the articulated cast for refinement of axial contours and occlusal anatomy (see Chapter 18). When completed, this pattern is returned to the die so that the margins can be readapted immediately before the pattern is invested.

An advantage of the solid cast–individual die system is that the definitive cast requires only minimal trimming. Also, because the gingival tissues around the prepared teeth are left intact, they can be used as a guide for shaping the tissue contact of pontics, and when the restorations are contoured. Training support personnel is easier for this system than for removable die systems.

Disadvantages of the solid cast technique include the following:

- It may be difficult to transfer complex or fragile wax patterns from cast to die.
- Seating the pattern on the definitive cast may be problematic because the second pour of some impression materials is slightly larger than the first; therefore, it may be necessary to relieve the stone slightly to seat the pattern before occlusal evaluation.
- The technique can be used only with elastomeric impression materials (if reversible hydrocolloid is used, separate impressions are needed for definitive cast and die).

Alternative Die Systems

In the Di-Lok (DentiFax/Di-Equi, Buffalo, New York) system (Fig. 17-9), a specially articulated tray is used for

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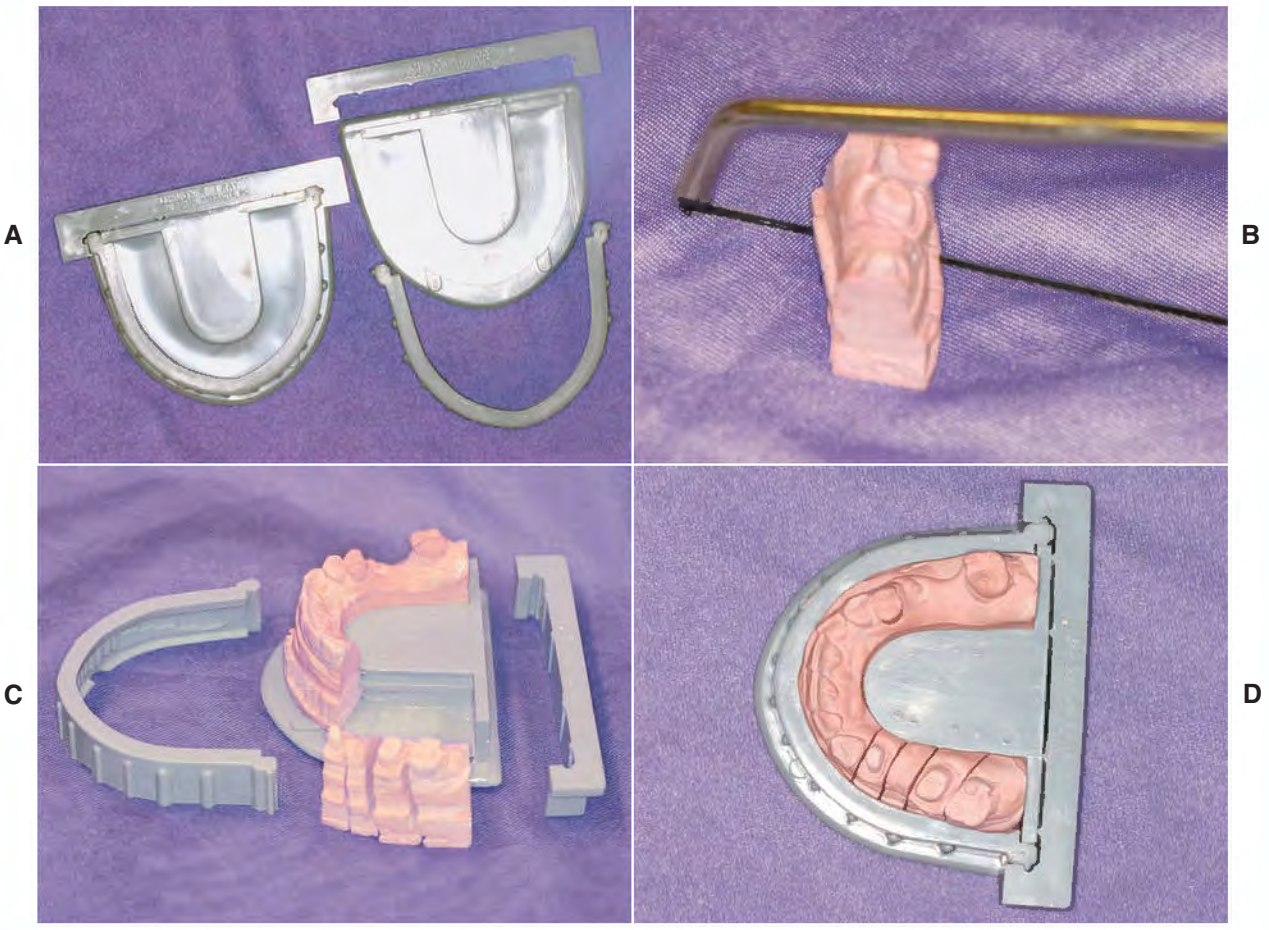

FIGURE 17-9 ■ The Di-Lok system. **A,** The system involves the use of specially segmented trays. With a single-pour technique, the impression is formed in the usual way, and the Di-Lok tray is filled. Then the tray is inserted into the impression while the stone is still wet. After the die stone has fully set, the locking and curved arms of the tray are removed. The clinician can then remove the cast by tapping the anterior pad of the tray base. **B,** The clinician sections the dies by sawing three-fourths through the stone and separates them by breaking the remaining stone base. **C,** Trimmed dies. **D,** Assembled cast, ready for articulating. (Courtesy DentiFax/Di-Equi, Buffalo, New York.)

precise reassembly of a sectioned definitive cast. The impression is poured, and the cast is trimmed into a horseshoe configuration that fits in the special tray. The tray is filled with a second mix, and the cast is seated. When the stone has set, the tray is disassembled, saw cuts are made on each side of the preparation, and the resulting die is trimmed. The cast and die can be reassembled in the tray, which is then mounted on an articulator. A disadvantage of this system is that the overall size of the tray can make articulation and manipulation awkward and difficult.

In the DVA Model System (Dental Ventures of America, Inc., Corona, Fig. 17-10) and the Zeiser model system (Zeiser Dentalgeräte GmBH, Hemmingen, Germany) (Fig. 17-11), a precision drill is used, and special baseplates are aligned and drilled to provide die removal. These systems offer the advantage of allowing for the expansion of stone, which is relieved by the saw cuts.

Choice of Definitive Cast-and-Die System

The choice of a specific technique is determined by the technician's personal preference and an assessment of each method's advantages and disadvantages. If used properly, all available systems achieve clinically acceptable accuracy.[24-26] When the dentist establishes a new relationship with a dental technician, it is important to determine which cast-and-die systems are preferred and why the technician has chosen them. Close cooperation between the dentist and technician is a key factor.

The solid cast technique simplifies cast-and-die fabrication, but makes the waxing and porcelain stages more difficult. However, there is no need for special equipment, and the soft tissues immediately adjacent to the preparation are not removed (which facilitates contouring the gingival areas of the restorations). The use of a solid definitive cast precludes errors caused by incomplete seating of a removable die. In practice, this means that the components of a fixed dental prosthesis (FDP) can be indexed from the cast for assembly; on the other hand, it also means that if an FDP is not fabricated accurately, the stone abutment teeth can be easily broken off, which makes subsequent steps more difficult.

The first pour from an elastomeric impression is the most accurate, and it is essential to readapt the margins of the wax pattern on the first-pour die immediately

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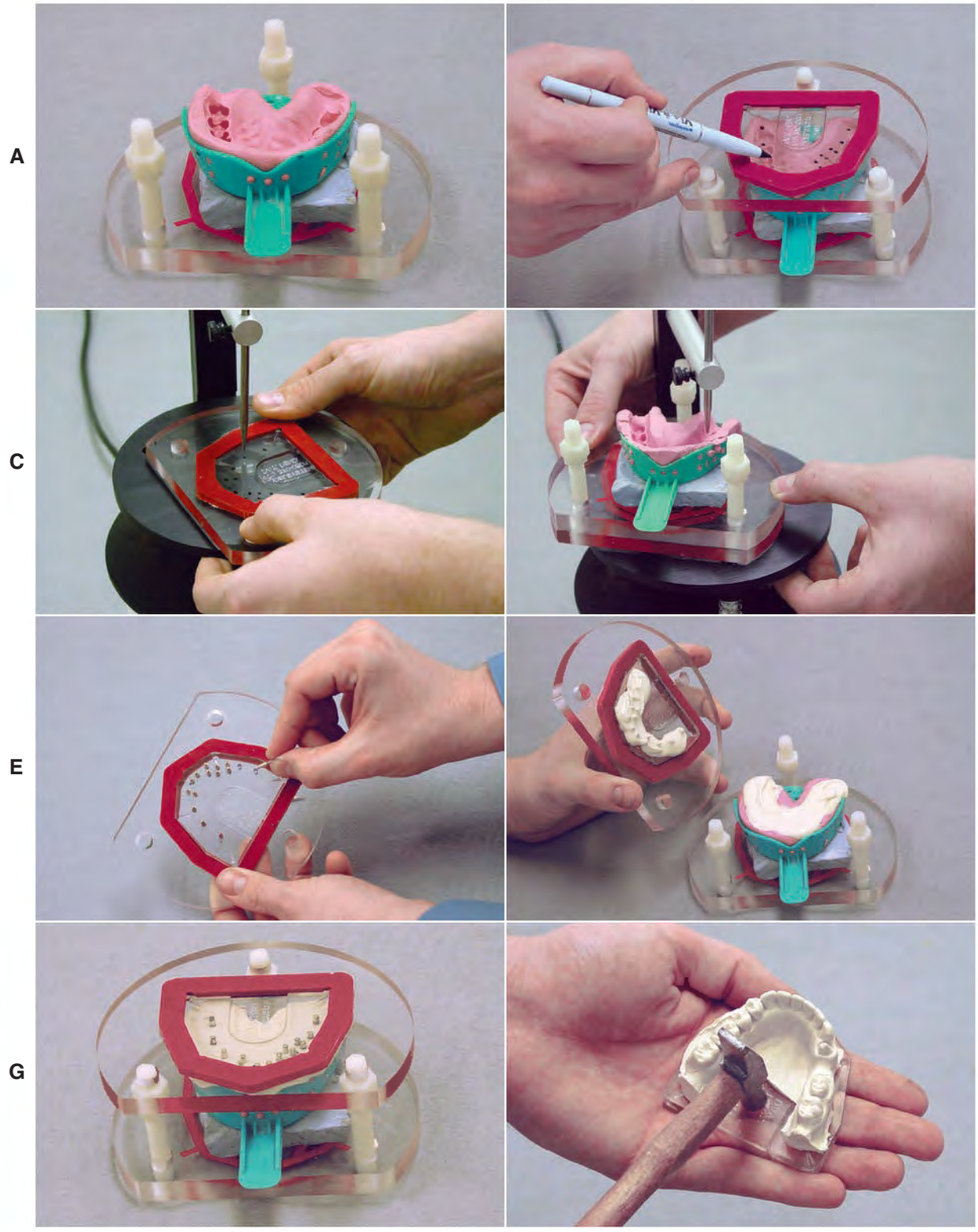

FIGURE 17-10 ■ DVA Model System. **A,** Trimmed impression on alignment fixture. **B,** Marking dowel pin locations on clear plate. **C,** Drilling holes for dowel pins as marked. **D,** Alternatively, the holes can be drilled with the top/baseplate positioned on the underside of the fixture base. The pointer identifies the pin location. **E,** Inserting dowels in the baseplate. An adhesive is not required. **F,** The impression is poured, and stone is placed around the dowel pins. **G,** The alignment fixture is re-placed over poured impression. **H,** Set cast is removed from the baseplate with gentle tapping.

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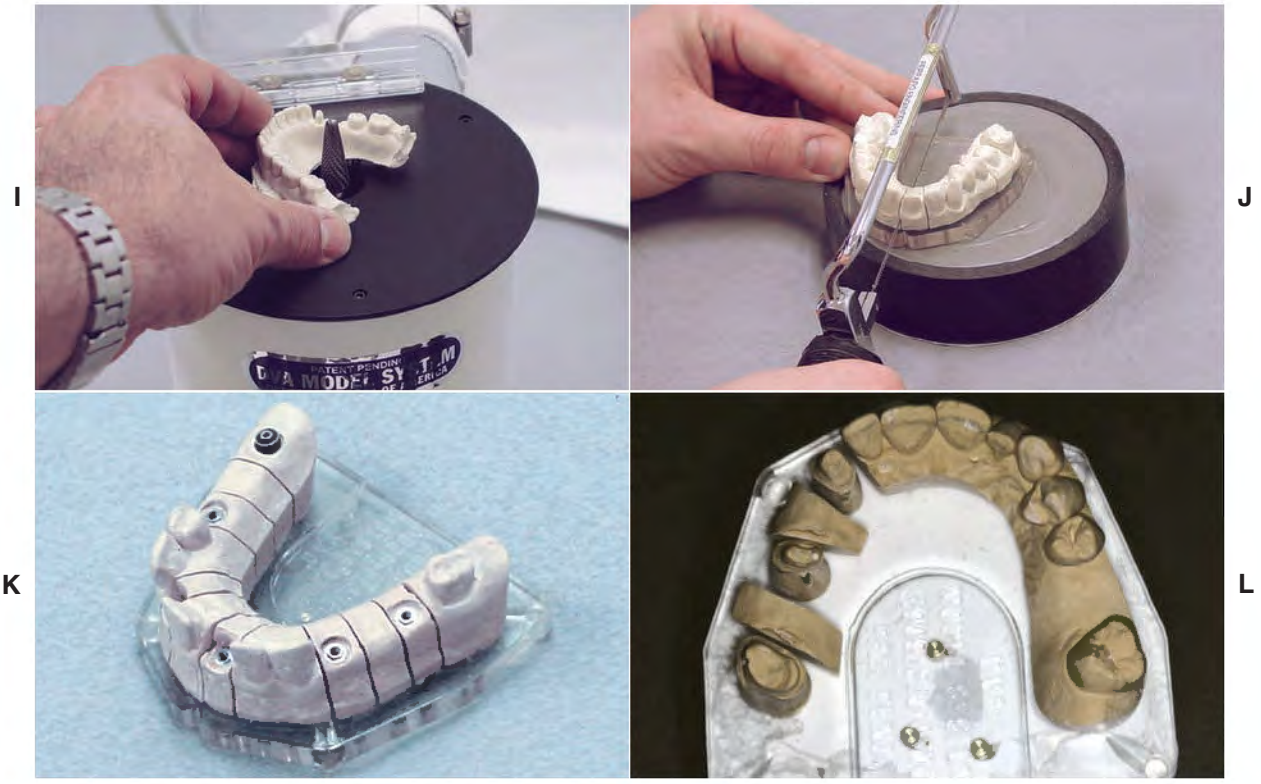

FIGURE 17-10, cont'd ■ **I,** The cast is trimmed. **J,** The cast is sectioned. **K** and **L,** Definitive casts trimmed with the DVA Model System. (**A** to **K,** Courtesy Dental Ventures of America, Inc., Corona, California. **L,** Courtesy Dr. A.G. Wee.)

before the pattern is invested. As the pattern is transferred back and forth from the solid cast to the individual die, the risk of pattern breakage is increased in comparison with removable die systems. After casting, some difficulty may be encountered in seating the metal casting on the solid model, and it may have to be relieved slightly to enable full seating.

In contrast to the solid model, a removable die system's main advantage is that it requires less manipulation of the wax pattern, which reduces the chances of pattern breakage during fabrication. In addition, the handling of porcelain restorations is easier, particularly if a porcelain labial margin is used. For these reasons, many technicians believe that the extra steps involved in making a cast with dowels and a removable die are worthwhile.

Nevertheless, the procedures are technically quite challenging. It is common to encounter dies that do not seat properly or that have poorly placed dowels. Difficulty may then be encountered in sawing the die out of the cast. Interproximal margins can be damaged easily during the sectioning procedure, particularly if clearance between a proximal preparation margin and the adjacent tooth is minimal.

In the popular Pindex system, a special drilling unit is used to ensure standardized pin placement. Careful model trimming of the initially poured cast is necessary before the holes for the pins are drilled. If the preparatory trimming is done correctly, the resulting removable dies are highly accurate and stable; however, the cost of the additional equipment must be considered.

The advantages and disadvantages of various cast-and-die systems are summarized in Table 17-2.

TECHNIQUE

The techniques for pouring stone dies are similar for most of the popular systems. To avoid repetition, the procedure involving single dowel pins is described in detail, with an emphasis on the differences between the solid cast (multiple-pour) system and the Pindex system.

Armamentarium

The following equipment is needed (Fig. 17-12):

- Impression
- Small camelhair brush
- Type IV or V stone
- Water
- Surfactant
- Dowel pins
- Retention devices
- Orientation aids
- Vacuum mixer and bowl
- Mixing spatula
- Vibrator
- Petrolatum
- Pencil
- Die saw

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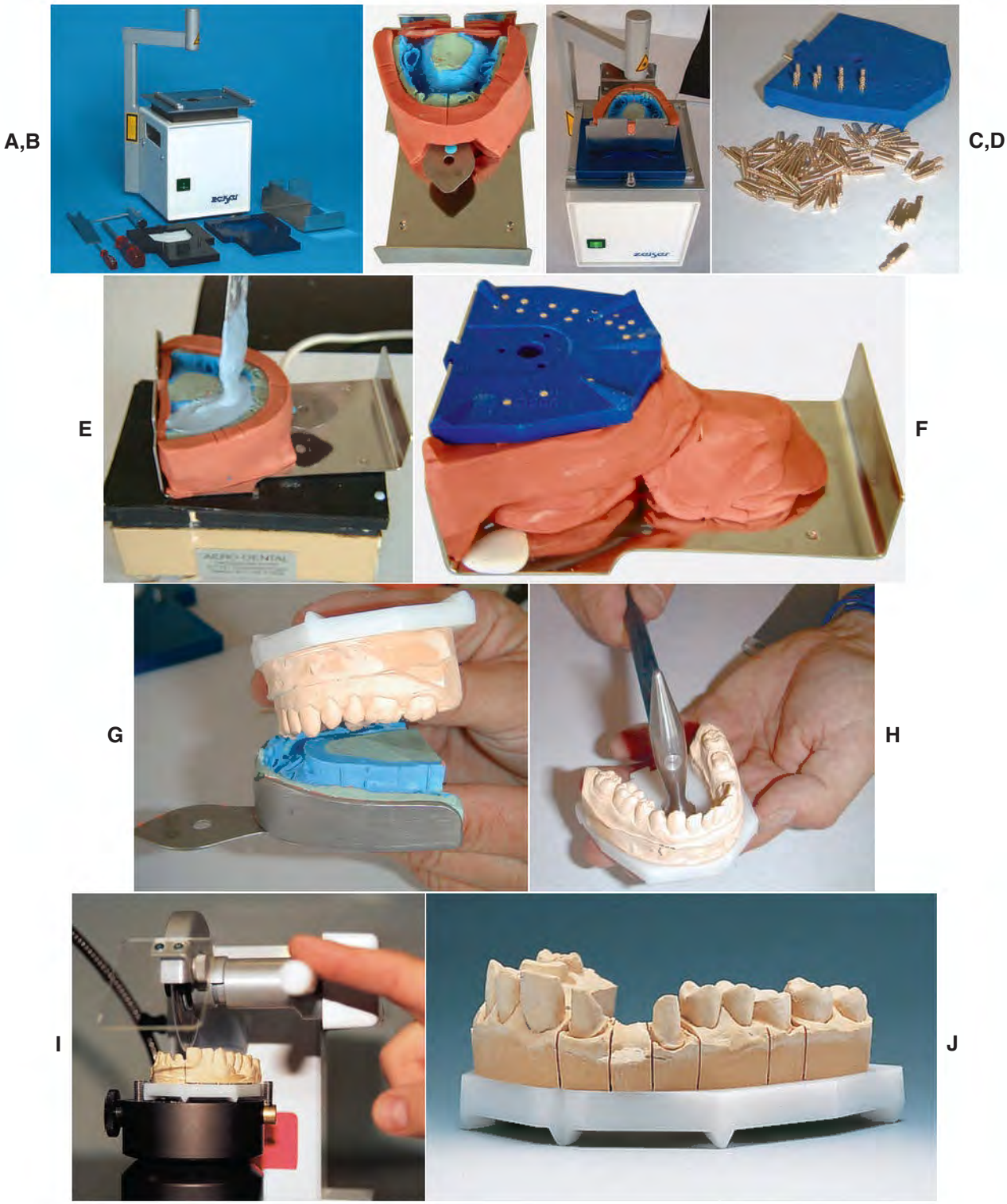

FIGURE 17-11 ■ **A**, Zeiser model system. **B**, The impression is leveled, blocked out with silicone putty, and positioned over the baseplate. **C**, The pin locations are determined and the pinholes drilled in the base. **D**, Pins are inserted into the base. **E,** The impression is poured. **F,** The base inverted into the stone. **G** and **H**, The cast is separated from the impression when set and then separated from the base. **I**, A precision saw aids sectioning. **J**, The sectioned cast. (Courtesy Zeiser Dentalgeräte GmbH, Hemmingen, Germany.)

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TABLE 17-2 **Cast-and-Die Systems**

System	Advantages	Disadvantages	Recommended Use	Precautions
Solid cast with individual die	Straightforward procedure No special equipment	Awkward wax and porcelain manipulation	Most situations Can be indexed with confidence from cast	Stone fixed dental prosthesis abutment easily broken
Brass dowel pin	Removable die facilitates waxing and porcelain No special equipment	Difficult to master	Most situations	Care needed in cast pouring and dowel placement
Pindex (Coltène/ Whaledent)	Removable die Cast pouring unimpeded	Special equipment needed	Excellent if equipment is well maintained	Careful attention to detail needed
Di-Lok (DentiFax/ Di-Equi)	Removable die Cast pouring unimpeded Much less costly than Pindex	Bulky Care needed during reassembly	Awkward to use on some articulators	Care needed when second pour is made
DVA Model System (Dental Ventures of America)	Removable die Cast pouring unimpeded Compensates for expansion of cast	Special equipment needed Quite technique sensitive	Excellent if carefully done	Care needed when seating pins
Zeiser (Dentalgeräte GmBH)	Single pour Removable die Cast pouring unimpeded Compensates for expansion of cast	Special equipment needed	Excellent if carefully done	—

FIGURE 17-12 ■ Armamentarium for pouring dies depending on system used.

After the impression has been removed from the patient's mouth, it is washed under running tap water, blown dry, inspected, and disinfected (see Chapter 14). When it is judged to be satisfactory, it is taken to the laboratory, where the necessary armamentarium should have been prepared in advance. A vacuum mixer (e.g., the Vac-U-Spat, Whip Mix Corp) is strongly recommended. At this time the impression can be sprayed with a surfactant or, in the case of hydrocolloid, placed in a potassium sulfate (K_2SO_4) solution (if recommended by the manufacturer).

Step-by-Step Procedure

1. If dowels are to be used, position them over the prepared teeth with one of the methods illustrated in Figure 17-13. Their correct location and orientation are important. For example, placing the head of a dowel too deep in the impression may weaken the die; positioning the dowel at an incorrect angle may prevent later die removal. At this stage, some technicians mark the best locations for the dowels in the buccal and lingual sulci or on the palate and place the dowels in the stone shortly after it is poured before its initial setting, because prepositioning the dowels makes pouring more difficult. In addition, the relatively brittle sticky wax commonly used to lute the pins in place can break loose during vibration. If dowels are not prepositioned, the viscosity of the stone should be carefully gauged, and correct timing of dowel placement is critical. If the stone is too runny, the dowels do not remain in place, and in many such cases, a new impression must be made.
2. Measure the proper proportions of type IV or V stone and water. To reduce air bubbles in the mix, the water should be placed in the mixing bowl first. The powder is then added and quickly incorporated by hand spatulation (Fig. 17-14, *A* and *B*). The spatula should be wiped clean on the blade of the mechanical mixer rather than on the edge of the mixing bowl, where stone can interfere with the vacuum seal. Some mixing units obviate the need for hand incorporation (see Fig. 17-14, *A*).

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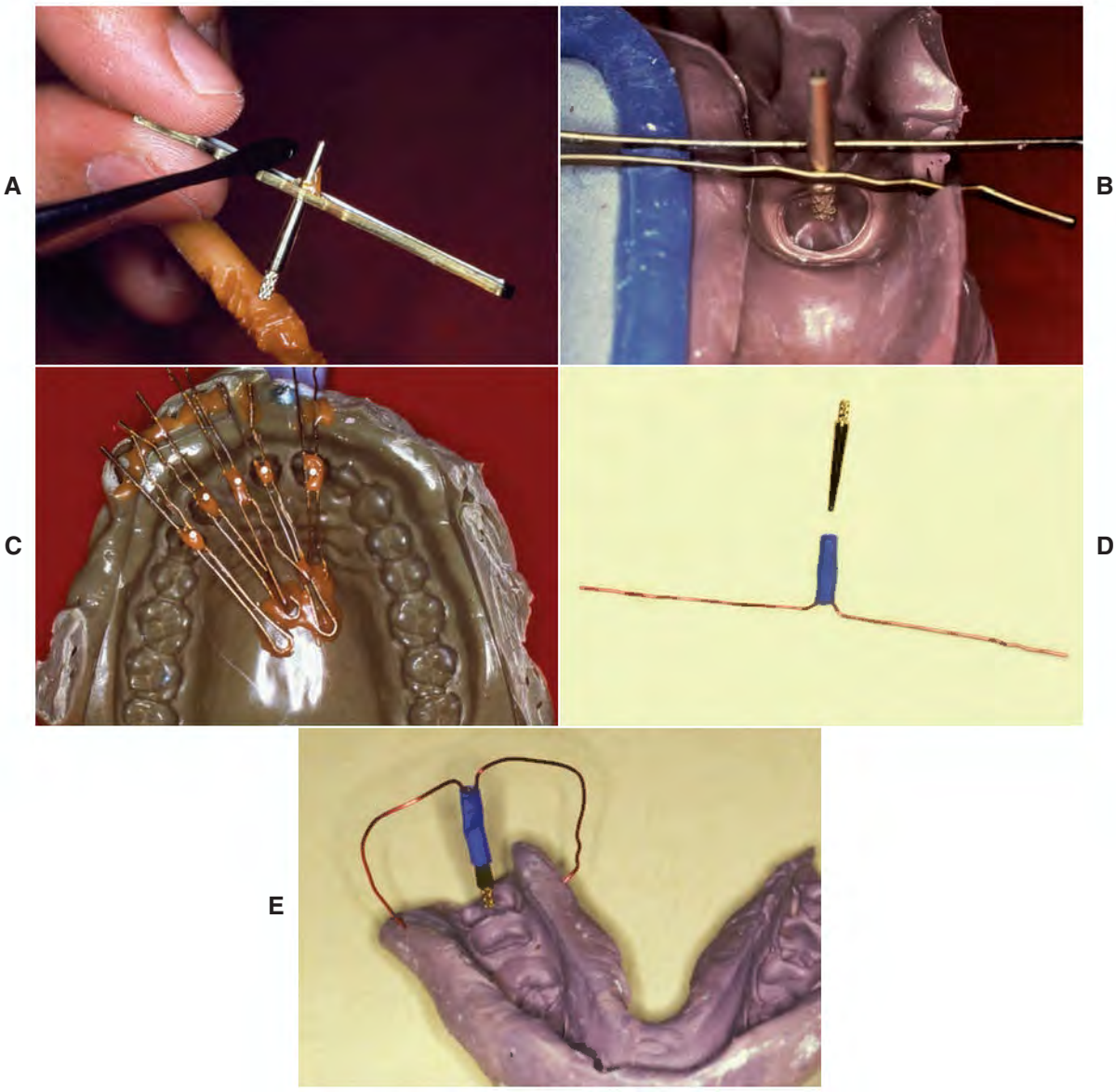

FIGURE 17-13 ■ Positioning dowel pins before cast pouring can be accomplished with bobby pins and sticky wax (**A** to **C**) or with prefabricated wire-tube aid (**D** and **E**).

3. Close the mixing bowl, and select the applicable mixing program (see Fig. 17-14, *B*).
4. Insert the drive shaft into the chuck of the mixer, and mix the stone for the recommended time. The mix is vibrated to allow the stone to settle in the bowl (see Fig. 17-14, *C*).
5. Blow or suction any excess surfactant out of the impression, pick up a small amount of stone with a suitable brush or instrument, and place it in the most critical area (usually the occlusal aspect of narrow preparations or immediately adjacent to the sulcus area). For small preparations, a thin instrument (e.g., a periodontal probe) may prove helpful with this procedure. Bubbles are trapped when too much stone is added abruptly or if two sizable masses of stone meet (Fig. 17-15). Therefore, small quantities of stone should be added incrementally in one area, which allows the stone to seek its own path (Fig. 17-16). During pouring, the tray should be held on a vibrator. For easy cleanup, the vibrator table can be covered with a paper towel or plastic bag.
6. Slowly tease the stone into the preparation along the axial walls by tilting the impression and guiding the material with the instrument. Be absolutely sure that the stone flows onto the margins of the preparation without trapping any air bubbles. Bubbles and voids are always a potential complication when impressions are poured. If the first pour is defective, a second pour will result in the loss of some accuracy, and a new impression is usually required. In addition, thin areas of the impression

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FIGURE 17-14 ■ Vacuum method of mixing type IV stone. **A,** The mixing bowl is rinsed, and excess water is shaken out. Measured distilled water is poured into the bowl, and weighed powder is added, or premeasured envelopes are used. The powder-to-liquid ratio should be in accordance with the manufacturer's recommended proportions. **B,** The mixture is mechanically spatulated under vacuum. **C,** At the end of the mixing cycle, the vacuum is broken and the lid is removed. **D,** Excess stone is removed from the paddle, and the impression is poured. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

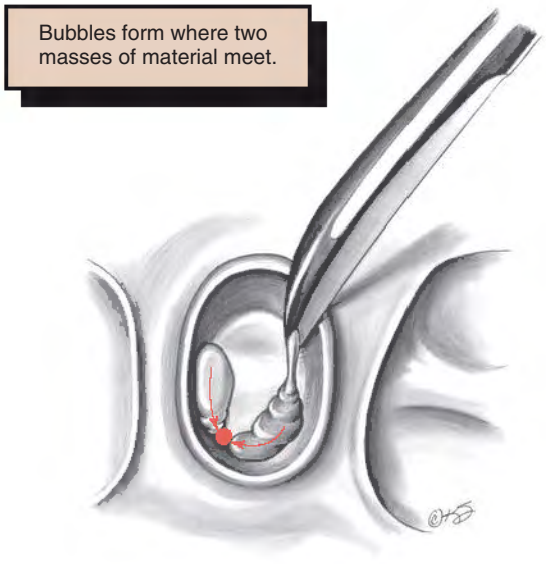

FIGURE 17-15 ■ Incorrect technique for pouring an impression. An air bubble *(red circle)* is trapped if two masses of stone *(arrows)* are allowed to meet.

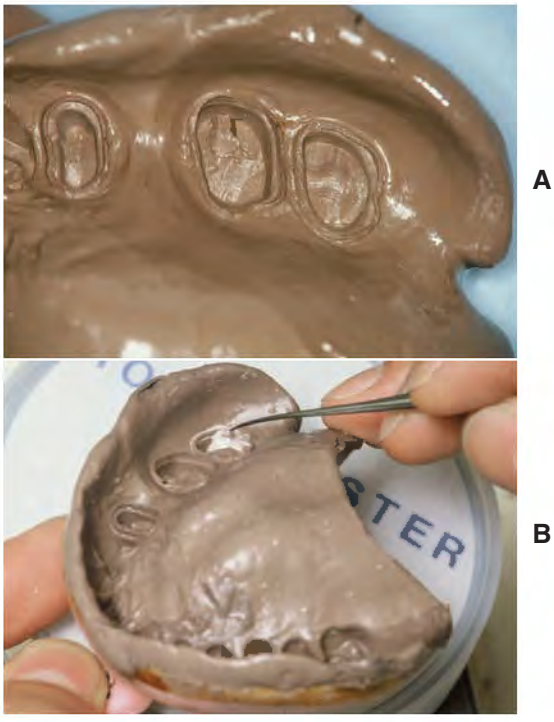

FIGURE 17-16 ■ Pouring an impression. **A** and **B,** To avoid trapping air, start with a very small amount of stone.

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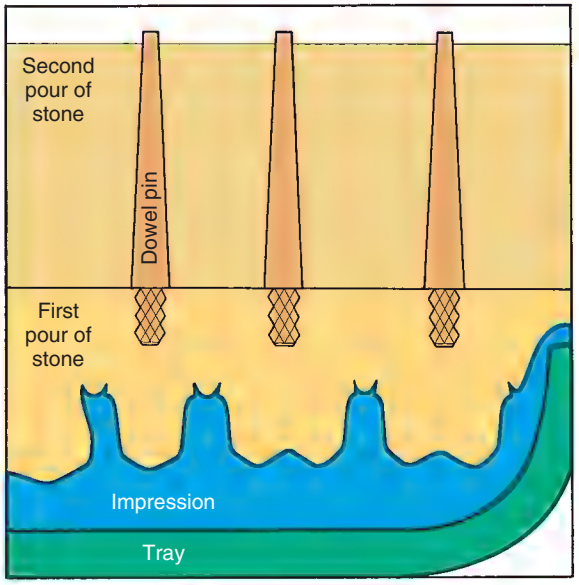

FIGURE 17-17 ■ Dowel pins must be carefully positioned so that the first pour of stone completely covers the knurled head of each pin; otherwise, the parts do not separate cleanly. However, the stone should not extend onto the shaft and reduce stability.

near the margin are often torn when the first pour is separated. For this reason, pouring a bubble-free cast the first time is essential for avoiding the need to make a new impression. The ease with which an impression can be poured without bubble formation depends on the contact angle that the advancing die stone makes when the impression material is wetted. Of the elastomers, polyethers have the lowest contact angle, which means they are the easiest to pour[27,28]; silicones have the highest contact angle and are the most difficult to pour, although the newer "surface-activated" or "hydrophilic" formulations are easier.[29] Overall, however, these materials do not seem to greatly facilitate impression making.[30]

7. Place a second amount of stone on top of the first, and continue with a third and so forth until the preparation is completely filled. The rest of the impression can then be filled to a height of at least 5 mm beyond the free gingival margins. If individual dowels are used, the head of each dowel must be covered with stone (Figs. 17-17 and 17-18).

Solid Cast–Multiple Pour Technique

For individual die pours, the stone mass must be built up to a height of approximately 25 mm to obtain a die handle of adequate length (see Fig. 17-18, *C*). The occlusal surfaces of teeth immediately adjacent to the preparation will be filled with stone, but this is of no concern (see Fig. 17-18). When the first pour has set, the cast is separated and repoured. The first pour is then sectioned into individual dies.

8. Place retentive devices[31] in areas where there are no dowels so that the two layers of stone do not separate in the wrong place (Fig. 17-19). Alternatively, lockwashers can be partially submerged in the wet stone to provide retention.
9. Allow the stone to set for the recommended time (usually 30 minutes).
10. Inspect the area where separation for the dies will be required, smooth it as necessary, and coat it with a separating medium (e.g., 10% sodium silicate). Then pour another layer of stone to act as a base and retain the dowels. This second layer should not cover the tips of the dowels. If for some reason the base must be built up more, wax or rubber tubing can be placed on the tip of the dowel to facilitate its retrieval later. Before the base of a mandibular impression is poured, the lingual aspect should be blocked out with a suitable molding material (e.g., Mortite Weatherstrip and Caulking Cord, Thermwell Products Co., Inc.); otherwise, the stone will lock around the tray and hamper removal of the cast from the impression. This is much easier than grinding excess stone away later to obtain access to the lingual aspect of mandibular preparations (Figs. 17-20 and 17-21). When the cast is separated from the impression, it must be carefully inspected for voids. If any are found in the marginal area of a prepared tooth, the cast is rejected, and a new impression must be made. Careful pouring technique prevents this. If the cast is satisfactory, it is ready for sectioning and trimming.
11. Trim the buccal and lingual vestibular areas adjacent to the removable sections first to facilitate die separation.
12. Mark the position of each saw cut (which should be parallel to the dowel) with a pencil.
13. Carefully insert the saw blade between the preparation and the adjacent tooth; make sure that neither the margin nor the proximal contact is damaged (Fig. 17-22). The cuts must pass completely through the first layer of stone. If this is not done, the die will not separate cleanly. When the saw cuts are made, the dies can be tapped out and are ready for trimming for waxing. (Typical trimmed and untrimmed dies are shown in Fig. 17-23.)

All excess stone, with the exception of the critical few millimeters immediately adjacent and cervical to the margin, should be removed with an Arbor band or a suitable cutting wheel in a lathe. The stone closer to the margin is removed with a large tungsten carbide bur. This is a critical step because easy access to the margin is mandatory for waxing and margination (see Chapters 18 and 22). Any residual flash is trimmed away with a sharp scalpel blade. The margin must not be damaged during this entire process. A binocular microscope is helpful during this step. It is important not to create a ditch apical to the margin, which could lead to poor gingival contour in the completed restoration (Fig. 17-24).

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FIGURE 17-18 ■ Pouring an impression for individual dies and solid cast (multiple-pour system). **A,** The critical margin area must be covered. **B,** Stone is added in the preparation area only. **C,** Bulk for the die handles must be sufficient. **D,** The first and second pours (individual dies) and the third pour (definitive cast). **E,** Sectioning the individual dies. **F,** The trimmed dies and definitive cast before articulation.

FIGURE 17-19 ■ Blobs of stone serve as retention devices in parts of the cast where separation is not desired.

When die trimming is completed, the dies are repositioned in the definitive cast, and their accurate and precise repositioning is verified. The definitive cast is then mounted on an articulator. Trimmed dies must be handled carefully. To minimize potential breakage, they should be secured in a container lined with foam plastic, gauze, or cotton.

MOUNTING CASTS ON AN ARTICULATOR

The articulation of diagnostic casts is discussed in Chapter 2. The technique for mounting a solid definitive (master) cast is identical. The procedure for attaching a definitive cast with removable dies to an articulator differs only in that access must be allowed to the area of the base into

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Pindex System*

When the Pindex system is used, the first pour of stone is removed from the impression once it has set. The base is ground flat in a plane that must be perpendicular to the intended orientation of the Pindex pins. The periphery of the cast is trimmed so that the resulting horseshoe-shaped cast will fit in a special mold. After the cast is completely dry, the locations of the pins are marked, and their holes are drilled with a special drill press. The pins are then cemented in place with cyanoacrylate resin, special sleeves are positioned over the cemented pins, and the cast is positioned in the second pour that is made in the mold (see Fig. 17-21).

Sawing in the cast between adjacent prepared teeth is often difficult, particularly with small anterior teeth. If this procedure is not performed carefully, the saw cuts can contact the dowel pin, rendering the die unusable. When the Pindex system is used, it is advantageous to remove the part of the first pour that contains the adjacent prepared teeth in one piece before the critical saw cuts are made. Then the cuts can be carefully marked and started from the base and the tooth side (see Fig. 17-21, *M*). When the operator saws from the base, it is important to protect the fragile dies with a soft cloth.

*Coltène/Whaledent, Inc., Cuyahoga Falls, Ohio.

FIGURE 17-20 ■ **A,** A molding material is used to block out the lingual aspect before a mandibular impression is poured. **B,** Otherwise, excess stone will have to be ground away to obtain access to the lingual surfaces, which is a tedious process.

FIGURE 17-21 ■ The Pindex system consists of a special drill press **(A)** and brass dowels and plastic sleeves **(B). C,** The impression is poured in stone, separated when set, and trimmed to a horseshoe shape. The base must be absolutely flat (a trimmer is provided).

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FIGURE 17-21, cont'd ■ **D,** The location of each dowel is marked on the occlusal surface. Two dowels are needed to stabilize each segment. (Alternative single pins are available for small preparations.) **E,** The cast is positioned on the drill stage; a light indicates the location of the drill. The cast is held firmly and the lever depressed; this activates the drill, which penetrates into the cast. **F,** Each hole should be cleanly drilled; a hand reamer is available if necessary. **G,** The pins are tried in and cemented in place. For accessibility, the short locating dowels should be used on the lingual surface. **H,** The assembly is coated with petrolatum to ensure clean separation. **I,** The plastic sleeves are positioned. **J,** The assembly is placed in the special mold. **K,** The second pour of stone is made into the mold. After some stone has been painted between the pins, the first pour is placed into this mix. **L,** Sawing the dies. **M,** With the Pindex system, it is sometimes helpful to remove the first pour, use it as a block, and commence sawing from the base. Marking all the saw cuts with a pencil is recommended. **N,** The Pindex cast after sectioning. (**A** to **M,** Courtesy Dr. J.O. Bailey. **N,** Courtesy Coltène/Whaledent Inc., Cuyahoga Falls, Ohio.)

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When the die is sectioned, the saw cuts should be parallel to each other or should slightly converge (A). Be careful not to create an undercut (B), because the die then will not be readily removable from the cast. Cutting into a pin when sectioning the cast will render it useless, and a new cast will need to be made.

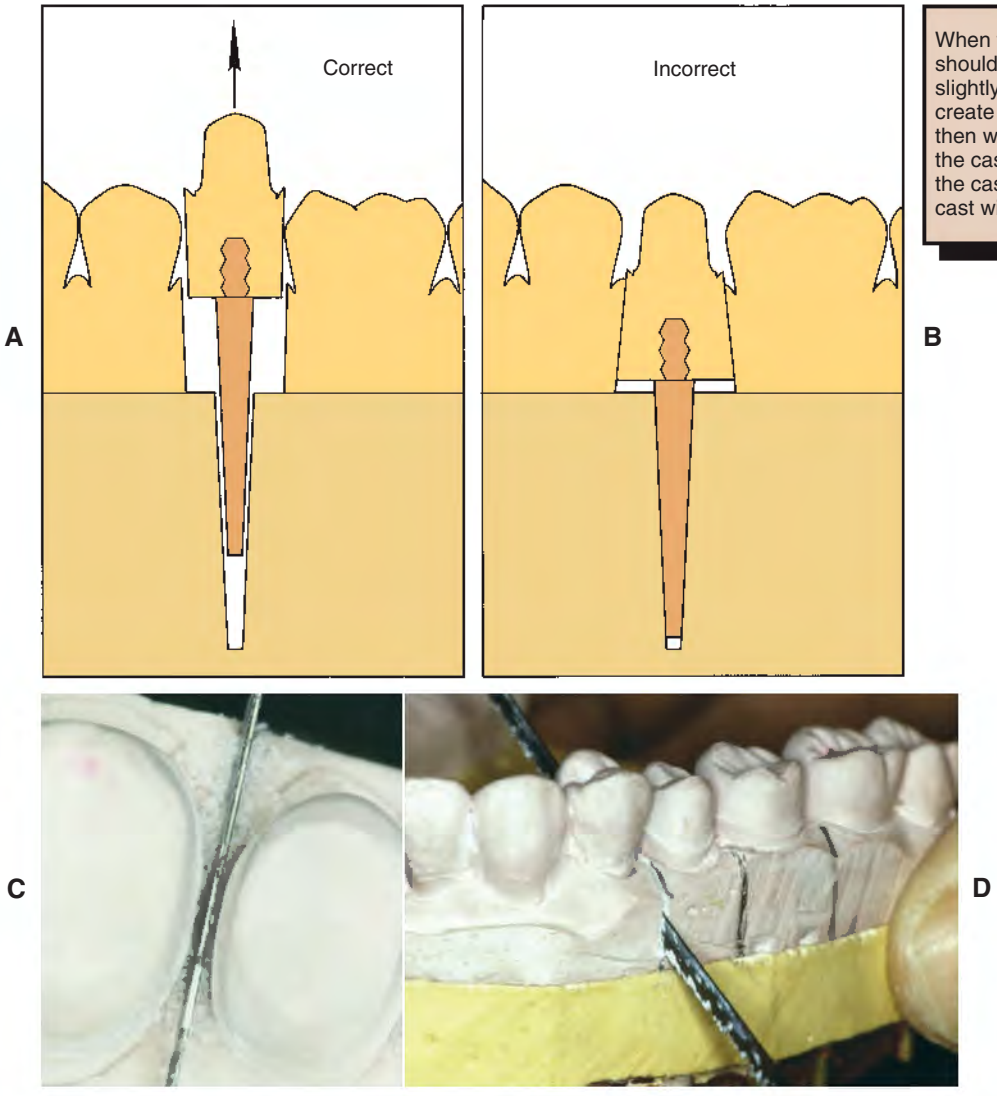

FIGURE 17-22 ■ Sectioning removable dies. **A,** The saw cuts should converge slightly toward the dowel; otherwise, the die will be locked in by undercuts **(B). C,** The intended saw cuts are marked in pencil, and the saw blade is carefully positioned. It must not touch the prepared tooth. **D,** The first pour is sawed completely through. Finishing the cut short of the second pour will prevent a clean separation.

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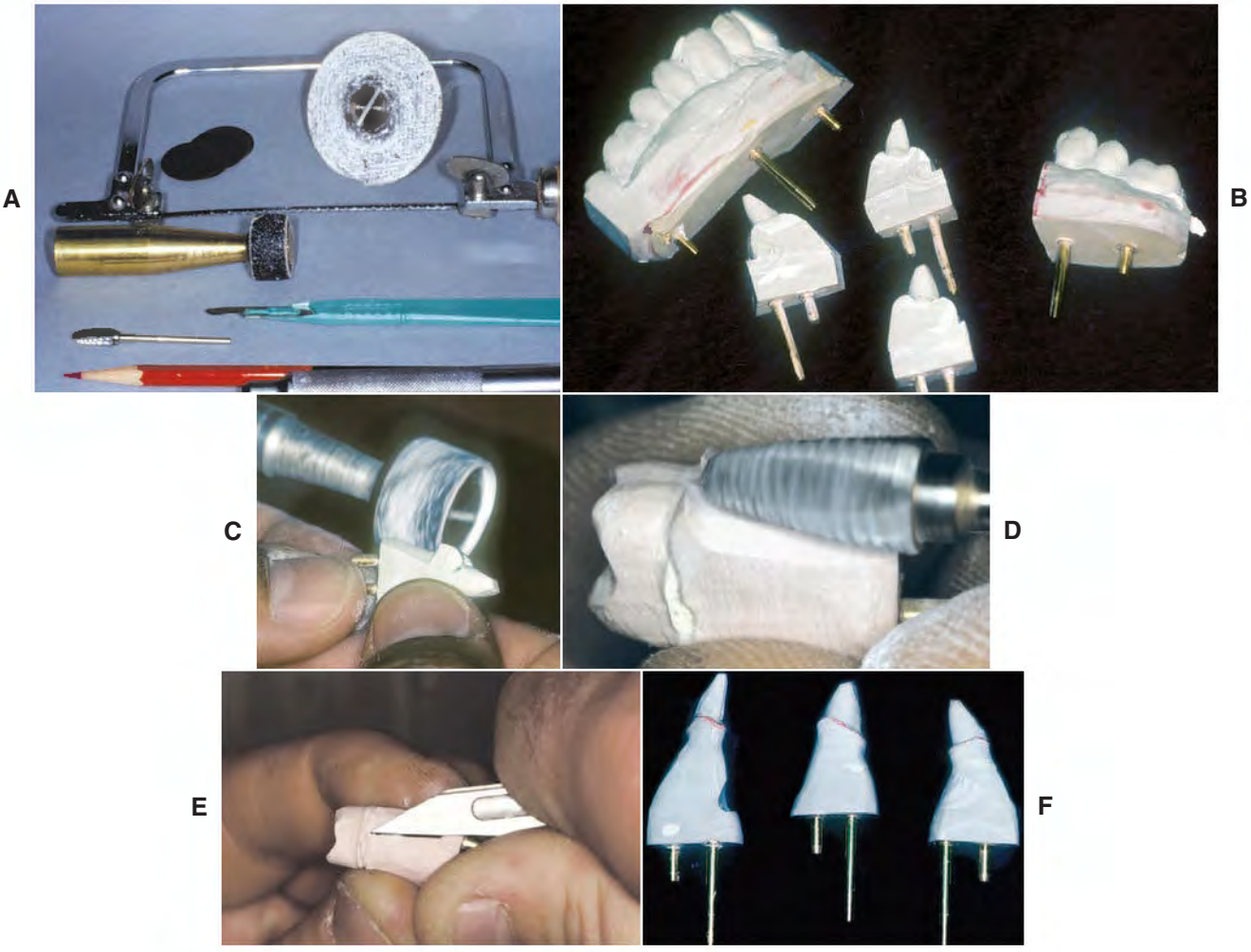

FIGURE 17-23 ■ Trimming dies. **A,** Armamentarium: saw, gypsum trimming disk, separating disks, Arbor band, scalpel, acrylic-trimming bur, colored pencil. **B,** Sectioned dies. In this instance, the Pindex system has been used. **C,** Bulk trimming is accomplished with an Arbor band on a lathe equipped with efficient dust collection. **D,** An acrylic-trimming bur is used near the margin. **E,** A sharp scalpel is used to trim to final contour, working away from the margin. **F,** The trimmed dies. (**B-F,** Courtesy Dr. W.V. Campagni.)

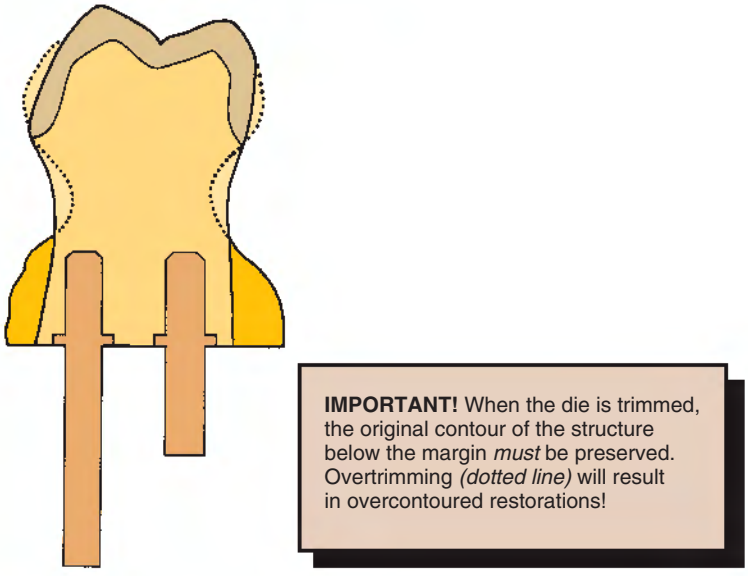

FIGURE 17-24 ■ Excessive trimming causes the resulting crown to be bulky because the trimmed die acts as a guide to gingival contour when the restoration is being waxed.

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FIGURE 17-25 ■ **A,** Definitive cast attached to an articulator. **B,** To facilitate removal, the mounting should allow access to the end of each dowel. This is achieved by adding wax or weather stripping to the tips of the pins.

which the dowels penetrate. This expedites removal of the dowels (Fig. 17-25).

Definitive Casts versus Diagnostic Casts

The accuracy of the casts and their mounting is even more crucial for definitive casts than for diagnostic casts. Although diagnostic casts can still provide much of the necessary information even when mounted slightly inaccurately, definitive casts must be mounted precisely if lengthy chairside adjustment of fabricated restorations is to be avoided.

Diagnostic casts are most useful when mounted with a centric relation (CR) record (see Chapter 2). This allows the practitioner to visualize the full range of mandibular movement for occlusal diagnosis, and on the articulator, it is possible to replicate any CR–maximum intercuspation (MI) difference diagnosed clinically. This enables the dentist to make appropriate decisions whether occlusal intervention is indicated before fabrication of definitive restorations (see Chapter 6).

Because of its material thickness, the CR record is made at an increased vertical dimension (see Chapter 2). Closing the articulator on removal of the record induces error if an arbitrary facebow is used.[32] There is a slight error even if a kinematic facebow is used.[33] Although such errors are probably not clinically significant with diagnostic casts, they are significant when definitive casts are involved because the degree of inaccuracy is transferred to restorations fabricated and adjusted on the casts. This subsequently translates into the necessity for additional chair time at the evaluation and clinical delivery appointment. Whenever possible, definitive casts should be mounted with a record made at the occlusal vertical dimension at which the restoration will be fabricated. If possible, the MI of unprepared teeth should be used.[34] This eliminates any arcing movement of the casts once the record is removed without resulting inaccuracy in the static occluded position. If this is not possible, a kinematic facebow recording is recommended because it relates the maxillary cast in its correct position in relation to the hinge axis. Subsequent articulation of the mandibular cast with a CR record at an increased vertical dimension enables closing the articulator without introduction of error. Weinberg[35] analyzed problems associated with mounting casts with a CR record when an arbitrary facebow was used. He calculated that a 3-mm-thick record can create an occlusal discrepancy in the first molar region of 0.2 mm when the arbitrary axis differs from the true hinge axis by 5 mm (a common error).

In addition, an elastomeric (rather than an irreversible hydrocolloid) impression should be made for the opposing cast. The elastomer's improved precision results in a more accurate opposing cast, which reduces the need to adjust the restoration at evaluation.

Conformative Occlusion

On many occasions, a cast restoration is made to conform to the patient's existing occlusion, even if CR and MI positions are discrepant. Typically, if no significant signs of clinical disease are detected, fabricating simple prostheses in the stable MI position is acceptable. The objective is to maintain rather than reorganize a healthy dentition.

When a patient has symptom-free occlusion and requires relatively few cast restorations (i.e., when only a small part of the dentition needs to be restored), the MI position is the most desirable treatment. Therefore, in many patients who need only one or two single crowns (or a small FDP), the best restorations conform to their existing occlusion.

Articulating a definitive cast for a restoration that is to be waxed to conform to existing occlusion poses certain problems. If the cast is mounted with a CR record (as described for diagnostic casts in Chapter 2), the MI position is not reproduced accurately enough for precise waxing because it is in a translated mandibular position. This position cannot be reached with absolute precision on a semiadjustable articulator. In addition, during closing of the instrument, the stone cast can be easily damaged.

The most practical solution is to articulate the definitive cast in MI through the use of a small interocclusal record (e.g., with polyvinyl siloxane) interposed between the tooth preparation and the opposing arch in the closed position (Fig. 17-26). At evaluation, after the restoration has been fabricated, only minimal inaccuracies should exist in the occluded MI position. The patient's CR closure is examined next, to ascertain that the restoration conforms to the dynamic occlusion, specifically the slide from CR to MI. No premature contacts should occur on

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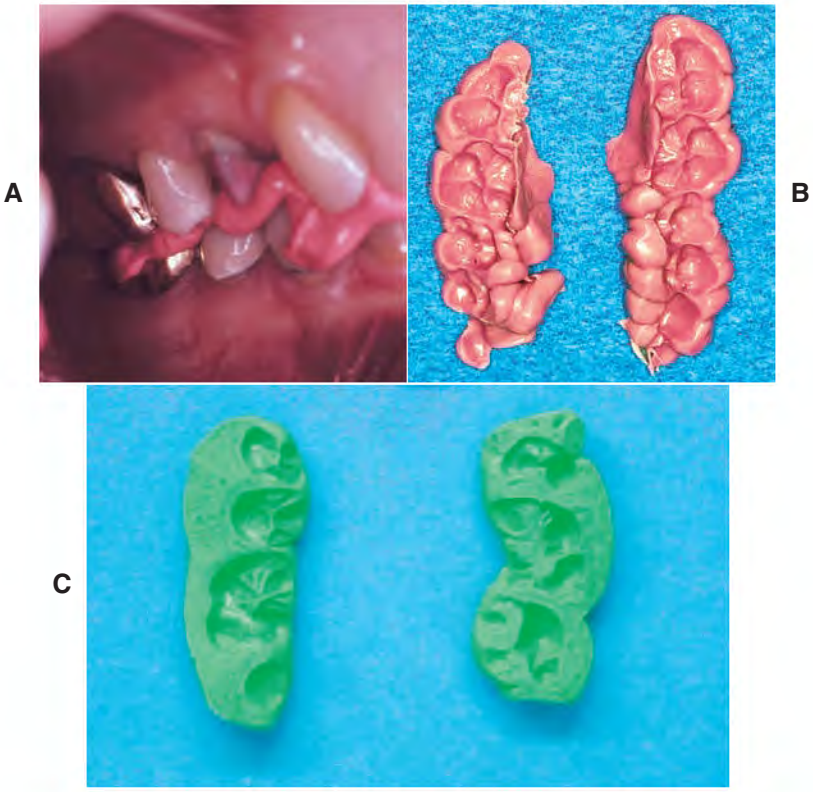

FIGURE 17-26 ■ **A,** Interocclusal record made with polyvinyl siloxane polymer, conforming to the patient's existing occlusion. **B,** Interocclusal records before trimming. **C,** Trimmed interocclusal records.

the new restoration. In CR closure, new occlusal interferences may have been introduced on the newly fabricated restoration, and the discrepancy between CR and MI may be effectively increased, which can lead to new problems (Fig. 17-27). It is therefore necessary to adjust the restoration to allow the original closing movement of the patient and to provide a smooth transition from the CR position to the MI position. After subsequent evaluation of excursive compatibility with the existing occlusion, the restoration is ready for cementation.

Reorganized Occlusion

The decision to reorganize a patient's occlusion (i.e., by making CR coincide with MI before the fabrication of the restoration begins) is made at the treatment planning stage (see Chapter 3). Treatment steps may then include occlusal adjustment of the existing dentition by selective reshaping (see Chapter 6) and reorganization of the anterior (incisal) guidance before tooth preparation for definitive cast restorations.

The following question should be asked during treatment planning: Has any discernible pathologic process arisen from malocclusion? In the presence of wear facets, widened periodontal ligament spaces, tooth mobility, elevated muscle tone, and muscle tenderness, the potential benefits of occlusal adjustment should be weighed. Two other questions must also be asked: Will reorganization of the occlusion benefit the patient? Will it enhance the overall prognosis of the dentition? If the answers are yes, occlusal adjustment can be performed (see Chapter 6), first diagnostically on articulated casts, and then clinically, after which definitive tooth preparation for fixed prosthodontics should be initiated.

The definitive casts can then be related at the occlusal vertical dimension with one of several techniques. Autopolymerizing resin may be used to record the relationship (Fig. 17-28). Alternative materials include impression plaster, zinc oxide–eugenol impression paste on a suitable carrier (e.g., autopolymerizing acrylic resin or gauze), and some of the stiffer elastomers (polyether or polyvinyl siloxane).

These records are optimal if they include only the cusp tips (see Fig. 17-26). If more detail of the grooves is inadvertently captured, it should be carefully trimmed away. Otherwise, the cast will not seat properly, and subsequently fabricated restorations will be in supraocclusion.

Verification of Mounting

It is essential to check the accuracy of the articulation before the laboratory phase of treatment. This is critical when prosthodontic treatment is complex (see Fig. 17-28) For less complex fixed prosthodontics, the dentist can check simply by comparing the occlusal contacts in the patient's mouth with those made by the casts. (Mylar shim

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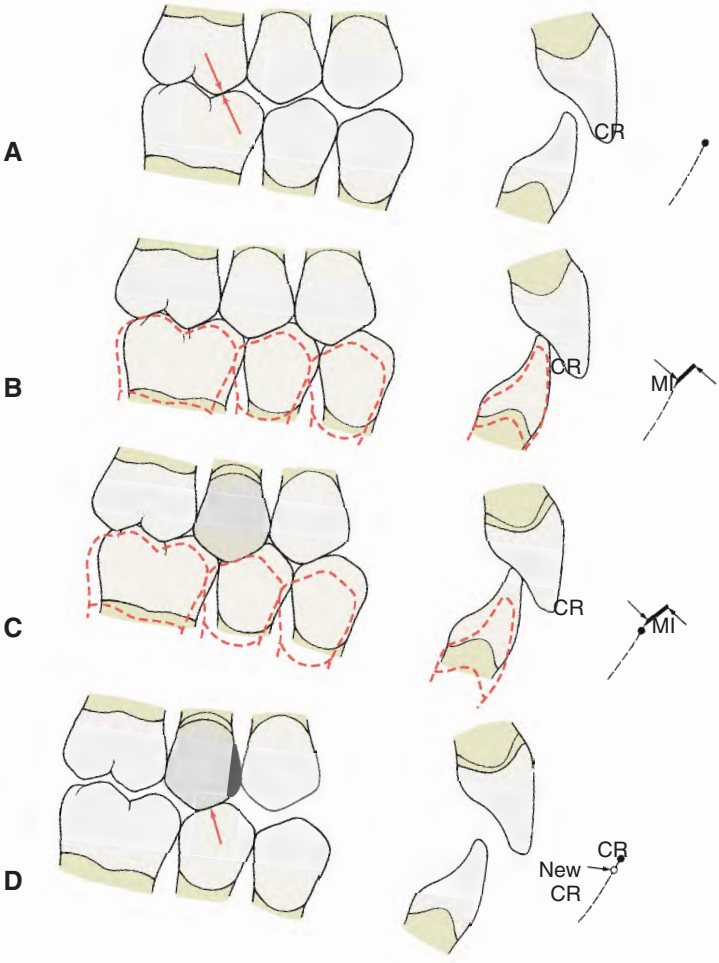

FIGURE 17-27 ■ In providing a restoration that conforms to an existing occlusion, it is important to assess both centric relation (CR) and maximum intercuspation (MI) carefully. **A,** Before treatment, the CR contact is on the first molar *(arrows).* **B,** Preoperative MI. **C,** The new restoration conforms to MI satisfactorily, but a new CR interference (**D,** *arrow*) has been created.

stock or articulating film is suitable.) Occlusal wax (see Chapter 6) is also useful. For more extensive procedures, a second occlusal record is needed that can be compared with the first in a split-cast mounting technique (Fig. 17-29) or a system such as the Denar Vericheck (Denar Corp.) (see Fig. 2-29).

TECHNIQUE FOR CLOSED-MOUTH IMPRESSIONS

The closed-mouth impression technique, also called the *dual-arch* or *triple-tray technique*, is popular for making impressions for single units and limited restorations made to conform to the existing occlusion[36,37] (see Chapter 14). The laboratory stages are extremely important. The procedure is different, depending on the articulator used. This description is for the V2 Quadrant Articulator (Monotrac Articulation, Fig. 17-30).

Step-by-Step Procedure

1. Trim the double-sided impression flat and parallel to the occlusal plane (see Fig. 17-30, *A*).
2. Pour the prepared tooth side of the impression and the articulator base with die stone (see Fig. 17-30, *B*).
3. Invert the impression, and align it onto the articulator base (see Fig. 17-30, *C*).
4. Pour the opposing side of the impression and articulator base.
5. Engage the hinge, and close the articulator (see Fig. 17-30, *D*).
6. Once the die stone has fully set, remove the base wall formers (see Fig. 17-30, *E*).
7. Eject the die side of the cast by grasping the cast and tapping the base (see Fig. 17-30, *F* and *G*).
8. Section and trim the cast (see Fig. 17-30, *H* and *I*). The individual dies can be accurately returned to the articulator.

VIRTUAL DEFINITIVE CAST-AND-DIE SYSTEMS

Optical Capture

Digital impressions may be acquired through the use of commercially available optical scanners (Fig. 17-31). Some of these are available as integrated computer-aided design and computer-aided manufacturing (CAD/CAM) packages, combining the acquisition unit, the design unit, and the fabrication component, which is often a milling system. Others are available solely as acquisition units that allow uploading of the acquired digital scan to a remote design and production center.

Types of Scanners

Scanners can be classified as contact scanners or noncontact scanners. A crude example of a contact scanner might be a key-duplicating machine that uses feeler gauges to trace the contours of a key. The mechanics of the unit are to use the position of the contacting styli to drive the milling machine that generates the duplicate key. The disadvantage of such contact scanners is that they are fairly slow. Early all-ceramic crown systems, such as Procera, initially relied on a contact probe that was used to make a scan of a stone die of the prepared tooth. For reasons of speed, the contact probe was eliminated and replaced with a much faster optical laser scanner, which significantly improved production speed (Fig. 17-32).[38]

Noncontact scanners can be based on radiation, ultrasound waves, or light. Dental scanners tend be to light based. Light-based (optical) scanners can be either confocal or triangulation based. The Itero scanner is an example of a confocal capturing device. Its capturing device consists of sensors that are preprogrammed for a set distance that can register only light reflected from that precise

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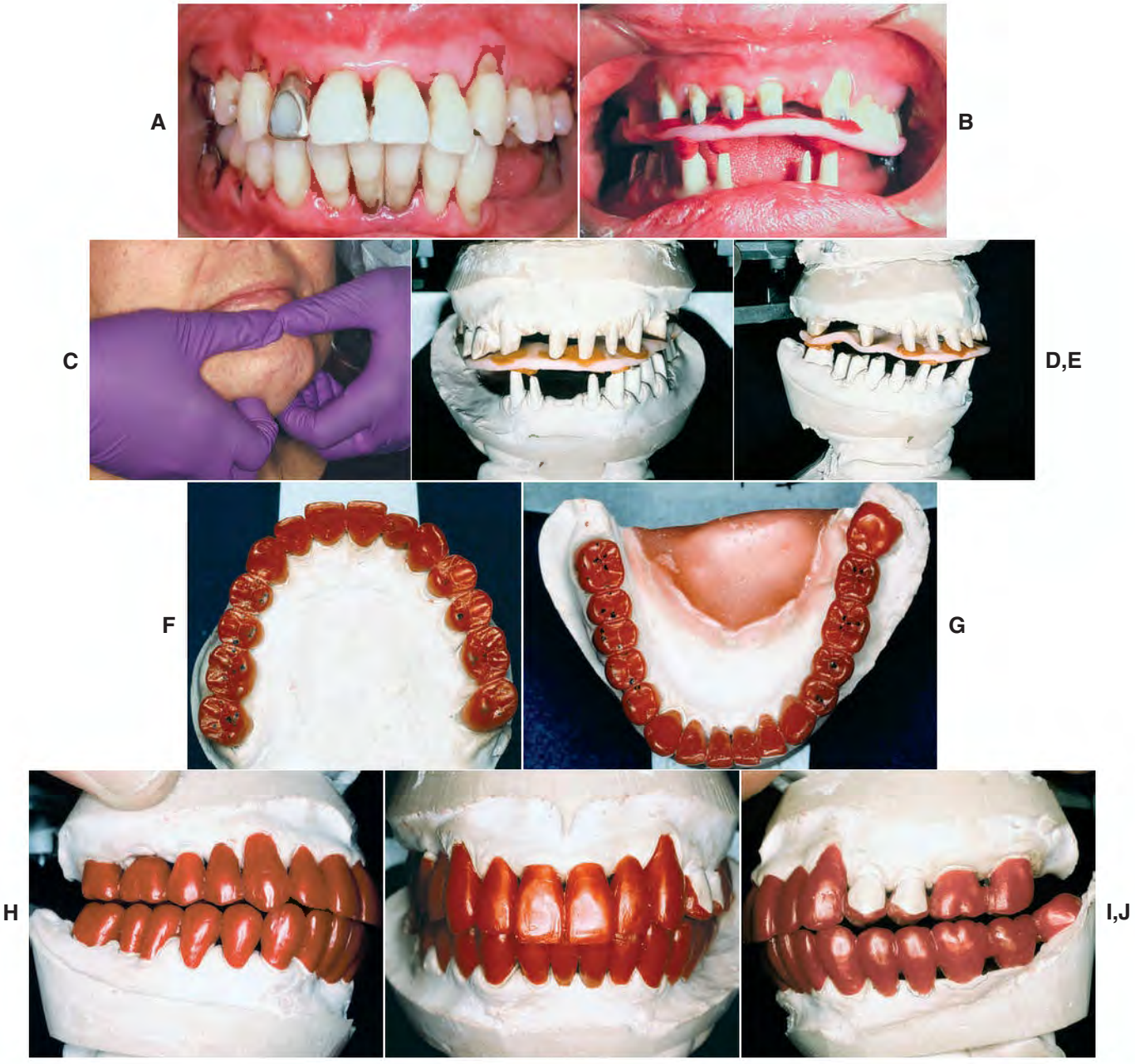

FIGURE 17-28 ■ Mounting definitive casts on the articulator. **A,** When extensive fixed prosthodontic care is necessary, accuracy of the articulation is essential for successful treatment. **B,** Recording centric relation (CR) at the occlusal vertical dimension minimizes the error inherent in a facebow transfer. Autopolymerizing acrylic resin was used as the recording medium. **C,** Manipulation of the mandible into CR. **D** and **E,** Definitive casts articulated with the CR record interposed. **F** to **J,** Restorations waxed to anatomic contour, with anterior guidance.

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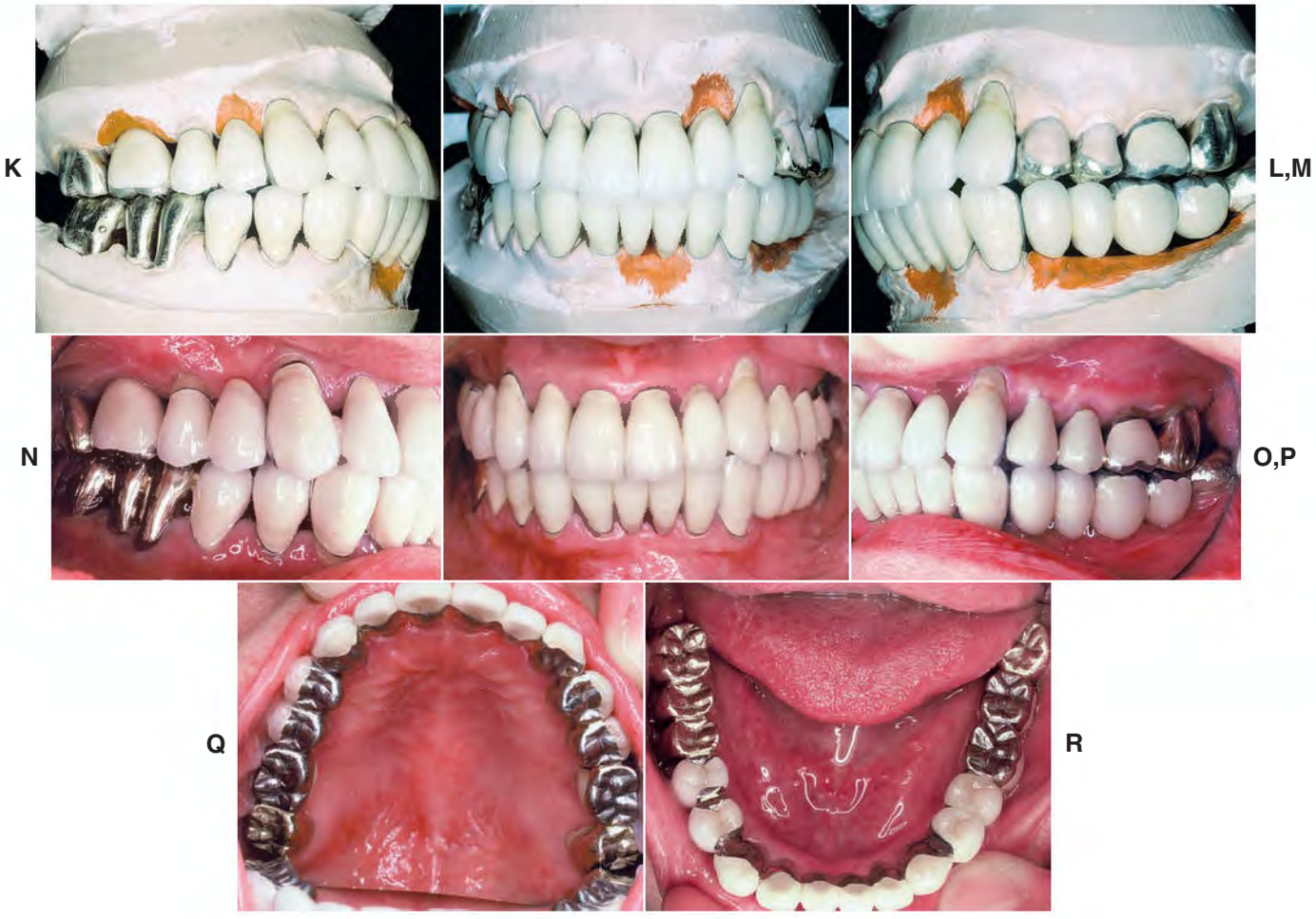

FIGURE 17-28, cont'd ■ **K** to **M,** Metal-ceramic restorations on the definitive cast. **N** to **R,** The completed restorations (see Fig. 31-45).

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FIGURE 17-29 ■ **A,** Magna-Split system. In this system, indexed magnetic plastic mounting plates (**A**) are used to facilitate split-cast mounting (**B** and **C**). **D-F,** The system is used to attach the maxillary cast. The second record is confirmed if the indices align precisely. (Courtesy Panadent Corporation, Colton, California.)

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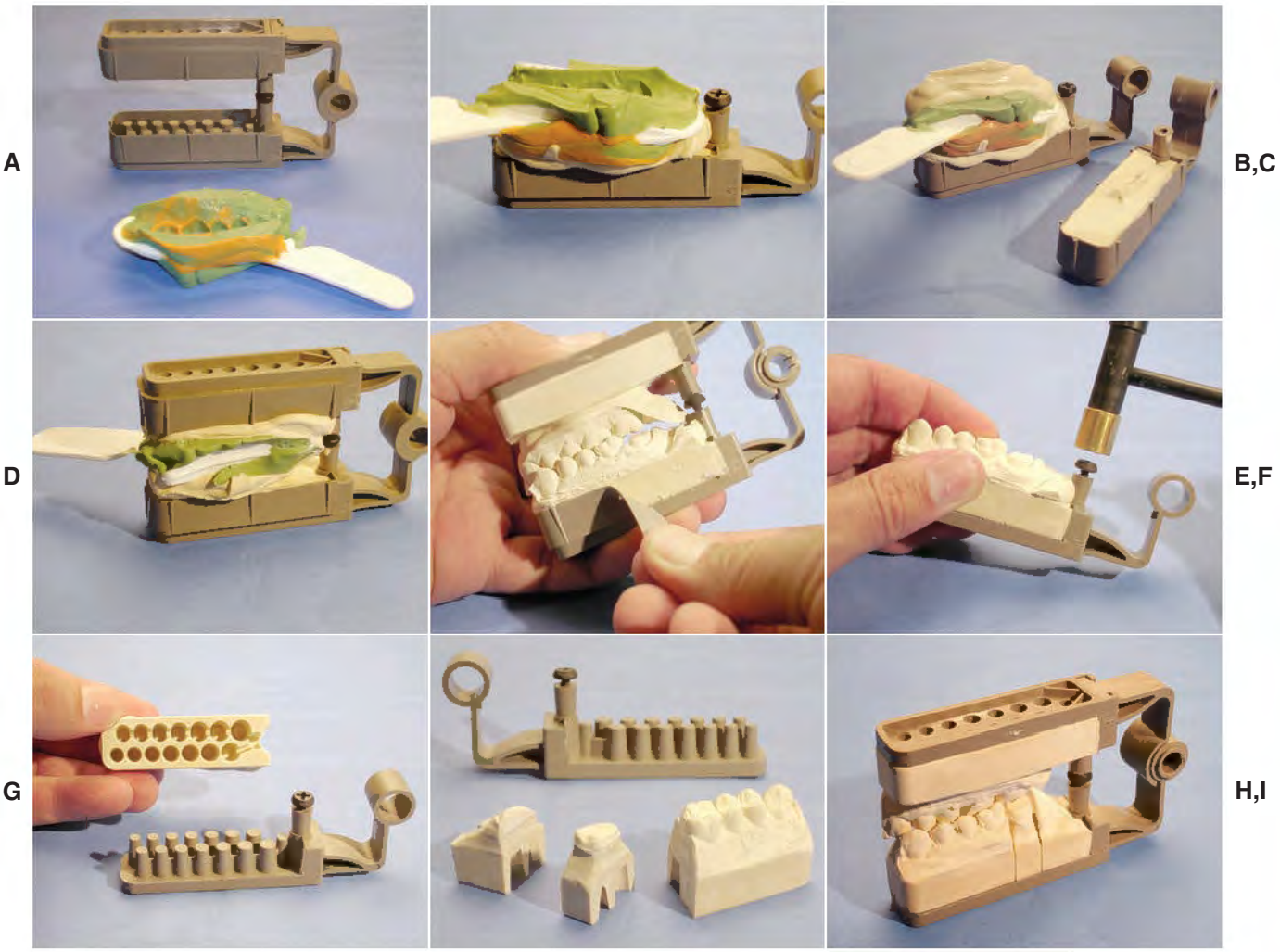

FIGURE 17-30 ■ The closed-mouth impression technique using the V2 Quadrant Articulator. **A,** Trim the double-sided impression flat and parallel to the occlusal plane. **B,** Pour the prepared tooth side of the impression and the articulator base with die stone. **C,** Invert the impression, and align it onto the articulator base. **D,** Pour the opposing side of the impression and articulator base. Engage the hinge, and close the articulator. **E,** Once the die stone has fully set, remove the base wall formers. **F** and **G,** Eject the die side of the cast by grasping the cast and tapping the base. **H** and **I,** Section and trim the cast. The individual dies can be accurately returned to the articulator. (Courtesy Monotrac Articulation, Salt Lake City, Utah.)

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FIGURE 17-31 ■ Chairside digital impression scanner. **A,** Cerec AC. **B,** iTero. **C,** Lava COS. (**A,** Courtesy Sirona Dental Systems, Inc; **B,** Courtesy Align Technology, Inc. **C,** Courtesy 3M ESPE Dental.)

FIGURE 17-32 ■ Laboratory digital scanner. NobelProcera's 3D laser scanner. (Courtesy Nobel Biocare.)

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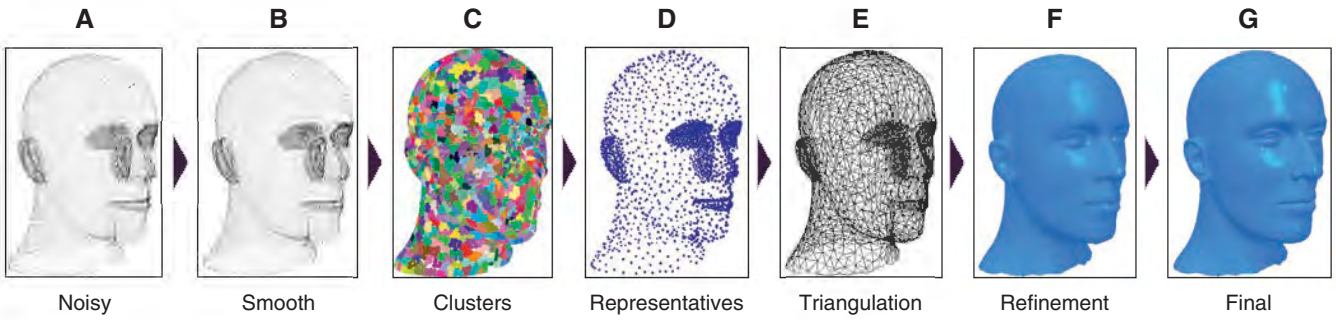

FIGURE 17-33 ■ The captured data undergo a number of computational transitions from the initial noisy scan to a smoothed rendering, clusters, representatives, and triangulation, after which refinement results in the definitive, final rendering. (From Mederos B, et al: Smooth surface reconstruction from noisy clouds. J Braz Comp Soc 9(3), 2004.)

distance. In contrast, scanning devices such as CEREC (Sirona Dental Systems) or Lava COS (3M ESPE Dental) rely on a triangulation approach. The object to be scanned, such as the prepared tooth and the adjacent portion of the dental arch, are illuminated, and the system registers the distance for every pixel. As object complexity increases, scanning from multiple directions is necessary to produce the pertinent information efficiently. Some systems accomplish this by generating still shots from various directions, whereas others take so many images while the scanning head is moved around the target that, for purposes of analogy, a "movie" is generated. Light sources in the scanners are often a lase or light-emitting diode (LED).

The captured data undergo a number of computational transitions from the initial noisy scan to a smoothed rendering, clusters, representatives, and triangulation, which after refinement is followed by the definitive rendering (Fig. 17-33).[39]

Virtual Casts

Virtual casts may be generated from data captured directly intraorally or by a scan of a solid model of the dentition obtained through a conventional impression technique in the dental laboratory with a special scanning device. Many large commercial laboratories use virtual casts to improve productivity.

The digital data are used to generate a virtual replica of the scanned portion of the dentition. Software can be restrictive in that it can be used with only the equipment provided by a single manufacturer (closed source), or it can allow data manipulation with equipment generated by other manufacturers (open source). In chairside fabrication systems, the virtual model is used to generate the restoration design, which is fabricated immediately. No solid definitive cast is ever generated. The disadvantage of this technique is that no die is available for correction of contours or occlusion to help support the restoration. Also, it limits the number of materials in which the restoration can be fabricated.

Alternatively, the digital data can be used to generate solid definitive casts, which can be stereolithographic casts, made in an additive process in which incremental layers of resin are polymerized by a laser or milled from specially formulated urethane resins (Fig. 17-34). Such casts have been shown to have accuracy similar to that of conventional gypsum dies.[40] In the workflow, such models are generally articulated on hinge articulators, which limits the degree of precision with which subsequent restorations can be fabricated (see Chapter 2). For one system, special mounting brackets have been developed to enable positioning them arbitrarily on a conventional articulator (Fig. 17-35).

Alternatively, instead of using the data to generate solid definitive casts, the virtual casts can be positioned in a virtual rendering of an articulator (Fig. 17-36). Most of the current software systems position such virtual casts arbitrarily within the virtual instrumentation. One company has devised a method with a laboratory scanner to scan articulated solid casts, to generate virtual casts and place them in their correct position relative to the hinge axis within the virtual articulator (Fig. 17-37), Chapter 2. Current systems enable the dentist to adjust posterior articulator controls, but anterior guidance tends to be a function of average values that have been preprogrammed in the software. Developments in this area are extremely rapid, and precise capture of dynamic mandibular movement is one of the next logical steps in software development.

SUMMARY

Accurate definitive casts and dies are essential for the success of cast restorations. Various materials and techniques provide an extremely precise reproduction of the prepared teeth. Type IV stone is recommended in most instances, although careful handling is necessary to avoid chipping or abrading margins. Epoxy resin and electroplated metal (silver or copper) are durable alternatives. The die of the prepared tooth can be made removable by the use of dowels or the more convenient Pindex system. Alternatively, a solid definitive cast and separate die can be used. Whatever system is chosen, it must articulate precisely with an accurately made opposing cast. Virtual casts may be acquired from data captured with optical intraoral scanners or from solid casts scanned in the dental laboratory.

Text continued on p. 488

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FIGURE 17-34 ■ Virtual cast-and-die system: Cerec Omnicam. **A,** After optical scanning of both quadrants, a scan is made of the buccal surfaces in maximum intercuspation. **B,** The buccal "occlusal registration" is superimposed on both quadrant scans, and the software then relates the two virtual renderings to each other. **C,** Occlusal view demonstrating location and intensity of occlusal contacts. **D,** The quadrant scan containing the tooth preparation is oriented in the arch form. Orientation in relation to the curve of Spee and the curve of Wilson can be adjusted to some extent. **E,** The preparation margin has been delineated *(blue line).* **F,** The software generates a virtual crown that best fits in the available space. **G,** The virtual cast can be sectioned at any desired location, and resulting segments **(H)** can be manipulated individually.

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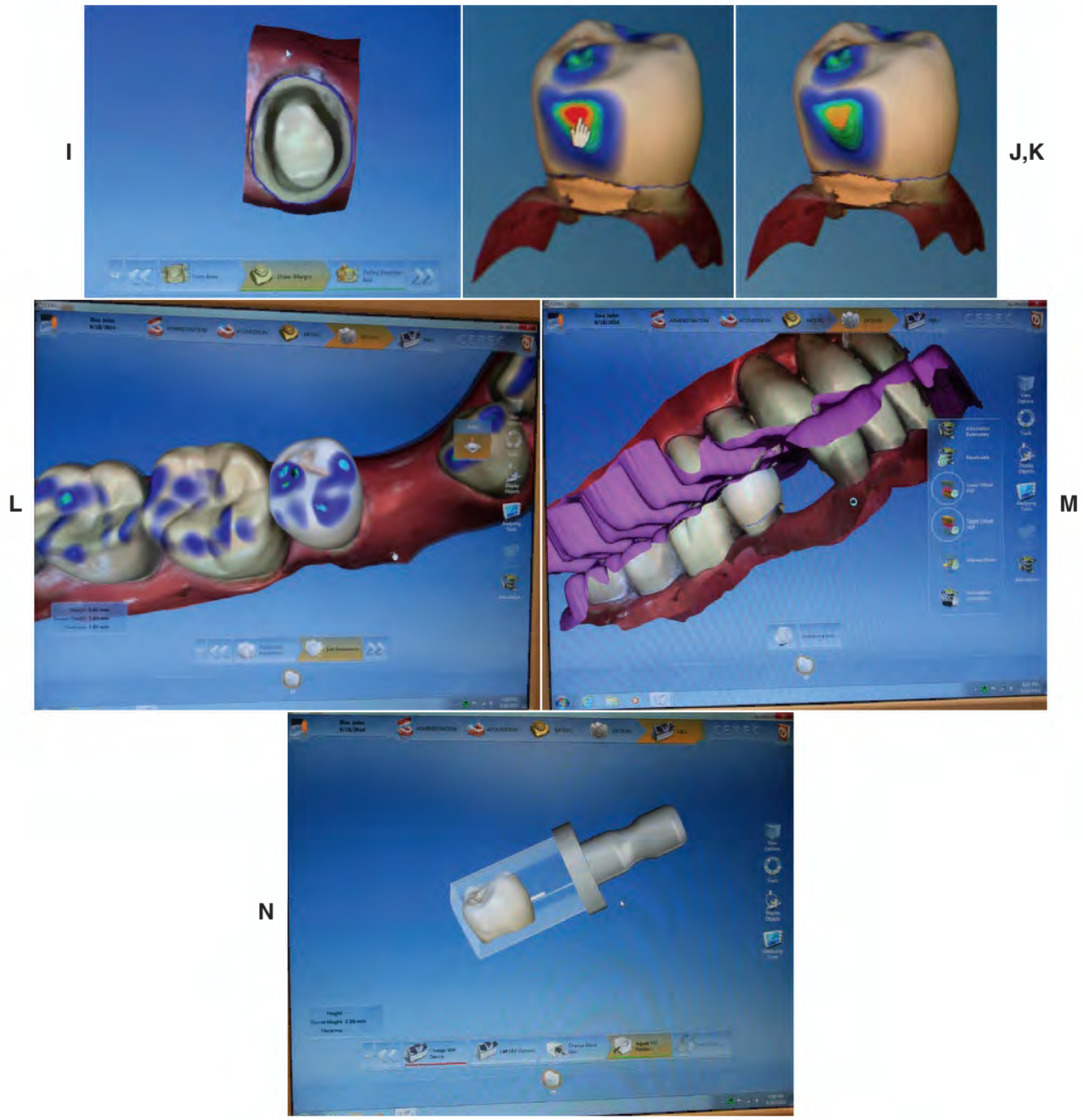

FIGURE 17-34, cont'd ■ **I,** Any final refinements to the delineation of the margin are made at this time. **J,** Proximal contact intensity (penetration) is represented by the colors and can be reduced from tight (red) to passive (yellow/light blue) **(K). L,** Occlusal form can be manipulated to achieve the desired occlusal contact relationships. **M,** An approximation of a functionally generated path is graphically represented, and mandibular motion can be simulated to assist in evaluation and further adjustment of the virtually designed restoration. **N,** On-screen preview of the position of the mill in the selected block. (Software manipulation courtesy Dr. J. Schmidt.)

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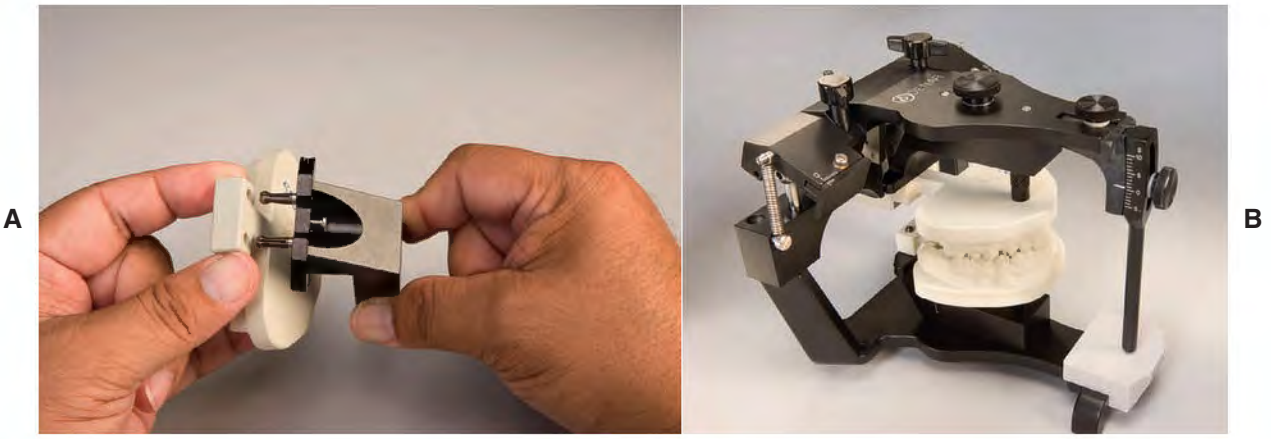

FIGURE 17-35 ■ **A,** Special mounting brackets have been developed to enable positioning stereolithographic casts arbitrarily on a conventional articulator **(B).** (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

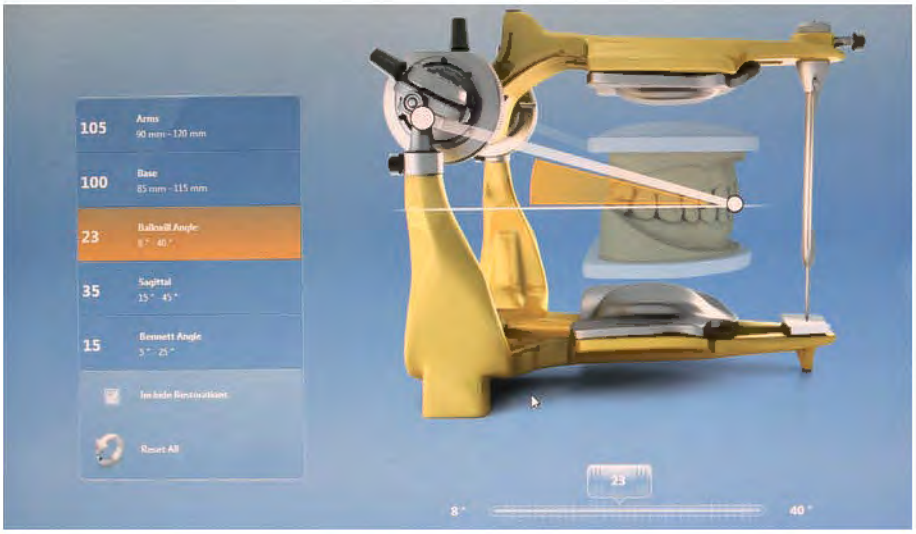

FIGURE 17-36 ■ Virtual rendering of an articulator in which virtual casts are positioned.

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FIGURE 17-37 ■ Articulation of virtual casts on the Denar Mark 330 Articulator. **A,** A conventional arbitrary facebow transfer is used to transfer a solid maxillary cast to the articulator. Note the thickness of the mounting plate and the V-shaped notches that will enable transfer to the scanner. **B,** Mounting stone is added. **C,** The mandibular mounting plate also has substantial height. **D** and **E,** The mandibular cast has been stabilized and is mounted conventionally. **F,** Condylar controls are adjusted on the basis of occlusal records or a Cadiax recording (see Chapter 2). **G,** The articulated solid casts on the articulator with adjusted controls. **H,** Mandibular cast is removed from the articulator. **I,** The casts are scanned individually. **J,** The combined thickness of the two mounting plates reduces the height of the articulated models, which allows them to fit inside the scanner. The transfer platform in the scanner corresponds geometrically to the mounting plates. In this case, centric relation (CR) and maximum intercuspation (MI) were coincident. **K,** Screenshot of the virtually articulated casts in their correct relationship to the axis of the articulator. The virtual controls are then set to correspond with the adjusted controls of the initial solid cast articulation. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

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REFERENCES

1. Revised American Dental Association specification no. 19 for non-aqueous, elastomeric dental impression materials. J Am Dent Assoc 94:733, 1977.
2. Schelb E, et al: Compatibility of type IV dental stone with polysulfide impression materials. J Prosthodont 1:32, 1992.
3. Omana HM, et al: Compatibility of impressions and die stone material. Oper Dent 15:82, 1990.
4. Toreskog S, et al: Properties of die materials: a comparative study. J Prosthet Dent 16:119, 1966.
5. Fukui H, et al: Effectiveness of hardening films on die stone. J Prosthet Dent 44:57, 1980.
6. Campagni WV, et al: Measurement of coating agents used for surface protection of stone dies. J Prosthet Dent 55:470, 1986.
7. Zakaria MR, et al: The effects of a liquid dispersing agent and a microcrystalline additive on the physical properties of type IV gypsum. J Prosthet Dent 60:630, 1988.
8. Alsadi S, et al: Properties of gypsum with the addition of gum arabic and calcium hydroxide. J Prosthet Dent 76:530, 1996.
9. Wee AG, et al: Evaluation of the accuracy of solid implant casts. J Prosthodont 7:161, 1998.
10. Yaman P, Brandau HE: Comparison of three epoxy die materials. J Prosthet Dent 55:328, 1986.
11. Chaffee NR, et al: Dimensional accuracy of improved dental stone and epoxy resin die materials. I. Single die. J Prosthet Dent 77:131, 1997.
12. Schaffer H, et al: Distance alterations of dies in sagittal direction in dependence of the die material. J Prosthet Dent 61:684, 1989.
13. Chaffee NR, et al: Dimensional accuracy of improved dental stone and epoxy resin die materials. II. Complete arch form. J Prosthet Dent 77:235, 1997.
14. Derrien G, Le Menn G: Evaluation of detail reproduction for three die materials by using scanning electron microscopy and two-dimensional profilometry. J Prosthet Dent 74:1, 1995.
15. Nomura GT, et al: An investigation of epoxy resin dies. J Prosthet Dent 44:45, 1980.
16. Nash RW, Rhyne KM: New flexible model technique for fabricating indirect composite inlays and onlays. Dent Today 9:26, 1990.
17. Roberts DB: Flexible casts used in making indirect interim restorations. J Prosthet Dent 68:372, 1992.
18. Rada RE: In-office fabrication of indirect composite-resin restorations. Pract Periodont Aesthet Dent 4:25, 1992.
19. Trushkowsky RD: One-visit composite onlay utilizing a new flexible model material. Am J Dent 1:55, 1997.
20. Gerrow JD, Price RB: Comparison of the surface detail reproduction of flexible die material systems. J Prosthet Dent 80:485, 1998.
21. Smith CD, et al: Fabrication of removable stone dies using cemented dowel pins. J Prosthet Dent 41:579, 1979.
22. Serrano JG, et al: An accuracy evaluation of four removable die systems. J Prosthet Dent 80:575, 1998.
23. Aramouni P, Millstein P: A comparison of the accuracy of two removable die systems with intact working casts. Int J Prosthodont 6:533, 1993.
24. Covo LM, et al: Accuracy and comparative stability of three removable die systems. J Prosthet Dent 59:314, 1988.
25. Schaefer O, et al: Qualitative and quantitative three-dimensional accuracy of a single tooth captured by elastomeric impression materials: an in vitro study. J Prosthet Dent 108:165, 2012.
26. Sivakumar I, et al: A comparison of the accuracy of three removable die systems and two die materials. Eur J Prosthodont Restor Dent 21:115, 2013.
27. Chong YH, et al: Relationship between contact angles of die stone on elastomeric impression materials and voids in stone casts. Dent Mater 6:162, 1990.
28. Lepe X, et al: Effect of mixing technique on surface characteristics of impression materials. J Prosthet Dent 79:495, 1998.
29. Vassilakos N, Fernandes CP: Surface properties of elastomeric impression materials. J Dent 21:297, 1993.
30. Boening KW, et al: Clinical significance of surface activation of silicone impression materials. J Dent 26:447, 1998.
31. Balshi TJ, Mingledorff EB: Matches, clips, needles, or pins. J Prosthet Dent 34:467, 1975.
32. Walker PM: Discrepancies between arbitrary and true hinge axes. J Prosthet Dent 43:279, 1980.
33. Bowley JF, et al: Reliability of a facebow transfer procedure. J Prosthet Dent 67:491, 1992.
34. Peregrina A, Reisbick MH: Occlusal accuracy of casts made and articulated differently. J Prosthet Dent 63:422, 1990.
35. Weinberg LA: An evaluation of the face-bow mounting. J Prosthet Dent 11:32, 1961.
36. Wilson EG, Werrin SR: Double arch impressions for simplified restorative dentistry. J Prosthet Dent 49:198, 1983.
37. Donovan TE, Chee WWL: A review of contemporary impression materials and techniques. Dent Clin North Am 48:445, 2004.
38. Denissen H, et al: Marginal fit and short-term clinical performance of porcelain-veneered CICERO, CEREC, and Procera onlays. J Prosthet Dent 84:506, 2000.
39. Mederos B, et al: Smooth surface reconstruction from noisy clouds. J Braz Comp Soc 9(3), 2004.
40. Kim SY, et al: Accuracy of dies captured by an intraoral digital impression system using parallel confocal imaging. Int J Prosthodont 26:161, 2013.

STUDY QUESTIONS

1. Discuss the material considerations for gypsum, resin, and electroplated die systems. List advantages, disadvantages, and typical indications for each category.

2. Contrast the advantages, disadvantages, and limitations of the following definitive cast-and-die systems:
   a. Solid cast with individual die
   b. Single brass dowel pin
   c. Pindex
   d. Di-Lok
   e. DVA

3. Discuss the Pindex system in a step-by-step manner. Identify critical steps and precautions.

4. For articulating definitive casts, which interocclusal record system results in the most accurate mounting? Why?

5. Describe how optical capture systems differ.

6. Describe current applications of virtual casts.

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CHAPTER 18

Wax Patterns

A large percentage of time and effort spent in fabricating metal or pressed-ceramic fixed prostheses is devoted to producing a very accurate wax pattern. From this pattern, the finished restoration is duplicated through the use of the lost-wax process as part of the indirect procedure.

The technique consists of obtaining an accurate impression of the prepared tooth (Fig. 18-1, *A*) and making a cast from the impression (see Fig. 18-1, *B*) on which a wax pattern that resembles the shape of the definitive restoration is shaped (see Fig. 18-1, *C*). A mold is then made around the wax pattern with a refractory investment material (see Fig. 18-1, *D*). When the investment has set, the wax is vaporized in an electric furnace. The hollow mold is then filled with molten casting alloy, reproducing every detail of the wax pattern (see Fig. 18-1, *E*). The metal casting is retrieved, excess metal is removed, and after polishing, the cast restoration is ready for clinical evaluation (see Fig. 18-1, *F*).

If an optical capture is used (see Chapter 14), a virtual cast can be generated on which the crown can be designed (Fig. 18-2). The wax pattern can then be milled from a solid block of specially formulated wax, or it can be printed (Fig. 18-3).[1] The margins of the resulting patterns are then readapted manually to ensure optimal adaptation, invested, and cast as described previously.

As the solidifying metal (casting) cools to room temperature, it shrinks. Dimensional accuracy of the casting is achieved by balancing this shrinkage against precisely controlled expansion of the mold (see Chapter 22). Wax is used to make the patterns because it can be conveniently manipulated and precisely shaped. With heating, it can be completely eliminated from the mold after investing.

The lost-wax technique is widely used in industrial and jewelry manufacturing. The first bronze castings reportedly were made in the third millennium BCE with beeswax and clay refractory materials. Ancient lost-wax castings such as Chinese bronzes, Egyptian deities, and Greek statues have withstood the centuries, yielding information about ancient societies and cultures. The lost-wax method may have been used in Sumer as early as the Second Early Dynastic Period (2700-2500 BCE) for figurines and even larger body parts.[2]

In the dental laboratory, *successful results depend on careful handling of the wax*. It must be understood that every defect or void in the wax will appear in the casting. Most defects can be corrected easily in wax but not in a metal casting. Compensating for an error in waxing technique is typically impossible once the metal casting has been formed. Careful evaluation of the pattern, preferably under low-power (up to 10 times) magnification, is crucial to obtain a good casting.

This chapter approaches the waxing procedure in a logical sequence. As with most aspects of fixed prosthodontics, a restoration is successful only if each step is carefully followed and evaluated before the dentist moves on to the next.

PREREQUISITES

The definitive die and cast may require small modifications before waxing is started. Depending on the procedure, the dentist can increase the size of the die slightly by applying a thin layer of painted-on spacer, which helps slightly enlarge the internal diameter of the restoration.

Correction of Defects

Even a very small undercut on the die of a tooth preparation makes wax pattern removal very difficult. Small dimples in the die (resulting from caries removal or loss of a previous restoration) may be undercut in relation to the path of placement of the planned restoration. Such areas are normally blocked out intraorally with glass ionomer or restored with amalgam or another suitable foundation material as part of the mouth preparation phase (see Chapter 6). On occasion, however, blocking them out on the working die may be more practical and convenient, as long as the defect does not extend to within 1 mm of the cavity margin. Zinc phosphate cement is a suitable material (see Chapter 30), but other commercial products (e.g., resin) are available for this purpose (Fig. 18-4).

Provision of Adequate Space for the Luting Agent

Since the 1920s,[3] practitioners have recognized that a space should exist between the internal surface of the casting and the prepared surface of the tooth everywhere except immediately adjacent to the margin. The space provides room for the luting agent (a material that on hardening fills the space and binds the tooth and crown together) and allows complete seating of the restoration during cementation (see Chapters 7 and 30). At the preparation margin, there should be a band of close adaptation (about 1 mm wide) to prevent disintegration and dissolution of the luting agent. The ideal dimension[4-6] for the luting agent space has been suggested at 20 to 40 μm for each wall, which implies that a complete crown should have an internal diameter between 40 and 80 μm larger than the diameter of the prepared tooth. Through the use of available techniques in an appropriately standardized manner, such a degree of casting adaptation can be obtained routinely, independent of the geometry of the finish line.[7,8]

If the luting agent space is too narrow, the restoration will not seat properly during cementation because of hydraulic pressure that develops when the viscous mass

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The "lost-wax" casting technique dates to the Bronze Age (approximately 3000-3500 BCE), when sandstone molds were used to cast molten metal. Today, the underlying principles remain virtually identical.

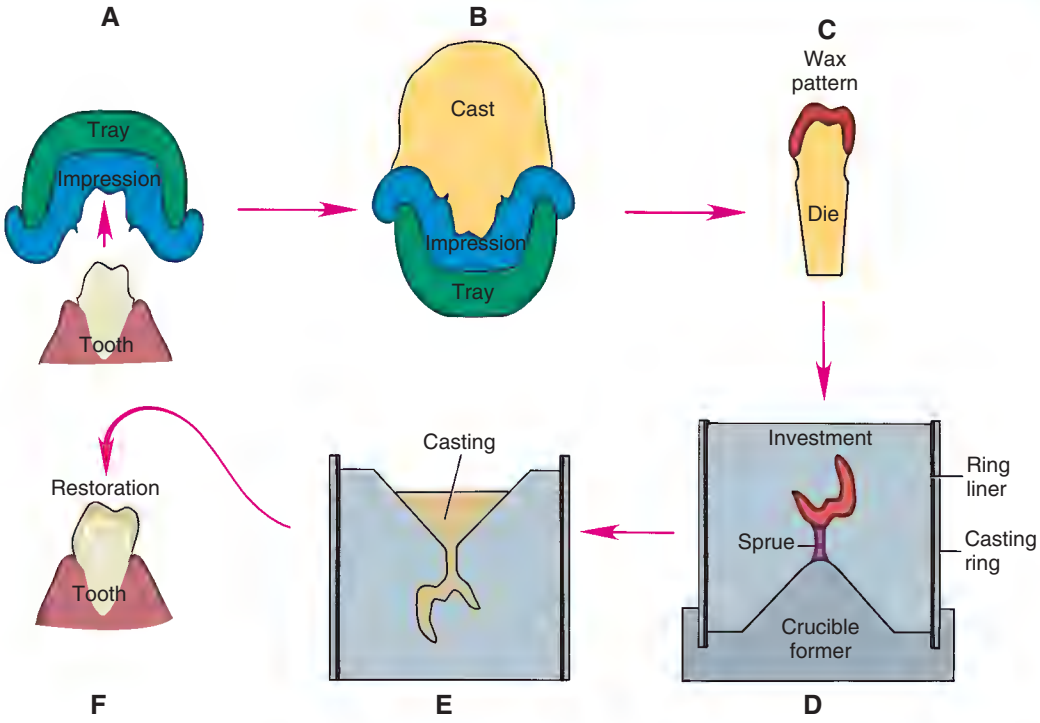

FIGURE 18-1 ■ Most dental castings are made indirectly by the lost-wax process. **A,** Impression. **B,** Cast. **C,** Wax pattern on die. **D,** The pattern is attached with sprue to a rubber crucible former and invested. **E,** Casting. **F,** Luted restoration.

of luting agent cannot escape through the narrow gap between crown and preparation as the restoration is seated. Conversely, if the luting agent space is too wide, the casting is loose on the tooth, resistance form (see Chapter 7) is reduced, and the position of the crown is difficult to maintain accurately during evaluation and occlusal adjustment (see Chapter 28). In addition, the risk that the crown will loosen during function increases considerably, and its longevity is adversely affected. The precise amount of space for the luting agent that is obtained depends on the materials and techniques used in the indirect process, particularly the choice of impression material (see Chapter 14), die material (see Chapter 17), investment (see Chapter 22), and casting alloy (see Chapters 19 and 22 and Fig. 18-1). These factors directly affect the size of the cement space.

Increasing the Space for the Luting Agent

A number of factors increase the space for the luting agent for a complete crown:

- Increased thermal and polymerization shrinkage of the impression material (see Chapter 14)
- Use of a solid cast with individual stone dies (see Chapter 17)
- Use of an internal (initial) layer of soft wax in the wax pattern
- Use of die spacers
- Increased expansion of the investment mold (see Chapter 22)
- Removal of metal from the fitting surface by grinding, airborne-particle abrasion, etching with aqua regia, or electrochemical milling

All other conditions remaining equal, each of these factors individually results in an increased distance between the internal surface of the casting and the surface of the prepared tooth. Although the dentist has little control over the polymerization shrinkage of impression materials, die system selection has a direct influence on the size of the wax pattern. With some impression materials, using a multiple-pour system for fabrication of a solid definitive cast and a separate die yields a die that is slightly larger than the prepared tooth. The pattern is, in effect, stretched during manipulation, which results in a proportionally larger internal casting diameter. An internal layer of soft wax is subject to slightly more compression by the setting refractory investment material, which leads to a looser fit. Spacers enlarge the die by coating the occlusal surface and vertical axial walls with a thin layer of rapidly drying paint. To increase the expansion

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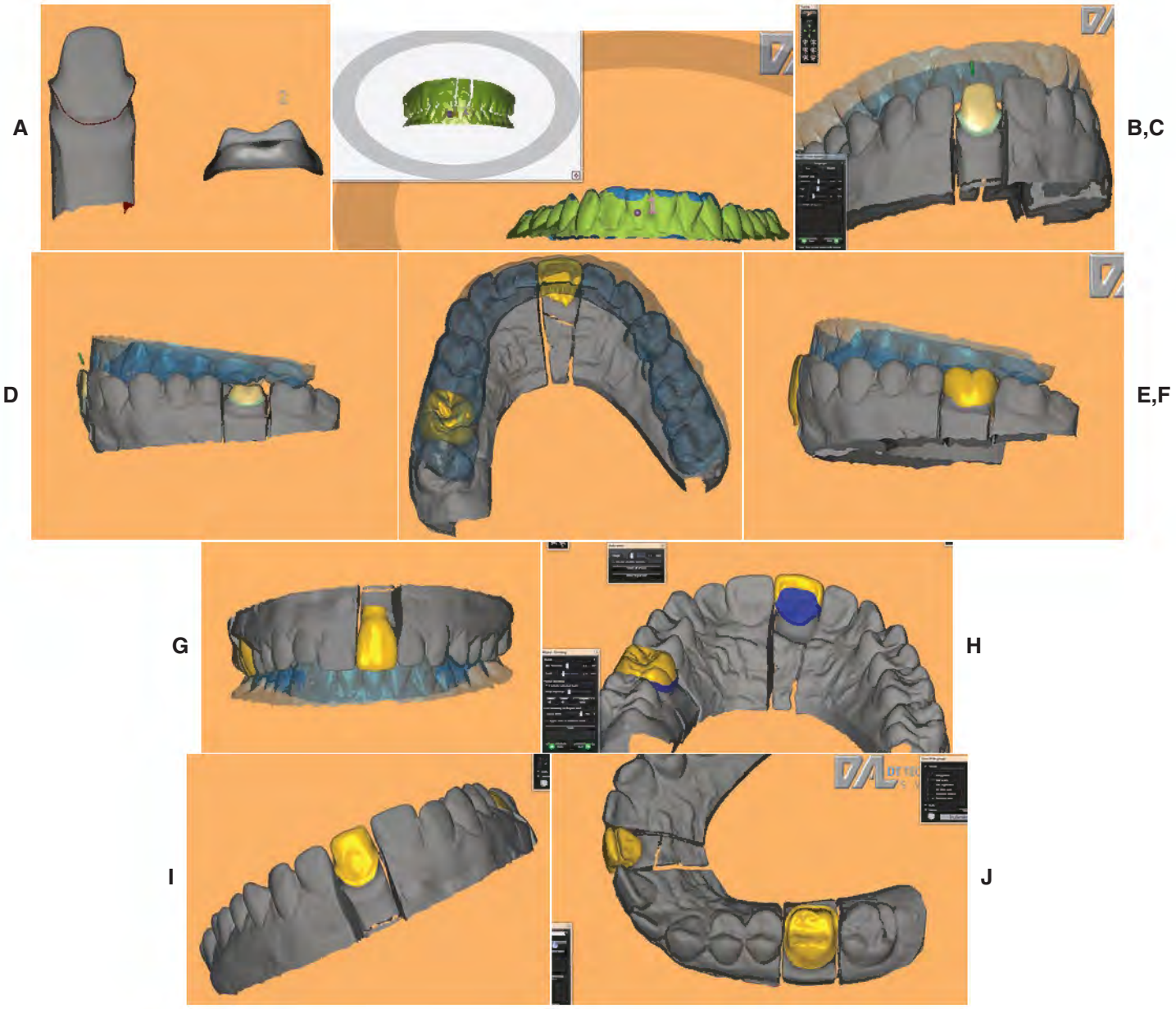

FIGURE 18-2 ■ Virtual renderings of substructures. **A,** The margin has been delineated on the virtual die *(red line).* **B,** The optical scan of the occluded position (index) used to properly relate the definitive virtual cast to the opposing cast. **C** and **D,** Insertion of the opposing cast in relation to the molar and incisor preparations. **E, F,** and **G,** Anatomic contour renderings are then morphed, after which the area that is to be veneered is delineated **(H). I** and **J,** Virtual renderings of the completed substructure designs. (Courtesy Mr. William Schwenk, CDT, Dental Arts Laboratories, Inc., Peoria, Illinois.)

of the investment mold, the mold can be heated to a slightly higher temperature during the wax elimination phase, and metal can be removed from the internal surface of a cast crown through air abrasion, etching, or milling procedures.

Reduction of the Space for the Luting Agent

A number of factors reduce the cement space:

- Reduced thermal and polymerization shrinkage of the impression material (see Chapter 14)
- Use of resin or electroplated dies
- Use of alloys with a higher melting temperature range
- Reduced expansion of the investment

Resin and electroplated dies are slightly smaller than stone dies and therefore result in a smaller casting. As alloys cool over a larger temperature range, the additional shrinkage that takes place also results in a smaller casting. There are multiple ways in which to reduce investment expansion; technique selection, burnout temperature, and water-to-powder ratio are the most convenient (see Chapter 22). If the investment is mixed with an adjusted water-to-powder ratio, which results in less

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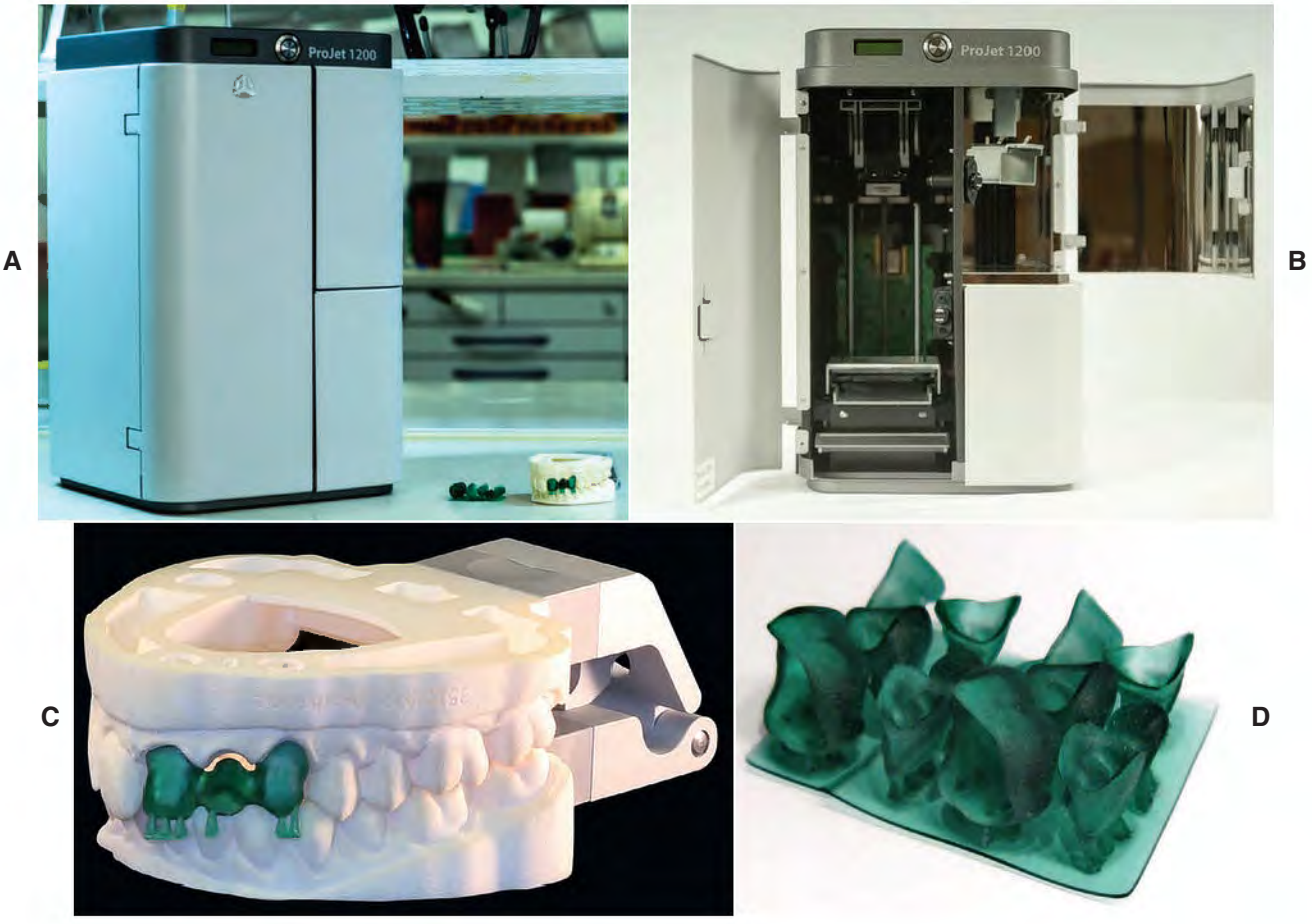

FIGURE 18-3 ■ Printing wax patterns. **A** and **B,** ProJet 1200 3D printer. **C,** Printed pattern for a three-unit metal-ceramic fixed dental prosthesis seated on its corresponding solid cast. **D,** Printed patterns for crowns. Note the supporting struts to maintain positional stability during the printing process. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

FIGURE 18-4 ■ Blocking out undercuts on a die. **A,** Photopolymerizing resin being applied **(A)** and light-polymerized **(B)**. Alternatively, autopolymerizing resin **(C)** can be used. **D,** Autopolymerizing resin being applied. **E,** Monomer spray results in almost instantaneous polymerization.

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setting expansion, the size of the resulting casting is again reduced. When problems routinely surface with castings that are either too loose or too tight, any of the previously mentioned variables may be altered, which leads to more predictable results.

Problems with fitting castings become apparent at two stages of the indirect procedure: when the casting is evaluated on the die and when it is cemented. Recognizing problems at each stage and correcting them before proceeding is crucial. Difficulty with seating the casting on the die is generally caused by *wax distortion*, the presence of *flash* (excess wax that was not removed before the investing and casting procedure) extending cervical to the preparation margin, *improper investment expansion* (underexpansion; Fig. 18-5), or a *casting nodule*. Modification of the investing and casting protocol solves these problems (see Chapter 22). Consistent problems with castings that do not seat completely when evaluated on the prepared tooth may be corrected by a change in just one variable in the protocol. Although many technicians advocate the routine use of die spacer, this is just one of many options to influence the size of the resulting cement space.

Die Spacer

This material (Fig. 18-6) (similar to model airplane paint[9]) is applied to the die to increase the cement space between axial walls of the prepared tooth and the restoration. It is formulated to maintain constant thickness when painted on the die. However, it should not coat the entire preparation. For adequate marginal adaptation, a band of about 1 mm immediately adjacent to the preparation margin must be left unpainted.[10] Thinner is provided to replace the solvent, which tends to evaporate. Use of thickened die spacer can result in an excessive thickness of spacer.

Marking the Margins

The technician's awareness of the precise location of the preparation margin is crucial. By marking it with the side of a colored pencil tip, the technician can pinpoint this location (Fig. 18-7). The color should contrast with that of the wax that will be used (e.g., a red pencil can be used for green wax). An ordinary lead pencil is not recommended because it can abrade the die, its darker color can interfere with efforts to verify that the wax has been properly adapted at the margin, and traces of the graphite (an antiflux) can prevent complete casting of the margins. The marked margins can be coated with low-viscosity cyanoacrylate resin and immediately blown dry. If performed properly, this procedure adds no more than 1 µm to the die.[11] Although removing the excess with acetone is sometimes possible, care must be taken not to create a thick layer of cyanoacrylate, which can result in an unacceptable fit of the definitive cast restoration. For this reason, higher viscosity resins must be avoided.

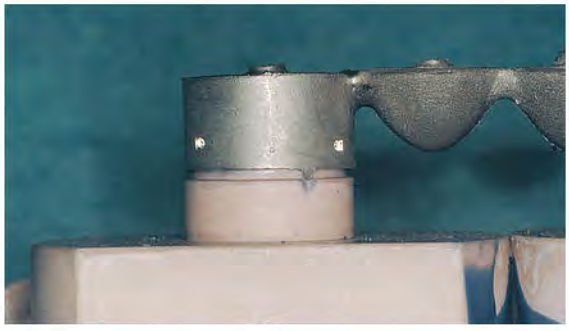

FIGURE 18-5 ■ This experimental near-cylindrical casting failed to seat because of inadequate expansion of the investment, not because of inadequate die spacing.

FIGURE 18-7 ■ Marking the preparation margin. Note that the side of the colored pencil tip is used to keep line width to a minimum.

FIGURE 18-6 ■ Applying die spacer. **A,** The material is available in contrasting colors to facilitate applying the required number of coats. **B,** Care must be taken to keep the material at least 1 mm from the margin.

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MATERIALS SCIENCE

M.H. Reisbick

Inlay casting wax (the name given all wax used in forming the pattern for cast restorations) is actually composed of several waxes. Paraffin is usually the main constituent (40% to 60%). The remaining balance consists of dammar resin (to reduce flaking) plus carnauba, ceresin, candelilla wax (to raise the melting temperature), or beeswax. Sometimes a synthetic wax is substituted for the natural material. Dyes are added to provide color contrasts. Exact formulations are trade secrets, but Coleman[12] published the formula for an experimental compound.

The American National Standards Institute (ANSI) and the American Dental Association (ADA)[13] categorized waxes into two types:

1. Type I: a medium-hardness wax (generally used with the direct technique for making patterns in the oral cavity)
2. Type II: a softer wax (generally used for the indirect fabrication of castings)

Waxes used with direct techniques must not flow appreciably at mouth temperature. Those used with indirect techniques must resist flow at room temperature to maintain their newly shaped forms.

Specifications of the ANSI and ADA govern use of the important properties of residue, flow, and expansion. Because the mold must burn out cleanly to allow the escape of gases and the complete entry of molten alloy, there can be no residual ash. However, the specifications allow a 0.1% residue, which apparently is negligible. Flow requirements, as previously stated, are necessary to control the stability of the wax once it has reached the temperature (37° C [99° F] for type I waxes, 25° C [77° F] for type II waxes) at which it is carved, burnished, and polished. In addition, the wax must flow well at typical forming temperatures. Curves of temperature plotted against percentage flow (Fig. 18-8) are furnished by reputable manufacturers and should be consulted when a casting wax is chosen. All waxes expand and contract when heated and cooled, respectively. Manufacturers' curves of percentage expansion and contraction at various working temperatures (Fig. 18-9) are helpful when methods to use in the investing and casting process are considered. For example, a wax that solidifies at a higher temperature shrinks more and therefore necessitates more compensation to control fit than does a wax that solidifies at a lower temperature (a reason for not interchanging type I and type II waxes within an established technique). These properties can be adversely affected by repeated heating of the wax, which drives off the more volatile components.[14] When waxes are selected for optimal casting accuracy, the use of waxes with different properties for the margin and occlusal portions may be necessary.[15] If a casting is to be accurate, the wax pattern must not become significantly distorted. One reason for distortion is that wax has "memory," which means that it exhibits some elasticity unless it is thoroughly liquefied. To overcome this problem, the initial layer of wax is applied in melted increments or drops. An alternative method is to make the initial coping by dipping the die into thoroughly melted wax.

However, a serious problem arises when the added wax incorporates strain within the pattern as each increment

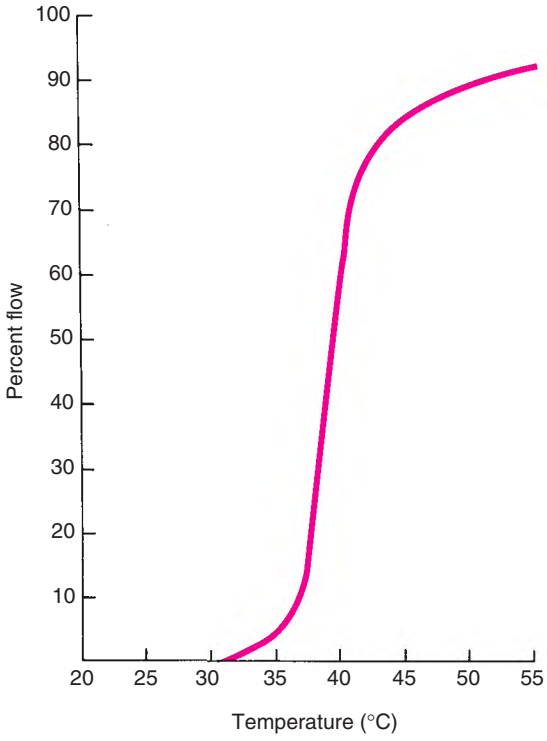

FIGURE 18-8 ■ Wax flow curve.

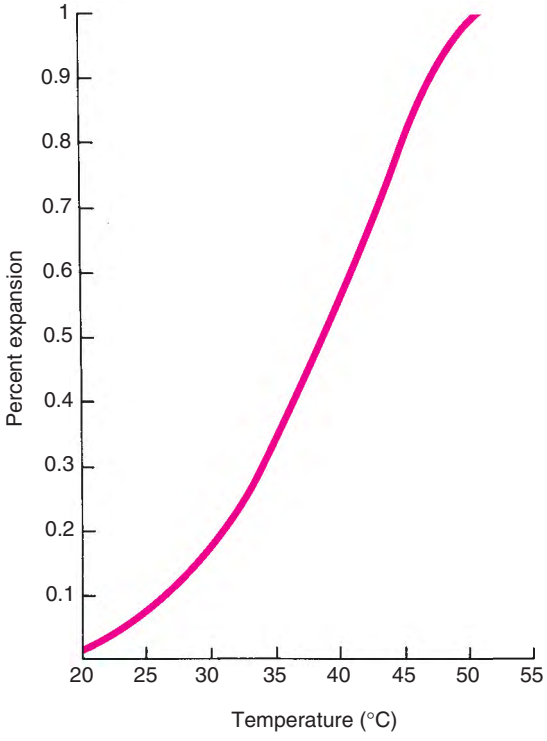

FIGURE 18-9 ■ Wax expansion curve.

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solidifies. This strain tends to be released with time and subsequently distorts the wax pattern. The rate of wax change is temperature dependent, which means that it increases at higher ambient temperatures. Because wax has a relatively high coefficient of thermal expansion and changes dimension subject to air temperature changes, and because the pattern tends to release its incorporated strain, the margins must be remelted, readapted, and resmoothed immediately before investing. The internal fit of the remelted portion is then closer to the prepared surface of the tooth than is the rest of the casting and therefore may help create the necessary space for the luting agent.

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TECHNIQUE

A step-by-step approach to development of optimal form in wax is recommended. The dentist evaluates each step before proceeding to the next, which minimizes extra work. The finished wax patterns should be an accurately shaped anatomic replica of the original teeth that meets all functional dynamic requirements. Information needed to shape the restoration correctly is derived from the contours of the unprepared tooth surface, adjacent tooth surfaces, the opposing occlusal surfaces, and reproduction of mandibular movement in the dental laboratory. The dentist's thorough knowledge of tooth anatomy and the ability to copy three-dimensional structures accurately are needed as well.

When making a drawing or painting, artists constantly refer to the real-life scene they are trying to reproduce. Similarly, when waxing a restoration, the technician should refer to a suitable model (e.g., diagnostic casts, unworn extracted teeth, a contralateral tooth) or casts of unworn natural teeth. It is unwise to copy reproductions of natural teeth (i.e., plastic teeth or casts of restored mouths), no matter how skillfully they have been made. This would be like an artist trying to render a scene from another artist's painting, rather than from real life.

Evaluating a three-dimensional shape correctly is difficult. The finished wax pattern for a tooth may be too bulbous or too flat. Although it appears "wrong," pinpointing and correcting the exact problem are skills achieved only after in-depth study of what constitutes "normal" anatomic form and with the ability to interpret that shape. To evaluate occlusal form, breaking down the complex surfaces into individual components is helpful. When evaluating axial contours, the practitioner should assess a series of two-dimensional outlines by rotating the wax pattern. These outlines can easily be compared with an appropriate model, and any aberrations can be corrected. It is helpful to recognize that the human eye excels at interpreting even very small differences in height and width of objects (two dimensions) but is not as adept at interpreting similarly subtle differences in depth. Therefore, the practitioner must systematically look at cross sections through the pattern and evaluate its silhouette (Fig. 18-10). Rotation of the pattern and repeating this process from all angles of observation speed up this intricate process.

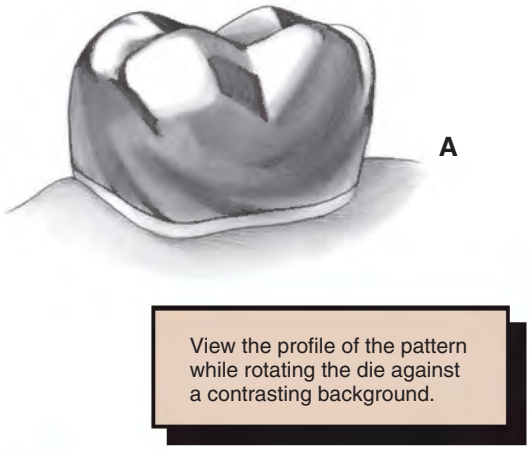

FIGURE 18-10 ■ **A,** Incorrect midfacial contour is difficult to determine from a direct view of a three-dimensional object. **B,** It is more easily seen *(dashed red line)* by sequential evaluation of the profile of the pattern as it is rotated.

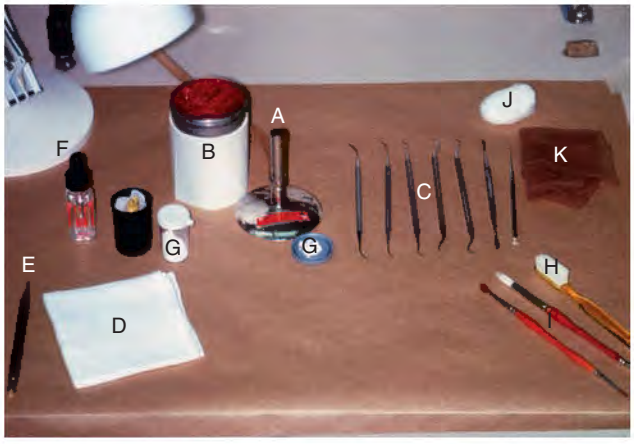

FIGURE 18-11 ■ Waxing armamentarium: Bunsen burner *(A);* inlay wax *(B);* waxing instruments *(C);* cotton cleaning cloth *(D);* sharp colored pencil *(E);* separating liquid *(F);* occlusal indicator powder *(G);* soft toothbrush *(H);* double-sided brushes *(I);* cotton balls *(J);* and fine nylon hose *(K).*

Armamentarium

The following equipment is needed (Fig. 18-11):

- Bunsen burner
- Inlay wax
- Waxing instruments
- Cotton cleaning cloth
- Sharp colored pencil (in color that contrasts with wax)

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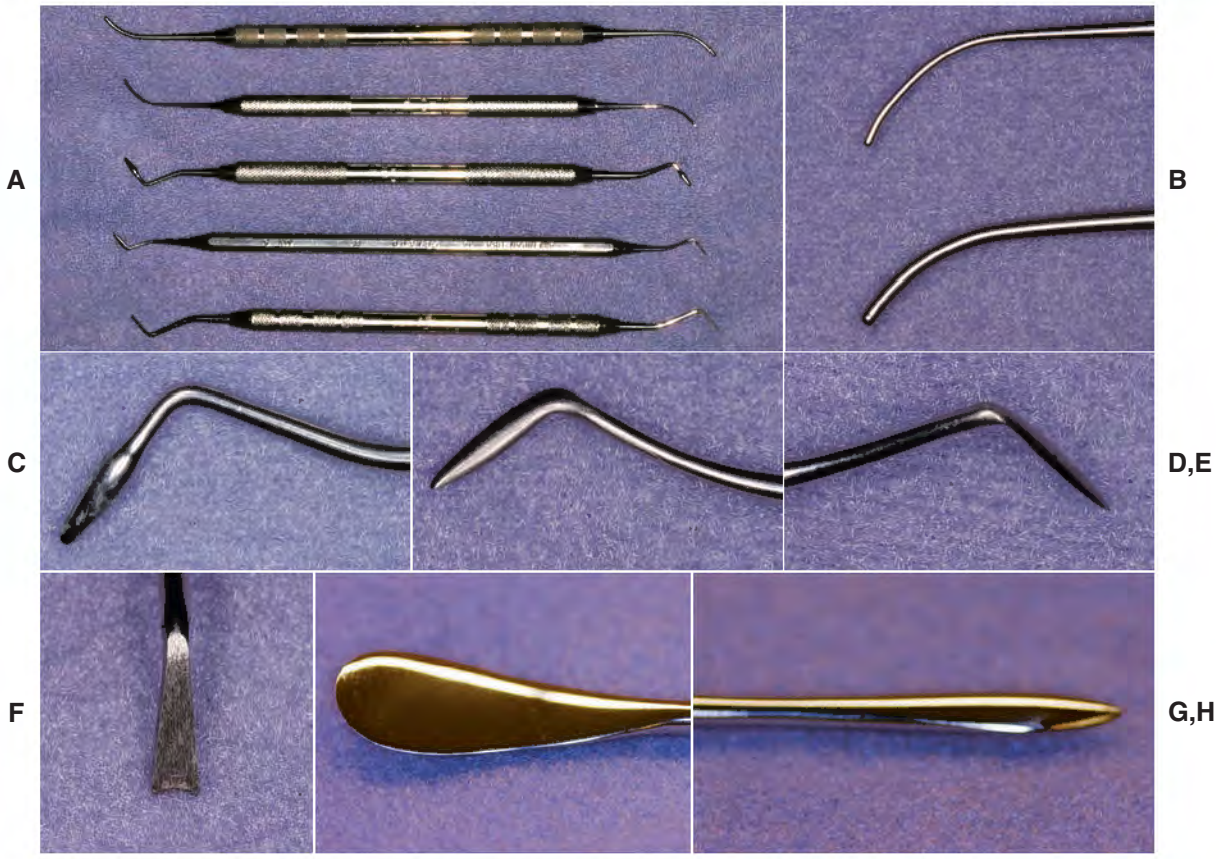

FIGURE 18-12 ■ Waxing instruments. **A,** Top to bottom: PKT Nos. 1 to 5 instruments. **B,** Top to bottom: PKT Nos. 1 and 2 wax addition instruments. **C,** PKT No. 3 burnisher. **D** and **E,** PKT No. 4 wax carver. **F,** PKT No. 5 wax carver instrument. **G** and **H,** PKT No. 7 waxing spatula.

- Separating liquid
- Occlusal indicator powder: zinc stearate or powdered wax (note: Zinc stearate may present a health hazard if inhaled; powdered wax is a safer alternative)
- Soft toothbrush
- Double-sided brushes (soft/rigid)
- Cotton balls
- Fine nylon hose

Waxing Instruments

Waxing instruments can be categorized by the intent of their design: wax addition, carving, or burnishing. Of the popular PKT instruments (Fig. 18-12) (designed by Dr. Peter K. Thomas specifically for the additive waxing technique), No. 1 and No. 2 are wax addition instruments, No. 3 is a burnisher for refining occlusal anatomy, and Nos. 4 and 5 are wax carvers.

Wax is added by heating the shank of the instrument in the Bunsen flame, touching it to the wax, and quickly reheating its shank in the flame. Wax flows away from the hottest part of the instrument, so that if the shank is heated, a bead of wax flows off the tip (Fig. 18-13). However, if the tip is heated, the wax flows up the shank of the instrument (to the considerable annoyance of inexperienced operators). The PKT No. 1 instrument is used

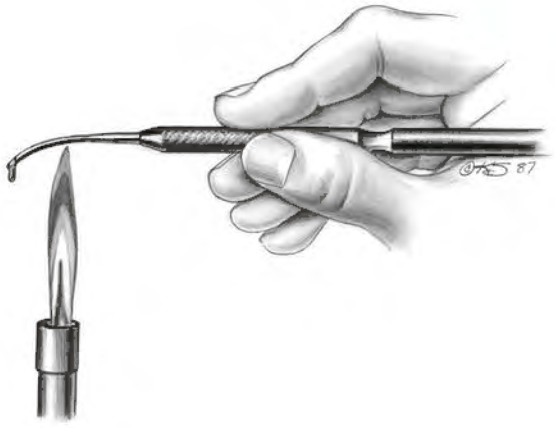

FIGURE 18-13 ■ The practitioner must always heat the shank of the instrument so that wax flows off its tip.

for large increments; the smaller No. 2 is used for lesser additions. A No. 7 or 7A waxing spatula (see Fig. 18-12, *G* and *H*) is useful for adding large amounts of wax, particularly in forming the initial coping (the thimble-like layer of wax that covers all prepared surfaces). Some technicians prefer electric waxing instruments (Fig. 18-14) because they enable precise control of the wax temperature, which is important for proper manipulation. Another advantage is that they minimize carbon

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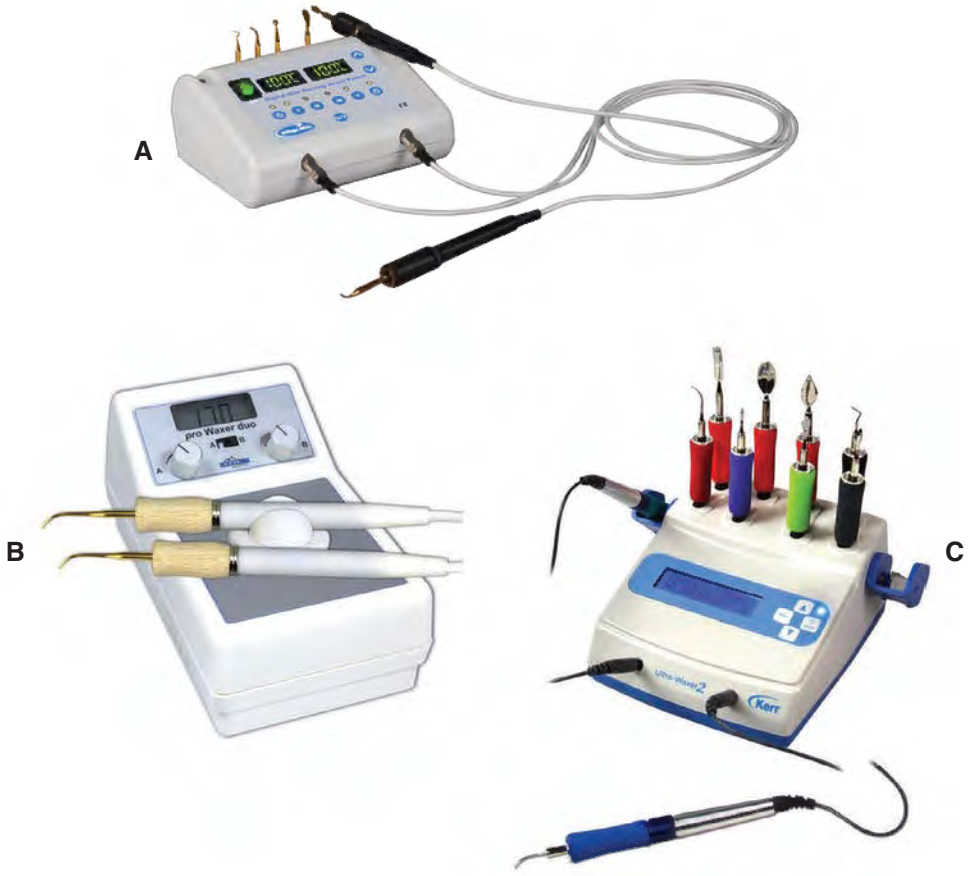

FIGURE 18-14 ■ Electric waxing instruments. **A,** Dual Digital Wax Carving Touch Pencils. **B,** Pro Waxer Duo. **C,** Ultra-Waxer 2. (**A,** Courtesy Whip Mix Corporation, Louisville, Kentucky. **B,** Courtesy Keystone Industries, Gibbstown, New Jersey. **C,** Courtesy Kerr Corporation, Orange, California.)

buildup, which easily results from overheating a waxing instrument in a Bunsen flame. However, because the instrument remains hot, it is not possible to draw solidifying wax in the required direction.

Wax carvers should be kept sharp and should never be heated. In addition to the PKT instruments, the Nos. ½ and 3 Hollenback and the No. 2 Ward carvers (Fig. 18-15) are popular. When wax is carved, light pressure should be used to obtain the desired smooth surface.

Burnishing is an alternative to carving for obtaining a smooth wax pattern of the desired contour. Burnishing entails slightly warming a blunt instrument and rubbing the wax. The instrument should not be so hot that it melts the wax surface. The PKT No. 3 instrument is useful for burnishing the occlusal surfaces. The PKT Nos. 1 and 2 instruments can be used for burnishing, as well as for wax addition. Another popular burnisher, the PFI Land trimmer (Fig. 18-16; available on special order from Hu-Friedy Mfg. Co., Chicago), is based on the DPT6 Darby Perry trimmer.

For excess wax removal, burnishing is less effective than carving, but it is probably easier to control. It leaves a smoother surface, which can be particularly important when excess wax is trimmed near the margin. Careless (excessive) carving in this area can lead to

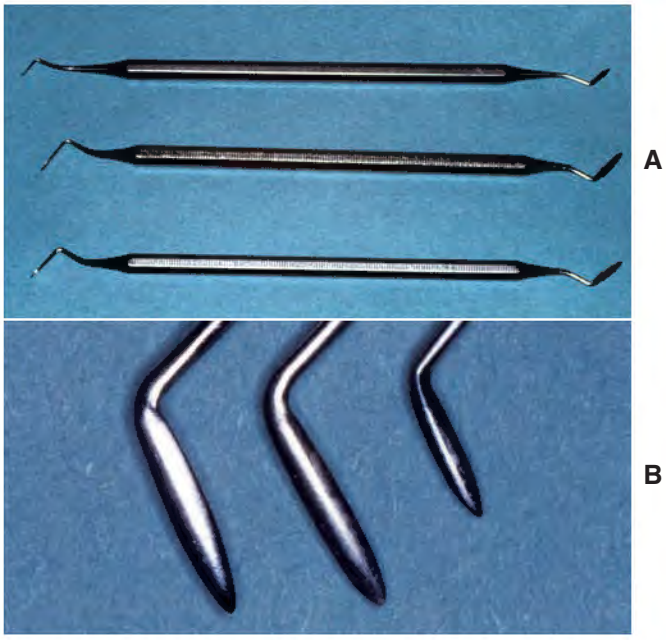

FIGURE 18-15 ■ Wax carvers. **A,** Top to bottom, No. 2 Ward and Nos. ½ and 3 Hollenback. **B,** Left to right, closer view of the tips of these three instruments.

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abrasion of the die, which results in a ledge at the margin of the finished casting.

Waxing Posterior Teeth

The following sequence is recommended for waxing posterior teeth:

1. Internal surface
2. Wax pattern removal and evaluation
3. Proximal surfaces
4. Axial surfaces
5. Occlusal surfaces
6. Margin finishing

Internal Surface

Forming a closely adapted internal surface is the first step in waxing. The wax *must* reproduce all retention features of the restoration.

Step-by-Step Procedure

1. Apply die lubricant generously with a clean brush (Fig. 18-17, *A*). Allow the lubricant to dry, and paint on a second coat (repeat periodically as needed). Waxing should not begin until the lubricant has been allowed to soak in completely. (On dies that have been coated with cyanoacrylate resin, lubricant must be reapplied more frequently.)
2. If pinholes have been prepared, fit in plastic pins that match the bur used to prepare the hole. Seat the pins in the die, and use a heated PTK No. 7 instrument to flatten their tops to provide retention in the wax (see Fig. 18-17, *B*).

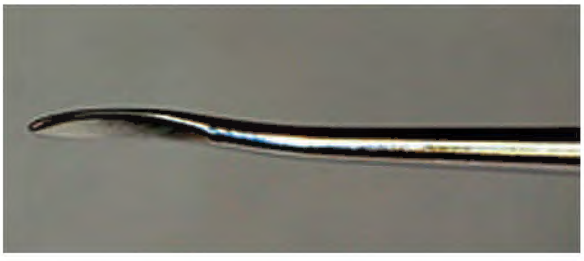

FIGURE 18-16 ■ PFI Land trimmer (wax burnisher), available from Hu-Friedy, Chicago.

3. Flow wax onto the die from a well-heated, large waxing instrument (Fig. 18-18, *A*), making sure that any previous application is partially remelted. A large instrument holds sufficient heat to partially remelt previous wax increments and to prevent folds or lines from developing in the fitting surface. Waxing is easier if the instruments are kept clean and only the shank is heated.
4. When applying the initial layer, be sure that the wax is fully molten. If it is not, wax solidity may cause distortion. Very hot wax flows rapidly over the die. Use cooler instruments for subsequent waxing of external anatomic details, which allows small additions to be placed accurately. Dipping the lubricated die in a pot of melted wax is another method for making well-adapted internal surfaces (Fig. 18-19). This method works well for complete-coverage restorations.
5. Add sufficient wax with a large instrument to allow the coping to be handled without deformation or breakage (see Fig. 18-18, *B*). A large instrument keeps the wax hot more effectively than does a small instrument.
6. Give the proximal areas extra bulk for strength and to help grip the coping and prevent its distortion on removal from the die. The wax should cool between applications. At this point, no attempt should be made to contour the axial walls.
7. Trim the wax back to the margin (see Fig. 18-18, *C*) so that the coping can be removed and evaluated. Excess bulk can be removed safely with a carving instrument. When only a thin excess layer remains, trimming is performed most safely with a burnisher. Careless use of a sharp carver at this stage may scratch the fragile margin of the die or chip it. Therefore, a slightly warmed blunt instrument should be used and the margins rubbed with a burnishing action. A carver can be used, but meticulous technique and great care are required.

Wax Pattern Removal

The wax should be allowed to cool thoroughly before the coping is removed from the die (Figs. 18-19 and 18-20). To remove the coping, the thumb and forefinger of one hand maintain a constant light grip on the pattern while

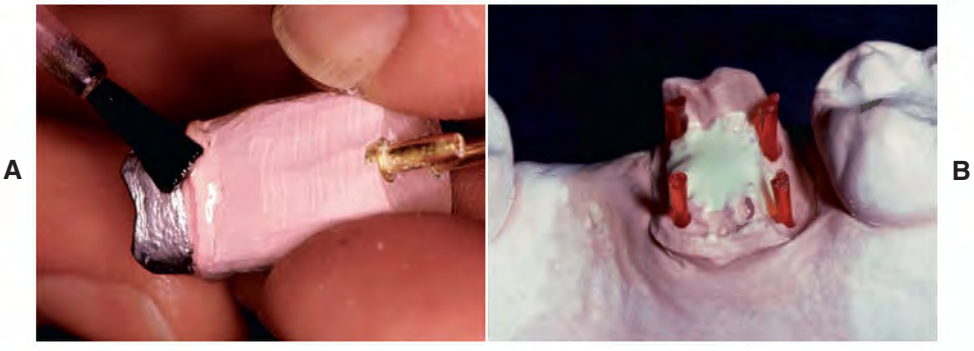

FIGURE 18-17 ■ Starting the waxing procedure. **A,** Lubricating the die. **B,** Adapting plastic pins.

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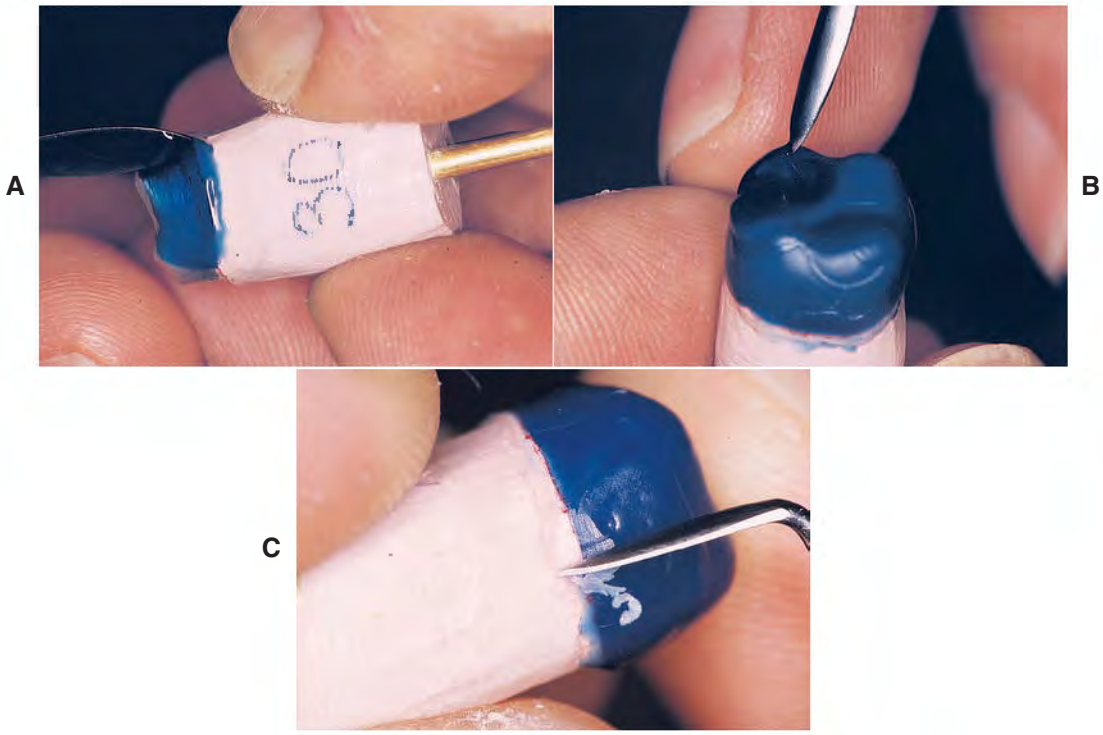

FIGURE 18-18 ■ Forming the initial copings. **A,** A large instrument is used to keep the wax sufficiently hot. Previous applications should be remelted as additional wax is added. **B,** Wax is added to build up adequate bulk for rigidity. **C,** The wax is trimmed very carefully to the margin.

FIGURE 18-19 ■ Wax dipping pot. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

pressure is applied against them with the thumb and forefinger of the other hand, which also holds the die (see Fig. 18-20, *B*). A small square of washed rubber dam increases friction between the fingers and the pattern. If the pattern fails to move, excess wax may be present beyond the margin, locking the pattern in place.

Evaluation. The objective of the first waxing step is a perfectly adapted reproduction of the prepared tooth surfaces. Identifying defects may take some practice. The examiner rotates the pattern under a bright light and looks for shadows formed by folds or creases (Fig. 18-21). A binocular microscope or a high-quality magnifying loupe is helpful not only for this step but also throughout the laboratory phase. Ten-power magnification is practical and helpful. Using higher power interferes with maintaining orientation.

Proximal Surfaces

The proximal surfaces of natural teeth are not convex (Fig. 18-22). They tend to be flat or slightly concave from the contact area to the cementoenamel junction, and any restoration must reproduce this feature. Overcontouring often makes maintaining periodontal health difficult, particularly if drifting of teeth has increased root proximity.[16] Excessively concave or undercontoured proximal surfaces also make flossing ineffective and must be avoided.[17]

Contact Areas. The size and location of the contact areas should be established before the remaining proximal surfaces are waxed. Reference is made to contacts between the contralateral teeth and knowledge of anatomic form.

Abnormally large proximal contact areas make plaque control more difficult, which can lead to periodontal disease. Very small (point) contacts may be unstable and cause drifting. Deficient contacts can also lead to food impaction; although this is not a direct cause of chronic periodontal disease, it can be very uncomfortable and painful for the patient.

Most posterior contact areas (Fig. 18-23) are located in the occlusal third of the crown. However, the maxillary first and second molars make contact in the middle

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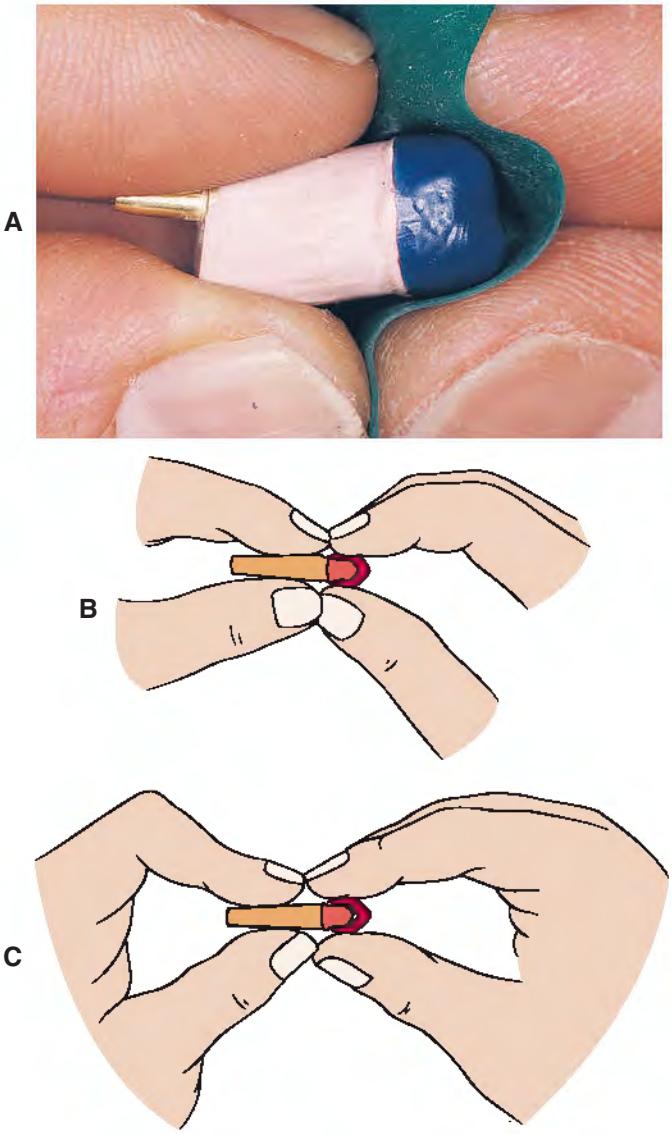

FIGURE 18-20 ■ Wax pattern removal. **A,** A sheet of washed rubber dam increases friction and aids removal. **B,** The fingers of the left hand hold the die. The right hand holds the pattern. **C,** To pull the die from the pattern, the fingers of the left hand squeeze the die.

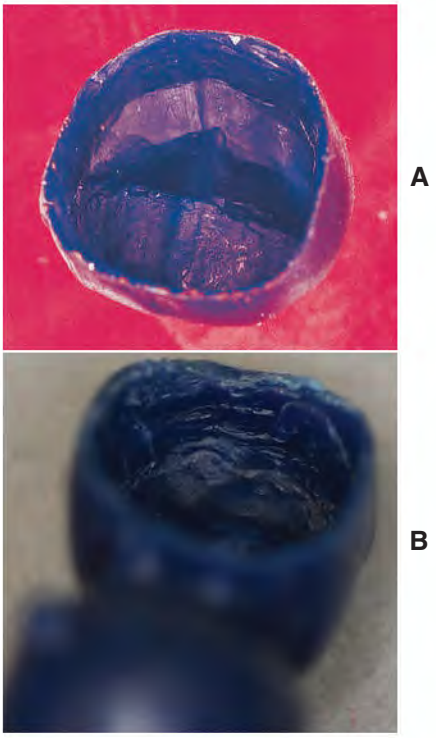

FIGURE 18-21 ■ Evaluation. **A,** Well-adapted pattern. **B,** Poor adaptation. Folds and creases indicate that the wax was not hot enough when applied.

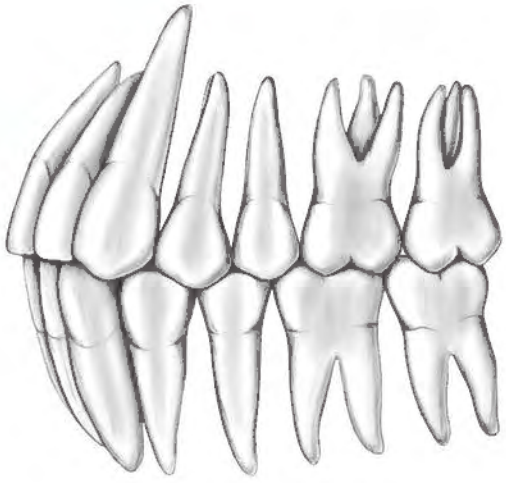

FIGURE 18-22 ■ Proximal surfaces gingival to the contact area are normally flat or concave. Note the triangular shape of the posterior embrasures.

third.[18] The contact areas between mandibular teeth and maxillary molars are generally central. Between maxillary premolars and molars, the contact areas are usually toward the buccal surface (which makes the lingual embrasure larger than the buccal). Under no circumstances should a proximal contact area in the restoration be concave. If overlooked during waxing or rendering, concavities must be recontoured in the finished restoration.

Step-by-Step Procedure

1. Replace the wax coping on the lubricated definitive cast or removable die. When a removable die system is used, care must be taken to ensure that the locating pin or pins and stone surfaces are absolutely free of excess wax or other debris that could prevent complete seating of the die (Fig. 18-24). To ensure that proximal contacts are not deficient, relieve the adjacent proximal surface slightly by scraping.
2. Adjust the coping as necessary to be completely clear of the opposing occlusal surfaces. The structure will be developed with the wax additive technique later.
3. Add wax to the contact areas until they are the correct size, properly located, and consistent with anatomic form (Fig. 18-25).

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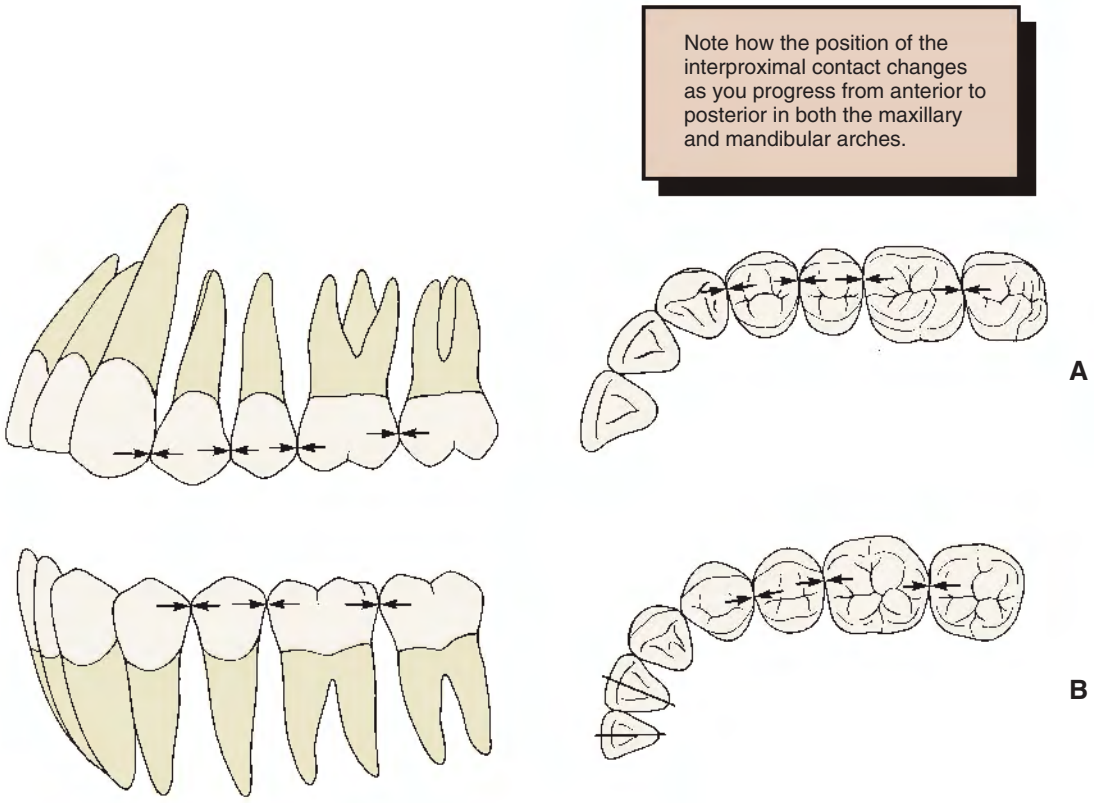

FIGURE 18-23 ■ Location of the proximal contact areas. **A,** On maxillary teeth: progressively more occlusal and buccal the more anterior the tooth. **B,** On mandibular posterior teeth: central.

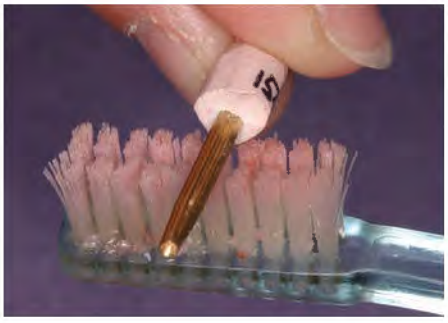

FIGURE 18-24 ■ Wax chips that accumulate on the dowel pin or in the sleeve prevent a die from seating. Periodic cleaning with a brush is recommended.

4. When this has been accomplished, shape the proximal surfaces gingival to the contacts to the correct contour. A properly trimmed die is of great assistance in accomplishing this. The unprepared tooth structure that was reproduced in the "cuff" of the impression now serves as an effective guide to orienting the waxing instruments properly.

Evaluation. The location of the contact area is checked once again. Where multiple restorations are being made, the proximal embrasure is shaped symmetrically to provide adequate room for the free gingival tissues of adjacent teeth (Fig. 18-26). The proximal

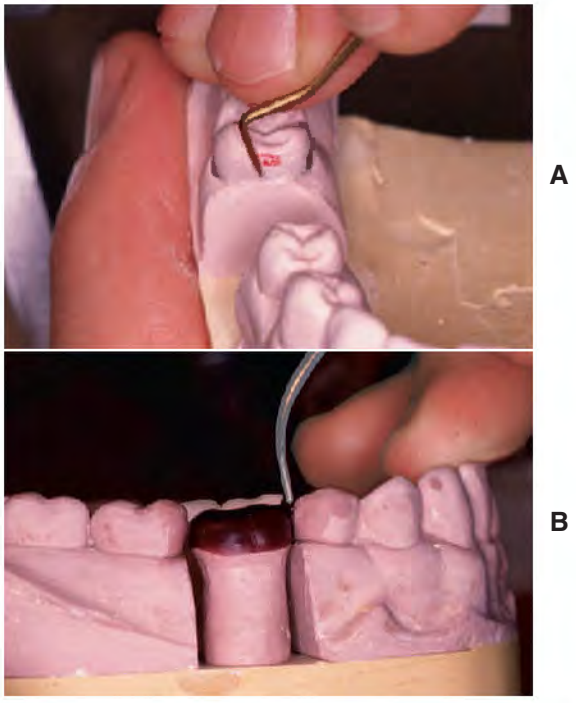

FIGURE 18-25 ■ **A,** To ensure that proximal contacts are not deficient, a slight amount of stone is scraped from the adjacent tooth before waxing. **B,** Wax is added to the contact area to establish a correctly located proximal contact.

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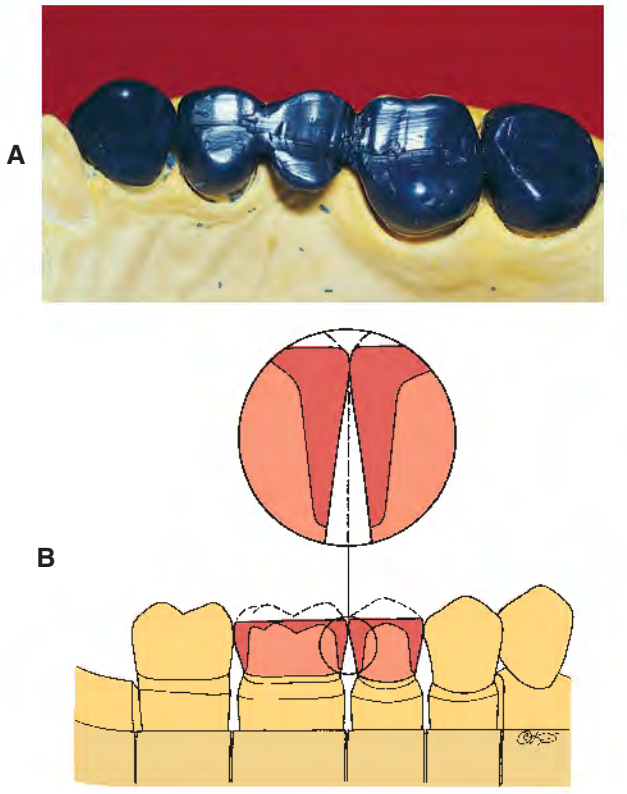

FIGURE 18-26 ■ **A,** From the occlusal view, proper buccal and lingual embrasure form have been established. **B,** The contact areas should be shaped so that the gingival embrasures are symmetric.

surfaces should be flat or slightly concave and should be shaped to eliminate any directional change between the root surface and the finished restoration. The cervical contour of the restoration should be continuous, with the contour of the unprepared tooth structure immediately cervical to the preparation margin.

Axial Surfaces

The buccal and lingual surfaces should be shaped to follow the contours of the adjacent teeth. The location of the height of contour (or, alternatively, the survey line for retainers for removable dental prostheses) is particularly important. It is generally located in the gingival third of most teeth, although on mandibular molars it is usually in the middle third of the lingual surface.

Restorations are often made too bulky. Natural teeth are rarely more than 1 mm wider at their height of contour than at the cementoenamel junction. This width should not be exaggerated when a tooth is re-created in wax. The tooth surface gingival to its height of contour immediately adjacent to the gingival soft tissues, sometimes called the *emergence profile*,[19] is usually flat or concave. Creation of a convexity in this area or a shelf or ledge[20] makes bacterial plaque removal more difficult and has been shown to cause inflammatory and hyperplastic changes in the marginal gingiva. Before dental plaque was identified as the direct etiologic agent in periodontal disease,[21] an excessive axial contour was considered necessary to keep food from entering the gingival sulci.[22] However, no evidence supports this concept. Indeed, artificially reduced axial contours (as when a prepared tooth is left unprotected for an extended period)[23] are associated with healthy gingival tissue. Overcontoured axial surfaces result if axial reduction during tooth preparation has been insufficient. Special care is needed where bone loss has occurred as a result of periodontal disease, particularly when this has caused exposure of the root near the furcation. The axial contour should then be modified to improve access for plaque removal (Fig. 18-27).

Step-by-Step Procedure

Axial Contours

1. Establish the location, position, and overall outline of the contour, using the adjacent and contralateral teeth as a guide.
2. Wax the axial surfaces gingivally to form a smooth, flat profile. There should be no change of direction from unprepared tooth structure to the axial restoration contour.
3. Shape the middle third of the axial surface, using the adjacent tooth as a guide (Fig. 18-28, *A*).
4. Add wax to join the axial and proximal surfaces, and smooth them, paying particular attention to the location and shape of the mesial and distal transitional line angles. A Boley gauge may prove helpful (see Fig. 18-28, *B*). The line angles should correspond to those on the contralateral teeth if those are intact.

Evaluation. The examiner should evaluate the shape of the tooth at its greatest convexity by looking at the wax pattern and comparing its shape with that of the contralateral tooth. Each part of the outline should be carefully scrutinized. An outline that is too square or too round is modified. The buccal and lingual contours and the embrasures should all be assessed. Initially, assessing individual components rather than the entire contour or outline is helpful. The practitioner should try to relate the shape under evaluation to a "neutral" reference point, such as the midsagittal plane in viewing from the occlusal surface. With more experience, the practitioner will find it easier to review multiple forms simultaneously.

Each contact area has four embrasures: gingival, buccal, lingual, and occlusal. All but the occlusal will have been completed by this stage. The embrasures are normally symmetric about a line drawn through the contact area (Fig. 18-29).

Occlusal Surfaces

The cusps and ridges of the occlusal surfaces should be shaped to allow even contact with the opposing teeth while the teeth are stabilized and forces are directed along their long axes (see Chapter 4). Nonfunctional cusps (buccal cusps of the maxillary teeth, lingual cusps of the mandibular teeth) should overlap vertically and horizontally, preventing accidental biting of the cheek or tongue and keeping food on the occlusal surface.

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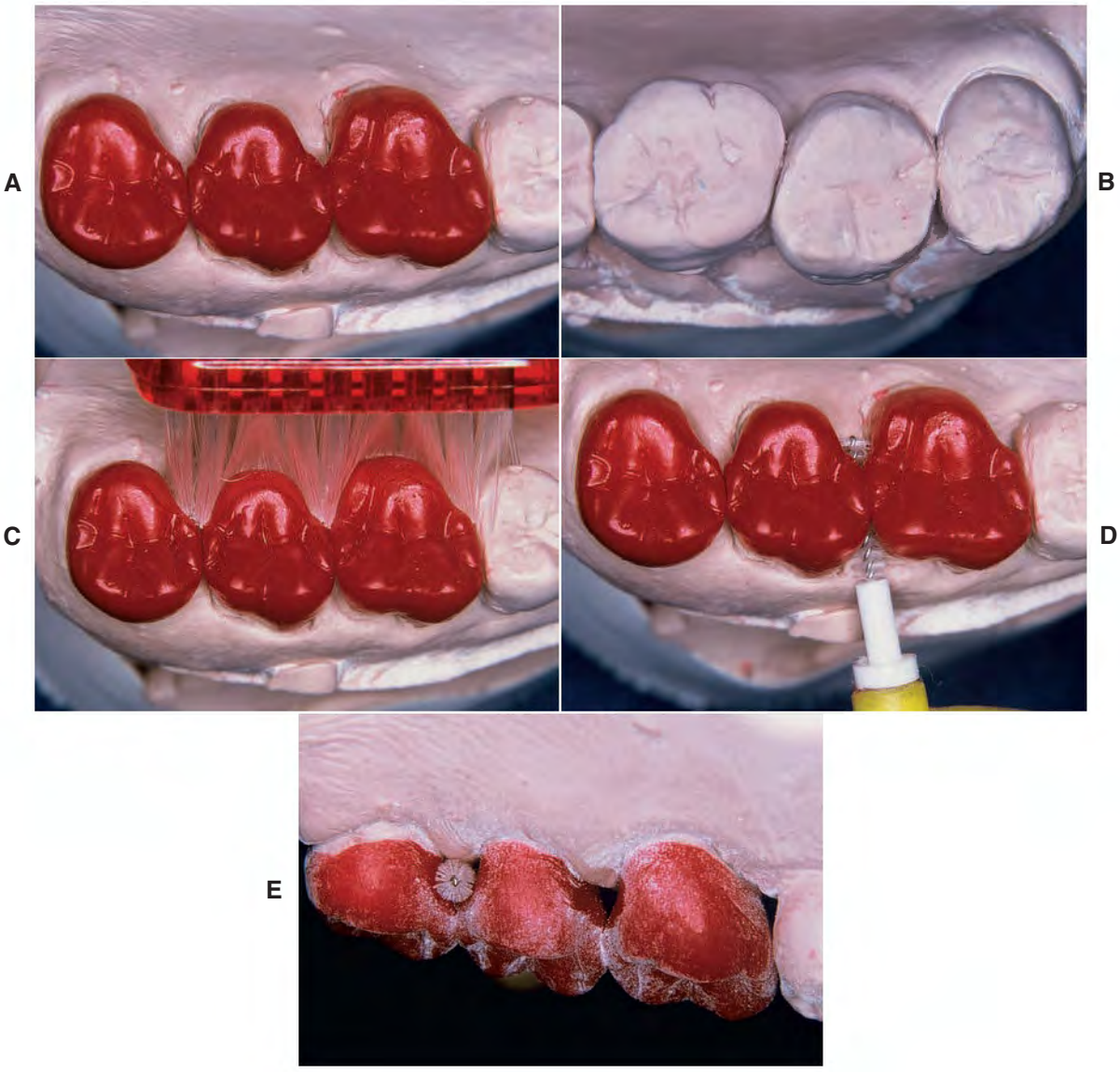

FIGURE 18-27 ■ As the cervical margin is placed near root furcations, the axial contour is modified to improve access for plaque control in patients with extensive bone loss. **A,** Modified wax patterns for a periodontally compromised patient. Note the change in the outline form of the occlusal tables. **B,** The contralateral teeth have normal axial contour. **C** to **E,** Modified contour allows better access for oral hygiene.

Point contacts between opposing teeth are preferable to broad, flat occlusal contacts because wear of the restorations is minimized and mastication of tough or fibrous foods is improved. The occlusal surfaces of natural teeth consist of a series of convexities with developmental grooves where the convex ridges meet. The opposing cusps should travel through pathways paralleling these grooves without tooth contact in excursive jaw movements. The occlusal surfaces can be precisely developed with a wax addition technique similar to the one devised by Payne[24] that is used in many schools to teach occlusal structure and function[25-27](Figs. 18-30 and 18-31).

Occlusal Scheme. Two occlusal schemes are generally recognized and should be understood when the restorations are planned: cusp–marginal ridge and cusp-fossa (see Chapter 4). In the cusp–marginal ridge scheme, the buccal cusps of the mandibular premolars and the mesiobuccal cusps of the mandibular molars contact the embrasures between the maxillary teeth (i.e., they each contact two teeth). In the cusp-fossa scheme, these mandibular functional cusps contact farther distally into the fossa of the maxillary tooth and contact only one tooth (Tables 18-1 and 18-2). The lingual functional cusps of the maxillary teeth contact the fossae of the mandibular teeth in both schemes.

Most adults with an Angle class I occlusion and unworn teeth have a cusp–marginal ridge scheme. In natural dentitions, the cusp-fossa arrangement is found only when a slight Angle class II malocclusion is present. However,

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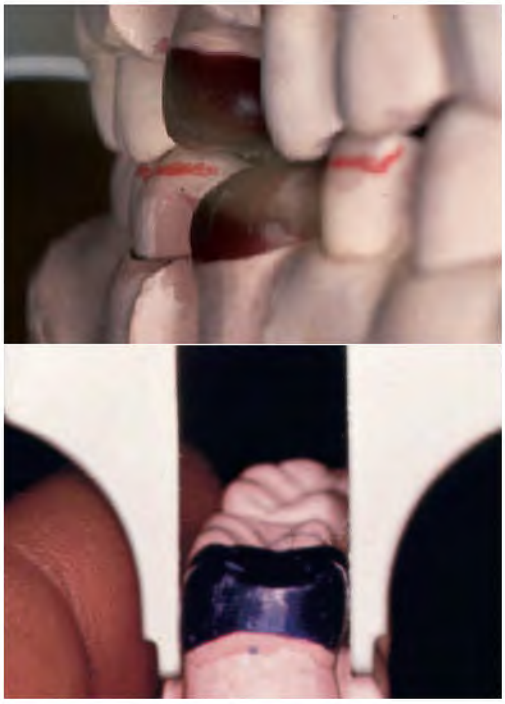

FIGURE 18-28 ■ **A,** Waxing axial contours. **B,** Evaluating the buccolingual dimension with a Boley gauge. This instrument is also helpful in assessing axial shape and height of contour.

Establishing the correct embrasure form is essential. Only when proper anatomic form is obtained can the patient maintain plaque control.

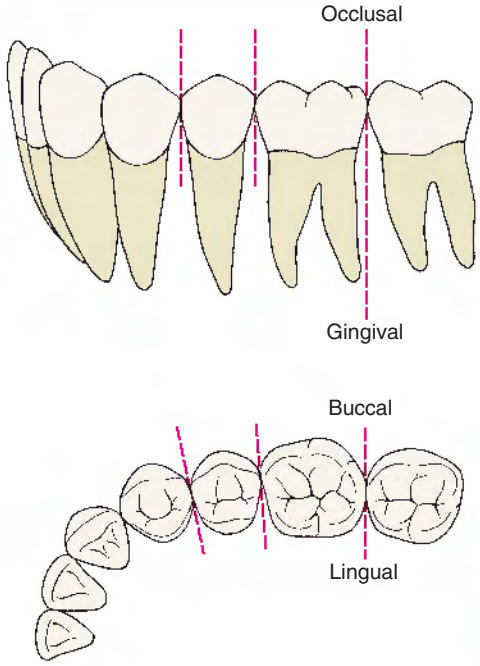

FIGURE 18-29 ■ Symmetry of embrasures.

for the following reasons, the cusp-fossa arrangement has been recommended over the cusp–marginal ridge when occlusal reconstruction is undertaken:

- Food impaction is prevented.
- Centric relation closure forces are nearer the long axes of the teeth.
- Improved stability results from the tripod contacts for each functional cusp.

When the mesiodistal relationships of opposing teeth favor it, the cusp-fossa scheme is optimal. If these relationships are not present, the choice is between (1) distorting coronal axial form to accommodate the preferred occlusal scheme and (2) altering the occlusal structure to accommodate normal axial form. Significant deviation from normal axial form by overcontouring invariably results in periodontal disease. Altering axial form by undercontouring rarely causes such problems. Depending on the specific spatial relationship between the antagonists, the cusp–marginal ridge scheme may be a better choice in such situations. However, the decision is not always a clear one. Tooth size and position variations among patients produce a continuum between the optimal cusp–marginal ridge and cusp-fossa schemes. Common sense dictates using the scheme that produces the best overall functional and esthetic result. In many cases, this can be determined only by trial and error. The placement of cones before any other occlusal waxing is often the most expedient way to accomplish this.

Cusp Height and Location

1. Determine the position and height of the cusps with wax cones (Fig. 18-32). This is done so that necessary modifications can be made rapidly. Add wax cones for each cusp, and mark the central fossae of opposing teeth to help position the cusps correctly.
2. Position the centric or functional cusps (mandibular buccal and maxillary lingual) so that they occlude along the buccolingual center of the opposing tooth. The actual cusp tips do not contact the opposing tooth. Greater stability and reduced wear are possible with small points of contact distributed around the cusp tips.
3. Use the mesiodistal location of the cones to determine the type of occlusal scheme to be attempted: cusp–marginal ridge or cusp-fossa (Fig. 18-33; see also Fig. 18-30, *H* to *K*, and Tables 18-1 and 18-2).

Evaluation. The cones should be positioned so that they follow the anteroposterior curve (sometimes referred to as the *curve of Spee;* Fig. 18-34). This is the anatomic curve established by the occlusal alignment of the teeth, as projected onto the median plane, beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of the premolar and molar teeth, continuing through the anterior border of the mandibular ramus, ending with the most anterior portion of the mandibular condyle. The mandibular cusps should become

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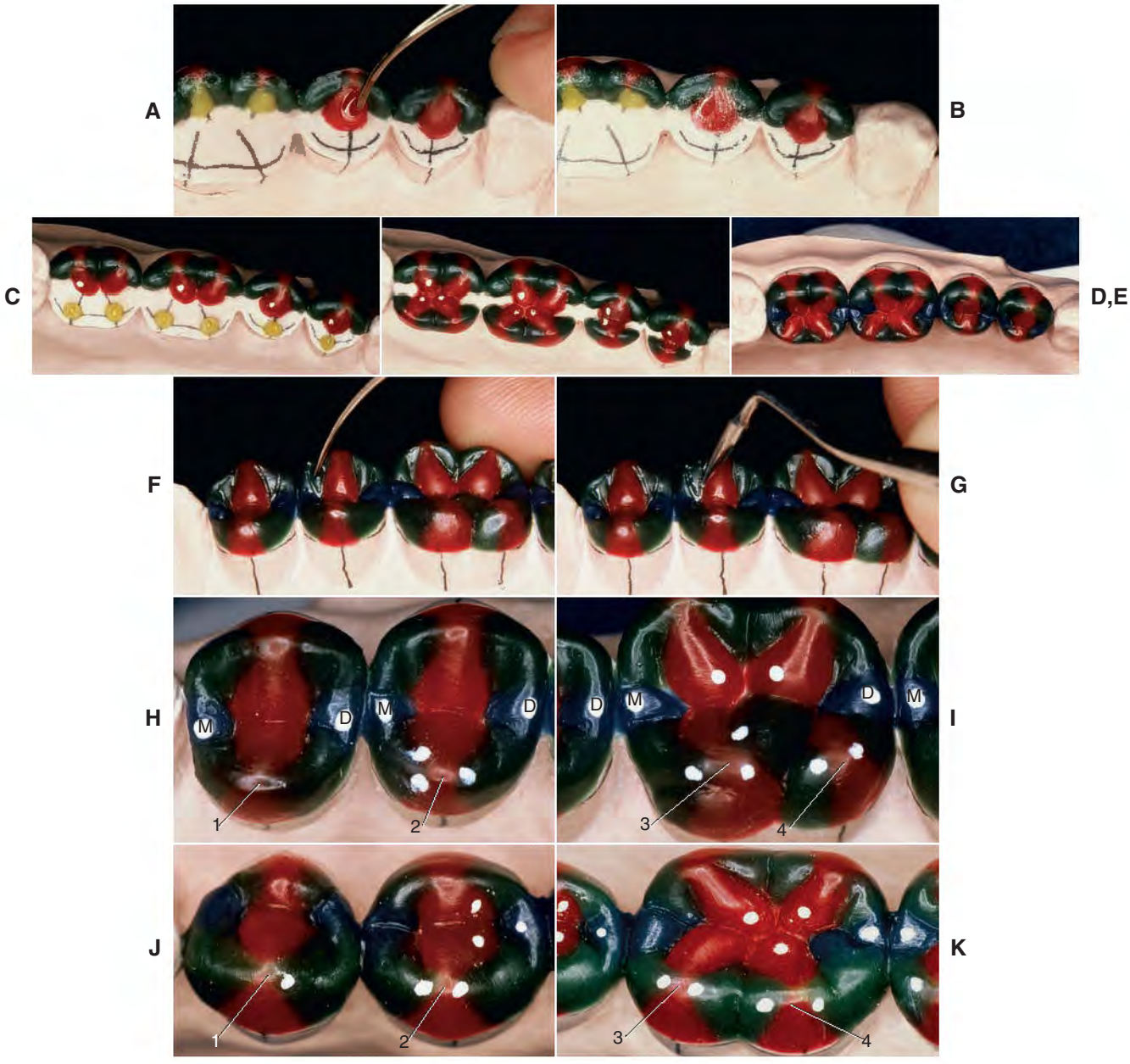

FIGURE 18-30 ■ Occlusal waxing with the sequential wax addition technique. **A,** To develop accurate occlusal contacts, wax is added in small increments, and the articulator is closed while the added wax is still soft. **B,** Powder is used to verify the location and size of the contact. **C,** Cones are used to determine the location of the lingual cusp tips. **D** and **E,** The various features of the occlusal surface are developed sequentially in wax. **F** and **G,** Secondary occlusal features can be refined by reflowing the wax and burnishing the fissures. **H** to **K,** Completed waxing with occlusal contacts marked. (For the cusp–marginal ridge scheme, numbers refer to cusp position in Table 18-1.)

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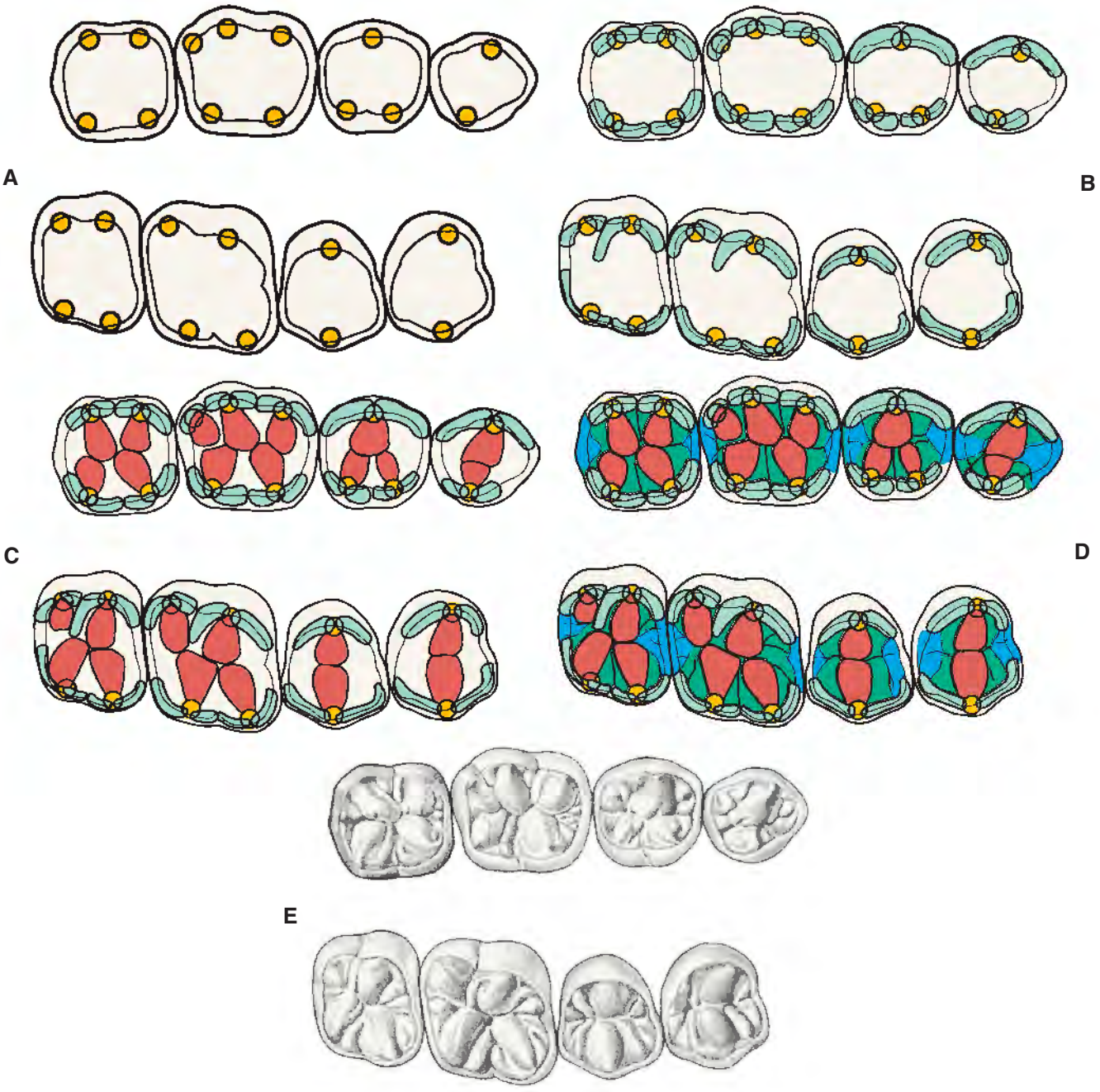

FIGURE 18-31 ■ Sequence of occlusal wax addition. **A,** Step 1: placement of cones. **B,** Step 2: superimposition of cuspal ridges. **C,** Step 3: placement of cones, cuspal ridges, and triangular ridges. **D,** Step 4: placement of cones, cuspal ridges, triangular ridges, and secondary and marginal ridges. **E,** Step 5: finished occlusal waxing.

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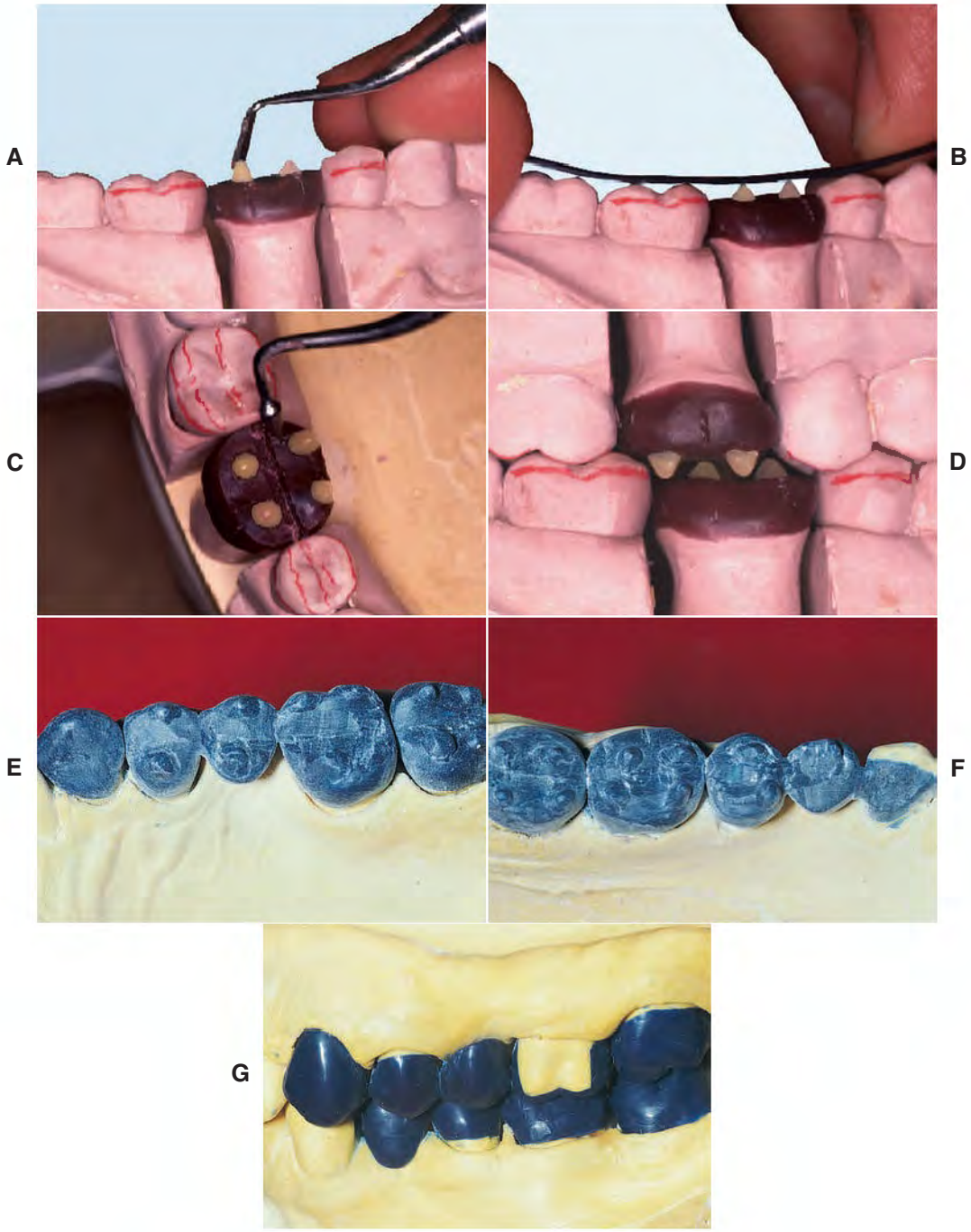

FIGURE 18-32 ■ **A,** Adding wax cones to determine cusp height and location. **B,** The cusp's height is determined by the anteroposterior curve (curve of Spee). **C,** Marking the central fossae of opposing teeth helps position the functional cusps correctly. **D,** All cones are positioned and tested for interferences in all excursions. **E** to **G,** The wax additive technique is especially useful when multiple restorations are provided simultaneously.

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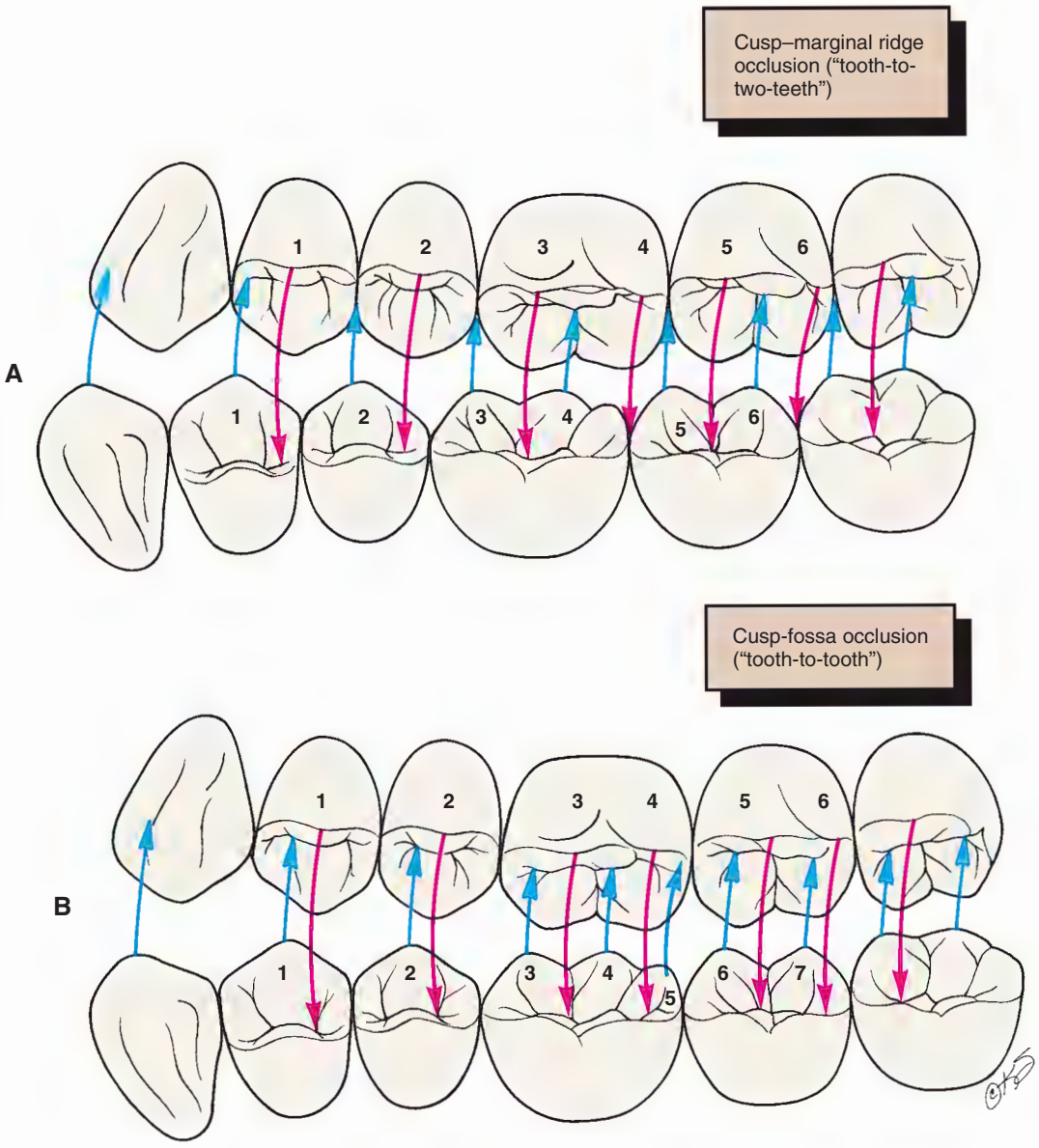

FIGURE 18-33 ■ **A,** Cusp–marginal ridge occlusion ("tooth-to-two-teeth"). **B,** Cusp-fossa occlusion ("tooth-to-tooth"). The numbers refer to those in Tables 18-1 and 18-2.

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TABLE 18-1 Features of Cusp–Marginal Ridge Scheme: Functional Cusp Articulation*

Tooth	Cusp Position	Functional Cusp	Opposing Fossa	Opposing Marginal Ridge (Same Tooth unless Otherwise Specified)
Maxilla				
First premolar	1	L	D	—
Second premolar	2	L	D	—
First molar	3	ML	C	—
	4	DL	—	D and M (second molar)
Second molar	5	ML	C	—
	6	DL	—	D
Mandible				
First premolar	1	B	—	M
Second premolar	2	B	—	D and M (first premolar)
First molar	3	MB	—	D and M (second premolar)
	4	DB	C	—
Second molar	5	MB	—	D and M (first molar)
	6	DB	C	—

B, Buccal; *C,* central; *D,* distal; *DB,* distobuccal; *DL,* distolingual; *M,* mesial; *MB,* mesiobuccal; *ML,* mesiolingual.
*See Figure 18-33, *A*.

TABLE 18-2 Cusp-Fossa Scheme: Functional Cusp Articulation*

Tooth	Cusp Position	Centric Cusp	Opposing Marginal Ridge (Same Tooth unless Otherwise Specified)
Maxilla			
First premolar	1	L	D
Second premolar	2	L	D
First molar	3	ML	C
	4	DL	D
Second molar	5	ML	C
	6	DL	D
Mandible			
First premolar	1	B	M
Second premolar	2	B	M
First molar	3	MB	M
	4	DB	C
	5	D	D
Second molar	6	MB	M
	7	DB	C

Courtesy Dr. A.G. Gegauff.
B, Buccal; *C,* central; *D,* distal; *DB,* distobuccal; *DL,* distolingual; *M,* mesial; *MB,* mesiobuccal; *ML,* mesiolingual.
*See Figure 18-33, *B*.

The most critical step in waxing occlusal surfaces is the correct placement of the cusp tips. Use the information provided by adjacent and opposing teeth to determine the optimal position for each cone.

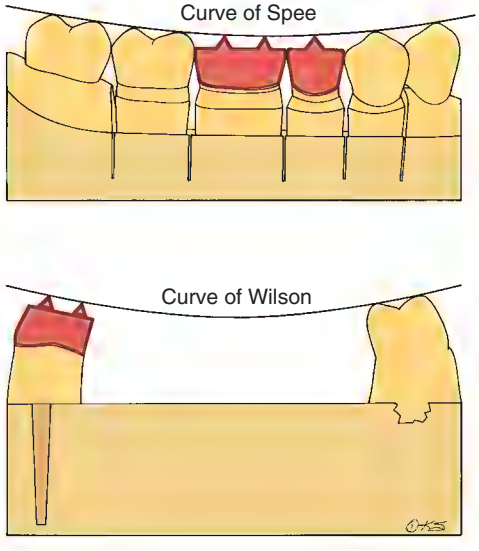

FIGURE 18-34 ■ Cones should follow the anteroposterior curve (curve of Spee) and the mediolateral curve (curve of Wilson).

taller farther distally, and the maxillary cusps should become shorter. The cusps should also follow a mediolateral curve (sometimes referred to as the *curve of Wilson*). In the mandibular arch, this is the curve (viewed in the frontal plane) that is concave above and contacts the buccal and lingual cusp tips of the mandibular molars; in the maxillary arch, it is the curve (viewed in the frontal plane) that is convex below and contacts the buccal and lingual cusp tips of the maxillary molars. When viewed from the front, the nonfunctional cusps are slightly shorter than the centric cusps. All eccentric movements should be reproduced on the articulator; if unwanted contact results in protrusive, working, and nonworking excursions, they should be eliminated by either reduction

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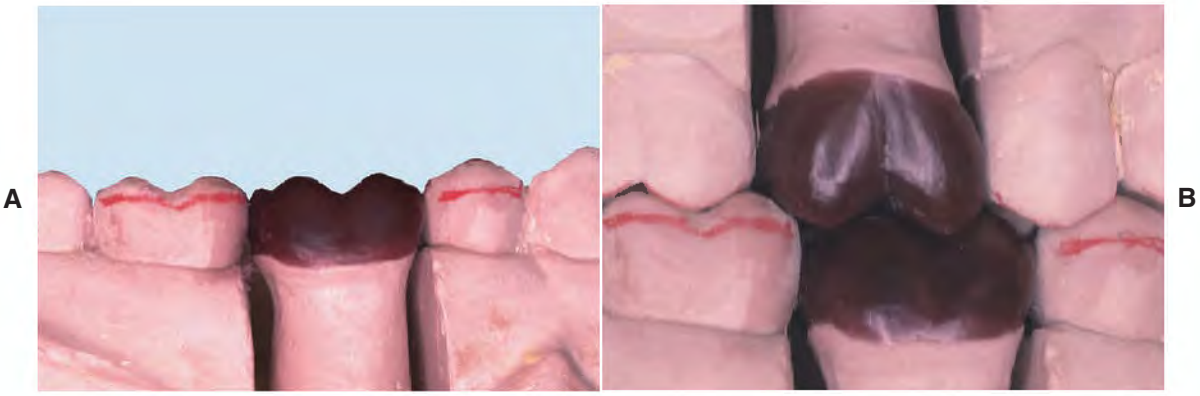

FIGURE 18-35 ■ Completed axial contours. **A,** The maxillary buccal cusp ridges. **B,** At this stage, the buccal surface is complete and should be evaluated for correct contour.

FIGURE 18-36 ■ Waxing maxillary triangular ridges.

FIGURE 18-37 ■ Evaluating occlusal contacts.

or repositioning of the cones. Proper cone height and position are key to the development of proper occlusal form.

Completion of Axial Contours

4. Complete the axial contours (marginal ridges and cuspal ridges; Fig. 18-35). Be especially careful not to alter the location or height of the cusps as previously determined with the cones.
5. After each addition of wax, check for occlusal contact by closing the articulator. Do not increase the occlusal vertical dimension.

Evaluation. At this stage, the buccal, mesial, lingual, and distal surfaces have been completed (see Fig. 18-35). When viewed from these perspectives, the wax pattern should appear identical to an intact tooth. When viewed from the buccal perspective, each cusp should have a distinct profile, with the cusp tip highest and a gentle slope down to the marginal ridges. Adjacent marginal ridges should be of the same height. Occlusal contacts in excursive movements must also be evaluated. If there is unwanted contact, grooves can be created in the cuspal ridges to allow the passage of opposing cusps.

Triangular Ridges

6. Give each cusp a triangular ridge (Fig. 18-36; see also Fig. 18-30, *A*) that runs toward the center of the occlusal surface. The apex (or point) of the triangle should be at the cusp tip, and the base should be in the center of the occlusal surface.
7. Make the bases of the buccal and lingual triangular ridges convex mesiodistally and buccolingually.
8. As each ridge is added, close the articulator. Where the occlusal surface meets an opposing tooth, note the small depression and adjust this to form a convex surface so that pinpoint contact exists.

Evaluation. The triangular ridges are dusted with zinc stearate or powdered wax (Fig. 18-37; see also Fig. 18-30, *B*). The cusps should still have their correct sharp contour and should not be rounded by improper polishing.

Secondary Ridges

9. Make two secondary or supplemental ridges adjacent to each triangular ridge (Fig. 18-38; see also Fig. 18-30, *F*). All cusps should have a single triangular ridge and two secondary ridges. The degree of specific delineation between the triangular and secondary ridges varies, depending on the prominence of the cusp within the occlusal surface of the tooth that is being waxed.
10. Make the secondary ridges convex with grooves where they meet the convexities of the triangular

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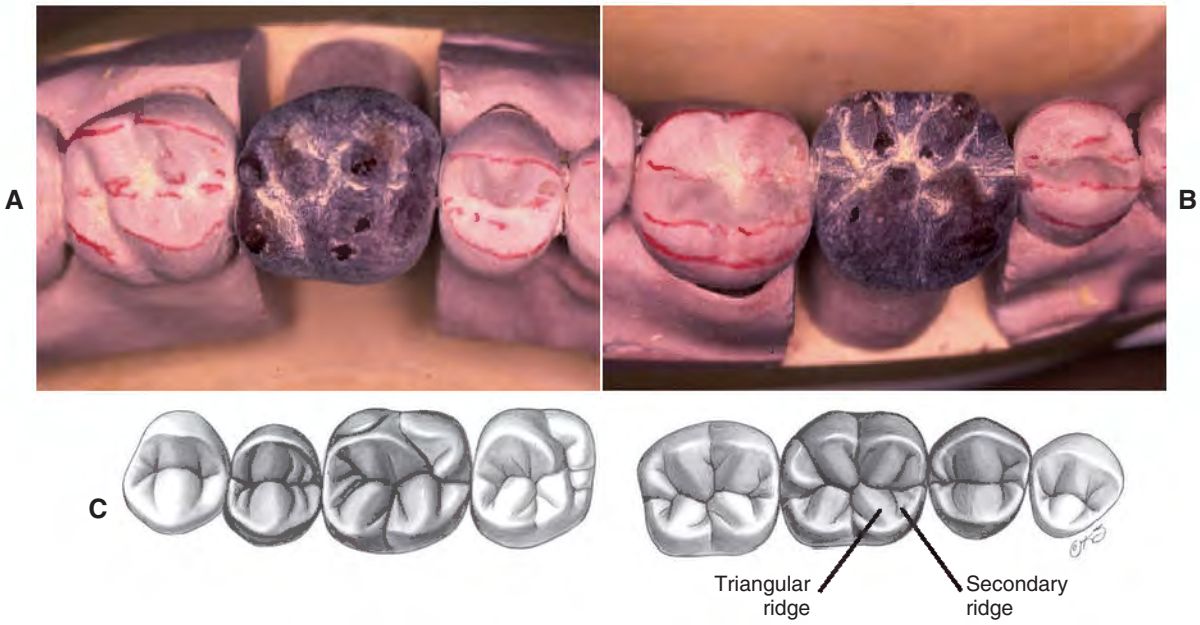

FIGURE 18-38 ■ Adding secondary ridges.

FIGURE 18-39 ■ Evaluating the completed wax patterns.

ridges. The most mesial and most distal secondary ridges are often contiguous with the marginal ridges.

Evaluation. If the ridges have been carefully formed, only a small amount of finishing is needed at this stage (Figs. 18-39 and 18-40). Any pits can be filled with wax and the grooves carefully smoothed (see Fig. 18-30, *G*). Initially, obtaining smooth transitions between the occlusal components may be difficult. Smoothing from the grooves onto the individual occlusal features, rather than back and forth, prevents unnecessary accumulations of wax residue in the grooves.

The occlusal surfaces are redusted with zinc stearate or powdered wax, and the occlusal contacts are checked. If a contact has inadvertently been polished away, it can be quickly re-formed by the addition of a drop of wax, closing of the articulator to verify that contact was restored, and subsequent reflowing and reshaping of the occlusal feature to reestablish a convex contour.

Margin Finishing

To optimize the adaptation of the wax pattern (and the cast restoration) to the die, the margins must be reflowed

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FIGURE 18-40 ■ Completed cusp–marginal ridge waxing. **A** and **B,** The occlusal contacts have been marked.

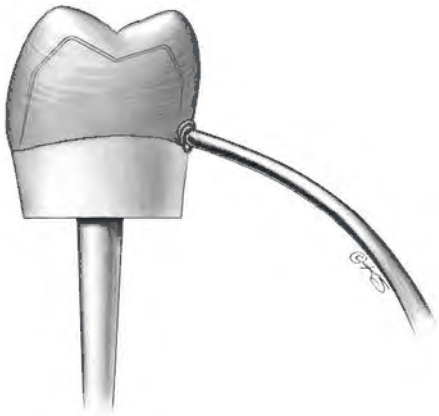

FIGURE 18-41 ■ Reflowing the margins. The objective is to create a well-adapted, 1-mm zone to prevent cement dissolution.

and refinished immediately before the wax pattern is invested. The two principal objectives are (1) minimizing dissolution of the luting agent and (2) facilitating plaque control.

If a zone of superior adaptation (i.e., minimum marginal gap width) between the casting and the prepared tooth surface is created, cement dissolution is reduced[28] and the exposure of the rough cement surface is minimized. To obtain this superior adaptation, the pattern should be reflowed over a band approximately 1 mm wide, measured from the margin onto the prepared surface (Fig. 18-41).

Plaque control is facilitated when the transition from cast restoration to tooth is smooth, without any sudden directional change. In addition, the axial surface of the restoration must be highly polished (see Chapter 28). Because the use of any metal polishing compound or abrasive material results in removal of restoration material, metal finishing procedures should be kept to a minimum near the margin. The best way to prepare for this step is to ensure superior smoothness of the wax pattern when the reflowing process is complete. This should be verified under magnification with loupes or a binocular microscope.

Step-by-Step Procedure

1. Relubricate the die and reseat the wax pattern (Fig. 18-42, *A*). Because of the time and attention devoted to developing occlusal and axial form, the margins of the pattern are not properly adapted at this stage. Use a large, well-heated waxing instrument to melt completely through the wax.
2. Push the heated instrument through the pattern, and completely remelt the marginal 1 to 2 mm (see Fig. 18-41).
3. Draw the instrument along the margin until resistance is felt because the instrument has begun to cool and no longer easily melts the wax.
4. Reheat the instrument and repeat the procedure, always overlapping with the previously melted area to remelt it and to preclude internal folds, voids, and defects. When the entire margin has been reflowed circumferentially, a depression is seen around the margin as a result of the readaptation.
5. Fill the depression with additional wax (see Fig. 18-42, *B*).
6. Trim excess wax from beyond the margin (see Fig. 18-42, *C*).
7. Rectify any pits or defects in the axial surfaces, and smooth the wax pattern. Wax chips can be removed from the occlusal surface with a cotton pellet; however, the surface should not be rubbed. Otherwise, the occlusal contacts that were so carefully generated will be destroyed.

The wax pattern is removed from the die without distortion and may be re-placed for final evaluation before investing. However, if the pattern is not repositioned in exactly the same direction as that in which it was removed, reburnishing of the margins may be necessary.

Evaluation. Being thorough at this stage will contribute to the success of the restoration. Because of the wax pattern's color and glossy surface, small defects can be difficult to identify. If they are not noticed, a later remake may be necessary.

Overwaxing must be avoided. Very little finishing of a cast metal margin is possible without damaging the die. Any flash of wax that extends beyond the finish line *must* be trimmed at this stage; otherwise, it will cause distortion as the pattern is removed, or it will prevent the cast metal restoration from completely seating. A gap between the wax and the die, resulting in an open margin, can be difficult to detect. The die should be oriented so that the observer's line of sight is precisely along the wax-die interface. If the wax is not well adapted, a black shadow line will be visible. This is hard to see in wax but easier to see (but too late) in metal. A binocular microscope or

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FIGURE 18-42 ■ Reflowing margins. **A,** After waxing, a marginal discrepancy is normally apparent *(arrow).* This must be corrected before investment. **B,** A large, well-heated instrument is used to melt completely through the wax. *Then* the practitioner continues around the preparation margin and adds wax to fill the depression. **C,** When the pattern has cooled, the marginal excess is carefully trimmed or burnished.

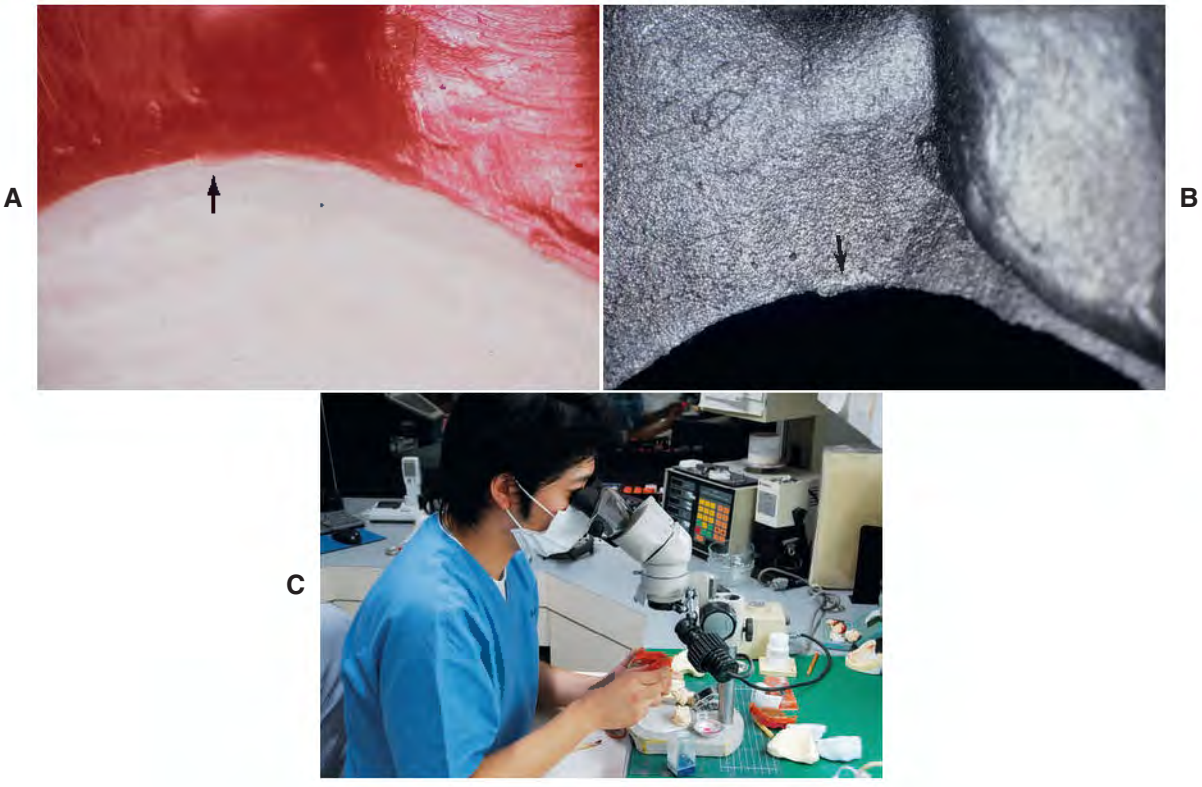

FIGURE 18-43 ■ Evaluation. Defects must be identified and corrected before investment. **A,** Marginal excess or flash *(arrow)* is difficult to see in wax but must be carefully removed. **B,** A small defect *(arrow)* is easier to see in the metal but harder to correct. **C,** Magnification is the most practical way to finish margins properly.

loupe is very helpful for detecting this line (Fig. 18-43). To ensure that new debris has not accumulated during the finishing procedures, a final evaluation of the occlusal and axial surfaces is performed. The pattern is now ready for investing (see Chapter 22).

Waxing Inlays and Onlays

The sequence of steps for fabricating a wax pattern for an inlay or onlay is similar to that for a complete crown, although the unprepared tooth can often serve as a guide to axial and occlusal contour (Fig. 18-44). Sometimes manipulation of a small inlay can be difficult. One approach is to embed a loop of floss into the pattern for easier removal.

Waxing Anterior Teeth

The approach to waxing anterior teeth is slightly different from the approach to waxing posterior teeth. Anatomic contour waxing is recommended for metal-ceramic restorations because there is better control over the thickness of porcelain and the smoothness of the metal-ceramic junction. When several anterior teeth are to be restored, a guide to the lingual and labial contours is essential (Fig. 18-45). The contour of the palatal and

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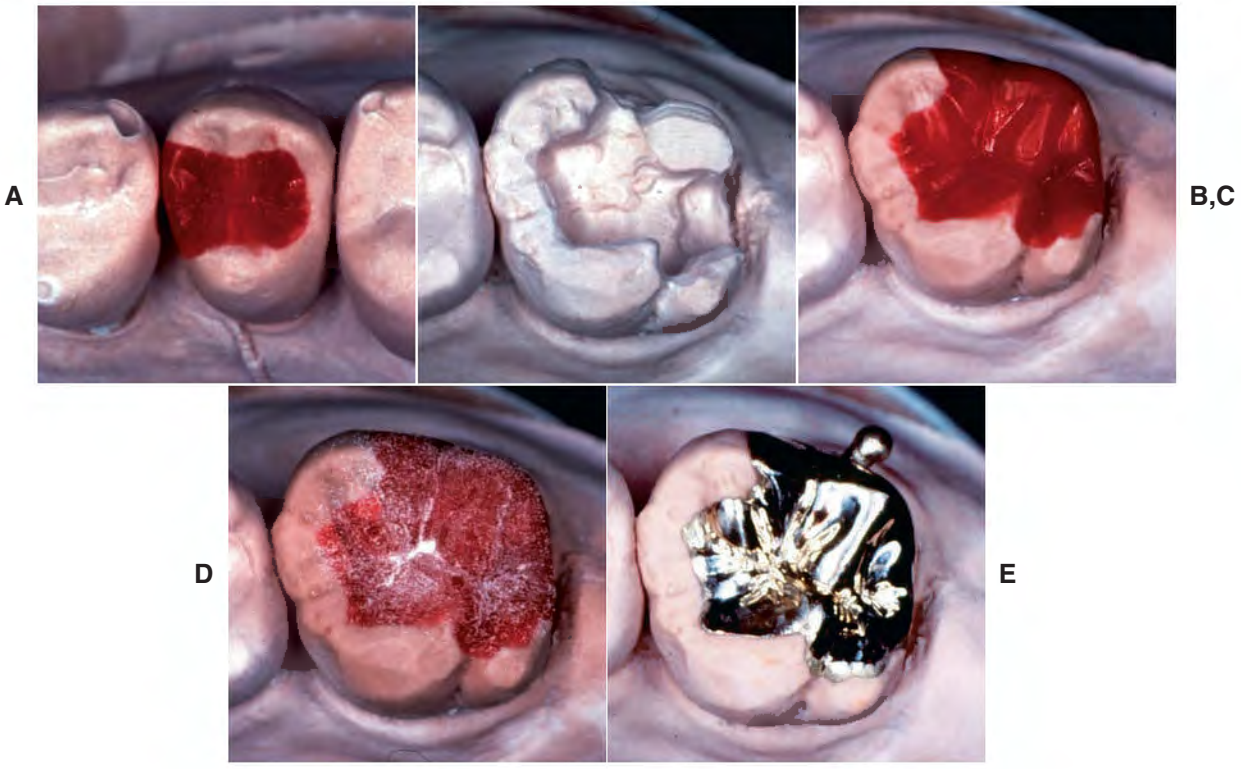

FIGURE 18-44 ■ Waxing inlay and onlay restorations. **A,** Mesio-occlusal inlay wax pattern. **B** to **E,** Disto-occlusal–distobuccal onlay wax pattern and casting.

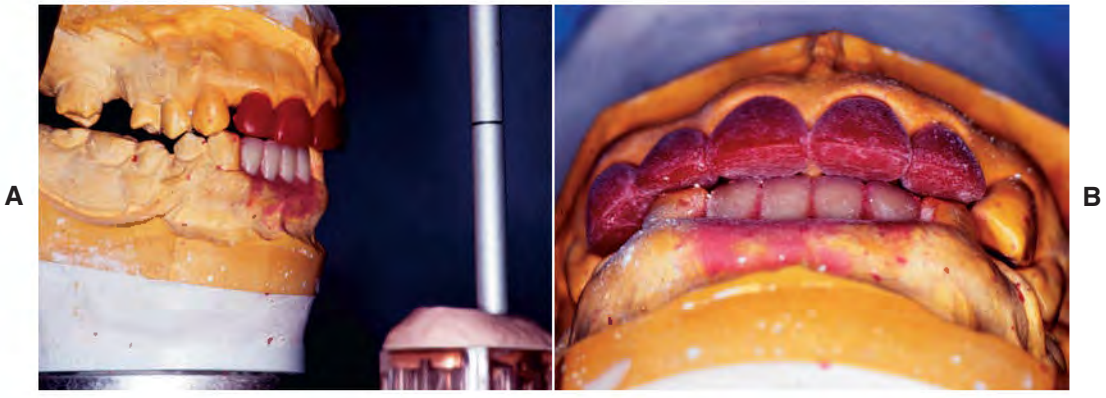

FIGURE 18-45 ■ **A** and **B,** Optimum contours for anterior restorations are developed with the aid of a custom anterior guide table (see Fig. 19-4).

incisal surfaces significantly influences the articulation. They are most effectively re-created with the use of a custom anterior guide table (see Chapter 2). This can be made from diagnostic casts (if their initial form was satisfactory) or from a diagnostic waxing or cast made from an impression of interim restorations. The latter can be used when the interim restorations resulted in clinically satisfactory function and appearance. The shape of the anterior teeth affects the patient's speech, lip support, and appearance. Those characteristics should be determined carefully and with as many diagnostic aids as necessary.

Lingual and Incisal Surfaces

The position of the incisal edges is determined by the overall arch form of the anterior teeth and the functional occlusal requirements (Fig. 18-46). As with waxing of posterior occlusal surfaces, cones can be used to initially delineate the approximate position of the incisal edge. Additional wax can then be applied as necessary.

Opposing incisors should contact evenly during protrusive movements but not during lateral excursions. To achieve this result, a concavity is made in the lingual surface of maxillary incisors. The ability to make this concavity smooth is very important. As a result, the patient acquires a smooth protrusive movement, and potential neuromuscular disturbances are avoided. In maximum intercuspation, anterior teeth ideally should be just out of contact. Mylar shim stock should just "drag" between the patterns. The lingual surfaces of mandibular incisors and canines are noncontacting

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FIGURE 18-46 ■ When the lingual surface of an anterior tooth is waxed, the contralateral tooth should be used as a guide.

surfaces. Nevertheless, they should be shaped for easy plaque control. They should not be overcontoured.

Labial Surfaces

The shape of the labial surfaces, particularly the locations of the mesiolabial and distolabial line angles, determines the appearance of anterior teeth (Fig. 18-47). If the labial surface is too bulbous, plaque control may be difficult, and there may be lingual tilting of the tooth, caused by the force exerted by the upper lip. When individual anterior teeth are waxed, careful study of the embrasure form of adjacent teeth can be particularly helpful.

Wax Cutback

If a ceramic veneer is to be used, once the definitive contour of the wax pattern has been completed, the pattern is cut back over an even thickness—usually approximately 1 mm—to provide room for the porcelain fused onto the cast metal substructure (Fig. 18-48). The design and technique are discussed in Chapter 19.

Waxing Connectors

The connectors that join the separate components of a fixed dental prosthesis are created in wax just before the margins are finalized (Fig. 18-49). Whether the connectors are cast or soldered, they must be shaped in wax so that their size, position, and configuration are controlled precisely. Connector size is important primarily from a mechanical perspective. To ensure optimal strength, the connector should be as large as possible. However, from a biologic perspective, connectors should not impinge on the gingival tissues and should be at least 1 mm above the crest of the interproximal soft tissue. Embrasure form gingival to the connectors must enable optimal plaque control. The cervical aspect of the connector must be shaped to a smooth, archlike configuration. In esthetic areas (i.e., anterior fixed dental prostheses), connectors should be hidden behind the esthetic ceramic veneer. Therefore, connectors are often placed slightly lingually when connectors are waxed for anterior prostheses (Fig. 18-50). Connector form and design are discussed in detail in Chapter 27.

Printed Wax Patterns

Additive fabrication of wax patterns is a rapidly developing field in dental technology.[29] With the advances in three-dimensional printing, dental applications include the printing of patterns from a computer-aided design (CAD; see Fig. 18-3). Laboratory three-dimensional printers have become a part of conversion to digital workflow in many dental laboratories. They expel microdroplets of proprietary wax blends or resins, developing a pattern from a CAD in a layer-by-layer manner. In some systems, heated wax that solidifies on cooling is used, much like conventional waxes. The materials that require polymerization can be activated by either ultraviolet or visible light, which can be provided by a light source such as a xenon lamp or a light-emitting diode (LED). Some manufacturers claim resolutions in the range from 13 to 50 μm.[30] The margins of the resulting patterns can be manually readapted before investing for subsequent conventional casting of metal prostheses (see Chapter 22) or pressing of all-ceramic crowns. Stabilization of the pattern requires printing supporting struts or matrix as the patterns are gradually built up. On completion of the printing procedure, the supporting sacrificial material is dissolved in a water or oil bath and rinsed away, after which the pattern can be invested (Fig. 18-51).

Milling Wax Patterns

The same technology that is used to mill all-ceramic crowns (see Chapter 25) has been applied to the fabrication of wax patterns.[31] Sophisticated milling machines can mill multiple patterns from a single specially formulated wax puck. The CADs are positioned in a virtual puck before the milling procedure, and the software is designed to attempt and nest the patterns in such a manner that the optimal number of patterns is derived from a single puck (Fig. 18-52).

REVIEW OF TECHNIQUE

Figure 18-53 summarizes the steps for waxing to anatomic form.

- The die is modified as necessary and lubricated (see Fig. 18-53, *A*).
- An initial coping is waxed; this forms the internal surface (see Fig. 18-53, *B*).
- The proximal surfaces are developed, with correctly located contact areas (see Fig. 18-53, *C*).
- The axial surfaces are waxed. Overcontouring near the gingival margin must be avoided (see Fig. 18-53, *D*).
- The occlusal surfaces are developed with a wax addition technique, which makes it easier to determine the best location of cusps and occlusal contacts (see Fig. 18-53, *E*).
- The margins are reflowed, and the wax pattern is finished (see Fig. 18-53, *F*).

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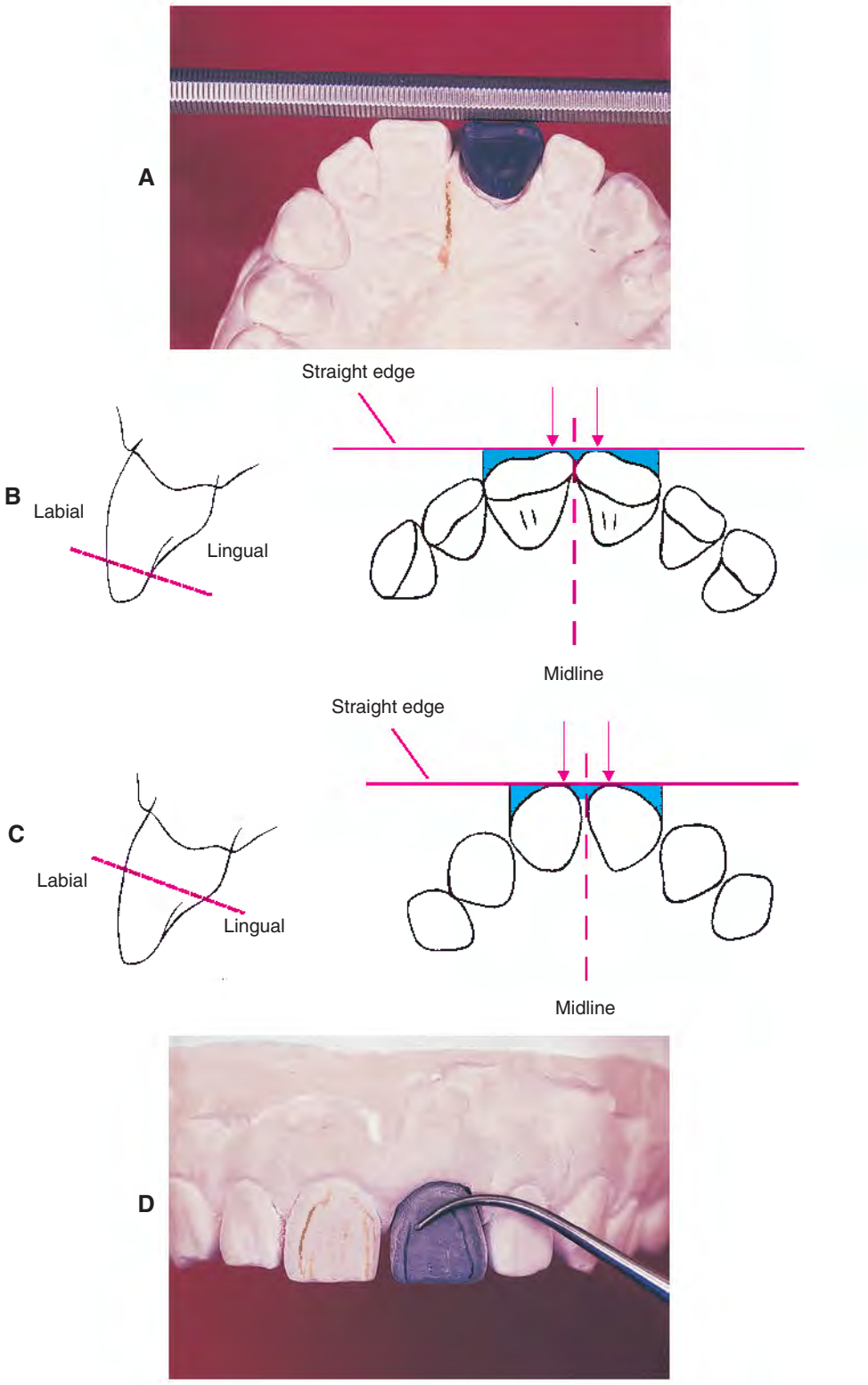

FIGURE 18-47 ■ Waxing the labial surfaces of maxillary incisors. Typically, the two central incisors should possess mirror symmetry around the midline. **A,** As the waxing progresses, symmetry can be judged by placing a straight edge near the incisal edge and exactly perpendicular to the palatal midline. **B,** The straight edge should contact each central incisor at precisely the same distance from the midline *(arrows).* The wax can be easily adjusted if proper contact does not occur. Then the spaces between the straight edge and the wax pattern *(blue areas)* are evaluated. The left and right teeth should be mirror images both mesially and distally. **C,** The straight edge is repositioned farther apically, and the analysis is repeated. Note how the form of the embrasures varies at the different locations. **D,** Dusting the wax pattern and marking the mesial and distal line angles. These should correspond to the line angles marked on the contralateral tooth.

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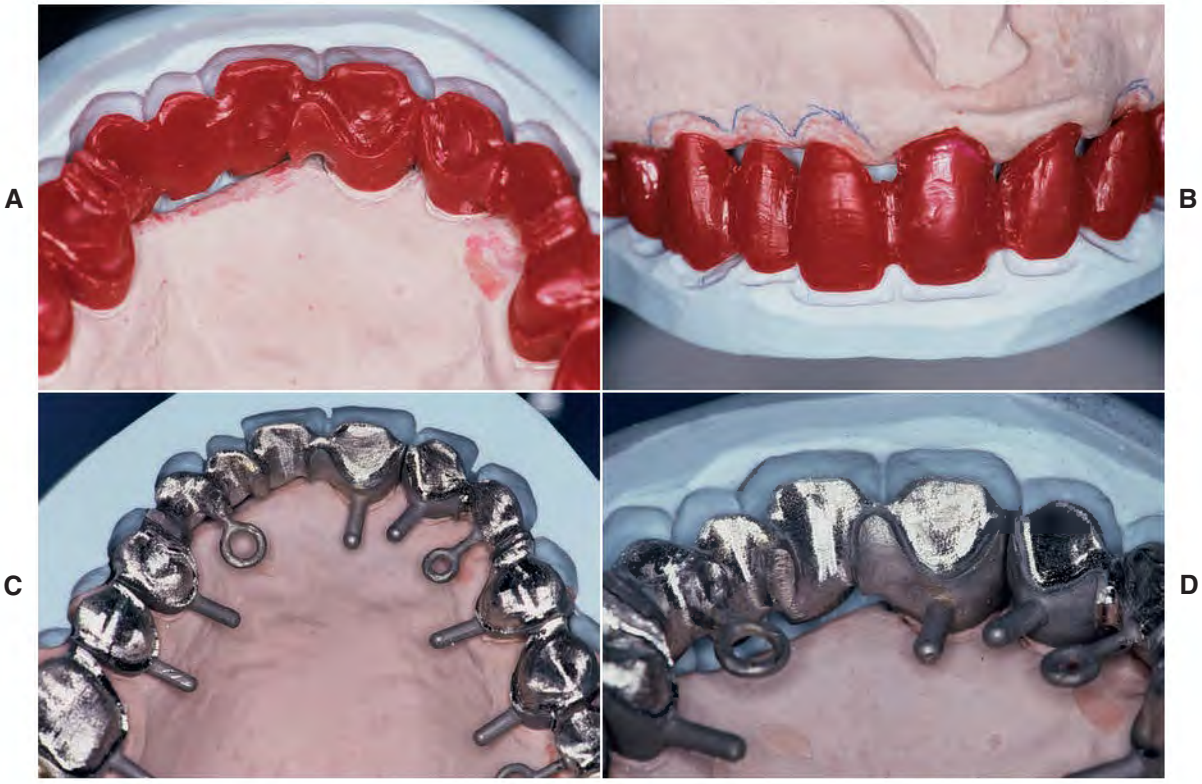

FIGURE 18-48 ■ **A** to **D,** Wax patterns cut back to provide room for the porcelain. (See Chapter 19.)

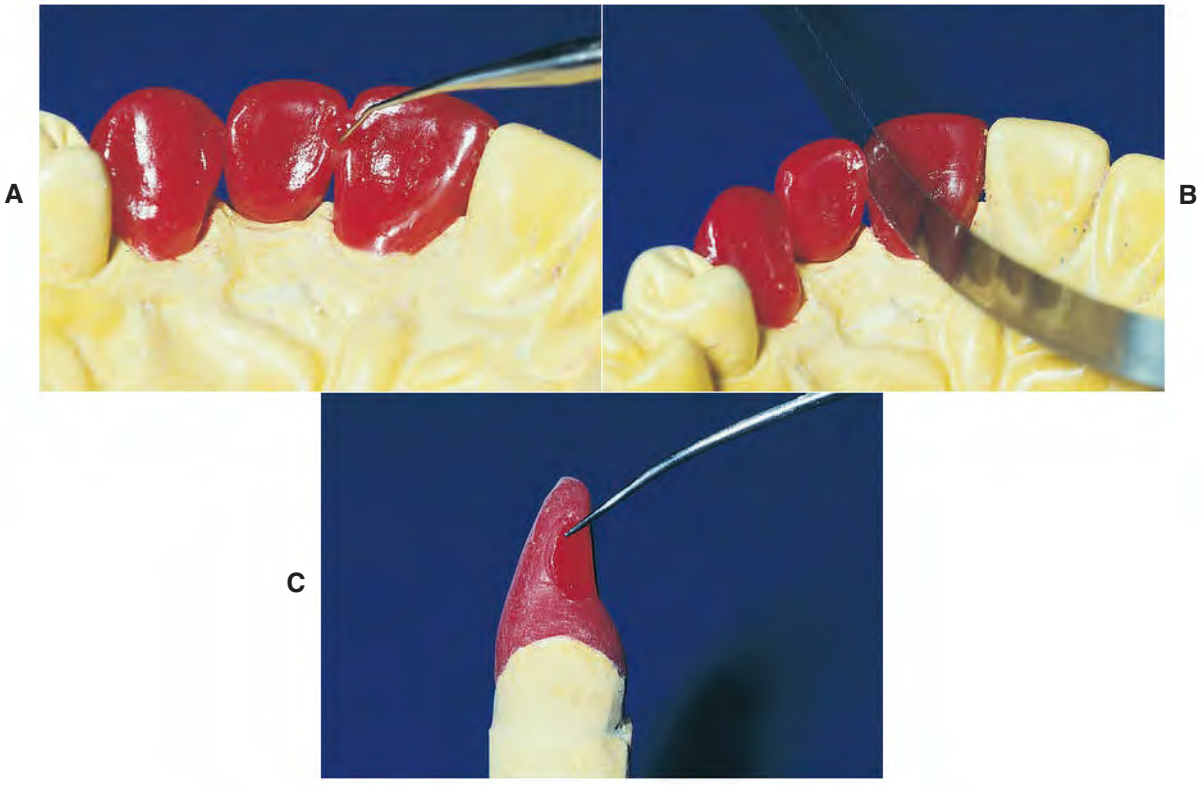

FIGURE 18-49 ■ Waxing connectors. **A,** The clinician can control the shape, size, and location of connectors by forming them in wax. **B,** A ribbon saw is then used to section them. **C,** The correct cross-sectional configuration of an anterior connector.

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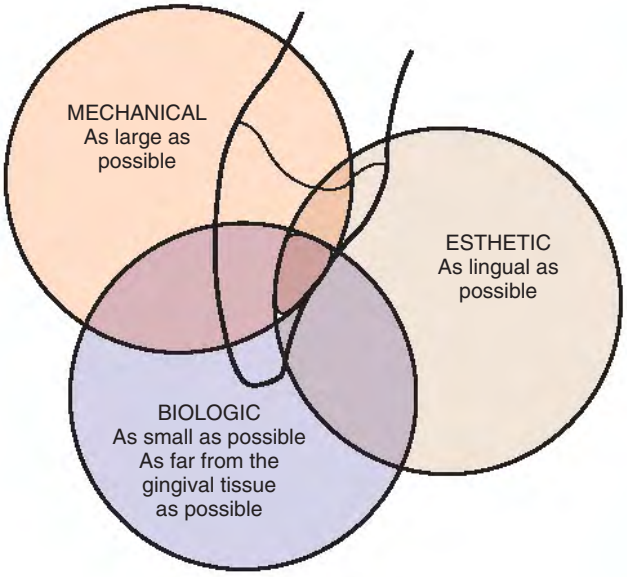

FIGURE 18-50 ■ Considerations for anterior connector placement. Mechanically, the connector should be as large as possible for strength. From a biologic perspective, the connector is most effectively placed in the incisal half of the proximal wall. For esthetics, the connector should be placed in the lingual (palatal) half of the proximal wall.

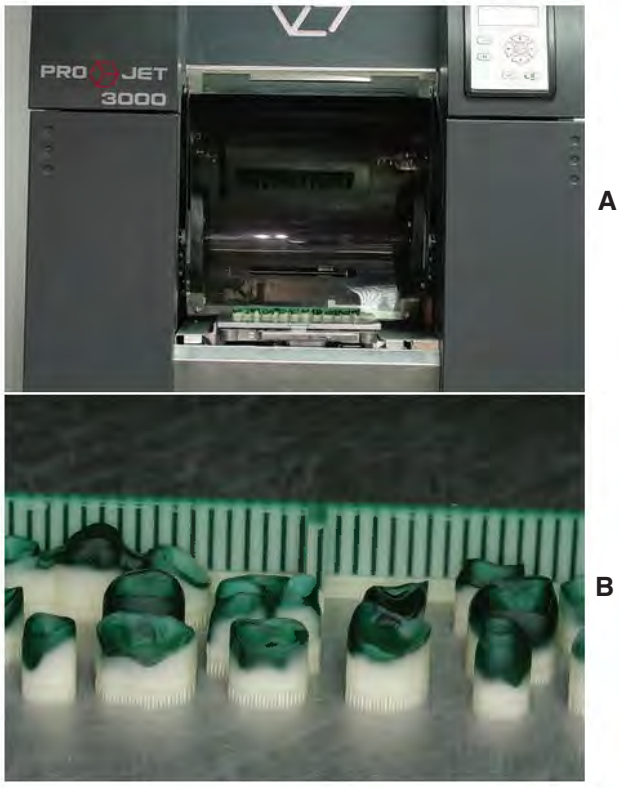

FIGURE 18-51 ■ Printing wax patterns. **A,** Wax pattern printer. **B,** Close-up of printed patterns. Note the supporting material (white) that is necessary for pattern stabilization during the additive printing process. This will be eliminated before investing. (Courtesy Dental Arts Laboratory, Peoria, Illinois.)

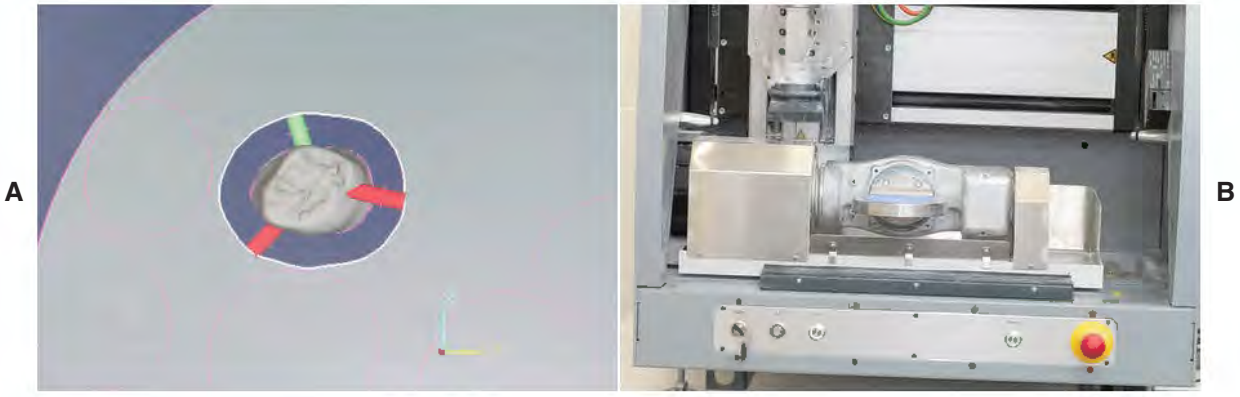

FIGURE 18-52 ■ Milling wax patterns. **A,** Computer-aided design (CAD) of a wax pattern for a complete cast crown. **B,** Specially formulated wax puck positioned in milling machine.

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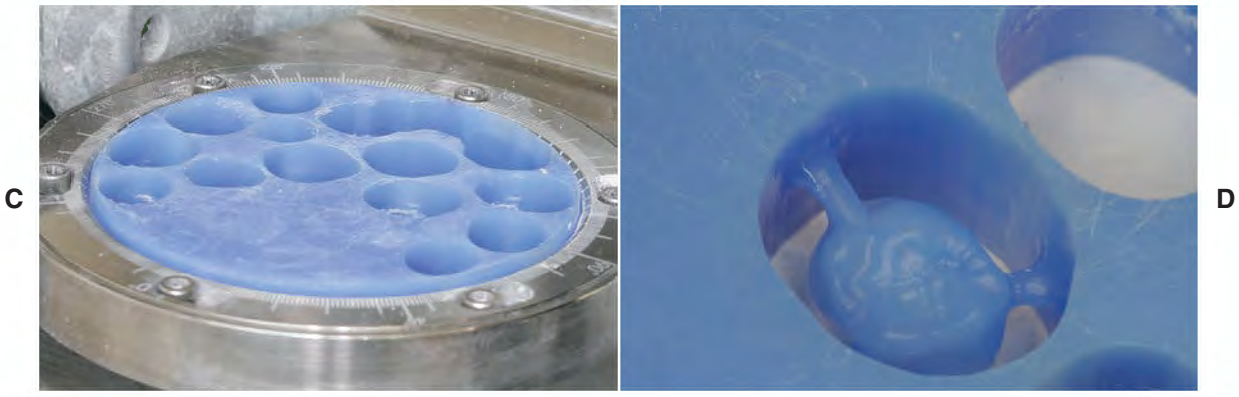

FIGURE 18-52, cont'd ■ **C,** Wax puck and close-up view **(D)** of milled wax pattern for complete cast crown. (Courtesy Dental Arts Laboratory, Peoria, Illinois.)

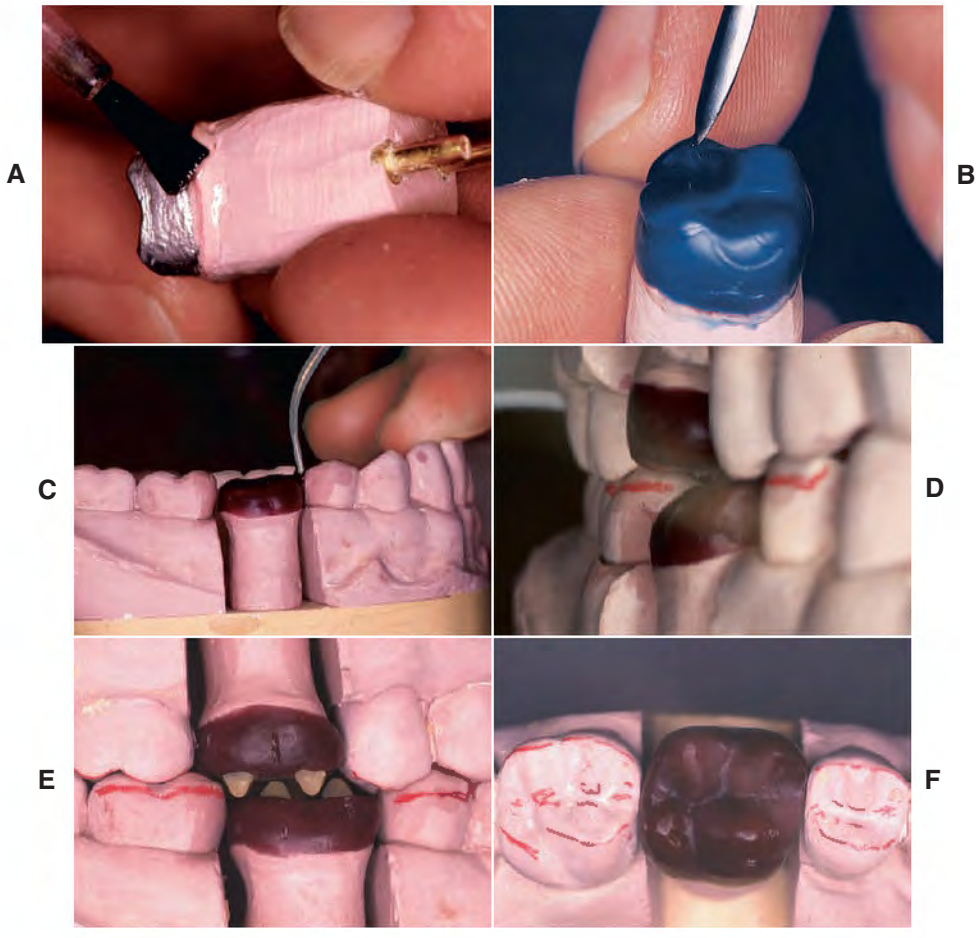

FIGURE 18-53 ■ Technique review. **A,** The die is modified as necessary and lubricated. **B,** An initial coping is waxed; this forms the internal surface. **C,** The proximal surfaces are developed, with correctly located contact areas. **D,** The axial surfaces are waxed. **E,** The occlusal surfaces are developed with a wax addition technique. **F,** The margins are reflowed, and the wax pattern is finished.

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SUMMARY

If the waxing procedure is followed in a sequential order, inexperienced but conscientious operators should have no problem achieving excellent results. With more experience, they can combine and modify some of these steps; however, waxing up teeth "from memory" is not advised. Even the most experienced technician should copy the shape of natural teeth rather than redesign them.

REFERENCES

1. Murphy EJ, et al: Investment casting utilizing patterns produced by stereolithography. Washington, D.C., U.S. Patent Office, Publication No. US4844144, July 4, 1989.
2. Frankfort H: The art and architecture of the ancient Orient, pp 26 ff. Harmondsworth-Middlesex, UK, Penguin Books, 1956.
3. Black GV: The technical procedures in filling teeth. In Black GV, Black A, eds: Operative dentistry, vol 2. New York, Medico-Dental Publishing, 1924.
4. Parkins BJ: The effect of electropolishing on the unprotected margins of gold castings. Thesis, Northwestern University, 1969. (Cited in Cherberg JW, Nicholls JI: Analysis of gold removal by acid etching and electrochemical stripping. J Prosthet Dent 42:638, 1979.)
5. Fusayama T, et al: Relief of resistance of cement of full cast crowns. J Prosthet Dent 14:95, 1964.
6. Eames WB, et al: Techniques to improve the seating of castings. J Am Dent Assoc 96:432, 1978.
7. Byrne G: Influence of finish-line form on crown cementation. Int J Prosthodont 5:137, 1992.
8. Syu JZ, et al: Influence of finish-line geometry on the fit of crowns. Int J Prosthodont 1:25, 1993.
9. Campagni WV, et al: Measurement of paint-on die spacers used for casting relief. J Prosthet Dent 47:606, 1982.
10. Emtiaz S, Goldstein G: Effect of die spacers on precementation space of complete-coverage restorations. Int J Prosthodont 10:131, 1997.
11. Fukui H, et al: Effectiveness of hardening films on die stone. J Prosthet Dent 44:57, 1980.
12. Coleman RL: Physical properties of dental materials [U.S. Bureau of Standards research paper 32]. J Res Natl Bur Stand 1:867, 1928.
13. Council on Dental Materials, Instruments, and Equipment: Revised ANSI/ADA specification No. 4 for inlay wax. J Am Dent Assoc 108:88, 1984.
14. Kotsiomiti E, McCabe JF: Stability of dental waxes following repeated heatings. J Oral Rehabil 22:135, 1995.
15. Ito M, et al: Effect of selected physical properties of waxes on investments and casting shrinkage. J Prosthet Dent 75:211, 1996.
16. Jameson LM, Malone WFP: Crown contours and gingival response. J Prosthet Dent 47:620, 1982.
17. Burch JG: Ten rules for developing crown contours in restorations. Dent Clin North Am 15:611, 1971.
18. Burch JG, Miller JB: Evaluating crown contours of a wax pattern. J Prosthet Dent 30:454, 1973.
19. Stein RS, Kuwata M: A dentist and a dental technologist analyze current ceramo-metal procedures. Dent Clin North Am 21:729, 1977.
20. Perel ML: Axial crown contours. J Prosthet Dent 25:642, 1971.
21. Löe H, et al: Experimental gingivitis in man. J Periodontol 36:177, 1965.
22. Wheeler RC: Complete crown form and the periodontium. J Prosthet Dent 11:722, 1961.
23. Herlands RE, et al: Forms, contours, and extensions of full coverage restorations in occlusal reconstruction. Dent Clin North Am 6:147, 1962.
24. Payne EV: Functional occlusal wax-up. In Eissmann HF, et al, eds: Dental laboratory procedures, vol 2: Fixed partial dentures. St. Louis, Mosby, 1980.
25. Lundeen HC: Introduction to occlusal anatomy. Lexington, University of Kentucky Press, 1969.
26. Thomas PK: Syllabus on full-mouth waxing technique for rehabilitation. San Diego, Calif., Instant Printing Service, 1967.
27. Shillingburg HT, et al: Guide to occlusal waxing, 2nd ed. Chicago, Quintessence Publishing, 1984.
28. Jacobs MS, Windeler AS: An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent 65:436, 1991.
29. van Noort R: The future of dental devices is digital. Dent Mater 28:3, 2012.
30. Dehue R: Dental 3D printing products, Accessed September 23, 2014, at http://3dprinting.com/products/dental/dental-3d-printing-products/.
31. Kopelman A, Taub E: Method for CNC milling a wax model of a dental prosthesis or coping. Washington, D.C., U.S. Patent Office, Publication No. US7383094 B2, June 3, 2008.
32. Monson GS: Occlusion as applied to crown and bridgework. J Natl Dent Assoc 7:399, 1920.
33. Monson GS: Some important factors which influence occlusion. J Natl Dent Assoc 9:498, 1922.
34. Spee FG: Die Verschiebrangsbahn des Unterkiefers am Schadell. Arch Anat Physiol (Leipz) 16:285, 1890.
35. Wilson GH: A manual of dental prosthetics, pp 22-37. Philadelphia, Lea & Febiger, 1911.

STUDY QUESTIONS

1. Discuss and explain the various techniques used to reduce or increase the resulting luting agent space. What is considered a desirable cement space?

2. What are the primary components of inlay casting waxes? What is wax "memory," and how does it affect the various technical procedures?

3. What is the recommended procedure and sequence for waxing a complete cast crown on a mandibular first molar?

4. What is the best way to evaluate wax pattern adaptation and contour?

5. Discuss how the location of posterior proximal contacts changes as a function of tooth position in the arch.

6. What are the fundamental differences between the cusp–marginal ridge and cusp-fossa occlusal schemes? What are the primary reasons for selecting one scheme over the other? Does one have advantages over the other? If so, what are they?

7. Define the curve of Wilson and the curve of Spee. What is their importance with regard to occlusal form?

8. Why is it necessary to wax connectors as a separate step in the fabrication of a fixed dental prosthesis?

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CHAPTER 19

Framework Design and Metal Selection for Metal-Ceramic Restorations

Esthetics is an essential part of restorative practice: All patients want a pleasing smile. Particular scrutiny must be given to color, shape, surface texture, and proportion. Because anterior and maxillary posterior teeth are the most visible, they require the greatest attention to esthetic detail.

Tooth-colored restorative materials have evolved from the soluble silicate cements of the past to the composite resin materials and resin-modified glass ionomer cements of today. Currently, metal-ceramic prostheses are widely accepted and, despite some esthetic limitations, remain commonly used and reliable extracoronal restorations. They combine the superior fit of a casting with the outstanding esthetics of dental porcelain. Because the ceramic veneer is chemically bonded to the metal substructure, such restorations are not subject to the discoloration problems associated with acrylic resin veneer crowns and, provided that appropriate clinical and laboratory protocols are followed, longevity can be excellent.[1,2] In addition, the material properties of dental porcelain are better able than resin to withstand wear under functional loading.

The concept of combining a brittle material with an elastic material to achieve more desirable physical properties has many engineering applications. Dental porcelains (which are, chemically speaking, glasses) resist compressive loading but tend to succumb to tensile stress. Therefore, the metal substructure must be designed so that any tensile stresses in the porcelain are minimized.

To avoid fracture, the thickness of a ceramic veneer must not exceed 2 mm; however, 1 mm is the minimum thickness needed for an esthetically pleasing restoration.

Restorations with porcelain occlusal surfaces must be planned carefully. Although they are esthetically very acceptable, these restorations have disadvantages, especially wear of the opposing enamel.[3] Ideally, an esthetic restoration should wear at approximately the same rate as the enamel it replaces (approximately 10 μm per year[4]). In addition, the restoration should not increase the wear rate of an opposing enamel surface. Dental porcelain is more abrasive of enamel than of other restorative materials (e.g., gold or amalgam[5-9]) and has been implicated in severe occlusal wear, particularly when the porcelain is not glazed or highly polished (Fig. 19-1).[10] This should be considered whenever a metal-ceramic restoration is being designed,[11] and the practitioner should realize that although abrasiveness may be correlated with the composition of the ceramic material, the selection of a lower fusing ceramic (sometimes labeled by the manufacturer as *low-wear*) does not necessarily mean less wear of opposing enamel.[12] Less wear has been cited as the most important need for improvement of posterior tooth-colored crowns.[13] In addition, porcelain occlusal coverage results in restorations with lower strength,[14] and anatomically correct occlusal form with sharp cusps can be difficult to obtain in dental porcelain.

Some technicians may attempt to fabricate a framework by dipping the die into molten wax, obtaining an even metal framework thickness. After the excess wax is trimmed away, a gingival collar is added, and the pattern is sprued, invested, and cast. When it is completed, the ceramic veneer is then applied. This technique almost always results in an uneven porcelain thickness, with increased potential for porcelain fracture as a result of lack of proper support (Fig. 19-2). If porcelain thickness is not well controlled, appearance suffers as well because the shade of the definitive crown depends on porcelain thickness.[15] For predictable success, the framework must be carefully designed and shaped.

PREREQUISITES

Framework design for a fixed dental prosthesis (FDP) should be considered during the treatment planning stage (see Chapter 3) and should be evaluated at the diagnostic tooth preparation and waxing stages, particularly for more complex treatments. Proper framework configuration for a metal-ceramic crown or FDP can be achieved routinely only through waxing of the restoration to final anatomic contour, followed by cutting back of a consistent amount for the veneer. This allows for even thickness of porcelain, proper porcelain-metal interfaces, good connector design, and optimally placed occlusal contacts.

Waxing to Anatomic Contour

The main objective is to shape a substructure that supports a relatively even thickness of porcelain. Simultaneously, if the retainer is to serve as part of an FDP, it must allow for proper connector configuration and location. Furthermore, the restoration must conform to the normal anatomic configuration of the tooth that is being replaced. At the porcelain-metal interface, the ceramic material should be at least 0.5 mm thick. The framework should be shaped to allow for a distinct margin so that the porcelain is not overextended (Fig. 19-3). There should be

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FIGURE 19-1 ■ **A** to **D,** Destructive enamel wear associated with metal-ceramic restorations. (Courtesy Dr. M.T. Padilla.)

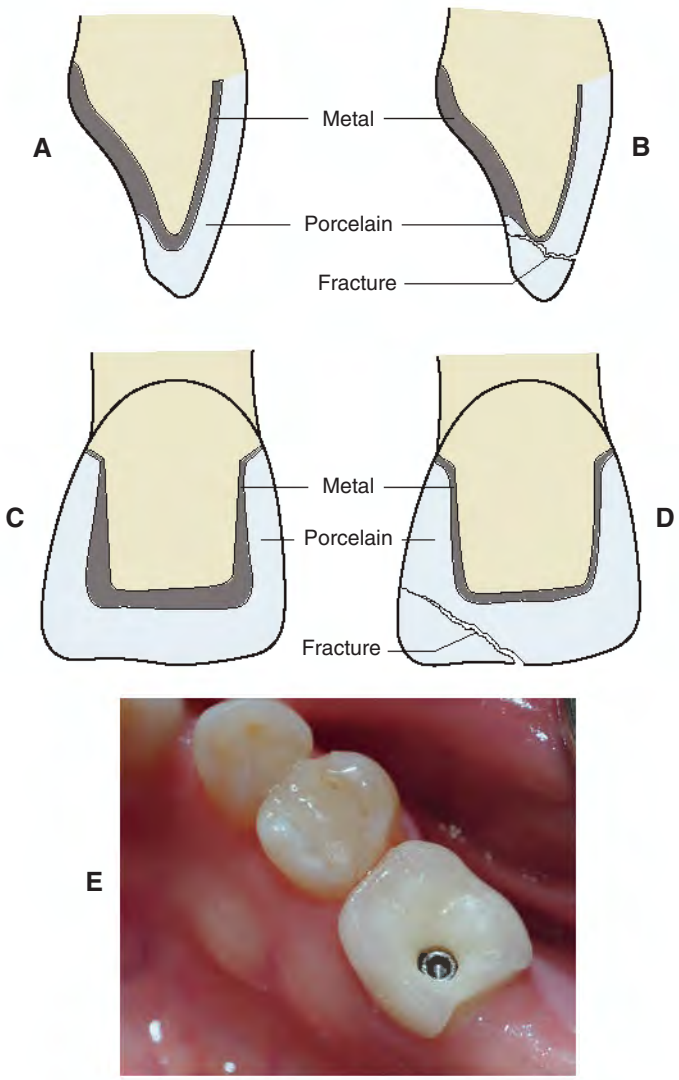

FIGURE 19-2 ■ Cross sections through a metal-ceramic restoration. **A** and **C,** Ideal porcelain thickness is ensured by waxing to the full anatomic contour and cutting back. **B** and **D,** Incorrect framework design has insufficient support for the incisal porcelain. This can lead to fracture. **E,** On this implant-supported crown with a zirconium substructure, the feldspathic veneer failed because support was insufficient.

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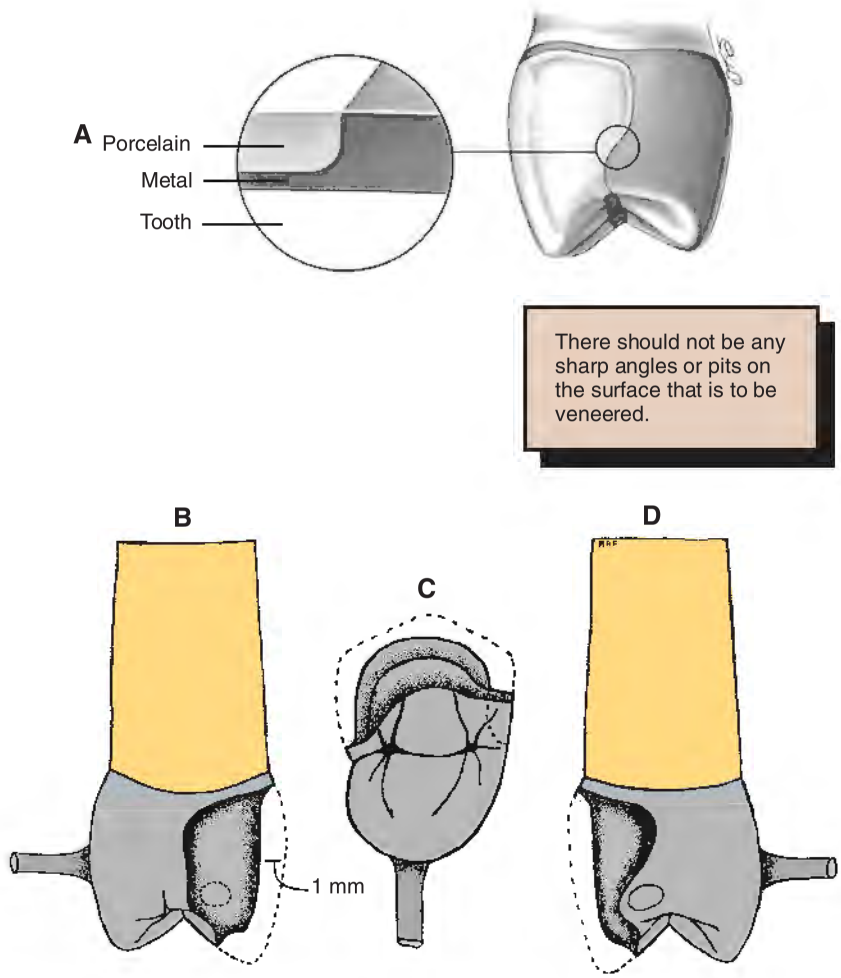

FIGURE 19-3 ■ **A,** The metal substructure should have a distinct margin for finishing the veneer. The location of the ceramic-metal interface varies, depending on the material chosen to contact adjacent and opposing teeth. **B,** Cutback for proximal contact in porcelain. **C,** Occlusal contact in metal. **D,** Proximal contact in metal. (**B** to **D**, Courtesy Dr. R. Froemling.)

no abrupt contour change between the metal and the adjacent porcelain, and the definitive restoration must exhibit an optimal emergence profile (see Chapter 18).

The most effective way to consistently meet these criteria, with a minimum number of failures, is to develop the definitive contours of the proposed restoration in wax (Fig. 19-4). Once this is completed, the area to be veneered can be demarcated and an even thickness of wax removed. If this technique is not followed, one or more of the objectives is almost certainly missed, and the contours of the framework are not in harmony with the optimal ceramic configuration (Fig. 19-5).

Occlusal Analysis

The centric stops of any metal-ceramic restoration can be located on either porcelain or metal. However, they must be at least 1.5 mm away from the junction[16] to prevent porcelain fracture from deformation of the metal (Fig. 19-6). Care is needed to minimize sliding contacts across the porcelain-metal interface. When this is not possible, the framework must be modified so that the porcelain is well supported in the area of functional contact.

Existing restorations in the opposing arch can influence framework design. Because sliding contact of a porcelain restoration with a cast crown abrades the gold, the framework design must be modified as necessary. A complete cast crown in the mandibular arch presents little difficulty. It can be opposed by a maxillary restoration with a metal occlusal surface and only a facial ceramic veneer (Fig. 19-7). An existing metal crown on a maxillary molar, however, restricts the design of a mandibular metal-ceramic restoration if metal-to-porcelain contact is to be avoided (Fig. 19-8). In this situation, the facial veneer can no longer be extended to include the buccal cusp tips and associated centric stops without contacting the opposing restoration. A complete cast crown is usually more conservative because most patients do not show the facial surfaces of their mandibular posterior teeth. In other situations, particularly on mandibular first premolars, a facial veneer is esthetically essential, and the design of opposing restorations should allow for it (Fig. 19-9).

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FIGURE 19-4 ■ **A** and **B,** Anterior metal-ceramic restorations after waxing. **C,** Right lateral excursion. **D,** Left lateral excursion. **E,** The anterior guidance is determined with a custom table fabricated from the diagnostic waxing procedure.

CUTTING BACK

The criteria for waxing to anatomic contour are discussed in Chapter 18. This section deals with cutting back the veneering area.

Armamentarium

- Bunsen burner
- Inlay wax
- Cloth
- Sharp pencil
- Die-wax separating liquid
- Powdered wax
- Waxing instruments
- Nylon hose and silk cloth
- Cutback instrument
- Scalpel
- Discoid carver
- Wax saw
- Waxing brushes

Step-by-Step Procedure

Designing the Cutback

Esthetic and functional needs govern the design of the veneering surface. The ceramic veneer should extend far enough interproximally, particularly in the cervical half of the restoration, to avoid metal display. Wherever possible, the functional occlusal surfaces should be designed in metal because an accurate occlusion is then easier to achieve (Fig. 19-10). However, esthetic demands may necessitate extension of the porcelain veneer (e.g., on the mesial incline of a mandibular buccal cusp). The extent to which a restoration can be veneered is determined largely by the location of the centric stops.

1. Do not place any proximal contacts on the junction between metal and porcelain: Plaque accumulation there may result in caries of the adjacent tooth. Normally, for good appearance and because it is more easily cleaned, proximal contacts are designed to be in porcelain. On some posterior teeth, however, where the interproximal area cannot be easily seen, a more conservative preparation may be possible, with the contacts entirely in metal (see Fig. 19-3, *D*).
2. Once the extent of the cutback area has been determined, use a sharp instrument (e.g., an explorer or scalpel) to mark a line delineating the porcelain-metal interface.
3. Dust the pattern with powdered wax, and close the articulator to determine the location of the centric contacts.
4. Inspect the design to verify that the proposed junction is far enough away from the contacts (1.5 mm) to prevent distortion of the metal and porcelain fracture.

Troughing the Pattern

Just as guiding grooves are used to mark the amount of substance to be removed in tooth preparation, depth cuts *(troughing)* can be used to standardize the amount of wax to be removed from the veneering area.

5. Modify an old or damaged hand instrument with a separating disk to serve as a cutback instrument (Fig. 19-11).* The cutting edge should resemble

*A suitable instrument is available from Hu-Friedy Manufacturing Co., Inc, Chicago, Illinois.

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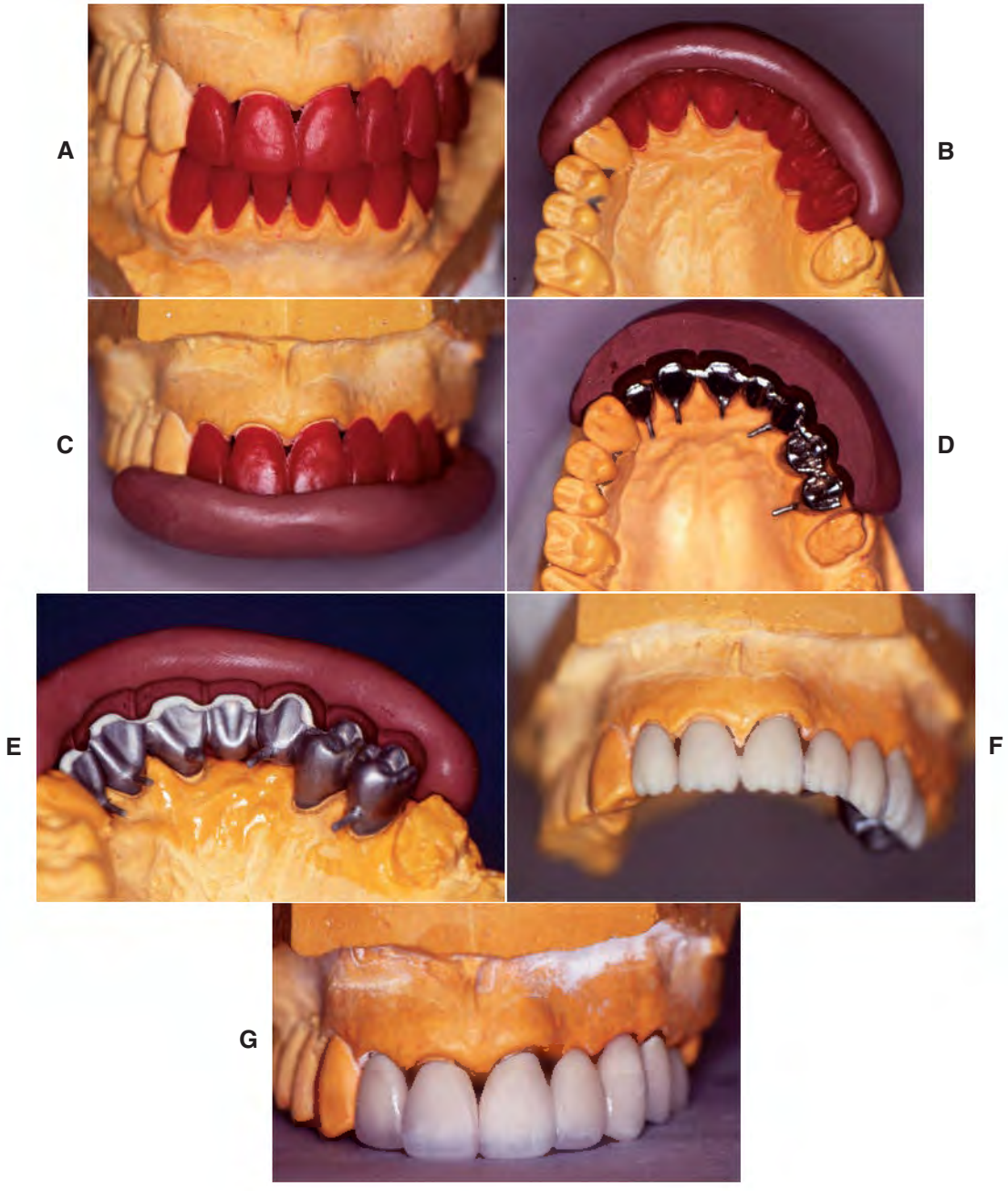

FIGURE 19-5 ■ Predictable esthetic result ensured by waxing to anatomic contour. **A,** Anatomic contour wax patterns. **B** and **C,** Incisal and labial indices were used to verify even cutback. **D,** Cast substructures. **E,** The labial index is reused during porcelain application. **F,** The porcelain application. **G,** After contouring, the restorations are ready for clinical evaluation. (Courtesy Dr. M. Chen.)

FIGURE 19-6 ■ **A,** The metal-ceramic junction must be carefully placed to avoid areas of high stress near occlusal contacts. **B,** Waxing to the anatomic contour ensures a smooth transition from porcelain to metal.

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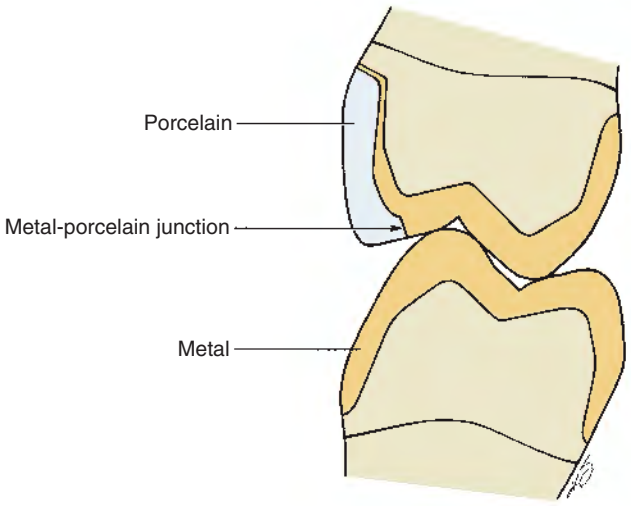

FIGURE 19-7 ■ The metal-ceramic restoration should be designed so that porcelain does not oppose an existing gold restoration. This presents few problems in the maxillary arch because the less visible lingual cusps are in contact.

FIGURE 19-9 ■ **A** and **B,** Opposing restorations must be carefully planned so that contacting surfaces are of the same material (i.e., metal opposing metal, porcelain opposing porcelain).

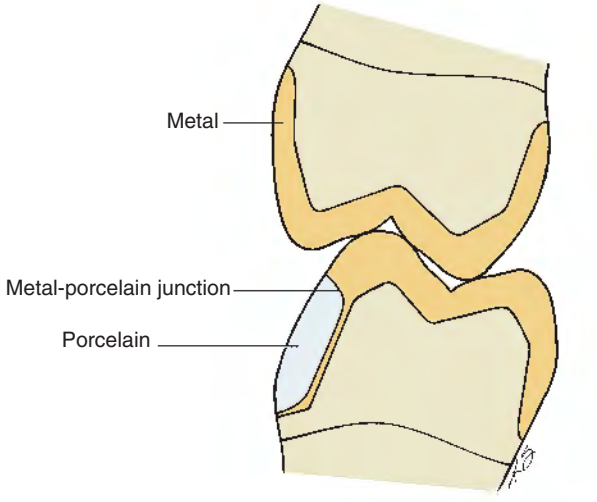

FIGURE 19-8 ■ In the mandibular arch, the functional cusps are visible, and only a buccal window of porcelain can be made without its contacting an opposing metal crown. Under these circumstances, it must be decided whether the patient should accept an esthetic or functional compromise.

the tip of a straight chisel. There should be a flat stop exactly 1 mm from the cutting edge.

6. Make depth cuts around the periphery of the cutback area that are perpendicular to the surface of the wax pattern. Depending on the size of the cutback area, one or more vertical and horizontal cuts can also be made.
7. Remove the islands in between with a scalpel or another carving instrument (Fig. 19-12, *A* to *E*).

Finishing

8. Once the bulk reduction has been completed, smooth the veneering surface of the wax. This ensures a rounded design and minimizes the time spent on metal finishing. Sharp angles on the veneering surface concentrate stresses, which may lead to fracture of the restoration.[17] Smoothing is much easier in wax than in metal, although this is not always appreciated initially.
9. Finish the porcelain-metal interface to a 90-degree butt joint (see Fig. 19-12, *F* to *J*). Reflowing the margin is essentially the same as for conventional wax patterns (see Chapter 18).
10. Reestablish the collar (obliterated during reflowing) immediately before investing. Make it slightly thicker (approximately 0.5 mm) to ensure an undistorted complete casting (Fig. 19-13). When waxing for the porcelain labial margin technique (see Chapter 24), some technicians prefer to wax a collar and cut back the metal; others wax to the collarless shape, but care should then be exercised to avoid distorting the fragile pattern.

Connector Design

11. Establish the connectors in wax as described in Chapters 18 and 27. Properly shaped and positioned connectors are very important. If soldering is planned before or after ceramic application, separate the patterns with a fine saw.
12. If only a facial veneer is involved, make the connectors identical to those for a conventional restoration. If the incisal or occlusal aspect is involved in the porcelain veneer, do not displace the connector cervically (a common error) because access for oral hygiene will be impeded (Fig. 19-14).

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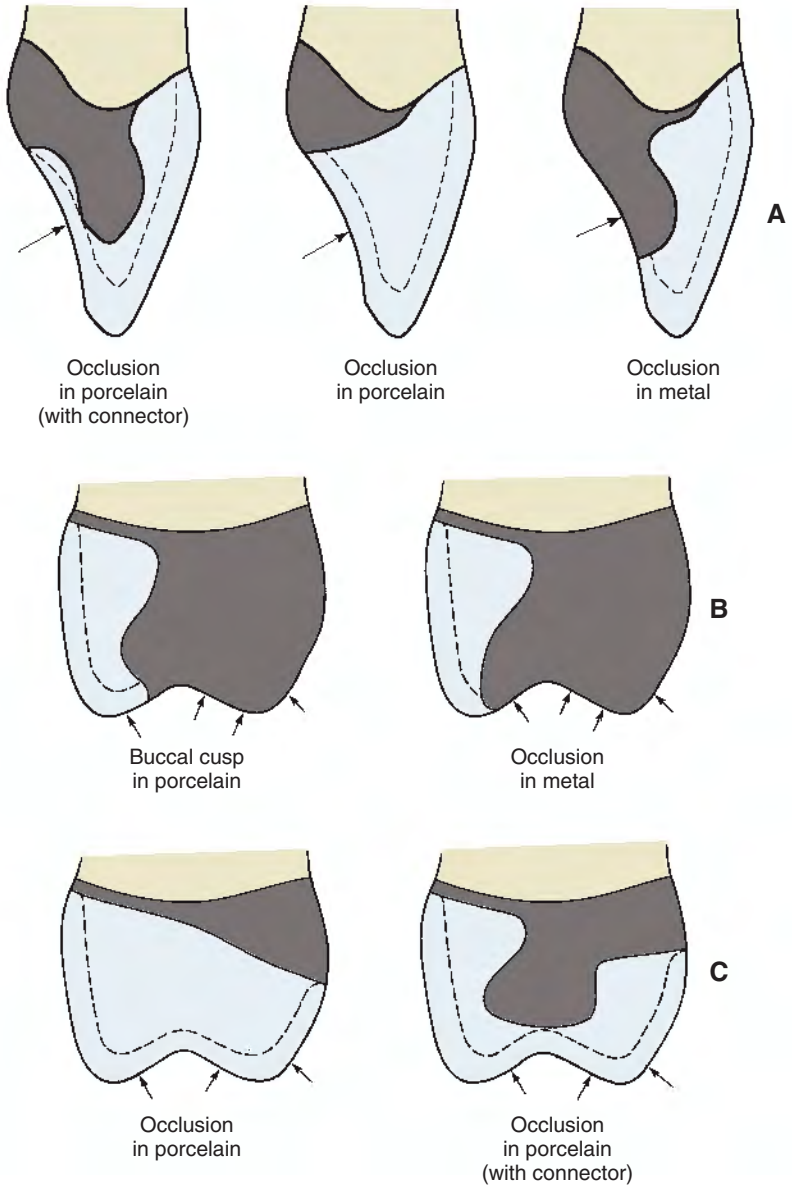

FIGURE 19-10 ■ Framework designs for a maxillary incisor **(A)** and a maxillary posterior tooth **(B).** The cutback should be designed so the occlusal contacts *(arrows)* are 1.5 mm away from the porcelain-metal junction. **C,** Framework designs for porcelain occlusal surfaces.

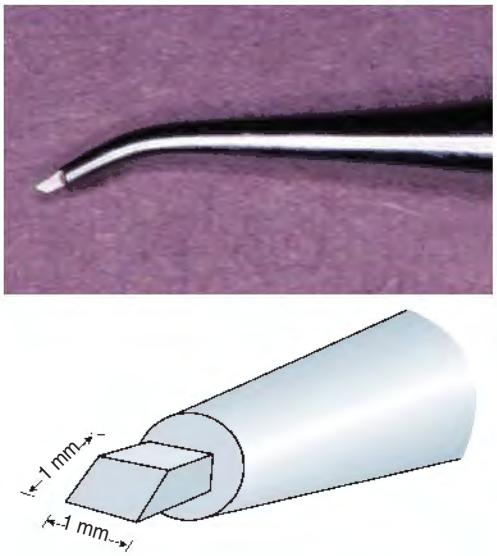

FIGURE 19-11 ■ A cutback instrument can be readily made from a damaged hand instrument.

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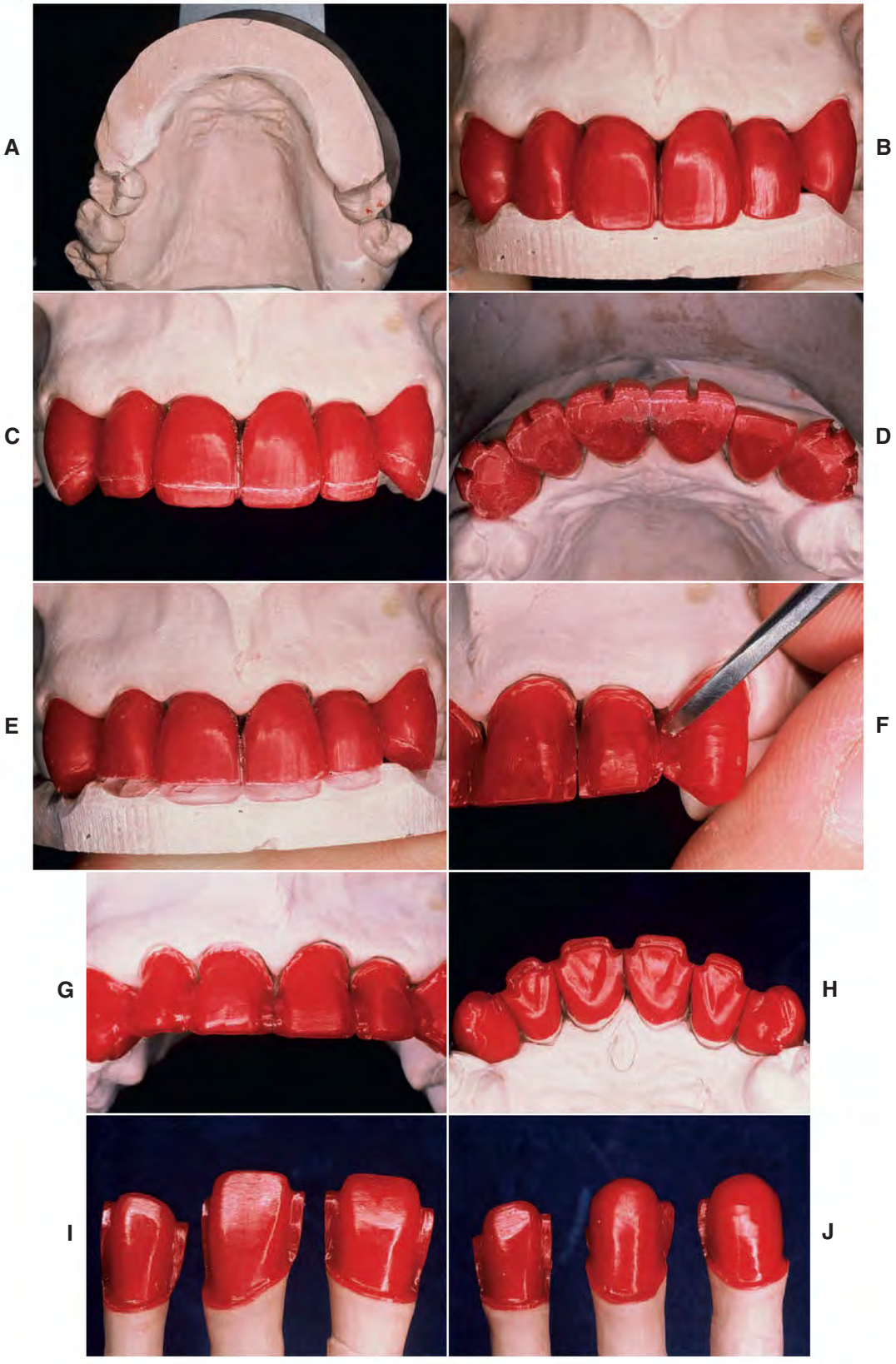

FIGURE 19-12 ■ Cutback procedure. **A** and **B,** For extensive restorations, a matrix or index can be made to assist with the evaluation of the cutback and subsequent porcelain application. **C,** It is important to follow the incisal contour carefully. **D,** Guiding troughs are prepared in the area to be veneered. **E,** Wax is removed from between the troughs. **F,** The porcelain-metal interface is carved to a distinct butt joint. **G,** Note the correctly shaped proximal contour. These units will have soldered connectors. **H,** The finished cutback. **I** and **J,** Patterns before reflowing of the margins.

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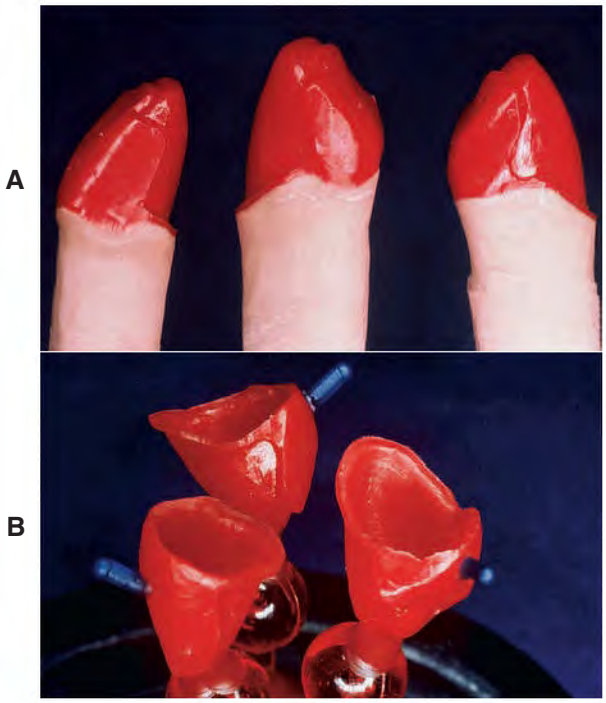

FIGURE 19-13 ■ **A,** Margins reflowed. This ensures optimum adaptation of the wax pattern in the critical margin area. **B,** Patterns before investing.

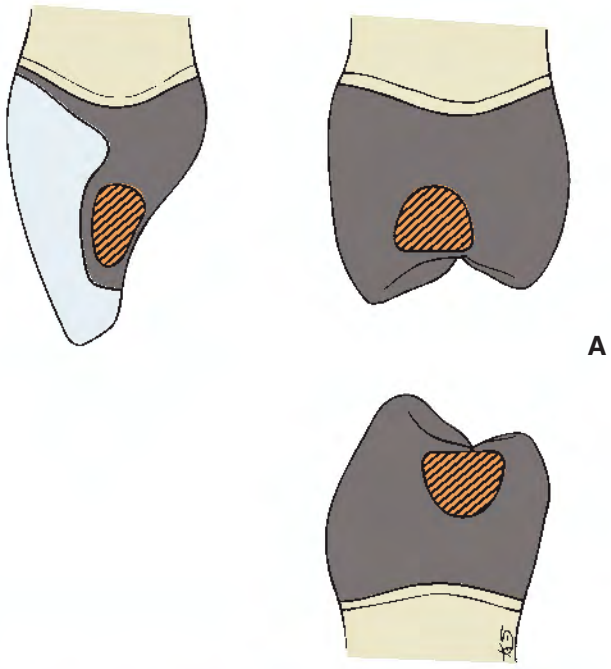

FIGURE 19-14 ■ **A** and **B,** Connectors should be in locations where they do not impede oral hygiene measures.

Pontics

13. Because glazed vacuum-fired porcelain is easy to keep clean, include the tissue-contacting surfaces of pontics in the veneering surface (Fig. 19-15).
14. To improve handling and stability of the wax pattern, be sure to cut back this area last (see Chapter 20).

Evaluation

Immediately before the investing stage, the following criteria should have been met:

1. The pattern should conform to normal anatomic form. Centric stops should be located at least 1.5 mm from the porcelain-metal junction.
2. The angle between the veneering surface and the metal framework should be 90 degrees.
3. The internal surface of the veneering area should be smooth and rounded.
4. The collar height should be approximately 0.5 mm in wax with connectors of adequate size, but it should not impinge on the soft tissue in the interproximal areas.
5. The pattern should be smooth, so that metal-finishing procedures are minimized.

PRINTED FRAMEWORK PATTERNS

Many dental laboratories now generate plastic patterns for metal ceramic restorations with a three-dimensional printing process (see Chapter 18).[18] The process is somewhat similar to that used for making household objects with a three-dimensional printer. The technician uses special computer software to generate a file of the framework design, and a pattern is fabricated by a stereolithographic process (see Chapter 17). An advantage of this technology is that space for the porcelain and its proper support can be accurately designed into the framework. Dental students have been found to prefer the CAD/CAM process.[19] The process is illustrated in Figure 19-16.

METAL SELECTION

William A. Brantley • Leon W. Laub (editions 1, 2, and 3) • Carl J. Drago (edition 4)

Clinicians and dental laboratories face a potentially bewildering set of choices in selecting alloys for metal-ceramic restorations. Both noble metal and base metal casting alloys are available, and there are different alloy

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FIGURE 19-15 ■ **A** and **B,** The tissue contact on the pontics of this extensive fixed prosthesis was established in porcelain.

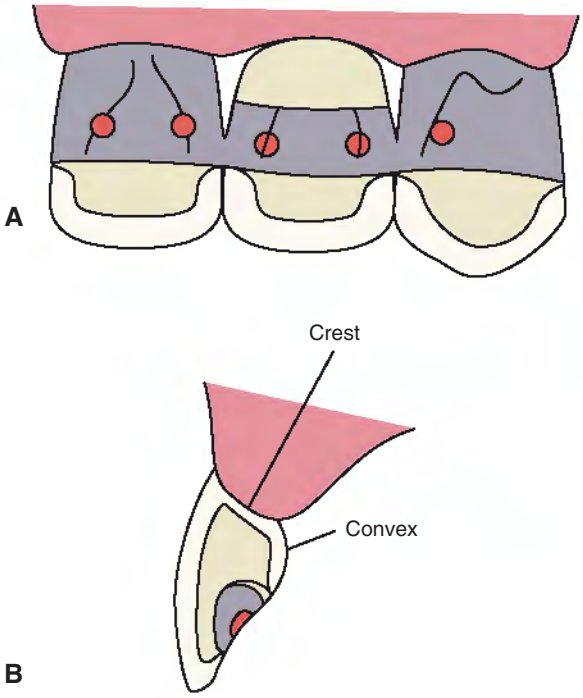

FIGURE 19-16 ■ Cutback design for a lateral incisor pontic with modified ridge-lap design (see Chapter 20). **A,** Lingual view of cutback. The design provides uniform porcelain thickness, adequate distance between occlusal stops *(red area)* and the metal-ceramic interface, and accessible cervical embrasures that allow for finishing and cleansability. **B,** Faciolingual view through the pontic. Note the porcelain tissue contact, the relationship of the metal-ceramic junction to the connector *(blue area),* and the location of the occlusal contacts *(red area).*

types for each of these two major groups. Each alloy type has advantages and disadvantages, including significant cost differences. Successful clinical practice depends on the selection of a compatible metal-porcelain combination that provides predictable results, depending on the particular patient's needs. Improper selection can cause catastrophic failure (Fig. 19-17). For a better understanding of the different properties provided on the packaging of casting alloys, the meanings and clinical relevance of these properties are discussed next.

FIGURE 19-17 ■ Failure caused by improper material selection.

Dental Connotations of Mechanical and Physical Properties for Ceramic Alloys

Mechanical properties of major clinical relevance are modulus of elasticity (elastic modulus), yield strength (or proportional limit), hardness, and creep or distortion at elevated temperatures. Ultimate tensile strength (UTS), ductility, and toughness should also be reviewed, although these properties have less relevance for metal-ceramic restorations. Except for hardness (and elevated temperature creep or distortion), all these mechanical properties are determined by the loading of a cast specimen of the alloy to the point of failure in a tension test at room temperature. The physical property of thermal contraction is crucial in the choice of an alloy that is compatible with the porcelain selected. From a practical standpoint, the density is important in both the economics of alloy selection and the dental laboratory procedure with the casting machine.

Modulus of Elasticity

Figure 19-18 illustrates schematically the tensile stress-strain plot for a ductile casting alloy that undergoes substantial permanent deformation before fracture. This plot consists of two portions: (1) a linear or elastic region that ends at the proportional limit, where the stress is proportional to strain, and (2) a subsequent curved region corresponding to plastic or permanent deformation (which terminates when the test specimen fractures). The modulus of elasticity (also called *Young's modulus*) is the

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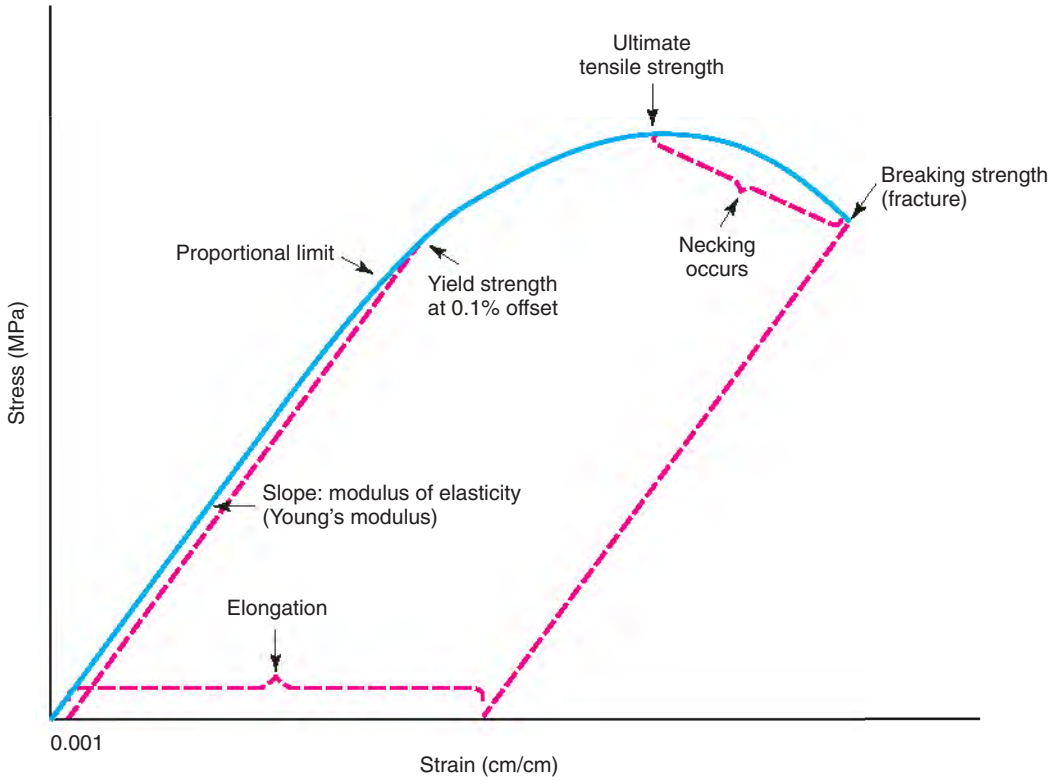

FIGURE 19-18 ■ Stress-strain curve.

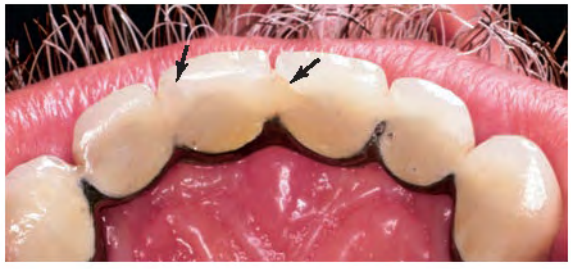

FIGURE 19-19 ■ Fracture *(arrows)* resulted from flexing of the substructure of this long-span partial fixed dental prosthesis.

slope of the stress-strain plot in the elastic region. The elastic modulus has the same value for tensile and compressive strains, which occur during bending of a prosthesis, in which regions on opposite sides of the neutral axis (center line for a symmetric cross section) undergo deformation in opposite directions. An alloy with a higher modulus of elasticity has greater stiffness or rigidity for elastic deformation. For the fabrication of a long-span FDP, an alloy with a relatively high elastic modulus to reduce the amount of bending deflection under loading is preferred because excessive flexure can cause fracture of the brittle porcelain (Fig. 19-19). The modulus of elasticity is represented as units of stress/strain and is reported for dental alloys in gigapascals (1 GPa = 10^9 Pa = 145,000 pounds per square inch [psi]). The unit of 1 Pa = 1 N/m^2 is much too small to be useful for the elastic modulus of materials.

Proportional Limit and Yield Strength

In standard testing practice, investigators determine the proportional limit of an alloy by placing a straight edge on the stress-strain plot (or performing this operation with computer software) and noting the value at which the plot first deviates from a straight line. The proportional limit is often considered synonymous with the *elastic limit*, which corresponds to the value of stress at which permanent deformation occurs. However, the value of the elastic limit is highly dependent on the sensitivity of the strain-measuring apparatus. Moreover, precise location of the proportional limit on the stress-strain plot is somewhat problematic. Consequently, the *yield strength* (sometimes called *offset yield strength*) corresponds to the amount of stress for a very small designated amount of permanent deformation, such as 0.1% or 0.2% (permanent strains of 0.001 or 0.002, respectively). In the current standard for dental alloys used in prosthodontics (ISO 22674),[20] the term *proof strength* (often called *proof stress*) is used instead of *yield strength*. Table 19-1 presents information from the standard about the two alloy classifications appropriate for this chapter. The unit for yield strength is megapascal: 1 MPa = 10^6 Pa = 145 psi. As shown in Figure 19-18, the investigator calculates the yield strength by constructing a line parallel to the initial straight-line portion of the stress-strain plot, starting with the specified value of offset on the horizontal strain axis and then noting the point of intersection with the curved portion of the plot. It follows that the 0.2% yield strength can be substantially higher than the 0.1% yield strength for a given alloy, depending on

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TABLE 19-1 **Relevant Portion of Alloy Classifications from Standard ISO 22674:2006**[20]

Alloy Type	Minimum 0.2% Yield Strength (MPa)	Minimum Elongation (%)	Examples of Uses
3	270	5	Multiple-unit fixed dental prostheses
4	360	2	Thin veneered crowns Long-span fixed dental prostheses Small cross-section fixed prostheses Implant superstructures

Note: The alloy classification is generally provided by the manufacturer. There are six classifications. Types 0 and 1 are applicable to low stress-bearing single-tooth fixed restorations. Type 2 is applicable to single-tooth fixed restorations (inlays or crowns). Type 5 is applicable to partial removable dental prostheses, other parts with thin cross sections, and clasps. The minimum Young modulus requirement is 150 GPa for type 5 alloys, but not for types 0 to 4.

the rate of work hardening (slope of the curved portion of the stress-strain plot). ISO 22674 stipulates that the value of the 0.2% yield strength is provided for a dental alloy by the manufacturer.[20] The yield strength is often called the *useful strength* of a dental alloy because stresses caused by mascatory forces should not exceed the yield strength, which would result in permanent deformation of the alloy. Although a sufficiently high yield strength is essential for a ceramic alloy, values that are too high create difficulties when the casting is adjusted in the dental laboratory or dental office.

Hardness

The Vickers hardness number (VHN) is generally measured for dental alloys by means of a symmetric diamond pyramidal indenter. The VHN is the quotient of the indenting load and the surface area of the permanent indentation, for which the square of the mean diagonal length is multiplied by a constant related to the indenter geometry.[21] The Knoop hardness number (KHN), obtained with a diamond indenter that has long and short axes, is sometimes reported for dental alloys. For the KHN, only the length of the long diagonal side of an indentation is measured, and the indenting load is divided by the unrecovered projected area of the indentation because the elastic recovery after removal of the indenting load is along the shorter diagonal.[21] Harder alloys, which have smaller indentations, have higher VHN and KHN values. Conversion scales available for the two different hardness tests should be used with caution because such conversions are alloy dependent. Both the VHN and KHN are measures of the microhardness, in contrast to the older Brinell and Rockwell tests, in which much larger indenters are used to measure the macrohardness. When the Vickers hardness of an alloy is measured, an understanding of the microstructure is crucial. Use of a large indenting load of 1 kgf (49 N) for dental alloys provides information about the overall hardness of the alloy microstructure, whereas light indenting loads (e.g., 0.5 N) can be used to obtain information about the hardness of individual grains, constituents, or phases. The hardness is an important practical property, inasmuch as very high values of hardness cause difficulty in the dental laboratory when the casting is ready to be finished. Alloys with VHN or KHN values exceeding that of enamel (approximately 350) cause abrasive wear of opposing teeth, although hardness values are not included in ISO 22674.[20]

Elevated-Temperature Creep and Distortion

During the porcelain firing cycles, castings undergo dimensional changes as a result of elevated temperature. These changes have many causes, such as bulk creep of the alloy from several metallurgical mechanisms, distortion of the alloy as a result of the relief of residual stresses from the casting process, and alloy oxidation. The latter may be higher for high-palladium and other alloys that undergo internal (bulk and grain boundary) oxidation with the formation of oxide precipitate particles, in addition to the formation of an external oxide layer. Measuring the dimensional changes that occur in alloys during the porcelain bonding sequence is tedious, but concern has been expressed about the clinical fit for castings prepared from certain alloys. Nevertheless, in most cases, an experienced dental laboratory should be able to vary techniques and obtain successful results.

Ultimate Tensile Strength

The UTS (also called *tensile strength* or simply *strength*) is the maximum point on the stress-strain curve (see Fig. 19-18) and represents the greatest value of stress that can be developed in the alloy without fracture. The unit of measure for UTS is the megapascal. Two types of stress-strain curves are observed for tensile testing of casting alloys. Alloys of high ductility undergo substantial necking in the central portion of the test specimen between the UTS and the breaking strength. The load required to impose increasing true stress over the instantaneous cross-section area actually decreases with increasing permanent strain (see Fig. 19-18). Other alloys of more limited ductility undergo much less necking, and the stress continues to increase after the yield strength until fracture occurs at the UTS. The UTS has minimal practical importance for a ceramic alloy because the corresponding permanent strain does not occur under clinical conditions for a restoration. Nevertheless, this property is easy to measure, inasmuch as a strain-gauge extensometer does not need to be attached to the specimen, and manufacturers often quote the UTS.

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Percentage of Elongation

For metals, ductility—the capability of undergoing permanent tensile deformation—is measured in two ways when the test specimen is loaded to fracture: as percentage of elongation or as reduction in area. For dental alloy castings, ductility is measured as the percentage of permanent elongation of the starting gauge length, after the two portions of the fractured specimen are placed back together. This measurement is made because castings typically fracture on inclined planes whose locations are determined by porosity, and a well-defined area for the fracture surface is not available for measurement of the reduction in area. It is difficult to obtain precise registration of the two fractured portions and to define the location of the original gauge length; therefore, it is difficult to determine the percentage of elongation to better than the nearest 1%, although values to the nearest 0.1% have been quoted. In principle, the percentage of elongation (often termed *elongation*) can be calculated during the stress-strain test if a breakaway extensometer is attached to the specimen. However, such extensometers are rarely available in dental materials laboratories. Figure 19-18 exaggerates the more important elastic range of the stress-strain curve, inasmuch as for current casting alloys used for porcelain veneering, the values of percentage of elongation generally exceed 10% (Table 19-2). The stress-strain plots for some alloys listed in Table 19-2 are instructive because they show readily that the region of permanent deformation is much more extensive on the strain axis than in the region of elastic deformation. An excellent example of a published stress-strain plot for an alloy with high percentage of elongation is provided in the classic article by Asgar and colleagues.[22] When considering the ease of adjustment for cast restorations, the practitioner must remember that both yield strength and percentage of elongation are involved.[23] Alloys with high yield strength cannot be burnished by hand, even if they have high percentages of elongation.

Toughness

Toughness, the total area under the stress-strain curve, was historically considered an important property of casting alloys. However, with the focus on stresses that do not exceed the yield strength, this property no longer receives as much attention. Toughness represents the total energy per unit volume necessary to fracture the alloy and is represented as units of stress × strain, or megapascals. For an alloy that does not work harden greatly and has substantial ductility, toughness is approximately equal to UTS × elongation. Determining toughness from stress-strain plots is laborious, and manufacturers do not report this property.

Thermal Expansion/Contraction

The linear coefficient of thermal expansion is a crucial property for an alloy that is to be bonded to dental porcelain. These coefficients should be closely matched to within approximately 0.5×10^{-6}/°C below the glass transition temperature of the porcelain (which can range from approximately 500° to 700°C, depending on the cooling rate and specific product[24-26]), at which the ceramic can no longer undergo viscous flow to relieve thermal incompatibility stresses. The thermal contraction coefficient (α), generally assumed to be the same as that for thermal expansion, should be slightly higher for the metal so that the ceramic is in a state of beneficial residual *compressive stress* at room temperature. Values of α typically range from 13.5 to 14.5×10^{-6}/°C for metals and 13.0 to 14.0×10^{-6}/°C for porcelains, and there is some dependence of α on the heating/cooling rate of the porcelain.[27]

Density

Density is the ratio of mass to volume; specific gravity is the ratio of the density of a substance to the density of water. Densities for the important types of noble and base metal casting alloys are provided in Table 19-2. The alloys with high gold content have much higher densities than those with low gold content, palladium-based alloys, and base metal casting alloys. This is because gold has a much higher density (19.3 g/cm^3) than do palladium (12.0 g/cm^3), nickel (8.9 g/cm^3), and cobalt (8.8 g/cm^3). These differences in density have two consequences. First, for cast restorations of the same size and configuration, less mass of metal is required for the lower density alloy; the difference in the metal cost for a restoration can be substantial when both the unit metal cost and the density difference are considered. Second, additional winding of the spring on the centrifugal casting machine is necessary to achieve the needed casting pressure for the lower density alloys.

Available Alloy Systems

The nomenclature for dental casting alloys usually creates confusion. Classifying noble and base metal casting alloys according to the mechanism for corrosion resistance is the preferred method of categorization. The gold-based and palladium-based noble metal casting alloys achieve corrosion resistance because of the inherent nobility of the gold and palladium atoms, which do not form stable oxides at room temperature. In contrast, the conventional base metal casting alloys—in which nickel and cobalt are the principal elements and chromium is present to provide corrosion resistance—oxidize rapidly to form a chromium oxide surface layer that blocks the diffusion of oxygen and prevents corrosion of the underlying metal (passivation). Titanium and titanium alloys also oxidize rapidly, and the thin surface layer of titanium oxide provides corrosion resistance.

Historically, terms such as *precious*, *semiprecious*, and *nonprecious* have been used to describe dental casting alloys. Precious or semiprecious alloys usually contain a greater quantity of silver, along with more palladium and less gold. Silver, which is not a noble metal in the oral environment, assumes some noble metal character in the presence of palladium. Because the terms *precious*, *semiprecious*, and *nonprecious*, which refer to unit metal cost, are now less preferable than the terms *noble* and *base* metals, which refer to the electrochemical character of the alloys.

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TABLE 19-2 **Alloys for Porcelain Veneering**

	High-Noble Alloys											
	GOLD-PLATINUM-PALLADIUM (Au-Pt-Pd)				GOLD-PALLADIUM-SILVER (Au-Pd-Ag)				GOLD-PALLADIUM (Au-Pd)			
Characteristic	*JELENKO O (JELENKO/ARGEN)*	*IMAGE 2 (DENTSPLY)*	*Y (IVOCLAR VIVADENT)*	*ARGEDENT Y86 (ARGEN)*	*CAMEO (JELENKO/ARGEN)*	*VERITAS (DENTSPLY)*	*W-2 (IVOCLAR VIVADENT)*	*ARGEDENT 52 (ARGEN)*	*OLYMPIA (JELENKO/ARGEN)*	*ECLIPSE (DENTSPLY)*	*W-3 (IVOCLAR VIVADENT)*	*ARGEDENT 65SF (ARGEN)*
Composition (weight %)	Au: 87.4 Pt: 4.5 Pd: 5.9 Ag: 1 Sn, In, Ir, Fe: <1	Au: 84.5 Pt: 6.9 Pd: 5.0 Ag: 1.0 Other: In, Fe, Zn, Re	Au: 84.0 Pt: 7.1 Pd: 5.7 Ag: 1.5 Sn, In, Re, Fe, Li: <1	Au: 86 Pt: 10 Pd: 1.9 In: 2 Ir: <1	Au: 52.5 Pd: 26.9 Ag: 16 In: 2.5 Sn: 2 Ru: <1	Au: 40.0 Pd: 45.0 Ag: 4.9 Other: Sn, Zn, In, Re	Au: 44.8 Pd: 40.5 Ag: 5.9 In: 3.3 Sn: 2.2 Ga: 1.8 Ru, Re, Al, Si, B, Ni, Li: <1	Au: 52.5 Pd: 26.9 Ag: 16 In: 2.5 Sn: 2 Ru: <1	Au: 51.5 Pd: 38.4 In: 8.5 Ga: 1.5 Ru: <1	Au: 52.0 Pd: 37.5 Other: Zn, Sn, In, Re	Au: 48.7 Pd: 39.6 In: 10.6 Sn, Ga, Ru, Re, B, Li: <1	Au: 65 Pd: 26 In: 8.7 Ga, Ru: <1
Yield strength (MPa)	401 (S) 448 (H)	671 (AF)	435 (AF)	405 (S) 469 (H)	540 (S) 586 (H)	425 (AF)	540 (AF)	540 (S) 586 (H)	550 (S)	575 (AF)	495 (AF)	550 (S)
Elastic modulus (GPa)	97	—	81	76	118	—	113	118	124	—	128	121
Tensile strength (MPa)	438 (S) 490 (H)	—	—	475 (S) 530 (H)	642 (S) 690 (H)	—	—	642 (S) 690 (H)	790 (S)	—	—	690 (S)
Elongation (%)	9 (S) 5 (H)	7 (AF)	10 (AF)	12 (S) 9 (H)	12 (S) 10 (H)	40 (AF)	20 (AF)	12 (S) 10 (H)	30 (S)	23 (AF)	17 (AF)	15 (S)
Vickers hardness number (VHN)	150 (AF) 185 (H)	230 (AF)	170 (AF)	160 (AF) 195 (H)	200 (AF) 225 (H)	232 (AF)	205 (AF)	200 (AF) 225 (H)	250 (AF)	254 (AF)	225 (AF)	250 (AF)
Density (g/cm^3)	18.5	18.0	17.4	18.4	14.2	13.0	13.4	14.2	14.4	13.8	13.8	15.2

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Noble Alloys

Characteristic	PALLADIUM-SILVER (Pd-Ag)					PALLADIUM-COPPER-GALLIUM (Pd-Cu-Ga)			
	JELSTAR (JELENKO/ARGEN)	*APPLAUSE (DENTSPLY)*	*W-1 (IVOCLAR VIVADENT)*	*ARGELITE 55 (ARGEN)*	*ARGISTAR YELLOW LF (ARGEN)*	*LIBERTY (JELENKO/ARGEN)*	*OPTION (DENTSPLY)*	*SPARTAN PLUS (IVOCLAR VIVADENT)*	*ARGELITE 76SF+ (ARGEN)*
Composition (weight %)	Pd: 59.9 Ag; 28 Sn: 6 In: 6 Ru: <1	Pd: 54.9 Ag: 35.0 Other: Sn, Zn, Ir	Pd: 53.3 Ag: 37.7 Sn: 8.5 In, Ru, Li: <1	Pd: 55 Ag: 34 In: 6 Sn: 3 Zn: 1 Ga, Ru: <1	Pd: 40 Ag: 24.8 In: 32 Au: 2 Zn: 1 Ir: < 1	Pd: 75.9 Cu: 10 Ga: 5.5 Sn: 6 Au: 2 Ru: <1	Pd: 78.9 Cu: 10.0 Au: 2.0 Other: Ga,* Ir, B	Pd: 78.8 Cu: 10.0 Ga: 9.0 Au: 2.0 Li, Ge, Ir: <1	Pd: 75.7 Cu: 7.5 Ga: 6.3 In: 8 Au: 1.8 B, Ru, Sn: <1
Yield strength (MPa)	462 (S)	590 (AF)	450 (AF)	400 (S) 724 (H)	271 (S)	689 (S)	900 (AF)	795 (AF)	1005 (S) 1103 (H)
Elastic modulus (GPa)	137	—	114	125	64	138	—	97	130
Tensile strength (MPa)	648 (S)	—	—	641 (S) 966 (H)	—	999 (S)	—	—	1,201 (S) 1,310 (H)
Elongation (%)	20 (S)	11 (AF)	11 (AF)	38 (S) 10 (H)	5 (S)	20 (S)	23 (AF)	20 (AF)	19 (S) 16 (H)
Vickers hardness number (VHN)	190 (AF)	240 (AF)	240 (AF)	170(AF) 330 (H)	180 (AF)	345 (AF)	425 (AF)	310 AF)	290 (AF) 315 (H)
Density (g/cm^3)	11.4	10.8	11.1	11.1	10.6	10.7	10.6	10.7	11.2

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TABLE 19-2 **Alloys for Porcelain Veneering—cont'd**

	Noble Alloys			**Predominantly Base Alloys**					
	PALLADIUM-GALLIUM (Pd-Ga)			NICKEL-CHROMIUM (Ni-Cr)			COBALT-CHROMIUM (Co-Cr)		
Characteristic	*LEGACY (JELENKO)*	*PROTOCOL (IVOCLAR VIVADENT)*	*ARGELITE 80 + 5 (ARGEN)*	*ARGELOY N.P. (ARGEN)*	*ARGELOY N.P. (BE-FREE) (ARGEN)*	*4ALL (IVOCLAR VIVADENT)*	*GENESIS II (JELENKO)*	*ARGELOY N.P. SPECIAL (ARGEN)*	*D.SIGN 30 (IVOCLAR VIVADENT)*
Composition (weight %)	Pd: 85.1 Ga: 10 In: 1.2 Ag: 1.2 Au: 2 Ru: <1	Pd: 75.2 Ga: 6.0 In: 6.0 Au: 6.0 Ag: 6.5 Ru, Li: <1	Pd: 79.9 Ga: 6.3 In: 6.5 Au: 4.8 Ag: 1.8 Ru, Zn: <1	Ni: 76 Cr: 14 Mo: 6 Al: 2 Be: 1.8 C, Si, Fe: <1	Ni: 54 Cr: 22 Mo: 9 Fe: 4 Nb: 4 Ta: 4 C, Si, Al: <1	Ni: 61.4 Cr: 25.7 Mo: 11.0 Si: 1.5 Mn, Al, C: <1	Co: 52.6 Cr: 27.5 W: 12 Ru: 2.5 Ga: 2.5 Fe: 1.0 Cu: 1.0 Si, Nb, Ta: <1	Co: 59.5 Cr: 31.5 Mo: 5 Si: 2 B, Fe, Mn: <1	Co: 60.2 Cr: 30.1 Ga: 3.9 Nb: 3.2 Mo, Si, B, Fe, Al, Li: <1
Yield strength (MPa)	634 (S)	500 (AF)	585 (S)	552(S)	360 (S)	375 (AF)	517 (S)	710 (S)	520 (AF)
Elastic modulus (GPa)	117	103	120	192	160	200	172	280	234
Tensile strength (MPa)	793 (S)	—	815 (S)	1,138 (H)	580 (S)	—	765 (H)	765 (S)	—
Elongation (%)	18 (S)	34 (AF)	33 (S)	12 (S)	6 (S)	12 (AF)	15 (S)	5 (S)	6 (AF)
Vickers hardness number (VHN)	265 (AF)	235 (AF)	260 (AF)	240 (AF)	240 (AF)	235 (AF)	325 (AF)	430 (AF)	385 (AF)
Density (g/cm^3)	11.4	11.0	11.5	7.8	8.6	8.4	8.8	8.8	7.8

Notes: Composition information was obtained from manufacturers' websites. Information about mechanical properties was also obtained from these websites, and they correspond to the condition after porcelain firing *(AF),* the hardened condition *(H)* after furnace heat treatment, or the soft condition *(S)* after quenching, depending on the manufacturer. Yield strength values correspond to 0.2% offset.[20] *Dash* indicates that no value of the mechanical property was provided by the manufacturer.

Information about Jelenko alloys can be accessed at http://www.jelenko.com. In February 2006, Jelenko was acquired by Argen Corporation (http://www.argen.com).

Dentsply Prosthetics (http://prosthetics.dentsply.com/fixed) markets the former Ney alloys.

Ivoclar Vivadent (www.ivoclarvivadent.us.com) markets the former Williams/Ivoclar alloys.

Al, Aluminum; *B,* boron; *Be,* beryllium; *C,* carbon; *Fe,* iron; *Ge,* germanium; *H,* hard; *In,* indium; *Ir,* iridium; *Li,* lithium; *Mn,* manganese; *Mo,* molybdenum; *Nb,* niobium; *Re,* rhenium; *Ru,* ruthenium; *Si,* silicon; *Sn,* tin; *Ta,* tantalum; *W,* tungsten; *Zn,* zinc.

*The amount of gallium in Option is not provided on the Dentsply Prosthetics website, but Carr and Brantley[29] described it as approximately 9%.

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TABLE 19-3 **Revised American Dental Association Classification of Alloys for Fixed Prosthodontics**

Classification	Requirement*
High-noble alloys	Noble metal content ≥ 60% (gold + platinum group metal) and gold ≥ 40%
Titanium and titanium alloys	Titanium ≥ 85%
Noble alloys	Noble metal content ≥ 25% (gold + platinum group metal)
Predominantly base alloys	Noble metal content < 25% (gold + platinum group metal)

*The platinum group metals are platinum, palladium, rhodium, iridium, osmium, and ruthenium.

The major noble metals in dental alloys are gold, platinum, and palladium. (The other noble metals are iridium, ruthenium, rhodium, and osmium.) The total percentage of gold, platinum, and palladium in a dental alloy is referred to as the *noble metal content*. Iridium (much less than 1% by weight) and ruthenium (up to approximately 1%) are used as grain-refining elements in gold-based and palladium-based casting alloys, respectively. The original metal-ceramic alloy compositions (e.g., Jelenko O, described in Table 19-2) had approximately 98% noble metal content by weight. Rapid increases in the price of gold during the 1970s stimulated the development of alloys with lower gold content (from approximately 85% to 50% by weight) and base metal alloys for fixed prosthodontics.[28] During the 1980s, the high-palladium alloys were developed as economic alternatives to the gold-based alloys.[29]*

After a report by its Council on Scientific Affairs,[30] the American Dental Association revised the classification system for alloys for fixed prosthodontics[31]; the revised system is presented in Table 19-3 and now includes a fourth group, which comprises titanium and titanium alloys. The classifications are based solely on gold, noble metal, or titanium content, and other, often crucial, alloying elements are ignored; therefore, general statements cannot be made about mechanical properties, clinical performance, and biocompatibility, even within each of the four groups in Table 19-3. Hundreds of dental alloys are commercially available, and appropriate testing is necessary to characterize the properties, safety, and efficacy of each. However, when major groups are further subdivided into alloy types, some accurate generalizations are possible. They are discussed in the following sections.

*In April 2015, the price of palladium was approximately $770 per Troy ounce, in comparison with a price of approximately $1200 per Troy ounce for gold. In January 2006, the price of palladium was approximately $275 per Troy ounce, in comparison with a price of approximately $555 per Troy ounce for gold. In January 1997, the price of palladium was $120 an ounce, which increased to approximately $1000 per ounce by January 2001 and then began to decline thereafter. The corresponding rapid increases in palladium dental alloy prices caused many problems at that time for alloy selection by dentists and the dental laboratory industry. The very large fluctuations in the price of gold since 2005 have renewed interest in alternative, less expensive alloys and new dental laboratory technologies for fixed prosthodontics.

High-Noble Alloys

The high-noble alloys are gold based and contain a minimum of 60% by weight of noble elements; at least 40% is gold. There are three systems in this class: gold-platinum-palladium (Au-Pt-Pd), gold-palladium-silver (Au-Pd-Ag), and gold-palladium (Au-Pd), in the historical order of their development. Table 19-2 lists some mechanical properties and the density for representative alloys of each system.

Gold-Platinum-Palladium. As previously noted, these were the first casting alloys formulated to bond with dental porcelain. Because of concern about adverse effects on the color of dental porcelain, copper (which was traditionally used for strengthening the high-noble casting alloys for all-metal restorations) could not be incorporated in the ceramic alloy compositions. Instead, these alloys were strengthened by precipitates of an iron-platinum (Fe-Pt) intermetallic compound.[32] Porcelain adherence was achieved by the incorporation of tin and indium in the alloys, in addition to the contribution from iron. During the initial alloy oxidation step for the porcelain firing cycles, tin and indium (as well as some iron) diffused to the alloy surface and became oxidized. Subsequent chemical bonding was achieved between this oxide layer and the dental porcelain (see Chapter 24). Although these alloys have excellent corrosion resistance, they are susceptible to some dimensional changes during the porcelain firing cycles and are not recommended for multiple-unit FDPs.

Gold-Palladium-Silver. These were the first lower gold content alternative alloys to be widely used in the 1970s. Platinum was eliminated from the alloy compositions, and the gold content was reduced to approximately 50%, with corresponding increases in the amounts of palladium and silver.[33,34] Some alloy strengthening was achieved by solid solution hardening from the dissimilar atomic sizes of the three major elements (gold, palladium, and silver), which form solid solutions with each other. Additional solid solution strengthening was hypothesized to be caused by tin or indium, which were again incorporated as oxidizable elements to provide porcelain bonding. Further alloy strengthening may be caused by precipitates formed by these elements. Although these alloys have excellent mechanical properties and porcelain adherence, green discoloration (resulting from diffusion of silver atoms into the porcelain) has been reported for some Au-Pd-Ag alloy–porcelain combinations.[35] Possible reasons for this effect may be the high sodium concentration of the porcelain or the relative sizes of the metal ions in the porcelain. The discolored region can be ground away, but this involves an additional processing step. In addition, silver vapor generated in the porcelain furnace during processing can contaminate the muffle, and periodic purging of the furnace with a carbon block is required. Green discoloration has apparently been

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eliminated in some porcelain compositions by the substitution of potassium ions for sodium ions; the larger potassium ions impede the diffusion of silver into the porcelain.

Gold-Palladium. Gold-palladium alloys that are silver free were developed during the late 1970s and have become very popular. Alloy strengthening is achieved with a combination of solid solution hardening and microstructural precipitates. The hardness (assumed to be related to strength) of these alloys is independent of heat-treatment temperature within the porcelain-firing range, unlike that of Au-Pd-Ag alloys.[34] The Au-Pd alloys have excellent mechanical properties, elevated-temperature creep behavior,[36] and porcelain adherence,[37] without the green discoloration associated with Au-Pd-Ag alloys.

Discussion. The data in Table 19-2 show that the Au-Pd and Au-Pd-Ag alloys, in comparison with the Au-Pt-Pd alloys, generally have higher values of yield strength and elastic modulus, along with lower density. Consequently, FDPs fabricated from alloys in the former two groups are more resistant to masticatory forces and undergo less bending deflection. They are also economically advantageous in that more restorations can be made per unit of alloy cost. Selection of the proper porcelain for Au-Pd-Ag alloys is essential if discoloration problems are to be avoided.

Noble Alloys

Noble alloys have a minimum of 25% by weight of noble metal, with no requirement for gold percentage, and are palladium based. There are three alloy systems in this class: palladium-silver (Pd-Ag), palladium-copper-gallium (Pd-Cu-Ga), and palladium-gallium (Pd-Ga), in the historical order of their development. Table 19-2 lists some mechanical properties and the density for representative alloys of each system.

Palladium-Silver. These alloys, developed in the 1970s, continued the trend by manufacturers of reducing the gold content (to between 0% and 2% by weight), with corresponding increases in the palladium and silver contents.[38] A small percentage of gold in these alloys and the high-palladium alloys has little effect on their properties but may facilitate third-party payments. As previously noted, in the presence of palladium, silver appears to assume noble metal character, which is beneficial for corrosion resistance. Because of their high silver content (approximately 30% to 35% by weight), these alloys have been called *semiprecious*, a term that should no longer be used. In comparison with the Au-Pd-Ag and Au-Pd alloys, the Pd-Ag alloys have similar values of yield strength and elastic modulus and much lower density values. Because of their high silver contents, porcelain greening and furnace contamination can result during fabrication of such FPDs, unless the porcelain is carefully selected. Nevertheless, these alloys are frequently chosen as a compromise between the more expensive high-noble alloys and the relatively inexpensive base metal alloys. Microstructural details have been reported for conventional Pd-Ag alloys, which can undergo age hardening and have excellent tolerance of casting porosity for fatigue behavior.[39-41]

An exciting development is the introduction of a new palladium-silver-indium (Pd-Ag-In) alloy composition for low-fusing and high–thermal expansion porcelains by Argen that contains only 2% gold by weight but has an esthetically pleasing yellow shade. This alloy (Argistar Yellow LF) is included in Table 19-2, where it can be seen that it has lower values for yield strength, elongation, and elastic modulus than do the other listed conventional Pd-Ag alloys. The yellow appearance results from the proportions of indium and palladium in the alloy's composition. Metallurgical characterization of a Pd-Ag alloy[42] that also contained large relative proportions of palladium and indium suggests that the Pd-In intermetallic compound has a pivotal role in the mechanical properties and appearance of this alloy.

Palladium-Copper-Gallium. The Pd-Cu-Ga alloys contain more than 70% by weight of palladium and were developed in the early 1980s as economical alternatives to the gold-based alloys.[29] The melting point of palladium (1555°C) is much higher than that of gold (1064°C); gallium has a melting point of 30°C. The addition of gallium to palladium yields high-palladium alloys that can be fused and cast with the same dental laboratory technology developed for the gold-based casting alloys. Multiorifice torches are necessary to fuse the high-palladium alloys, and the use of ceramic crucibles dedicated to individual alloys is recommended.[29] Carbon-containing investments should not be used because the incorporation of very small amounts of carbon in these alloys degrades the bond strength with porcelain.[43] The casting accuracy of Pd-Cu-Ga alloys appears comparable with that of the high-noble metal alloys.[44]

Measurements[45,46] of the mechanical properties of some Pd-Cu-Ga alloys have produced values of yield strength, elastic modulus, and percentage of elongation that differ from values in Table 19-2. This suggests some technique sensitivity in the fabrication of cast specimens for the tension test. Although a near-surface eutectic structure was present in castings from one Pd-Cu-Ga alloy that simulated copings for maxillary incisors,[29] this constituent was absent in the 3-mm diameter cast specimens for the tension test.[46] Some Pd-Cu-Ga alloys have hardness values comparable with or exceeding that of tooth enamel, and castings from these alloys may be difficult to finish in the dental laboratory. In addition, chairside adjustments may be difficult for patients. However, substitution of indium for tin yields Pd-Cu-Ga alloys with much lower hardness (VHN = 270).[47] All these alloys achieve substantial hardening by solid-solution incorporation of other elements within the palladium crystal structure. The hardest Pd-Cu-Ga alloys (VHN > 300) contain a hard grain boundary phase whose composition is close to that of Pd_5Ga_2.[47]

Transmission electron microscope studies indicate that representative high-palladium alloys (both Pd-Cu-Ga and Pd-Ga alloys) have the same bulk ultrastructure at the

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submicron level, termed *tweed structure*.[48,49] Analyses of x-ray diffraction patterns have revealed that oxidized Pd-Cu-Ga alloys have complex internal oxidation regions that can exhibit up to five different oxide phases.[50] Oxides of copper, gallium, tin, indium, and even palladium that were formed under the conditions present in the porcelain furnace were subsequently detected in the oxidized alloys at room temperature. The results of creep experiments on the Pd-Cu-Ga alloys have been mixed.[36] The creep rates associated with relatively high thermal incompatibility stresses near the glass transition temperature of dental porcelain were high for two Pd-Cu-Ga alloys, whereas these alloys had excellent creep resistance at high temperatures and low stresses simulating the deflection of a long-span FDP as a result of gravity during processing.

Palladium-Gallium. The copper-free Pd-Ga alloys were subsequently developed during the 1980s to provide compositions with hardnesses lower than those of the initial Pd-Cu-Ga formulations. The hard Pd_5Ga_2 phase is absent in these alloys, which are strengthened by solid solution hardening.[47] The alloys have a complex fine precipitate structure at the grain boundaries,[29,51] and their mechanical properties are generally more similar to those of Pd-Ag alloys than to the Pd-Cu-Ga alloys. A palladium-gallium-cobalt (Pd-Ga-Co) alloy[52] has a particularly dark oxide that is more difficult to mask with dental porcelain, and this alloy did not achieve widespread clinical acceptance.

Discussion. In one study, investigators compared the dimensional changes at various stages of the simulated porcelain firing cycles in copings for metal-ceramic single-unit restorations of selected high-palladium alloys.[53] They found that most of the selected high-palladium alloys had acceptable high-temperature distortion. Because the price of palladium has been considerably volatile since the mid-1990s, dentists and dental laboratories have tended to select Au-Pd alloys, Pd-Ag alloys, and alloys with lower gold content, rather than alloys with high palladium content. Currently, the unit metal cost of gold is substantially higher than that of palladium, and high-palladium alloys again have a significant economic advantage over gold-palladium alloys. When the high-palladium alloys were introduced in the 1980s, the unit metal cost was between half and one-third that of the Au-Pd alloys.[29] However, caution is needed with the Pd-Ag alloys to prevent porcelain from acquiring green discoloration. Some biocompatibility concerns have been raised about the high-palladium alloys, particularly in Germany with the Pd-Cu-Ga alloys. Two review articles[54,55] suggested that minimal health hazards are associated with the palladium dental alloys, and this has been supported by studies of potentiodynamic polarization,[56-58] cell culture,[59] elemental release,[57,60] and animal implantation.[61] However, another review article cautioned about drawing conclusions for the biocompatibility of casting alloys from in vitro studies.[62]

Predominantly Base Metal Alloys

Table 19-3 defines these alloys (sometimes termed *nonprecious*) as having less than 25% by weight of noble metal with no requirement for gold. Of these alloys, most used for fixed prosthodontics are nickel-chromium (Ni-Cr) alloys, but some cobalt-chromium (Co-Cr) alloys have also been formulated for porcelain application.

Nickel-Chromium. The complex metallurgy and manipulation of these alloys are described in a review article.[63] Yield strength, hardness, and elastic modulus can be greatly affected by small differences in weight percentages of secondary elemental components among the compositions of these alloys. Table 19-2 illustrates some of these variations. For example, values of yield strength for the three representative alloys listed vary from approximately 360 to 550 MPa, whereas the average VHN for these alloys is approximately 240. Consequently, the selection of a specific brand of Ni-Cr alloy depends on the strength needed for the particular clinical application. If burnishing or extended finishing of a crown is anticipated, a brand with a relatively low yield strength and low hardness should be used.

One benefit of these alloys is that their values of elastic modulus are much higher than those of the noble metal alloys. Therefore, long-span fixed prostheses fabricated from Ni-Cr alloys undergo much less flexure than do similar prostheses fabricated from noble metal alloys, and the brittle dental porcelain component is less likely to fracture. These base metal casting alloys are generally considered more technique sensitive and difficult to cast than the noble metal casting alloys. However, this assessment may reflect the lack of experience of some dental laboratories with the Ni-Cr alloys; excellent results for castability of these alloys have been published.[64] Therefore, the choice of dental laboratory is particularly important when these alloys are selected.

Beryllium. Many Ni-Cr alloy formulations contain up to 2% by weight of beryllium. The major reason for incorporating this element in the alloy is to lower the melting range and to decrease the viscosity of the molten alloy, thereby improving its castability. Beryllium also provides strengthening and affects the thickness of the oxide layer when the alloy is oxidized for porcelain firing. The thickness of the oxide layer is an important consideration for base metal casting alloys, which can form much thicker oxide layers than do noble metal casting alloys. Fracture through the oxide layer may occur and cause failure of the base metal–ceramic restoration.

The use of beryllium has created some doubt about the safety of some Ni-Cr alloys. Of importance is that when the densities of nickel (8.9 g/cm^3) and chromium (7.2 g/cm^3) are compared with that of beryllium (1.8 g/cm^3), 2% by weight of beryllium in the alloy composition can be equivalent to nearly 10% beryllium on an atomic basis. Consequently, the atomic proportion of beryllium atoms in these alloy compositions can be relatively large.

Nickel. The U.S. federal standard for exposure to metallic nickel and soluble nickel compounds (1 mg/m^3 for an 8-hour time-weighted average concentration) is much higher than the recommendation by the National Institute for Occupational Safety and Health for such exposure (15 $\mu g/m^3$ for a 10-hour time-weighted average workday). Occupational exposure of refinery workers to nickel has been associated with lung and nasal cancer.

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Acute effects of exposure to nickel include skin sensitization that can lead to chronic eczema. Therefore, as a health precaution, an operator should wear a mask and use efficient suction when grinding and finishing a dental nickel-based alloy.

It has been reported that 9% of the female population and 0.9% of the male population are sensitive to nickel.[65] This prompts a question: Are such individuals likely to manifest an adverse reaction to dental Ni-Cr alloys? In a 20-participant clinical study[66] to investigate this question, each of 10 control participants (who had no known sensitivity to nickel) showed a negative dermal response and a negative intraoral response to a dental Ni-Cr alloy. Of 10 participants with a known sensitivity, 8 showed a positive dermal response to the alloy. When the sensitive participants wore an intraoral appliance containing the Ni-Cr alloy, 30% manifested an allergic response within 48 hours.

According to the American Dental Association's labeling requirement for base metal alloys that contain nickel, such alloys should not be used in individuals with known nickel sensitivity. Another question now arises: Can patients who are not allergic to nickel become sensitive to it from FDPs made with nickel-containing alloys?

In one investigation,[67] researchers found that Ni-Cr alloys not containing beryllium were more resistant to in vitro corrosion than were beryllium-containing alloys. The four alloys studied showed lower corrosion rates in cell culture solutions after cold solution sterilization. Although the corrosion products released from the alloys did not alter the cellular structure and viability of human gingival fibroblasts, reductions in cellular proliferation were observed. The authors concluded that there still exist biocompatibility concerns relating to the exposure of local and systemic tissues to elevated levels of corrosion products from the Ni-Cr alloys.

Cobalt-Chromium. The potential health problems associated with beryllium- and nickel-containing alloys have led to the development of another alternative base metal alloy system: cobalt-chromium.[68,69] The representative Co-Cr alloys listed in Table 19-2 have higher hardness than do the Ni-Cr alloys listed, which suggests that finishing restorations made with the former alloys may be more difficult. The absence of other definitive comparisons in mechanical properties of these currently marketed Ni-Cr and Co-Cr alloys in Table 19-2 is the result of their complex metallurgic characteristics.

Titanium and Titanium Alloys. Titanium-based alloys have been studied since the late 1970s as potential dental casting alloys.[70] Advantages of titanium and titanium alloys include excellent biocompatibility and corrosion resistance, which results from the previously noted presence of a thin, adherent, passivating surface layer of titanium dioxide (TiO_2). The low density (4.5 g/cm^3) of titanium, in comparison with that of gold or palladium, also results in lighter restorations that are potentially less expensive. (However, the laboratory cost of fabricating cast restorations from titanium alloys may be high.) Pure titanium below approximately 882 °C exists in the α phase, which has a hexagonal close-packed structure; at higher temperatures, the atomic arrangement transforms to the body-centered cubic β phase. Some alloying elements, such as aluminum, stabilize in the α phase at higher temperatures, whereas other alloying elements, such as vanadium, stabilize in the β phase at lower temperatures.[71]

For fixed prosthodontics, the focus has been on (1) commercially pure titanium (sometimes termed *unalloyed titanium*), which is α phase and contains an upper limit of 1% by weight of impurities for American Society for Testing and Materials (ASTM) grade 4 (strongest grade), and (2) the highly popular engineering alloy titanium–6% aluminum–4% vanadium (Ti-6Al-4V), containing 90% titanium by weight. The Ti-6Al-4V alloy has a duplex microstructure containing both α and β phases and is much stronger than commercially pure titanium.

There has been interest in the titanium–6% aluminum–7% niobium (Ti-6Al-7Nb) α-β alloy, which was advocated because of concern with the cytotoxicity of vanadium and the poor wear resistance of commercially pure titanium.[72-75] According to one report of laboratory investigations of SaOS-2 (sarcoma osteogenic) cells, titanium, tantalum, niobium, and zirconium in bulk form (not powders) exhibited excellent cytotoxicity.[76] The titanium–35% niobium–5% zirconium (Ti-35Nb-5Zr; α-β structure) and titanium–35% niobium–10% zirconium (Ti-35Nb-10Zr; β structure) casting alloys for dental implants have been investigated,[77] but further studies of corrosion resistance and alloy biocompatibility are needed. The β-Ti alloys have lower values of elastic modulus than do the α-Ti and α-β Ti alloys, which make them desirable for orthopedic implant alloys, in which stress shielding of bone is a concern.[78]

The dental casting of titanium and titanium alloys poses special problems because of the high melting point of titanium (1668°C) and its strong tendency to oxidize and react with other materials.[79] These problems were well known by earlier investigators.[79-89] Titanium dental casting machines that represent a substantial expense must provide either a vacuum environment or an argon atmosphere. Both vacuum/argon pressure and centrifugal casting machines have been developed, and both argon-arc melting and induction melting have been used to fuse titanium and titanium alloys. Patterns for casting are coated, and special investments must be used to provide the appropriate expansion. Reaction of titanium or titanium alloy with the investment (and perhaps with the residual atmosphere in the casting machine) results in a very hard near-surface region (termed *α case*) that can exceed 50 μm in thickness. Selecting a dental laboratory experienced in fabricating titanium and titanium alloy castings is essential, and such dental laboratories are not common in the United States.

Advances have occurred in investments,[90-93] casting methodology,[94-98] and understanding of the castability and casting accuracy[99-101] of titanium, along with increased knowledge about α case and the grindability[87,102-104] of castings. Currently, titanium castings of clinically acceptable accuracy can be produced, whereby the marginal fit of cast complete crowns is superior to that for titanium crowns milled by the computer-aided design/computer-assisted manufacturing (CAD/CAM) technique.[105]

New Technologies for Base Metal Alloys

Optomec (http://www.optomec.com) developed laser deposition, or LENS (laser-engineered net shaping),

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technology in which a high-power laser in an argon environment is used for melting elemental or alloy powders, which are directed onto a small area of a substrate through special nozzles to build up, layer by layer, a complex part in a raster pattern. One study revealed that idealized Ti-6Al-4V crowns prepared by laser deposition had poor marginal adaptation, but no near-surface α case, and a desirable fine-scale microstructure because of the rapid solidification conditions.[106,107] This technique enables functionally graded titanium alloy compositions to be created with controlled microstructures and mechanical properties for orthopedic applications.[108] However, further development of the LENS system is needed for clinical usage in prosthodontics, because dental restorations are much smaller than orthopedic implants.

In laser sintering/melting dental technology, developed by several companies (BEGO, Phenix Systems, EOS, and Biomain AB [now Heraeus Kulzer]), a high-power laser is used to selectively fuse particles lying on a powder bed and build a complex part layer by layer. Successful results for a model system[109] and for single crowns, three-unit FPDs, and an implant framework have been achieved with this process.[110-116] Biocompatible Co-Cr alloys have been used in most of these reported studies, but laser sintering has also been performed on titanium[109] and a gold-platinum alloy[108] with EOS and BEGO apparatus, respectively. Studies have shown that the laser-sintered Co-Cr alloy has a fine-scale microstructure[116,117] because of the small starting particle size and rapid fusing. This should be advantageous for mechanical properties. Detailed metallurgical mechanisms involved in the selective laser sintering of the particles are complex and involve a binder used in the powder bed.[118] As a result of further developments in laser sintering, this technology may replace the dental casting technology that has served the profession well for the past century.

In addition to the foregoing areas of laser deposition and laser sintering, which are examples of additive manufacturing, the complementary approach of subtractive manufacturing also has promise for the future. Amann Girrbach AG introduced Ceramill Sintron partially sintered Co-Cr alloy blanks that can be readily dry-milled by means of a desktop machine and subsequently final sintered in a special furnace with an argon atmosphere.[119] Both the milling machine and the furnace can be obtained from the manufacturer, which claims that the process yields restorations and frameworks with homogeneous and distortion-free structures. In a review article, van Noort[120] discussed the use of additive and subtractive manufacturing with CAD/CAM, along with other promising digital technologies that have the potential to revolutionize dental laboratory practice. Kim and colleagues[121] reported that the fit of dental prostheses (single crowns) prepared from a Co-Cr alloy was superior for the laser sintering and the subtractive manufacturing techniques, compared to the traditional lost wax and casting process.

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REVIEW OF TECHNIQUE

Figure 19-20 summarizes the steps involved in producing wax patterns for metal-ceramic restorations.

1. The restorations are waxed to anatomic contour (see Fig. 19-20, *A*).
2. The patterns are troughed to obtain correct porcelain thickness in the completed restoration (see Fig. 19-20, *B*).
3. The cutback is completed (see Fig. 19-20, *C*).
4. The margins are finalized before investing (see Fig. 19-20, *D*).

FIGURE 19-20 ■ Technique review. **A,** The restorations are waxed to anatomic contour. **B,** The patterns are troughed to obtain correct porcelain thickness in the completed restoration. **C,** The cutback is completed. **D,** The margins are finalized before investing.

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SUMMARY

Framework design for metal-ceramic restorations must be based on an understanding of fundamental material properties. Restorations should be waxed to anatomic contour and then cut back in the area that is to be veneered (Fig. 19-21). This creates an even porcelain thickness, which provides superior mechanical properties in the completed restoration while simultaneously standardizing shade reproduction.

FIGURE 19-21 ■ Step-by-step fabrication of metal-ceramic restorations. **A** and **B,** Definitive casts are articulated with an arbitrary facebow transfer and interocclusal records. **C** to **E,** The restorations are waxed to full anatomic contour, and the desired occlusal arrangement is verified. **F** and **G,** Elastomeric indexes fabricated from the anatomic contour waxing are used during the cutback phase to create a uniform space for the ceramic veneer. **H,** The same index is used when the metal substructure is finished.

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FIGURE 19-21, cont'd ■ **I** to **K,** Bisque bake is completed. At this stage, all functional and esthetic aspects of the restorations are refined. **L** to **N,** The completed restorations after glazing and metal finishing.

REFERENCES

1. Pjetursson BE, et al: A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years, part I: single crowns. Clin Oral Implants Res 18(Suppl 3):73, 2007.
2. Sailer I, et al: A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years, part II: fixed dental prostheses. Clin Oral Implants Res 18(Suppl 3):86, 2007.
3. Oh W-S, et al: Factors affecting enamel and ceramic wear: a literature review. J Prosthet Dent 87:451, 2002.
4. Pintado MR, et al: Variation in tooth wear in young adults over a two-year period. J Prosthet Dent 77:313, 1997.
5. Monasky GE, Taylor DF: Studies on the wear of porcelain, enamel, and gold. J Prosthet Dent 25:299, 1971.
6. Ekfeldt A, Øilo G: Occlusal contact wear of prosthodontic materials. Acta Odontol Scand 46:159, 1988.
7. Kelly JR, et al: Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent 75:18, 1996.
8. Hacker CH, et al: An in vitro investigation of the wear of enamel on porcelain and gold in saliva. J Prosthet Dent 75:14, 1996.
9. Ramp MH, et al: Evaluation of wear: enamel opposing three ceramic materials and a gold alloy. J Prosthet Dent 77:523, 1997.
10. Al-Wahadni AM, Martin DM: An in vitro investigation into the wear effects of glazed, unglazed and refinished dental porcelain on an opposing material. J Oral Rehabil 26:538, 1999.
11. Magne P, et al: Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent 82:669, 1999.
12. Clelland NL, et al: Relative wear of enamel opposing low-fusing dental porcelain. J Prosthodont 12:168, 2003.
13. Christensen GJ: The use of porcelain-fused-to-metal restorations in current dental practice: a survey. J Prosthet Dent 56:1, 1986.
14. Marker JC, et al: The compressive strength of nonprecious versus precious ceramometal restorations with various frame designs. J Prosthet Dent 55:560, 1986.
15. Terada Y, et al: The influence of different thicknesses of dentin porcelain on the color reflected from thin opaque porcelain fused to metal. Int J Prosthodont 2:352, 1989.
16. Craig RG, et al: Stress distribution in porcelain-fused-to-gold crowns and preparations constructed with photoelastic plastics. J Dent Res 50:1278, 1971.
17. Warpeha WS, Goodkind RJ: Design and technique variables affecting fracture resistance of metal-ceramic restorations. J Prosthet Dent 35:291, 1976.
18. Bhaskaran E, et al: Comparative Evaluation of Marginal and Internal Gap of Co-Cr Copings Fabricated from Conventional Wax Pattern, 3D Printed Resin Pattern and DMLS Tech: An In Vitro Study. J Indian Prosthodont Soc 13:189, 2013.
19. Douglas RD, et al: Dental students' preferences and performance in crown design: conventional wax-added versus CAD. J Dent Educ 78:1663, 2014.

WWW.HIGHDENT.IR
همیار دندانسازان و دندانپزشکان

20. International Organization for Standardization: Dentistry—metallic materials for fixed and removable restorations and appliances [Standard ISO 22674:2006]. Geneva, International Organization for Standardization, 2006.
21. Dieter GE: Mechanical metallurgy. 3rd ed. New York, McGraw-Hill, 1986.
22. Asgar K, et al: A new alloy for partial dentures. J Prosthet Dent 23:36, 1970.
23. Moon PC, Modjeski PJ: The burnishability of dental casting alloys. J Prosthet Dent 36:404, 1976.
24. Fairhurst CW, et al: Glass transition temperatures of dental porcelain. J Dent Res 60:995, 1981.
25. Twiggs SW, et al: Glass transition temperatures of dental porcelains at high heating rates. J Biomed Mater Res 20:293, 1986.
26. Ban S, et al: Glass transition temperatures of dental porcelains determined by DSC measurement. Dent Mater J 16:127, 1997.
27. Twiggs SW, et al: A rapid heating and cooling rate dilatometer for measuring thermal expansion in dental porcelain. J Dent Res 68:1316, 1989.
28. Valega TM, ed: Alternatives to gold alloys in dentistry [DHEW Publication No. (NIH) 77-1227]. Washington, D.C., U.S. Department of Health, Education, and Welfare, 1977.
29. Carr AB, Brantley WA: New high-palladium casting alloys. I. Overview and initial studies. Int J Prosthodont 4:265, 1991.
30. American Dental Association Council on Scientific Affairs: Titanium applications in dentistry. J Am Dent Assoc 134:347, 2003.
31. American Dental Association: Revised classification system for alloys for fixed prosthodontics. Accessed December 27, 2012, at http://www.ada.org/2190.aspx.
32. Fuys RA, et al: Precipitation hardening in gold-platinum alloys containing small quantities of iron. J Biomed Mater Res 7:471, 1973.
33. Civjan S, et al: Further studies on gold alloys used in fabrication of porcelain-fused-to-metal restorations. J Am Dent Assoc 90:659, 1975.
34. Vermilyea SG, et al: Observations on gold-palladium-silver and gold-palladium alloys. J Prosthet Dent 44:294, 1980.
35. Moya F, et al: Experimental observation of silver and gold penetration into dental ceramic by means of a radiotracer technique. J Dent Res 66:1717, 1987.
36. Anusavice KJ, et al: Interactive effect of stress and temperature on creep of PFM alloys. J Dent Res 64:1094, 1985.
37. Papazoglou E, et al: Porcelain adherence to high-palladium alloys. J Prosthet Dent 70:386, 1993.
38. Goodacre CJ: Palladium-silver alloys: a review of the literature. J Prosthet Dent 62:34, 1989.
39. Guo WH, et al: Transmission electron microscopic investigation of a Pd-Ag-In-Sn dental alloy. Biomaterials 24:1705, 2003.
40. Guo WH, et al: Annealing study of palladium-silver dental alloys: Vickers hardness measurements and SEM microstructural observations. J Mater Sci Mater Med 18:111, 2007.
41. Li D, et al: Study of Pd-Ag dental alloys: examination of effect of casting porosity on fatigue behavior and microstructural analysis. J Mater Sci Mater Med 21:2723, 2010.
42. Lee HK, et al: Age hardening by dendrite growth in a low-gold dental casting alloy. Biomaterials 25:3869, 2004.
43. Herø H, Syverud M: Carbon impurities and properties of some palladium alloys for ceramic veneering. Dent Mater 1:106, 1985.
44. Byrne G, et al: Casting accuracy of high-palladium alloys. J Prosthet Dent 55:297, 1986.
45. Papazoglou E, et al: Mechanical properties of dendritic Pd-Cu-Ga dental alloys. Cells Mater 9:43, 1999.
46. Papazoglou E, et al: Comparison of mechanical properties for equiaxed fine-grained and dendritic high-palladium alloys. J Mater Sci Mater Med 11:601, 2000.
47. Wu Q, et al: Heat-treatment behavior of high-palladium dental alloys. Cells Mater 7:161, 1997.
48. Cai Z, et al: Transmission electron microscopic investigation of high-palladium dental casting alloys. Dent Mater 13:365, 1997.
49. Nitta SV, et al: TEM analysis of tweed structure in high-palladium dental alloys. J Mater Sci Mater Med 10:513, 1999.
50. Brantley WA, et al: X-ray diffraction studies of oxidized high-palladium alloys. Dent Mater 12:333, 1996.
51. Brantley WA, et al: X-ray diffraction studies of as-cast high-palladium alloys. Dent Mater 11:154, 1995.
52. Syverud M, et al: A new dental Pd-Co alloy for ceramic veneering. Dent Mater 3:102, 1987.
53. Papazoglou E, et al: Evaluation of high-temperature distortion of high-palladium metal-ceramic crowns. J Prosthet Dent 85:133, 2001.
54. Cai Z, et al: On the biocompatibility of high-palladium dental alloys. Cells Mater 5:357, 1995.
55. Wataha JC, Hanks CT: Biological effects of palladium and risk of using palladium in dental casting alloys. J Oral Rehabil 23:309, 1996.
56. Sun D, et al: Potentiodynamic polarization study of the in vitro corrosion behavior of 3 high-palladium alloys and a gold-palladium alloy in 5 media. J Prosthet Dent 87:86, 2002.
57. Sun D: On the corrosion behavior and biocompatibility of palladium-based dental alloys [PhD dissertation]. Columbus, The Ohio State University, 2004.
58. Sun D, et al: Corrosion characteristics of palladium-silver dental alloys evaluated by potentiodynamic methods [Abstract no. 1348]. J Dent Res 84(Special Issue A), 2005.
59. Sun D, et al: Influence of palladium alloy elements on cell proliferation and viability [Abstract no. 2698]. J Dent Res 84(Special Issue A), 2005.
60. Tufekci E, et al: Inductively coupled plasma-mass spectroscopy measurements of elemental release from 2 high-palladium dental casting alloys into a corrosion testing medium. J Prosthet Dent 87:80, 2002.
61. Sun D, et al: Initial biocompatibility evaluation of two palladium-based alloys and a high-gold alloy from animal study [Abstract no. 131]. J Dent Res 82(Special Issue A), 2003.
62. Geurtsen W: Biocompatibility of dental casting alloys. Crit Rev Oral Biol Med 13:71, 2002.
63. Baran GR: The metallurgy of Ni-Cr alloys for fixed prosthodontics. J Prosthet Dent 50:639, 1983.
64. O'Connor RP, et al: Castability, opaque masking, and porcelain bonding of 17 porcelain-fused-to-metal alloys. J Prosthet Dent 75:367, 1996.
65. American Dental Association, Council on Dental Materials, Instruments, and Equipment: Biological effects of nickel-containing dental alloys. J Am Dent Assoc 104:501, 1982.
66. Moffa JP, et al: An evaluation of nonprecious alloys for use with porcelain veneers. II. Industrial safety and biocompatibility. J Prosthet Dent 30:432, 1973.
67. Bumgardner JD, Lucas LC: Corrosion and cell culture evaluations of nickel-chromium dental casting alloys. J Appl Biomater 5:203, 1994.
68. Vermilyea SG, et al: Observations on nickel-free, beryllium-free alloys for fixed prostheses. J Am Dent Assoc 106:36, 1983.
69. Barakat MM, Asgar K: Mechanical properties and soldering of some cobalt base metal alloys. Dent Mater 2:272, 1986.
70. Waterstrat RM: Comments on casting of Ti-13Cu-4.5Ni alloy. In Valega TM, ed: Alternatives to gold alloys in dentistry [DHEW Publication No. (NIH) 77-1227, pp 224-233]. Washington, D.C., U.S. Department of Health, Education, and Welfare, 1977.
71. Donachie MJ Jr: Titanium: a technical guide, 2nd ed. Materials Park, OH, ASM International, 2000.
72. Kobayashi E, et al: Mechanical properties and corrosion resistance of Ti-6Al-7Nb alloy dental castings. J Mater Sci Mater Med 9:567, 1998.
73. Wang TJ, et al: Castability of Ti-6Al-7Nb alloy for dental casting. J Med Dent Sci 46:13, 1999.
74. Iijima D, et al: Wear properties of Ti and Ti-6Al-7Nb castings for dental prostheses. Biomaterials 24:1519, 2003.
75. Walkowiak-Przybyło M, et al: Adhesion, activation, and aggregation of blood platelets and biofilm formation on the surfaces of titanium alloys Ti6Al4V and Ti6Al7Nb. J Biomed Mater Res Part A 100A:768, 2012.
76. Li Y, et al: Cytotoxicity of titanium and titanium alloying elements. J Dent Res 89:493, 2010.
77. Ribeiro ALR, et al: Mechanical, physical, and chemical characterization of Ti-35Nb-5Zr and Ti 35Nb-10Zr casting alloys. J Mater Sci Mater Med 20:1629, 2009.
78. Long M, Rack HJ. Titanium alloys in total joint replacement—a materials science perspective. Biomaterials 19:1621, 1998.
79. Taira M, et al: Studies of Ti alloys for dental castings. Dent Mater 5:45, 1989.
80. Takahashi J, et al: Casting pure titanium into commercial phosphate-bonded SiO_2 investment molds, J Dent Res 69:1800, 1990.
81. Herø H, et al: Mold filling and porosity in casting of titanium. Dent Mater 9:15, 1993.
82. Takahashi J, et al: Effect of casting methods on castability of pure titanium. Dent Mater J 12:245, 1993.

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83. Syverud M, Herø H: Mold filling of Ti castings using investments with different gas permeability. Dent Mater 11:14, 1995.
84. Watanabe I, et al: Effect of pressure difference on the quality of titanium casting. J Dent Res 76:773, 1997.
85. Zinelis S: Effect of pressure of helium, argon, krypton, and xenon on the porosity, microstructure, and mechanical properties of commercially pure titanium castings. J Prosthet Dent 84:575, 2000.
86. Luo XP, et al: Titanium casting into phosphate bonded investment with zirconite. Dent Mater 18:512, 2002.
87. Koike M, et al: Corrosion behavior of cast titanium with reduced surface reaction layer made by a face-coating method. Biomaterials 24:4541, 2003.
88. Eliopoulos D, et al: Porosity of cpTi casting with four different casting machines. J Prosthet Dent 92:377, 2004.
89. Hung CC, et al: Pure titanium casting into zirconia-modified magnesia-based investment molds. Dent Mater 20:846, 2004.
90. Yan M, Takahashi H: Titanium casting using commercial phosphate-bonded investments with quick heating method. Dent Mater J 25:391, 2006.
91. Hsu HC, et al: Evaluation of different bonded investments for dental titanium casting. J Mater Sci Mater Med 18:605, 2007.
92. da Rocha SS, et al: Effect of phosphate-bonded investments on titanium reaction layer and crown fit. Braz Oral Res 24:147, 2010.
93. Nogueira F, et al: The influence of short-heating-cycle investments on the quality of commercially pure titanium castings. J Prosthet Dent 104:265, 2010.
94. Fragoso WS, et al: The influence of mold temperature on the fit of cast crowns with commercially pure titanium. Braz Oral Res 19:139, 2005.
95. Oliveira PCG, et al: The effect of mold temperature on castability of CP Ti and Ti-6Al-4V castings into phosphate bonded investment materials. Dent Mater 22:1098, 2006.
96. Pieralini ARF, et al: The effect of coating patterns with spinel-based investment on the castability and porosity of titanium cast into three phosphate-bonded investments. J Prosthodont 19:517, 2010.
97. Pieralini ARF, et al: Improvement to the marginal coping fit of commercially pure titanium cast in phosphate-bonded investment by using a simple pattern coating technique. J Prosthet Dent 108:51, 2012.
98. Rodrigues RCS, et al: Effect of different investments and mold temperatures on titanium mechanical properties. J Prosthodont Res 56:58, 2012.
99. Paulino SM, et al: The castability of pure titanium compared with Ni-Cr and Ni-Cr-Be alloys. J Prosthet Dent 98:445, 2007.
100. Fischer J, et al: Mold filling and dimensional accuracy of titanium castings in a spinel-based investment. Dent Mater 11:1376, 2009.
101. Reza F, et al: Effects of investment type and casting system on permeability and castability of CP titanium. J Prosthet Dent 104:114, 2010.
102. Okhubo C, et al: Effect of surface reaction layer on grindability of cast titanium alloys. Dent Mater 22:268, 2006.
103. Guilin Y, et al: The effects of different types of investments on the alpha-case layer of titanium castings. J Prosthet Dent 97:157, 2007.
104. Koike M, et al: Grindability of alpha-case formed on cast titanium. Dent Mater J 28:587, 2009.
105. Han HS, et al: Marginal accuracy and internal fit of machine-milled and cast titanium crowns. J Prosthet Dent 106:191, 2011.
106. Collins PC, et al: Laser deposition: A new technology for fabrication of titanium restorations [Abstract no. 3985]. J Dent Res 81(Special Issue A), 2002.
107. Le L, et al: SEM and Vickers hardness of laser-deposited, cast and wrought Ti-6Al-4V [Abstract no. 129]. J Dent Res 82 (Special Issue A), 2003.
108. Nag S, et al: A novel combinatorial approach for understanding microstructural evolution and its relationship to mechanical properties in metallic biomaterials. Acta Biomater 3:369, 2007.
109. Quante K, et al: Marginal and internal fit of metal-ceramic crowns fabricated with a new laser melting technology. Dent Mater 24:1311, 2008.
110. Akova T, et al: Comparison of the bond strength of laser-sintered and cast base metal dental alloys to porcelain. Dent Mater 24:1400, 2008.
111. Traini T, et al: Direct laser metal sintering as a new approach to fabrication of an isoelastic functionally graded material for manufacture of porous titanium dental implants. Dent Mater 24:1525, 2008.
112. Ucar Y, et al: Internal fit evaluation of crowns prepared using a new dental crown fabrication technique: laser-sintered Co-Cr crowns. J Prosthet Dent 102:253, 2009.
113. Abou Tara M, et al: Clinical outcome of metal-ceramic crowns fabricated with laser-sintering technology. Int J Prosthodont 24:46, 2011.
114. Örthop A, et al: The fit of cobalt-chromium three-unit fixed dental prostheses fabricated with four different techniques: a comparative in vitro study. Dent Mater 27:356, 2011.
115. Iseri U, et al: Shear bond strengths of veneering porcelain to cast, machined and laser-sintered titanium. Dent Mater J 30:274, 2011.
116. Fathalah A, et al: Microstructural observations of laser-sintered specimens for prosthodontic applications [Abstract no. 1293]. J Dent Res 91(Special Issue A), 2012.
117. Gurbuz G, et al: Microstructure and elemental composition characterization of laser-sintered CoCr dental alloy [Abstract no. 3248]. J Dent Res 91(Special Issue B), 2012.
118. Wang XC, et al: Direct selective laser sintering of hard metal powders: experimental study and simulation. Int J Adv Manuf Technol 19:351, 2002.
119. Ceramill Sintron [Product information]. Accessed March 26, 2015, at https://www.amanngirrbach.com.
120. van Noort R: The future of dental devices is digital. Dent Mater 28:3, 2012.
121. Kim K-B, et al: Three-dimensional evaluation of gaps associated with fixed prostheses fabricated with new technologies. J Prosthet Dent 112(6):1432, 2014.

STUDY QUESTIONS

1. Explain all reasons for full-contour waxing before cutting back a wax pattern for a metal-ceramic restoration.

2. Why should the framework of a metal-ceramic crown not be of consistent thickness on the veneering surface?

3. How does the practitioner determine the location of the metal-ceramic interface? Interproximally on a maxillary central incisor? Interproximally on a maxillary premolar? Occlusally on a mandibular premolar? Lingually on a maxillary canine?

4. Discuss the appearance of the stress-strain curve for a ductile dental alloy. What does it mean when the straight portion of the curve is steeper or more horizontal? What is the importance of a flatter curve versus a curve with a greater slope after the initial linear portion of the plot? What does it mean if the maximum point of the curve is higher or lower? What does the total surface area under the curve signify?

5. Explain the classification of alloy systems for metal-ceramic restorations. Select two categories, and give two examples of alloys in each category. Contrast the physical properties of the alloys chosen, and provide examples of recommended use.

6. Briefly discuss the health hazards that can be associated with the various alloys used in the metal-ceramic technique.

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CHAPTER 20

Pontic Design

R. Duane Douglas, Contributing Author

Pontics are the artificial teeth of a partial fixed dental prosthesis (FDP) that replace missing natural teeth, restoring function and appearance (Fig. 20-1). They must enable continued oral health and comfort. The edentulous areas where a fixed prosthesis is to be provided may be overlooked during the treatment-planning phase. Unfortunately, any deficiency or potential problem that may arise during the fabrication of a pontic is often identified only after the teeth have been prepared or even when the definitive cast is ready to be sent to the laboratory. Proper preparation includes a careful analysis of the definitive dimensions of the edentulous areas: mesiodistal width, occlusocervical distance, buccolingual dimension, and location of the residual ridge. To design a pontic that meets hygienic requirements and prevents irritation of the residual ridge, particular attention must be given to the form and shape of the gingival surface. Merely replicating the form of the missing tooth or teeth is not enough. The pontic must be carefully designed and fabricated not only to facilitate plaque control of the tissue surface and around the adjacent abutment teeth but also to adjust to the existing occlusal conditions. In addition to these biologic considerations, pontic design must incorporate mechanical principles for strength and longevity, as well as esthetic principles for satisfactory appearance of the replacement teeth (Fig. 20-2).

Because the pontic mechanically unifies the abutment teeth and covers a portion of the residual ridge, it assumes a dynamic role as a component of the prosthesis and cannot be considered a lifeless insert of gold, porcelain, or acrylic resin.[1]

PRETREATMENT ASSESSMENT

Certain procedures enhance the success of an FDP. In the treatment-planning phase, diagnostic casts and waxing procedures may prove especially valuable for determining optimal pontic design (see Chapters 2 and 3).

Pontic Space

One function of an FDP is to prevent tilting or drifting of the adjacent teeth into the edentulous space. If such movement has already occurred, the space available for the pontic may be reduced and its fabrication complicated. In such circumstances, creating an acceptable appearance without orthodontic repositioning of the abutment teeth is often impossible, particularly if esthetic appearance is important. (Modification of abutments with complete-coverage retainers is sometimes feasible.) Careful diagnostic waxing procedures help determine the most appropriate treatment (see Chapters 2 and 3). Even with a lesser esthetic requirement, as for posterior teeth, overly small pontics are unacceptable because they trap food and are difficult to clean. When orthodontic repositioning is not possible, increasing the proximal contours of adjacent teeth may be better than making an FDP with undersized pontics (Fig. 20-3). If there is no functional or esthetic deficit, the space can be maintained without prosthodontic intervention.

Residual Ridge Contour

The edentulous ridge's contour and topography should be carefully evaluated during the treatment-planning phase. An ideally shaped ridge has a smooth, regular surface of attached gingiva, which facilitates maintenance of a plaque-free environment. Its height and width should allow placement of a pontic that appears to emerge from the ridge and mimics the appearance of the neighboring teeth. Facially, it must be free of frenum attachment and be of adequate facial height to sustain the appearance of interdental papillae.

Loss of residual ridge contour may lead to unesthetic open gingival embrasures ("black triangles"; Fig. 20-4, *A*), food impaction (see Fig. 20-4, *B*), and percolation of saliva during speech. Siebert[2] classified residual ridge deformities into three categories (Table 20-1; Fig. 20-5):

- Class I defects: faciolingual loss of tissue width with normal ridge height
- Class II defects: loss of ridge height with normal ridge width
- Class III defects: a combination of loss in both dimensions

The incidence of residual ridge deformity after anterior tooth loss is high (91%)[3]; in the majority of these patients, the deformities are class III defects. Because many patients with class II and class III defects are dissatisfied with the esthetics of their FDPs,[4] preprosthetic surgery to augment such residual ridges should be carefully considered.

Surgical Modification

Although residual ridge width may be augmented with hard tissue grafts, this is usually not indicated unless the edentulous site is to receive an implant (see Chapter 13).

Class I Defects

Soft tissue procedures have been advocated for improving the width of a class I defect; however, because class I defects are infrequent and are not esthetically challenging, surgical augmentation of ridge width is uncommon. By paying careful attention to interim pontic contour, the

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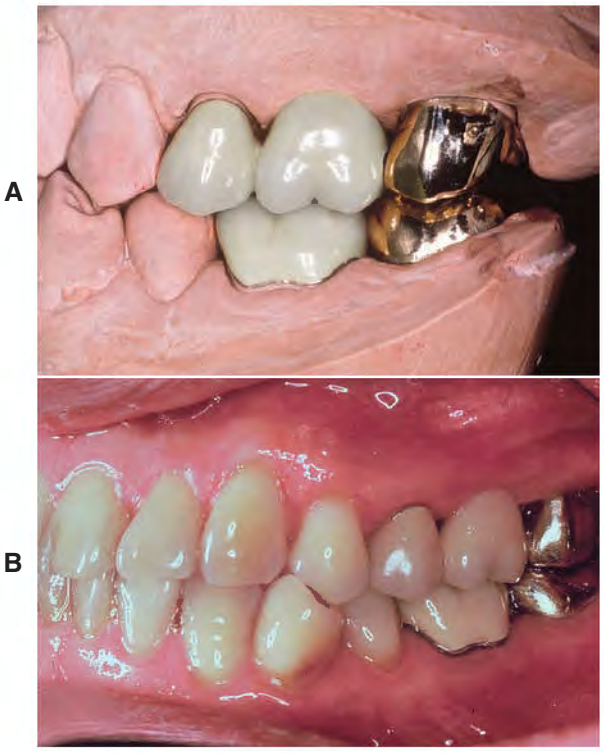

FIGURE 20-1 ■ **A** and **B,** A metal-ceramic pontic in this three-unit partial fixed dental prosthesis replaces the maxillary first molar.

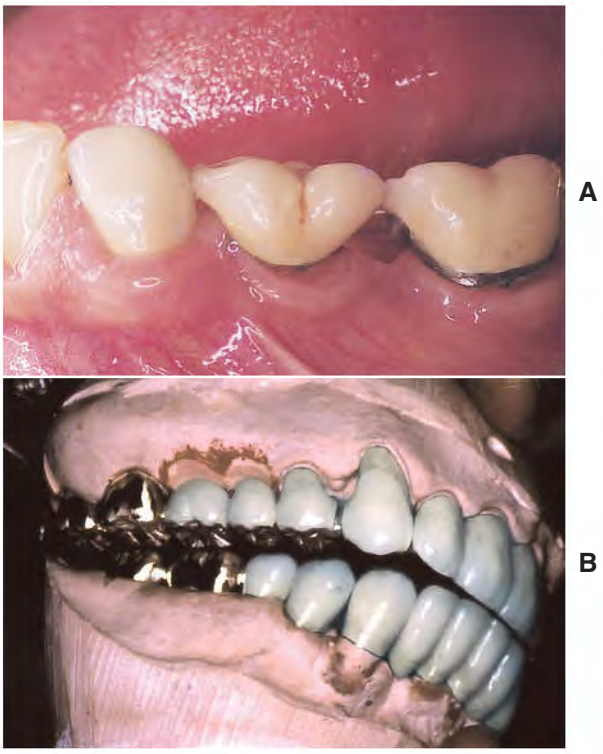

FIGURE 20-3 ■ Careful planning is always necessary in deciding how to restore an undersized pontic space when orthodontic treatment is not practical. **A,** In this patient, individual crowns of increased proximal contours were preferred over a partial fixed dental prosthesis with undersized pontics. Excellent plaque control has been demonstrated, and the design provided the optimum occlusal relationship. **B,** Two small pontics were used to replace the missing maxillary teeth.

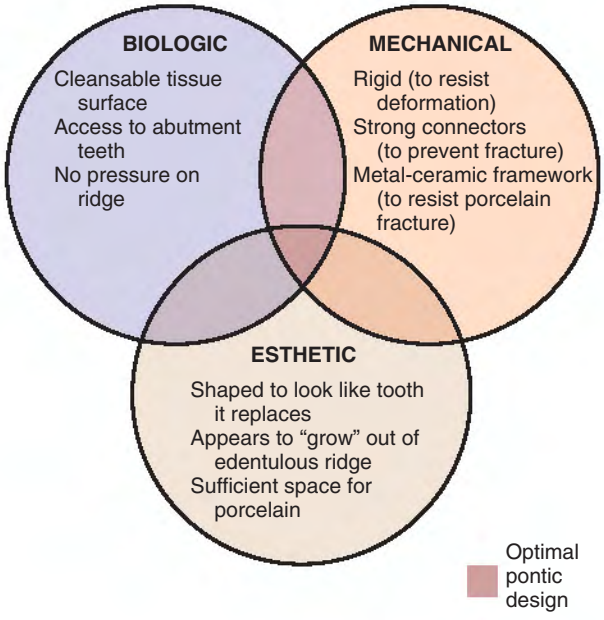

FIGURE 20-2 ■ Biologic, mechanical, and esthetic considerations for successful pontic design.

FIGURE 20-4 ■ Loss of residual ridge contour has led to unesthetic open gingival embrasures **(A)** and food entrapment *(arrow)* **(B).**

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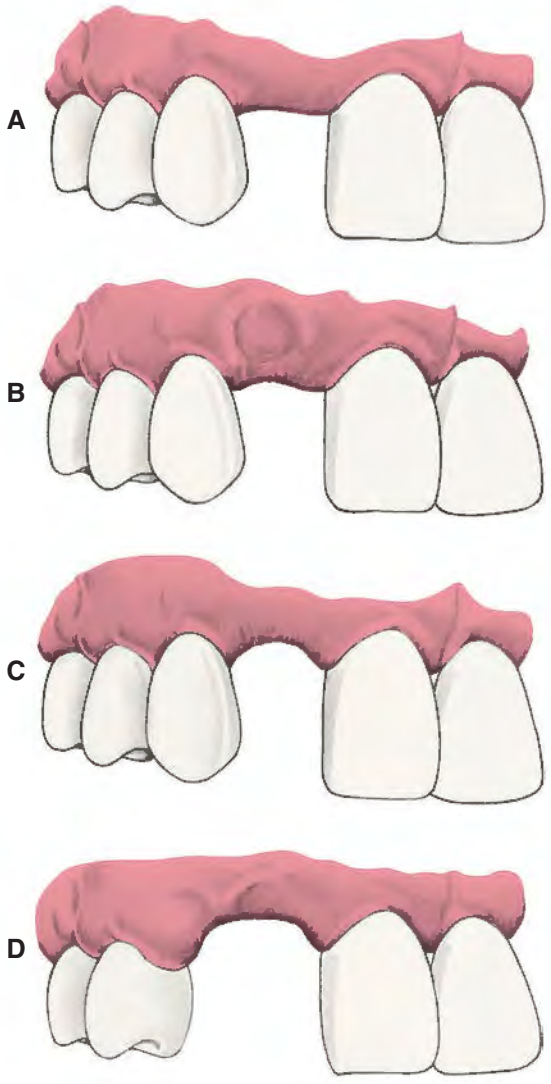

FIGURE 20-5 ■ Residual ridge deformities as classified by Siebert.[2] **A,** Class 0, no defect. **B,** Class I defect. **C,** Class II defect. **D,** Class III defect.

TABLE 20-1 **Incidence of Maxillary Anterior Residual Ridge Defects**

Class	Description	Incidence (%) Abrams et al[3]	Incidence (%) Siebert[2]
0	No defect	12	0
I	Horizontal loss	36	13
II	Vertical loss	0	40
III	Horizontal and vertical loss	52	47

Adapted from Edelhoff D, et al: A review of esthetic pontic design options. Quintessence Int 33:736, 2002.

operator can identify patients who would benefit from surgery. In the roll[5] technique, soft tissue from the lingual side of the edentulous site is used. The epithelium is removed, and the tissue is thinned and rolled back upon itself, thereby thickening the facial aspect of the residual ridge (Fig. 20-6). Pouches may also be prepared in the facial aspect of the residual ridge[6] into which subepithelial[7,8] or submucosal[9] grafts harvested from the palate or tuberosity may be inserted (Fig. 20-7).

Class II and Class III Defects

Unfortunately, few soft tissue surgical techniques can increase the height of a residual ridge with predictability. The interpositional graft[2,10] is a variation of the pouch technique, in which a wedge-shaped connective tissue graft is inserted into a pouch preparation on the facial aspect of the residual ridge. The epithelial portion of the wedge may be positioned coronally to the surrounding epithelium if an increase of ridge height is desired (Fig. 20-8). The onlay graft is designed to increase ridge height[2,11] but also contributes to ridge width, which makes it useful for treating class III ridge defects (Fig. 20-9). It is a thick "free gingival graft" harvested from partial- or full-thickness palatal donor sites. Because the amount of height augmentation can be only as thick as the graft, the procedure may have to be repeated several times to reestablish normal residual ridge height. Although the onlay graft has greater potential for increasing ridge height than does the interpositional graft, its survival is greatly dependent on revascularization, which requires meticulous preparation of the recipient site. Therefore, it is more technique sensitive than is the interpositional graft. In fact, connective tissue grafts have been demonstrated to achieve approximately 50% more ridge-volume increase 3.5 months after surgery than do free gingival grafts in single-tooth residual ridge defects.[12]

Gingival Architecture Preservation

Resorption of the alveolar ridge after tooth extraction occurs primarily at the buccal plate, typically resulting in a horizontal defect. Bone loss averages 3 to 5 mm at 6 months after extraction; 50% of the width of the alveolar ridge is lost at 12 months.[13,14] Although the degree of residual ridge resorption after tooth extraction is unpredictable, resulting deformities are not inevitable. The alveolar process can be preserved through immediate restorative and periodontal intervention at the time of tooth removal. By conditioning the extraction site and providing a matrix for healing, the dentist can preserve the preextraction gingival architecture, or "socket."

Preparing the abutment teeth before the extraction is the preferred technique. An interim FDP can be fabricated indirectly, ready for immediate insertion. Because socket preservation is dependent on underlying bone contour, the extraction of the tooth to be replaced should be atraumatic, with the aim of preserving the facial plate of bone. The scalloped architecture of interproximal bone forming the extraction site is essential for proper papilla form, as are facial bone levels in the prevention of alveolar collapse. If bone levels are compromised before or during extraction, the sockets can be grafted with an allograft material (hydroxyapatite, tricalcium phosphate, or freeze-dried bone).[13,15,16]

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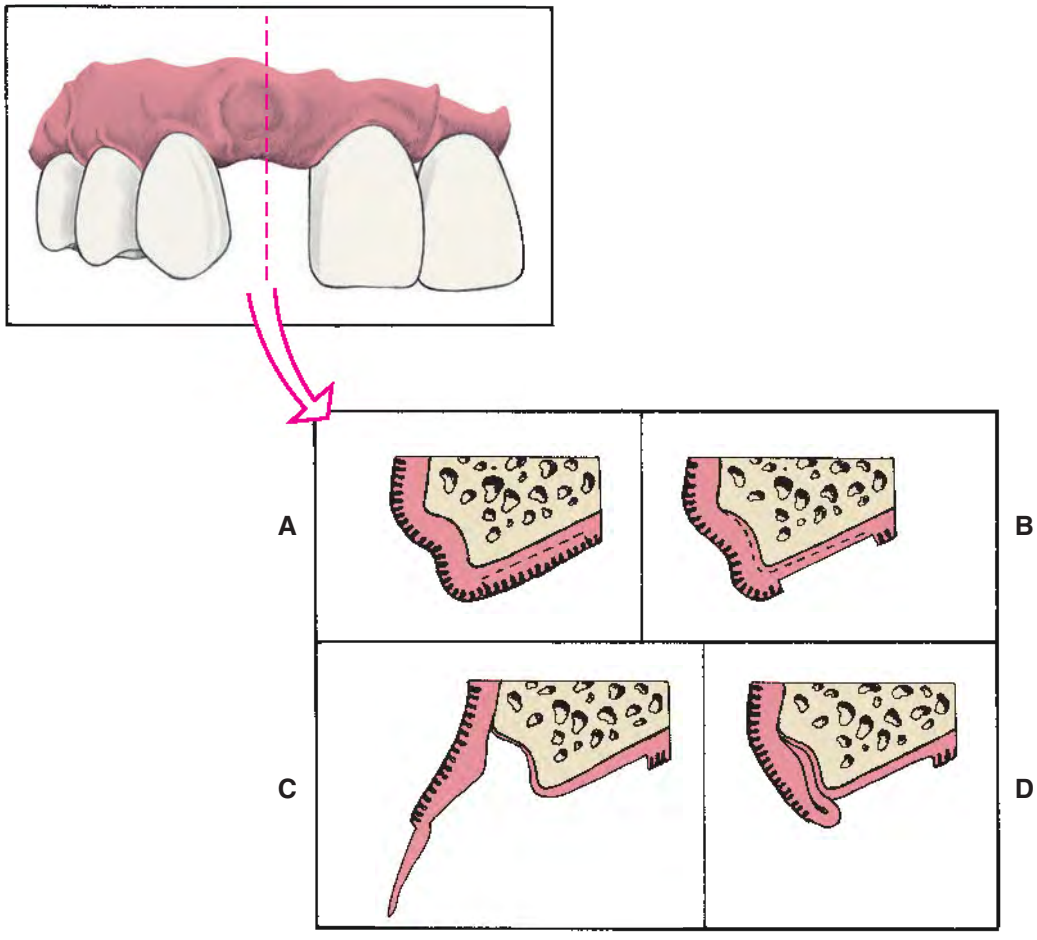

FIGURE 20-6 ■ Cross-section illustrations of the roll technique for soft tissue ridge augmentation. **A,** Class I residual ridge defect before augmentation. **B,** Epithelium is removed from palatal surface. **C,** The flap is elevated, which creates a pouch on the vestibular surface. **D,** The flap is rolled into the pouch, which enhances ridge width.

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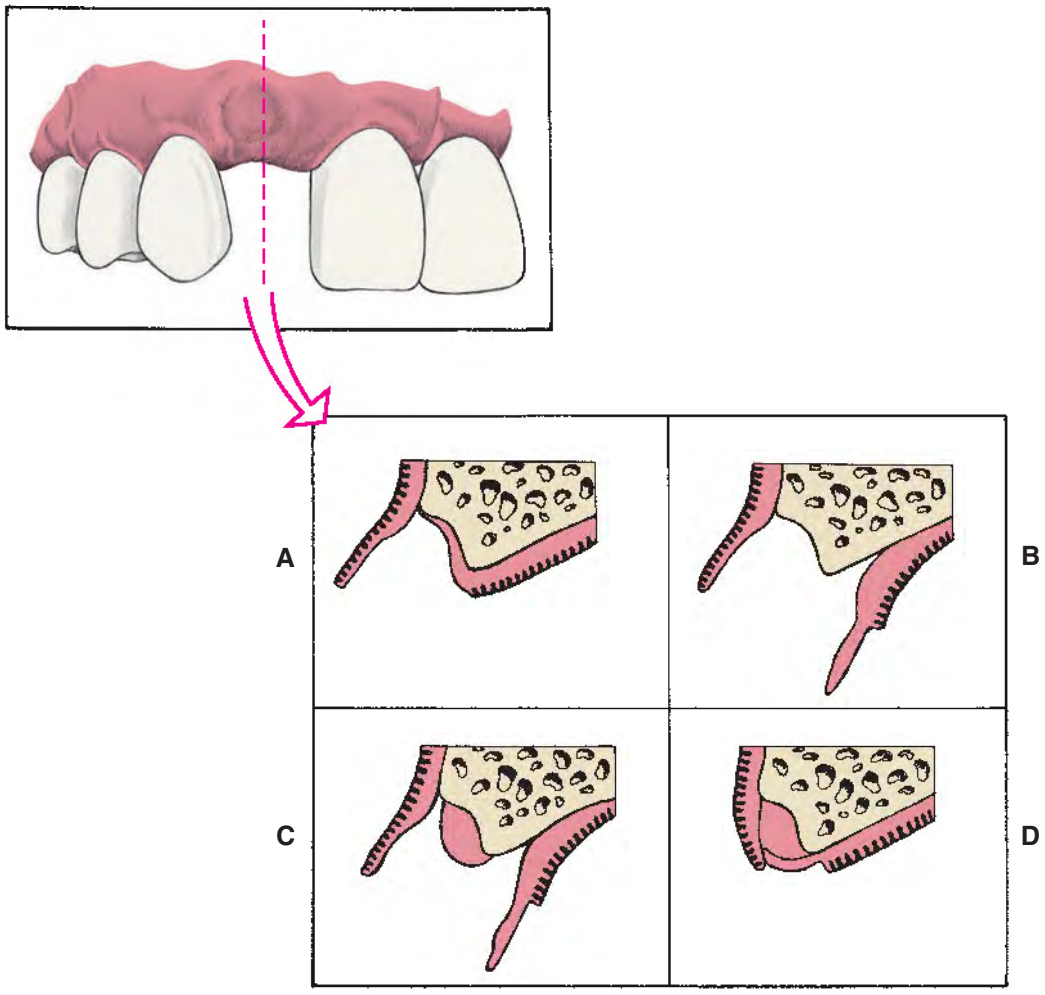

FIGURE 20-7 ■ Cross-section illustrations of the pouch technique for soft tissue ridge augmentation. **A** and **B,** Split-thickness flap is reflected. **C,** Graft material is placed in the pouch, which increases ridge width. **D,** Flaps are sutured in place.

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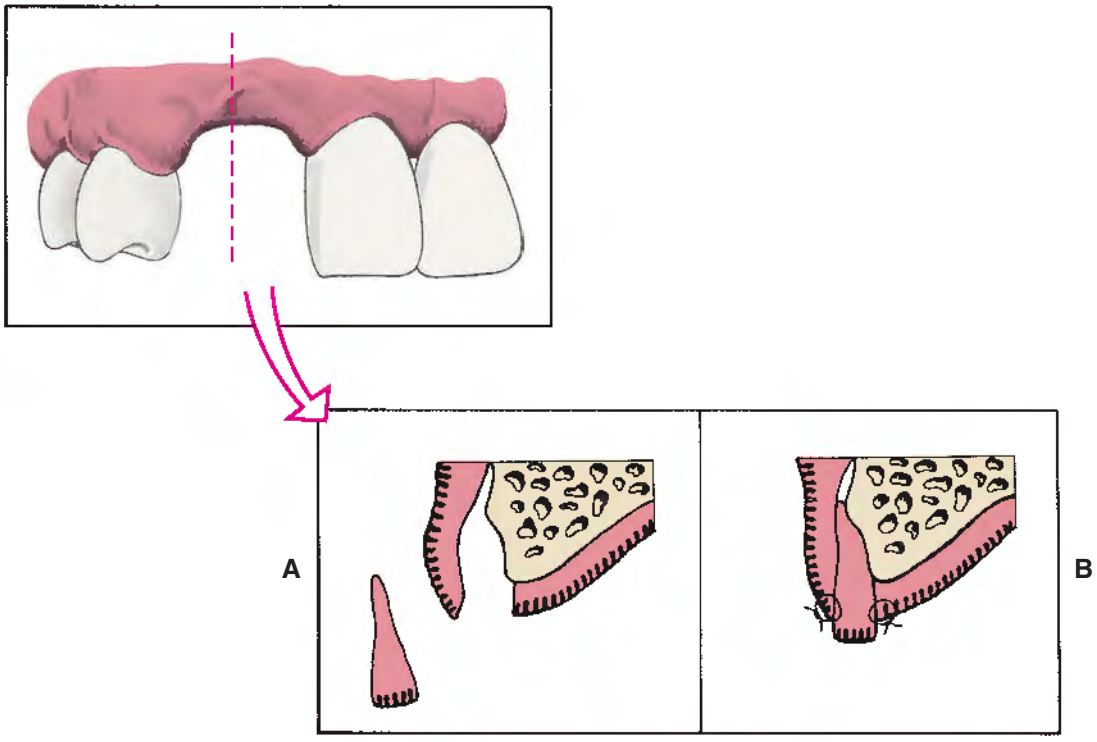

FIGURE 20-8 ■ Cross-section illustrations of an interpositional graft for augmentation of ridge width and height. **A,** Tissue is reflected. **B,** Graft is positioned and sutured in place.

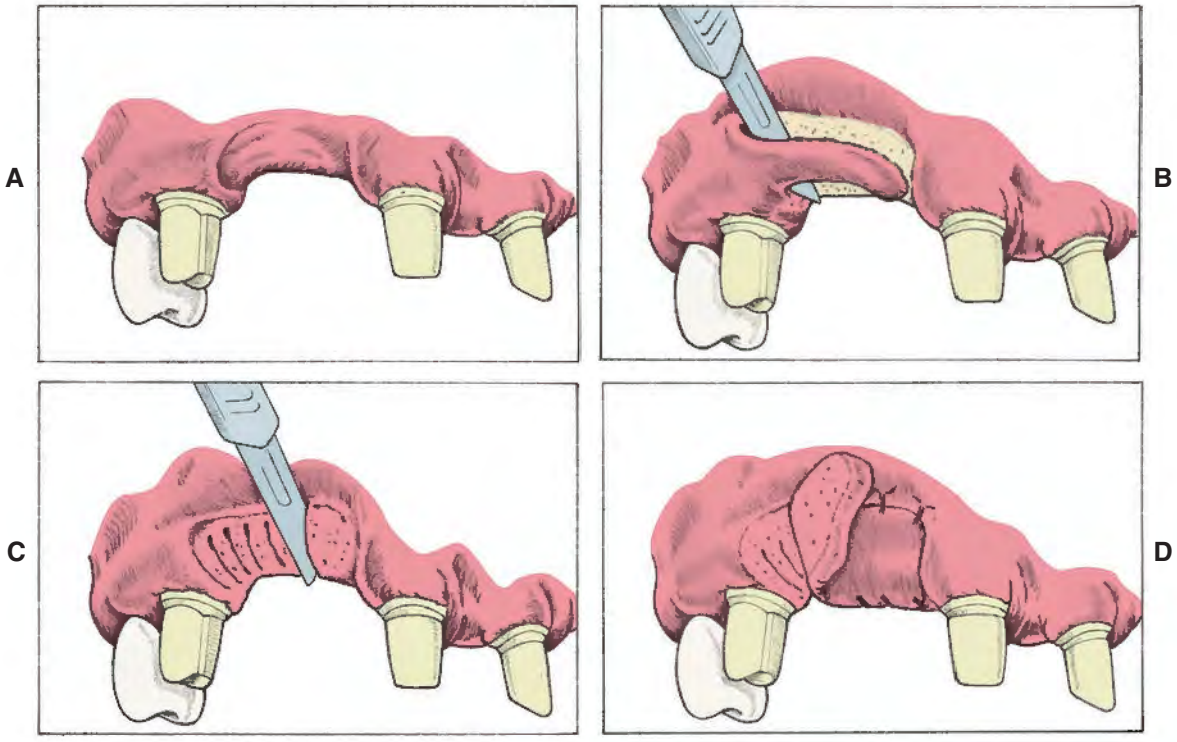

FIGURE 20-9 ■ An onlay graft for augmentation of ridge width and height. **A,** Presurgical illustration of class III residual ridge defect with abutment teeth prepared. **B,** Recipient bed is prepared by removal of epithelium. **C,** Striation cuts are made in connective tissue to encourage revascularization. **D,** Onlay graft is sutured in place.

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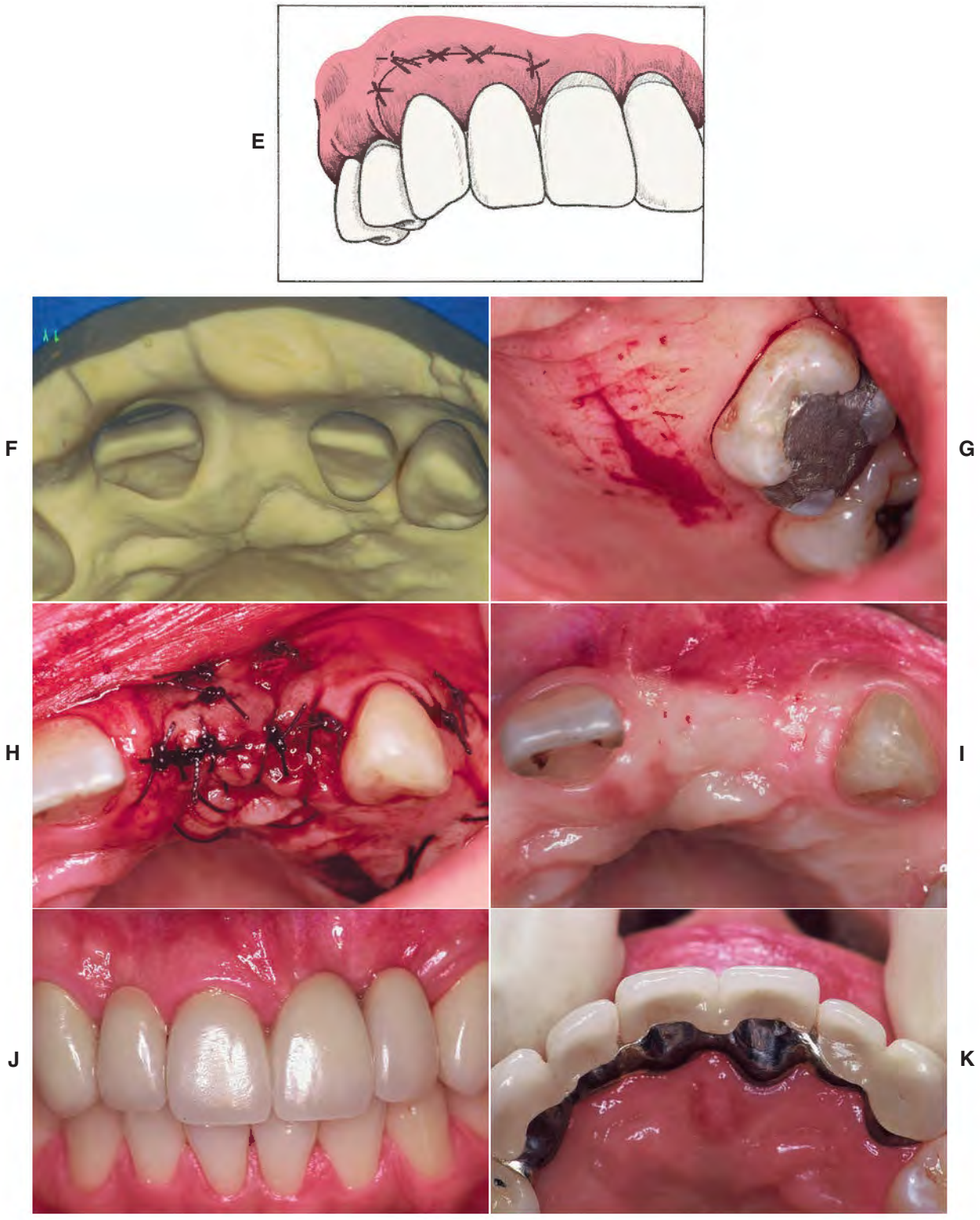

FIGURE 20-9, cont'd ■ **E,** An interim partial fixed dental prosthesis with open embrasures is placed immediately to allow adaptation of tissue during healing. **F,** Cast with class III residual ridge defect; the lateral incisor was unrestorable. **G,** Donor site for graft. **H,** Graft sutured in place. **I,** Augmented ridge. **J** and **K,** Definitive restoration with improved contours.

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Immediately after preparation of the extraction site, a carefully shaped interim FDP is placed (Fig. 20-10, *A* and *B*). The tissue side of the pontic should be an ovate form, and, according to Spear,[17] it should extend approximately 2.5 mm apical to the facial free gingival margin of the extraction socket (see Fig. 20-10, *C* and *D*). Because the soft tissues of the socket begin to collapse immediately after the tooth extraction, the pontic causes tissue blanching as it supports the papillae and facial/palatal gingiva. The contour of the ovate tissue side of the pontic is critical and must conform to within 1 mm of the interproximal and facial bone contour to act as a template for healing. Oral hygiene in this area is difficult during the initial healing period, and so the interim restoration should be highly polished to minimize plaque retention. After approximately 1 month of healing, oral hygiene access is improved by recontouring of the pontic to provide 1 to 1.5 mm of relief from the tissue. When the gingival levels are stable (approximately 6 to 12 months), the definitive restoration can be fabricated (see Fig. 20-10, *E*).

Techniques involving orthodontic extrusions have also been employed to preserve ridge form before extraction. In these proactive methods, light forces are used to extrude the teeth destined to be extracted. As the teeth are extruded, apposition of bone occurs at the root apex, thereby filling the socket with bone as the tooth is slowly extracted orthodontically. First employed to avoid ridge augmentation and to increase vertical ridge height before immediate implant placement,[18] the orthodontic extrusion technique has been used successfully to maintain ridge contour before treatment with conventional FDPs (Fig. 20-11). In addition to the additional time and

FIGURE 20-10 ■ Alveolar architecture preservation technique. **A,** Atraumatic tooth extraction. **B,** Cross-sectional view of the immediate interim partial fixed dental prosthesis, demonstrating ovate pontic form. **C,** Interim restoration. Note the 2.5-mm apical extension of the ovate pontic. **D,** The seated interim restoration should cause slight blanching of interdental papilla. **E,** Interim restoration 12 months after extraction. Note the preservation of interdental papilla. (Courtesy Dr. F.M. Spear and Montage Media, Mahwah, New Jersey.)

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FIGURE 20-11 ■ Orthodontic extrusion to preserve alveolar architecture. **A,** Pretreatment (note discrepancy in gingival crest heights between the maxillary central incisors). **B,** Orthodontic extrusion. **C,** Preextrusion and postextrusion radiographs. *Red line* denotes reference point; *blue* and *yellow lines* denote change in gingival crest height. **D,** Postextraction evaluation of interim restoration with ovate pontics. **E,** Gingival architecture immediately before pression. **F,** Definitive restoration.

expense of orthodontic treatment, endodontic treatment is necessary beforehand because the teeth to be extracted must continuously be adjusted as they are extruded.

Although maintenance of the residual ridge after extraction is desirable, socket-preservation techniques are technically challenging, require frequent patient monitoring, and necessitate conscientious hygiene by the patient. Even when the procedure is performed meticulously, success is unpredictable because of the variability in patients' healing responses. Rarely can socket preservation completely preserve the alveolar ridge frame[19]; additional surgical augmentation of the ridge may still be necessary for some patients.

As an alternative to socket preservation and ridge augmentation surgery, root submergence techniques have been recommended to preserve alveolar bone heights. Originally documented in the 1970s, root submergence technique involves the resection of the tooth crown and the subsequent covering of the remaining root with a gingival flap. This technique has been successfully employed to preserve ridge height for patients with complete dentures.[20] The technique has been performed with vital and nonvital roots. Root submergence can also be used to preserve the alveolar ridge for anterior pontic sites between natural tooth abutments[21] and implant abutments (Fig. 20-12).[22]

PONTIC CLASSIFICATION

Pontic designs are classified into two general groups: those that contact the oral mucosa and those that do not

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FIGURE 20-12 ■ Clinical (**A** and **B**) and radiographic **(C)** appearance of the teeth of a 55-year-old woman who presented with esthetic and masticatory disturbances. **D,** Periapical radiograph of the anterior teeth after orthodontic therapy. The plan was for both central incisors and the left lateral incisor to be replaced by an implant-supported restoration. **E,** Anterior view of the result. Esthetics and function were maintained. An interdisciplinary approach was needed. **F,** Posttreatment orthopantomograph. Positions of the teeth and implants were optimal. **G,** The pontic site shows excellent shape because of the submerged root. **H,** The definitive restoration looked natural. The submerged root of the right maxillary central incisor maintained the surrounding alveolar bone and soft tissues of the pontic in the most coronal position. A normal pontic is not typically able to reproduce these ideal tissue frames and papilla heights because the needed underlying bone support is lacking. **I,** Posttreatment periapical radiograph obtained 27 months after root submergence. The submerged root maintained an ideal mesiodistal alveolar bone level. (From Salama M, et al: Advantages of the root submergence technique for pontic site development in esthetic implant therapy. Int J Periodontics Restorative Dent 27:521, 2007.)

(Box 20-1). There are several subclassifications within these groups that are based on the shape of the gingival side of the pontic. Pontic selection depends primarily on esthetics and oral hygiene. In the anterior region, where esthetic appearance is a concern, the pontic should be well adapted to the tissue to make it appear as if it emerges from the gingiva. Conversely, in the posterior regions (mandibular premolar and molar areas), contours can be modified in the interest of designs that are less esthetic but amenable to oral hygiene. The advantages and disadvantages of the various pontic designs are summarized in Table 20-2.

BOX 20-1 Pontic Design Classification

Mucosal Contact

Ridge-lap
Modified ridge-lap
Ovate
Conical

No Mucosal Contact

Sanitary (hygienic)
Modified sanitary (hygienic)

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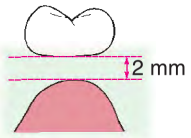
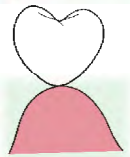
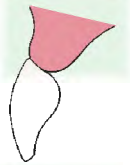
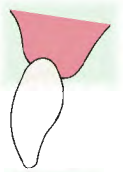
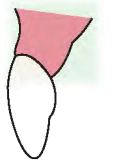
TABLE 20-2 **Pontic Design**

Pontic Design	Appearance	Recommended Location	Advantages	Disadvantages	Indications	Contraindications	Materials
Sanitary/hygienic		Posterior mandible	Good access for oral hygiene	Poor esthetics	Nonesthetic zones Impaired oral hygiene	Where esthetics is important Minimal vertical dimension	All metal
Saddle/ridge-lap		Not recommended	Esthetic	Not amenable to oral hygiene	Not recommended	Not recommended	Not applicable
Conical		Molars without esthetic requirements	Good access for oral hygiene	Poor esthetics	Posterior areas where esthetics is of minimal concern	Poor oral hygiene	Metal-ceramic All resin All ceramic
Modified ridge-lap		High esthetic requirement (i.e., anterior teeth and premolars, some maxillary molars)	Good esthetics	Moderately easy to clean	Most areas with esthetic concern	Where minimal esthetic concern exists	Metal-ceramic All resin All ceramic
Ovate		Very high esthetic requirement Maxillary incisors, canines, and premolars	Superior esthetics Negligible food entrapment Ease of cleaning	Necessitates surgical preparation Not for residual ridge defects	Desire for optimal esthetics High smile line	Patient's unwillingness to undergo surgery Residual ridge defects	Metal-ceramic All resin All ceramic
Modified ovate		Very high esthetic requirement Maxillary incisors, canines, and premolars	Superior esthetics Negligible food entrapment Ease of cleaning	Necessitates surgical preparation	Where horizontal ridge width is not sufficient for a conventional ovate pontic	Patient's unwillingness to undergo surgery	Metal-ceramic All resin All ceramic

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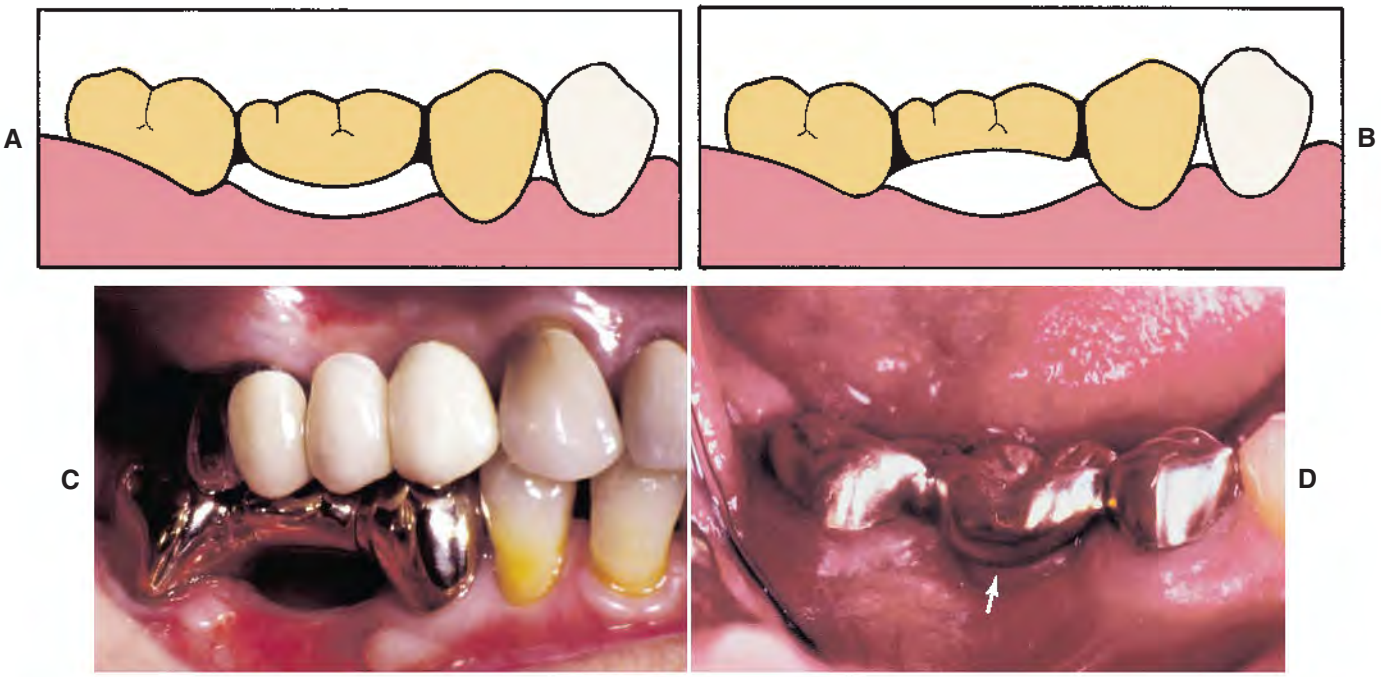

FIGURE 20-13 ■ **A,** Illustration of sanitary pontic. Illustration **(B)** and appearance **(C)** of a modified sanitary pontic. **D,** Placement of the pontic, close to the ridge, has resulted in tissue proliferation *(arrow).*

Sanitary or Hygienic Pontic

As its name implies, the primary design feature of the sanitary pontic allows easy cleaning because its tissue surface remains clear of the residual ridge (Fig. 20-13, *A*). This hygienic design enables easier plaque control by allowing gauze strips and other cleaning devices to be passed under the pontic and seesawed in a shoeshine manner. Disadvantages include entrapment of food particles, which may lead to tongue habits that annoy the patient. The hygienic pontic is the least toothlike design and is therefore reserved for teeth seldom displayed during function (i.e., the mandibular molars).

A modified version of the sanitary pontic has been developed[23] (see Fig. 20-13, *B* and *C*). Its gingival portion is shaped like an archway between the retainers. This geometry allows for increased connector size and a decrease in the stress concentrated in the pontic and connectors.[24] It is also less susceptible to tissue proliferation that can occur when a pontic is too close to the residual ridge (see Fig. 20-13, *D*).

Saddle and Ridge-Lap Pontics

The saddle pontic has a concave fitting surface that overlaps the residual ridge buccolingually, simulating the contours and emergence profile of the missing tooth on both sides of the residual ridge. However, saddle or ridge-lap designs should be avoided because the concave gingival surface of the pontic is not accessible to cleaning with dental floss, which leads to plaque accumulation (Fig. 20-14). This design deficiency has been shown to result in tissue inflammation[1] (Fig. 20-15).

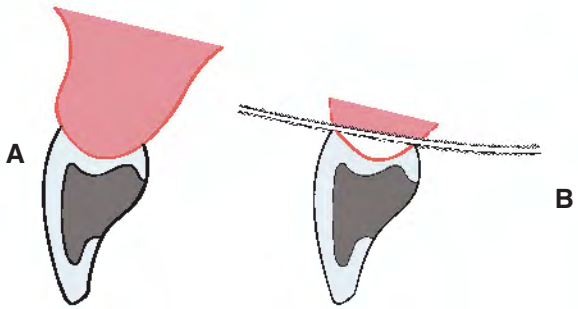

FIGURE 20-14 ■ **A,** Cross-sectional view of ridge-lap pontic. **B,** The tissue surface is inaccessible to cleaning devices.

Modified Ridge-Lap Pontic

The modified ridge-lap pontic combines the best features of the hygienic and saddle pontic designs, combining esthetics with easy cleaning. Figures 20-16 and 20-17 demonstrate how the modified ridge-lap pontic overlaps the residual ridge on the facial side (to achieve the appearance of a tooth emerging from the gingiva) but remains clear of the ridge on the lingual side. To enable optimal plaque control, the gingival surface must have no depression or hollow; rather, it should be as convex as possible from mesial to distal aspects (the greater the convexity, the easier the oral hygiene). Tissue contact should resemble a letter *T* (Fig. 20-18) whose vertical arm ends at the crest of the ridge. Facial ridge adaptation is essential for a natural appearance. Although this design was historically referred to as *ridge-lap design*,[25,26] the term *ridge-lap* is now used synonymously with *saddle design*. The

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FIGURE 20-15 ■ **A** and **B,** Partial fixed dental prosthesis (FDP) with a ridge-lap (concave) gingival surface. **C,** When it was removed, the tissue was found to be ulcerated. The defective FDP was recontoured and used as an interim restoration while the definitive restoration was being fabricated. **D,** Within 2 weeks, the ulceration had resolved.

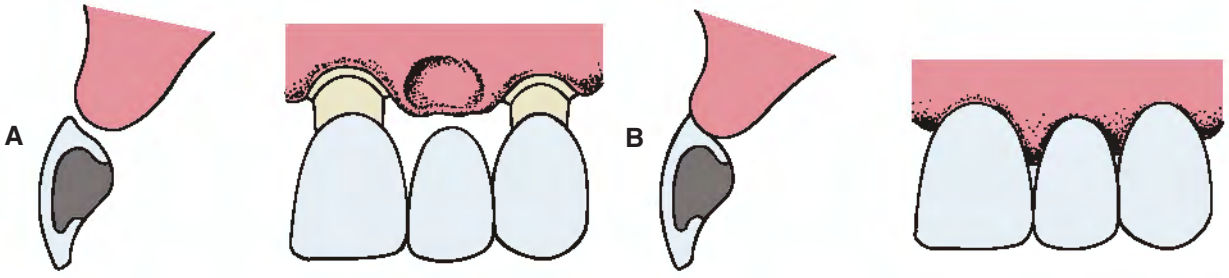

FIGURE 20-16 ■ Modified ridge-lap pontic. **A,** Partial fixed dental prosthesis (FDP) partially seated. **B,** FDP seated.

FIGURE 20-17 ■ Three-unit partial fixed dental prosthesis replacing the maxillary lateral incisor. **A,** To facilitate plaque control, the lingual surface is made convex. **B,** The facial surface is shaped to simulate the missing tooth.

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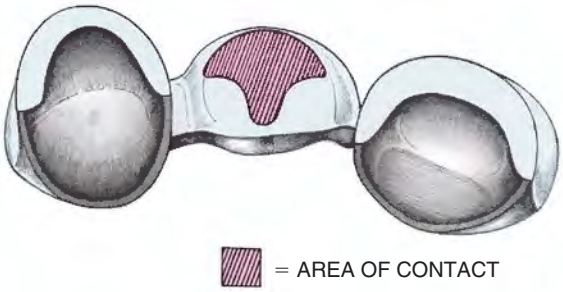

FIGURE 20-18 ■ Tissue contact of a maxillary partial fixed dental prosthesis (FDP) should resemble the letter *T*. In this illustration, the FDP is viewed from the gingival aspect.

modified ridge-lap design is the most common pontic form used in areas of the mouth that are visible during function (maxillary and mandibular anterior teeth and maxillary premolars and first molars).

Conical Pontic

Often called *egg-shaped*, *bullet-shaped*, or *heart-shaped*, the conical pontic (Fig. 20-19) is easy for the patient to keep clean. It should be made as convex as possible and should have only one point of contact: at the center of the residual ridge. This design is recommended for the replacement of mandibular posterior teeth, for which esthetic appearance is a lesser concern. The facial and lingual contours are dependent on the width of the residual ridge; a knife-edged residual ridge necessitates flatter contours with a narrow tissue contact area. This type of design may be unsuitable for broad residual ridges because the emergence profile associated with the small tissue contact point may create areas of food entrapment (Fig. 20-20). The sanitary or hygienic pontic is the design of choice in these clinical situations.

Ovate Pontic

The ovate pontic is the pontic design that is most esthetically appealing. Its convex tissue surface resides in a soft tissue depression or hollow in the residual ridge, which makes it appear that a tooth is literally emerging from the gingiva (Fig. 20-21). Careful treatment planning is necessary for successful results. Socket-preservation techniques should be performed at the time of extraction to create the tissue recess from which the ovate pontic form will appear to emerge. For a preexisting residual ridge, surgical augmentation of the soft tissue is typically required. When an adequate volume of ridge tissue is established, a socket depression is sculpted into the ridge with surgical diamonds, electrosurgery, or a dental laser. With every option, meticulous attention to the contour of the pontic of the interim restoration is essential when the residual ridge that will receive the definitive prosthesis is conditioned and shaped.

The advantages of an ovate pontic include its pleasing appearance and its strength. When it is used successfully with ridge augmentation, its emergence from the ridge appears identical to that of a natural tooth. In addition, its recessed form is not susceptible to food impaction.

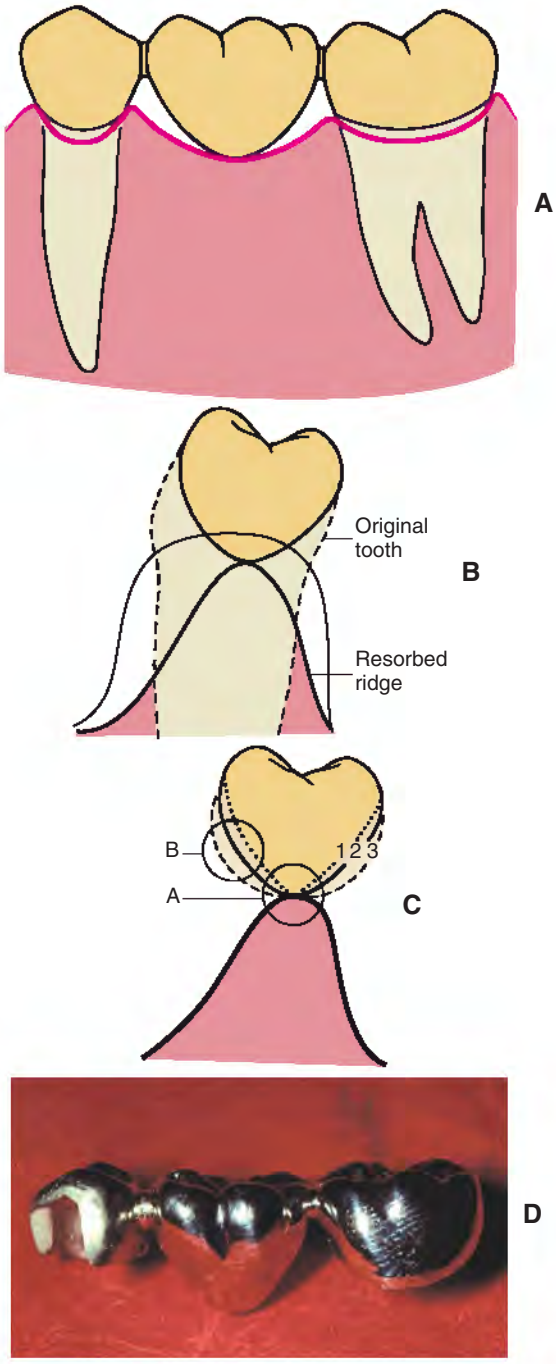

FIGURE 20-19 ■ **A** and **B,** A pontic with maximum convexity and a single point of contact with the tissue surface is the design easiest to keep clean. **C,** Evaluating the contour of three possible pontic shapes (*1, 2,* and *3*). Contour *3* is the most convex in area *B* but is too flat in area *A*. Contour *1* is convex in area *A* but is too flat in area *B*. Contour *2* is the best. **D,** An all-metal partial fixed dental prosthesis with a conical pontic, suitable for replacement of a mandibular molar.

The broad convex geometry is stronger than that of the modified ridge-lap pontic because the porcelain at the gingivofacial extent of a pontic is supported (Fig. 20-22). Because the tissue surface of the pontic is convex in all dimensions, it is accessible to dental floss; however, meticulous oral hygiene is necessary to prevent tissue inflammation resulting from the large area of tissue

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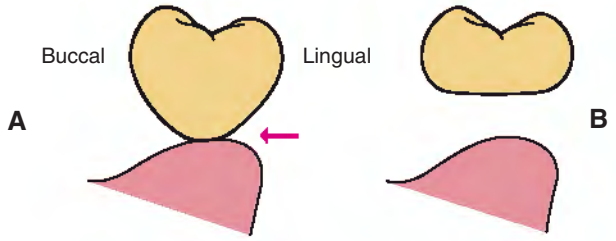

FIGURE 20-20 ■ **A,** Conical pontics may be conducive to food entrapment on broad residual ridges *(arrow).* **B,** The sanitary pontic form may be a better alternative.

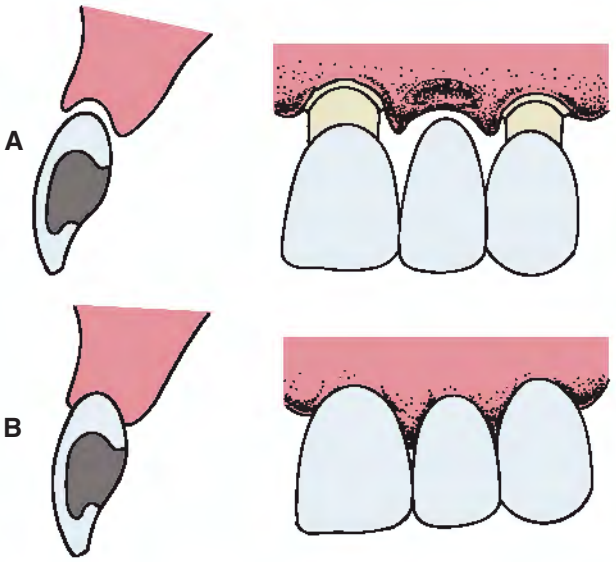

FIGURE 20-21 ■ Ovate pontic. **A,** Partial fixed dental prosthesis (FDP) partially seated. **B,** FDP seated.

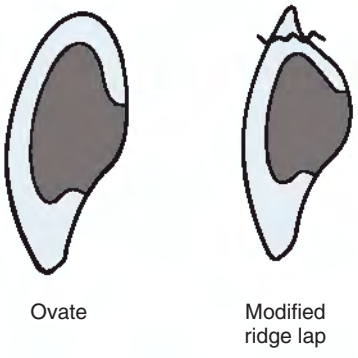

FIGURE 20-22 ■ The ovate pontic design eliminates the potential for unsupported porcelain in the cervical portion of an anterior pontic.

contact. Other disadvantages include the need for surgical tissue management and the associated cost. Furthermore, an additional evaluation appointment is typically necessary to achieve an esthetic result. The socket depression, with its pseudopapillae, requires the support of the interim ovate pontic and will collapse when the interim restoration is removed before an impression is made. To compensate for this three-dimensional change in the

FIGURE 20-23 ■ Pressure of a pontic on the mucosa inevitably leads to ulceration.

socket that occurs during the impression making, it is necessary to scrape the cast in this area to ensure positive contact and support of the pseudopapillae with the definitive pontic. Alternatively, special impression techniques can be used, such as the one described by de Vasconcellos and colleagues.[27] Because these adjustments are made somewhat arbitrarily, it may also be necessary to make revisions to the tissue surface of the pontic (reshaping or porcelain additions) at the evaluation phase.

Modified Ovate Pontic

Liu[28] described a modified version of the ovate pontic that expands the clinical indications for the ovate pontic. The modified ovate pontic possesses an ovate form with the apex positioned more facially on the residual ridge, rather than at the crest of the ridge. This alteration allows the use of the pontic in clinical scenarios in which horizontal ridge width is not sufficient for a conventional ovate pontic. Cleansing of this pontic is also purported to be easiest of all pontic types.

BIOLOGIC CONSIDERATIONS

The biologic principles of pontic design pertain to the maintenance and preservation of the residual ridge, abutment and opposing teeth, and supporting tissues. Factors of specific influence are pontic-ridge contact, amenability to oral hygiene, and the direction of occlusal forces.

Ridge Contact

Pressure-free contact between the pontic and the underlying tissues prevents ulceration and inflammation of the soft tissues.[1,29] If any blanching of the soft tissues is observed at evaluation, the pressure area should be identified with a disclosing medium (e.g., pressure-indicating paste), and the pontic should be recontoured until tissue contact is entirely passive. This passive contact should occur exclusively on keratinized attached tissue. When a pontic rests on mucosa, some ulceration may appear as a result of the normal movement of the mucosa in contact with the pontic (Fig. 20-23). Positive ridge pressure (hyperpressure) may be caused by excessive scraping of

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FIGURE 20-24 ■ Blanching of soft tissue at evaluation indicates pressure of the pontic on the mucosa.

FIGURE 20-25 ■ The patient must be instructed in how to clean the gingival surface of a pontic with floss.

the ridge area on the definitive cast (Fig. 20-24). This was once promoted as a way to improve the appearance of the pontic-ridge relationship. However, because of the ulceration that inevitably results when flossing is not meticulously performed, the concept is not recommended[1,30,31] unless followed as previously described for an ovate pontic.[29,32] Although ovate pontics maintain positive tissue contact to support the pseudopapillae, healthy mucosa can be maintained if the contact to the mucosa is tight but noncompressive and the gingival portion of the pontic is regularly cleaned.[33]

Oral Hygiene Considerations

The chief cause of ridge irritation is the toxins released from microbial plaque, which accumulate between the gingival surface of the pontic and the residual ridge, causing tissue inflammation and calculus formation.

Unlike removable partial dental prostheses, FDPs cannot be taken out of the mouth for daily cleaning. Patients must be taught efficient oral hygiene techniques, with particular emphasis on cleaning the gingival surface of the pontic. The shape of the gingival surface, its relation to the ridge, and the materials used in its fabrication influence ultimate success.

Normally, where tissue contact occurs, the gingival surface of a pontic is inaccessible to the bristles of a toothbrush. Therefore, the patient must develop excellent hygiene habits. Devices such as proxy brushes, pipe cleaners, Oral-B Super Floss (Oral-B, Procter & Gamble), and dental floss with a threader are highly recommended (Fig. 20-25). Gingival embrasures around the pontic should be wide enough to allow oral hygiene aids. However, to prevent food entrapment, they should not be opened excessively. To enable passage of floss over the entire tissue surface, tissue contact between the residual ridge and pontic must be passive.

If the pontic has a depression or concavity in its gingival surface, plaque accumulates because the floss cannot clean this area, and tissue irritation[34] follows. This is usually reversible; when the surface is subsequently modified to eliminate the concavity, inflammation disappears (see Fig. 20-15). Therefore, an accurate description of pontic design should be submitted to the laboratory, and the prosthesis should be checked and corrected if necessary before cementation. Prevention is the best solution for controlling tissue irritation.

Pontic Material

Any material chosen to fabricate the pontic should provide good esthetic results where needed; biocompatibility, rigidity, and strength to withstand occlusal forces; and longevity. FDPs should be made as rigid as possible because any flexure during mastication or parafunction may cause pressure on the gingiva and cause fractures of the veneering material. Occlusal contacts should not fall on the junction between metal and porcelain during centric or eccentric tooth contacts, nor should a metal-ceramic junction be in contact with the residual ridge on the gingival surface of the pontic.

Investigations into the biocompatibility of materials used to fabricate pontics have centered on two factors: (1) the effect of the materials and (2) the effects of surface adherence. Glazed porcelain is generally considered the most biocompatible of the available pontic materials,[35-37] and clinical data[30,38] tend to support this opinion, although the crucial factor seems to be the material's ability to resist plaque accumulation[39] (rather than the material itself). Well-polished gold is smoother, less prone to corrosion, and less retentive of plaque than is an unpolished or porous casting.[40] However, even highly polished surfaces accumulate plaque if oral hygiene measures are ignored.[41,42]

Glazed porcelain looks very smooth, but when viewed under a microscope, its surface shows many voids and is rougher than that of either polished gold or acrylic resin[43] (Fig. 20-26). Nevertheless, highly glazed porcelain is easier to clean than are other materials. For easier plaque removal and biocompatibility, the tissue surface of the pontic should be made in glazed porcelain. However, ceramic tissue contact may be contraindicated in edentulous areas where there is minimal distance between the residual ridge and the occlusal surface. In these instances, placing ceramic on the tissue side of the pontic may weaken the design of the metal substructure, particularly with porcelain occlusal surface (Fig. 20-27). If metal is placed in tissue contact, it should be highly polished. Regardless of the choice of pontic material, patients can prevent inflammation around the pontic with meticulous oral hygiene.[44]

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Occlusal Forces

Reducing the buccolingual width of the pontic by as much as 30% has been suggested[45,46] as a way to lessen occlusal forces on, and thus the loading of, abutment teeth. This practice continues today, although it has little scientific basis. Critical analysis[47] has revealed that forces are lessened only when food of uniform consistency is chewed and that a mere 12% increase in chewing efficiency can be expected from a one-third reduction of pontic width. Potentially harmful forces are more likely to be encountered if an FDP is loaded by the accidental biting on a hard object or by parafunctional activities such as bruxism, rather than by chewing of foods of uniform consistency. Narrowing the occlusal surface does not reduce these forces.

In fact, narrowing the occlusal surface may actually impede or even preclude the development of a harmonious and stable occlusal relationship. Like a malposed tooth, it may cause difficulties in plaque control and may not provide proper cheek support. For these reasons, pontics with normal occlusal widths (at least in the occlusal third) are generally recommended. One exception is the situation in which the residual alveolar ridge has collapsed buccolingually. Reducing pontic width may then be desired and would thereby lessen the lingual contour and facilitate plaque-control measures.

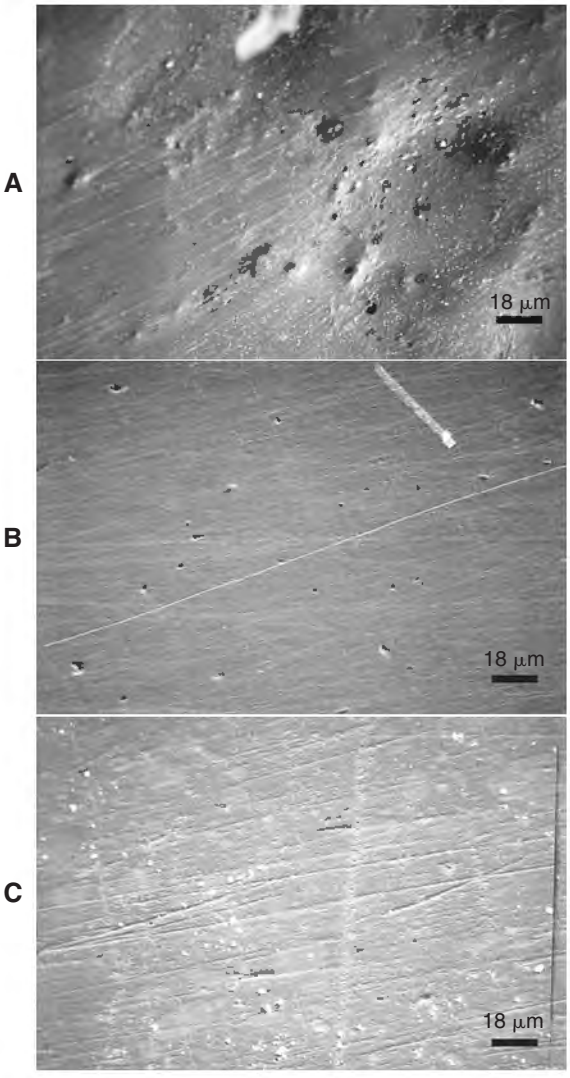

FIGURE 20-26 ■ Scanning electron micrographs of glazed porcelain **(A)**, polished gold **(B)**, and polished acrylic resin **(C)**. (Microscopy by Dr. J.L. Sandrik.)

MECHANICAL CONSIDERATIONS

The prognosis of FDP pontics is compromised if mechanical principles are not followed closely. Mechanical problems may be caused by improper choice of materials, poor framework design, poor tooth preparation, or poor occlusion. These factors can lead to fracture of the prosthesis or displacement of the retainers. Long-span posterior FDPs are particularly susceptible to mechanical problems. Inevitably, significant flexing occurs as a result of high occlusal forces and because the displacement effects increase with the cube of the span length (see Chapter 3). Therefore, evaluating the likely forces on a pontic and designing accordingly are important. For example, a strong all-metal pontic, rather than a metal-ceramic pontic (Fig. 20-28), may be needed in high-stress situations, in which it would be more susceptible to fracture. When metal-ceramic pontics are chosen, extending porcelain onto the occlusal surfaces to achieve better esthetics should also be carefully evaluated. In addition to its potential for fracture, porcelain may abrade the opposing dentition if the occlusal contacts are on enamel or metal.

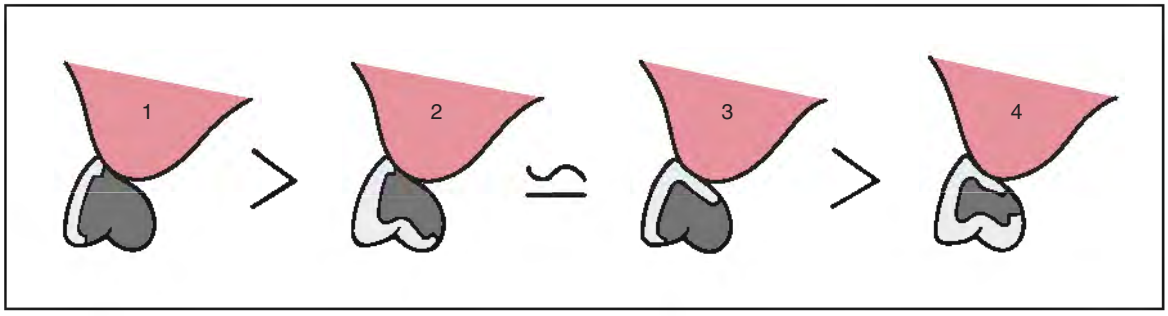

FIGURE 20-27 ■ Four pontic designs in descending order of strength, according to cross-sectional diameter of the metal substructure. When vertical space is minimal, the fourth design (porcelain tissue and occlusal coverage) may be contraindicated.

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FIGURE 20-28 ■ Failure of a long-span metal-ceramic partial fixed dental prosthesis subjected to high stress.

FIGURE 20-29 ■ Pontic failure resulting from improper laboratory technique.

Available Pontic Materials

Some FDPs are fabricated entirely of metal, porcelain, or acrylic resin, but most consist of a combination of metal and porcelain. The acceptance of acrylic resin–veneered pontics has been limited because of their reduced durability (wear and discoloration). The newer indirect composites, which are based on high inorganic content–filled resins and fiber-reinforced materials (see Chapter 15), have revived interest in composite resin and resin-veneered pontics.

Metal-Ceramic Pontics

Most pontics are fabricated by the metal-ceramic technique. If properly used, this technique is helpful in solving commonly encountered clinical problems. A well-fabricated metal-ceramic pontic is strong, is easy to keep clean, and looks natural. However, mechanical failure (Fig. 20-29) can occur and often is attributable to inadequate framework design. The principles of framework design are discussed in Chapter 19, but the following points are emphasized in this chapter:

- The framework must provide a uniform veneer of porcelain (approximately 1.2 mm). Excessive thickness of porcelain contributes to inadequate support and predisposes to eventual fracture (Fig. 20-30). This is often true in the cervical portion of an anterior pontic. A reliable technique for ensuring uniform thickness of porcelain is to wax the fixed prosthesis to complete anatomic contour and then accurately cut back the wax to a predetermined depth (Fig. 20-31).
- The metal surfaces to be veneered must be smooth and free of pits. Surface irregularities cause incomplete wetting by the porcelain slurry, which leads to voids at the porcelain-metal interface that reduce bond strength and increase the possibility of mechanical failure.
- Sharp angles on the veneering area should be rounded. They produce increased stress concentrations that can cause mechanical failure.
- The location and design of the external metal-porcelain junction require particular attention. Any deformation of the metal framework at the junction

FIGURE 20-30 ■ Failure of unsupported gingival porcelain.

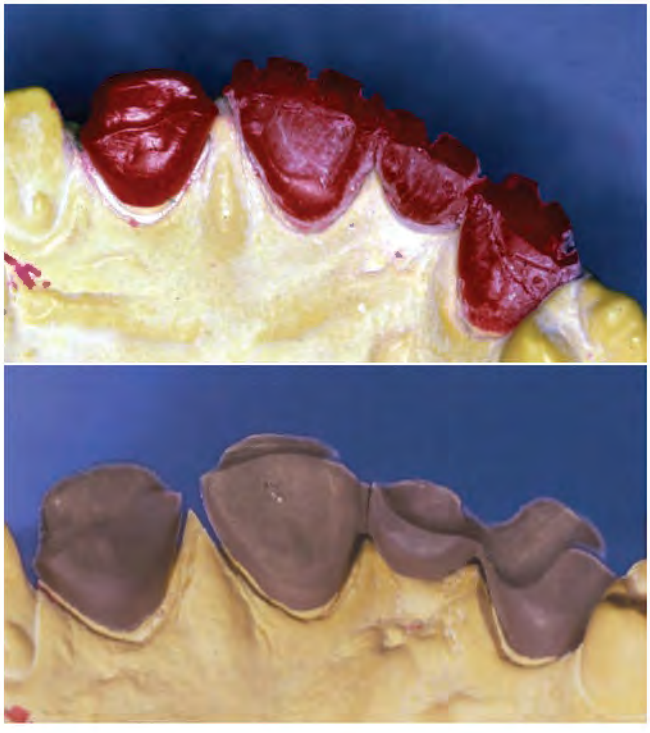

FIGURE 20-31 ■ Waxing to anatomic contour and controlled cutback **(A)** are the most reliable approaches to fabricating a satisfactory metal substructure **(B)**.

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FIGURE 20-32 ■ Porcelain chipping caused by occlusal contact across the metal-ceramic junction.

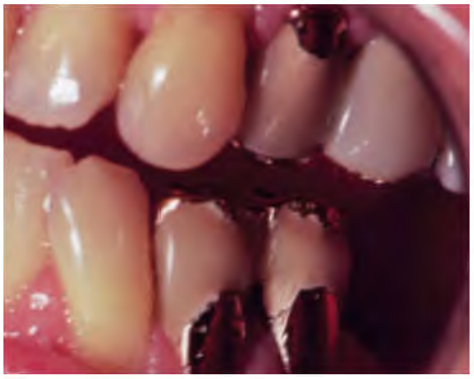

FIGURE 20-33 ■ Wear of an acrylic resin-veneered prosthesis.

can lead to chipping of the porcelain (Fig. 20-32). For this reason, occlusal centric contacts must be placed at least 1.5 mm away from the junction. Excursive eccentric contacts that might deform the metal-ceramic interface must be evaluated carefully.

Resin-Veneered Pontics

Historically, acrylic resin–veneered restorations had deficiencies that made them acceptable only as longer term interim restorations. Their resistance to abrasion was lower than that of enamel or porcelain, and noticeable wear occurred with normal toothbrushing (Fig. 20-33). Furthermore, because of the relatively high ratio of surface area to volume of a thin resin veneer, dimensional change from water absorption and thermal fluctuations (thermocycling) caused problems. No chemical bond existed between the resin and the metal framework, and so the resin was retained by mechanical means (i.e., undercuts). Continuous dimensional change of the veneers often caused leakage at the metal-resin interface, with subsequent discoloration of the restoration.

Nevertheless, there are certain advantages to using polymeric materials instead of ceramics: They are easy to manipulate and repair and do not require the high–melting range alloys needed for metal-ceramic techniques. Indirect composite resin systems introduced since the 1990s have resolved some of the problems inherent in previous indirect resin veneers. These new-generation indirect resins have a higher density of inorganic ceramic filler than do traditional direct and indirect composite resins. Most are subjected to a postcuring process that results in high flexural strength, minimal polymerization shrinkage, and wear rates comparable with those of tooth enamel.[48] In addition, improvements in the bond between the composite resin and metal[49] may lead to a reappraisal of resin veneers.

Fiber-Reinforced Composite Resin Pontics

Composite resins can be used in partial FDPs without a metal substructure (see Chapter 15). A substructure matrix of impregnated glass or polymer fiber provides structural strength. Because of the physical properties of this system, combined with its excellent marginal adaptation and esthetics, it is a possible metal-free alternative for FDPs, although long-term clinical performance is not yet known.

ESTHETIC CONSIDERATIONS

No matter how well biologic and mechanical principles have been followed during fabrication, the patient evaluates the result by how it looks, especially when anterior teeth have been replaced. Many esthetic considerations that pertain to single crowns also apply to pontics (see Chapter 23). Several problems unique to pontics may be encountered in the attempt to achieve a natural appearance.

The Gingival Interface

An esthetically successful pontic replicates the form, contours, incisal edge, gingival and incisal embrasures, and color of adjacent teeth. The pontic's simulation of a natural tooth is most often betrayed at the tissue-pontic junction. The greatest challenge in this situation is to compensate for anatomic changes that occur after extraction. To achieve a "natural" appearance, special attention should be paid to the contour of the labial surface as it approaches the tissue-pontic junction. This cannot be accomplished by merely duplication of the facial contour of the missing tooth; after a tooth is removed, the alveolar bone undergoes resorption or remodeling, or both. If the original tooth contour were followed, the pontic would look unnaturally long incisogingivally (Fig. 20-34). For an esthetic pontic to achieve the illusion of a natural tooth, observers must think that they are seeing a natural tooth.

The modified ridge-lap pontic is recommended for most anterior situations; it compensates for lost buccolingual width in the residual ridge by overlapping what remains. Rather than emerging from the crest of the ridge as a natural tooth would, the cervical aspect of the pontic sits in front of the ridge, covering any abnormal ridge structure that results from tooth loss. Fortunately, because most teeth are viewed from only two dimensions, this relationship remains undetected. A properly designed, modified ridge-lap pontic provides the required convexity on the tissue side, with smooth and open embrasures on the lingual side for ease of cleaning. This is difficult

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FIGURE 20-34 ■ Correct incisogingival height is critical in esthetic pontic design. **A,** Esthetic failure of a four-unit partial fixed dental prosthesis (FDP) replacing the right central and lateral incisors. The pontics have been shaped to follow the facial contour of the missing teeth, but because of bone loss, they look too long. **B,** The replacement FDP. Note that the gingival half of each pontic has been reduced. Esthetic appearance is much improved. **C,** This esthetic failure is the result of excessive reduction. The central incisor pontics look too short.

to accomplish. Clinically, many pontics have suboptimal contour, which results in an unnatural appearance. This can be avoided with careful preparation at the diagnostic waxing stage (see Chapter 3). Sometimes the ridge tissue must be surgically reshaped to enhance the result.

In normal situations, light falls from above, and an object's shadow is below it. Unexpected lighting or unexpectedly positioned shadows (Fig. 20-35) can be confusing to the brain. Because of past experience, the brain "knows" that a tooth grows out of the gingiva, and it therefore "sees" a pontic as a tooth unless telltale shadows suggest otherwise. The dentist must carefully study where shadows fall around natural teeth, particularly around the gingival margin. If a pontic is poorly adapted

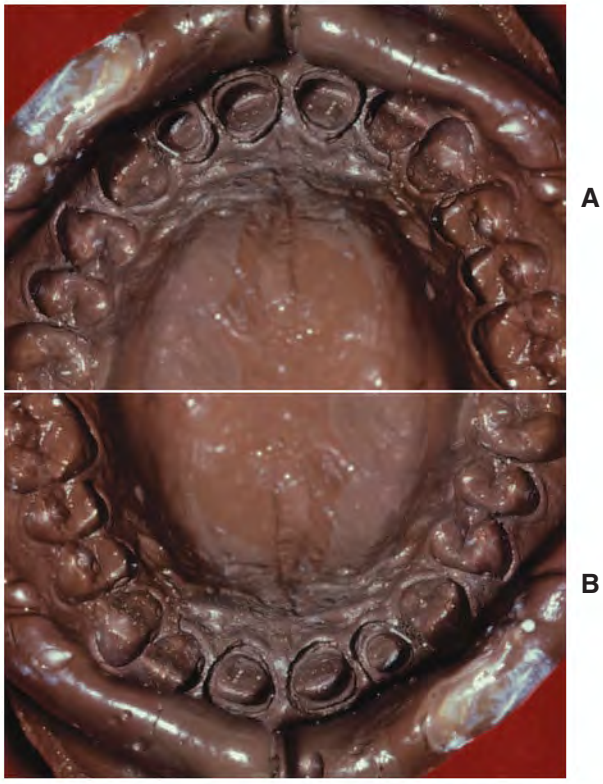

FIGURE 20-35 ■ Optical illusion. The two images (**A** and **B**) are identical except that one image is upside down. Most people make different three-dimensional interpretations of each photograph, interpreting one as a negative impression and the other as a positive cast. (Verify the illusion by turning the book.) The interpretation is based on how shadows fall; in normal situations, objects are seen illuminated from above.

to the residual ridge, there is an unnatural shadow in the cervical area that looks odd and spoils the illusion of a natural tooth (Fig. 20-36). In addition, recesses at the pontic-gingival interface collect food debris, further ruining the illusion of a natural tooth.

When appearance is of utmost concern, the ovate pontic, used in conjunction with alveolar preservation or soft tissue ridge augmentation, can provide an appearance at the gingival interface that is virtually indistinguishable from that of a natural tooth. Because it emerges from a soft tissue recess, this pontic is not susceptible to many of the esthetic pitfalls applicable to the modified ridge-lap pontic. However, in most circumstances, the patient must be willing to undergo the additional surgical procedures that are necessary for placement of an ovate pontic.

Incisogingival Length

Correctly sizing a pontic simply by duplicating the original tooth is not possible. Ridge resorption makes such a pontic look too long in the cervical region. The height of a tooth is immediately obvious when the patient smiles and shows the gingival margin (Fig. 20-37). An abnormal labiolingual position or cervical contour, however, is not immediately obvious. This fact can be used to produce a pontic of good appearance by recontouring the gingival

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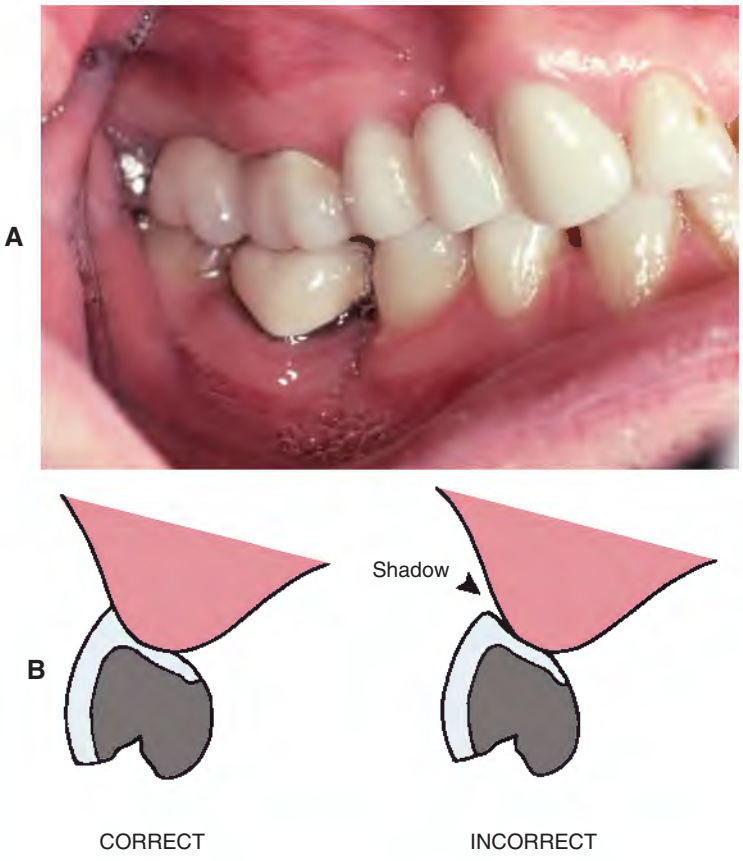

FIGURE 20-36 ■ A pontic should be interpreted as "growing" out of the gingival tissue. The second premolar pontic in this four-unit partial fixed dental prosthesis **(A)** is successful because it is well adapted to the ridge; however, it is evident that the first premolar a pontic because of its poor adaptation to the ridge, which creates a shadow. **B,** Shadows around the gingival surface *(arrowhead)* spoil the esthetic illusion.

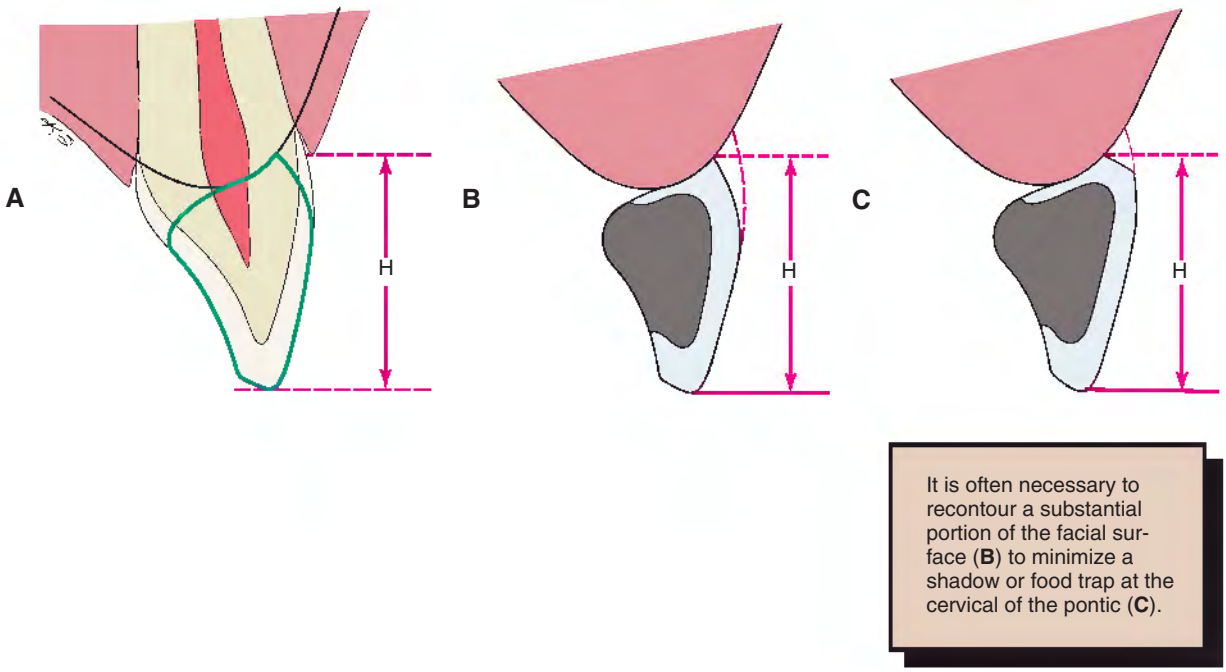

FIGURE 20-37 ■ **A,** A pontic should have the same incisogingival height *(H)* as the original tooth. **B,** Correctly contoured pontic. **C,** Incorrectly contoured pontic. (The *dashed lines* in **B** and **C** represent the original tooth contour.) The shelf at the gingival margin may trap food and create an esthetically unacceptable shadow.

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half of the labial surface (see Fig. 20-36). The observer sees a normal tooth length but is unaware of the abnormal labial contour. The illusion is successful.

Even with moderately severe bone resorption, obtaining a natural appearance by exaggerated contouring of the pontics may still be possible. In areas where tooth loss is accompanied by excessive loss of alveolar bone, however, a pontic of normal length would not touch the ridge at all.

One solution is to shape the pontic to simulate a normal crown and root with emphasis on the cementoenamel junction. The root can be stained to simulate exposed dentin (Fig. 20-38). Another approach is to use pink porcelain to simulate the gingival tissues (Fig. 20-39). However, such pontics then have considerably increased tissue contact and require scrupulous plaque control for long-term success. Ridge augmentation procedures have been successful in correcting areas of limited resorption. When bone loss is severe, the esthetic result obtained with a partial removable dental prosthesis is often better than that obtained with an FDP.

Mesiodistal Width

Frequently, the space available for a pontic is greater or smaller than the width of the contralateral tooth. This is usually because of uncontrolled tooth movement that occurred when a tooth was removed and not replaced.

If possible, such a discrepancy should be corrected by orthodontic treatment. If this is not possible, an acceptable appearance may be obtained by incorporating visual perception principles into the pontic design. In the same way that the brain can be confused into misinterpreting the relative sizes of shapes or lines because of an erroneous interpretation of perspective (Fig. 20-40), a pontic of abnormal size may be designed to give the illusion of being a more natural size. The width of an anterior tooth is usually identified by the relative positions of the mesiofacial and distofacial line angles, and the overall shape by the detailed pattern of surface contour and light reflection between these line angles. The features of the contralateral tooth (Fig. 20-41) should be duplicated as precisely as possible in the pontic, and the space

FIGURE 20-38 ■ It is difficult without surgical augmentation to fabricate an esthetic fixed prosthesis for a patient with extensive alveolar bone loss. **A** to **D,** One approach is to contour the crowns normally and to shape and stain the apical extension to simulate exposed root surface. (**A** and **B,** Redrawn from Blancheri RL: Optical illusions and cosmetic grinding. Rev Asoc Dent Mex 8:103, 1950.)

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FIGURE 20-39 ■ Partial fixed dental prosthesis replacing maxillary left central and lateral incisors. The patient had lost significant bone from the edentulous ridge. **A** and **B,** Appearance of the prosthesis was enhanced with the use of pink porcelain between the pontics to simulate gingival tissue. The patient has been able to maintain excellent tissue health through the daily use of Oral-B Super Floss.

discrepancy can be compensated by alteration in the shape of the proximal areas. The retainers and the pontics can be proportioned to minimize the discrepancy. (This is another situation in which a diagnostic waxing procedure helps solve a challenging restorative problem.)

Space discrepancy presents less of a problem when posterior teeth are being replaced (Fig. 20-42) because their distal halves are not normally visible from the front. A discrepancy here can be managed by duplicating the visible mesial half of the tooth and adjusting the size of the distal half.

PONTIC FABRICATION

Available Materials

Over time, several techniques for pontic fabrication have evolved. Prefabricated porcelain facings were traditionally very popular for use with conventional gold alloys. As use of the metal-ceramic technique increased during the 1970s, prefabricated facings lost their popularity and essentially disappeared. Although custom-made metal-ceramic facings were an acceptable substitute, they never gained widespread acceptance. Table 20-3 summarizes the various techniques (Fig. 20-43).

Most pontics are now made with the metal-ceramic technique, which provides the best solution to the biologic, mechanical, and esthetic challenges encountered in pontic design. Their fabrication, however, differs slightly from the fabrication of individual crowns. These differences are emphasized in the following paragraphs.

Metal-Ceramic Pontics

A well-designed metal-ceramic pontic allows for easy plaque removal and has good strength, wear resistance, and esthetics (see Fig. 20-43, *D*). Its fabrication is relatively simple if at least one retainer is also metal-ceramic. The metal framework for the pontic and one or both of its retainers is then cast in one piece. This facilitates pontic manipulation during the successive laboratory and clinical phases. In the following discussion, it is assumed that either one or both of the retainers are metal-ceramic complete crowns. When this is not the case, an alternative approach is necessary.

Anatomic Contour Waxing

For strength and esthetics, the thickness of porcelain must be controlled accurately in the finished restoration. To ensure this, a wax pattern is made to the final anatomic contour. This also enables the dentist to assess connector design adequacy and the relationship between the connectors and the proposed configuration of the ceramic veneer (see Chapter 27).

Armamentarium. The following equipment is needed (Fig. 20-44):

- Bunsen burner
- Inlay wax
- Sticky wax
- Waxing instruments
- Cotton cleaning cloth
- Die-wax separating liquid
- Zinc stearate or powdered wax
- Double-ended brushes
- Cotton balls
- Fine-mesh nylon hose

Step-by-Step Procedure

1. Wax the internal, proximal, and axial surfaces of the retainers as described in Chapter 18.
2. Soften the inlay wax, mold it to the approximate desired pontic shape, and adapt it to the ridge. This is the starting point for subsequent modification. An alternative (and perhaps preferable) method is to make an impression of the diagnostic waxing or interim restoration. Molten wax can then be poured into this to form the initial pontic shape. Prefabricated pontic shapes are also available (Fig. 20-45).
3. If a posterior tooth is being replaced, leave the occlusal surface flat because the occlusion is best developed with the wax addition technique outlined in Chapter 18.
4. Lute the pontic to the retainers and, for additional stability, connect its cervical aspect directly to the definitive cast with sticky wax. Then wax the pontic

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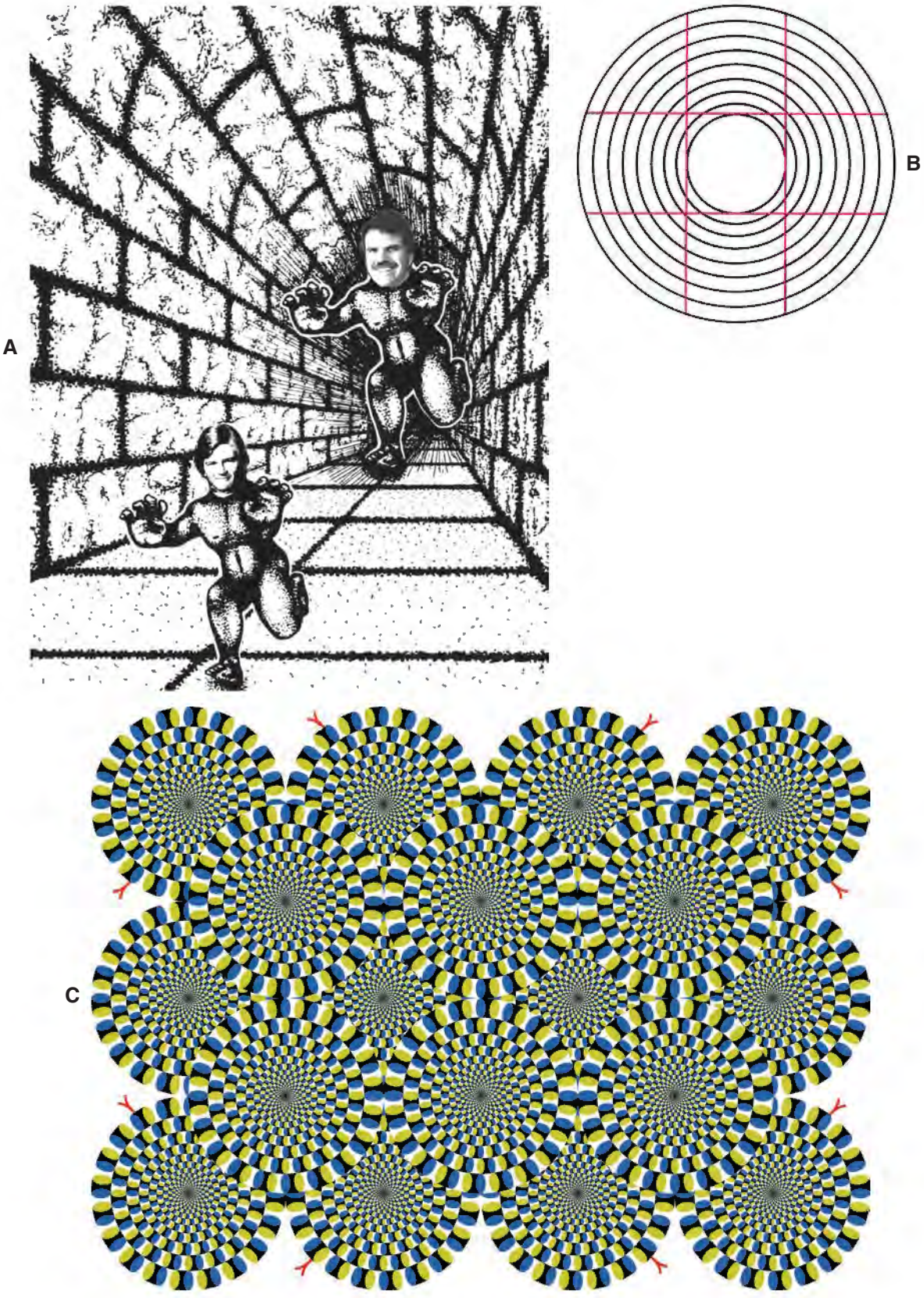

FIGURE 20-40 ■ Optical illusions. **A,** The people are the same size. **B,** The lines are straight. (Tilt the book to verify this.) **C,** Kitaoka's "rotating snake" illusion. Rotation of the "wheels" occurs in relation to eye movements. On steady fixation close up, the effect vanishes.[51] (**A,** Modified from Shepard RN: MindSights. New York, WH Freeman, 1990. **C,** Copyright Akiyoshi Kitaoka, 2003; reproduced with permission.)

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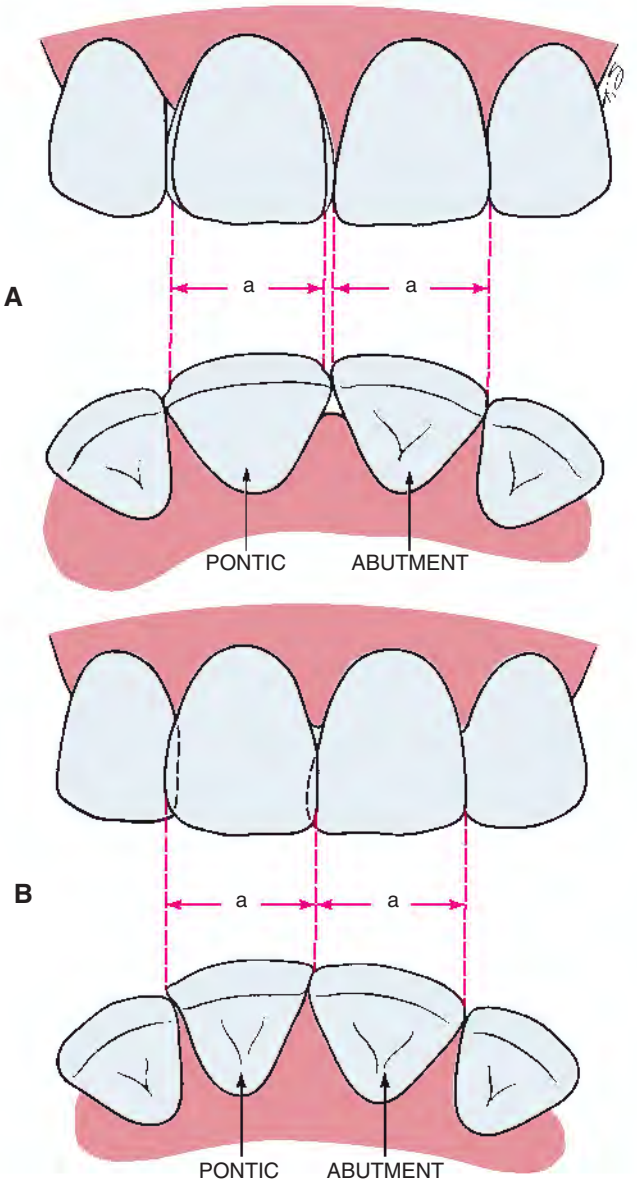

FIGURE 20-41 ■ An abnormally sized anterior pontic space can be restored esthetically by matching the location of the line angles and adjusting the interproximal areas. Large **(A)** and small **(B)** pontic spaces. Dimension *a* should be matched in the replacement. (Redrawn from Blancheri RL: Optical illusions and cosmetic grinding. Rev Asoc Dent Mex 8:103, 1950.)

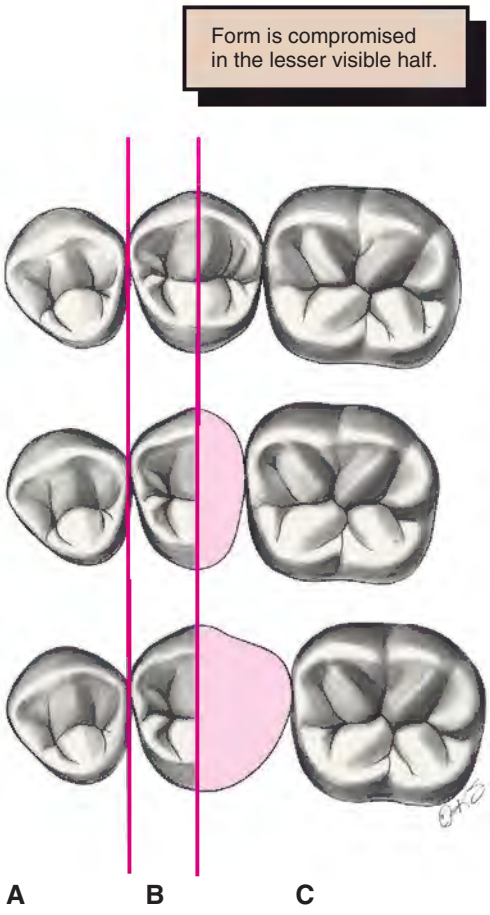

FIGURE 20-42 ■ When a posterior tooth is replaced **(A),** the dimension of the more visible mesial half of the adjacent tooth should be duplicated. Narrow **(B)** and wide **(C)** pontic spaces. (Redrawn from Blancheri RL: Optical illusions and cosmetic grinding. Rev Asoc Dent Mex 8:103, 1950.)

TABLE 20-3 **Available Pontic Systems**

Material	Advantages	Disadvantages	Indications	Contraindications
Metal-ceramic	Esthetics Biocompatible	Difficult to fabricate if an abutment is not metal-ceramic Weaker than all metal	Most situations	Long spans with high stress
All metal	Strength Straightforward procedure	Nonesthetic	Mandibular molars, especially under high occlusal force	Where esthetics is important
All ceramic	Best esthetics Biocompatible	Risk of fracture Unable to be sectioned and reconnected Large connectors needed	High esthetic demand	Long spans with high stress

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FIGURE 20-43 ■ **A,** Eight-unit partial fixed dental prosthesis (FDP) with porcelain facings. **B** and **C,** A three-unit posterior FDP that was fabricated by post-ceramic soldering of a metal-ceramic facing to conventional gold. **D,** Metal-ceramic FDP with a modified ridge-lap pontic (canine) that appears to emerge from the gingiva.

FIGURE 20-44 ■ Waxing armamentarium.

FIGURE 20-45 ■ Prefabricated wax pontics.

to proper axial and occlusal (or incisal) contour (Fig. 20-46).

5. Complete the retainers, and contour the proximal and tissue surfaces of the pontic for the desired tissue contact. The pontic is now ready for evaluation before cutback.

Evaluation. The form of the wax pattern is evaluated (Fig. 20-47), and any deficiencies are corrected. Particular attention is given to the connectors, which should have the correct shape and size. The connectors provide firm attachment for the pontic so that it does not separate from the retainers during the subsequent cutback procedure.

Cutback

Armamentarium

- Bunsen burner
- Waxing instruments
- Cut back instrument
- Scalpel
- Thin ribbon saw blade or sewing thread
- Explorer

Step-by-Step Procedure

1. Use a sharp explorer to outline the area that will be veneered with porcelain (Fig. 20-48, *A*). The porcelain-metal junction must be placed sufficiently lingually to ensure good esthetics.

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2. Make depth cuts or grooves in the wax pattern (see Chapter 19 and Fig. 20-48, *B*).
3. Complete the cutback as far as access allows, with the units connected and on the definitive cast.
4. Section one wax connector with a thin ribbon saw (sewing thread is a suitable alternative), and remove the isolated retainer from the definitive cast (see Fig. 20-48, *C*).
5. Finish the cutback of this retainer; ensure there is a distinct 90-degree porcelain-metal junction.
6. Reflow and finalize the margins. The pontic is held in position by the other retainer during this procedure.
7. Refine the pontic cutback where access is improved by removal of the first retainer.
8. Reseat the first retainer, reattach it to the pontic, section the other connector, and repeat the process.
9. Sprue the units, and do any final reshaping as needed.
10. Invest and cast in the manner described in Chapter 22.

When one connector of a three-unit FDP is to be cast and the other soldered, the cast connector should be sectioned first when the foregoing procedure is followed. The gingival surface of the pontic should be cut back in the metal rather than in the wax because the tissue contact helps stabilize the pontic. Access is difficult, and it is easy to break the fragile wax connector.

FIGURE 20-46 ■ Luting the pontic to the retainers.

FIGURE 20-47 ■ Anatomic contour wax patterns.

Metal Preparation

Armamentarium

- Separating disk
- Ceramic-bound finishing stones
- Sandpaper disks (nonveneered surfaces only)
- Rubber wheel (nonveneered surfaces only)
- Round carbide bur (No. 6 or 8)
- Airborne abrasion unit (with 25-µm aluminum oxide)

Step-by-Step Procedure

1. Recover the castings from the investment and prepare the surfaces to be veneered as described in Chapter 19 (Fig. 20-49).
2. Finish the gingival surface of the pontic. Do not overreduce this area.

Evaluation. Less than 1 mm of porcelain thickness is needed on the gingival surface because once it is cemented, the restoration is seen from the facial side, rather than from the gingival side. Excessive gingival porcelain is a common fault in pontic framework design and may lead to fracture and poor appearance (see Fig. 20-30).

To facilitate plaque control, the metal-ceramic junction should be located lingually. Then tissue contact is on the porcelain and not on metal, which retains plaque more tenaciously.[50]

A

B,C

FIGURE 20-48 ■ Cutback procedure for a three-unit anterior partial fixed dental prosthesis. **A,** Delineating the porcelain-metal junction. **B,** Wax patterns cut back for porcelain application. **C,** A ribbon saw is used to section the connector.

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FIGURE 20-49 ■ Metal substructure ready for airborne particle abrasion and oxidation.

FIGURE 20-50 ■ Armamentarium for porcelain application.

Porcelain Application

Many of the steps for porcelain application are identical to those in individual crown fabrication (see Chapter 24). There are some features peculiar to pontic fabrication, however, and these are emphasized.

Armamentarium. The following equipment is needed (Fig. 20-50):

- Paper napkin
- Glass slab
- Tissues or gauze squares
- Distilled water
- Glass spatula
- Serrated instrument
- Porcelain tweezers or hemostat
- Ceramist's brushes (No. 2, 4, or 6)
- Whipping brush
- Razor blade
- Cyanoacrylate resin
- Colored pencil
- Articulating tape
- Ceramic-bound stones
- Diamond stones
- Diamond disk

Step-by-Step Procedure

1. Prepare the metal and apply opaque as described in Chapter 24 (Fig. 20-51).
2. Apply cervical porcelain to the gingival surface of the pontic, and seat the castings on the definitive cast. A small piece of tissue paper adapted to the residual ridge on the cast by moistening with a brush prevents porcelain powder from sticking to the stone. (Cyanoacrylate resin or special separating agents can be used for the same purpose.)
3. Build up the porcelain (as described in Chapter 24) with the appropriate distribution of cervical, body, and incisal shades. The tissue paper acts as a matrix for the gingival surface of the pontic.
4. When the porcelain has been condensed, section between the units with a thin razor blade. This prevents the porcelain from pulling away from the framework as a result of firing shrinkage. A second application of porcelain is needed to correct any deficiencies caused by firing shrinkage. Such additions usually are needed proximally and gingivally on the pontic.
5. Apply a porcelain separating liquid (e.g., VITA Modisol, Vident) to the stone ridge so that the additional gingival porcelain can be lifted directly from the cast as in the fabrication of a porcelain labial margin (see Chapter 24).
6. Mark the desired tissue contact and contour the gingival surface to create as convex a surface as possible. The pontic is now ready for clinical evaluation and soldering procedures, characterization, glazing, finishing, and polishing (see Chapters 27 to 29).

Evaluation. The porcelain on the tissue surface of the pontic should be as smooth as possible (Fig. 20-52). Pits and defects hamper plaque control and promote calculus formation. The metal framework must be highly polished, with special care directed to the gingival embrasures (where access for plaque removal is more difficult).

All-Metal Pontics

Pontics made from metal (Fig. 20-53) require fewer laboratory steps and are therefore sometimes used for posterior FDPs. However, they have some disadvantages (e.g., their appearance). In addition, investing and casting must be done carefully because the mass of metal in the pontic is prone to porosity as the bulk increases. A porous pontic retains plaque and tarnishes and corrodes rapidly.

SUMMARY

Designs that allow easy plaque control are especially important to the long-term success of a pontic. Minimizing tissue contact by maximizing the convexity of the

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FIGURE 20-51 ■ Porcelain application. **A,** Substructure ready for opaque application. **B,** Opaque application. **C,** Body porcelain application. **D,** The porcelain after the first firing.

FIGURE 20-52 ■ Metal-ceramic pontic replacing a lateral incisor.

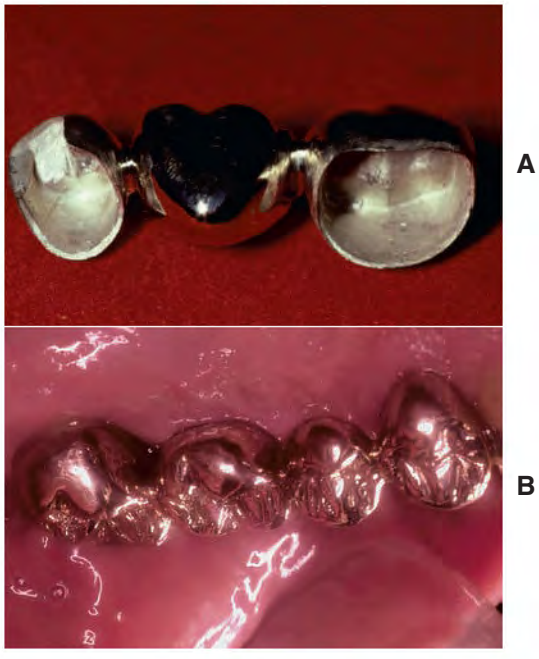

FIGURE 20-53 ■ All-metal partial fixed dental prostheses.

pontic's gingival surface is essential. Special consideration is also needed to create a design that combines easy maintenance with natural appearance and adequate mechanical strength. When the appropriate design has been selected, it must be accurately conveyed to the dental technician.

There are subtle differences between metal-ceramic pontic fabrication and the fabrication of other types of pontics. Under most circumstances, the metal-ceramic technique is used because it is straightforward and practical. However, it requires careful execution for maximum strength, esthetic appearance, and effective plaque control. Alternative procedures are sometimes helpful, particularly when gold alloys are used for the retainers. Resin-veneered pontics should be restricted to use as longer term interim restorations, and all-metal pontics may be the restoration of choice in nonesthetic situations, particularly those in which forces are high.

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REFERENCES

1. Stein RS: Pontic-residual ridge relationship: a research report. J Prosthet Dent 16:251, 1966.
2. Siebert JS: Reconstruction of deformed, partially edentulous ridges, using full thickness onlay grafts. I. Technique and wound healing. Compend Contin Educ Dent 4:437, 1983.
3. Abrams H, et al: Incidence of anterior ridge deformities in partially edentulous patients. J Prosthet Dent 57:191, 1987.
4. Hawkins CH, et al: Ridge contour related to esthetics and function. J Prosthet Dent 66:165, 1991.
5. Abrams L: Augmentation of the deformed residual edentulous ridge for fixed prosthesis. Compend Contin Educ Dent 1:205, 1980.
6. Garber DA, Rosenberg ES: The edentulous ridge in fixed prosthodontics. Compend Contin Educ Dent 2:212, 1981.
7. Langer B, Calagna L: The subepithelial connective tissue graft. J Prosthet Dent 44:363, 1980.
8. Smidt A, Goldstein M: Augmentation of a deformed residual ridge for the replacement of a missing maxillary central incisor. Pract Periodont Aesthet Dent 11:229, 1999.
9. Kaldahl WB, et al: Achieving an esthetic appearance with a fixed prosthesis by submucosal grafts. J Am Dent Assoc 104:449, 1982.
10. Meltzer JA: Edentulous area tissue graft correction of an esthetic defect: a case report. J Periodontol 50:320, 1979.
11. McHenry K, et al: Reconstructing the topography of the mandibular ridge with gingival autografts. J Am Dent Assoc 104:478, 1982.
12. Studer SP, et al: Soft tissue correction of a single-tooth pontic space: a comparative quantitative volume assessment. J Prosthet Dent 83:402, 2000.
13. Nemcovsky CE, Vidal S: Alveolar ridge preservation following extraction of maxillary anterior teeth. Report on 23 consecutive cases. J Periodontol 67:390, 1996.
14. Bahat O, et al: Preservation of ridges utilizing hydroxylapatite. Int J Periodontol Res Dent 6:35, 1987.
15. Lekovic V, et al: A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. J Periodontol 68:563, 1997.
16. Schropp L, et al: Bone healing and soft tissue contour changes following single tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent 23:313, 2003.
17. Spear FM: Maintenance of the interdental papilla following anterior tooth removal. Pract Periodont Aesthet Dent 11:21, 1999.
18. Ingber JS: Forced eruption. II. A method of treating nonrestorable teeth—periodontal and restorative considerations. J Periodontol 47:203, 1976.
19. Nevins M, et al: A study of the fate of the buccal wall of extraction sockets of teeth with prominent roots. Int J Periodontics Restorative Dent 26:19, 2006.
20. Guyer S: Selectively retained vital roots for partial support of overdentures: a patient report. J Prosthet Dent 33:258, 1975.
21. Harper K: Submerging an endodontically treated root to preserve the alveolar ridge under a bridge—a case report. Dent Update 29:200, 2002.
22. Salama M, et al: Advantages of root submergence for pontic site development in esthetic implant therapy. Int J Periodontics Restorative Dent 27:520, 2007.
23. Perel ML: A modified sanitary pontic. J Prosthet Dent 28:589, 1972.
24. Hood JA, et al: Stress and deflection of three different pontic designs. J Prosthet Dent 33:54, 1975.
25. Shillingburg HT, et al: Fundamentals of fixed prosthodontics, 2nd ed, p 387. Chicago, Quintessence Publishing, 1981.
26. Eissmann HF, et al: Physiologic design criteria for fixed dental restorations. Dent Clin North Am 15:543, 1971.
27. de Vasconcellos DK, et al: Impression technique for ovate pontics. J Prosthet Dent 105:59, 2011.
28. Liu C: Use of a modified ovate pontic in areas of ridge defects: a report of 2 cases. J Esthet Restor Dent 16:273, 2004.
29. Tripodakis AR, Constandinides A: Tissue response under hyperpressure from convex pontics. Int J Periodontics Restorative Dent 10:409, 1990.
30. Cavazos E: Tissue response to fixed partial denture pontics. J Prosthet Dent 20:143, 1968.
31. Henry PJ, et al: Tissue changes beneath fixed partial dentures. J Prosthet Dent 16:937, 1966.
32. Jacques LB, et al: Tissue sculpturing: an alternative method for improving esthetics of anterior fixed prosthodontics. J Prosthet Dent 81:630, 1999.
33. Zitzmann NU, et al: The ovate pontic design: a histologic observation in humans. J Prosthet Dent 88:375, 2002.
34. Hirshberg SM: The relationship of oral hygiene to embrasure and pontic design: a preliminary study. J Prosthet Dent 27:26, 1972.
35. McLean JW: The science and art of dental ceramics, vol 2, p 339. Chicago, Quintessence Publishing, 1980.
36. Harmon CB: Pontic design. J Prosthet Dent 8:496, 1958.
37. Henry PJ: Pontic form in fixed partial dentures. Aust Dent J 16:1, 1971.
38. Allison JR, Bhatia HL: Tissue changes under acrylic and porcelain pontics [Abstract No. 168]. J Dent Res 37:66, 1958.
39. Silness J, et al: The relationship between pontic hygiene and mucosal inflammation in fixed bridge recipients. J Periodont Res 17:434, 1982.
40. Gildenhuys RR, Stallard RE: Comparison of plaque accumulation on metal restorative surfaces. Dent Surv 51(1):56, 1975.
41. Keenan MP, et al: Effects of cast gold surface finishing on plaque retention. J Prosthet Dent 43:168, 1980.
42. Ørstavik D, et al: Bacterial growth on dental restorative materials in mucosal contact. Acta Odontol Scand 39:267, 1981.
43. Clayton JA, Green E: Roughness of pontic materials and dental plaque. J Prosthet Dent 23:407, 1970.
44. Tolboe H, et al: Influence of pontic material on alveolar mucosal conditions. Scand J Dent Res 96:442, 1988.
45. Smith DE: The pontic in fixed bridgework. Pacific Dent Gaz 36:741, 1928.
46. Ante IH: Construction of pontics. J Can Dent Assoc 2:482, 1936.
47. Beke AL: The biomechanics of pontic width reduction for fixed partial dentures. J Acad Gen Dent 22(6):28, 1974.
48. Ferracane JL, Condon JR: Post-cure heat treatments for composites: properties and fractography. Dent Mater 8:290, 1992.
49. Rothfuss LG, et al: Resin to metal bond strengths using two commercial systems. J Prosthet Dent 79:270, 1998.
50. Wise MD, Dykema RW: The plaque-retaining capacity of four dental materials. J Prosthet Dent 33:178, 1975.
51. Kitaoka A, Ashida H: Phenomenal characteristics of peripheral drift illusion. Vision 15:261, 2003.

STUDY QUESTIONS

1. Outline and discuss a logical classification of pontics.
2. How does pontic design change as a function of location in the dental arch?
3. What are the materials available for pontic fabrication? What are their respective advantages, disadvantages, indications, and contraindications?
4. Discuss the factors that govern the shaping of the facial and lingual surfaces of a modified ridge-lap pontic.
5. What common clinical problems might be encountered if a pontic is improperly shaped or fabricated?
6. Discuss the various techniques for soft tissue augmentation and the residual ridge defects that these techniques are designed to resolve.
7. What factors should be considered in the selection of the pontic material that will be in contact with the residual ridge?

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CHAPTER 21

Retainers for Partial Removable Dental Prostheses

Different philosophies exist regarding the need to fabricate cast restorations for abutment teeth before a partial removable dental prosthesis (RDP) is made. Successful removable prostheses can be made with minimal need for fixed prosthodontic preparatory treatment. Instead of the routine use of cast restorations to achieve optimal contours on the abutment teeth that will support the removable prosthesis, the remaining natural dentition may be modified through enamoplasty or addition of composite resin, or both. This has the obvious advantage of reducing both treatment time and expense. However, the use of cast restorations on abutment teeth enables precise shaping of the axial contours of such restorations, which in turn allows the masticatory and retentive forces to be directed more favorably through appropriate use of occlusal rest seats and precisely shaped guide planes. Also, cast retainers enable the incorporation of intracoronal rest seats or precision attachments, which can offer significant esthetic advantages over clasp-retained partial RDPs. Use of cast crowns also allows splinting of abutment teeth with resultant reduction of mobility (Fig. 21-1).[1]

The correct treatment choice for any patient depends on the findings in a thorough history and examination and on an accurate diagnosis and prognosis (see Chapters 1 and 2). Decisions concerning the restoration of RDP abutment teeth involve many factors—caries, existing restorations, tooth vitality, shape and angulation, oral hygiene, and cost and experience—that must be assessed and evaluated. Only then is the selected treatment likely to achieve the planned outcome that is based on the functional requirements of the patient.

TREATMENT PLANNING

The fabrication of a precisely fitting partial RDP is challenging. Without a careful, comprehensive diagnostic evaluation and a well-designed treatment plan, the chances of success are minimal. Most patients who require an RDP have sustained extensive damage as a consequence of caries, periodontal disease, or trauma and may have extensive prosthodontic treatment needs. They also may exhibit acquired or congenital intraoral defects. As a result of prolonged loss of arch integrity, there may be drifting or tipping, and the occlusion is often less than ideal.

Treatment plans that include an RDP may necessitate additional diagnostic procedures besides those described in Chapters 1 and 2. Accurate diagnostic casts mounted in centric relation are extremely important. If all posterior teeth are absent, it is much more difficult to relate opposing diagnostic casts, and stable record bases must be made under these circumstances (Fig. 21-2). The necessary degree of stability can be obtained only if such record bases are fabricated on the cast that is to be articulated.

The use of a dental surveyor (Fig. 21-3) is essential during treatment planning for the following reasons:

- To help evaluate tissue undercuts and their influence on partial RDP design
- To help evaluate the relative alignment of the long axes of teeth that support the partial RDP
- To help determine the optimum path of placement and removal of the RDP (and, by inference, its effect on the geometry of crown preparations)

The most appropriate anteroposterior and mediolateral tilt of the cast must be selected. Careful analysis is essential because a compromise between the requirements of an ideal tooth preparation (see Chapter 7) and the requirements for a particular tooth to be used as an abutment to support and retain an RDP is often necessary. The path of placement of the RDP is the most important factor in determining how much tooth reduction is needed to meet mechanical and esthetic requirements simultaneously (Fig. 21-4).

When the diagnostic cast is surveyed, the anteroposterior tilt is established first. The lateral inclination is determined next. The operator should focus on any tissue undercuts, the relative alignment of selected abutment teeth, and the available occlusocervical dimension for planned proximal and reciprocal guide planes. The feasibility of recontouring axial walls and the possible consequences of such recontouring must also be considered. Teeth with short clinical crowns are often poor candidates for survey restorations. Favorable tooth alignment in relation to the planned path of placement of the partial RDP is critical, and unfavorable tooth position may warrant adjunctive treatment. For instance, it may be necessary to treat a malposed tooth orthodontically or endodontically if recontouring alone will not produce the desired geometry. Similarly, removal of a tooth that unnecessarily complicates partial RDP design should be considered and weighed carefully against the effect of that decision on partial RDP stability. Compromised teeth need to be assessed carefully in terms of their prognosis. If future loss of such a tooth would render the partial RDP useless, it may be better to remove that tooth than to resort to heroic efforts to preserve it for the short term.

When anterior teeth have been lost, the path of placement of a partial RDP should parallel the proximal surfaces of the abutment teeth adjacent to the space (Fig. 21-5). This results in superior esthetics because it

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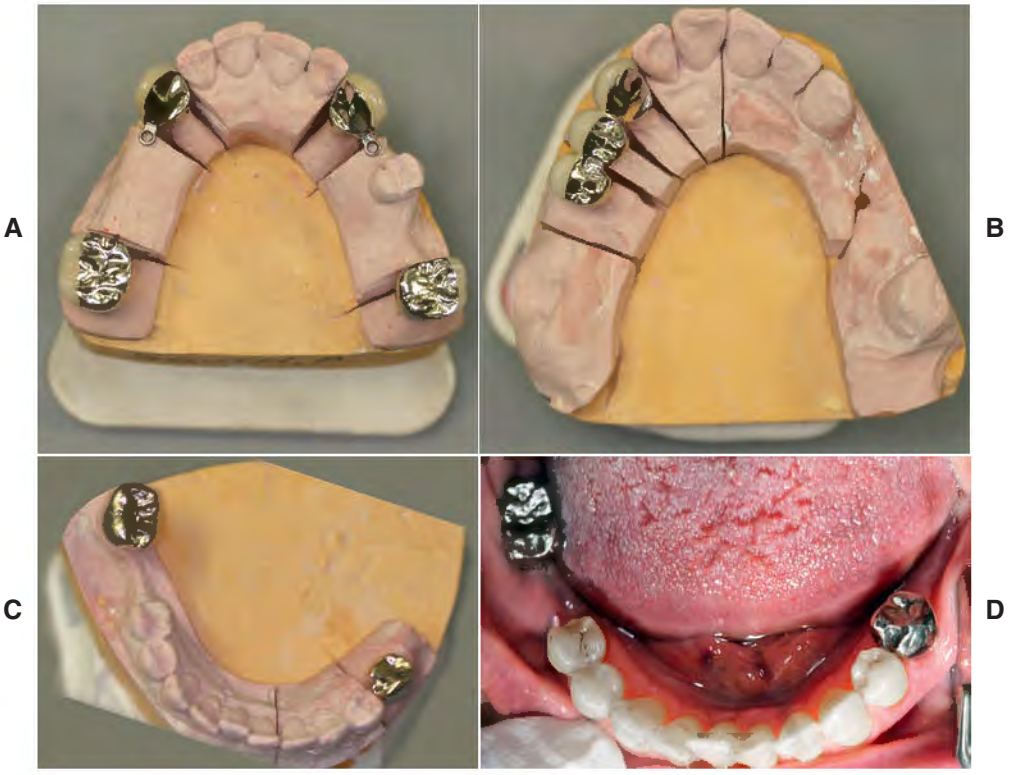

FIGURE 21-1 ■ Survey crowns are useful to create desired coronal contours to optimally support a removable dental prosthesis (RDP). **A,** Four survey crowns used to support a planned RDP. Occlusal rests were created on the mesial of the posterior crowns, with appropriate buccal undercuts and lingual reciprocal guide planes. The anterior crowns incorporate cingulum rests and extracoronal attachments. It is generally not desirable to retain a lone standing tooth in the middle of a modification space. **B,** In the preferred approach, the dentist eliminates a modification space by fabricating a fixed dental prosthesis. Note the cingulum rest on the canine and the mesial occlusal rest on the posterior retainer. **C,** Two complete cast crowns used to obtain improved contours for a partial mandibular RDP. **D**, Clinical view.

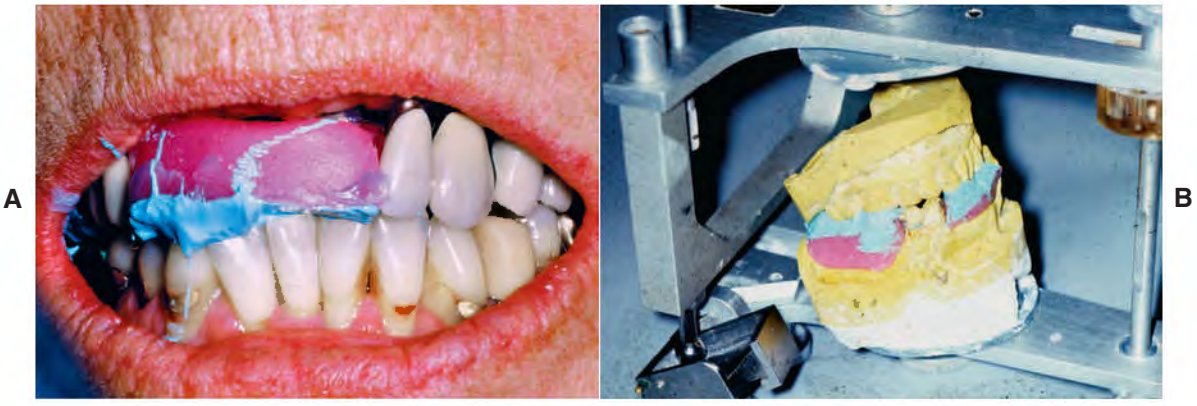

FIGURE 21-2 ■ When multiple teeth are missing **(A),** a clasp-retained record base with wax rims (used here with zinc oxide–eugenol paste) should be used to ensure accurate articulation **(B).** This minimizes the risk of tipping of the casts in relation to one another.

minimizes the space between the artificial and natural teeth. Sometimes esthetics can be improved by use of a rotational placement path.[2]

Apparently complex decisions as to the best combination of tooth preparation and path of placement can be greatly simplified through diagnostic tooth preparation, waxing, and denture tooth setting (Figs. 21-6 and 21-7). These trial procedures on diagnostic casts help determine how to achieve the best mechanical and esthetic result without deviating from the principles of occlusion or making excessively bulky restorations that inevitably cause periodontal complications. The concept is to use interchangeably articulator-mounted casts of the pretreatment and posttreatment condition, before treatment

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is initiated, to determine the precise goals for occlusion and appearance. The use of such cross-mounted casts (see also Chapter 3) helps simplify the treatment sequence by allowing one arch to be treated at a time. The restorations on the first arch to be restored are fabricated against the diagnostically waxed opposing cast (Fig. 21-8; see also Fig. 3-33).

Prerequisites for Success

The clinician and laboratory technician must have a good understanding of partial RDP design (Fig. 21-9). An in-depth discussion of the approaches to framework design is beyond the scope of this text. Instead, the modifications that must be incorporated in the cast restoration to accommodate a partial RDP are considered.

FIGURE 21-3 ■ A dental surveyor is essential during treatment planning and in designing retainers for partial removable dental prostheses.

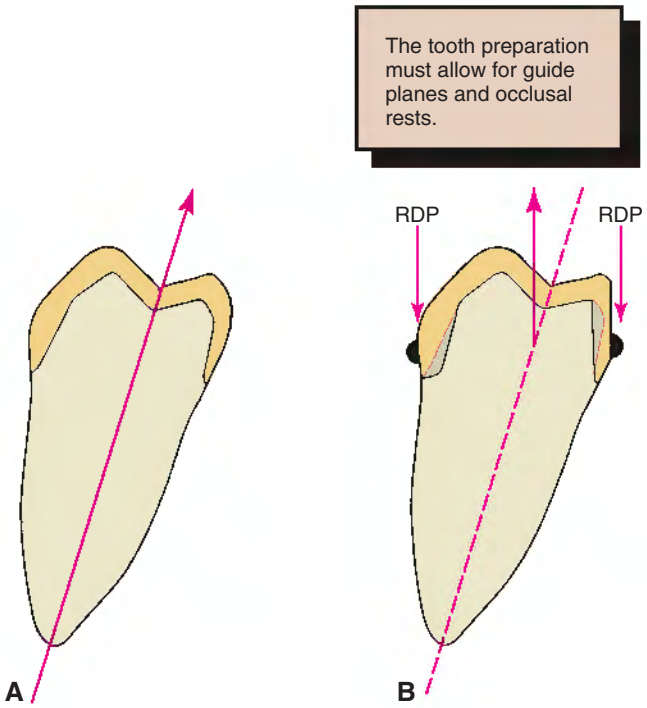

FIGURE 21-4 ■ **A,** Normal tooth preparation for a complete cast crown. The path of placement is in the long axis of the tooth. **B,** Modified tooth preparation for a partial removable dental prosthesis (RDP) retainer with lingual guide planes. This preparation has a more buccal path of placement.

FIGURE 21-5 ■ The appearance of an anterior partial removable dental prosthesis is improved by careful selection of the path of placement.

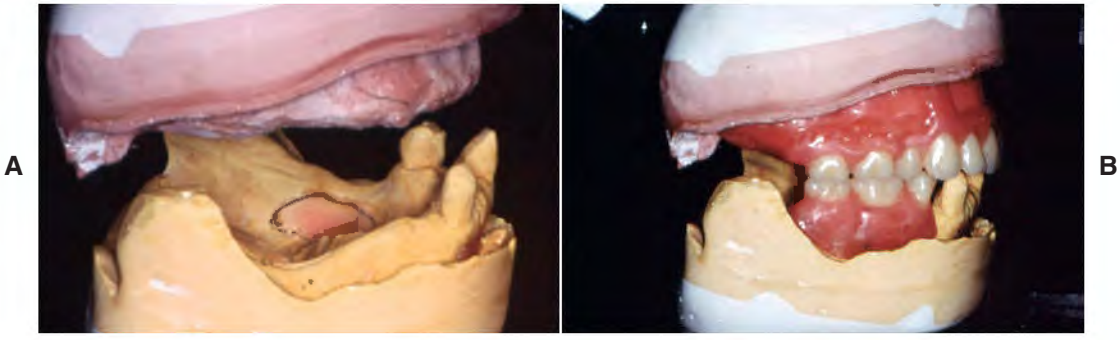

FIGURE 21-6 ■ Diagnostic mounted casts and waxing are essential prerequisites for extensive prosthodontic care. **A,** Diagnostically mounted casts. **B,** Diagnostic tooth arrangement. (Courtesy Dr. N.L. Clelland.)

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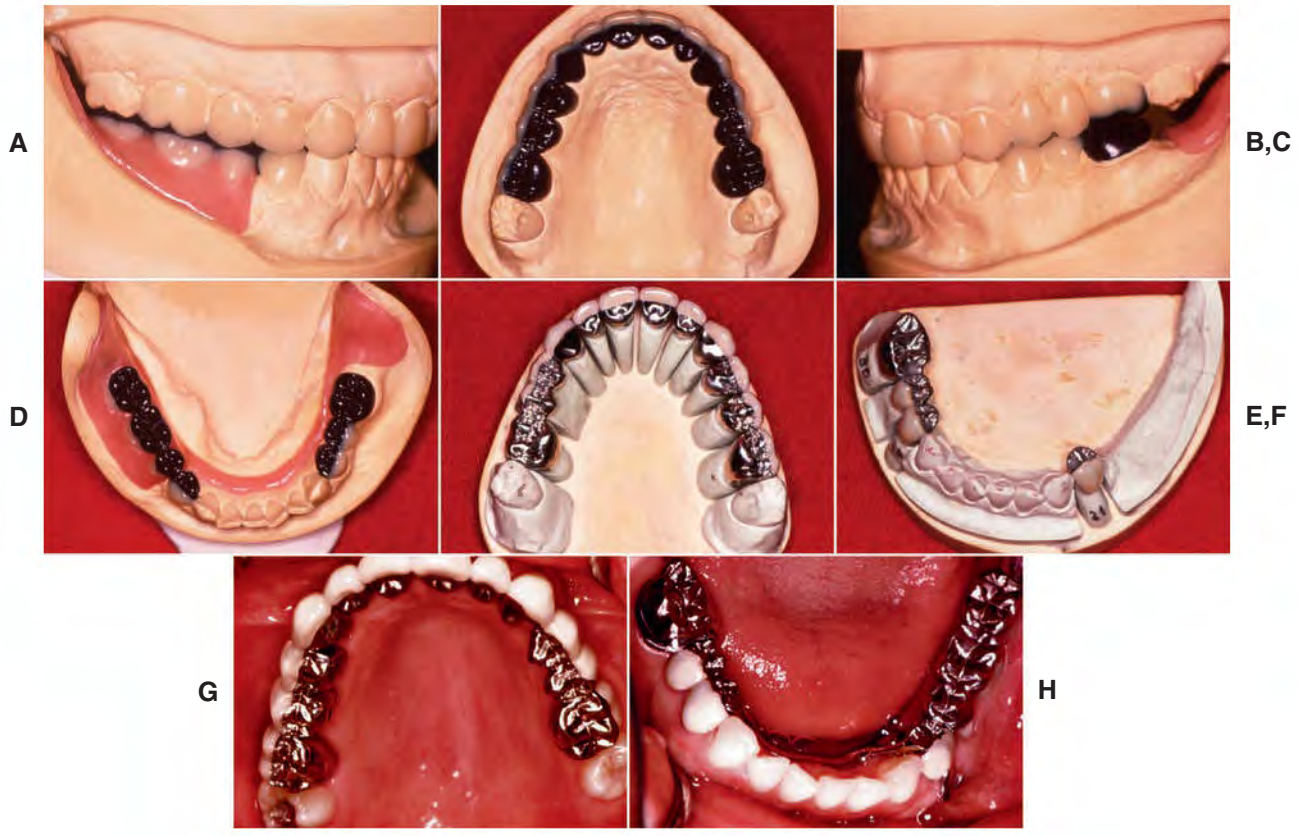

FIGURE 21-7 ■ Diagnostic tooth preparation and waxing are especially valuable in treating patients who require a combination of fixed and removable prostheses. **A** to **D,** Diagnostic waxing. **E** and **F,** Fixed prostheses. **G** and **H,** Completed restorations. Mandibular partial removable dental prosthesis has cast metal occlusal surfaces. (Courtesy Dr. J.H. Bailey.)

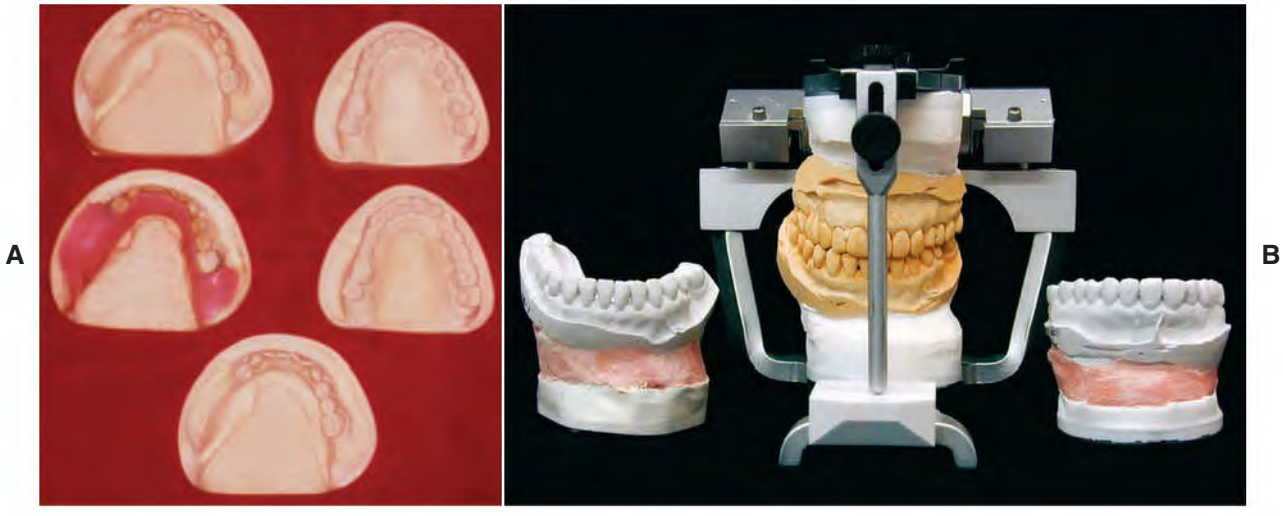

FIGURE 21-8 ■ Cross-mounted casts are used to simplify complex prosthodontic treatments. One set of casts is waxed to reflect the endpoint of treatment, whereas the other set is left unaltered to enable mounting of the definitive casts. An additional cast is needed for surveying a removable prosthesis. **A,** Casts needed for treating a patient who required a maxillary fixed prosthesis opposed by mandibular fixed and removable prostheses (see Fig. 21-7). **B,** The duplicated casts are mounted in the identical relationship on an articulator. Treatment can then be undertaken in phases. First the mandibular teeth are prepared, and a definitive cast is obtained. This is mounted against the maxillary unaltered cast, which is then replaced by the identically oriented, diagnostically waxed cast for the laboratory fabrication of the mandibular fixed prosthesis. (See also Fig. 3-33.) (**A,** Courtesy Dr. J.H. Bailey.)

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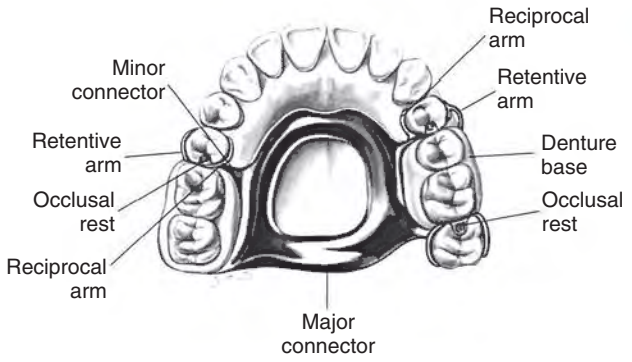

FIGURE 21-9 ■ Design of a partial removable dental prosthesis. The component parts are labeled.

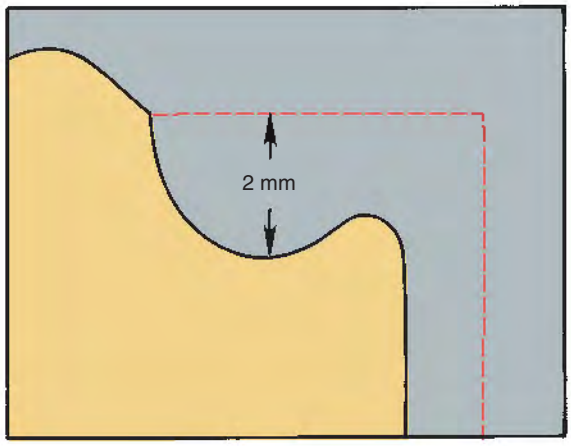

FIGURE 21-11 ■ Cross-sectional view through an occlusal rest seat. Note the rounded junction between the rest seat and the proximal guiding plane.

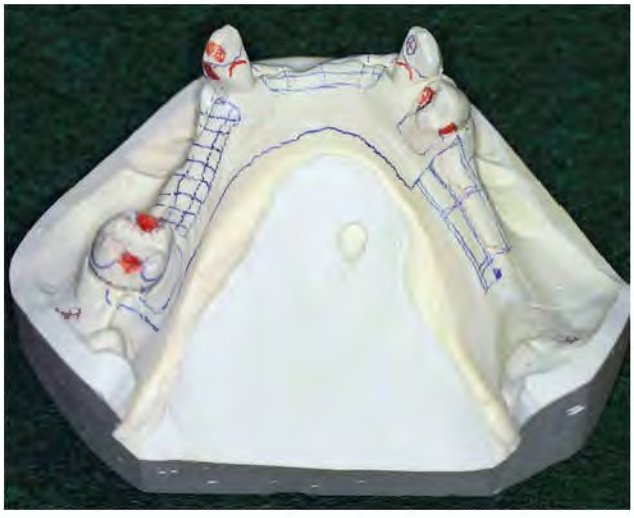

FIGURE 21-10 ■ Initial partial removable dental prosthesis design sketched on the diagnostic cast. (From Carr AB, Brown DT: McCracken's removable partial prosthodontics, ed 12, St. Louis, Mosby, 2011)

FIGURE 21-12 ■ A No. 8 round bur was used to carve the distal rest seat for this mandibular second premolar into the wax pattern.

Design

Multiple concepts of partial RDP design have been advocated. Regardless of the concept chosen, a keen understanding of the requirements placed on fixed retainers is essential to success. Their design should allow the forces developed during placement, removal, and function of the partial RDP to be so directed as to cause the least harm to the remaining dentition. The proposed design (Fig. 21-10) should be carefully sketched at the initial treatment planning stage. In general, this effort will reveal any existing problems. Each fixed restoration should be designed to be fully compatible with the RDP while concurrently meeting all criteria to properly fulfill the functional requirements of mastication and facilitating the performance of oral hygiene. Decisions made about the path of placement of the partial RDP often necessitate removal of additional tooth structure in order to maintain the minimally required material thickness for the fixed prosthesis (see Fig. 21-4).

Denture Bases. The denture base areas are shaped to avoid interference with the abutment retainer during placement and removal. Therefore, the fixed prosthesis affects denture base configuration, rather than vice versa.

Occlusal Rest Seat. The rest seat (Fig. 21-11) is the prepared recess in a tooth or restoration created to receive the occlusal, incisal, cingulum, or lingual rest. The occlusal rest of the partial RDP is the rigid extension that contacts the occlusal surface of a tooth or restoration. The occlusal rest of a partial RDP should fit precisely into the corresponding rest seats on the retainers. To reduce laterally directed forces, the rest seats should be spoon-shaped. The junction between the internal aspect of the rest seat and the proximal guide plane should be rounded to minimize stress on the partial RDP framework and thereby reduce the chance of partial RDP fracture at the interface between the occlusal rest and the minor connector.

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FIGURE 21-13 ■ **A,** V-shaped cingulum rest seat in wax pattern. **B** and **C,** Minimal tooth preparation accommodates a pin-retained casting to create a cingulum rest. Similar designs can be resin-bonded (see Chapter 26).

FIGURE 21-14 ■ Incisal rest on a mandibular canine. (Courtesy Dr. M.T. Padilla.)

FIGURE 21-15 ■ Minor connector *(arrow)*, lingual view. Note the close adaptation of the distal proximal plate, the minor connector, and the retentive clasp arm to the survey crown.

Occlusal rest seats are most predictably placed in healthy enamel or cast metal. If they are placed in weaker materials such as amalgam, composite resin, or dental porcelain, fracture or distortion is likely to result. The size of the rest seat remains a matter of controversy. Ordinarily, when crowns are made, the use of a No. 8 round bur to remove wax from an anatomic contour wax pattern produces an adequately sized rest seat (Fig. 21-12). On small teeth (e.g., mandibular premolars), a No. 6 round bur can provide adequate space if functional loading is normal. On anterior teeth, a cingulum rest seat may be created to support the removable prosthesis. Rests that are convex mesiodistally and resemble a V-shaped groove labiolingually have proved successful in clinical practice. This configuration prevents displacement of the abutment while simultaneously assisting in directing forces more parallel to its long axis.

Unfortunately, a distinct cingulum rest of adequate size can rarely be placed in the cingulum of an unrestored tooth without penetration through the enamel.[3] Sometimes a pin-retained or resin-bonded restoration[4] is used to provide a cingulum rest (Fig. 21-13). Porcelain labial veneers (see Chapter 25) and composite resin have also been used to provide undercuts for RDP retention.[5,6] An incisal rest may be used on unrestored mandibular canines (Fig. 21-14). This provides good support for the partial RDP but may be unacceptable esthetically. When a rest is placed on a metal-ceramic restoration, adequate thickness of metal must remain between the lateral walls of the occlusal rest seat and the porcelain-metal junction. About 1 mm is sufficient. Similarly, a minimal metal thickness of 1 mm between the rest seat and the occlusal aspect of the prepared tooth is advisable (see also Fig. 21-24). To reduce the risk of porcelain fracture, an occlusal rest seat should not be placed directly on porcelain.

Minor Connectors. The minor connectors of a partial RDP (Fig. 21-15) are the connecting link between the major connector or base of a partial RDP and the other units of the prosthesis, such as the clasp assembly, indirect retainers, occlusal rests, and cingulum rests. They join the rest seats and the clasps to the major connector and should fit intimately against the proximal guide plane on the cast restoration. Within the tenets of partial RDP design, guide planes should be as tall as possible occlusocervically and should follow the normal configuration of the tooth buccolingually. All proximal and reciprocal guide planes should parallel each other.

Clasp Retention

The clasp engages a portion of the tooth surface and either enters an undercut for retention or remains entirely above the height of contour to act as a reciprocating

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(bracing) element. In general, clasps stabilize and retain a partial RDP. The amount of retention is related to, among other things, the configuration of the retentive arm, the material from which the clasp is made, and the extent of the undercut into which it is placed and from which it is dislodged when the partial RDP is removed from the mouth.

Partial RDP frameworks are usually fabricated from base metal alloys, although some dentists prefer titanium or even an American Dental Association type IV gold alloy. In addition to conventional cast clasps, wrought retention clasp arms can be made from platinum-gold-palladium or nickel-chromium alloy wires.

The modulus of elasticity of the base metals is considerably higher than that of a type IV gold alloy. Hence, shallower retentive undercuts, approximately 0.12 to 0.25 mm (0.005 to 0.010 inch), can be used with the former. Undercuts of 0.25 to 0.50 mm (0.010 to 0.020 inch) can routinely be used with clasps made of either type IV gold or wire.

When a clasp is in its normal position with the partial RDP fully seated, it should fit passively against the retainer; a clasp should be at least 2 mm occlusal to the crest of the free gingiva so that it does not interfere with maintenance of periodontal health. This means that the survey line—a line produced on a cast by a surveyor marking the greatest prominence of contour in relation to the planned path of placement of a restoration—must not be placed too far cervically.

Likewise, the height of contour must not be placed too far occlusally; otherwise, binding of the retentive arm may occur during partial RDP placement. Ideally, this height should be within the middle third of the retentive surface of the retainer. A properly contoured surface enables the retentive arm to flex gradually along the path of placement. For cast clasps, only the terminal third of the retentive arm should be placed gingival to the survey line. If a wrought clasp is used, the height of contour can be modified to engage the terminal half of the clasp in the undercut (Fig. 21-16). If more than the terminal third of the retentive arm is placed cervical to the height of contour, placement and removal of the RDP may be impeded.

A typical survey line for occlusally approaching clasps has an undulating configuration somewhat reminiscent of the letter *S*, with its most gingival portion adjacent to the minor connector. If a gingivally approaching clasp is used, the undercut may be immediately adjacent to the proximal guide plane, although with the popular rest, proximal plate, and I-bar (RPI) design, it is placed at or mesial to the midline of the tooth (see Fig. 21-15).[7] Several factors—rest seat location, origin of the clasp, tissue undercuts, and degree of clasp encirclement—influence the actual configuration of the survey line for individual retainers.

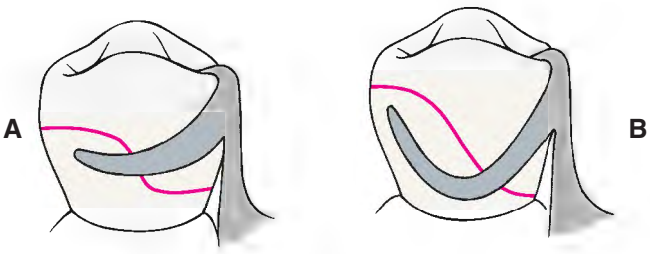

FIGURE 21-16 ■ The shape of the survey line is influenced by the material selected for the clasp. **A,** Cast clasp. Only the terminal third engages the undercut. **B,** Wrought clasp. The terminal half is retentive.

To minimize lateral loading, the reciprocal arm should engage before the retentive arm starts to flex.

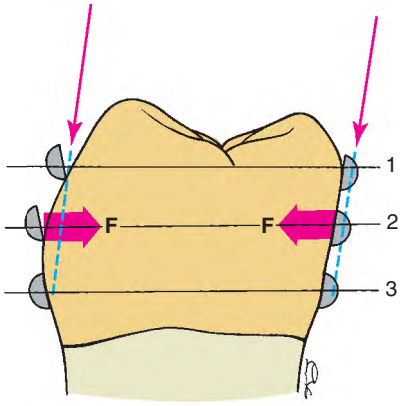

FIGURE 21-17 ■ Reciprocal arms prevent harmful lateral forces from being generated by the retentive arms during placement of a partial removable dental prosthesis (RDP). *1,* Initial contact of the retentive arm; the reciprocal arm is in passive contact. *2,* Maximum flexure of the retentive arm; the forces exerted *(F)* are resisted by the reciprocal clasp. *3,* The partial RDP fully seated; both the retentive and the reciprocal clasps should be in passive contact.

Reciprocation

Reciprocation is the mechanism by which lateral forces generated by a retentive clasp passing over a height of contour are counterbalanced (Fig. 21-17). This is usually done by a reciprocal clasp or plate that engages a reciprocal guiding plane. Reciprocal clasps have two functions: They guide the prosthesis into place on insertion, and they support the abutments against horizontal forces exerted by the flexing retentive arms during seating. The retentive arms should flex rather than displace the abutments laterally. Guide planes are needed on the crowns to allow for successful reciprocation. These should extend from the proximal guide plane to an area directly opposite the terminal position of the retentive clasp. Reciprocal clasps must contact the guide plane before the retentive arms start to flex, so that the periodontium is protected against excessive lateral loading.

TOOTH PREPARATION

Once the proposed path of placement for the partial RDP has been determined and any necessary enamel

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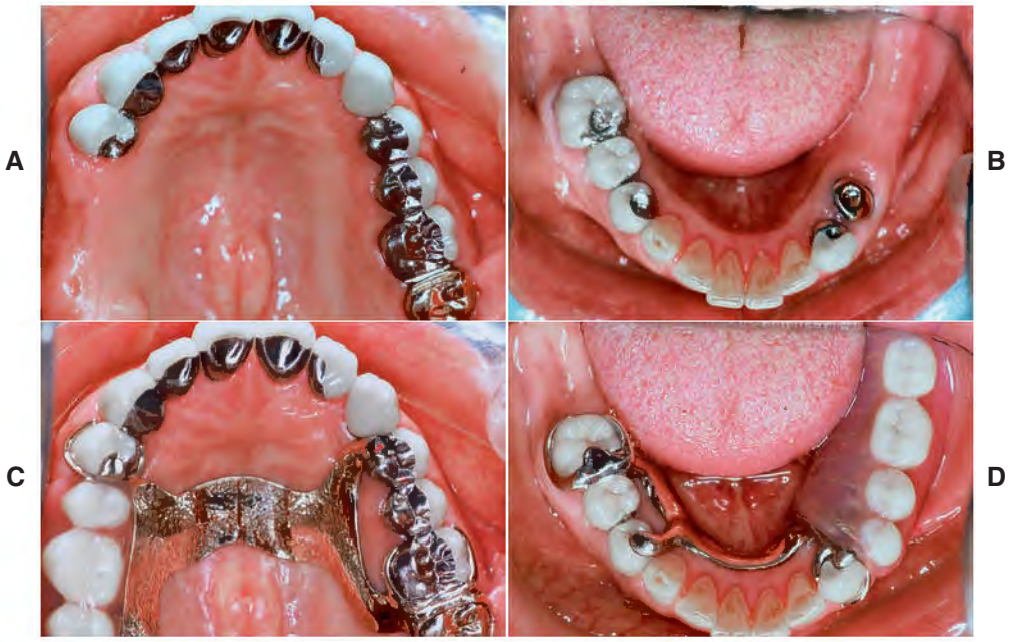

FIGURE 21-18 ■ Integration of fixed and removable prosthodontic treatment. **A,** All teeth in this maxillary arch have been restored with fixed prostheses to accommodate the planned removable partial dental prosthesis. **B,** This mandibular arch has been restored with a simple three-unit fixed dental prosthesis, a single crown, and a gold dome that will provide support for the removable prosthesis. **C** and **D,** Maxillary and mandibular arches with the removable prostheses in place.

modifications made to the natural teeth, those teeth that require abutment crowns can be prepared (Fig. 21-18). Making complete crowns is often necessary, but when the buccal contour does not require modification, partial coverage is sometimes possible.

Path of Placement

Careful planning is required when the path of placement of tooth preparations for RDP retainers is selected. Although conventional crowns generally have a path in the long axis of the tooth, partial RDP retainers may not. Surfaces on which both guide planes and reciprocal planes are planned, as well as areas that require survey lines in the gingival third, typically require additional reduction, in comparison to optimal conservative technique used on individual teeth. Because of the lingual inclination of mandibular molars, reducing them slightly more in the occlusal two thirds of the lingual axial surface is often necessary to allow the development of lingual guide planes that parallel each other across the dental arch.

Similarly, the axial reduction of surfaces adjacent to an edentulous RDP modification space often involves removal of additional tooth structure to enable development of the proximal plate parallel to the path of placement of the partial RDP. These modifications must not lessen the retention form excessively because during prosthesis removal, the retainers are often subjected to forces parallel to their path of placement, and retention becomes even more important. Additional features (e.g., grooves, boxes, pinholes) are frequently needed. It is certainly not mandatory that all retainers for a partial RDP have identical paths of placement.

Rest Seats

An adequate amount of tooth structure must be removed to allow for the minimally required metal thickness of 1 mm in the area of an occlusal rest seat. To achieve adequate reduction, some dentists prepare a rest seat in the tooth before starting the retainer preparation. They then use 1-mm reduction grooves to ensure adequate thickness. Although this approach can work well, problems may occur if it becomes necessary to alter the position of the rest seat during the laboratory phase. Preference therefore should be given to the slightly less conservative approach seen in Figure 21-19 because having flexibility to move the rest seat during the laboratory phase can be extremely helpful. Esthetic needs, such as the necessary interproximal extent of a cutback for a metal-ceramic restoration, are often evaluated best in the laboratory during waxing procedures.

Axial Contours

When a crown is to serve as a partial RDP abutment, modifications may be necessary in the normal axial reduction. The extent of additional axial reduction depends on the RDP design (see Fig. 21-9).

Additional tooth reduction is necessary if a retainer must be undercontoured with regard to the original tooth form to accommodate proximal or reciprocal guide planes and to allow the nonretentive part of an occlusally

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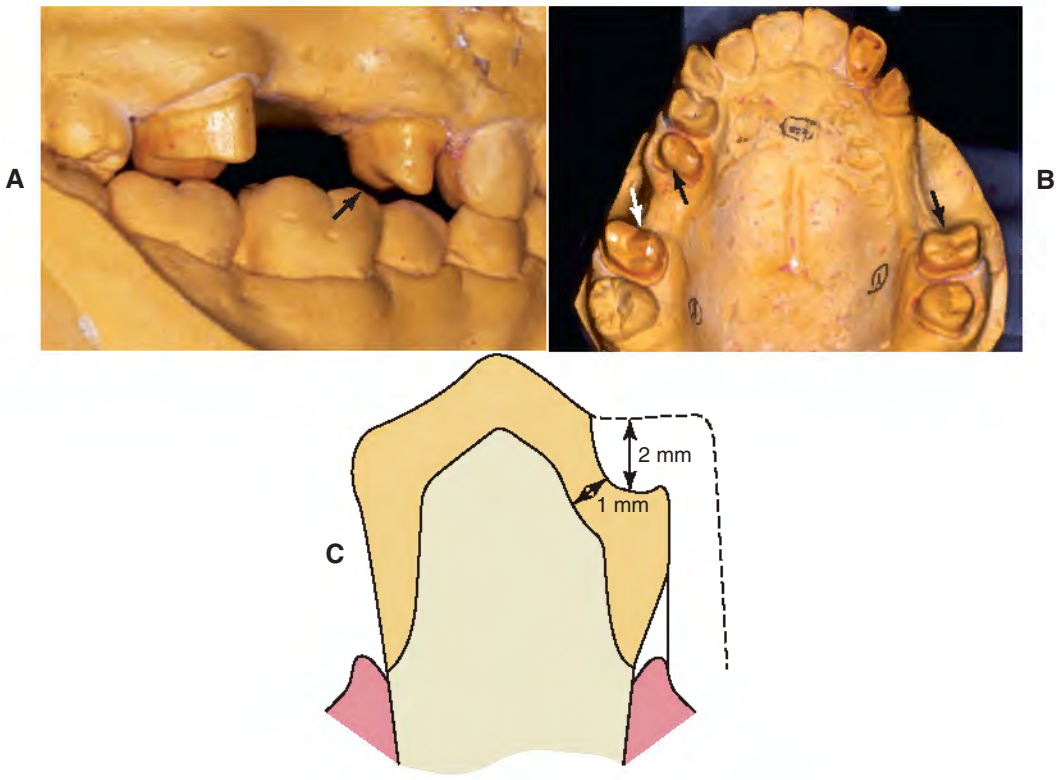

FIGURE 21-19 ■ Retainer preparation. **A** and **B,** The rest seat preparation *(arrows)* allows some adjustment of rest seat location during the waxing phase. **C,** Cross-section view through survey crown. Occlusal rest and minor connector with minimum dimensions.

approaching clasp to be positioned as far gingivally as possible. (This is another situation in which diagnostic preparations and diagnostic waxing procedures often prove very helpful in assessing the need for additional axial reduction.)

Another possible advantage of providing an abutment crown is the opportunity to shape the axial contours to accommodate the partial RDP clasps within the normal crown contours (Fig. 21-20). Although this allows for a less bulky removable prosthesis contour, it requires additional axial reduction. The use of a precision machine-tool milling device (see Fig. 21-27) is essential for these restorations.

IMPRESSION MAKING

Because of the relative interdependence of partial RDP abutment preparations, a diagnostic irreversible hydrocolloid impression should be made after the preparations have been completed. This is poured in accelerated-setting stone or plaster. The resulting cast is then surveyed, and the need for any further modifications is determined; such modifications can then be incorporated with minimum loss of chair time. The same cast can also be used for fabricating the interim restorations (see Chapter 15). A definitive impression is obtained with either an elastomeric or a reversible hydrocolloid technique, as described for conventional restorations (see Chapter 14). When multiple teeth in an arch require crowns so as to provide proper support for a partial RDP,

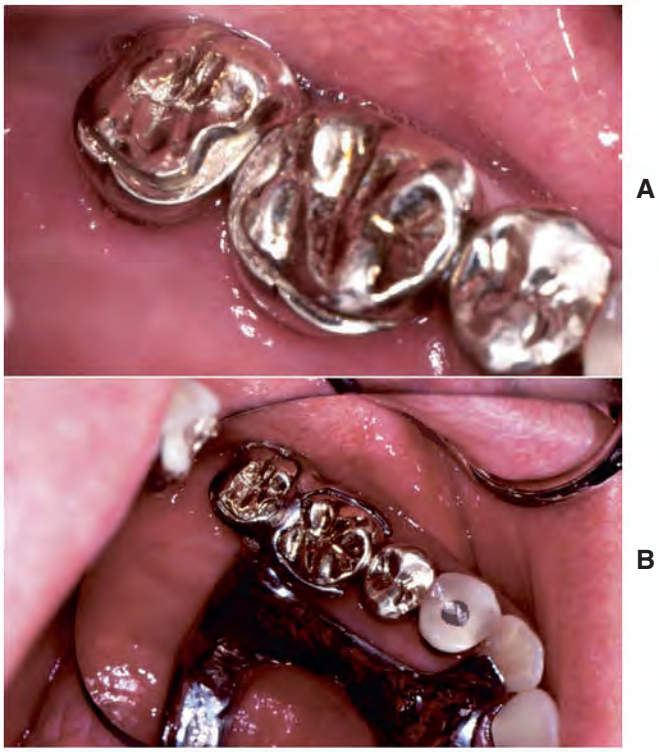

FIGURE 21-20 ■ Abutment crowns contoured to receive the partial removable dental prosthesis (RDP) clasp precisely. **A,** The cast crowns have received milled-in shelves that enable the partial RDP clasp to settle into the coronal form of the restored tooth. **B,** Partial RDP in place. (Courtesy Drs. K. Seckler and J. Jankowski.)

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ideally they are captured in a single elastomeric impression. In the maxillary arch, this usually can be accomplished without too much difficulty. However, in the mandibular arch, bilateral posterior impressions may present great difficulty. A practical solution is to make separate impressions and, at the evaluation appointment, to make a pickup impression over the top of the separately fabricated restorations. A new cast is then generated (see the remount technique in Chapter 29; Fig. 29-17). This cast is then used to refine the axial contours through milling procedures.

Occlusal Records

A record base with wax rims is needed to articulate the casts unless an adequate number of posterior teeth are present to relate the opposing casts with a conventional centric relation record.

Because a record base is stable only on the cast from which it was made, it should not be fabricated in advance. Therefore, an additional patient visit must be planned to obtain an interocclusal record. The maxillary cast orientation is transferred by means of a facebow to the articulator, and the mandibular cast is then articulated in the usual manner.

WAX PATTERN FABRICATION

Waxing partial denture abutments to optimally meet all requirements can be difficult, even for experienced operators. It is common to encounter crowns with guide planes that are significantly overcontoured. Overcontouring adversely affects the long-term prognosis, as plaque control measures are compromised. To the novice operator, the need for good occlusion, anatomic form, and proper contours for plaque control often appears to conflict with the need for guide planes and retentive undercuts. Careful analysis is essential at the treatment planning stages, when a diagnostic waxing procedure can prove helpful. An organized approach to waxing partial RDP retainers must be maintained. The operator makes the wax patterns in the usual way (see Chapter 18), creating normal axial form and embrasures and allowing for optimum distribution of the forces of occlusion. This is followed by adjustment of the axial walls to accommodate the survey line and guide planes. The resulting occlusal table is typically smaller than a pattern that is shaped to optimal anatomic form. The rest seats are placed as the final step in this process, immediately before reflowing of the margins and investing (see Chapter 22).

Survey Line

When normal axial coronal contour has been established in wax, the cast is removed from the articulator and placed on the surveyor (Fig. 21-21). The preliminary path of placement that was established during the treatment planning and tooth preparation phases may require slight modification. However, only a minor alteration should be necessary, and it often compensates for small, previously unrecognized errors that may have occurred at the tooth preparation stage.

The first step in generating the desired heights of contour is to generate a nearly cylindrical pattern that, when viewed from the occlusal side, corresponds with the normal outline form of the tooth being restored (see Fig. 21-21, *A*). A straightforward way in which this can be accomplished is to slightly overcontour the wax coping and then use the carving attachment of the surveyor to create the cylindrical shape (see Fig. 21-21, *B*). Once normal outline form has been established satisfactorily (or alternatively, the outline form may be slightly undercontoured, depending on the path of placement of the partial RDP), the carved band can be coated with waxing powder, and the desired height of contour is scribed directly on the pattern with any suitable waxing instrument (see Fig. 21-21, *C* and *D*). Excess wax above and below the desired height of contour is carved away, and an undercut gauge is used to evaluate the undercut (see Fig. 21-21, *E*). All surfaces are then blended together through selective reflowing (see Fig. 21-21, *F*). Because the definitive size of the occlusal surface is now known, occlusal detail is added, and the occlusal rest seat can be carved in with a round bur of a suitable size (see Fig. 21-21, *G* and *H*).

The operator can relocate a survey line by tilting the cast (e.g., enlarging a mesial undercut by increasing the mesial tilt; moving a buccal survey line farther occlusally by increasing the tilt toward the buccal surface). When the cast tilt for the final path of placement has been selected, the cast is marked at three points (some technicians also mark the side of the cast). This "tripodizing" allows the selected path to be reestablished with minimum inconvenience. The surveyor carving attachment is then used. Some dental surveyors have a movable arm, which makes carving the wax easier. Identical results can usually be obtained with the rigid-arm type, but more care is necessary to prevent fracture of the wax pattern or tilting of the surveyor table. The final evaluation of the survey contour consists of dusting the pattern with zinc stearate or waxing powder, marking the height of contour with the analyzing rod, and measuring with the undercut gauge.

Guide Planes

The operator forms the proximal and reciprocal guide planes (Fig. 21-22) by trimming all excess wax from the patterns. Cervico-occlusally, the typical guide plane should remain within normal contours. Cervical to the guide plane, the form of the wax pattern should follow the configuration of the remaining tooth structure at the margin.

The minimum cervico-occlusal length for guide planes allows the reciprocal arms of the clasps to make initial contact and remain in contact during seating of the partial RDP (see Fig. 21-17).

Occlusal Rest Seats

Occlusal rest seats (Fig. 21-23) are most commonly located in the interproximal marginal ridge area and can

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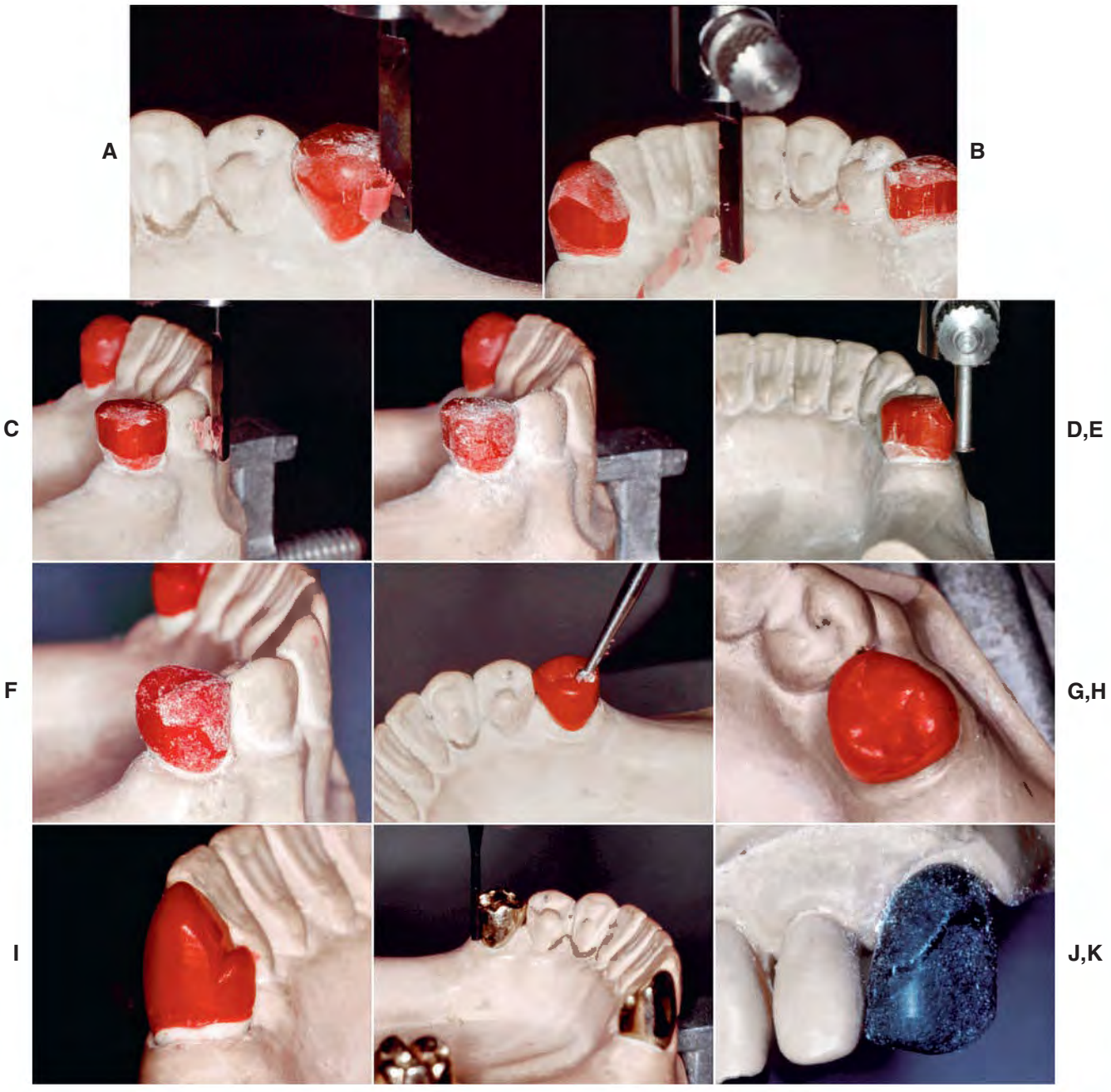

FIGURE 21-21 ■ Waxing partial removable dental prosthesis retainers. **A,** After the path of placement has been established, the carving attachment of the surveyor is used to make a 2- to 4-mm-wide band on the pattern. **B,** Note that the band includes the proximal and lingual walls of the pattern where the proximal and reciprocal guide planes, respectively, will be established. **C,** The band is carried onto the buccal surface, where the retentive clasp is to be placed. Viewed from the occlusal aspect when complete, the band remains within the normal anatomic contour. **D,** The pattern is dusted with zinc stearate or powdered wax, and the desired survey line is scribed. **E,** After excess wax has been carved away occlusally and gingivally to create the desired contour, the undercut gauge is used to verify that the proper amount of wax has been removed. **F,** After smoothing and blending of the various surfaces, the pattern is again dusted with powder, and the configuration of the final survey line is verified. **G,** Then a round bur is used to place the occlusal rest seat. On premolars, a No. 6 bur is adequate; on molars, a No. 8 bur may be used. **H,** At least 1 mm of wax is maintained around the perimeter of the rest seat. **I,** A cingulum rest seat on a canine pattern can be carved with conventional waxing instruments. The lingual aspect of the rest seat must withstand lingual displacement. Mesiodistally, the rest seat is slightly curved, with the highest point in the middle of the pattern. **J,** After casting, the crowns are evaluated, and any adjustments are made to refine the height of contour, guide planes, and occlusal rest seats. **K,** Typical survey line for a wrought clasp. Note that the distal half of the clasp can easily be placed above the height of contour. The terminal half engages the undercut. A sufficiently long trajectory must remain incisal to the height of contour to allow gradual flexing of the clasp.

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FIGURE 21-22 ■ **A,** A proximal guide plane and the correct axial survey lines are incorporated in the anatomic contour wax pattern. **B,** The contours are duplicated in porcelain. **C,** The fixed prostheses are cemented. **D,** An accurately contoured retainer provides proper support for the partial removable dental prosthesis.

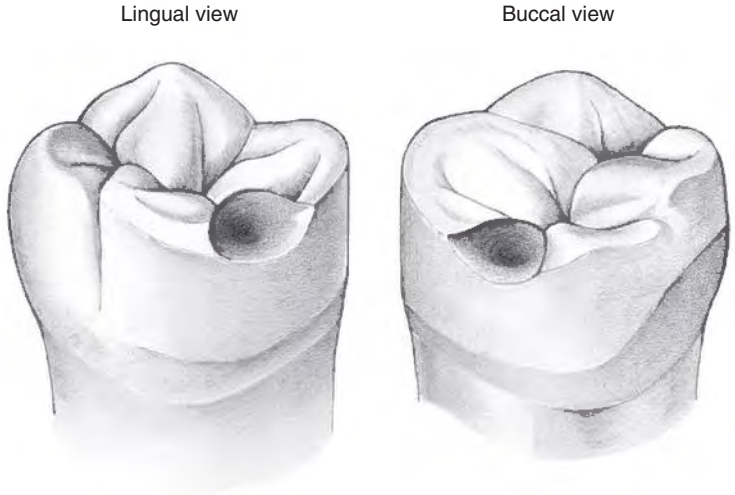

FIGURE 21-23 ■ Completed wax pattern for a partial removable dental prosthetic retainer with occlusal rest seat, distobuccal retention, and proximal and lingual guide planes.

easily be cut into the wax patterns with a hand-held round bur (see Fig. 21-21). When metal-ceramic restorations are the retainers, the rest seat should be located in metal at least 1 mm from the metal-ceramic junction (Fig. 21-24). When a rest is to be placed in a wax pattern for a metal-ceramic restoration, this is best done after the pattern has been cut back for the metal-ceramic veneer. It can prove helpful to displace occlusal rests on metal ceramic crowns slightly lingually: This enables maintaining adequate metal thickness between the rest and the area that has been cut back for the ceramic veneer, and it is often easier to ensure continuity between the minor connector of the partial RDP and the occlusal rest.

Cingulum rest seats (Fig. 21-25; see also Fig. 21-13) are placed with a carver. Buccolingually, they have a *V*-shaped configuration in cross section; mesiodistally, they are slightly curved, with the highest point in the center of the tooth.

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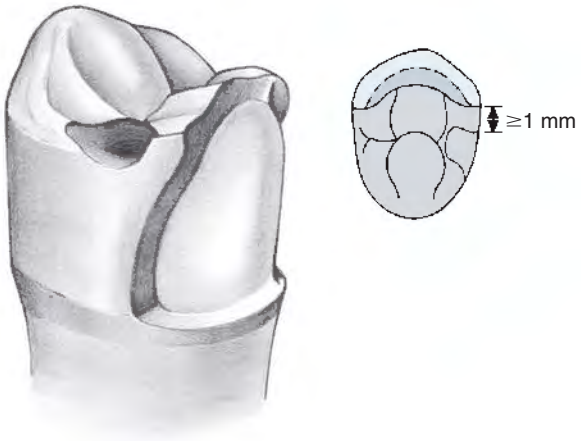

FIGURE 21-24 ■ Maxillary premolar wax pattern after cutback for the porcelain application. The rest seat should be at least 1 mm from the metal-ceramic junction. The guide plane continues in the porcelain.

FIGURE 21-26 ■ Handpiece holder for milling guide planes. The holder attaches a conventional straight handpiece parallel to the shaft of a dental surveyor.

FIGURE 21-25 ■ Cingulum rest seat on a mandibular canine. Note its mesiodistal curvature (compare with Fig. 21-21, *I*). (Courtesy Dr. X. Lepe.)

FIGURE 21-27 ■ Machine-tool milling device allows precise control of the milling process.

SPECIAL FINISHING PROCEDURES

After the wax patterns have been invested and the retainers have been cast, the restoration is carefully seated on the die. When the individual fit is satisfactory, the casting is transferred to an indexed cast for milling. The survey table is adjusted so the cast is oriented at the correct angulation, and cylindrical rotary instruments are used to refine the guide planes and to make any needed corrections.

Milling

Many precision parallel milling devices are available commercially. The simplest consists of a clamp that holds a conventional straight handpiece parallel to the shaft of the surveyor (Fig. 21-26). This works satisfactorily when used carefully. There are also expensive machine-tool milling devices that can be controlled with great precision and are particularly useful for extensive attachment prostheses (Fig. 21-27).

Cylindrical tungsten carbide burs without crosscuts are recommended for refining metal proximal and reciprocal guide planes. Light pressure should be used throughout the milling procedure. Once the desired contour has been obtained, only minimum finishing with paper disks or rubber wheels is necessary. A complete- or partial-coverage crown is finished through the normal sequence of abrasives until a high polish has been attained. If the retainer is a metal-ceramic crown, the veneering surface is prepared after completion of the milling procedure. Then the desired survey line and retentive

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undercuts are established in porcelain. The porcelain can then either be glazed or polished while care is taken to maintain the desired heights of contour throughout the polishing procedures.

Caution is needed when survey lines are scribed on a bisque bake of porcelain. Red or green pigments must be used because they do not cause contamination after firing. Graphite from a soft lead pencil produces discoloration in the fired porcelain, and such pencils must not be used (see Fig. 21-22, *B*).

EVALUATION AND CEMENTATION

The clinical evaluation of the prosthesis proceeds as for any restoration. The RDP should have good marginal integrity and proper axial contour, and it should be stable with accurate occlusal and proximal contact (see Chapters 29 and 30).

When these criteria have been met, a precementation irreversible hydrocolloid impression is poured in fast-setting stone, and the resulting cast is analyzed on the surveyor. Any change in contour that may have occurred during finishing is easily detected at this time, when corrective action is still possible. For a metal-ceramic restoration, recontouring, repolishing, reglazing, or a combination of these may be necessary.

Cementation procedures for survey crowns are identical to those for conventional restorations (see Chapter 30). When multiple restorations involving prefabricated attachments are to be cemented, postponing cementation of the retainers until after the completion of the RDP can sometimes prove advantageous.

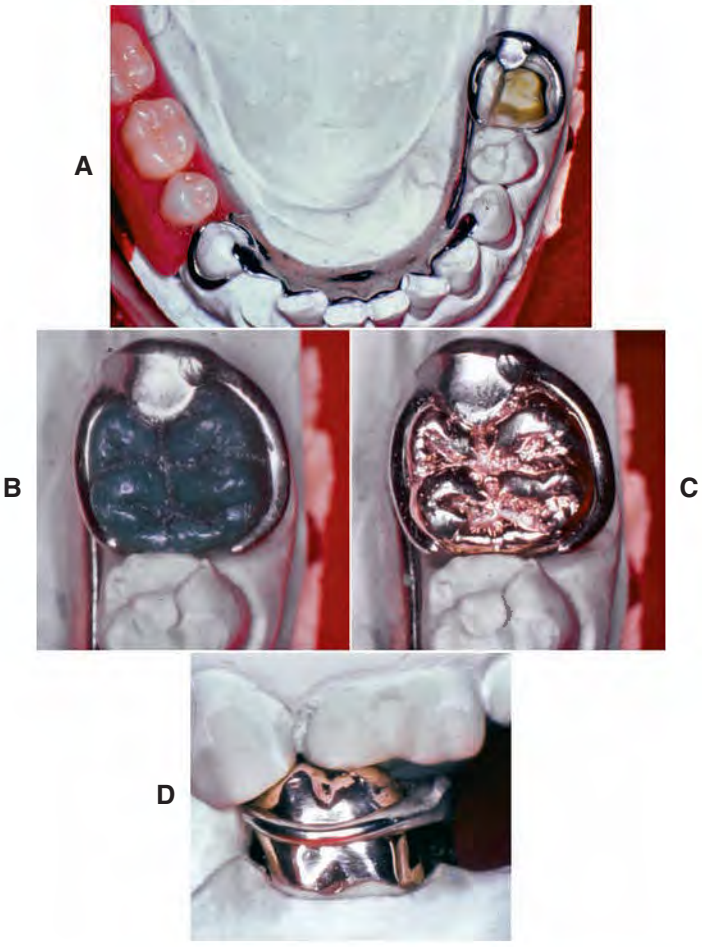

FIGURE 21-28 ■ Crown fabricated to fit an existing partial removable dental prosthesis (RDP) through the indirect procedure. **A,** After a pickup impression, the partial RDP is fitted to the definitive cast. **B,** Wax pattern. **C** and **D,** Completed crown. (Courtesy Dr. M.T. Padilla.)

FABRICATION OF A CROWN FOR AN EXISTING PARTIAL REMOVABLE DENTAL PROSTHESIS

Occasional patients have a defective abutment crown under an otherwise satisfactory partial RDP. Although a new RDP is often the more appropriate choice, at least 15 methods have been described for making a crown fit an existing partial RDP.[8,9] These can be classified as direct, direct-indirect, or indirect procedures.

When a direct-indirect procedure is used, a pattern is fabricated from autopolymerizing acrylic resin and wax. The resin is applied onto the tooth preparation, and resin is added until it contacts the internal aspect of the RDP clasps, thus duplicating the axial contours of the original abutment crown. This resin pattern is repositioned on a die on which the margins are refined by wax is added and the restoration is shaped. The combined resin-wax pattern is invested, and after wax and resin elimination, the crown is cast.

The indirect procedure consists of a "pickup" impression of the prepared tooth and the seated partial RDP. This is poured in the conventional way after any undercuts in the denture have been waxed out. The crown is fabricated in the conventional way, the RDP being removed and replaced on the cast to establish appropriate contours. Additional wax (or porcelain for a metal-ceramic crown) is added where the retentive undercut is needed (Fig. 21-28). A disadvantage of this technique in comparison with the direct approach is that the partial RDP is required in the laboratory throughout the crown fabrication. This may not be acceptable to the patient, particularly if the patient's appearance is affected.

With all these techniques, extra care is necessary in finishing the areas of the crown where contact with the RDP occurs. Small clasp-adaptation imperfections often result, but with some practice, it is possible to routinely fabricate quite acceptable restorations that eliminate the need to fabricate a new RDP.

If the contours of the existing but defective retainer are acceptable, it is possible to obtain an optical scan of the desired contours and the occlusal surfaces of the adjacent teeth. After the defective crown has been removed, and the tooth preparation completed, a conventional or optical impression can be made. In the dental laboratory, the software is manipulated to merge the information previously captured during the design phase of the new crown, which is then fabricated in the specified material. If finishing procedures are performed in a cautious manner, this approach is successful in fabricating crowns

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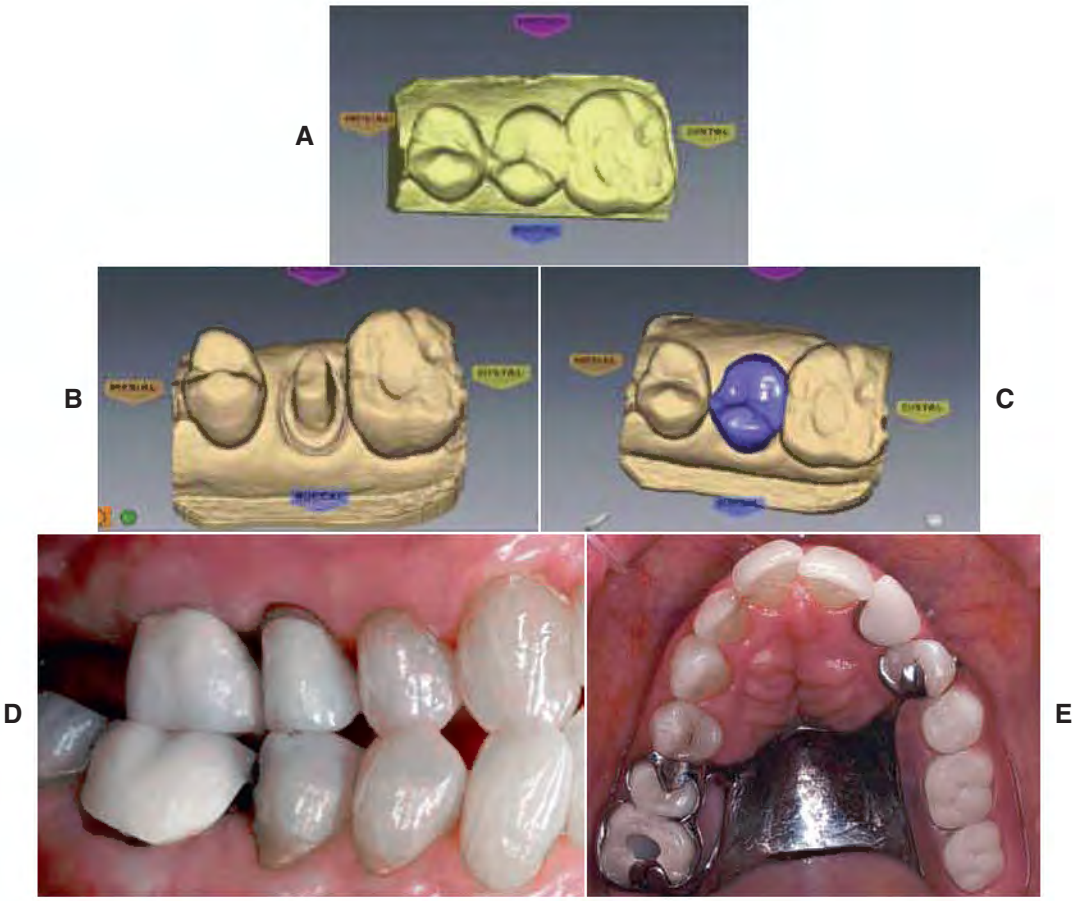

FIGURE 21-29 ■ **A,** Scanned image of maxillary right second premolar from existing diagnostic cast. **B,** Scanned image of prepared maxillary right second premolar from definitive cast after impression. **C,** Duplicated image of maxillary right second premolar crown from diagnostic cast is superimposed on prepared tooth of definitive cast. **D,** Computer-aided design and computer-aided manufacturing (CAD/CAM) milled ceramic crown is adjusted and cemented. **E,** Retrofit ceramic crown is well adapted under patient's existing partial removable dental prosthesis. (From Yoon TH, Chang WG: The fabrication of a CAD/CAM ceramic crown to fit an existing partial removable dental prosthesis: a clinical report. J Prosthet Dent 108:143, 2012.)

that offer reasonable partial RDP stability on delivery (Fig. 21-29).[10]

ATTACHMENTS

A wide range of prefabricated attachments are available for use with partial RDPs.[11,12] Most of these consist of two components: one that is incorporated in the crown, and one that becomes part of the RDP. Both extracoronal and intracoronal designs are available (Fig. 21-30).

In general, the use of attachments, whether extracoronal or intracoronal, should be limited. Attachments add to the complexity and cost of the restorative service and often necessitate remaking the fixed retainers when the attachments wear out. In one study, only 22 of 57 prostheses were free of complications during the first 2 years.[13] When used with distal extensions, attachments lead to higher stresses in the abutment teeth.[14] When the teeth that will support a partial RDP are located in the esthetic zone, the use of attachments can be justified to enhance appearance inasmuch as they can offer a means to avoid visible unsightly clasps.

FIGURE 21-30 ■ An intracoronal and an extracoronal attachment were used in this anterior fixed dental prosthesis. (Courtesy Dr. F.F. Hsu.)

Extracoronal Attachments

Any prefabricated attachment for support and retention of an RDP in which the "male" and "female" components are positioned outside the normal contour of the abutment tooth is considered an extracoronal attachment

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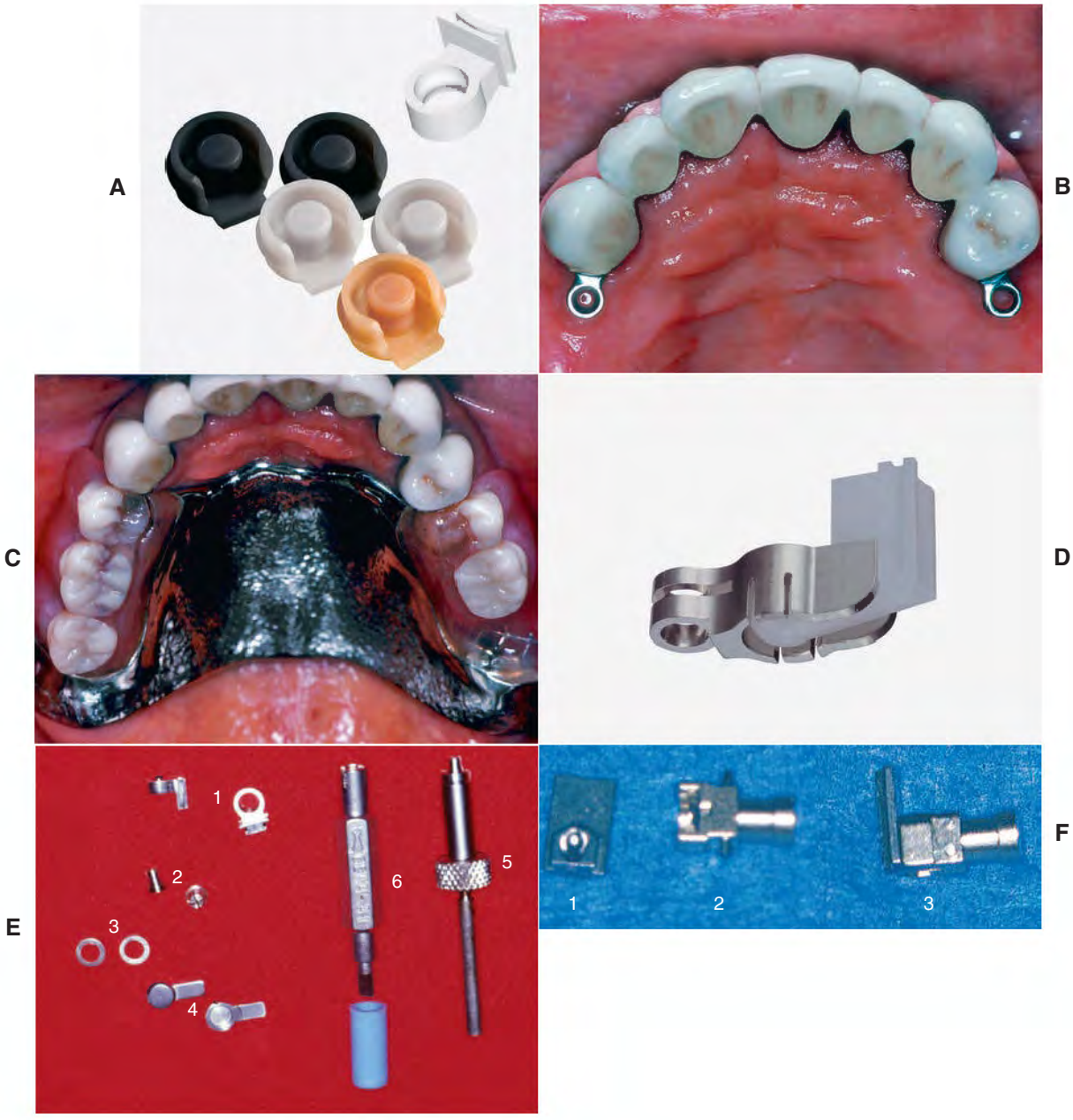

FIGURE 21-31 ■ Prefabricated extracoronal attachments. **A,** The ERA. These attachments are designed to be resilient and to direct stress to both the abutment teeth and edentulous ridges when supporting a distal extension of a partial removable dental prosthesis (RDP). The color-coded "male" components are processed directly into the acrylic denture base and have different levels of retention. **B,** Abutment crowns incorporating ERA attachments. **C,** Completed prostheses. **D,** The Dalbo Mini. This attachment provides some movement between "male" and "female" components. **E,** The Ceka: *1,* "female" component; *2,* "male" component; *3,* spacer; *4,* "male" partial RDP connector; *5,* positioning mandrel; *6,* adjustment tool. **F,** The 2.7 Dawson: *1,* "male" component; *2,* "female" component, which has a built-in replaceable plunger for retention; *3,* the 2.7 Dawson attachment assembled. (**A** and **D,** Courtesy Sterngold Dental, LLC, Attleboro, Massachusetts. **B, C,** and **F,** courtesy Dr. W.V. Campagni.)

(Fig. 21-31). Careful judgment is needed in deciding when to use such attachments (e.g., ERA [Sterngold Dental, LLC], Ceka [AlphaDent NV], Dalbo [Cendres & Métaux SA], or Dawson [Comdent, Inc.]) because they place unfavorable stresses on the abutment teeth, similar to the stresses exerted by a cantilever. In addition, they make oral hygiene more difficult. In some instances, however, extracoronal attachments offer esthetic advantages that may outweigh their biologic and mechanical disadvantages (Fig. 21-32). Resin bonding has been used for the retention of extracoronal attachments directly to the teeth by means of the same principles as for resin-bonded prostheses (see Chapter 26).[15] It is doubtful however, that the retention obtained in that manner is adequate to prevent eventual dislodgment of the attachment.

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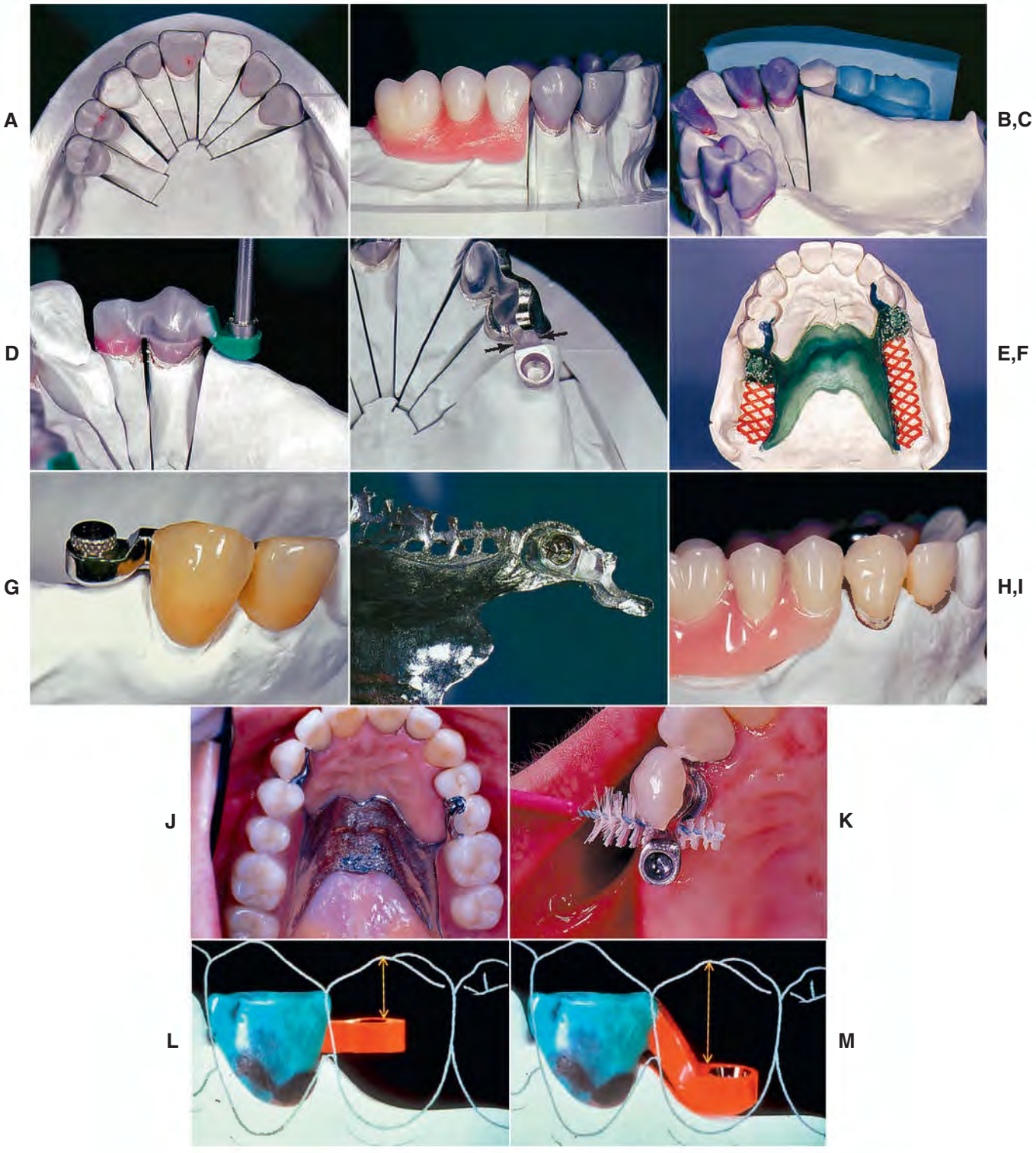

FIGURE 21-32 ■ Use of Ceka extracoronal attachments to retain a distal extension of a partial removable dental prosthesis (RDP). **A** and **B,** Anatomic contour waxing and occlusal plane development. **C,** A buccal index is used to allow repositioning of the denture teeth to help identify correct attachment placement. **D,** The "female" attachment pattern is positioned in relation to the wax pattern by means of a special mandrel in the dental surveyor. **E,** The substructures have been cast. Adequate strength is present where the extracoronal "female" attachment joins the retainer *(arrows).* **F,** Refractory cast with RDP wax pattern. **G,** "Male" component positioned in the "female" attachment. **H,** Attachment picked up. **I,** The completed prosthesis hides the attachment from sight. **J,** The RDP in place. **K,** Proxy brush enables appropriate plaque control around the attachment. **L** and **M,** "Female" patterns are available in different angulations to provide optimal access for oral hygiene and adequate space for the RDP. (**A** to **K**, Courtesy Dr. S. Freijlich and Mr. T. Behaeghel. **L** and **M**, Courtesy Preat Corporation, Grover Beach, California.)

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Intracoronal Attachments

Intracoronal attachments have "male" and "female" components that are positioned within the normal contour of the abutment tooth. These can be prefabricated or made in the dental laboratory.

Prefabricated Attachments

The more commonly used prefabricated intracoronal attachments (e.g., Stern Latch, The C&M McCollum [Sterngold Dental, LLC] or Ney-Cheyes No. 9 [Ney Dental International]) typically consist of a precision-milled "male-female" assembly (Fig. 21-33) similar to the dovetail configuration described for nonrigid connectors (see Chapter 2).

The precision of the fit between components of an intracoronal precision attachment is so fine that retention results from friction. An intracoronal precision attachment partial RDP is not readily dislodged because it can be removed only in a single direction, which may present difficulties for patients with limited dexterity. However, retention can be significantly reduced after wear of the retentive surfaces. Most precision attachments are made of platinum-palladium alloys, necessary to withstand the high temperature associated with casting of metal-ceramic alloys directly onto the attachment.

The "female" attachment is incorporated in the retainer wax pattern, and the assembly is invested. After wax elimination, the attachment is retained inside the investment and the restoration is cast directly onto the attachment. Although multiple parallel attachments can be fabricated in this manner, most technicians prefer to solder a second or third attachment to the respective retainers. This allows the technician to verify alignment with the attachment in the first retainer.

Alternatively a metal tray may be incorporated in the secondary retainer for added flexibility during positioning of the second attachment parallel to the first attachment. The secondary retainer is luted into place, invested, and soldered. "Male" components can then be inserted. After the partial RDP framework has been made, the "male" attachments are either soldered to the frame or attached to the acrylic resin denture base with autopolymerizing resin (Figs. 21-34 and 21-35).

The preceding paragraph condenses an intricate sequence of technically highly demanding steps. The less experienced operator is strongly cautioned not to underestimate the high level of skill and meticulous attention to detail that are required.

The best advantage of intracoronal attachments is that they eliminate the need for an often unesthetic facial clasp. Simultaneously, however, the size of most intracoronal precision attachments limits their application, especially on vital teeth. To facilitate maintaining the health of supporting tissues, the proximal surface of the restoration should not be overcontoured. Therefore, the optimum placement of attachments is within the normal contours of the tooth and thus the restoration. However, this is usually possible only on large teeth. On small teeth, few intracoronal precision attachments can be kept within the confines of normal tooth contour without endodontic treatment. In addition, clinical crown height must be sufficient for adequate cervico-occlusal length to allow a positive friction fit (a minimum attachment height of 4 mm or more is recommended).

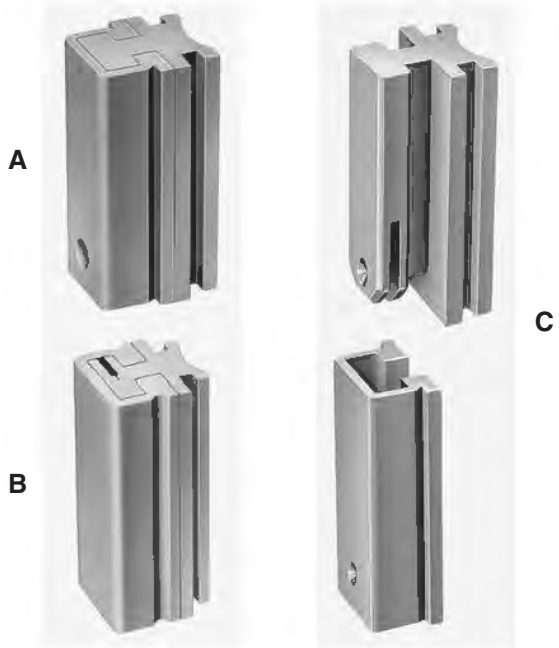

FIGURE 21-33 ■ Prefabricated intracoronal attachments. **A** and **B,** The Stern Latch. **C,** The C&M McCollum. (Courtesy Sterngold Dental, LLC, Attleboro, Massachusetts.)

Laboratory-made Attachments

Many laboratory-made (semiprecision) attachments are in use today. Often they are referred to as *dovetails* because of the shape of their interlocking components. They can be made by incorporation of a prefabricated plastic insert in the wax pattern; the pattern is then invested and the insert is eliminated, and the pattern is cast (Fig. 21-36). The "female" dovetail can also be milled, after which the "male" component is waxed and cast.

An alternative method of fabrication is to use a tapered metal mandrel (e.g., Ticon [CMP Industries LLC]) that is heated and inserted in the wax pattern. When the wax is eliminated after investing, the exposed portion of the mandrel in the mold oxidizes. The crown is then cast directly onto the mandrel, which is later removed (see Fig. 21-36). A "male" attachment can be waxed and cast separately. After seating, the attachment is then soldered or welded to the partial RDP framework.

Because of the inaccuracies inherent in their fabrication, most laboratory-made attachments have a limited amount of frictional retention in comparison with the commercially available precision attachments. The majority are tapered for ease of fabrication and therefore necessitate the use of lingual retentive clasps for positive retention.

When attachments are used with a metal-ceramic restoration, adequate metal must remain between the

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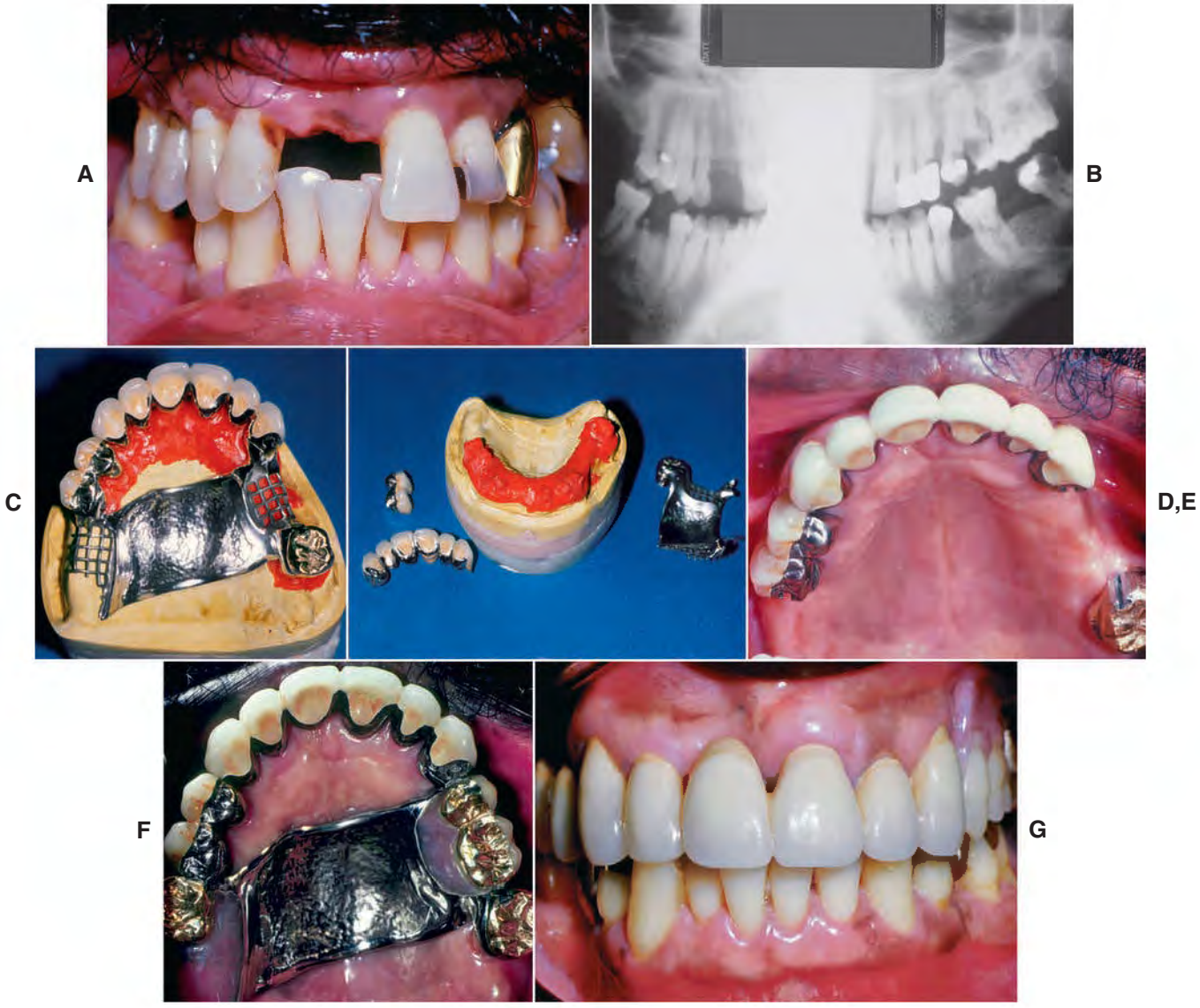

FIGURE 21-34 ■ Use of Stern Latch intracoronal attachments to support and retain a maxillary partial removable dental prosthesis (RDP). The Stern Latch attachment has frictional retention augmented by an internal gingival spring latch. The matrix may be waxed and then cast directly to the metal components. The "male" component may be soldered to the framework or embedded in the resin of the finished partial RDP. **A** and **B,** Extensive periodontal disease and caries necessitated the loss of several teeth with a hopeless prognosis. **C,** The resin-reinforced definitive cast with the finished fixed prostheses and partial RDP framework. **D,** Restorations and framework removed from the cast. **E,** Cemented fixed restorations without the partial RDP. **F,** Intraoral view of finished prostheses. **G,** Anterior view of completed prosthesis. (Courtesy Dr. W.V. Campagni.)

"female" component and the facial veneer of dental porcelain. As for occlusal rests, a minimum metal thickness of 1 mm is recommended between any intracoronal attachment and the metal-ceramic interface (Fig. 21-37).

Bars, Studs, and Magnets

Stud attachments[16] and magnets[17] (Fig. 21-38) are sometimes used to retain overdentures. They are incorporated in post-retained castings or implant abutments and offer the advantage of allowing increased occlusal force and improved denture stability[18] (Fig. 21-39). In order to have adequate room for all attachment components, the denture resin, and a hollowed-out shell of a denture tooth (see Fig. 21-38, *B*), a minimal vertical space of 7 to 9 mm is recommended.

A bar-retained partial RDP or overdenture can be very stable while it braces individual abutment teeth. The bar should attach to the retainer without interfering with oral hygiene.

In general, this means that considerable coronal length is necessary for the bar to produce an acceptable result. The bar should not be placed in contact with an edentulous ridge; it should be positioned about 2 mm away from the soft tissues (Fig. 21-40).

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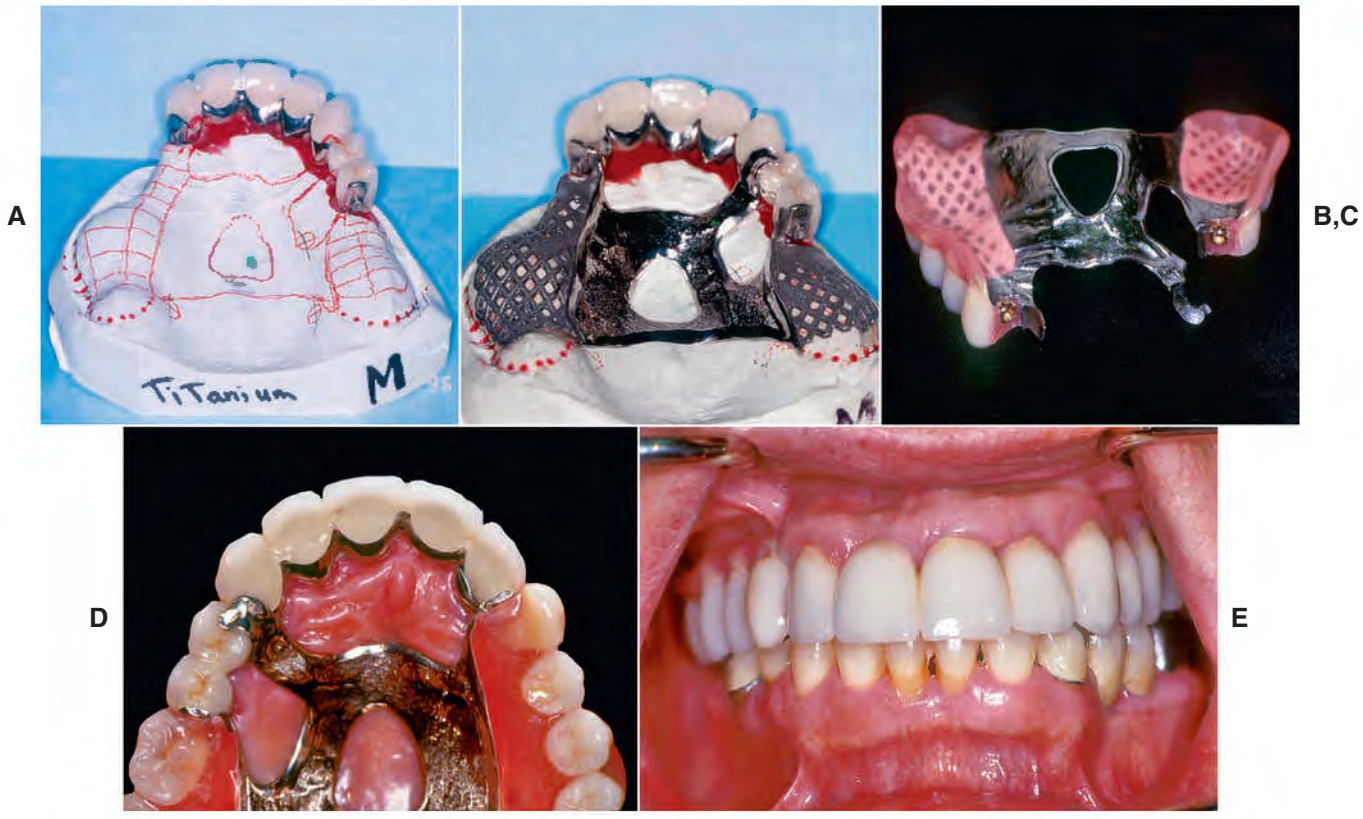

FIGURE 21-35 ■ Use of the Dawson 2.7 extracoronal attachment to support and retain a maxillary partial removable dental prosthesis (RDP). This precision attachment comprises an extracoronal patrix, which is waxed into the fixed abutment prosthesis and then cast directly to the metal components. The matrix comprises a housing with a spring-loaded plunger for retention. The plunger engages a dimple on the distal side of the patrix. The plunger and spring can be removed from the housing for replacement with a special U-shaped pin. **A,** Definitive cast with finished crowns on resin replica dies for fabrication of partial RDP framework. **B,** Framework on definitive cast. The matrix will be luted to the frame with resin for the try-in. **C,** View of finished partial RDP, showing matrix processed in place. **D,** Occlusal view of partial RDP intraorally. **E,** Anterior view of completed prosthesis. (Courtesy Dr. W.V. Campagni.)

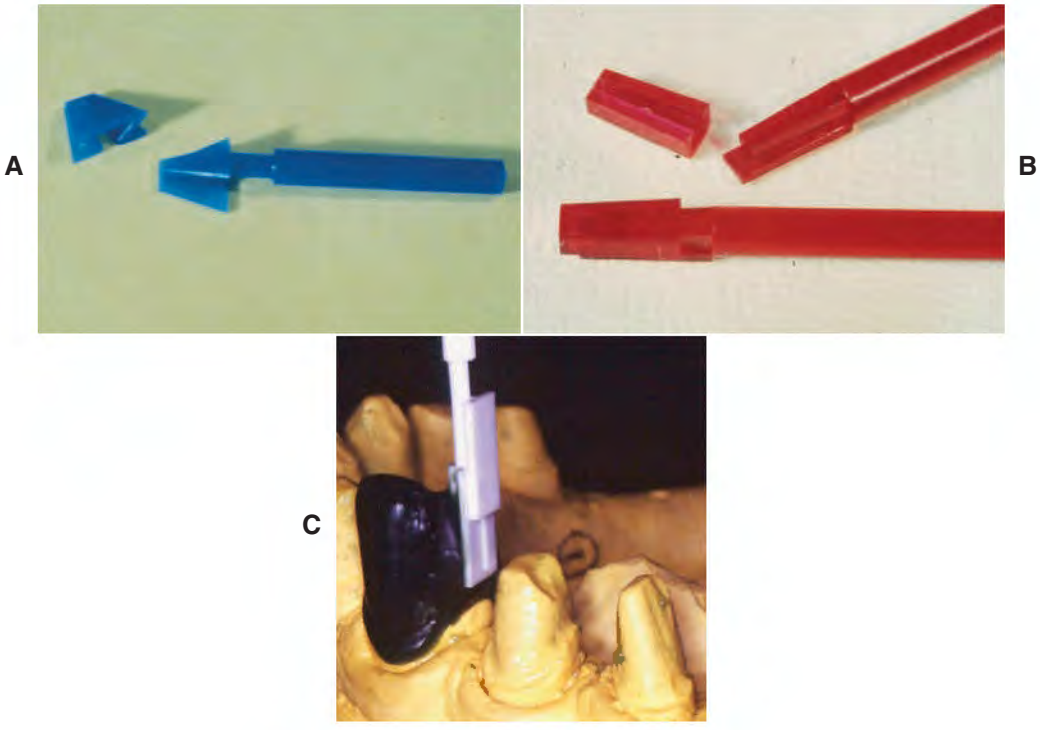

FIGURE 21-36 ■ **A** to **C,** Plastic preformed patterns for an intracoronal rest. (**C,** Courtesy Dr. F.F. Hsu.)

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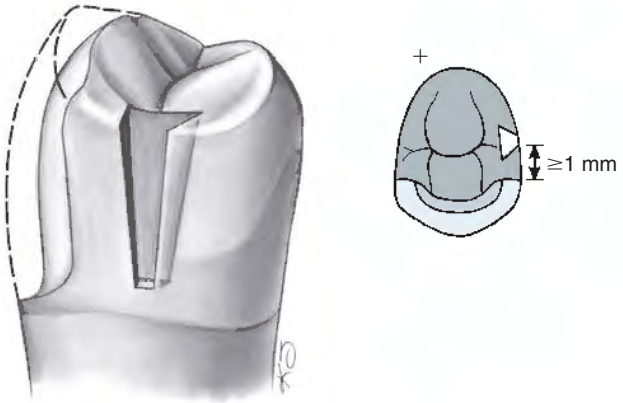

FIGURE 21-37 ■ "Female" intracoronal rest incorporated in a metal-ceramic restoration. The attachment should be at least 1 mm from the metal-ceramic junction. Retention is provided by a lingual undercut into which a clasp engages. Reciprocation is provided internally by the rest seat.

SUMMARY

Along with conventional diagnostic procedures, an in-depth survey analysis of the diagnostic cast must be performed for any patient who requires a partial RDP. The coronal surfaces of the abutment teeth should be shaped to allow for optimum retention and stability of the RDP during function. Simultaneously, proximal and reciprocal guide planes should be established to guide and stabilize the prosthesis during placement and to minimize horizontal forces on the abutment teeth.

To achieve harmony with the necessary RDP design, making cast restorations on otherwise intact and caries-free teeth is sometimes necessary. The contours or axial configuration of unaltered crowns of natural teeth may not be suitable for the best clasp design.

FIGURE 21-38 ■ **A** and **B,** The ERA stud attachment. Like the ERA extracoronal attachment (see Fig. 21-31, *A* to *C*), this resilient attachment is available in different sizes (Stern ERA and Micro ERA) and color-coded retention levels. **C** and **D,** The Stern Root Anchor. This stud attachment comprises an intraradicular ball-and-socket joint. The nylon "male" part **(C)** is processed into the denture acrylic. The titanium "female" part **(D)** is cemented directly into the prepared root. **E,** The Dalla Bona Spherical attachment, a gold alloy stud attachment with adjustable frictional resistance. **F** and **G,** The Hader bar. In this bar system, a plastic bar is incorporated into the fixed prosthesis before casting. Color-coded nylon rider clips are incorporated into the denture and are available with varying retention. Alternatively, a gold rider can be used for greater strength. **H,** The Dolder bar. This gold alloy bar is available in rigid *(1)* and resilient or hinging *(2)* configurations. **I,** Parts of the Dolder bar: *1,* sleeve; *2,* spacer; *3,* bar. (**A** to **H,** Courtesy Sterngold Dental, LLC, Attleboro, Massachusetts.)

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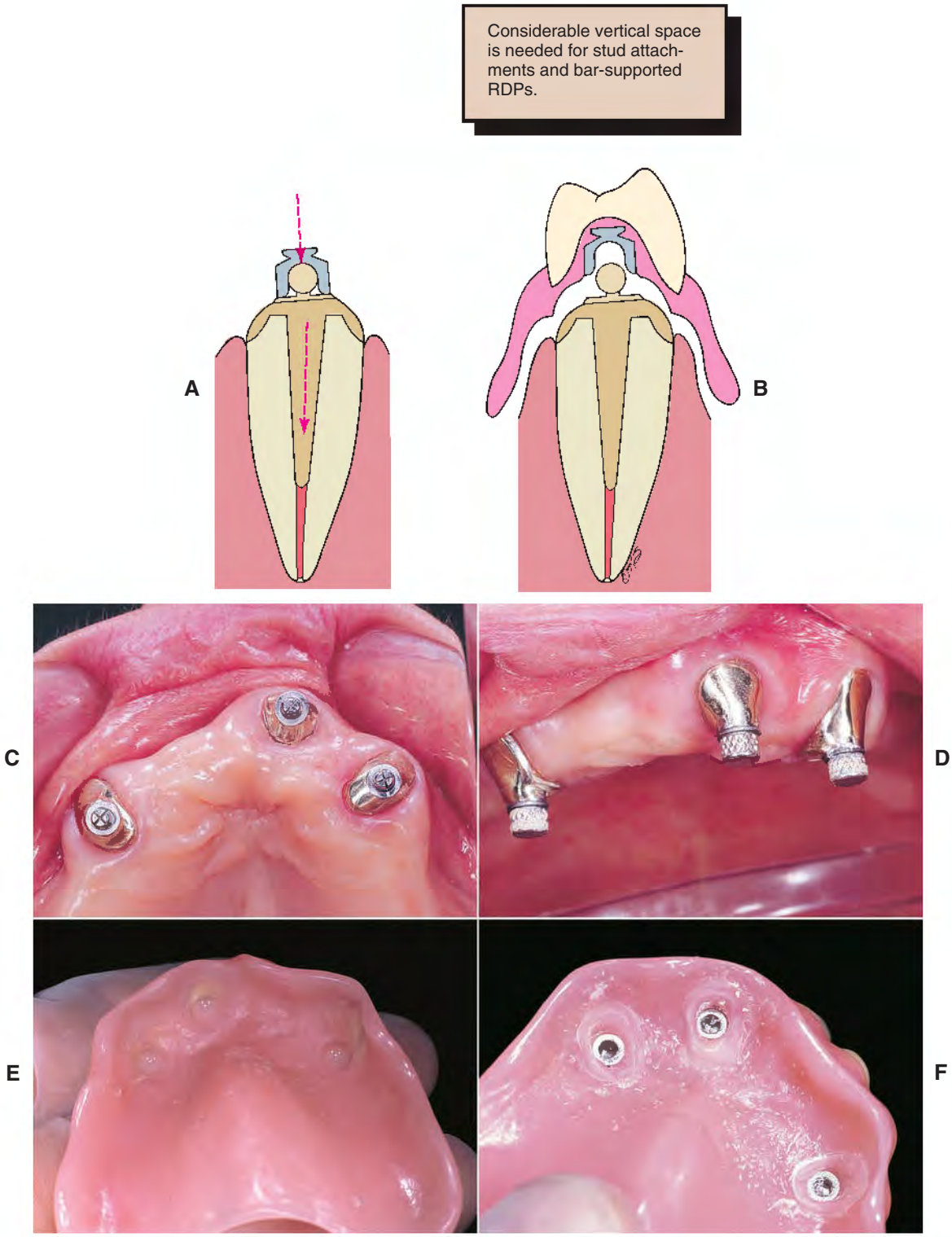

FIGURE 21-39 ■ **A,** Illustration of post-retained casting incorporating the "male" component of a stud attachment. The design allows for slightly different paths of insertion *(arrows)* of the post and overdenture. **B,** Illustration of the "female" component attached to the overdenture with acrylic resin. RDP, removable dental prosthesis. **C,** Occlusal view of three cemented copings with the "male" components in place. **D,** "Female" attachments have been positioned over the "male" attachments. **E,** Resin is applied to the internal surface of the prosthesis immediately before the denture is inserted. **F,** Denture immediately after removal of excess resin around the "female" components, which are now mechanically retained in the prosthesis. (Courtesy Dr. M.A. S. Freijlich and Mr. T. Behaeghel.)

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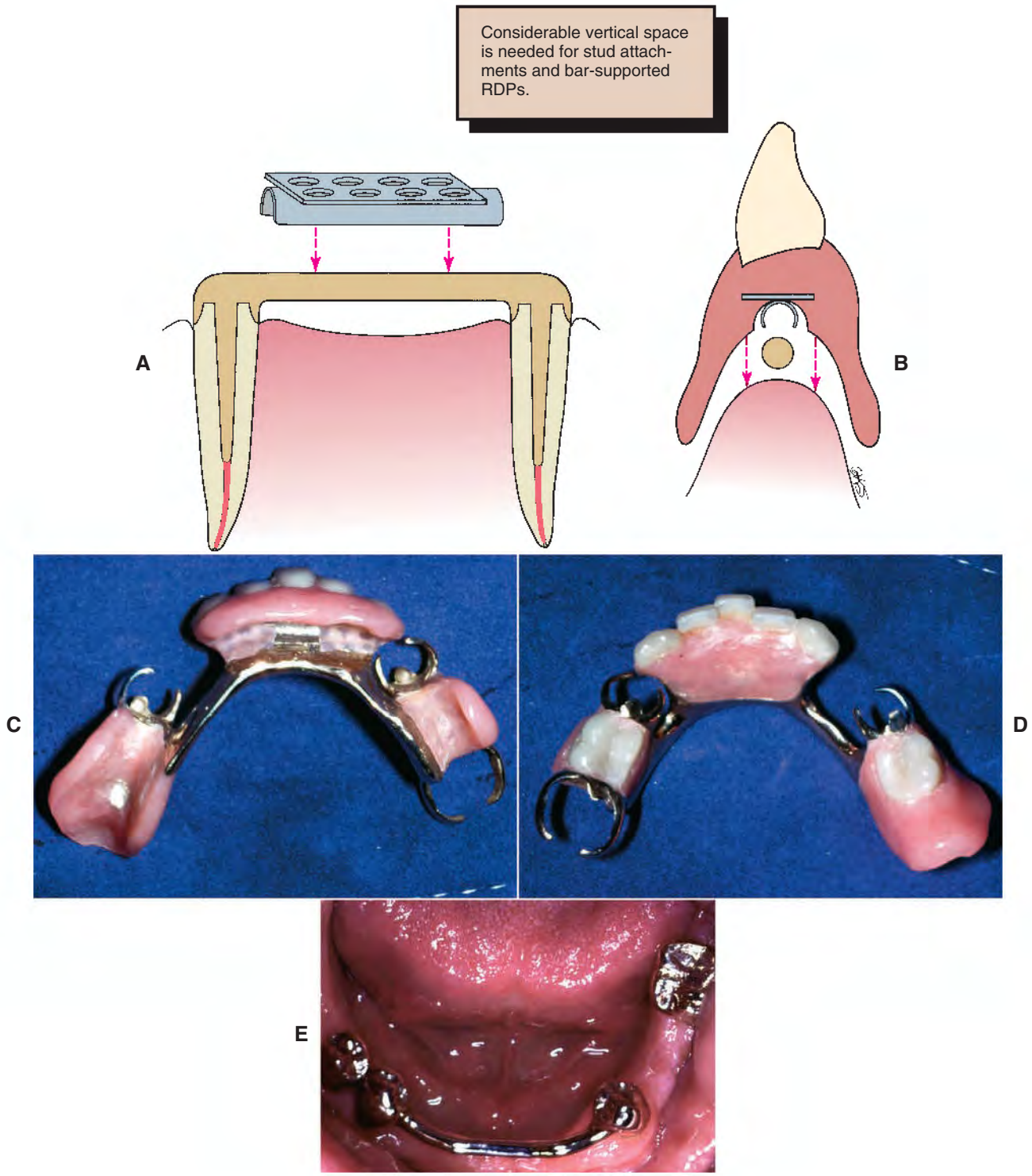

FIGURE 21-40 ■ Bar attachment. **A,** The bar is retained by posts on conventional fixed restorations. The clip provides support and retention for the partial removable dental prosthesis (RDP). **B,** Incisogingival height must be sufficient to accommodate a bar prosthesis. **C,** Internal view of the bar-retained partial RDP. **D,** Occlusal view. **E,** Cemented fixed prosthesis with a bar to accommodate an RDP.

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The amount of tooth reduction needed to fabricate restorations with the desired survey contours is often slightly greater than that needed if the respective abutment teeth are prepared for conventional restorations. Allowances must be made for occlusal rest seats and guide planes. Precision and semiprecision attachments can offer esthetic and retentive advantages (Fig. 21-41).

Intracoronal attachments are often more esthetic than are conventional clasps. They work well if kept within the normal contours of the teeth.

Extracoronal attachments should be used sparingly because of their unfavorable loading of abutment teeth and the associated problems in maintaining oral hygiene.

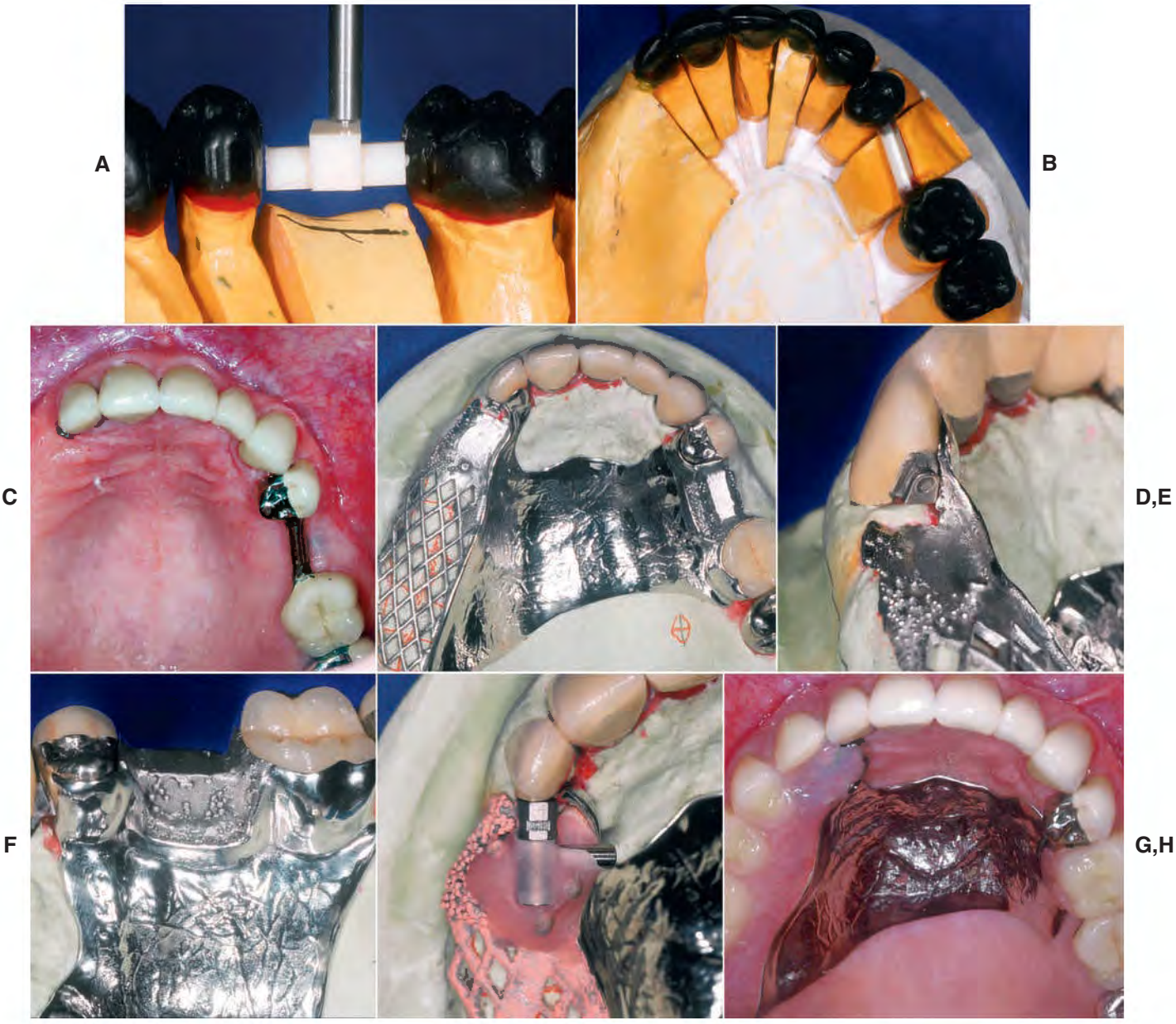

FIGURE 21-41 ■ Use of a combination of bar and extracoronal attachments for support and retention of a maxillary partial removable dental prosthesis (RDP) according to the rotational path concept. The COMPAS attachment system was chosen as the extracoronal attachment. This system was designed by Dr. Peter Dawson and is an evolution of the D 2.7 attachment (see Fig. 21-35), which was also designed by Dr. Dawson. It includes preformed plastic parts that are placed by mandrels and waxed into the crown forms for cutback and casting. It also includes a spring-loaded plunger that is incorporated into the matrix, which is luted to the partial RDP framework by being embedded into the resin. Preformed plastic bar and matrix forms were used and were incorporated into the fixed prostheses wax patterns. **A,** Curved bar is positioned and waxed for placement. **B,** Anatomic contour waxing with bar on left and extracoronal attachment on right abutment. **C,** Evaluation of completed crowns. The fixed restorations were picked up in an impression that was used to fabricate the definitive cast for the RDP framework. **D,** Framework and restorations on definitive cast. **E,** Attachment on distal side of abutment. **F,** Framework cast to fit over curved bar. **G,** Plunger assembly luted to framework for evaluation. **H,** Intraoral view of completed prostheses. (Courtesy Drs. W.V. Campagni and F. Munguia.)

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Attachments and occlusal rest seats in metal-ceramic restorations should be placed at least 1 mm from the metal-ceramic interface.

Survey crowns necessitate finishing procedures for which special milling equipment is needed.

A precementation impression should be obtained for verifying that the best coronal contours have been created in harmony with the partial RDP.

REFERENCES

1. Altay OT, et al: Abutment teeth with extracoronal attachments: the effects of splinting on tooth movement. Int J Prosthodont 3:441, 1990.
2. Krol AJ, Finzen FC: Rotational path removable partial dentures. II. Replacement of anterior teeth. Int J Prosthodont 1:135, 1988.
3. Jones RM, et al: Dentin exposure and decay incidence when removable partial denture rest seats are prepared in tooth structure. Int J Prosthodont 5:227, 1992.
4. Seto BG, et al: Resin bonded etched cast cingulum rest retainers for removable partial dentures. Quintessence Int 16:757, 1985.
5. Dixon DL, et al: Use of a partial coverage porcelain laminate to enhance clasp retention. J Prosthet Dent 63:55, 1990.
6. Davenport JC, et al: Clasp retention and composites: an abrasion study. J Dent 18:198, 1990.
7. Berg T: I-bar: myth and countermyth. Dent Clin North Am 28:371, 1984.
8. Tran CD, et al: A review of techniques of crown fabrication for existing removable partial dentures. J Prosthet Dent 55:671, 1986.
9. Elledge DA, Schorr BL: A provisional and new crown to fit into a clasp of an existing removable partial denture. J Prosthet Dent 63:541, 1990.
10. Yoon TH, Chang WG: The fabrication of a CAD/CAM ceramic crown to fit an existing partial removable dental prosthesis: a clinical report. J Prosthet Dent 108:143, 2012.
11. Becerra G, MacEntee M: A classification of precision attachments. J Prosthet Dent 58:322, 1987.
12. Burns DR, Ward JE: Review of attachments for removable partial denture design. I. Classification and selection. Int J Prosthodont 3:98, 1990.
13. Owall B, Jonsson L: Precision attachment-retained removable partial dentures. III. General practitioner results up to 2 years. Int J Prosthodont 11:574, 1998.
14. Chou TM, et al: Photoelastic analysis and comparison of force-transmission characteristics of intracoronal attachments with clasp distal-extension removable partial dentures. J Prosthet Dent 62:313, 1989.
15. Doherty NM: In vitro evaluation of resin-retained extracoronal precision attachments. Int J Prosthodont 4:63, 1991.
16. Mensor MC: Removable partial overdentures with mechanical (precision) attachments. Dent Clin North Am 34:669, 1990.
17. Gillings BR, Samant A: Overdentures with magnetic attachments. Dent Clin North Am 34:683, 1990.
18. Sposetti VJ, et al: Bite force and muscle activity in overdenture wearers before and after attachment placement. J Prosthet Dent 55:265, 1986.

STUDY QUESTIONS

1. Explain the principles underlying reciprocation and their effect on the coronal contour of individual retainers.

2. Discuss the principles that govern the determination of the location of height of contour and the survey line on the retentive surface of a retainer that is to support a partial removable dental prosthesis (RDP).

3. How does tooth preparation for a retainer for a partial RDP differ from a conventional tooth preparation for the same tooth? What are the various factors that must be considered, and how do they influence the result?

4. What is the recommended fabrication sequence of a wax pattern for a retainer for a partial RDP?

5. Discuss the classification of attachments and the respective indications, contraindications, advantages, and disadvantages.

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CHAPTER 22

Investing and Casting

Lost-wax castings have been made since ancient times. In this technique, wax patterns are converted to cast metal patterns. As a means of making dental castings, it was first described[1,2] at the end of the nineteenth century.

The process consists of surrounding the wax pattern with a mold made of heat-resistant investment material, then eliminating the wax by heating, and introducing molten metal into the mold through a channel called the *sprue*. In dentistry, the resulting casting must be a highly accurate reproduction of the wax pattern both in surface details and in overall dimensions. Small variations in investing or casting can significantly affect the quality of the definitive restoration. Routine success in making castings depends on attention to detail and consistency of technique.

An in-depth understanding of the precise influence of each variable in the technique is necessary to be able to make rational decisions to adjust specific steps in the technique as needed for a given procedure.

PREREQUISITES

When the wax pattern has been completed and its margin has been reflowed (see Chapter 18, the section on Margin Finishing), it is carefully evaluated for smoothness, finish, and contour (see Chapter 18). The pattern is inspected under magnification, and any residual flash (wax that extends beyond the preparation margin) is removed. A sprue is attached to the pattern. The pattern is then removed from the die and attached to a crucible former (Fig. 22-1). The wax pattern must be invested immediately because any delay leads to distortion of the pattern as a result of stress relief of the wax.[3]

Sprue

Sprue design (Fig. 22-2) varies depending on the type of restoration being cast, the alloy used, and the casting machine. There are three basic requirements, as follows:

- The sprue must allow the molten wax to escape from the mold.
- The sprue must enable the molten metal to flow into the mold with as little turbulence as possible.
- The metal within it must remain molten slightly longer than the alloy that has filled the mold. This provides a reservoir to compensate for the shrinkage that occurs during solidification of the casting alloy.

The shape of the channel in the refractory mold is determined by the sprue that connects the wax pattern to the crucible former. The sprue can be made from wax, plastic, or metal. Wax sprues are preferred for most castings because they melt at the same rate as the pattern and thus allow easy escape of the molten wax. Solid plastic sprues soften at a higher temperature than does the wax pattern and may block the escape of wax, which results in increased casting roughness. However, plastic sprues can be useful when fixed dental prostheses are cast in one piece because their added rigidity minimizes distortion. Also, hollow plastic sprues that allow the escape of wax are available.

If a metal sprue is used, it should be made of noncorroding metal to avoid possible contamination of the casting. Many metal sprues are hollow, so as to increase contact surface area and strengthen the attachment between the sprue and pattern. They are usually separated from the investment at the same time the crucible former is. The technician must then examine the orifice very carefully for small particles of investment that may break off when such a sprue is removed because these can cause incompleteness of the casting if they are undetected (see the section on Incompleteness later in this chapter).

Diameter

In general, a sprue with a relatively large diameter is recommended because this improves the flow of molten metal into the mold and ensures a reservoir during solidification.[4,5]

A 2.5-mm (10-gauge) sprue is recommended for molar and metal-ceramic patterns. A smaller 2.0-mm (12-gauge) sprue is adequate for premolar castings and most partial-coverage restorations.

In some casting techniques other than the commonly used centrifugal technique, a narrow sprue, or a sprue design that narrows at the point of attachment to the wax pattern, is essential. For instance, with air-pressure machines, the melting occurs directly in the depression created by the crucible former and the metal then is forced into the mold by the sudden change in air pressure. With this technique, a narrow sprue that necks in prevents the molten metal from flowing into the mold prematurely.

Location

The sprue should be attached to the bulkiest noncritical part of the pattern, away from margins and occlusal contacts. Normally, the largest nonfunctional cusp is used (Fig. 22-3). The point of attachment should allow a stream of metal to be directed to all parts of the mold without having to flow in an opposite direction to the casting force (Fig. 22-4).

The sprue must also allow for proper positioning of the pattern in the ring. The objective is to center the pattern.

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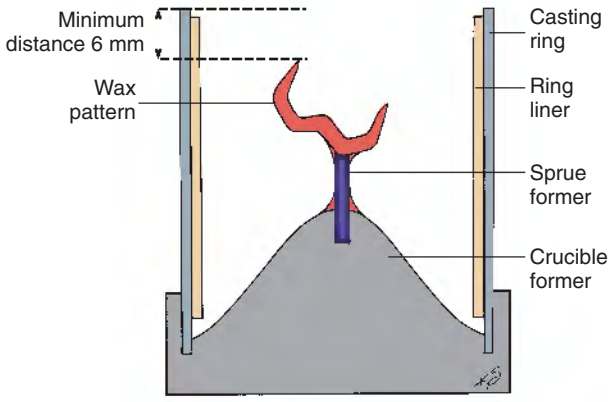

FIGURE 22-1 ■ Wax pattern attached to the crucible former with a sprue ready for investing. A ring liner is in place.

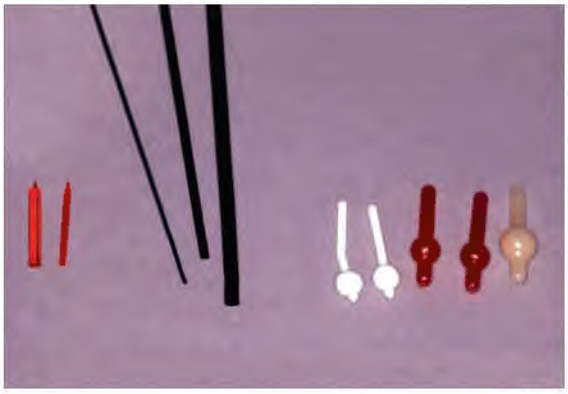

FIGURE 22-2 ■ Prefabricated plastic and wax sprues. These are preferred over metal sprues because plastic and wax are eliminated during the heating cycle.

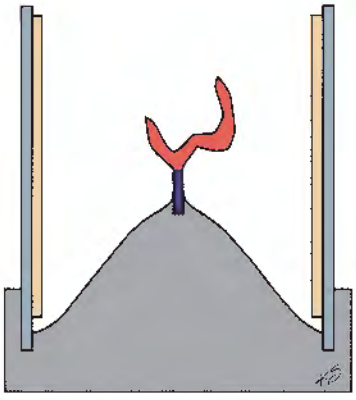

FIGURE 22-3 ■ Correct sprue placement on the bulkiest nonfunctional cusp allows molten alloy to flow to all parts of the mold.

This can be crucial because expansion within the mold is not uniform.[6,7] For example, positioning the sprue on the cusp tip can yield good results, but positioning it on the proximal contact may produce a casting that is too wide mesiodistally and too short occlusocervically.

Attachment

The sprue's point of attachment to the pattern should be carefully smoothed to minimize turbulence. For the centrifugal casting technique, the attachment area should not be restricted because necking increases casting porosity and reduces mold filling.[8] Similarly, excessively widening the attachment can cause this part of the cooling melted portion to solidify last, causing a void on the internal aspect of the casting, known as *shrink-spot porosity*.

Incorrect sprue placement. The gold needs to change direction at an angle of almost 90 degrees after entering the mold. Better placement is at a 45-degree angle on the thickest portion of the pattern.

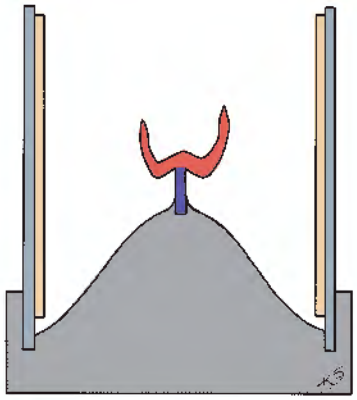

FIGURE 22-4 ■ Incorrect sprue placement in the central fossa obliterates occlusal anatomy and may result in poor mold filling because the molten metal is not pushed into the cusp tips by centrifugal force.

Venting

Small auxiliary sprues or vents have been recommended to improve casting of thin patterns. Their action may help gases escape during casting[9] or may ensure that solidification begins in critical areas by acting as a heat sink[10] (Fig. 22-5).

Crucible Former

The sprue is attached to a crucible former (sometimes referred to as a *sprue former*; Fig. 22-6), usually made of rubber, which serves as a base for the casting ring during investing. The exact shape of the crucible former depends on the type of ring and casting machine used. With most modern machines, the crucible former is tall, to allow use of a short sprue and also to enable the pattern to be positioned near the end of the casting ring.

Casting Ring and Liner

The casting ring serves as a container for the investment while it sets and restricts the setting expansion of the mold. Normally a liner is placed inside the ring to allow

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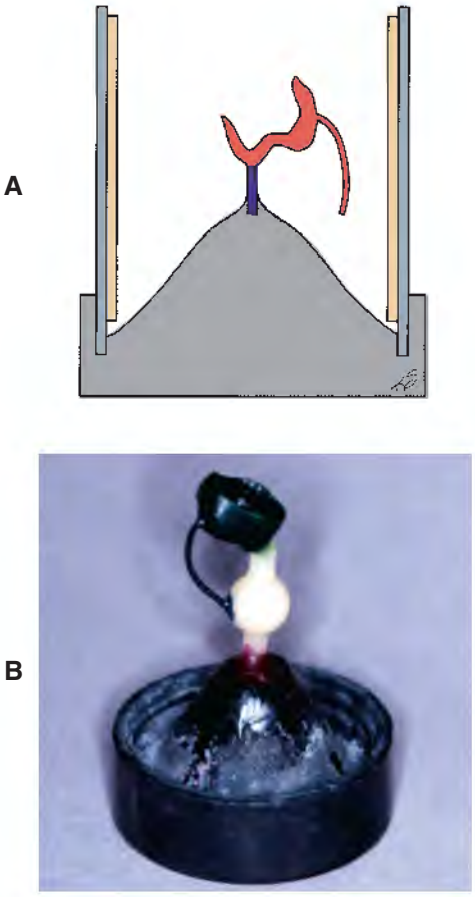

FIGURE 22-5 ■ **A** and **B,** Thin auxiliary sprues may help gases escape and ensure that casting solidifies in a critical area.

FIGURE 22-6 ■ Rubber crucible formers and corresponding casting rings. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

for more expansion because the liner is somewhat compressible. Use of two liners allows for additional compression and enables increased setting expansion of the investment material. At one time, asbestos was used as the liner; to avoid the health risks associated with

Various methods to influence the amount of *setting expansion* of the investment.

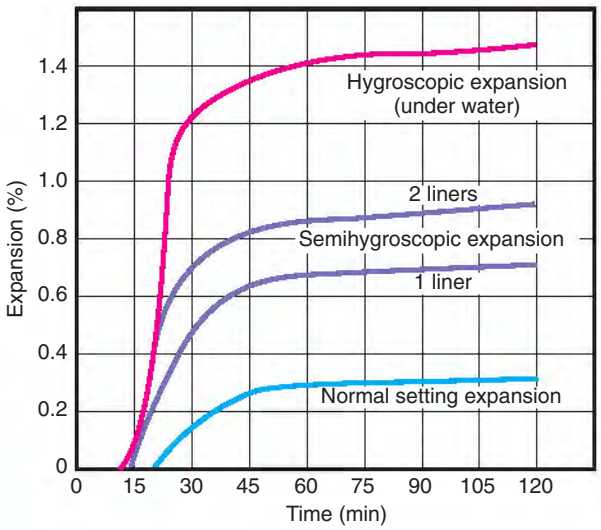

FIGURE 22-7 ■ Setting expansions of dental casting investments. Note that expansion can be increased by a hygroscopic technique, as well as by the particular type of ring liner used. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

asbestos fibers, cellulose paper liners or refractory ceramic fiber liners are now used. Like many other factors that come into play in achieving consistent casting with the proper quality of fit, changes in the liner are important. Wetting the liner increases the hygroscopic expansion of the mold and should be carefully controlled. An absorbent dry liner removes water from the investment and causes the mix to become thicker, which leads to increase in the total expansion.[11,12] To prevent expansion restriction, care must be taken not to squeeze the liner against the ring. Expansion can be increased if the mold is placed in a water bath. This is because of hygroscopic expansion (Fig. 22-7). The position of the pattern in the casting ring also affects expansion. For consistent results, a single crown should be centered in the ring, equidistant from its walls. When fixed prostheses are cast as one piece, accuracy is better if the pattern is placed near the center of a large or special oval ring, rather than if a portion of a multiunit wax pattern is only partially centered and partially near the edge of a smaller ring.[6]

Ringless Investment Technique

With the use of higher strength, phosphate-bonded investments, the ringless technique has become quite popular (Fig. 22-8).[13] This method entails the use of a paper or plastic casting ring and is designed to allow unrestricted expansion.[14] This can be useful with higher melting alloys that shrink more because of a longer cooling trajectory.

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FIGURE 22-8 ■ Crucible formers and cone-shaped plastic rings for a ringless investment technique in casting. The crucible former and plastic ring are removed before wax elimination, which leaves the invested wax pattern. The systems are designed to achieve expansion that is unrestricted by a metal ring. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

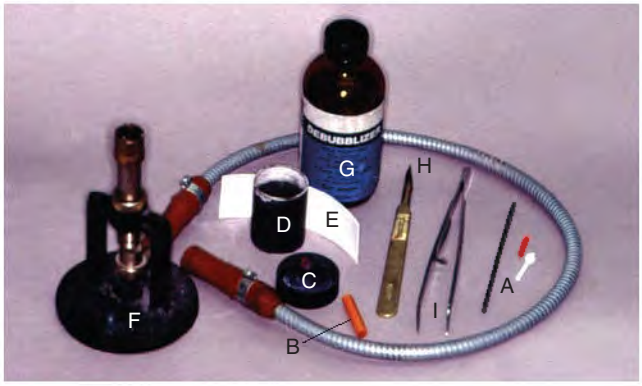

FIGURE 22-9 ■ Armamentarium for sprue technique with the wax pattern. *A,* Sprue; *B,* sticky wax; *C,* rubber crucible former; *D,* casting ring; *E,* ring liner; *F,* Bunsen burner; *G,* pattern cleaner; *H,* scalpel blade; *I,* forceps.

Sprue Technique

Armamentarium

The following equipment is needed (Fig. 22-9):

- Sprue
- Sticky wax
- Rubber crucible former
- Casting ring
- Ring liner
- Bunsen burner
- Pattern cleaner
- Scalpel blade
- Forceps

Step-by-Step Procedure for a Single Casting

A 2.5-mm (10-gauge) sprue form is recommended for molar crowns or metal-ceramic castings, and a 2-mm (12-gauge) sprue for premolar and partial-coverage restorations. The procedure is as follows:

1. Attach a 12-mm wax sprue to the bulkiest nonfunctional cusp of the wax pattern, and position it to form an obtuse angle with the adjacent axial walls and occlusal surface (Fig. 22-10, *A*). This angle is usually about 135 degrees to the axial walls, and it facilitates filling of the mold.
2. Add wax to the point of attachment and smooth it to prevent turbulence during casting.
3. Remove the pattern from the die, using extreme caution not to distort it (see Fig. 22-10, *B*).
4. Holding the sprue with forceps, insert it into the hole in the crucible former (see Fig. 22-10, *C*). It should now be luted into place with wax, and the junction between sprue and crucible should be smoothed. Use of a surfactant enhances wetting of the pattern during investing (see Fig. 22-10, *D*).
5. Line the casting ring, keeping it flush with the open end, and moisten the liner (see Fig. 22-10, *E* and *F*).
6. Place the ring over the pattern to ensure that it is long enough to cover the pattern with about 6 mm of investment (see Fig. 22-10, *G*). If necessary, the sprue may be shortened, or a longer ring may be chosen.

Procedure for Multiple Castings

When more than two units are being cast together, each is joined to a runner bar (Fig. 22-11). A single sprue is used to feed the runner bar. Two units may be cast with a runner bar, or each unit may be fed from a separate sprue.

MATERIALS SCIENCE

M.H. Reisbick

Several investment materials are available for fabricating a dental casting mold. These typically consist of a refractory material (usually silica) and a binder material, which provides strength. Additives are used by the manufacturer to improve handling characteristics.

When investments are classified by binder, three groups are recognized: gypsum-bonded, phosphate-bonded, and silica-bonded investments. Each has specific applications. The gypsum-bonded investments are used for castings made from American Dental Association (ADA) type II, type III, and type IV gold alloys. The phosphate-bonded materials are recommended for metal-ceramic frameworks. The silica-bonded investments are for high-melting base metal alloys used in casting partial removable dental prostheses. However, because of their limited application in fixed prosthodontics, silica-bonded investments are not included in the following discussion.

Gypsum-Bonded Investments

Gypsum is used as a binder, along with cristobalite or quartz as the refractory material, to form the mold. The cristobalite and quartz are responsible for the thermal expansion of the mold during wax elimination. Because gypsum is not chemically stable at temperatures exceeding 650°C (1202°F), these investments are typically

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FIGURE 22-10 ■ Sprue technique for a single casting. **A,** Attaching the sprue to the pattern. **B,** Removing the pattern from the die. **C,** Positioning the pattern on the crucible former. **D,** Application of surfactant. **E,** A ring liner increases the setting expansion. **F,** The ring liner has been stabilized with sticky wax. **G,** The pattern must be positioned a sufficient distance from the end of the ring.

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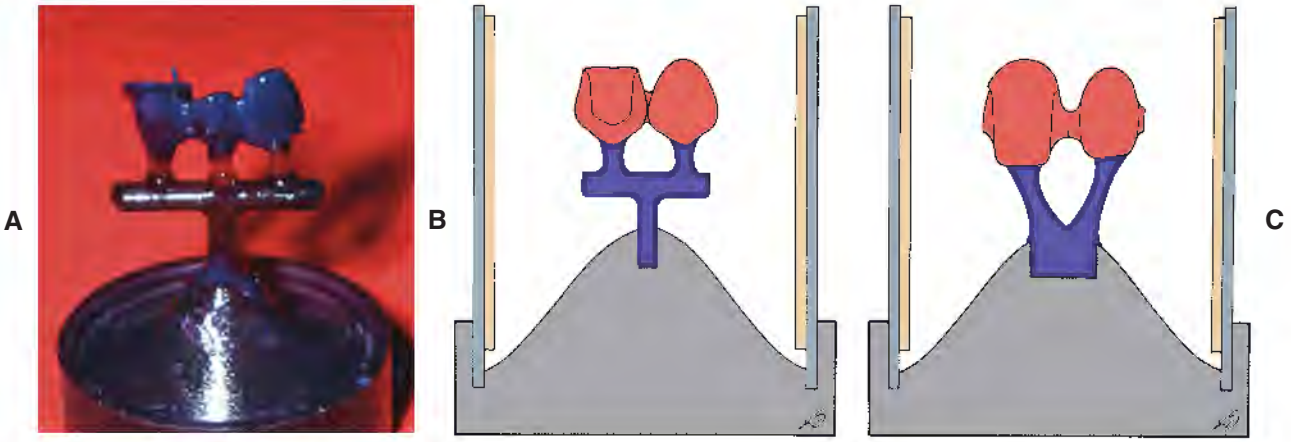

FIGURE 22-11 ■ Sprue technique with multiple units. For more than two castings, a runner bar is used **(A)**. For two castings, a runner bar may be used **(B)**, or each casting may be fed through separate sprues **(C)**.

restricted to castings of conventional types II, III, and IV gold alloys.

Expansion

Three types of expansion can be manipulated to obtain the desired size of casting: setting, hygroscopic, and thermal.

Setting Expansion. As the gypsum investment sets after mixing, it expands and slightly enlarges the mold. The pattern, metal casting ring, and compressibility of the ring liner all influence this expansion.

The water-to-powder ratio can be altered to reduce or increase the amount of setting expansion. The use of less water increases the setting expansion and results in a slightly larger casting. Use of an additional ring liner increases the setting expansion, as does a slight increase in mixing time. If a smaller casting is desired, more water can be used or the liner can be eliminated, both of which curtail the amount of expansion. In attempts to alter setting expansion, the changes should not deviate more than minimally from the manufacturer's recommendations, to ensure that there are no changes in the essential properties of the investment.

Hygroscopic Expansion. Hygroscopic expansion occurs when water is added to the setting gypsum investment immediately after the ring has been filled. To accomplish this, the ring is usually submerged in a water bath at 37°C (100°F) for up to 1 hour immediately after investment. A significant amount of additional setting expansion results, enabling the use of a slightly lower wax elimination temperature. A wet ring liner also contributes hygroscopic expansion to the portion of the mold with which it is in contact (see Fig. 22-7).

Thermal Expansion. As the mold is heated to eliminate the wax, thermal expansion occurs (Fig. 22-12). The silica refractory material is principally responsible for this because of solid-state phase transformations. Cristobalite changes from the α (low-temperature) to the β (high-temperature) form between 200°C (392°F) and 270°C

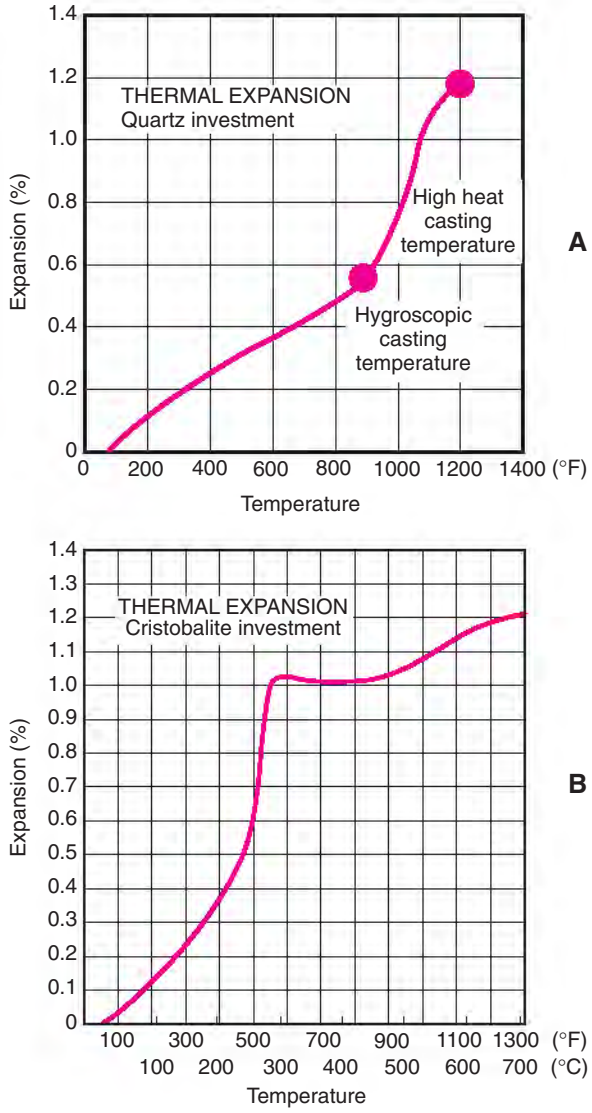

FIGURE 22-12 ■ Thermal expansions of quartz-based **(A)** and cristobalite-based **(B)** investments. (Courtesy Whip Mix Corporation, Louisville, Kentucky.)

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(518°F); quartz transforms at 575°C (1067°F). These transitions involve a change in crystal form, an accompanying change in bond angles and axis dimension, and a decrease in density, which produce a volume increase in the refractory components.

Phosphate-Bonded Investments

Because most metal-ceramic alloys fuse at approximately 1400°C (≈2550°F) (as opposed to conventional gold alloys at 925°C [≈1700°F]), additional shrinkage occurs when the casting cools to room temperature. To compensate for this, a larger mold is necessary. The added expansion can be obtained with phosphate-bonded investments.

The principal difference between gypsum-bonded and phosphate-bonded investments is the composition of the binder and the relatively high concentration of silica refractory material in the latter. The binder consists of magnesium oxide and an ammonium phosphate compound. In contrast to gypsum-bonded products, this material is stable at burnout temperatures above 650°C (1202°F) (Fig. 22-13), which allows for additional thermal expansion. Investment strength increases with increasing temperature (Fig. 22-13, *C*). Most phosphate-bonded investments are mixed with a specially prepared

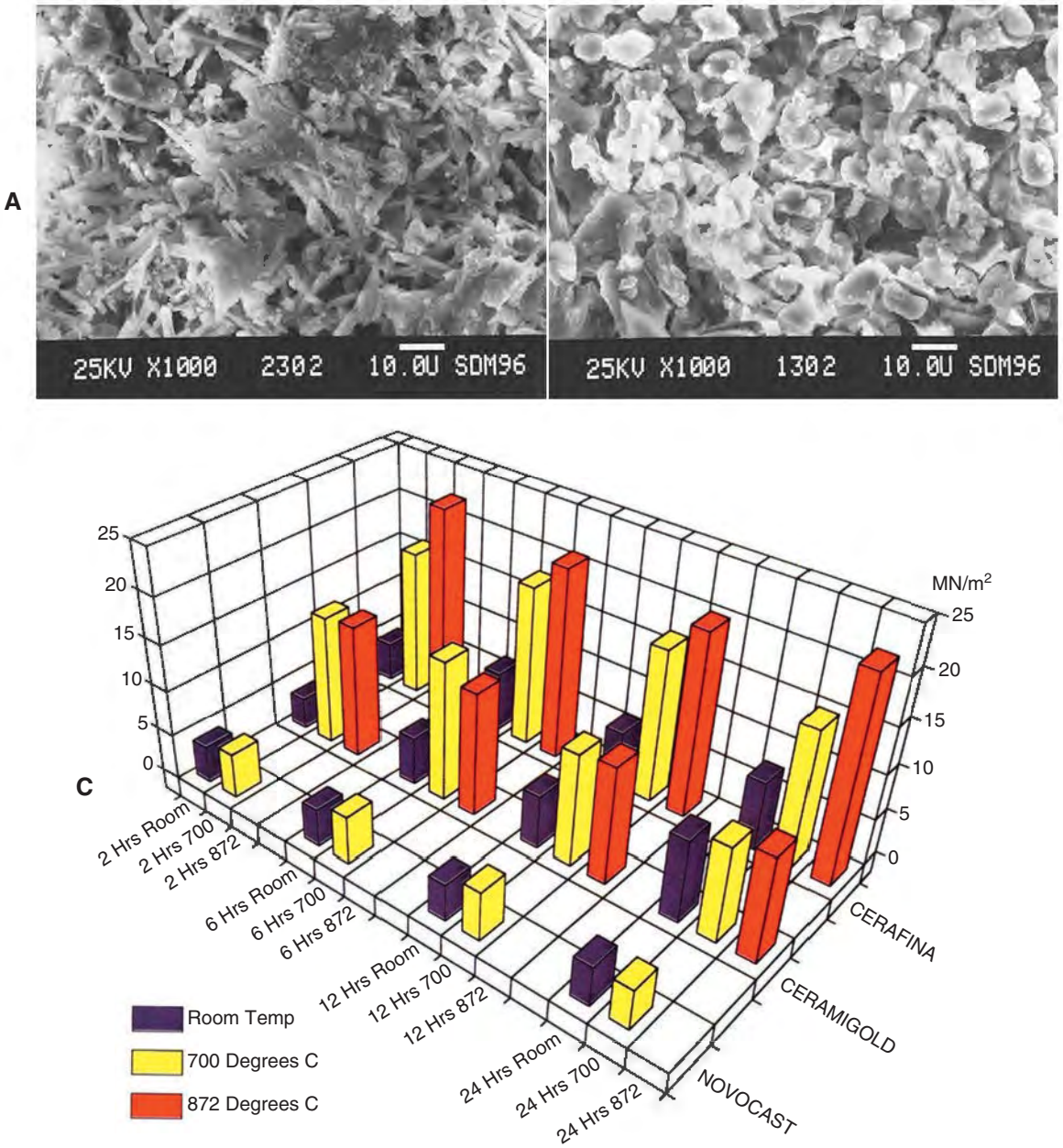

FIGURE 22-13 ■ Scanning electron micrographs of a gypsum-bonded investment **(A)** and a phosphate-bonded investment **(B),** each heated to 700°C (1292°F). **C,** Relationship between investment temperature and strength. (**C,** From Chew CL et al: Investment strength as a function of time and temperature. J Dent 27:297, 1999.)

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suspension of colloidal silica in water. (Some, however, can be mixed with water alone.)

Some phosphate-bonded investments contain carbon and therefore are gray in color. Carbon-containing materials should not be used for casting base metals because the carbon residue affects the final alloy composition. They may be used for casting alloys with high gold or palladium content.

Expansion

In comparison with gypsum-bonded investments, phosphate-bonded investments offer greater flexibility in controlling the amount of expansion. The liquid-to-powder ratio needs only slight modification to effect a significant change in setting expansion. Increasing the proportion of special liquid (colloidal silica) also increases expansion.

Working Time

Phosphate-bonded investments have a relatively short working time in comparison with gypsum materials. Their exothermic setting reaction accelerates as the temperature of the mix rises during manipulation. The filled ring feels warm to the touch even shortly after it has been filled. A longer mixing time significantly accelerates the setting reaction and temperature and thus reduces the working time even further. The addition of water to the colloidal silica suspension increases the working time, with some loss of setting expansion. Many technicians therefore vary the quantity of special liquid and water between batches and make trial mixes for each new shipment. This has been a reliable means of adjusting expansion.[15]

Gas is formed during the reaction and must be removed for a sufficiently long period to minimize nodules on the casting.[16] Maintaining a vacuum for about 60 seconds appears to be adequate.

• • •

SELECTION OF MATERIALS

Selecting a Casting Alloy

The choice of casting alloy largely determines the selection of investment and casting techniques and therefore is discussed first.

The number and variety of alloys suitable for casting have expanded dramatically, largely because of changes in the price of gold. Many alloys are available, especially for metal-ceramic restorations (see Chapter 19). The dentist must be able to make a rational choice on the basis of current information.

Factors to Be Considered

Intended Use. Alloys for casting were traditionally classified on the basis of their intended use, as follows:

- Type I: simple inlays
- Type II: complex inlays
- Type III: crowns and fixed dental prostheses
- Type IV: partial removable dental prostheses and pinledges
- Porcelain: metal-ceramic alloys

Physical Properties. In 1965, the ADA adopted the specifications of the Fédération Dentaire Internationale (FDI), which classified casting alloys according to their physical properties (specifically their hardness), as follows:

- Type I: soft
- Type II: medium
- Type III: hard
- Type IV: extra hard

Porcelain-type alloys with a high noble metal content were found to have hardness similar to that of type III alloys, and base metal alloys were found to be harder than type IV alloys (see Chapter 19).

Color. Manufacturers place considerable emphasis on the color of their alloys, and color preference is often for gold over silver. The patient's views on the subject should be sought if the metal will be visible in the mouth; otherwise, the color of the dental alloy is irrelevant.

Color is not a good guide to gold content: 9-carat jewelry alloy with only 37.5% gold looks considerably more yellow than does a metal-ceramic dental alloy with 85% gold but no copper.

Composition. For an alloy to be accepted by the ADA as suitable for dental restorations,[17] the manufacturer must list the percentage composition by weight of the three main ingredients and any noble metal percentage. The functional characteristics of corrosion resistance and tarnish resistance were traditionally predicted on the basis of gold content. In general, if at least half the atoms in the alloy are gold (which would be 75% by weight), good resistance to corrosion and tarnish can be predicted. Nevertheless, clinical evaluations have failed to show statistically significant differences in the tarnish resistance of high-gold (77%) and low-gold (59.5% to 27.6%) alloys.[18] However, a poorly formulated alloy, even of high gold content, can rapidly tarnish intraorally.

Cost. Treatment plans are often modified to suit the financial capabilities of the patient or a third party. Base metal alloys have found favor principally because of their low cost. Similarly, alloys containing approximately 50% gold have been found to offer some economic advantage (although the savings are not proportional to the reduced gold content of the alloy). Alloys containing primarily palladium and only a small percentage of gold are an alternative for use in the metal-ceramic technique, although soldering procedures may be less predictable.

When the intrinsic metal cost of a restoration is calculated, the volume of the casting, rather than its weight, should be determined. Dental casting alloys can vary considerably in density from below 8 g/mL to over 18 g/mL (see Table 19-2). An "average" restoration has a volume of 0.08 mL; an all-metal pontic may have a volume reaching 0.25 mL.[19] Therefore, it is conceivable

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that the cost of a large pontic cast in a low-density alloy would be equal to or less than the cost of a complete cast crown fabricated from a high-density alloy. When noble metal prices are high, more sophisticated techniques of scrap recovery are economically attractive. These can range from installing conventional metal catchers in all areas where castings are finished to equipping all workstations with filtered suction machines.

Clinical Performance. In most respects, clinical performance (biologic and mechanical) is more important than cost. Biologic properties that can be evaluated include gingival irritation, recurrent caries, plaque retention, and allergies. Mechanical properties include wear resistance and strength, marginal fit, ceramic bond failure, connector failure, and resistance to tarnish and corrosion.

A risk in choosing a new alloy is that defective clinical performance may fail to be evident in laboratory testing or in short-term animal and clinical trials. For example, manufacturers introduced copper-based casting alloys with very poor corrosion resistance[20] when the price of gold was rapidly rising (these formulations were very similar to those for aluminum-bronze alloys sold as dental gold in the 1920s). Although the clinically established alloys all have disadvantages, their performance is likely to have been well documented, and the quality of restorative treatment can be more accurately predicted.

Laboratory Performance. Sound laboratory data are essential in the selection of a casting alloy. Important areas of consideration are casting accuracy, surface roughness, strength, sag resistance, and metal-ceramic bond strength. Currently available data suggest that nickel-chromium alloys have lower casting accuracy[21] and greater surface roughness[22] than do gold alloys (Fig. 22-14) but higher strength and sag resistance because of their higher melting ranges.[23]

Handling Properties. The ease with which an alloy can be manipulated may influence its selection. An alloy that produces satisfactory clinical results, but only under extremely critical conditions or with expensive equipment, may be rejected in favor of one that produces acceptable results with less critical manipulation.

The ability to burnish an alloy to reduce marginal gap width and thus reduce the exposed thickness of the luting agent is important,[24] although the areas where marginal adaptation is clinically most important (interproximally and subgingivally) are usually not very accessible for such manipulation.

Biocompatibility. All materials for intraoral use should be biocompatible. In addition, it should be possible to handle them safely in the office or laboratory. Many hazardous materials—such as mercury, chloroform, silver cyanide, and hydrofluoric acid—are commonly used in dentistry. Consequently, restrictions have been imposed on their shipping and use. For instance, asbestos is no longer used in casting ring liners and uranium salts in dental porcelain. There is also concern[25] for the possible health hazards (see Chapter 19) associated with alloys containing nickel and beryllium. Although no definite conclusions can be drawn, appropriate safety precautions are advisable when these alloys are being ground. Filtered suction units and appropriate barriers (masks) should be used. The ADA[26] requires nickel-containing alloys to carry a precautionary label stating that their use should be avoided in patients with a known nickel allergy (Fig. 22-15).

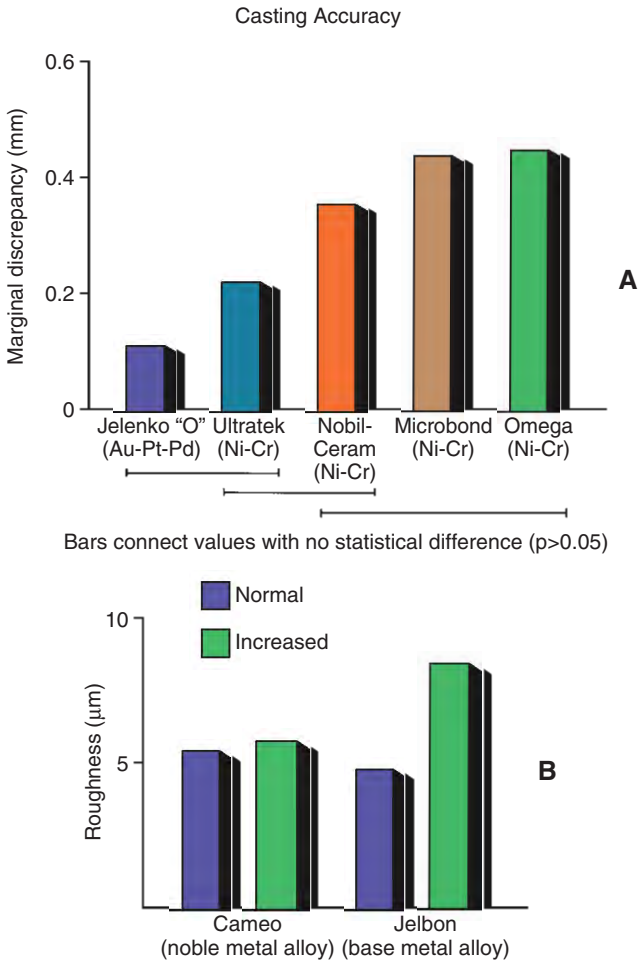

FIGURE 22-14 ■ **A,** Comparison of casting accuracies with different alloys. Au-Pt-Pd, gold-platinum-palladium; Ni-Cr, nickel-chromium. **B,** Influence of metal casting temperature and alloy selection on casting roughness. (**A,** From Duncan JD: The casting accuracy of nickel-chromium alloys for fixed prostheses. J Prosthet Dent 47:63, 1982. **B,** From Ogura H, et al: Inner surface roughness of complete cast crowns made by centrifugal casting machines. J Prosthet Dent 45:529, 1981.)

Selecting an Investment Material

After the choice of casting alloy has been made, the investment material can be selected.

Ideal Properties

An ideal investment should incorporate the following features:

- Controllable expansion to compensate precisely for shrinkage of the cast alloy during cooling

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FIGURE 22-15 ■ **A** and **B,** Dramatic gingival reactions to nickel-containing metal-ceramic restorations. (Courtesy Dr. W.V. Campagni.)

- The ability to produce smooth castings with accurate surface reproduction and without nodules
- Chemical stability at high casting temperatures
- Adequate strength to resist casting forces
- Sufficient porosity to allow for gas escape
- Easy recovery of the casting

Gypsum-bonded Investments. Gypsum-bonded investments satisfy most of the requirements for an ideal material, although they are not suitable for casting metal-ceramic alloys because the gypsum is unstable at the high temperatures required and sulfide contamination of the alloy can occur. In addition, with some materials, obtaining adequate expansion may be difficult. This is critical in casting complete crowns. A casting that is slightly oversized (in a controlled manner) is advantageous for accurate seating (see Chapters 7 and 28). Factors that increase expansion[27] of gypsum-bonded investments include the following:

- Use of a full-width ring liner
- Prolonged spatulation
- Storage at 100% humidity
- Lower water-to-powder ratio
- Use of a dry liner
- Use of two ring liners
- Hygroscopic technique with the pattern in the upper part of the ring[28]

Phosphate-bonded Investments. Phosphate-bonded investment materials offer certain advantages over gypsum-bonded investments. They are more stable at high temperatures and thus are the material of choice for casting metal-ceramic alloys. They expand rapidly at the temperatures used for casting alloys, and their expansion can be conveniently and precisely controlled. The expansion is increased as a result of a combination of the following factors:

- Heat from the setting reaction softens the wax and allows freer setting expansion.
- The increased strength of the material at high temperatures restricts shrinkage of the alloy as it cools.
- The powder mixed with colloidal silica reduces the surface roughness of the castings and also increases expansion. Thus, expansion can be conveniently controlled by slightly diluting the colloidal silica with distilled water.

However, castings made with phosphate-bonded investments are rougher than those made with gypsum-bonded investments[29] and are more difficult to remove from the investment.[30] Because phosphate-bonded investments have lower porosity,[31] complete mold filling is more difficult. Castings also are more likely to have surface nodules, which must be removed. (Vacuum mixing and a careful investing technique help reduce but do not eliminate the occurrence of nodules.)

INVESTING

Vacuum mixing of investment materials (Fig. 22-16) is highly recommended for consistent results in casting with minimal surface defects, especially when phosphate-bonded investments are used. Good results are possible with brush application of vacuum-mixed investment or when the investment is poured into the ring under vacuum pressure. Vacuum mixing with brush application of the investment is the suggested mode. To expedite the procedure and minimize distortion, all necessary items and materials should be prepared before the wax pattern is reflowed and removed from the die.

Armamentarium

The following equipment is needed (Fig. 22-17):

- Vacuum mixer and bowl
- Vibrator
- Investment powder (gypsum or phosphate bonded)
- Water or colloidal silica
- Spatula
- Brush
- Surfactant graduated cylinder
- Crucible former
- Casting ring and liner

Step-by-Step Procedure

Brush Technique

In this technique, the pattern is first painted with surface tension reducer; the surface must be wet completely. The procedure is as follows:

1. Select the correct program on the mixing unit in accordance with the manufacturer's instructions (Fig. 22-18, *A*). The mixing bowl can be either wiped completely dry or shaken dry. If it is shaken dry, remember that the residual water adds about

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FIGURE 22-16 ■ Vacuum investing machines. **A,** The Whip Mix combination unit. **B,** The Multivac Compact. (**A,** Courtesy Whip Mix Corporation, Louisville, Kentucky, **B,** Courtesy Dentsply Ceramco, York, Pennsylvania.)

FIGURE 22-17 ■ Investing armamentarium. *A,* Vacuum mixer and bowl; *B,* vibrator; *C,* investment powder (gypsum or phosphate bonded); *D,* water; *E,* colloidal silica; *F,* spatula; *G,* brush; *H,* surfactant graduated cylinder; *I,* crucible former; *J,* casting ring; *K,* ring liner.

1 mL to the mix. Add investment powder to the liquid in the mixing bowl (see Fig. 22-18, *B*).

2. Attach the bowl to the mixer, and mechanically spatulate (see Fig. 22-18, *C* and *D*).
3. Coat the entire pattern with investment, pushing the material ahead of the brush from a single point (see Fig. 22-18, *E*). Gently vibrate throughout the application of investment, being especially careful to coat the internal surface and the margin of the pattern (see Fig. 22-18, *F*). A finger positioned under the crucible former on the table of the vibrator minimizes the risk of excessive vibration and possible breaking of the pattern from the sprue. After the pattern has been completely coated, attach the ring and immediately fill by causing the remaining investment to vibrate out of the bowl.
4. Place the lined casting ring over the pattern (see Fig. 22-18, *G*) and, with the aid of vibration, pour the investment down the side of the ring (see Fig. 22-18, *H*). Fill the ring slowly, starting from the bottom and moving up (see Fig. 22-18, *I*).
5. When the investment reaches the level of the pattern, tilt the ring several times to cover and uncover the pattern, thereby minimizing the possible entrapment of air. Investing must be performed quickly within the working time of the investment. If the investment begins to set too soon, rinse it off quickly with cold water. The wax pattern can then be replaced on the die, and material can reflow into its margins again.
6. After the ring is filled to the rim, allow the investment to set.
7. If the hygroscopic technique is used, place the ring in a 37°C (100°F) water bath for 1 hour.

Wax Elimination

Wax elimination, or wax burnout, consists of heating the investment in a thermostatically controlled furnace (Fig. 22-19) until all traces of the wax are vaporized. The temperature reached by the investment determines its thermal expansion.

All water in the investment must be driven off during wax elimination. The temperature to which the ring is heated during wax elimination must be sufficiently high. It should be maintained long enough ("heat soak") to minimize a sudden drop in temperature upon removal from the furnace. Such a drop may result in an incomplete casting because of excessively rapid solidification of the alloy as it enters the mold. Once the investment is heated during the wax-elimination procedure, heating must be continued, and casting must be completed. Cooling and reheating of the investment can cause casting inaccuracy because the refractory mold and binder do not revert to their original forms (hysteresis). Inadequate expansion and cracking of the investment are typical results.

Step-by-Step Procedure

1. Allow the investment to set for the recommended time (usually 1 hour), and then remove the rubber crucible former (Fig. 22-20). If a metal sprue is

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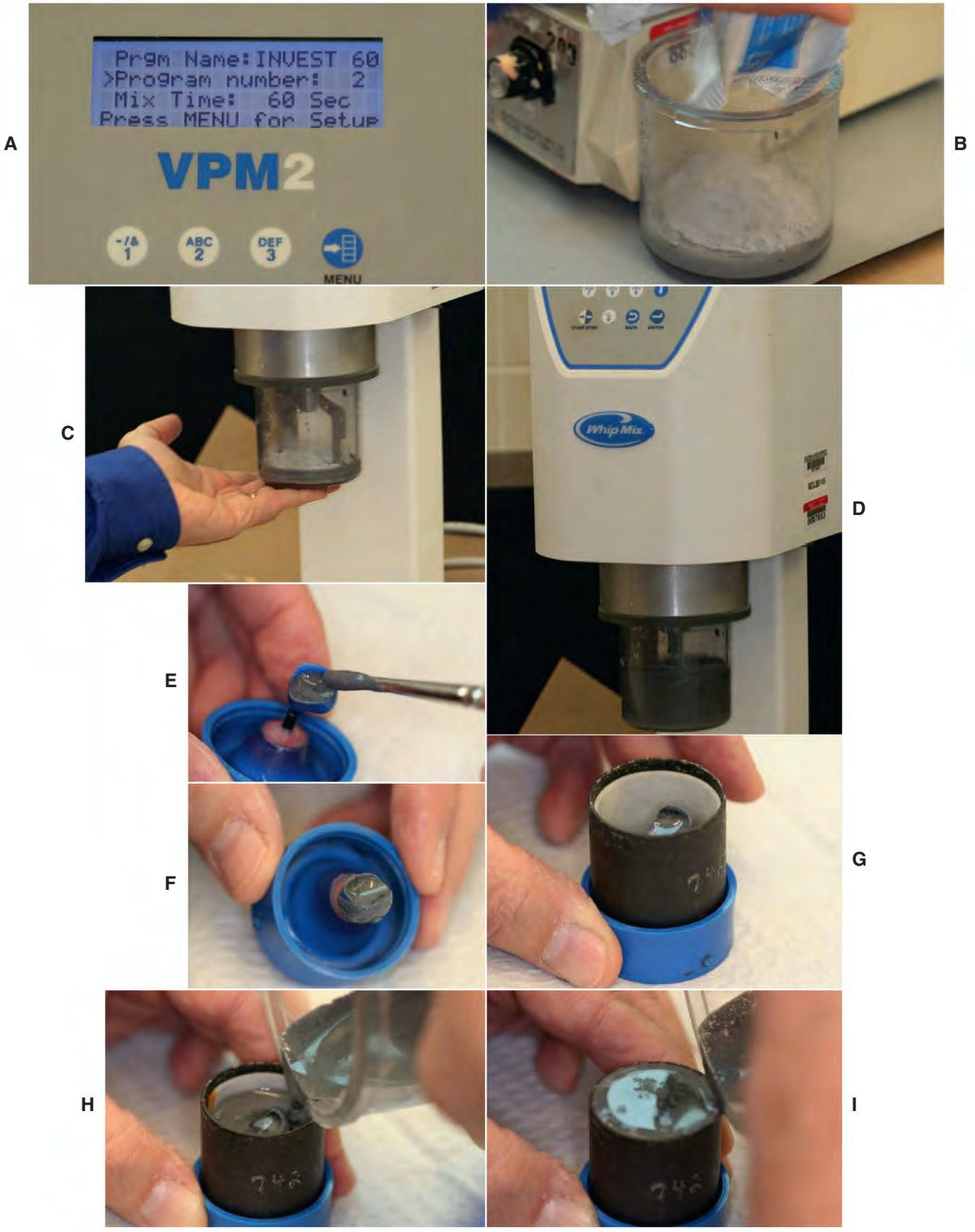

FIGURE 22-18 ■ Investing procedure: brush technique. **A,** The correct program on the mixing unit is selected. **B,** Investment is added to precisely measured-out liquid. **C,** The chuck of the mixing bowl is inserted into the slot of the vacuum mixer. **D,** The bowl is stabilized by the vacuum created between its lid and the base of the unit as mixing progresses. **E,** A No. 6 or No. 8 brush is used to coat the pattern. **F,** The pattern is completely coated, and the casting ring can now be attached. **G,** Casting ring with liner affixed to the crucible former. **H,** The bowl is vibrated, and the ring is filled. When the investment reaches the level of the wax pattern, the ring must be tilted to reduce the risk of trapping air inside the pattern. **I,** The ring is completely filled.

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FIGURE 22-19 ■ Burnout ovens are available with manual, semiautomatic, or fully programmable controls. **A,** FIRELITE. **B,** Ney Vulcan. (**A,** Courtesy Whip Mix Corporation, Louisville, Kentucky. **B,** Courtesy Dentsply Ceramco, York, Pennsylvania.)

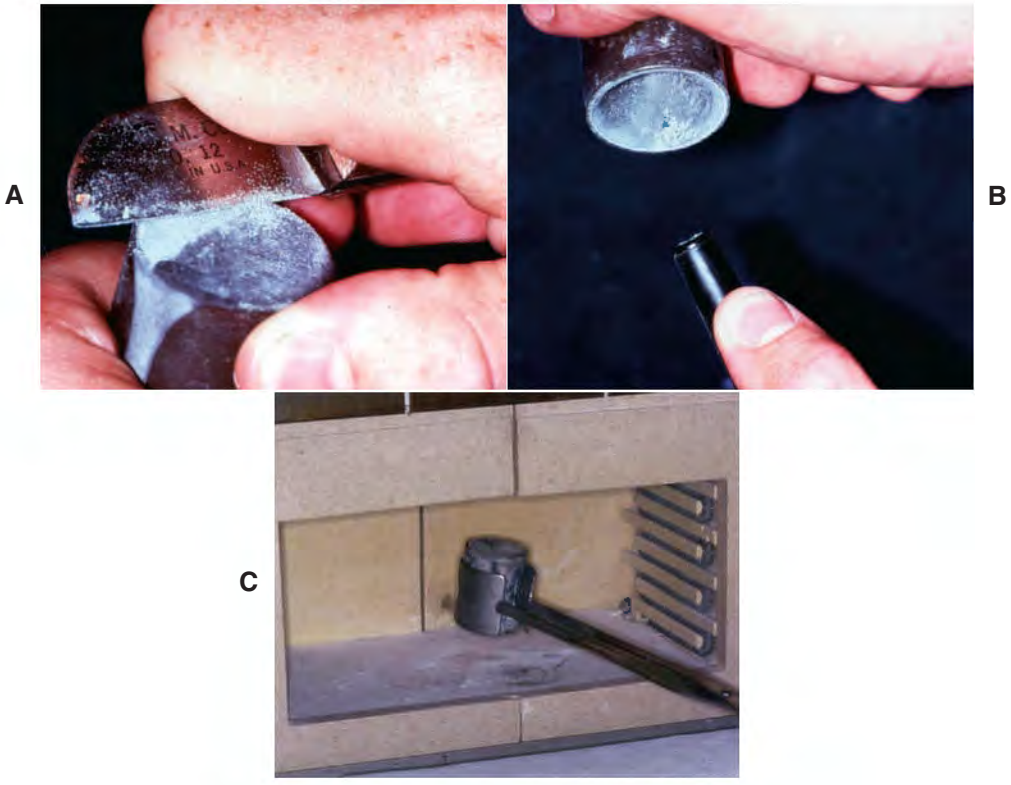

FIGURE 22-20 ■ **A,** When the investment has set, the "skin" at the top of the ring is trimmed off. **B,** The rubber crucible former is removed, and any loose particles of investment are blown off. **C,** The ring is then placed in the furnace for the recommended burnout schedule.

used, remove it as well. The ring should be placed in a humidor if stored overnight. The smooth "skin" that forms on the ring with phosphate-bonded investments should be removed with a plaster knife, and any loose particles of investment should be blown off with compressed air.

2. Reexamine the ring for any residual particles, and then place it with the sprue facing down in the furnace on a ribbed tray. The tray allows the molten wax to flow out freely.
3. Heat the furnace to 200°C (392°F), and hold this temperature for 30 minutes. Most of the wax is by then eliminated.
4. Increase the heat to the final burnout temperature (generally 650°C [1202°F] or 480°C [896°F] if a hygroscopic technique is used; follow the manufacturer's instructions), and hold that temperature for 45 minutes. Because the heating rate affects expansion,[32] it also should be standardized as part of the investing and casting protocol in order to routinely

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obtain accurately fitting castings. The mold is now ready for casting, although a large casting ring requires increased heating time. If preferred, two burnout furnaces can be set at 200°C and 650°C or 480°C, or a programmable two-stage furnace can serve equally well. However, the investment should not be overheated or kept at the chosen temperature too long. Gypsum-bonded investments are not stable above 650°C. Also, some carbon in carbon-containing investments burns off, which causes increased surface roughness of the casting.[22]

When the casting ring is transferred to the casting machine, a quick visual check of the sprue in shaded light is helpful to see whether it is properly heated. It should be a cherry-red color.

ACCELERATED CASTING METHOD

Conventional casting techniques require considerable time, typically 1 hour for bench set (generally judged as the time taken for the investment to reach its maximum exothermic setting reaction temperature) for the investment and 1 to 2 hours for the wax elimination. An accelerated casting procedure that reduces this time to 30 to 40 minutes has been proposed.[33-36] Initially suggested as a way to make cast post and core restorations in a one-visit procedure (also for castings made for dental licensure examinations), the procedure has been found to produce castings with accuracy and surface roughness similar to those produced by traditional methods.[37,38] The technique entails the use of a phosphate-bonded investment in which approximately 15 minutes is needed for bench set and 15 minutes for wax elimination by placement of the ring in a furnace preheated to 815°C (1500°F).

CASTING

Casting Machines

A casting machine (Fig. 22-21) requires a heat source, to melt the alloy, and a casting force. For a complete casting, the casting force must be high enough to overcome the high surface tension of the molten alloy,[39] as well as the resistance of the gas within the mold.

The heat source can be either the reducing flame of a torch or electricity. Conventional alloys can be melted with a gas-air torch (Fig. 22-22, *A* and *B*), but for the metal-ceramic alloys in a higher melting range, a gas-oxygen torch (see Fig. 22-22, *C*) is needed. For base metal alloys, a multiorifice gas-oxygen torch (see Fig. 22-22, *D*) or an oxyacetylene torch is needed. Electric heating can occur by convection from a heating muffle or by generation of an induction current in the alloy (Fig. 22-23). Advocates of the latter[40] maintain that heating can be more evenly controlled, which prevents undesirable changes in alloy composition caused by volatilization of the elements with lower melting points. In general, the electric machines are expensive and more appropriate for larger dental laboratories, whereas a torch may be the equipment of choice for smaller laboratories and dental offices. The combination of alloy and casting technique influences the marginal fit of the restorations.[41,42]

In present-day casting machines, either air pressure or centrifugal force is still used to fill the mold; both were first proposed in the early days of lost-wax castings.[2,43] Some machines evacuate the mold before it is filled with metal, and vacuum has been shown to improve mold filling,[44] although it is not clear whether the difference is clinically significant.[45]

Casting Technique

The ring is not removed from the burnout furnace until the alloy has been melted and is ready to cast.

Cleaning a previously cast alloy is necessary to remove investment debris and oxides before its reuse. Noble metal alloys can be melted on a charcoal block with a gas-air torch, which provides a reducing atmosphere. Remaining impurities are removed through pickling and ultrasonic or steam cleaning. Alloys from different manufacturers should not be mixed, even if they are similar. According to one report, recasting nickel-containing alloys with 65% surplus metal addition significantly increased the cytotoxic activity.[46]

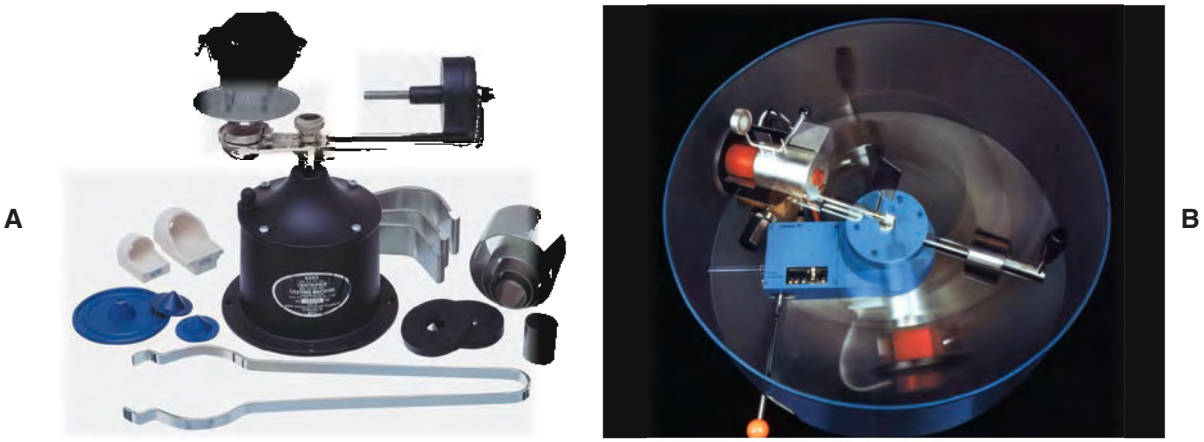

FIGURE 22-21 ■ Casting machines. **A,** Kerr Broken-Arm. **B,** Degussa Model TS-1. (**A,** Courtesy Kerr Corporation, Orange, California. **B,** Courtesy Dentsply Ceramco, York, Pennsylvania.)

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FIGURE 22-22 ■ **A,** Gas-air casting torch. **B,** Gas-air tip. **C,** Gas-oxygen casting torch. **D,** Multiorifice tip.

Similarly, a dedicated crucible should be used for each alloy. Overheated or otherwise abused alloys, as well as grindings and old restorations, should be returned to the manufacturer as scrap materials, rather than being reused.

Armamentarium

The following equipment is needed (Fig. 22-24):

- Broken-arm (Kerr) centrifugal casting machine
- Crucible
- Blowtorch
- Protective colored goggles
- Tongs
- Casting alloy
- Flux

Procedure

The casting machine is given three clockwise turns (four if metal-ceramic alloys are used) and locked in position with the pin. The cradle and counterbalance weights are checked for the appropriate size of the casting ring. A crucible for the alloy being cast is placed in the machine. The torch (gas-air for regular alloys, gas-oxygen for metal-ceramic) is lit and adjusted. For metal-ceramic alloys, the clinician should wear a pair of colored goggles to protect the eyes and also to enable direct viewing of the melt.

The crucible is preheated (Fig. 22-25, *A*), particularly over the trajectory that will be in contact with the alloy, and the alloy is added. Preheating avoids excessive slag formation during casting. Also, when metal-ceramic alloys are cast, a crucible that is too cool can "freeze" the alloy, which results in an incomplete casting. The mass of the alloy must be sufficient to sustain adequate casting pressure. With a high-density noble metal alloy, 6 g (4 dwt*) is typically adequate for premolar and anterior castings, 9 g (6 dwt) is adequate for molar castings, and 12 g (8 dwt) is adequate for pontics.

The alloy is heated in the reducing part of the flame until it is ready to cast. A little flux can be added to conventional gold alloys (not to metal-ceramic alloys). Gold alloys ball up and have a mirror-like shiny surface that appears to be spinning. Nickel-chromium and cobalt alloys are ready to cast when the sharp edges of the ingot round over. The mold is placed in the cradle of the casting machine (see Fig. 22-25, *B*) and kept on the alloy with the reducing flame until the crucible is moved into position (see Fig. 22-25, *C* to *G*). The casting machine arm is then released to make the casting (see Fig. 22-25, *H*). The machine is allowed to spin until it has slowed enough that it can be stopped by hand, and the ring is removed with casting tongs.

Recovery of the Casting. After the red glow has disappeared from the button, the casting ring is plunged under running cold water into a large rubber mixing bowl (Fig. 22-26).

Gypsum-bonded investments disintegrate quickly, and residue is eliminated easily with a toothbrush. Final traces can be removed ultrasonically. Oxides are removed by pickling in 50% hydrochloric acid (or, preferably, a nonfuming substitute; Fig. 22-27). Phosphate-bonded investments do not disintegrate equally well, and some must be removed forcibly from the casting ring. They can be

*Pennyweight (*d* is an abbreviation for *denarius*, a Roman silver coin).

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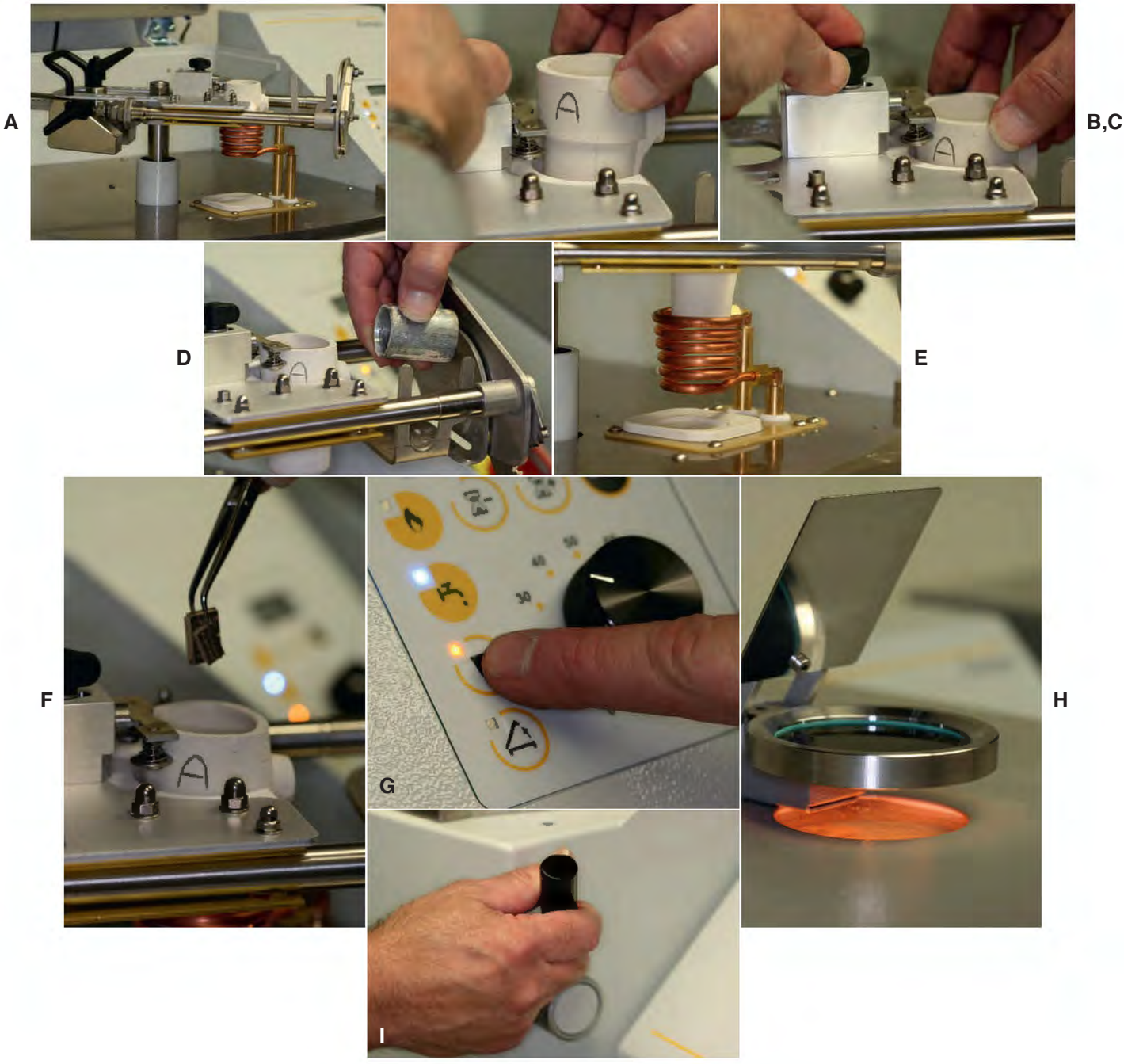

FIGURE 22-23 ■ Induction casting. **A,** The motorized casting machine consists of a quartz crucible that is surrounded by a water-cooled copper induction coil that serves as the heat source. The counterweight (on left) can be adjusted as a function of the size of the casting ring. The quartz crucible is inserted **(B)** and secured **(C). D,** An unused casting ring is used to verify alignment of the cradle (and the ring) with the crucible opening through which the gold alloy will enter the investment mold. **E,** The induction coil is raised until it surrounds the crucible. **F,** The alloy is inserted in the crucible. Depending on alloy type, a carbon insert may be placed inside the quartz crucible. **G,** The necessary current intensity for the alloy is set. **H,** Visual confirmation of the melt being ready for casting is possible through the closed lid of the casting machine. A dark filter offers eye protection. **I,** The operator initiates the casting procedure by throwing the lever on the side of the unit. Casting pressure is sustained by the electric motor in the base of the unit and switches off automatically after 30 seconds, at which time the lid is unlatched automatically.

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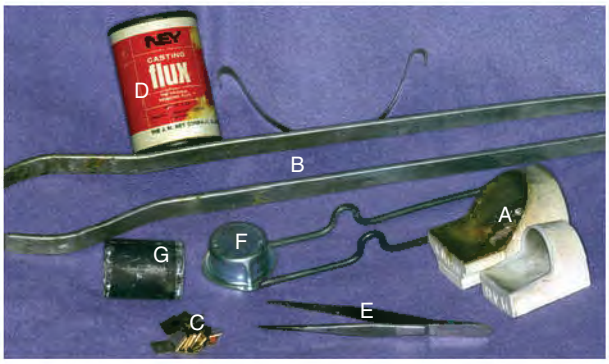

FIGURE 22-24 ■ Casting armamentarium. *A,* Crucibles; *B,* tongs; *C,* casting alloy; *D,* flux; *E,* tweezers; *F,* lighter; *G,* casting ring.

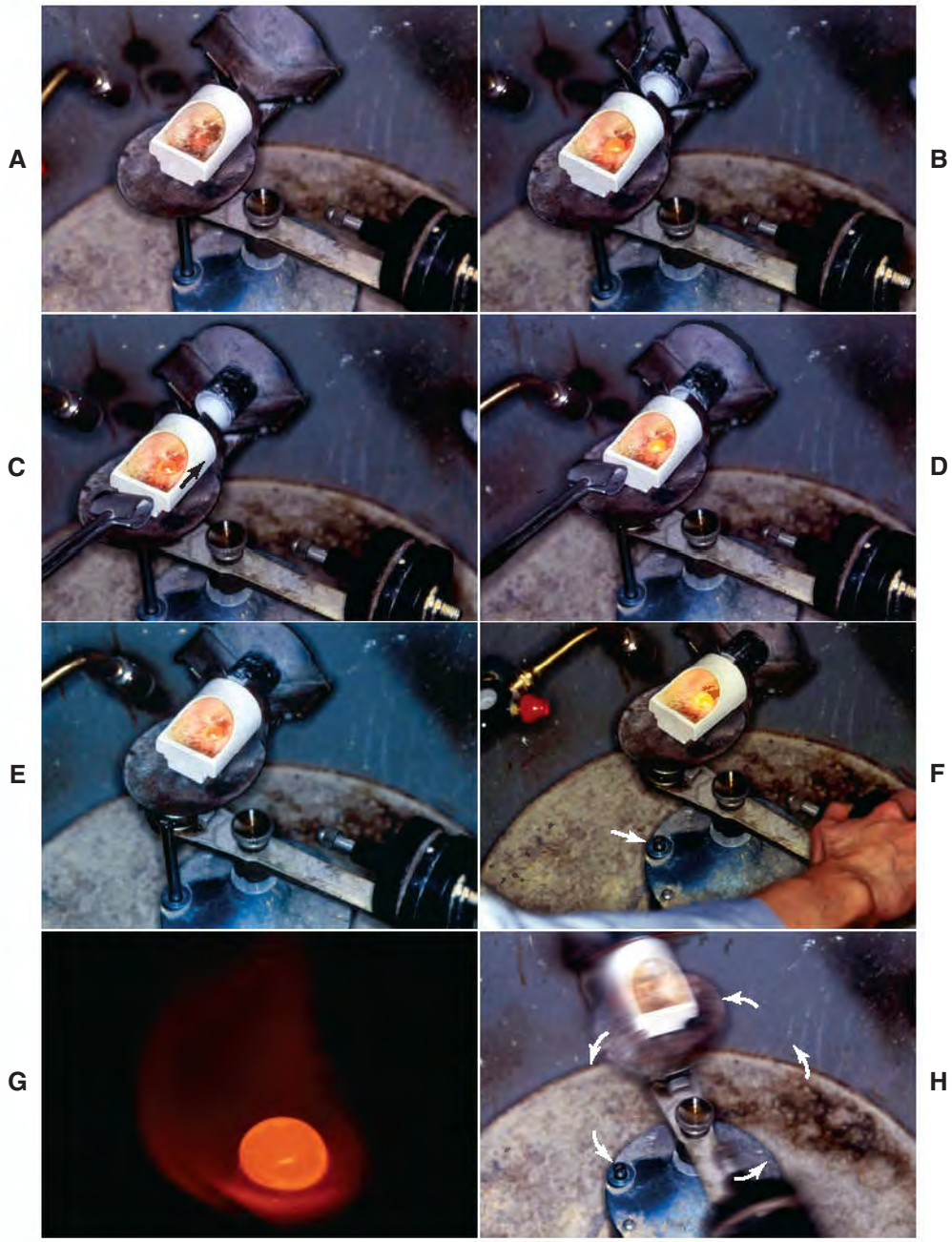

FIGURE 22-25 ■ Casting technique. **A,** The crucible is preheated. **B,** The alloy is melted. When the alloy is molten, the casting ring is removed from the furnace and placed in the cradle. **C,** Tongs are used to slide the crucible platform into contact with the casting ring *(arrow).* **D,** The orifice of the crucible aligns with the sprue. **E,** Heating continues for a few seconds so that the melting is complete and casting can proceed. **F,** The casting arm is pulled forward until the pin drops *(arrow).* **G,** The melted alloy, seconds before casting. **H,** Centrifugal force carries the melted alloy into the mold cavity (*arrows* show the direction of spin).

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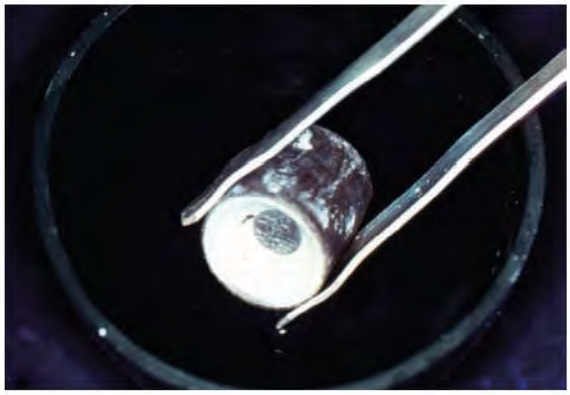

FIGURE 22-26 ■ The ring is quenched in cold water in a plaster bowl. Gypsum-bonded investments readily disintegrate; phosphate-bonded investments are much stronger and need to be devested carefully.

FIGURE 22-27 ■ Nonfuming pickling acid can be used in conjunction with this covered pickling unit.

FIGURE 22-28 ■ Recovery of a casting from phosphate-bonded investment. **A,** Trimming is done from the button end of the ring. **B,** Investment is being pushed out of the casting ring. **C,** The mold is broken open. **D,** Investment is removed from the casting. Care must be taken to avoid damaging the margin.

handled as soon as they have been sufficiently cooled under running water.

A knife is used to trim the investment at the button end of the ring (Fig. 22-28, *A*). The other end is not trimmed because of the risk of damaging the margin. When the ring liner is exposed, the investment can be pushed out of the ring (see Fig. 22-28, *B*). It is then broken apart under running water (because it is still hot; see Fig. 22-28, *C*). The remaining investment is carefully removed with a small blunt instrument (see Fig. 22-28, *D*), and any traces are dissolved in hydrofluoric acid or a less caustic substitute. Care must be taken to prevent scratching of the internal surface of the casting or damage to the margins.

Evaluation. The casting is never fitted on the die until the inner surface has been carefully evaluated under magnification; even tiny imperfections can cause damage to the stone die. A die may be rendered useless in a matter of seconds if a casting is fitted prematurely.

Defects in the Casting. Investing and casting require meticulous attention to detail in order to obtain a successful, properly fitting casting. Table 22-1 summarizes

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TABLE 22-1 **Common Causes of Casting Failure**

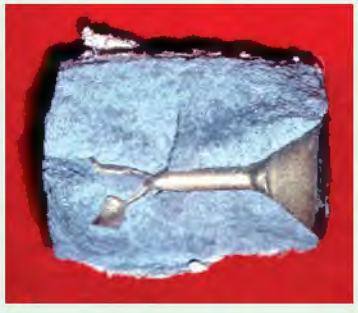
Problem	Possible Causes	Appearance
Rough casting	Excess surfactant Improper water-to-powder ratio Excessive burnout temperature	
Large nodule	Air trapped during investing procedure	
Multiple nodules	Inadequate vacuum during investing Improper brush technique Lack of surfactant	
Nodules on occlusal surface	Excessive vibration	
Fins	Increased water-to-powder ratio Pattern too near edge of investment Premature heating (mold still wet) Too-rapid heating Dropped mold	
Incomplete casting	Wax pattern too thin Cool mold or melted alloy Inadequate metal	

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TABLE 22-1 **Common Causes of Casting Failure—cont'd**

Problem	Possible Causes	Appearance
Incomplete casting with shiny, rounded defect	Incomplete wax elimination	
Solidification shrinkage ("suck-back") porosity	Improper pattern position Narrow, long sprue	
Inclusion porosity	Particle of investment dislodged during casting	
Marginal discrepancy	Wax pattern distortion Uneven expansion	
Inadequate or excessive expansion	Improper water-to-powder ratio Improper mixing time Improper burnout temperature	

and provides examples of the more common causes of various problems.

Roughness. The surface of a casting should be smooth, although finishing and polishing are still required (see Chapter 28). Lines or grooves in the casting are usually present but overlooked in the wax pattern. They may necessitate a remake, particularly if they were positioned near the margin or on the fitting surface. Generalized casting roughness may indicate a breakdown of the investment from excessive burnout temperature.

Nodules. Bubbles of gas trapped between the wax pattern and the investment produce nodules on the casting surface. Even minute nodules can limit the seating of the casting to a considerable degree. When they are large or situated on a margin, they usually necessitate remaking of the restoration. When small, they can often be removed with a No. ¼ or No. ½ round bur (Fig. 22-29). A binocular microscope is extremely helpful for detecting and removing nodules. A slight excess of metal should be removed to ensure that the nodule does not interfere with complete seating.

Keys to avoiding nodules include a careful investing technique, use of a surfactant, vacuum spatulation, and careful coating of the wax pattern with investment. Castings made with phosphate-bonded investment are especially prone to imperfections, and experience and care are necessary to routinely produce castings that are free of nodules.

Fins. Fins are caused by cracks in the investment that have been filled with molten metal. These cracks can result from a weak mix of investment (high ratio of water to powder), excessive casting force, steam generated from too-rapid heating, reheating an invested pattern, an

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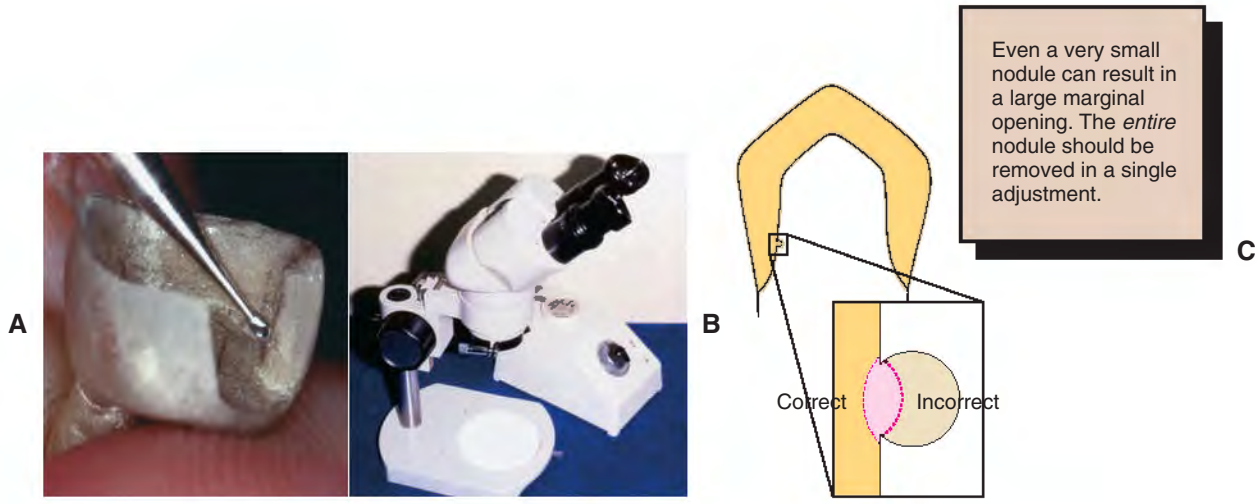

FIGURE 22-29 ■ Removing casting nodules. Small nodules are frequently present, particularly with phosphate-bonded investments. They interfere with seating and must be identified before the casting is placed on the die. **A,** Once they are identified, a small round bur can be used to remove them. **B,** Magnification is helpful for this. **C,** Slightly more, rather than less, metal than the size of the nodule should be removed to ensure that the casting does not bind during seating.

improperly situated pattern (too close to the periphery of the casting ring), or even premature or rough handling of the ring after investing.

Incompleteness. If an area of wax is too thin (less than 0.3 mm), which occurs occasionally on the veneering surface of a metal-ceramic restoration, an incomplete casting may result. Thickening of the wax in these areas is recommended. Incomplete casting of normal-thickness wax patterns may result from inadequate heating of the metal, incomplete wax elimination, excessive cooling ("freezing") of the mold, insufficient casting force, not enough metal, or metal spillage.

Voids or Porosity. Voids in the casting (in particular in the margin area) may be caused by debris trapped in the mold (usually a particle of the investment undetected before wax elimination). A well-waxed smooth sprue helps prevent this. Porosity resulting from solidification shrinkage ("suck-back") occurs if the metal in the sprue solidifies before the metal in the mold, as may happen when a sprue is too narrow, too long, or incorrectly located or when a large casting is made in the absence of a chill vent. Gases may dissolve in the molten alloy during melting and leave porosity.

Back-pressure porosity[47] may be caused by air pressure in the mold as the molten metal enters. Its occurrence is reduced through the use of a more porous investment, location of the pattern near the end of the ring (6 to 8 mm), and casting with a vacuum technique.

Marginal Discrepancies. Inaccuracies of fit at the margin can be caused by distortion during removal of the wax pattern from the die. They may also result from increased setting expansion (hygroscopic technique) after uneven expansion of the mold.

Dimensional Inaccuracies. The casting can be either too small or too large. Attention to detail is essential for an accurately expanded mold. A standardized procedure is needed in regard to liquid-to-powder ratio, spatulation, the ring liner, the amount of liquid added, and mold heating.

REVIEW OF TECHNIQUE

The following list summarizes the steps involved in investing and casting (Fig. 22-30) and should prove helpful in reviewing the material covered in this chapter:

1. A sprue 2 or 2.5 mm in diameter (10- or 12-gauge) is attached to the bulkiest nonfunctional cusp (the larger size for molar and metal-ceramic patterns, the smaller size for premolar and partial coverage). Sprues can be attached to multiple units with a runner bar (see Fig. 22-30, *A*).
2. The pattern is carefully removed from the die and attached to a crucible former (sprue length should be 6 mm or less; see Fig. 22-30, *B*).
3. The pattern is painted with surface tension reducer (see Fig. 22-30, *C*) and then carefully coated with vacuum-mixed investment (see Fig. 22-30, *D*).
4. The ring is filled, and the investment is allowed to bench set for a minimum of 1 hour.
5. After wax elimination, the casting machine is prepared, and the crucible is preheated. The alloy is melted, the ring is transferred, and the casting is made promptly (see Fig. 22-30, *E*).
6. The casting is recovered from the investment (see Fig. 22-30, *F*).
7. Defects are identified and corrected if possible (see Fig. 22-30, *G*).

SUMMARY

Investing and casting comprise a series of highly technique-sensitive steps in which the wax pattern is converted into a metal casting. Accurate and smooth

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FIGURE 22-30 ■ Technique review. **A,** A sprue 2 or 2.5 mm in diameter (10- or 12-gauge) is attached to the bulkiest nonfunctional cusp; sprues can be attached to multiple units with a runner bar. **B,** The pattern is carefully removed from the die and attached to a crucible former. **C,** The pattern is painted with surface tension reducer. **D,** The pattern is then carefully coated with vacuum-mixed investment. **E,** After wax elimination, the casting machine is prepared, and the crucible is preheated. The alloy is melted, the ring is transferred, and the casting is made promptly. **F,** The casting is recovered from the investment. **G,** Defects *(arrow)* are identified and corrected if possible.

restorations can be obtained if the operator pays special attention to each step in the technique. When initial attempts at casting produce errors or defects, appropriate corrective measures must be taken so that they do not recur.

REFERENCES

1. Philbrook D: Cast fillings. Iowa State Dent Soc Trans p 277, 1897.
2. Taggart WH: A new and accurate method of making gold inlays. Dent Cosmos 49:1117, 1907.
3. Anusavice KJ: Phillips' science of dental materials, 10th ed. Philadelphia, WB Saunders, 1996.
4. Ryge G, et al: Porosities in dental gold castings. J Am Dent Assoc 54:746, 1957.
5. Johnson A, Winstanley RB: The evaluation of factors affecting the castability of metal ceramic alloy—investment combinations. Int J Prosthodont 9:74, 1996.
6. Mahler DB, Ady AB: The influence of various factors on the effective setting expansion of casting investments. J Prosthet Dent 13:365, 1963.
7. Takahashi J, et al: Nonuniform vertical and horizontal setting expansion of a phosphate-bonded investment. J Prosthet Dent 81:386, 1999.
8. Verrett RG, Duke ES: The effect of sprue attachment design on castability and porosity. J Prosthet Dent 61:418, 1989.
9. Strickland WD, Sturdevant CM: Porosity in the full cast crown. J Am Dent Assoc 58:69, 1959.
10. Rawson RD, et al: Photographic study of gold flow. J Dent Res 51:1331, 1972.
11. Earnshaw R: The effect of casting ring liners on the potential expansion of a gypsum-bonded investment. J Dent Res 67:1366, 1988.
12. Davis DR: Effect of wet and dry cellulose ring liners on setting expansion and compressive strength of a gypsum-bonded investment. J Prosthet Dent 76:519, 1996.
13. Engelman MA, et al: Oval ringless casting: simplicity, productivity, and accuracy without the health hazards of ring liners. Trends Tech Contemp Dent 6:38, 1989.
14. Shell JS: Setting and thermal expansion of investments. III. Effects of no asbestos liner, coating asbestos with petroleum jelly, and double asbestos liner. J Alabama Dent Assoc 53:31, 1969.
15. Ho EK, Darvell BW: A new method for casting discrepancy: some results for a phosphate-bonded investment. J Dent 26:59, 1998.
16. Lacy AM, et al: Incidence of bubbles on samples cast in a phosphate-bonded investment. J Prosthet Dent 54:367, 1985.
17. American Dental Association: Dentist's desk reference: materials, instruments and equipment, 1st ed. Chicago, The American Dental Association, 1981.
18. Sturdevant JR, et al: The 8-year clinical performance of 15 low-gold casting alloys. Dent Mater 3:347, 1987.
19. Goldfogel MH, Nielsen JP: Dental casting alloys: an update on terminology. J Prosthet Dent 48:340, 1982.
20. Johansson BI, et al: Corrosion of copper, nickel, and gold dental casting alloys: an in vitro and in vivo study. J Biomed Mater Res 23:349, 1989.
21. Duncan JD: The casting accuracy of nickel-chromium alloys for fixed prostheses. J Prosthet Dent 47:63, 1982.
22. Ogura H, et al: Inner surface roughness of complete cast crowns made by centrifugal casting machines. J Prosthet Dent 45:529, 1981.
23. Moffa JP, et al: An evaluation of nonprecious alloys for use with porcelain veneers. I. Physical properties. J Prosthet Dent 30:424, 1973.
24. Moon PC, Modjeski PJ: The burnishability of dental casting alloys. J Prosthet Dent 36:404, 1976.
25. Moffa JP, et al: An evaluation of nonprecious alloys for use with porcelain veneers. II. Industrial safety and biocompatibility. J Prosthet Dent 30:432, 1973.
26. American Dental Association Council on Dental Materials, Instruments, and Equipment: Biological effects of nickel-containing dental alloys. J Am Dent Assoc 104:501, 1982.

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همیار دندانسازان و دندانپزشکان

27. Lacy AM, et al: Three factors affecting investment setting expansion and casting size. J Prosthet Dent 49:52, 1983.
28. Vieira DF, Carvalho JA: Hygroscopic expansion in the upper and lower parts of the casting ring. J Prosthet Dent 36:181, 1976.
29. Cooney JP, Caputo AA: Type III gold alloy complete crowns cast in a phosphate-bonded investment. J Prosthet Dent 46:414, 1981.
30. Chew CL, et al: Investment strength as a function of time and temperature. J Dent 27:297, 1999.
31. Abu Hassan MI, et al: Porosity determination of cast investment by a wax-infiltration technique. J Dent 17:195, 1989.
32. Papadopoulos T, Axelsson M: Influence of heating rate in thermal expansion of dental phosphate-bonded investment material. Scand J Dent Res 98:60, 1990.
33. Campagni WV, Majchrowicz M: An accelerated technique for casting post-and-core restorations. J Prosthet Dent 66:155, 1991.
34. Campagni WV, et al: A comparison of an accelerated technique for casting post-and-core restorations with conventional techniques. J Prosthodont 2:159, 1993.
35. Bailey JH, Sherrard DJ: Post-and-core assemblies made with an accelerated pattern elimination technique. J Prosthodont 3:47, 1994.
36. Scherer MD, Campagni WV: An accelerated clinical chairside technique for casting overdenture attachment copings. J Prosthet Dent 106:337, 2011.
37. Konstantoulakis E, et al: Marginal fit and surface roughness of crowns made with an accelerated casting technique. J Prosthet Dent 80:337, 1998.
38. Schilling ER, et al: Marginal gap of crowns made with a phosphate-bonded investment and accelerated casting method. J Prosthet Dent 81:129, 1999.
39. Henning G: The casting of precious metal alloys in dentistry: a rational approach. Br Dent J 133:428, 1972.
40. Preston JD, Berger R: Some laboratory variables affecting ceramometal alloys. Dent Clin North Am 21:717, 1977.
41. Scherer MD, Campagni WV: An accelerated clinical chairside technique for casting overdenture attachment copings. J Prosthet Dent 106:337, 2011.
42. Gómez-Cogolludo P, et al: Effect of electric arc, gas oxygen torch and induction melting techniques on the marginal accuracy of cast base-metal and noble metal-ceramic crowns. J Dent 41:826, 2013.
43. Jameson A: British patent no. 19801, 1907.
44. Hero H, Waarli M: Effect of vacuum and supertemperature on mold filling during casting. Scand J Dent Res 99:55, 1991.
45. Eames WB, MacNamara JF: Evaluation of casting machines for ability to cast sharp margins. Operative Dent 3:137, 1978.
46. Imirzalioglu P, et al: Influence of recasting different types of dental alloys on gingival fibroblast cytotoxicity. J Prosthet Dent 107:24, 2012.
47. Anusavice KJ: Phillips' science of dental materials, 12th ed. Philadelphia, Elsevier, 2012.

STUDY QUESTIONS

1. Discuss in detail the requirements of a sprue and the factors and special considerations involved in selecting the sprue position.

2. Discuss gypsum-bonded and phosphate-bonded investments, and explain the various ways that investment expansion can be influenced, including pertinent materials science considerations.

3. What is the difference between gypsum- and phosphate-bonded investments?

4. What determines investment selection? What are the ideal properties of an investment material?

5. What factors can result in rough castings, nodules on castings, finning of a casting, or incomplete castings?

6. Identify the various types of casting porosity. What are the causes for each?

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CHAPTER 23

Description of Color, Color-Replication Process, and Esthetics

Alvin G. Wee, Contributing Author

To achieve an esthetic restoration, it is necessary to understand the process in which the color and translucency of fixed restorations are planned and obtained so as to replicate the color and contours of its adjacent teeth. Errors, especially in the color replication process, have been a problem and a source of frustration for dentists and technicians and may lead to dissatisfaction for the patient. This chapter outlines some of the principles of color, light, and human perception as they relate to the color replication process and esthetics of fixed restorations.

DESCRIPTION OF COLOR

Just as a solid body can be described by three dimensions of physical form (length, width, and depth), color can be described with the same precision by three primary attributes. Describing these attributes, however, depends on the color system used. Two systems are explained: the more visually descriptive Munsell color order system and the more quantitative Commission Internationale de l'Éclairage L*a*b* (CIELAB) color system.

Munsell Color Order System[1]

This system was widely used in the dental literature and also used in the past to quantify color.[2,3] It is still a popular method of visually describing color. The three attributes of color in this system are called *hue*, *chroma*, and *value*. (When used in reference to the Munsell coordinates, these terms are capitalized.)

Hue

Hue is defined as the particular variety of a color. The hue of an object can be red, green, yellow, and so on, and is determined by the wavelength of the reflected or transmitted light observed. The place of that wavelength (or wavelengths) in the visible range of the spectrum determines the hue of the color. The shorter the wavelength, the closer the hue is to the violet portion of the spectrum; the longer the wavelength, the closer it is to the red portion. In the Munsell color system, Hues are arranged around a wheel (Fig. 23-1).

Chroma

Chroma is defined as the intensity of a hue. The terms *saturation* and *chroma* are used interchangeably in the dental literature; both mean the strength of a given hue or the concentration of pigment. A simple way to visualize differences in chroma is to imagine a bucket of water. When one drop of ink is added, a solution of low chroma results. Adding a second drop of ink increases the chroma, and so on, until a solution is obtained that is almost all ink and consequently of high chroma. In the Munsell color system, the intensity of Chroma of a particular Hue is more intense on the outer rim than near the hub of the wheel (Fig. 23-2).

Value

Value is defined as the relative lightness or darkness of a color or the brightness of an object. The brightness of any object is a direct consequence of the amount of light energy the object reflects or transmits (see Fig. 23-2).

It is possible for objects of different hues to reflect the same number of photons and thus have the same brightness or value. A common example is the difficulty experienced in trying to distinguish a green object from a blue object in a black and white photograph. The colors of the two objects reflect the same amount of light energy and therefore appear identical in the picture.

A restoration that has too high a value (is too bright) may be easily detected by an observer and is a common esthetic problem in metal-ceramic prosthodontics.

CIELAB Color System

The CIELAB color system is used almost exclusively for color research in dentistry around the world.[4-7] It was introduced in 1976 and recommended by the International Commission on Illumination. This system, unlike the Munsell system, is easy to interpret clinically, as equal distances across the CIELAB color space (color differences, or ΔE) represent approximately uniform steps in human color perception, which improves the interpretation of color measurements. This means that it is possible to define the magnitude of perceptible or acceptable color difference between, for example, a porcelain crown and the adjacent natural dentition.

The CIELAB color order system defines color space by three coordinates: L*, a*, and b*. L* is similar to the Munsell system's Value and represents the lightness, brightness, or black/white character of the color. The coordinates a* and b* describe the chromatic characteristics of the color. L* describes the achromatic character of the color. Colors with high value, or L* (such as tooth colors), are located near the top of the color space, as

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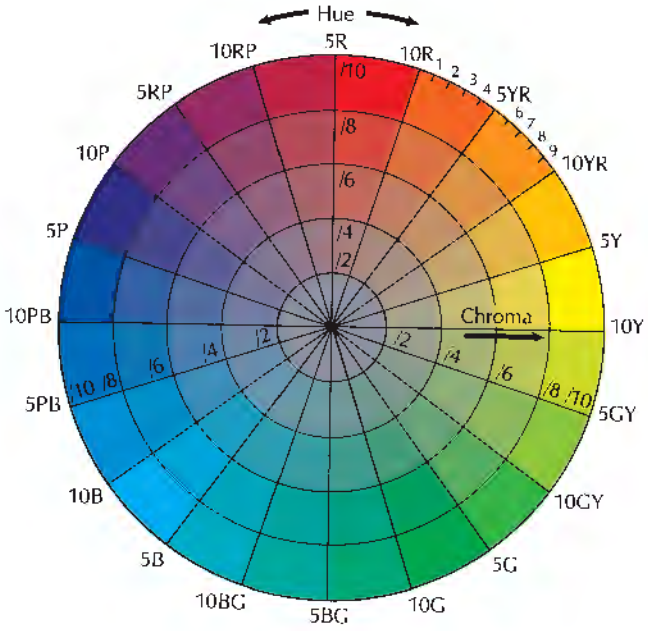

FIGURE 23-1 ■ Arrangement of Hue and Chroma in the Munsell system. Hue is represented by letters: *R,* Red; *YR,* yellow-red; *Y,* yellow; *GY,* green-yellow; *G,* green; *BG,* blue-green; *B,* blue; *PB,* purple-blue; *P,* purple; *RP,* red-purple. Chroma is represented by the numbers (see Fig. 23-2).

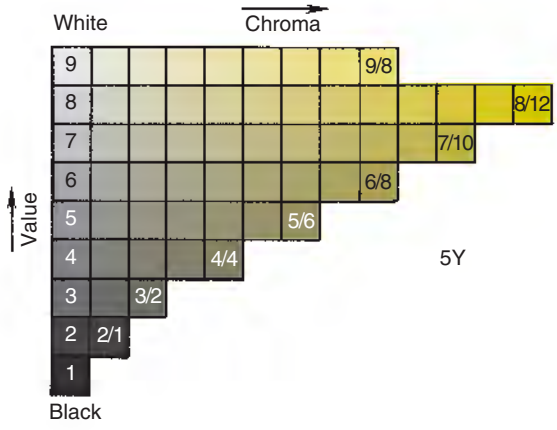

FIGURE 23-2 ■ Arrangement of Value and Chroma in the Munsell system. *Y,* Yellow.

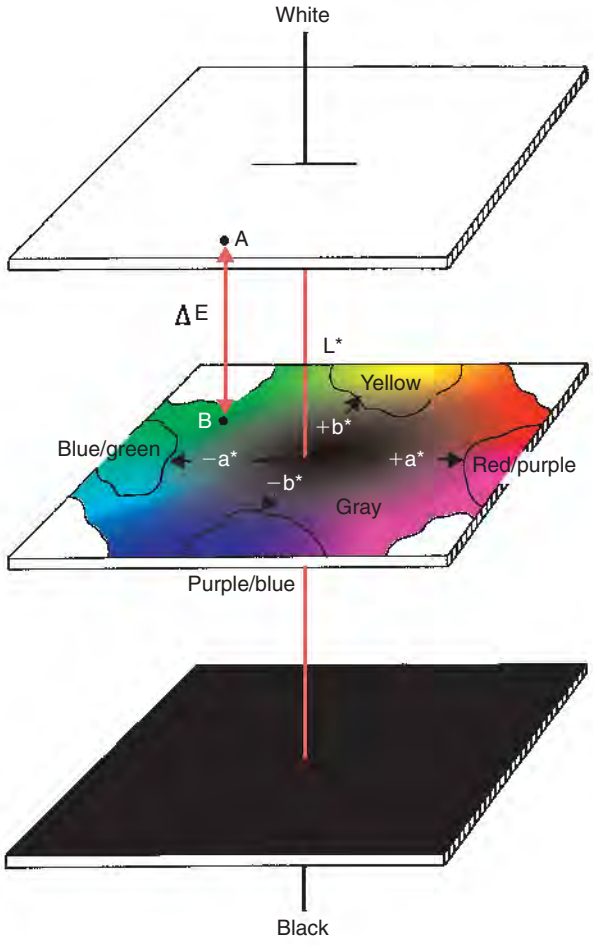

FIGURE 23-3 ■ Commission Internationale de l'Éclairage L*a*b* (CIELAB) color space. Any color can be defined in terms of these coordinates. L* (the vertical axis) defines the lightness or darkness of the color and corresponds to Value in the Munsell system; a* and b* define the chromatic characteristics. The color difference (ΔE) between two colors (A and B) can be calculated from the sum of the squares of the differences among the three coordinates. The system is arranged so that a color difference of 1 is perceivable by 50% of observers with normal color vision.[64] (From Rosenstiel SF, Johnston WM: The effect of manipulative variables on the color of ceramic metal restorations. J Prosthet Dent 60:297, 1988.)

depicted in Figure 23-3. The chromatic (non–black/white) characteristics of a color are represented in the Munsell system by Hue and Chroma and in the CIELAB system by a* and b*. In each system, these two coordinates define the location of color on a plane of given lightness, such as the one depicting color *B* in Figure 23-3. In the Munsell system, the color is identified by one polar coordinate (Hue) and one linear, or Cartesian* coordinate (Chroma); in the CIELAB system, both coordinates (a* and b*) are Cartesian. For an analogy, consider how the location of a house in a city might be described. It could be said that someone lived a distance of 11.85 miles (linear coordinate) in the north-northwest direction (polar coordinate) from downtown. This is analogous to describing a color in the Munsell system. The identical location could also be defined as being 10.6 miles north and 5.3 miles west of downtown (two Cartesian coordinates) (Fig. 23-4). This is analogous to a CIELAB description of a color. The descriptions represent the same location in space. However, unlike the Munsell coordinates, the CIELAB coordinates define the color space in approximately uniform steps of human color perception. This means that equal distances across the CIELAB color space (color differences, or ΔE) represent approximately equally perceived shade gradations, an arrangement that makes interpretation of color measurements more meaningful.

*L**

L* is a lightness variable proportional to Value in the Munsell system. It describes the achromatic character of the color.

*From the Latin form of René Descartes (1596-1650), the French philosopher and mathematician.

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a and b**

The a* and b* coordinates describe the chromatic characteristics of the color. Although they do not correspond directly to Munsell's Hue and Chroma, they can be converted by numerical parameters[8] (see Fig. 23-3). The a* coordinate corresponds to the red-purple/blue-green axis in the Munsell color space. A positive a* relates to a predominantly red-purple color, whereas a negative a* denotes a color that is more blue-green. Similarly, the b* coordinate corresponds to the yellow/purple-blue axis.

COLOR REPLICATION PROCESS

In this chapter, the process in which the color of adjacent teeth is replicated in a metal-ceramic or all-ceramic crown is termed the *color replication process*. The color replication process for fixed restorations (Fig. 23-5) consists of the shade-matching phase, followed by a shade-duplication phase. Shade matching can be accomplished through either the more common visual shade matching or the increasingly popular instrumental analysis. The shade duplication takes place in the dental laboratory, in which either the corresponding porcelain, selected in the shade-duplication phase, or more sophisticated porcelain mixtures are used to fabricate the fixed restoration. If differences between the definitive restoration and the originally matched restoration are visually perceptible, it is possible for the clinician to apply surface characterization porcelains to the restoration to adjust any color discrepancy.

FIGURE 23-4 ■ Locations in space can be defined in polar *(dashed line)* or Cartesian *(solid lines forming right angle)* coordinates.

SHADE-MATCHING PHASE

This phase occurs in the dentist's office, in which the information on the color and translucency of the adjacent teeth to be matched is recorded through either visual shade matching or instrumental color analysis.

Visual Shade Matching

Visual assessment of the shade and translucency is the method most frequently applied in dentistry.[9] Studies have shown that this often-used method is difficult to apply with accuracy and often yields unreliable and inconsistent results.[10,11] Fortunately, a lifelike and successful restoration does not have to be an exact duplicate of the color and translucency of the adjacent teeth. It should, however, blend with the teeth as a result of the distribution of ceramic materials in the restoration. The apparent color of an object is influenced by its physical properties, by the nature of the light to which the object is exposed, and by the subjective assessment of the observer; however, the variability of two of the three factors (e.g., lighting and subjectivity of the observer) can cause the same object (e.g., tooth) to look very different. By understanding the three main factors (lighting, subjectivity of human vision, and the object) that influence the outcome of visual shade matching, the dentist can improve the accuracy and reliability of this process.

Lighting

Light is necessary for color to exist. An object that is perceived as a certain color absorbs all light waves

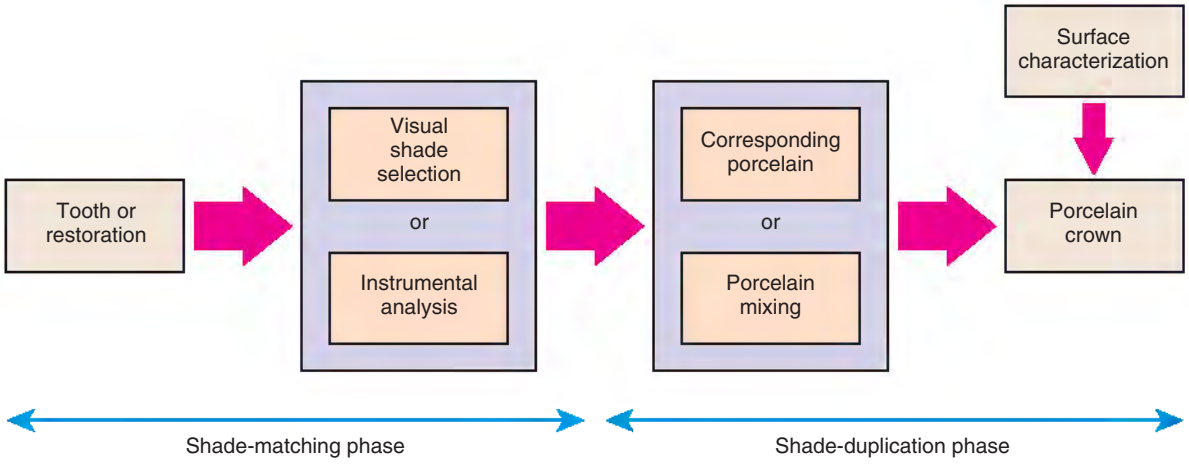

FIGURE 23-5 ■ Color replication process for fixed restorations.

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corresponding to other colors and reflects only the waves of the object's color. For example, an object that absorbs blue and green light and reflects red light appears red. The quality and quantity of the light source and the environment in which the teeth and shade guides are being visually matched are important.

Although daylight was initially thought to be the ideal light source for color matching,[10] its use is not recommended, in view of inconstant color characteristics. The color of daylight can vary from red-orange at sunset to blue when the sky is clear. The relative intensity of daylight also fluctuates with cloud cover.[12] An ideal light source for visual shade matching is one that is diffuse and comfortable for the eyes, allowing observers to assess the color accurately and comfortably.[12] In one study, evaluators obtained better visual shade matching in controlled stable, constant, and standard full-spectrum lighting than in daylight.[13]

Description of Light. Scientifically, light is described as visible electromagnetic energy whose wavelength is measured in nanometers, or billionths of a meter. The eye is sensitive only to the visible part of the electromagnetic spectrum, a narrow band with wavelengths from 380 to 750 nm. At the shorter wavelengths are ultraviolet rays, x-rays, and gamma rays; at the longer wavelengths are infrared radiation, microwaves, and television and radio transmission waves (Fig. 23-6).

Pure white light consists of relatively equal quantities of electromagnetic energy over the visible range. When white light is passed through a prism (Fig. 23-7), it is split into its component colors because the longer wavelengths are bent (refracted) less than the shorter ones.

Quality of Light Source. A light source of the appropriate quality should be used during visual shade matching. The appropriate color temperature with appropriate spectral energy distribution and color-rendering index (CRI) must be considered in the selection of a light source.

A light source with a color temperature close to 5500° K (D55) that is spectrally balanced throughout the visible spectrum is ideal for color matching. Color temperature is related to the color of a standard black body when heated and is reported in degrees Kelvin (K; 0°K = –273°C). Accordingly, 1000°K is red; 2000°K is yellow; 5555°K is white; 8000°K is pale blue. D65 (Fig. 23-8) is considered to be the true color temperature of white light as perceived by human observers.[14] D65 is very commonly used in dental shade matching as the standard lighting for visual shade matching. A light source with a CRI greater than 90 is recommended for shade matching.[15] The CRI, on a scale of 1 to 100, indicates how well a particular light source renders color in comparison with a specific standard source. Dental personnel's shade-matching ability on a designed color test[16] was significantly better with a full-spectrum light source of 5700°K (CRI = 91) than with light sources of 6000°K (CRI = 93), 4200°K (CRI = 65), and 7500°K (CRI = 94).[17]

Unfortunately, the most common light sources in dental operatories are incandescent and fluorescent, neither of which is ideal for shade matching. An ordinary incandescent light bulb emits relatively higher concentrations of yellow light waves than of blue and blue-green light waves, whereas fluorescent ceiling fixtures give off relatively high concentrations of blue waves. The quality of the lighting used to carry out visual shade matching in 32 private dental practices in the Midwestern region of the United States were measured with an illuminance spectrophotometer (Konica Minolta CL-500A). The average color temperature and CRI was found to be 4089.3° K (SE = 131.66) and 82.8° K (SE = 1.39) respectively (unpublished data). Color-corrected fluorescent

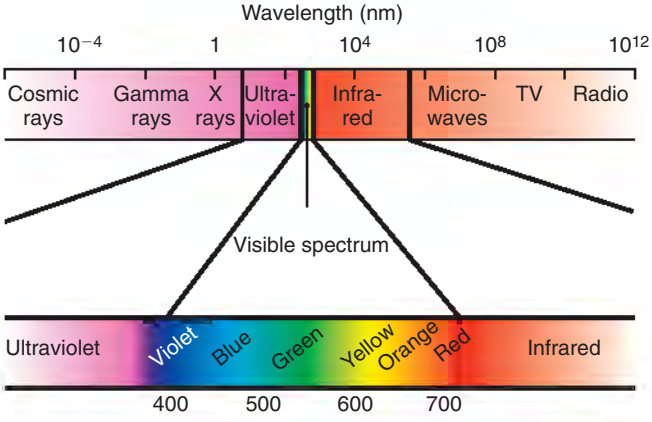

FIGURE 23-6 ■ Electromagnetic energy spectrum. One nanometer (nm) is 10^{-9} meter (m).

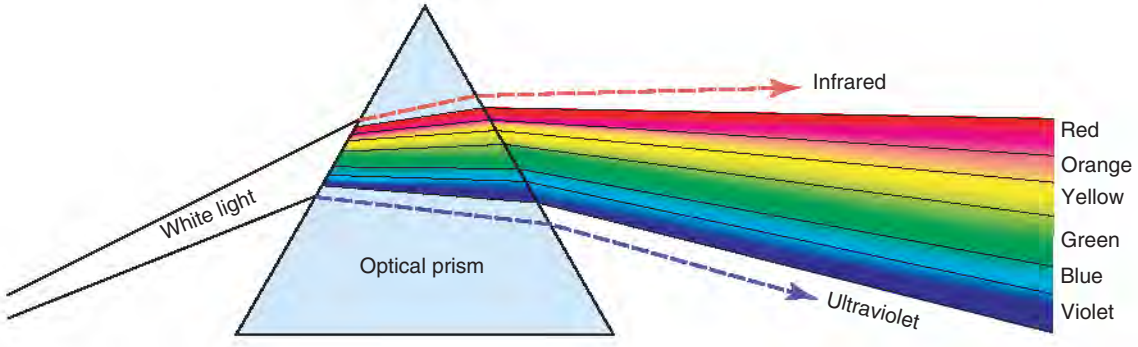

FIGURE 23-7 ■ A prism bends or refracts long wavelengths of light less than shorter wavelengths, thereby separating the colors.

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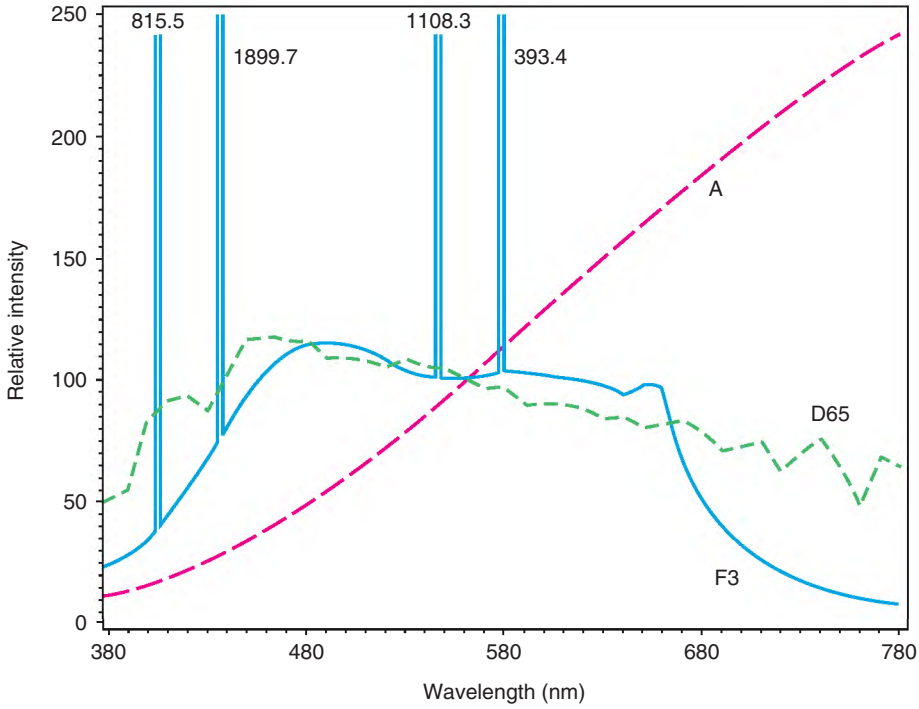

FIGURE 23-8 ■ Relative intensity versus wavelength of three light sources: D65 illuminant is relatively balanced; A illuminant (tungsten filament) has high amounts of orange and red wavelengths; F3 illuminant (fluorescent tube light) has peaks of blue and yellow wavelengths.

lighting is recommended because it approaches the necessary type of balance. Recommended commercial color-corrected ambient lighting, ideal for shade matching, for the dental operatory is described in Table 23-1.

Quantity of Light Source. Appropriate intensity of the ambient lighting in the dental operatory provides the dentist with visual comfort, particularly in terms of contrast. It is recommended that the light intensity be between 2000 and 3200 lux[†] for the dental operatory and 28 lux for the dental laboratory.[18] The intensity of the dental operatory lighting has not been found to be crucial for color matching when the light intensity ranges from 800 to 3200 lux.[19]

Auxiliary Light Sources. If ambient lighting in the dental operatory is not ideal in terms of quality and quantity for visual shade matching, the use of auxiliary lighting is recommended. The auxiliary light source for shade matching should be intense enough to overcome the influence of the ambient light. It has been recommended that the ratio of task (shade matching) to ambient light should not exceed 3 : 1; too much intensity does not allow discrimination of small color differences.[18] Commercial auxiliary lighting, such as the Demetron Shade Light (Kerr Corp.; Fig. 23-9) or the Shade Wand (Authentic Products, Inc.), is recommended for shade matching (see Table 23-1).

[†]Lux is a unit of illumination, equal to 1 lumen per square meter; it was originally based on the illumination provided by a household candle at a distance of 1 m.

Shade-Matching Environment. The ambient and direct lighting used for shade matching scatters and reflects from surfaces before reaching the structure that it illuminates. The colors of the dental operatory, the clothing of the dentist and dental assistants, the patient's clothing, and the dental drape may influence the perceived color of the patient's teeth and shade guide.[20] To maintain the necessary lighting quality for shade matching, the chroma of the environment should be carefully controlled. It is recommended that the walls, staff clothing, patient drape, and shade-matching environment have a Chroma of four Munsell units or less, which are the pastel[18] or the ideal neutral gray tones.[21] Among the further recommendations is that the ceiling have a Munsell Value of 9. All other major reflectors (e.g., walls, cabinets) should present at least a Munsell Value of 7 and a Munsell Chroma of no more than 4. Countertops not within the working area can have a Munsell Chroma of up to 6 but a Munsell Value retained at 7 or greater.[22]

Human Vision

Light from an object enters the eye and acts on receptors in the retina (rods and cones). Impulses from these are passed to the optical center of the brain, where an interpretation is made. Shade matching is therefore subjective: Different individuals have different interpretations of the same stimulus.

The Eye. Under low lighting conditions, only the rods are used (scotopic vision). These receptors allow the brightness (but not the color) of objects to be interpreted. The rods are most sensitive to blue-green objects. Color

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TABLE 23-1 **Examples of Commercial Balanced Lighting Available**

Product Name	Manufacturer	Type	CRI	CCT (°K)	Estimated Life (hours)
CRS Light	CRS Light, Cleveland, Ohio	Fluorescent tube	91	5750	20,000
Full Spectrum, Supreme	NaturalLighting.com, Houston, Texas	Compact fluorescent tube	96	5000	20,000
Lumichrome 1XX	Lumiram, White Plains, New York	48-inch fluorescent tube	98	6500	24,000
Lumichrome 1XZ	Lumiram, White Plains, New York	24-inch fluorescent tube	95	5700	24,000
Demetron Shade Light	Kerr Corporation, Orange, California	Handheld fluorescent tube (3 hours' battery life)	93	6500	20,000
Shade Wand	Authentic Products, Inc., San Antonio, Texas	Handheld fluorescent tube	—	5500	—
Hand Held	Great Lakes Lighting, Bay City, Michigan	Handheld fluorescent tube	94	—	9000
Vita-Lite	Duro-Test Lighting, Inc., Philadelphia, Pennsylvania	Handheld fluorescent tube	91	5500	10,000 to 28,000
Light-A-Lux (40-watt T-12)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent tube	90	5900	20,000
Super Daylite (32-watt T-8)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent tube	98	6500	20,000
Super Daylite (40-watt T-12)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent tube	96	5000	20,000
Super 10,000Lux (40-watt T-10)	American Environmental Products, Fort Collins, Colorado	Compact fluorescent tube	91	5000	20,000
F40/C50/RS/WM	General Electric Company, GE Lighting, Cleveland, Ohio	48-inch fluorescent tube	90	5000	20,000

Data from Wee AG: Color matching: color matching conditions. In Paravina RD, Powers JM, eds: Esthetic color training in dentistry. St. Louis, Mosby, 2004; and from Paravina RD, personal communication, 2004.
CCT, Correlated color temperature; *CRI,* color-rendering index.

FIGURE 23-9 ■ The Rite-Lite 2 Shade Matching Light device. (Courtesy AdDent, Inc., Danbury, Connecticut.)

vision is dependent on the cones, which are active under higher lighting conditions (photopic vision). The change from photopic to scotopic vision is called *dark adaptation* and takes about 40 minutes.[23]

The area with the most cones is in the center of the retina, which is free of rods. The rods predominate toward the periphery. This means that the central field of vision is more color perceptive. Although the exact mechanism of color vision is not known, there are three types of cones—sensitive to red, green, and blue light[24]—that form an image in much the same way as the additive effect of the pixels in a television picture.

Color Adaptation. Color vision decreases rapidly as a person stares at an object. The original color appears to become less and less saturated until it appears almost gray.

Deceptive Color Perception. The brain can be tricked in how it perceives color. A classic example of such a trick

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is the Benham disk (Fig. 23-10). When this black and white disk is illuminated and rotated at an appropriate speed, it appears to be highly colored.

Color is also influenced by surrounding colors, particularly complementary ones (those diametrically opposed in Fig. 23-1). For example, when blue and yellow are placed side by side, their chroma may appear to be increased. The color of teeth can also look different if the patient is wearing brightly colored clothing or lipstick (Fig. 23-11).

Metamerism. Two colors that appear to be a match under a given lighting condition but have different spectral reflectance (Fig. 23-12) are called *metamers*, and the phenomenon is known as *metamerism*. For example, two objects that appear to be an identical shade of yellow may absorb and reflect light differently. Yellow objects normally reflect yellow light, but some may actually absorb yellow light and reflect orange and green. To an observer, the orange and green combination looks yellow, although when the lighting is changed, the metamers no longer match. This means that a sample that appears to match

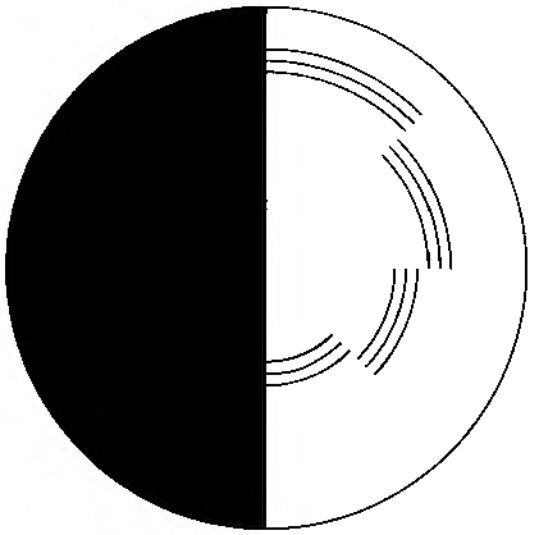

FIGURE 23-10 ■ The Benham disk. When it rotates, red, green, and blue rings are seen. The order of the colors is reversed if the disk rotates in the opposite direction. This is a purely sensory phenomenon caused by afterimages.

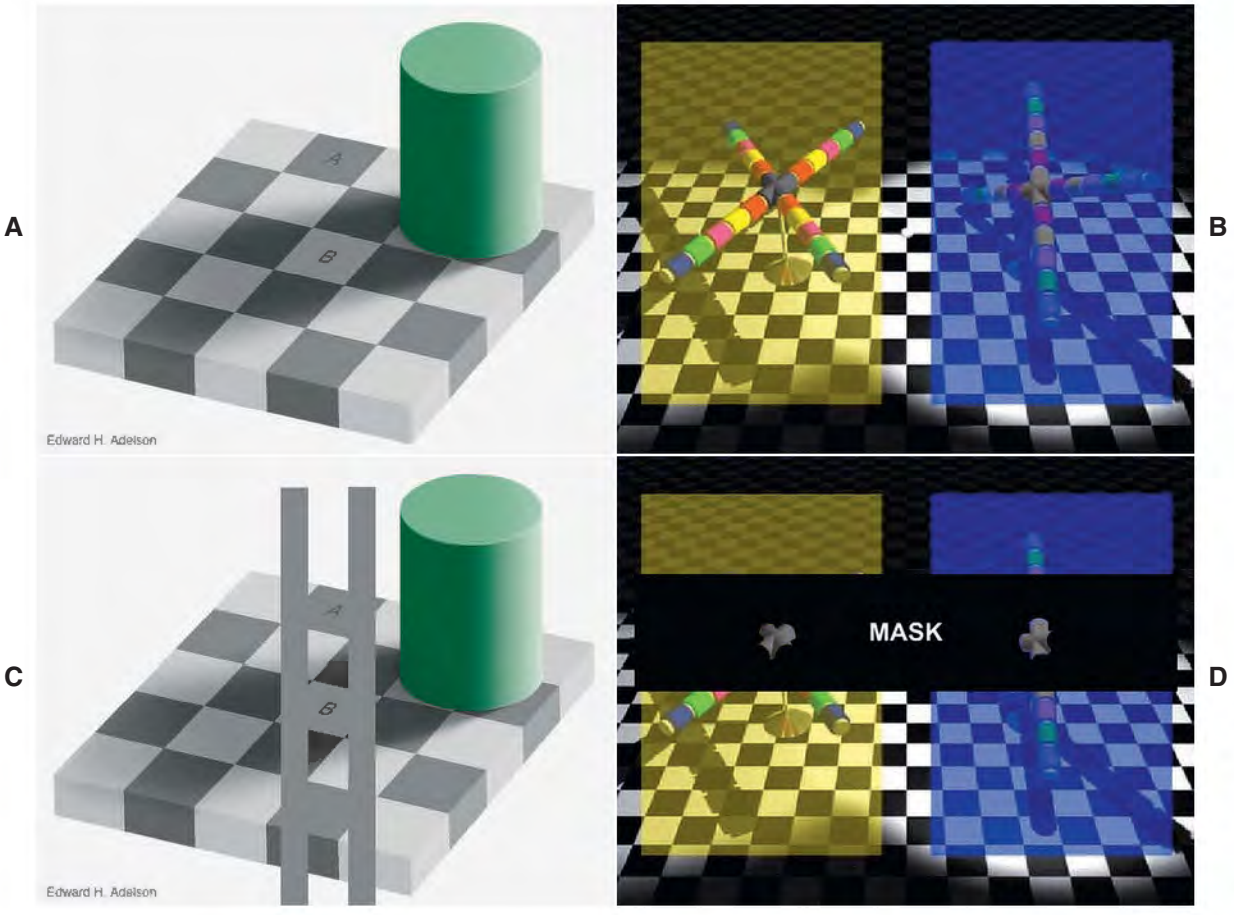

FIGURE 23-11 ■ **A,** The checker shadow illusion. The squares marked *A* and *B* are the same shade of gray. For proof, see part **C. B,** The colored cross illusion. The central elements of the two *X*-shaped objects appear very different in color but are, in fact, exactly the same. For proof, see part **D. C,** The checker shadow Illusion. The original image in part **A** plus two stripes. When the squares marked *A* and *B* are joined with two vertical stripes of the same shade of gray, it becomes apparent that both squares are the same. **D,** When a mask that isolates the central elements from the surrounding colors is placed, the illusion is revealed. As with many so-called illusions, both of these effects really demonstrate the success rather than the failure of the visual system. The visual system is not very good at being a physical light meter, but that is not its purpose. The important task is to break the image information down into meaningful components, thereby allowing the nature of the objects in view to be perceived. However, when appropriate tooth shades are selected, it is important not to be influenced by the surrrounding colors. (**A** and **C,** Courtesy Dr. E.H. Adelson. **B** and **D,** Courtesy Dr. R.B. Lotto.)

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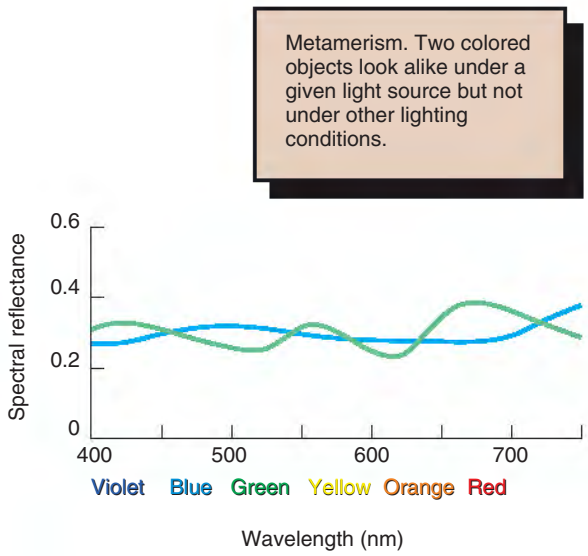

FIGURE 23-12 ■ Spectral reflectance curves of a metameric pair. The two objects represented appear to match under some lighting conditions but not under others.

under the operatory light, for example, may not be satisfactory in daylight. The dentist can avoid the problem of metamerism by selecting a shade and confirming it under different lighting conditions (e.g., natural daylight and fluorescent light).

Fluorescence. Fluorescent materials, such as tooth enamel, re-emit radiant energy at a frequency lower than that absorbed.[25] For example, ultraviolet radiation is re-emitted as visible light. In theory, a mismatch can occur if the dental restoration has different fluorescence than the natural tooth. In practice, fluorescence does not play a significant role in color matching dental restorations.[26]

Opalescence. Natural teeth, particularly at their incisal edges, exhibit a light-scattering effect[‡] that creates the appearance of bluish-white colors as the teeth are seen at different angles. This is similar to the bluish-white background seen in opal gemstones (hence the term *opalescence*). Manufacturers try to match this effect when formulating dental porcelains.[27,28]

Color Blindness. Defects in color vision (color blindness) affect about 8% of the male population and less of the female population.[29] Different types exist, such as achromatism (complete lack of hue sensitivity), dichromatism (sensitivity to only two primary hues; usually either red or green is not perceived), and anomalous trichromatism (sensitivity to all three hues with deficiency or abnormality of one of the three primary pigments in the retinal cones). Dentists should therefore have their color perception tested. If any deficiency is detected, the dentist should seek assistance when selecting tooth shades.[30]

[‡]Called *Mie scattering* after Gustav Mie (1868-1957), German physicist.

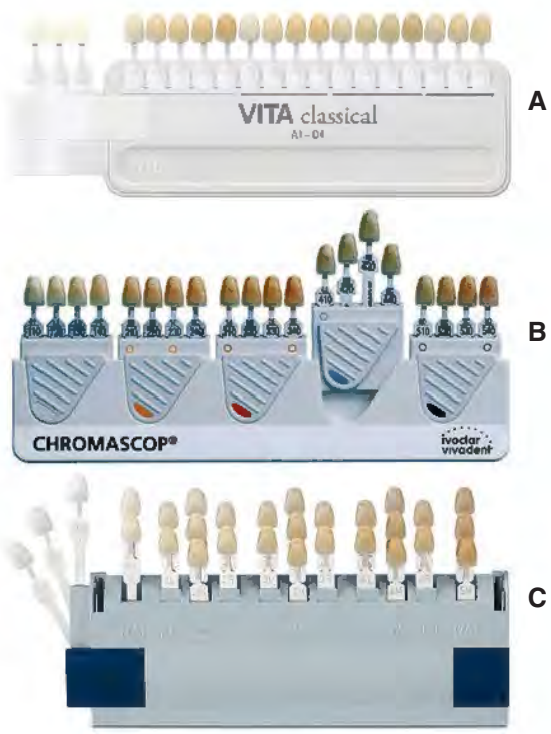

FIGURE 23-13 ■ Commercial shade guides. **A,** The VITA classical (Lumin Vacuum) shade guide. **B,** Ivoclar Vivadent Chromascop shade guide. **C,** VITA Toothguide 3D-MASTER®. (**A** and **C**, Courtesy VITA North America, Yorba Linda, California. **B**, Courtesy Ivoclar Vivadent, Amherst, New York.)

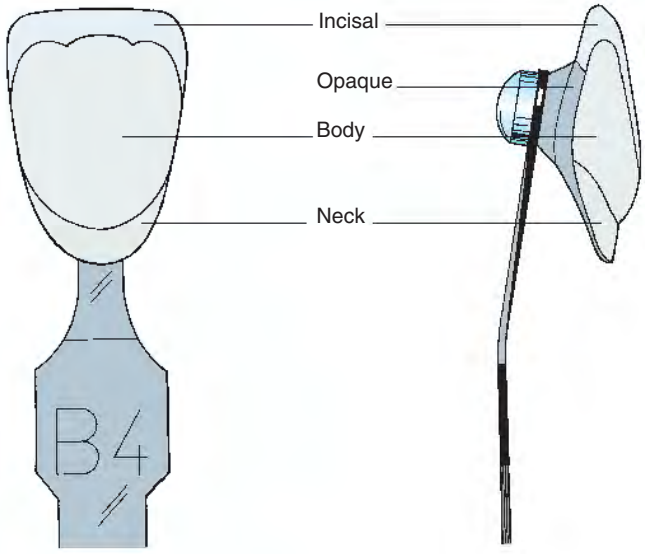

FIGURE 23-14 ■ Illustration of porcelain shade sample.

Shade Selection Systems

The most convenient method for selecting a shade is a commercially available porcelain shade guide (Fig. 23-13). Table 23-2 presents color measurement values made from VITA classical (Lumin Vacuum), Ivoclar Vivadent Chromascop, and VITA Toothguide 3D-MASTER® guides with a spectroradiometer. Each shade tab (Fig. 23-14) has an opaque backing color, a neck color, a body color, and

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TABLE 23-2 **CIELAB Values: Shade Guides Measured with Spectroradiometer with 45° Illumination and 0° Observer without an Aperture**

Shade Guide	Tab	L*	a*	b*
VITA Toothguide 3D-MASTER®	1M1	83.1 (0.9)	–0.1 (0.3)	12.5 (0.4)
	1M2	84.0 (0.8)	–0.2 (0.5)	18.8 (0.9)
	2L1.5	79.0 (1.0)	0.0 (0.2)	18.5 (0.2)
	2L2.5	79.5 (0.8)	0.2 (0.2)	24.5 (0.7)
	2M1	78.0 (0.6)	0.8 (0.3)	14.0 (0.6)
	2M2	78.7 (0.6)	0.9 (0.4)	19.9 (0.5)
	2M3	79.2 (0.8)	0.7 (0.2)	25.3 (0.4)
	2R1.5	77.8 (1.0)	1.5 (0.2)	16.3 (0.7)
	2R2.5	79.5 (1.1)	1.7 (0.3)	23.3 (0.6)
	3L1.5	73.1 (0.9)	1.5 (0.2)	20.3 (0.4)
	3L2.5	73.9 (1.1)	1.9 (0.2)	26.2 (0.8)
	3M1	73.4 (0.6)	1.8 (0.3)	15.4 (0.5)
	3M2	74.6 (1.0)	2.0 (0.4)	21.5 (0.8)
	3M3	75.0 (1.4)	2.6 (0.2)	27.9 (0.8)
	3R1.5	73.4 (1.1)	2.7 (0.3)	17.9 (0.6)
	3R2.5	73.6 (1.0)	3.5 (0.3)	25.9 (0.7)
	4L1.5	69.2 (0.8)	2.8 (0.3)	21.7 (0.3)
	4L2.5	69.1 (0.8)	3.7 (0.4)	28.5 (0.7)
	4M1	68.3 (0.9)	2.9 (0.2)	17.0 (0.5)
	4M2	70.1 (1.4)	3.7 (0.4)	23.7 (0.6)
	4M3	69.5 (0.7)	4.8 (0.3)	30.7 (0.4)
	4R1.5	69.6 (0.6)	4.3 (0.2)	20.8 (0.3)
	4R2.5	69.2 (1.1)	5.1 (0.2)	26.3 (0.4)
	5M1	64.4 (0.6)	4.2 (0.2)	19.4 (0.5)
	5M2	65.1 (1.0)	5.7 (0.2)	26.3 (0.8)
	5M3	65.9 (0.5)	7.0 (0.4)	33.4 (1.3)
Ivoclar Vivadent Chromascop	110	82.5 (1.0)	0.1 (0.1)	18.3 (0.3)
	120	80.2 (1.8)	0.7 (0.1)	19.7 (0.6)
	130	78.2 (0.8)	0.1 (0.1)	20.2 (0.5)
	140	78.9 (1.1)	1.6 (0.2)	23.7 (0.5)
	210	77.4 (1.5)	1.8 (0.1)	25.6 (0.8)
	220	76.4 (2.5)	3.4 (0.0)	23.4 (0.7)
	230	74.7 (1.8)	3.7 (0.2)	25.6 (0.9)
	240	73.8 (0.6)	5.6 (0.1)	28.2 (0.5)
	310	73.6 (1.0)	1.2 (0.1)	28.1 (0.7)
	320	71.4 (1.6)	2.7 (0.1)	28.2 (0.8)
	330	71.5 (1.4)	3.4 (0.1)	31.1 (0.5)
	340	68.3 (2.0)	4.9 (0.2)	28.9 (0.8)
	410	73.5 (1.2)	2.2 (0.2)	20.2 (0.7)
	420	72.1 (0.9)	1.7 (0.1)	20.5 (0.3)
	430	72.2 (0.9)	0.6 (0.1)	20.8 (0.7)
	440	69.1 (1.0)	0.9 (0.1)	21.1 (0.3)
	510	69.9 (1.5)	1.9 (0.1)	22.5 (0.6)
	520	67.6 (1.0)	2.7 (0.2)	24.7 (0.9)
	530	67.2 (0.2)	3.4 (0.1)	26.8 (1.0)
	540	64.0 (1.2)	7.6 (0.1)	26.2 (0.6)
VITA classical (Lumin Vacuum)	A1	82.4 (1.9)	–1.4 (0.4)	14.3 (0.7)
	A2	79.1 (1.1)	0.6 (0.3)	19.2 (0.5)
	A3	77.6 (0.9)	1.0 (0.3)	21.0 (0.9)
	A3.5	73.4 (1.2)	2.3 (0.1)	24.5 (0.6)
	A4	69.0 (0.9)	2.4 (0.6)	25.4 (0.8)
	B1	80.1 (2.3)	–1.9 (0.5)	12.6 (0.9)
	B2	80.1 (2.2)	–1.0 (0.5)	18.2 (1.0)
	B3	74.8 (1.4)	0.9 (0.5)	25.0 (0.9)
	B4	75.5 (2.7)	1.0 (0.2)	26.1 (1.8)

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TABLE 23-2 **CIELAB Values: Shade Guides Measured with Spectroradiometer with 45° Illumination and 0° Observer without an Aperture—cont'd**

Shade Guide	Tab	L*	a*	b*
	C1	76.6 (0.9)	–0.7 (0.2)	14.2 (0.8)
	C2	72.7 (0.4)	0.2 (0.3)	20.0 (0.4)
	C3	70.5 (0.9)	0.8 (0.1)	19.1 (0.5)
	C4	64.2 (1.2)	2.6 (0.2)	22.1 (0.5)
	D2	74.9 (1.5)	–0.4 (0.4)	13.2 (0.8)
	D3	74.7 (2.6)	1.1 (0.4)	18.3 (0.9)
	D4	73.5 (0.7)	–0.6 (0.2)	21.1 (0.5)

From Bayindir F, et al: Coverage error of three conceptually different shade guide systems to vital unrestored dentition. J Prosthet Dent 98:175, 2007.

an incisal color. Shade matching consists of picking the shade tab that looks the most natural and reproducing this color in a laboratory with materials and techniques recommended by the manufacturer. The procedure is easier if specimens of the same hue are grouped together in the shade guide. In the past, shade guides were produced in response to the demand for denture teeth rather than on the range of natural tooth color.[31] More recently, shade guides have covered the color space occupied by natural teeth,[§] such as the VITA Toothguide 3D-MASTER® (see Fig. 23-13, *C*). In one study, this shade guide resulted in the lowest coverage error (ΔE = 3.93)[32] in comparison with VITA classical (Lumin Vacuum) (ΔE = 5.39) or Chromascop shade guides (ΔE = 5.28).[33] The VITA Toothguide 3D-MASTER® did not differ significantly from the coverage errors of the combination of all three shade guides (ΔE = 3.69).

VITA Classical (Lumin Vacuum) Shade Guide: Hue Matching. In the popular VITA classical (Lumin Vacuum) shade guide (see Fig. 23-13, *A*), A1, A2, A3, A3.5, and A4 are similar in hue, as are the B, C, and D shades. Spectroradiometric measurement of 359 nonrestored vital unbleached dentition and the VITA classical (Lumin Vacuum) shade guide demonstrates the frequency distribution of the shade guide (Fig. 23-15).[33] One study revealed that D3 was the most common shade tab selected. Choosing the nearest hue first and then selecting the appropriate match of chroma and value from the tabs available is the recommended technique.

If the chroma or intensity is low, accurately determining a given hue may be difficult. Therefore, the region with the highest chroma (i.e., the cervical region of canines) should be used for initial hue selection (Fig. 23-16, *A*).

Chroma Selection. Once the hue is selected, the best chroma match is chosen. For example, if a B hue is determined to be the best match for color variety, four gradations (tabs) of that hue are available: B1, B2, B3, and B4 (see Fig. 23-16, *B*). Several comparisons are usually necessary for determining which sample best represents the

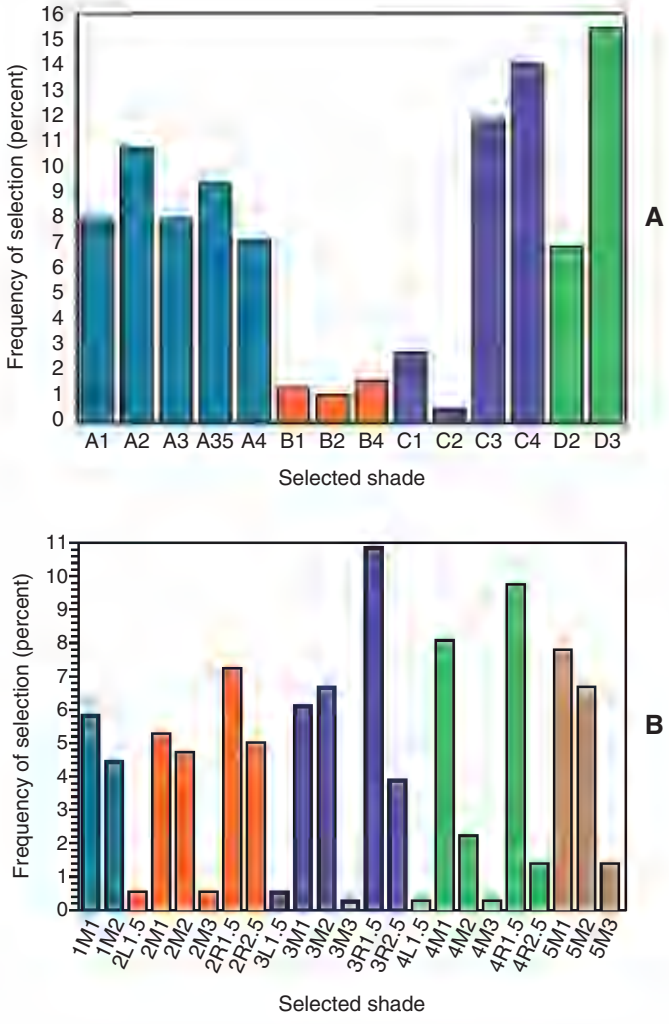

FIGURE 23-15 ■ **A,** Frequency of selection for the VITA classical (Lumin Vacuum) shade guide. **B,** Frequency of selection for the VITA Toothguide 3D-MASTER®. (From Bayindir F, et al: Coverage error of three conceptually different shade guide systems to vital unrestored dentition. J Prosthet Dent 98:175, 2007.)

[§]Shades that match artificially bleached teeth are also available.

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FIGURE 23-16 ■ Shade matching with the use of the VITA classical (Lumin Vacuum) shade guide. **A,** Selecting hue by matching samples with high chroma (e.g., A4, B4, C4, or D3) to a tooth with high chroma (i.e., canine). **B,** Selecting chroma from within the hue group (e.g., B1, B2, B3, or B4). **C,** Value-ordered shade guide is used to check lightness. (**C,** Courtesy VITA North America, Yorba Linda, California.)

hue and its corresponding chroma (saturation) level. Between comparisons, glancing at a gray object rests the operator's eyes and helps avoid retinal cone fatigue.

Value Selection. Finally, value is determined with a second commercial guide whose samples are arranged in order of increasing lightness (see Fig. 23-16, *C*). (The lightness readings—L* in Table 23-2—can be used as a guide to the sample sequencing.) By holding the second shade guide close to the patient, the operator should be able to determine whether the value of the tooth is within the shade guide's range. Attention is then focused on the range of shade that best represents the value of the tooth and how that range relates to the tab matching for hue and saturation. An observer is able to assess the value most effectively by observing from a distance, standing slightly away from the chair, and squinting the eyes. By squinting, the observer can reduce the amount of light that reaches the retina. Stimulation of the cones is reduced, and a greater sensitivity to achromatic conditions may result.[34] While squinting, the observer concentrates on which disappears from sight first: the tooth or the shade tab. The one that fades first has the lower value.

When the proper value selection has been made, it is the exception rather than the rule for this to coincide with the determinations for hue and chroma. The operator must decide whether to change the previously selected shade sample. If the independent value determination is lower than the value of the sample selected for hue and chroma, a change is usually necessary because increasing the value of an object by adding surface stain (which always reduces brightness) is not possible. If the value determination is higher than the hue determination, the operator should decide whether this difference can be bridged through internal or surface characterization of the restoration. The final decisions about hue, chroma, and value are then communicated to the laboratory.

VITA Toothguide 3D-MASTER® (VITA North America)

The manufacturer of this shade system (Fig. 23-17, *A*) claims that it covers the entire tooth color space. The shade samples are grouped in six lightness levels, each of which has chroma and hue variations in evenly spaced steps (see Fig. 23-17, *B*). The shade guide is spaced in steps (ΔE) of four CIELAB units in the lightness dimension and two CIELAB units in the hue and chroma dimensions. The difference between lightness and color steps seems a logical approach to reducing the number of shade samples needed in the guide because of the way the CIELAB units are visually perceived. It seems to match the color difference formula of the Colour Measurement Committee of the Society of Dyers and Colourists.[35] Because the guide

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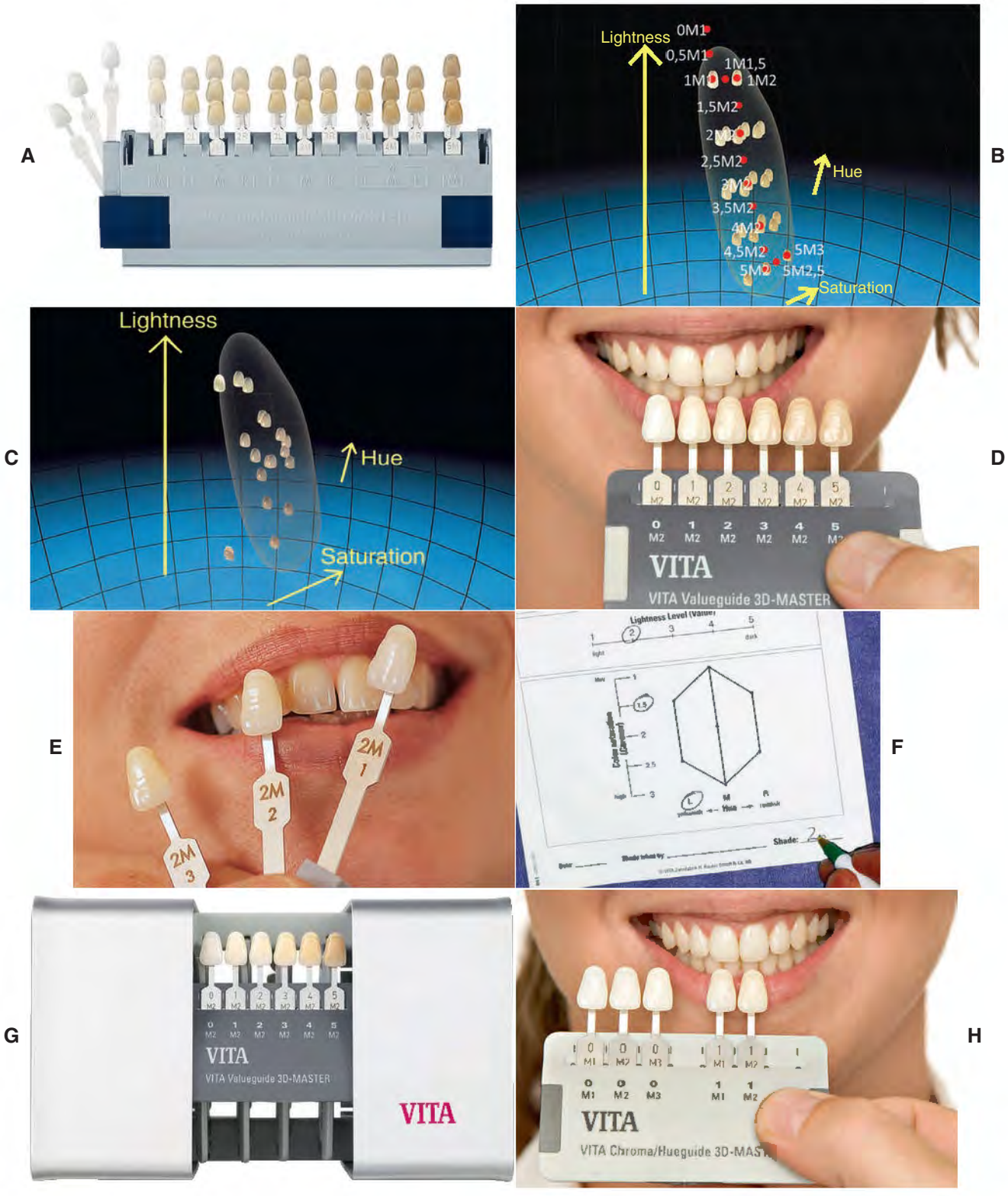

FIGURE 23-17 ■ Shade selection with the VITA Toothguide 3D-MASTER®. **A,** The shade guide is arranged in five lightness levels (plus an additional level for bleached teeth). **B,** Each lightness level has sufficient variations in chroma and hue to cover the natural tooth color space. **C,** This is in contrast to traditional shade guides, which are not uniformly spaced. Lightness is selected first **(D),** then chroma or saturation **(E),** and finally hue. **F,** The color communication form allows convenient laboratory shade prescription and intermediate shades if necessary. **G,** The system is also available in a linear arrangement. In this arrangement, the dentist first selects from five value tabs **(H)** and then chooses the appropriate mix of chroma and hue within the selected value range. (Courtesy VITA North America, Yorba Linda, California.)

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is evenly spaced, intermediate shades can be predictably formulated by combinations of porcelain powders.[36] Spectroradiometric measurement of 359 nonrestored vital unbleached dentition and the VITA Toothguide 3D-MASTER® demonstrates the frequency distribution of the shade guide (see Fig. 23-15, *B*).[33] This study revealed that 3R1.5 was the most common shade tab selected.

The manufacturer recommends selecting the lightness (see Fig. 23-17, *D*) first, then chroma (see Fig. 23-17, *E*), and finally the hue (see Fig. 23-17, *F*). A form is available to facilitate the laboratory shade prescription, which can include intermediate steps (see Fig. 23-17, *G*).

Extended-Range Shade Guides

Most commercial shade systems cover a range more limited than the colors found in natural teeth, and the steps in the guide are greater than can be perceived visually.[33] Some porcelain systems are available with extended-range shade guides, and other manufacturers have extended their ranges over the years. The use of two or more shade guides is a practical way to extend the range of commercial guides.

Translucency

Assessment of the inherent translucency of the adjacent teeth[37] is important in determining whether the tooth or teeth need to be restored with which type of all-ceramic or a metal-ceramic system. In general, an all-ceramic crown system for anterior teeth is a more esthetic restoration mainly because of the translucency match. Table 23-3 is useful for determining which system to use to improve translucency match for the fixed restoration.[38]

Dentin Shade Guides

When a translucent all-ceramic system for a crown or veneer is used (see Chapter 25), communicating the shade of the prepared dentin to the dental laboratory is helpful. One system (IPS Empress [Ivoclar Vivadent]) provides specially colored die materials that match the dentin shade guide and enable the technician to judge restoration esthetics (Fig. 23-18).

Custom Shade Guide

Unfortunately, certain teeth cannot be matched to commercial shade samples. In addition, difficulties may be encountered in reproducing the shade guides in the definitive restorations. The extensive use of surface characterization has severe drawbacks because the stains increase surface reflection and prevent light from being transmitted through the porcelain.[39]

One approach to this problem is to extend the concept of a commercial shade guide by making a custom shade guide (Fig. 23-19). An almost infinite number of samples can be made with different combinations of porcelain powders in varying distributions. However, the procedure is time consuming and is generally confined to specialty practice.

Another approach is to custom stain the closest matching selected shade guide, at chairside during the shade-matching phase, with a light polymerized porcelain staining system (GC Fuji ORBIT LC [GC America]). This system comes as a 14-stain kit or a 6-stain introductory kit. The shade tap can be custom stained several times till it matches the adjacent teeth satisfactorily. This shade tap is then sent to the dental laboratory so that the crown can be fabricated identically in the required color.

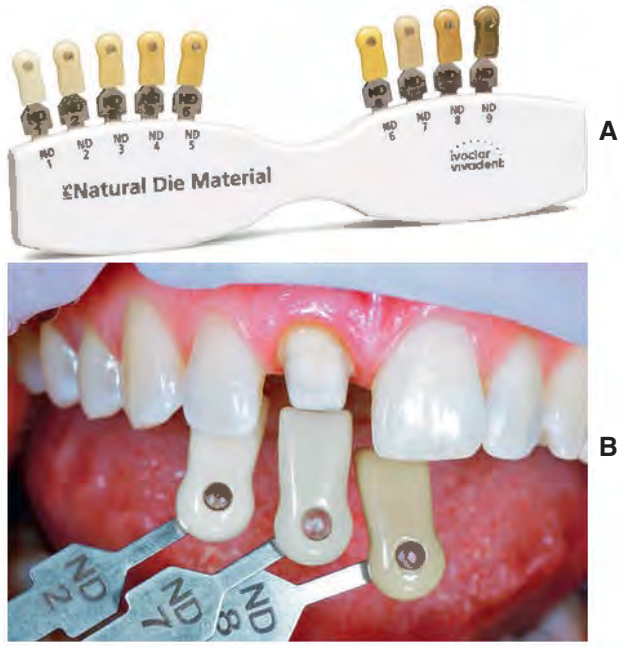

FIGURE 23-18 ■ Dentin shade guide **(A)** is used to communicate the color of the prepared tooth **(B)** to the technician when translucent ceramic systems are used. (Courtesy Ivoclar Vivadent, Amherst, New York.)

TABLE 23-3 **Recommendations for Selection of Crown Material, Based on Translucency of Natural Teeth**

Natural Teeth	In-Ceram Spinell	Empress	e-Max	Procera All-Ceram	In-Ceram Alumina	Zirconia	Metal Ceramic
Low value, high translucency	X	X	X				
Average value and translucency	X	X	X	X			
Opaque, high value					X	X	X

Adapted from Chu SJ, et al: Dental color matching instruments and systems. Review of clinical and research aspects. J Dent 38(Suppl 2): e2, 2010.

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FIGURE 23-19 ■ **A,** A custom shade guide. **B,** Commercially available tabs for fabricating custom shade samples. (**A,** Courtesy Dr. A.M. Peregrina.)

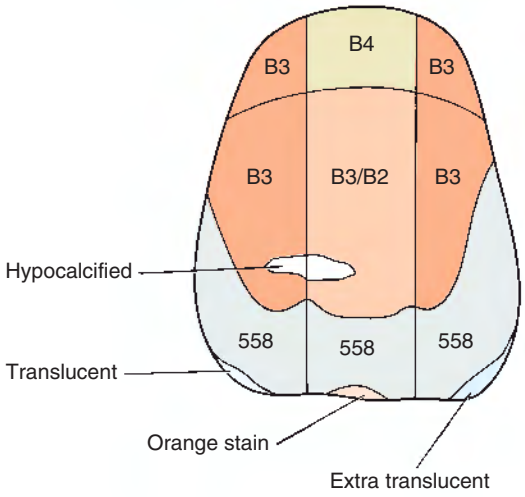

FIGURE 23-20 ■ Shade distribution chart.

Shade Distribution Chart or Images. Shade distribution charting (Fig. 23-20) is a practical approach to accurate shade matching and is recommended even when a fairly good match is available from the commercial shade sample.

The tooth is divided into three regions: cervical, middle, and incisal. Each region is matched independently, either to the corresponding area of a commercial shade sample or to a single-color porcelain chip. Because only a single color is matched, intermediate shades can usually be estimated rather easily and duplicated by means of mixing porcelain powders. The junctions between these areas are normally distinct and can be communicated to the laboratory in the form of a diagram. The shade distribution and thickness of the enamel porcelain are particularly important.[40] Individual characteristics are marked on such a sketch and enable the ceramist to mimic details such as hairline fractures, hypocalcification, and proximal discolorations. Alternatively, the information on the individual characteristics can be transferred to the laboratory through a digital image with the close matching shade tap. Having the shade tap in the image allows the technician to calibrate the color of the digital image on the computer monitor.[41]

Summary of Guidelines for Visual Shade Matching

Regardless of which shade guide system is used, the following principles should be followed:

1. Shade matching should be made under balanced lighting and in an appropriate shade-matching environment with gray or pastel-colored walls and cabinets.
2. Anything on the patient that influences the shade matching, including brightly colored clothing, should be draped, and lipstick should be removed.
3. The teeth to be matched should be clean. If necessary, stains should be removed by prophylactic treatment.
4. Shade matching should be made at the beginning of a patient's visit. Tooth color increases in value when the teeth are dry, particularly if a rubber dam has been used.
5. Cheek retractors should be used to provide an unhindered intraoral shade-matching area.
6. The dentist can expand the choices of shade tab by using several shade guides or mentally noting that the shade of the tooth could be between two shade tabs. The technician should be asked to mix the porcelain in equal amounts to obtain an in-between shade.
7. The patient should be viewed at eye level so that the most color-sensitive part of the dentist's retina is used. The viewing working distance should be approximately 25 cm (10 inches).
8. If the tooth and shade tab have different surface characteristics, wetting the surface of both helps remove the differences.
9. Shade matching should be made quickly (less than 5 seconds), with the shade tab placed directly next to the tooth being matched. This ensures that the background of the tooth and the shade sample are the same, which is essential for accurate matching. The dentist should be aware of eye fatigue,

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particularly if very bright fiberoptic illumination has been used.

10. The dentist should rest his or her eyes between viewings by focusing on a neutral gray surface immediately before a matching; this balances all the color sensors of the retina. Resting eyes on a blue card was once advised, but it is no longer recommended because it results in blue fatigue.
11. To select the appropriate hue, the canine tooth is recommended for comparison because it has the highest chroma of the dominant hue.
12. The dentist can select an appropriate value by squinting.
13. The number of shade tabs should be reduced and separated to approximately three as quickly as possible. Then one or two of the shade tab that matches the best should be reselected.
14. Shade matching should be confirmed at one or two other visits and, if possible, confirmed with an auxiliary staff member. It is also recommended that shade selection be confirmed under several different lightings.
15. If an exact match cannot be selected, a shade tab with the lower chroma and highest value should be selected because extrinsic characterization can be used to increase chroma and reduce the value (see Chapter 29).
16. The dentist should map the polychromatic nature of the tooth being matched—its special characteristics (e.g., cracks, hypocalcification, and translucency of the incisal enamel of the tooth)—with one of the following: (1) a shade distribution chart, (2) a digital image with the closest shade tab beside the tooth, or (3) staining of the closest matching shade tab.

INSTRUMENTAL COLOR ANALYSIS

Color-Measuring Instruments

Color matching for dental restorative materials is generally done visually by matching with a shade sample. In industry, electronic color-measuring instruments such as spectrophotometers, spectroradiometers, and colorimeters are used. Spectrophotometers and spectroradiometers measure light reflectance at wavelength intervals over the visible spectrum. Spectrophotometers differ from spectroradiometers primarily in that they have a stable light source and usually have an aperture between the detector and sample. Colorimeters provide direct color coordinate specifications without mathematical manipulation. This is accomplished by sampling of light reflected from an object through three color filters that simulate the response of the color receptors in the eye.

Color-measuring instruments with an aperture between the translucent object and the illumination and sensor have been shown to exhibit "edge loss" when carrying out measurements.[42,43] Edge loss is a phenomenon in which light scattered through a translucent material ordinarily would be seen by the eye but is simply not measured by the instrument. This happens when the light is scattered in the translucent object away from the aperture and does not return back through the aperture to the sensor; the phenomenon has been shown to be wavelength dependent. Thus, color-measuring instruments measuring translucent objects with an aperture assign incorrect color coordinates.[43] The phenomenon must be avoided if accurate color measurements of translucent objects, such as teeth and porcelain, are to be obtained, which is done with a combination of an external light source that does not cause shadowing and a spectroradiometer (Fig. 23-21). CIELAB data measured with this arrangement for three different shade guides and 359 anterior teeth from 120 participants[44] are shown in Figure 23-22.[33]

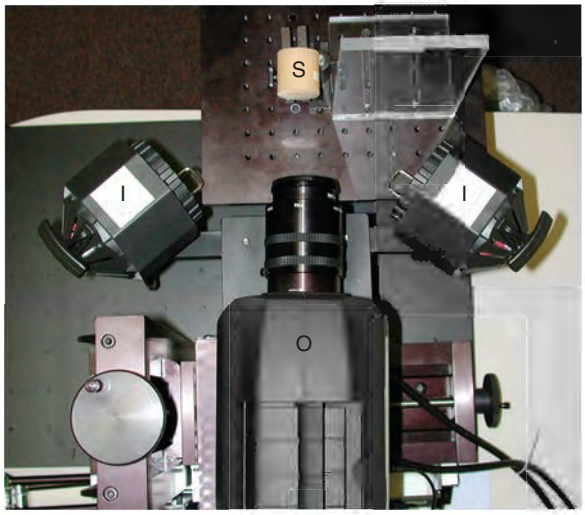

FIGURE 23-21 ■ Spectroradiometer (PR 705, Photo Research, Inc.) with an optical setup of 45-degree illumination *(I)* and 0-degree observer *(O)* for measurements of a translucent material specimen *(S)*.

Various clinical color-measuring devices used to be available, but currently only different versions of the VITA Easyshade (VITA North America) are widely available (Fig. 23-23). According to in vitro testing of some of these devices with various shade tabs, their reliability is approximately 90%, whereas their accuracy ranges from approximately 60% to 90%.[45,46] Initial clinical testing of some of these instruments shows similar clinical outcomes for visual matching.[47,48]

A different approach to the "hardware" method described previously is a software approach with image analysis. Images are captured by a clinical digital camera, and each is "calibrated" after the image is taken (Fig. 23-24). The calibration entails mathematically adjusting known references in the image. ShadeWave (ShadeWave, LLC) has a library of shade guides with their corresponding shade tabs. This includes not only tabs for teeth but also tabs for gingiva and stump shades.

Once an image is calibrated, the unknown image components are discovered and segmented on the tooth. These include not only the shade but also translucency and value.

Images and processing are done in the cloud by Health Insurance Portability and Accountability Act

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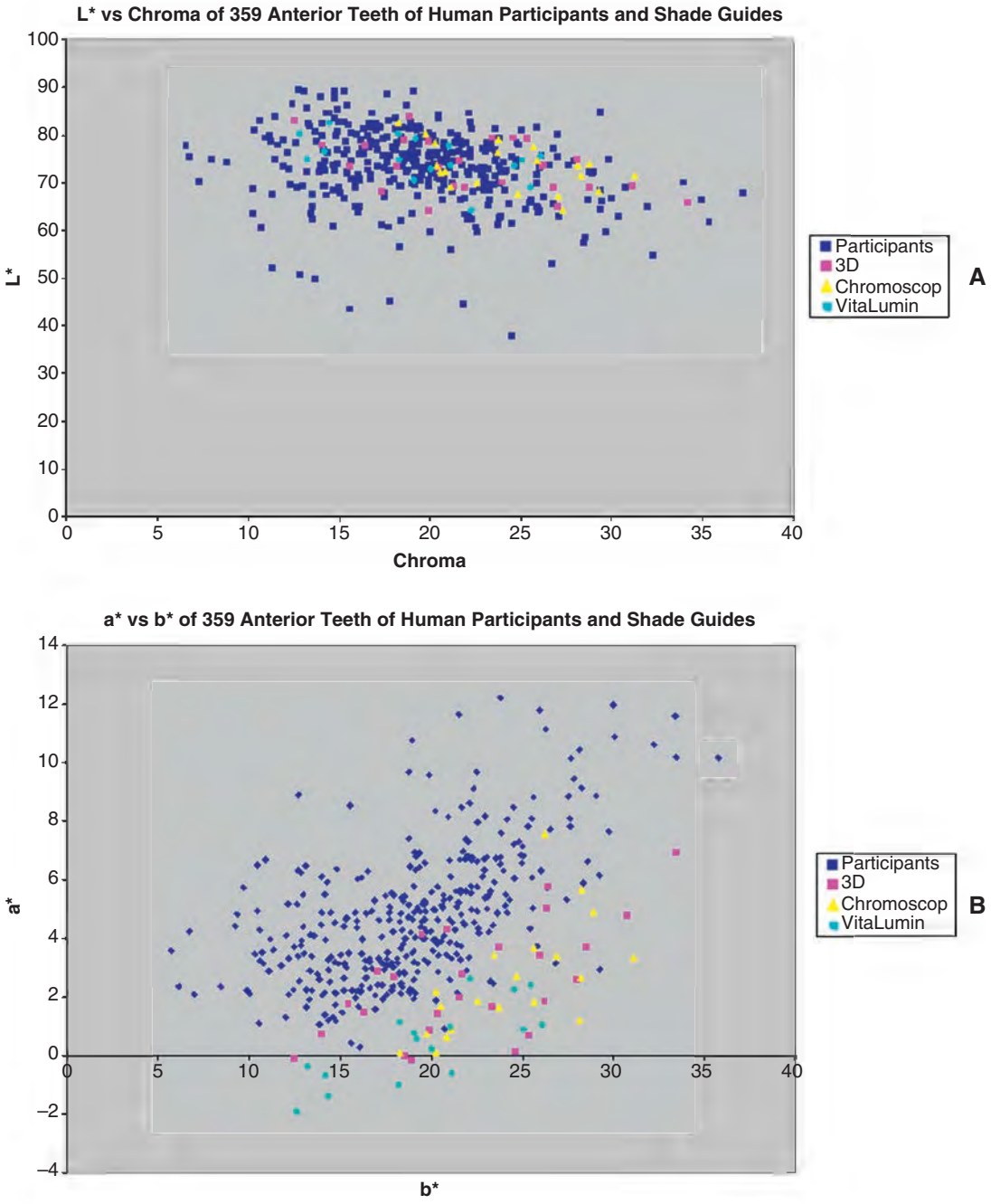

FIGURE 23-22 ■ **A** and **B,** Comparison between colors of 359 anterior teeth and three shade guides: VITA Toothguide 3D-MASTER®, Ivoclar Vivadent Chromascop (Chromascop), and VITA classical (Lumin Vacuum) (VitaLumin). **A,** L* versus chroma. **B,** a* versus b*. (From Bayindir F, et al: Coverage error of three conceptually different shade guide systems to vital unrestored dentition. J Prosthet Dent 98:175, 2007.)

(HIPAA)–compliant remote servers. The advantage of this is global communication of information to and from dentist, laboratory, and specialist in one location.

SHADE-DUPLICATION PHASE

Errors associated with the duplication of the selected shade with dental porcelain are well documented. These errors are related to the underlying metal used,[49,50] the batch of porcelain powder,[51] the brand of porcelain,[6,52] and the number of times that glazing was performed.[53]

Visually detectable differences between the color of the shade tab and the fired porcelain are not uncommon.[52,54] Surface corrections of these errors include surface characterization, as discussed in Chapter 29. Another strategy that has been used is to include custom shade guides (see Fig. 23-18) in the shade-matching

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FIGURE 23-23 ■ **A**, The VITA Easyshade Advance 4.0 shade-measuring system. **B**, The VITA Easyshade Compact system. The probe tip is placed on the tooth, and the tooth shade is recorded in VITA classical (Lumin Vacuum) or VITA Toothguide 3D-MASTER® units. (**A**, Courtesy VITA North America, Yorba Linda, California.)

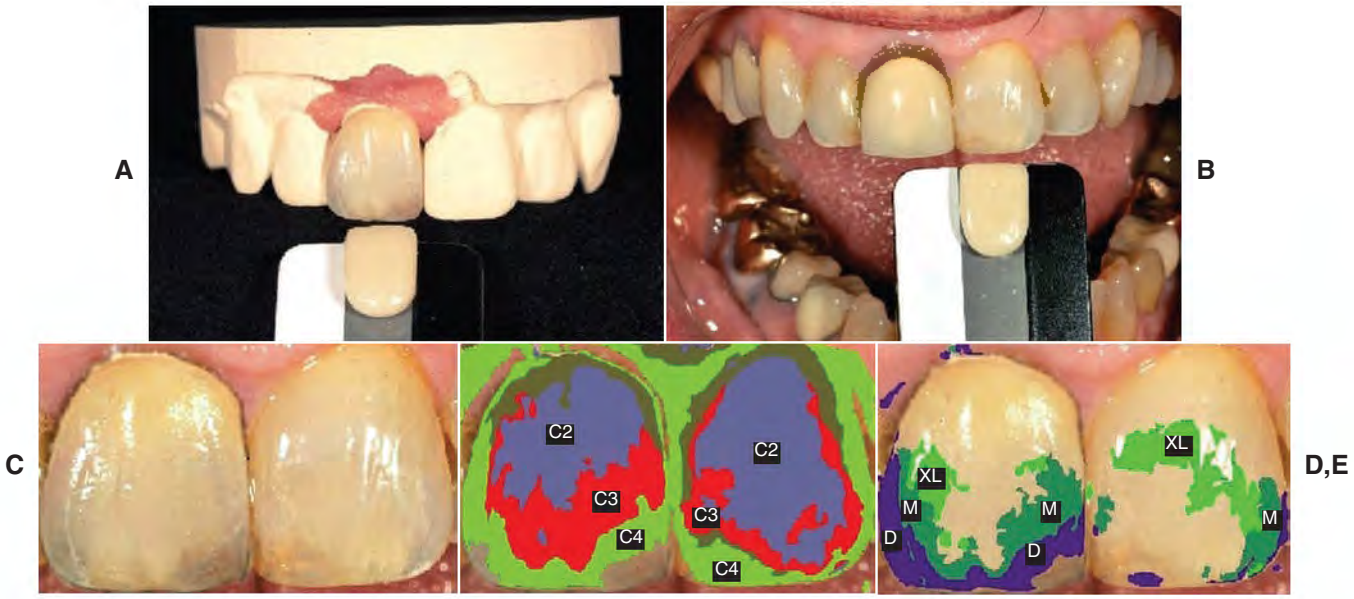

FIGURE 23-24 ■ The shade reference **(A)** is placed beside the adjacent tooth **(B)**, and a digital image is made **(C)**. The image is uploaded and viewed within the ShadeWave program **(D)**. The selected shade and translucency are then mapped on to the image **(E)**. (Courtesy ShadeWave; L. Lammott, Technician; and Dr. J. Gutierrez, Brookfield, CT)

process. The custom shade guide should be from the same metal and porcelain type that will be used when the metal-ceramic crown is fabricated.

In summary, as shown in Figure 23-25, the strategies for porcelain shade replication are as follows:

- Use fabricated custom shade taps with ceramic materials that you commonly use for fixed restorations.
- If you are using instrumental color analysis, verify the selected shade visually at that appointment.
- Duplicate the polychromatic nature, translucency, and individual characteristics of the adjacent teeth.
- Mix porcelain to obtain in-between shades; this can be used to refine the shade duplication.

ESTHETICS

Esthetics is the study of beauty. Knowledge of esthetics helps the dentist achieve an appearance pleasing to the patient. A successful prosthodontic restoration provides the patient with excellent long-term function. It should also produce an attractive smile; esthetics is often the

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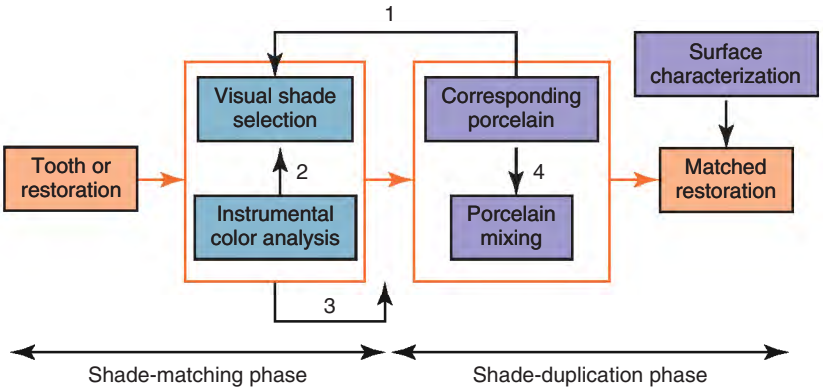

FIGURE 23-25 ■ Summary of the strategies for porcelain shade replication.

primary motivating factor for patients to seek dental care.[55] In fact, correction of esthetic problems has a positive effect on self-esteem.[56]

Anatomy of a Smile

Most people believe they can recognize an attractive smile, but individual opinion varies, particularly when cultural factors are considered. In research, investigators show participants photographs or computer-manipulated images of various smiles, and participants grade the images for attractiveness[57,58] (Fig. 23-26). Such research is quantified in the standard "dental aesthetic index" (DAI), an orthodontic treatment-need index based on perceptions of dental esthetics in the United States.[59] In general, an extensive smile that showed the complete outline of the maxillary anterior teeth and teeth posterior to the first molar was considered the most attractive and youthful (Fig. 23-27). (A smile in an aging individual shows less of the maxillary incisors and more of the mandibular incisors.)

The *buccal corridor* refers to the amount of space between the cheeks and teeth in a smile and is related to the width of the dentition and the width of the mouth during a smile[60] (Fig. 23-28). The *smile arc* is the relative curvature of incisal edges of the maxillary teeth and the curvature of the lower lip. In smiles that were considered the most attractive, these curvatures were very similar,[61] a factor that should be considered when restorations are shaped.

Proportion

Esthetics depends largely on proportion. An object is considered beautiful if it is properly proportioned and unattractive if it is top-heavy, squat, or out of proportion. Concepts of proportion are probably based on what is found in nature. Leaves, flowers, shells, and pine cones normally develop in proportion. Their growth is closely related to a mathematical progression (the *Fibonacci series*[‖]) in which each number is the sum of the two

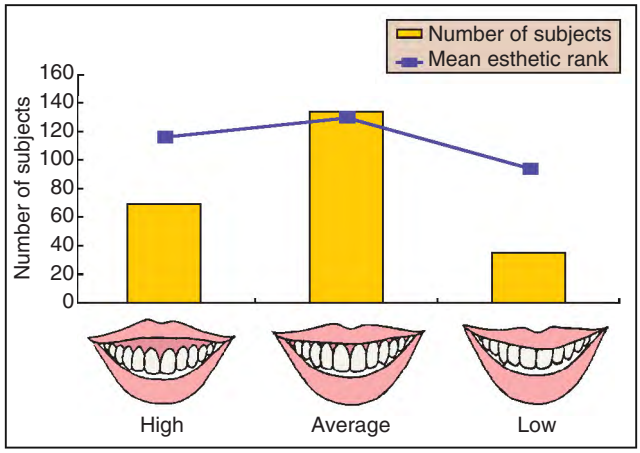

FIGURE 23-26 ■ Mean esthetic ranking of smiles with three upper lip positions. (From Dong JK, et al: The esthetics of the smile: a review of some recent studies. Int J Prosthodont 12:9, 1999.)

immediately preceding it (i.e., 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, and so on). The ratio between succeeding terms converges on approximately 1.618:1, known as the *golden proportion*. When a line is bisected in the golden proportion, the ratio of the smaller section to the larger section is the same as the ratio of the larger section to the whole line (Fig. 23-29). The golden proportion was used extensively in ancient Greek architecture and is exemplified in the Parthenon.

Claims have been made[62] that the golden proportion exists in natural dentitions in the ratio of the widths of incisors and canines, as seen from the front. Waxing guides, grids, or special calipers (Panadent Corporation) that always extend to the golden proportion can be used, which may be helpful in designing a well-proportioned prosthesis (Fig. 23-30). However, studies of simulated smiles (Fig. 23-31) have revealed that designing prostheses to match the golden proportion is by no means optimal, except for patients in whom incisor length may be increased after periodontal disease.[63,64] Other investigators have attempted to apply mathematical concepts to

[‖]After Leonardo Fibonacci (c. 1170-c. 1250), Italian mathematician, who devised it in the thirteenth century.

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FIGURE 23-27 ■ Computer image manipulation was used to determine the attractiveness of various smiles. Light colors and oval-shaped teeth in women (**A** to **D**) and rectangular teeth in men (**E** to **G**) were considered the most attractive. (From Carlsson GE, et al: An international comparative multicenter study of assessment of dental appearance using computer-aided image manipulation. Int J Prosthodont 11:246, 1998.)

FIGURE 23-28 ■ Computer imaging illustrating variations in buccal corridor and smile arc. *Acc,* Accentuated. (Courtesy Dr. J. Parekh.)

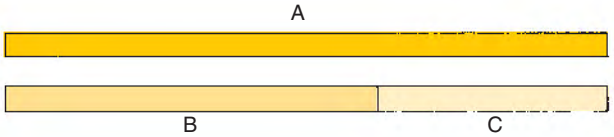

FIGURE 23-29 ■ The golden proportion. The ratio of *A* to *B* (1.618 to 1) is the same as that of *B* to *C.*

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FIGURE 23-30 ■ The calipers always extend to the golden proportion.

FIGURE 23-31 ■ Computer-simulated smiles. **A,** The anterior teeth are manipulated to give average proportion values. The lateral incisors are 66% the width of the central incisors, and the canines are 84% the width of the lateral incisors. **B,** These anterior teeth have been manipulated to reflect the golden proportion. The lateral incisors are 62% the width of the central incisors, and the canines are 62% the width of the lateral incisors. In an Internet survey, only 8% of general public respondents preferred or much preferred the golden proportion image. (From Rosenstiel SF, Rashid RG: Public preferences for anterior tooth variations: a Web-based study. J Esthet Restor Dent 14:97, 2002.)

dental esthetics.[65] Of particular importance to anterior tooth esthetics appears to be the ratio of height to width of the maxillary incisors. When dentists were asked to select the most attractive smile, they consistently chose the image in which the maxillary incisor height-to-width ratio was closest to the range of 75% to 78% (Fig. 23-32).[63,66] These findings are consistent with the preferences of the general population.

Balance

Balance, including the location of the midline (Fig. 23-33), is an important prosthodontic concept.[67] The observer expects the left and right sides of the mouth to balance out, if not to match precisely. An obvious restoration on one side may be balanced if there is a diastema or a large tooth on the other side. If something is out of balance, the brain infers that there is an unreciprocated force and an unstable arrangement; a balanced arrangement implies stability and permanence.

Midline

Coincidence of facial and incisal midlines is stressed when orthodontic treatment planning is assessed and should be carefully evaluated in the planning of prosthodontic treatment. Studies have shown that the mean threshold for acceptable dental midline deviation is 2.2 ± 1.5 mm[68] and that there was no difference in the perception of midline discrepancies between orthodontists and young laypeople; differences in this perception increased with the size of the discrepancy but not by sex.[64,69]

Incisal Embrasure Form

The shape of incisal embrasures can have a dramatic effect on dental esthetics (Fig. 23-34). Embrasure form is increased in young dentition, and a restoration with unnaturally reduced embrasures can appear unattractive. However, some patients demand reduced embrasures, seeking "perfectly" even incisal edges, although this appearance was "preferred" or "strongly preferred" by fewer than 30% of respondents to an Internet survey.[64] As with all aspects of personal esthetics, the patient's opinion is paramount; the dentist provides expert knowledge. In restoring with multiple ceramic restorations, a sensible approach to achieving optimal incisal embrasure form is to instruct the dental laboratory to return restorations with reduced embrasure form. During the evaluation procedure, the embrasures can be carefully increased intraorally according to the patient's wishes.

Incisor Angulation

The mesial or distal angulation of the maxillary incisor teeth can have a dramatic effect on esthetics (Fig. 23-35). In general, slight mesial angulation is acceptable, but distal angulation should be avoided.[66] Knowledge of these principles and attention to detail in designing anterior restorations is the key to highly esthetic restorations.

SUMMARY

An understanding of the science of color and color perception is crucial for success in the ever-expanding field of esthetic restorative dentistry. Although limitations in

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FIGURE 23-32 ■ Computer-simulated smiles in which the central incisors had different height-to-width ratios: 89% **(A),** 85% **(B),** 77% **(C),** and 73% **(D). C** was chosen as best by 65% of dentists responding, followed in popularity by **B, D,** and **A.** (From Rosenstiel SF, et al: Dentists' perception of anterior esthetics: a Web-based survey [Abstract no. 1481]. J Dent Res 83 [Special Issue A], 2004.)

FIGURE 23-33 ■ Poor esthetics resulting from a lack of balance. The differences in central incisor and canine heights and misaligned midline contribute to lack of symmetry.

materials and techniques may make a perfect color match impossible, a harmonious restoration can almost always be achieved. Shade matching should be approached in a methodical and organized manner. This enables the practitioner to make the best choice and communicate it accurately to the laboratory. Newly developed shade systems and instruments may help the practitioner achieve a reliable restoration match.

The size and shape of restorations are equally important when a highly esthetic result is sought. Knowledge of the optimal proportion and the relative position of the teeth to each other and the soft tissues is essential.

FIGURE 23-34 ■ Computer-simulated smiles used to evaluate the response to incisal embrasure form. **A,** Natural embrasures. **B,** Reduced embrasures. In an Internet survey with 1934 responses, **A** was much preferred by 25% and preferred by 36%, and **B** was much preferred by 9% and preferred by 19%. Ten percent expressed no preference. (From Rosenstiel SF, Rashid RG: Public preferences for anterior tooth variations: a Web-based study. J Esthet Restor Dent 14:97, 2002.)

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FIGURE 23-35 ■ Computer-simulated images used to evaluate the effect of incisor angulation on anterior esthetics. Three-degree distal inclination of the central incisor **(A)** is preferred to 3-degree mesial inclination **(B).** Three-degree distal inclination of the lateral incisor **(C)** is preferred to 3-degree mesial inclination **(D).** (From Rosenstiel SF, et al: Dentists' perception of anterior esthetics: a Web-based survey [Abstract no. 1481]. J Dent Res 83 [Special Issue A], 2004.)

REFERENCES

1. Munsell AH: A color notation, 11th ed. Baltimore, Munsell Color Co., 1961.
2. Sproull RC: Color matching in dentistry, II. Practical applications of the organization of color. J Prosthet Dent 29:556, 1973.
3. Hammad IA, Stein RS: A qualitative study for the bond and color of ceramometals. II. J Prosthet Dent 65:169, 1991.
4. Rinke S, et al: Colorimetric analysis as a means of quality control for dental ceramic materials. Eur J Prosthodont Restor Dent 4:105, 1996.
5. Seghi RR, et al: Spectrophotometric analysis of color difference between porcelain systems. J Prosthet Dent 56:35, 1986.
6. Rosenstiel SF, Johnston WM: The effect of manipulative variables on the color of ceramic metal restorations. J Prosthet Dent 60:297, 1988.
7. Okubo SR, et al: Evaluation of visual and instrument shade matching. J Prosthet Dent 80:642, 1998.
8. Wyszecki G, Stiles WS: Color science: concepts and methods, quantitative data and formulae, 2nd ed, p 840. New York, Wiley & Sons, 1982.
9. van der Burgt TP, et al: A comparison of new and conventional methods for quantification of tooth color. J Prosthet Dent 63:155, 1990.
10. Culpepper WD: A comparative study of shade-matching procedures. J Prosthet Dent 24:166, 1970.
11. Geary JL, Kinirons MJ: Colour perception of laboratory-fired samples of body-coloured ceramic. J Dent 27:145, 1999.
12. Saleski CG: Color, light and shade matching. J Prosthet Dent 27:263, 1972.
13. Paravina RD, et al: Color comparison of two shade guides. Int J Prosthodont 15:73, 2002.
14. Romney AK, Indow T: Estimating physical reflectance spectra from human color-matching experiment. Proc Natl Acad Sci USA 99:14607, 2002.
15. Sproull RC, Preston JD: Understanding color. In Goldstein RE, ed: Esthetics in dentistry, vol 1, p 207. London, BC Decker, 1998.
16. Bergen SF: Color education in the dental profession [Master's thesis]. New York, New York University, 1975.
17. Bergen SF, McCasland J: Dental operatory lighting and tooth color discrimination. J Am Dent Assoc 94:130, 1977.
18. Preston JD, et al: Light and lighting in the dental office. Dent Clin North Am 22:431, 1978.
19. Barna GJ, et al: The influence of selected light intensities on color perception within the color range of natural teeth. J Prosthet Dent 46:450, 1981.
20. Preston JD, Bergen SF: Color science and dental art. St. Louis, Mosby, 1980.
21. Lemire PA, Burk B: Color in dentistry. Hartford, CT, JM Ney Co., 1975.
22. Hall GL, Bobrick M: Improved illumination of the dental treatment rooms. SAM-TR-68-103. Tech Rep SAM-TR (December):1, 1968.
23. Wyszecki G, Stiles WS: Color science: concepts and methods, quantitative data and formulae, 2nd ed, p. 519. New York, Wiley & Sons, 1982.
24. Land EH: The retinex theory of color vision. Sci Am 237:108, 1977.
25. Wyszecki G, Stiles WS: Color science: concepts and methods, quantitative data and formulae, 2nd ed, p. 236. New York, Wiley & Sons, 1982.
26. Seghi RR, Johnston WM: Estimate of colorimetric measurement errors associated with natural tooth fluorescence [Abstract no. 1578]. J Dent Res 71:303, 1992.
27. Yamamoto M: Newly developed opal ceramic and its clinical use with respect to relative breaking indices. I. Significance of opalescence and development of opal ceramic. Quintessenz Zahntech 15:523, 1989.
28. Hegenbarth EA: Opalescence effect in low melting ceramic. Quintessenz Zahntech 17:1415, 1991.
29. Rushton WAH: Visual pigments and color blindness. Sci Am 232:64, 1975.
30. Davidson SP: Shade selection by color vision defective dental personnel. J Prosthet Dent 63:97, 1990.

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31. Hall NR: Tooth colour selection: the application of colour science to dental colour matching. Aust Prosthodont J 5:41, 1991.
32. Bayindir F, et al: Coverage error of three conceptually different shade guide systems to vital unrestored dentition. J Prosthet Dent 98:175, 2007.
33. O'Brien WJ, et al: Coverage errors of two shade guides. Int J Prosthodont 4:45, 1991.
34. McPhee ER: Light and color in dentistry. I. Nature and perception. J Mich Dent Assoc 60:565, 1978.
35. Ragain JC, Johnston WM: Color acceptance of direct dental restorative materials by human observers. Color Res Appl 25:278, 2000.
36. Wee AG, et al: Color formulation and reproduction of opaque dental ceramic. Dent Mater 21:665, 2005.
37. Wee AG, et al: Categorizing translucency of anterior dentition. J Dent Res 92(Special Issue B):2781, 2013.
38. Heffernan MJ, et al: Relative translucency of six all-ceramic systems. Part II: Core and veneer materials. J Prosthet Dent 88:10, 2002.
39. McLean JW: The science and art of dental ceramics, vol 2, p 308. Chicago, Quintessence Publishing, 1980.
40. Blackman RB: Ceramic shade prescriptions for work authorizations. J Prosthet Dent 47:28, 1982.
41. Chu SJ, et al: Dental color matching instruments and systems. Review of clinical and research aspects. J Dent 38(Suppl 2):e2, 2010.
42. Johnston WM, et al: Analysis of edge-losses in reflectance measurements of pigmented maxillofacial elastomer. J Dent Res 75:752, 1996.
43. Bolt RA, et al: Influence of window size in small-window color measurement, particularly of teeth. Phys Med Biol 39:1133, 1994.
44. Gozalo-Diaz DJ, et al: Measurement of color for craniofacial structures using 45/0-degree optical configuration. J Prosthet Dent 97:45, 2007.
45. Kim-Pusateri S, et al: In-vitro model to evaluate reliability and accuracy of a dental shade matching instrument. J Prosthet Dent 98:353, 2007
46. Kim-Pusateri S, et al: Reliability and accuracy of four dental shade-matching devices. J Prosthet Dent 101:193, 2009.
47. Wee AG, et al: Evaluating porcelain color match of different porcelain shade-matching systems. J Esthet Dent 12:271, 2000.
48. Raigrodski AJ, Chiche GJ: Computerized shade selection in matching anterior metal-ceramic crowns [Abstract no. 395]. J Dent Res 83(Special Issue A), 2004.
49. Brewer JD, et al: Spectrometric analysis of the influence of metal substrates on the color of metal-ceramic restorations. J Dent Res 64:74, 1985.
50. Stavridakis MM, et al: Effect of different high-palladium metal ceramic alloys on the color of opaque porcelain. J Prosthodont 9:71, 2000.
51. O'Brien WJ, et al: Sources of color variation on firing porcelain. Dent Mater 7:170, 1991.
52. Groh CL, et al: Differences in color between fired porcelain and shade guides. Int J Prosthodont 5:510, 1992.
53. Jorgenson MW, Goodkind RJ: Spectrophotometric study of five porcelain shades relative to the dimensions of color, porcelain thickness, and repeated firings. J Prosthet Dent 42:96, 1979.
54. Douglas RD, Przybylska M: Predicting porcelain thickness required for dental shade matches. J Prosthet Dent 82:143, 1999.
55. Elias AC, Sheiham A: The relationship between satisfaction with mouth and number and position of teeth. J Oral Rehabil 25:649, 1998.
56. Davis LG, et al: Psychological effects of aesthetic dental treatment. J Dent 26:547, 1998.
57. Dong JK, et al: The esthetics of the smile: a review of some recent studies. Int J Prosthodont 12:9, 1999.
58. Carlsson GE, et al: An international comparative multicenter study of assessment of dental appearance using computer-aided image manipulation. Int J Prosthodont 11:246, 1998.
59. Proffit WR, Fields HW: Contemporary orthodontics, 3rd ed. St. Louis, Mosby, 2000.
60. Johnson DK, Smith RJ: Smile esthetics after orthodontic treatment with and without extraction of four first premolars. Am J Orthod Dentofacial Orthop 108:162, 1995.
61. Sarver DM: The importance of incisor positioning in the esthetic smile: the smile arc. Am J Orthod Dentofacial Orthop 120:98, 2001.
62. Levin EI: Dental esthetics and the golden proportion. J Prosthet Dent 40:244, 1978.
63. Rosenstiel SF, et al: Dentists' preferences of anterior tooth proportion—a Web-based study. J Prosthodont 9:123, 2000.
64. Rosenstiel SF, Rashid RG: Public preferences for anterior tooth variations: a Web-based study. J Esthet Restor Dent 14:97, 2002.
65. Ahmad I: Geometric considerations in anterior dental aesthetics: restorative principles. Pract Periodont Aesthet Dent 10:813, 1998.
66. Rosenstiel SF, et al: Dentists' perception of anterior esthetics. A Web-based survey [Abstract no.1481]. J Dent Res 83 (Special Issue A), 2004.
67. Lombardi RE: The principles of visual perception and their clinical application to denture esthetics. J Prosthet Dent 29:358, 1973.
68. Beyer JW, Lindauer SJ: Evaluation of dental midline position. Semin Orthodont 4:146, 1998.
69. Johnston CD, et al: The influence of dental to facial midline discrepancies on dental attractiveness ratings. Eur J Orthod 21:517, 1999.

STUDY QUESTIONS

1. Discuss the relationship of the visible spectrum to the electromagnetic energy spectrum, color, and invisible waves.

2. What is the Munsell color order system? Define the individual measures used.

3. What is the CIELAB color system? Define the individual measures used.

4. How does the human eye function? How does it recognize color, light, and dark?

5. What is metamerism? How can it be avoided or minimized? What is color adaptation? Color blindness? Fluorescence? The Benham disk is an example of which phenomenon?

6. How should a shade be selected?

7. Explain the differences between the VITA classical (Lumin Vacuum) shade guide and the VITA Toothguide 3D-MASTER®.

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CHAPTER 24

Metal-Ceramic Restorations

HISTORICAL PERSPECTIVE

Ceramic objects have been fabricated for thousands of years. The earliest techniques consisted of shaping the item in clay or soil and then firing it to fuse the particles together. The initial attempts resulted primarily in coarse and somewhat porous products, such as goblets and other forms of pottery. Later developments led to very detailed stoneware items. The Egyptian faiences are the first known effort to coat a substructure with a ceramic veneer (Fig. 24-1). Their typical blue-green hues result from metal oxides forming during the firing process.

Later in antiquity, Chinese ceramists developed porcelain, which was characterized by vitrification, translucency, hardness, and impermeability. European attempts at developing porcelain of similar quality were conducted in the seventeenth century. These efforts spread the knowledge of porcelain's basic components: kaolin and feldspar.

As early as the second half of the eighteenth century, Pierre Fauchard and others attempted to use porcelain in dentistry. These early efforts were largely unsuccessful. However, porcelain was successfully used for dental prostheses by the end of the 1800s, when the technique to fire all-porcelain jacket crowns on a platinum matrix was first developed.[1] It was not until the mid-1950s that a dental porcelain was developed with a coefficient of thermal expansion similar to that of dental casting alloys. The metal-ceramic restoration first became available commercially during the later 1950s.[2] Today this technique is considered a routine procedure with excellent clinical performance.[3]

OVERVIEW

The metal-ceramic restoration (Fig. 24-2) consists of a metal substructure (see Chapter 19) supporting a ceramic veneer that is mechanically and chemically bonded to it. The chemical component of the bond is achieved through firing.

Porcelain powders of varying composition and color are applied to the metal and fired to produce the desired appearance. The first ceramic layer, which is opaque, masks the dark metal oxide and is the primary source of color for the completed restoration. The opaque layer is covered with slightly translucent body porcelain, which is then veneered with an even more translucent enamel overlay that contains relatively little pigmentation. Achieving an accurate appearance match may warrant incorporating either translucent or highly pigmented powders into selected areas of the buildup. The shiny, lifelike appearance of the completed metal-ceramic restoration results from a surface glaze formed during an additional firing after the restoration has been shaped.

Historically, the metal-ceramic restoration was fabricated with metal margins, and the veneer was limited to visible areas. With technological advances, the use of porcelain on occlusal and lingual surfaces has become common.[4] Several techniques[5,6] have been developed to obtain porcelain margins on the facial aspect of the restoration. The latter technique is common for teeth in the esthetic zone, whereas a metal collar may be used in posterior areas in which esthetic appearance is a lesser issue.

METAL PREPARATION

Shape

Sharp angles or pits on the veneering surface of a metal-ceramic restoration should be avoided because they can contribute to internal stress in the final porcelain.[7] Convex surfaces and rounded contours should be created so that the porcelain is supported without development of stress concentrations (Fig. 24-3). In addition, a smooth surface facilitates wetting of the framework by the porcelain slurry.

The intended metal-ceramic junction should be as definite (90-degree angle) and as smooth as possible to make finishing easier during all fabrication stages (Fig. 24-4). The metal framework must be thick enough to prevent distortion during firing. A minimum thickness of 0.3 mm is advocated for the noble metal alloys; 0.2 mm is sufficient for base metal alloys, which can be finished thinner and still withstand distortion because of their higher fusing ranges, moduli of elasticity, and yield strengths (see Chapter 19).

The mechanical properties of a metal-ceramic restoration depend largely on the design of the substructure that supports the ceramic veneer. The metal-ceramic interface must be far away (ideally, at least 1.5 mm) from all centric occlusal contacts and must be distinct to facilitate the removal of excess porcelain. The veneering surface must be finished to a smooth texture with rounded internal angles to allow proper wetting by the opaque porcelain.

Investment Removal

After the framework has been cast, all investment material should be removed ultrasonically with airborne-particle abrasion or with steam (according to the alloy manufacturer's directions). The phosphate-bonded investment material, which must be used with the high-fusing metal-ceramic alloys, is more difficult to remove

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FIGURE 24-1 ■ Glazed Egyptian faience tile from the Western Doorway or Gate of the Mortuary Temple of Ramses III, with a "Rekhyet" bird worshipping the cartouche of Ramses III, "Lord of the Two Lands" (ca. 1182–1151 BCE), Dynasty XX, excavated at Medinet Habu by the Oriental Institute. This is an early example of a substructure coated with a ceramic veneer. (Courtesy the Oriental Institute, The University of Chicago.)

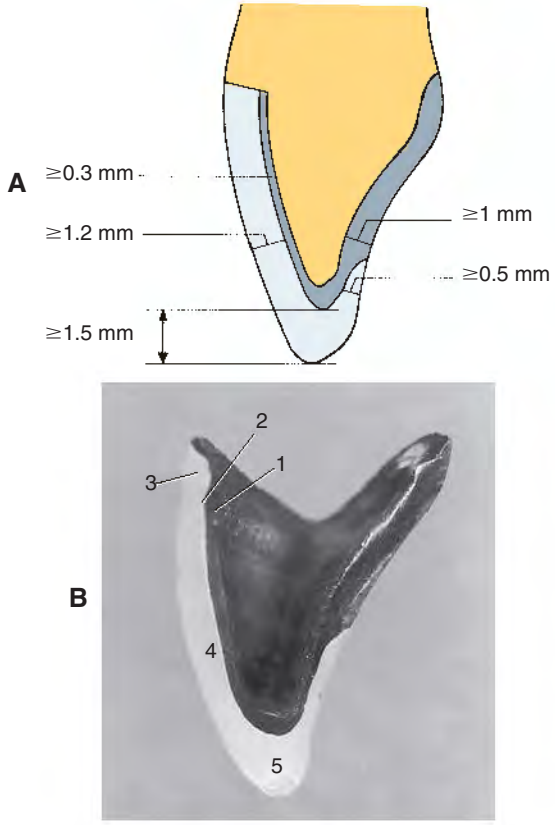

FIGURE 24-2 ■ **A,** Longitudinal section through a metal-ceramic crown. Note the minimum dimensions. **B,** Sectioned metal-ceramic restoration. *1,* Metal substructure; *2,* opaque porcelain; *3,* gingival porcelain; *4,* body porcelain; *5,* incisal porcelain.

from the metal surface than is conventional gypsum-bonded investment material. Hydrofluoric acid dissolves the refractory silica component of the investment material. However, this highly corrosive acid is extremely dangerous and must be handled very cautiously.[8] A small spill

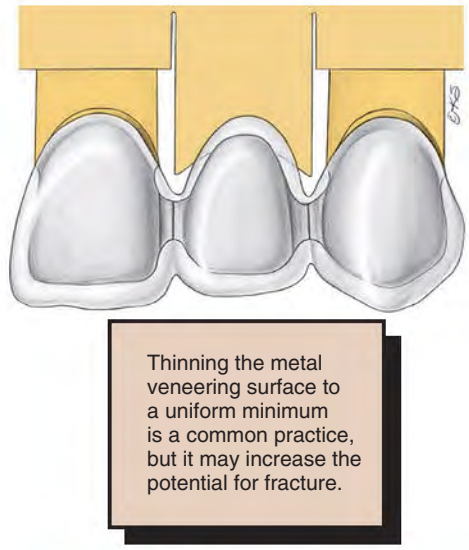

FIGURE 24-3 ■ Substructure design for an anterior partial fixed dental prosthesis. The metal should be shaped to support an even thickness of porcelain.

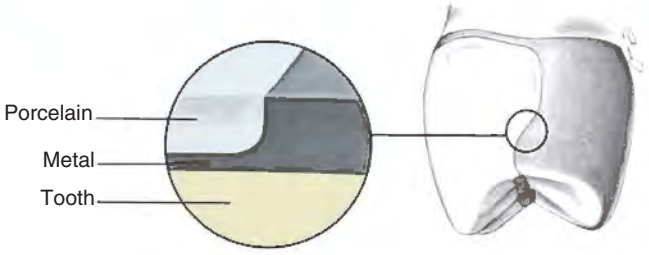

FIGURE 24-4 ■ The metal substructure should have a distinct margin for finishing the veneer.

on the skin results in painful acid burns, and slight exposure to the fumes may produce severe corneal damage. An acid burn on the skin is treated by injection of calcium gluconate in the area, providing a means for the free fluoride from the acid to precipitate. Less dangerous substitute solutions (e.g., Stripit, Keystone Industries) are available.

Careful examination of the internal aspect of the framework under magnification may reveal residual small investment particles. Several cycles of ultrasonic cleaning may be necessary to eliminate all investment material. If airborne-particle abrasion is used for investment removal, the margins of the framework must be protected to prevent damage by the abrasive particles.[9]

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Oxide Removal

The oxide layer that has been formed on the metal surface during casting must be partially removed with either acid or airborne-particle abrasion. For optimal metal-porcelain bonding, the alloy manufacturer's directions should be followed precisely, because achieving a successful bond depends on a controlled thickness of the metal-oxide layer.

Metal Finishing

When the veneering surfaces are ground, care is needed to avoid dragging the metal over itself, which may entrap air and grinding debris (which later can cause bubbling or contamination of the porcelain). Finishing the surface in one direction with light pressure helps avoid trapping debris between folds of the metal, which is a potential problem when alloys with high gold content and high elongation values are used (Fig. 24-5).

The surface should be finished with ceramic-bound stones because the organic binders used in conventional rotary instruments are a potential source of contamination. Tungsten carbide burs also may be used safely. After the surface has been smoothed, it should be airborne-particle abraded with aluminum oxide according to the manufacturer's instructions. This creates a satin finish on the veneering surface that is easily wettable by the porcelain slurry (Fig. 24-6).

Thickness

A dial (or metric) caliper is necessary to verify that the metal substructure conforms to all specified minimum dimensions (Fig. 24-7). Metal thickness of less than 0.3 mm may lead to distortion during firing. Typically, the margin is thinned to a knife edge so that a metal line is not visible. There is no evidence that thinning the margin will adversely affect the fit of restorations cast in contemporary alloys.[10,11] The all-porcelain labial margin

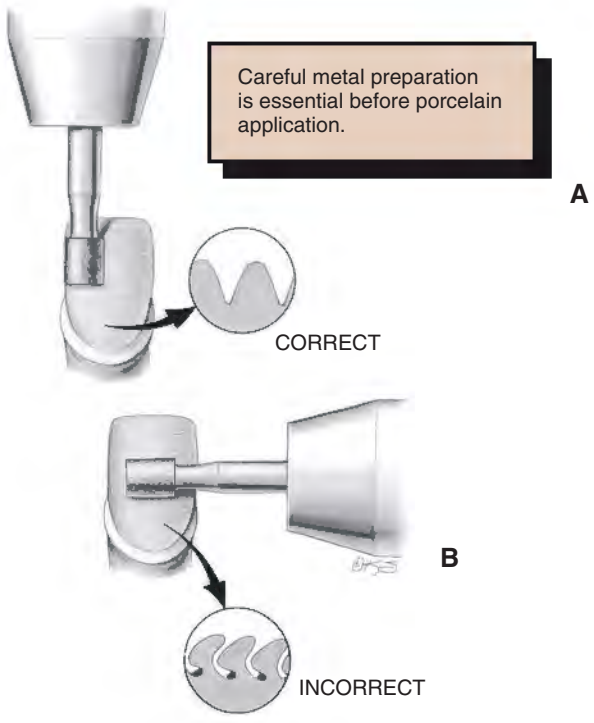

FIGURE 24-5 ■ **A,** Correct way to prepare the veneer area. The metal should be ground in the same direction. **B,** Incorrect multidirectional grinding can cause trapping of debris in the high-noble alloys.

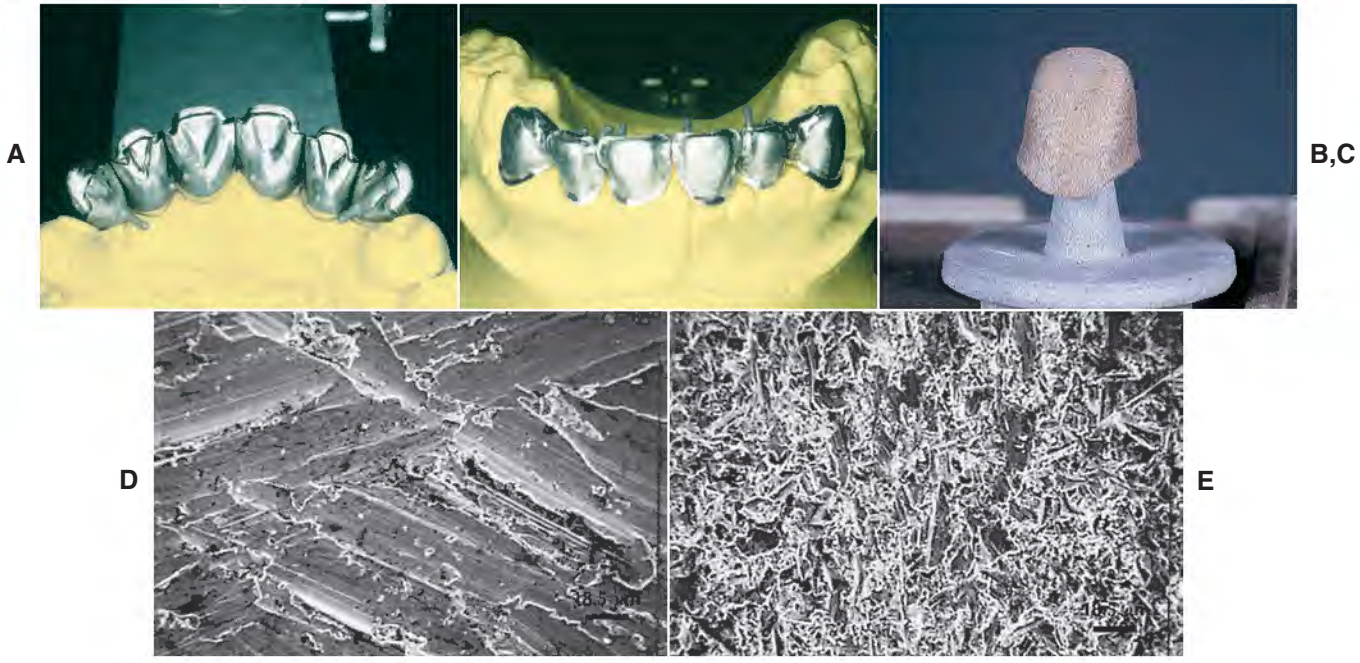

FIGURE 24-6 ■ Metal preparation. **A** and **B,** Castings prepared by grinding. **C,** Satin finish obtained by airborne-particle abrasion. **D** and **E,** Scanning electron micrographs of metal after grinding with a stone **(D)** and with airborne-particle abrasion **(E).** (**D** and **E,** Courtesy Dr. J.L. Sandrik.)

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design can provide a better appearance, particularly when anterior or premolar teeth necessitate good esthetics at the labial margin.

Finishing

Finishing of the metal-ceramic interface is a challenging laboratory procedure that requires attention to detail. The axial surfaces and visible portion of the metal collar should be contoured and finished to a rubber wheel stage before preparation of the veneering surface is attempted (Fig. 24-8, *A* and *B*). At this time, the margin itself is left untouched. Round stones and tungsten carbides can be used to finish the veneering surface at the metal-ceramic interface (see Fig. 24-8, *C*), and the desired right-angle configuration is then easily obtained. Any remaining irregularities can be blended easily with barrel-shaped stones (see Fig. 24-8, *D*).

FIGURE 24-7 ■ Dimensions should be verified with calipers.

When the grinding phase is completed, a satin finish is obtained by airborne-particle abrasion of the veneering surface with a fine-grit alumina (see Fig. 24-8, *E*).

Cleaning

Although a properly prepared framework appears smooth to the naked eye, its appearance is still quite rough when viewed with a microscope. Small particles, grinding debris, oil, and finger grease must be removed because they interfere with the wetting process, which is crucial for a good metal-to-ceramic bond.

The substructure can be cleaned by immersion in a general-purpose cleaning solution in an ultrasonic unit. The duration of the cleaning cycle depends on the unit, but 5 minutes is adequate in most cases. Residual soap can be removed by rinsing of the substructure in distilled water. Some manufacturers recommend following this with a rinse in 92% alcohol (conventional 70% isopropyl alcohol should not be used because it contains aromatic and mineral oils, which may cause contamination). Steam cleaning is an excellent and time-saving alternative to ultrasonic cleaning. To prevent further contamination, the veneering surface should not be touched once the cleaning procedures have been completed.

Oxidizing

To establish the chemical bond between metal and porcelain, a controlled oxide layer must be created on the metal surface (Fig. 24-9). In noble-metal alloys, iron, tin, indium, and gallium are the base elements used for oxide formation (see p. 653).

FIGURE 24-8 ■ Preparing the substructure. **A,** Nonveneering surface finished to the rubber wheel stage. **B** and **C,** Metal-ceramic junction delineated with a tungsten carbide bur. **D,** Veneering surface dressed with a ceramic-bound stone. (To avoid perforation, the metal thickness should be checked regularly with calipers.) **E,** Airborne-particle abrasion of the veneering area. The margins have been protected by soft wax.

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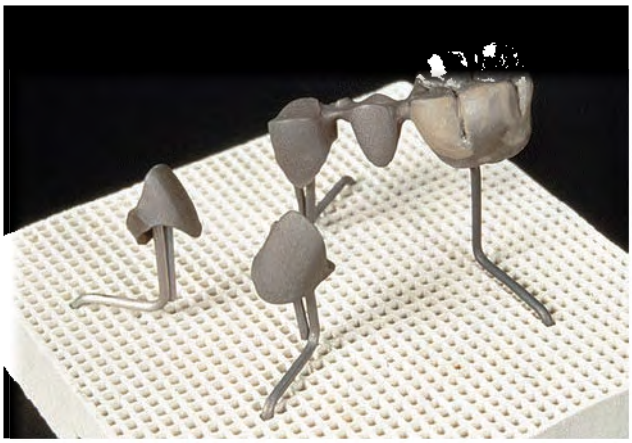

FIGURE 24-9 ■ Metal-ceramic substructure after cleaning and before oxidizing in the porcelain furnace.

TABLE 24-1 **Composition of High-, Medium-, and Low-Fusing Body Porcelains (Weight Percentage)**

	High-Fusing	Medium-Fusing	Low-Fusing (Vacuum Fired)	Metal-Ceramic
SiO_2	72.9	63.1	66.5	59.2
Al_2O_3	15.9	19.8	13.5	18.5
Na_2O	1.68	2.0	4.2	4.8
K_2O	9.8	7.9	7.1	11.8
B_2O_3	—	6.8	6.6	4.6
ZnO	—	0.25	—	0.58
ZrO_2	—	—	—	0.39

Modified from Yamada HN, Grenoble PB: Dental porcelain: the state of the art—1977. Los Angeles, University of Southern California School of Dentistry, 1977.

To obtain the oxide layer, the substructure is typically placed on a firing tray and inserted into the muffle of a porcelain furnace, and the temperature is raised to a specified level that sufficiently exceeds the firing temperature of the porcelain. A vacuum is created in the firing chamber, which, although insufficient to remove adherent gases, reduces the thickness of the oxide layer. The incorrect term *degassing* often is used interchangeably with *oxidizing* (see Factors Affecting the Bond later in this chapter).

Specific procedures may vary slightly, depending on the alloy used. Ceramic alloys with high gold content are usually held at the oxidizing temperature for several minutes. The first porcelain application can be performed as soon as the casting has cooled to room temperature after it is removed from the furnace.

Many of the alloys with lower gold content contain more base elements, which can result in a thicker oxide layer. With some of these alloys, it is therefore not necessary for the casting to be held at the oxidizing temperature for any length of time. To reduce excessive surface oxides, some manufacturers recommend brief airborne-particle abrasion of the casting with alumina or placing it in hydrofluoric acid after firing.

Because of lower costs, the use of nonnoble or base metal alloys for metal-ceramic restorations is now widespread. These alloy systems undergo continuous oxide formation. Although the techniques for different systems vary, most manufacturers prefer not to oxidize substructures made of base metal alloys. Instead, they recommend performing the first porcelain application immediately after cleaning. Because the extent of oxide formation cannot be easily controlled, there is a potential for failure through the thick and brittle oxide layer with these alloy systems. However, it may be of no significance with other alloy systems.

MATERIALS SCIENCE

Isabelle L. Denry • Leon W. Laub

Dental ceramics are generally classified into three groups according to their maturation or fusion range: high-fusing (1290°C to 1370°C [≈2350°F to ≈2500°F]), medium-fusing (1090°C to 1260°C [≈2000°F to 2300°F]), and low-fusing (870°C to 1070°C [≈1600°F to ≈1960°F]). In contrast to denture teeth and the original porcelain jacket crowns, which are fired in the medium- and high-fusing ranges, metal-ceramic veneer restorations are fired in the range of 950°C to 1020°C (≈1750°F to ≈1870°F). This discussion is limited to these low-fusing porcelains.

Porcelain Manufacture

Dental porcelain is produced from a blend of quartz (SiO_2), feldspar (potassium aluminum silicate orthoclase, sodium aluminum silicate albite), and other oxides. During manufacture, the materials are heated to high temperature to form a glassy mass and then are cooled rapidly by quenching in water, which causes the glassy mass to fracture into many small fragments. The resulting product is called a *frit*. This process may be repeated several times, after which the frit is ball-milled until the desired particle size distribution is obtained. Because fritting takes place at temperatures much higher than those used in the fabrication of a dental restoration, most of the chemical reactions between raw materials occur before they are used in the dental laboratory. Typical compositions are listed in Table 24-1, although the actual compositions vary according to the proposed use of the end product. Most formulations designed for metal-ceramic use are similar to that described by Weinstein and colleagues.[12,13] They consist of a mixture of two frits: a low-fusing glass frit and a high-expansion frit consisting of crystalline leucite ($KAlSi_2O_6$; Fig. 24-10) with tetragonal symmetry (Fig. 24-11). This mixture overcomes the two principal difficulties in veneering metal with ceramic: having a porcelain firing temperature well below the melting range of the metal and having a sufficiently high thermal expansion compatible with the metal.

After firing in the laboratory, dental ceramics consist of about 20% volume tetragonal leucite crystals dispersed in a glassy matrix.[14] The structure of this glassy matrix is a random silicon-oxygen network. The silicon atom combines with four oxygen atoms in a tetrahedral configuration (Fig. 24-12). These tetrahedra may be linked into a

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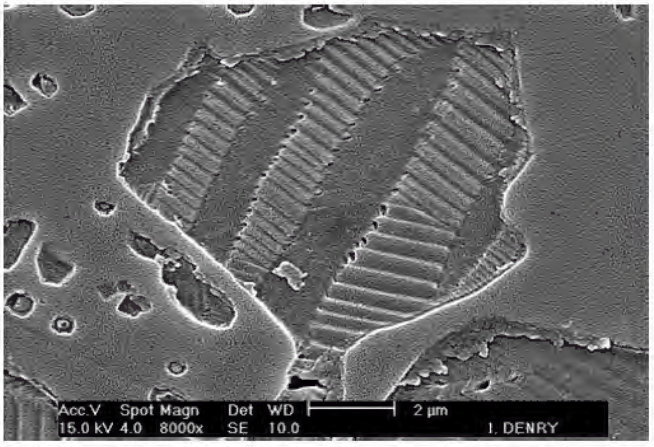

FIGURE 24-10 ■ Scanning electron micrograph of polished and etched leucite-containing dental ceramic, showing a tetragonal leucite crystal.

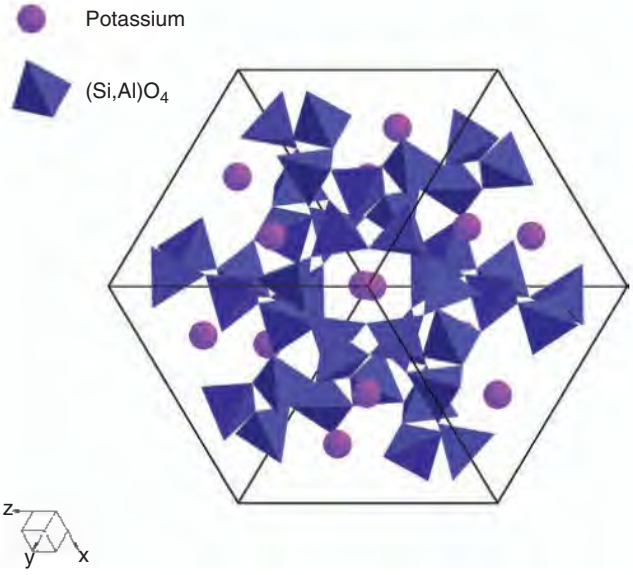

FIGURE 24-11 ■ Crystalline structure of low-temperature (tetragonal) leucite.

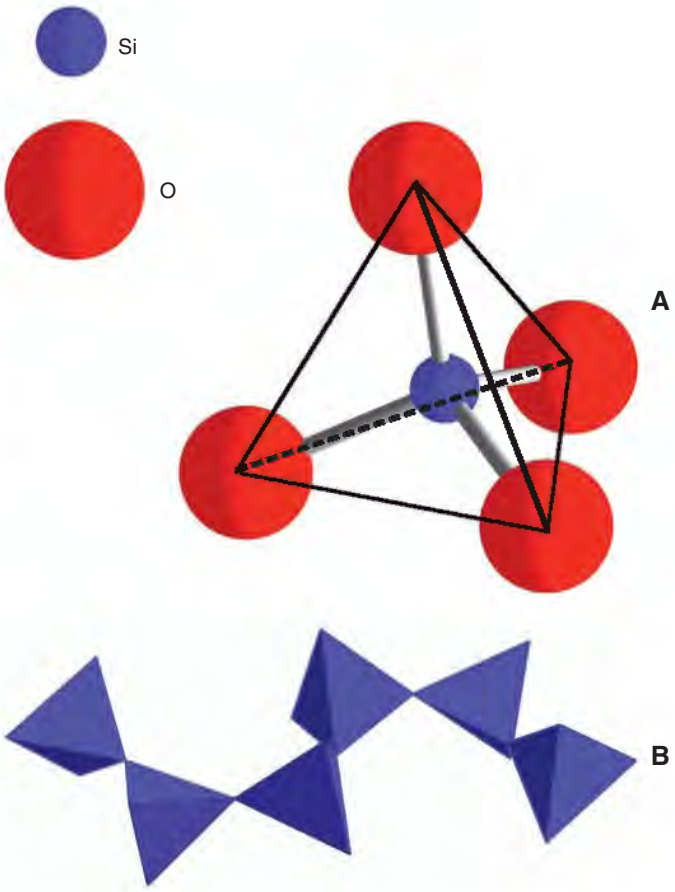

FIGURE 24-12 ■ **A** and **B,** The silicon-oxygen tetrahedral configuration.

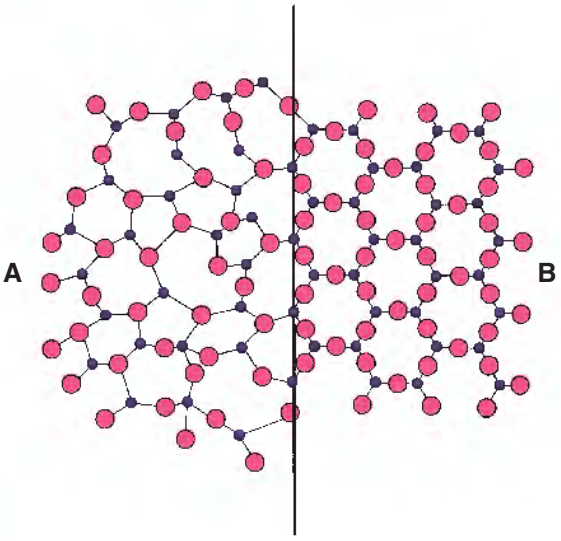

FIGURE 24-13 ■ Change in the silicon-oxygen network structure from a glassy **(A)** to a crystalline **(B)** form. (Modified from Kingery WD, et al: Introduction to ceramics, 2nd ed. New York, Wiley & Sons, 1976.)

chain with both covalent and ionic bonds, which leads to a metastable structure. However, such a silicon-oxygen network would have a very high melting point. Usually, potassium and sodium are added to the glass composition to help break down the silicon-oxygen network and are therefore known as *glass modifiers*. In dental ceramics, potassium and sodium are initially provided by the feldspars. Two desirable consequences result: (1) The softening temperature of the glass is reduced, and (2) the coefficient of thermal expansion is increased. The manufacturer adjusts the oxide content so that the dental ceramic's coefficient of thermal expansion is close to the corresponding value for the alloys used to make the substructure. If the composition of the glass is not properly adjusted, extensive breakdown and reorganization of the silicon-oxygen network may occur, leading to a crystallization of the glass (also called *devitrification*). The change in lattice structure from a vitreous to a crystalline form (devitrification) is shown schematically in Figure 24-13.

Some devitrification may occur in dental ceramics if a ceramic restoration is fired too often, and it is typically associated with an increase in the coefficient of thermal expansion and opacity.

Feldspar also contains alumina (Al_2O_3), which acts as an intermediate oxide to increase the viscosity and

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hardness of the glass. As a result, dental porcelain has a good resistance to slump or pyroplastic flow; this resistance is necessary for obtaining the desired configuration of the restoration.

Porcelain Technique

Dental porcelain is usually received from the manufacturer in powder form, which is mixed with either water or a water-based glycerin-containing liquid to form a paste of workable consistency. This mixture is then used to make a restoration with the required configuration. Several condensation techniques (e.g., vibration and blotting) are used to remove as much excess water as possible. The porcelain particles are drawn together during condensation by capillary action. Proper condensation minimizes steam generation during the drying phase of firing. When the mass is heated, individual porcelain particles conglomerate by sintering. The viscous flow of unfused particles results in wetting and bridging between such particles (Fig. 24-14). Consequently, interstitial space is lost, with as much as a 27% to 45% volumetric shrinkage after firing.[15]

Types of Porcelain

The following porcelain blends are produced for the different roles they play in the fabrication of metal-ceramic restorations: opaque, body, and incisal porcelains.

Opaque Porcelain

This is applied as a first ceramic coat and performs two major functions: It masks the color of the alloy, and it is responsible for the metal-ceramic bond.

Opacifying oxides are added to the original porcelain blend. The density of these oxides is greater than that of the glass matrix. Consequently, the oxides of tin, titanium, and zirconium have a higher refractive index than do the components of the glass matrix (feldspar 2.01 to 2.61 and quartz 1.52 to 1.54). When a specific range of oxide particle sizes is used, most of the incident light is scattered and reflected rather than transmitted through the porcelain, effectively masking the color of the alloy substrate.

A scanning electron microscope (SEM) view of the alloy-porcelain interface[16] for an alloy with high noble metal content is shown in Figure 24-15. When the region

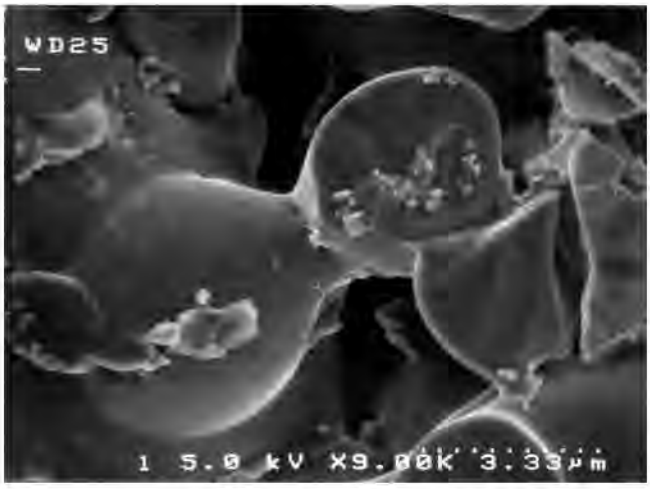

FIGURE 24-14 ■ Vitreous sintering. Partial melting of the unfused particles leads to their bonding. Observe the necking caused by the glass flow. (Modified from Van Vlack LH: Elements of materials science, 2nd ed. Reading, Mass., Addison-Wesley, 1964.)

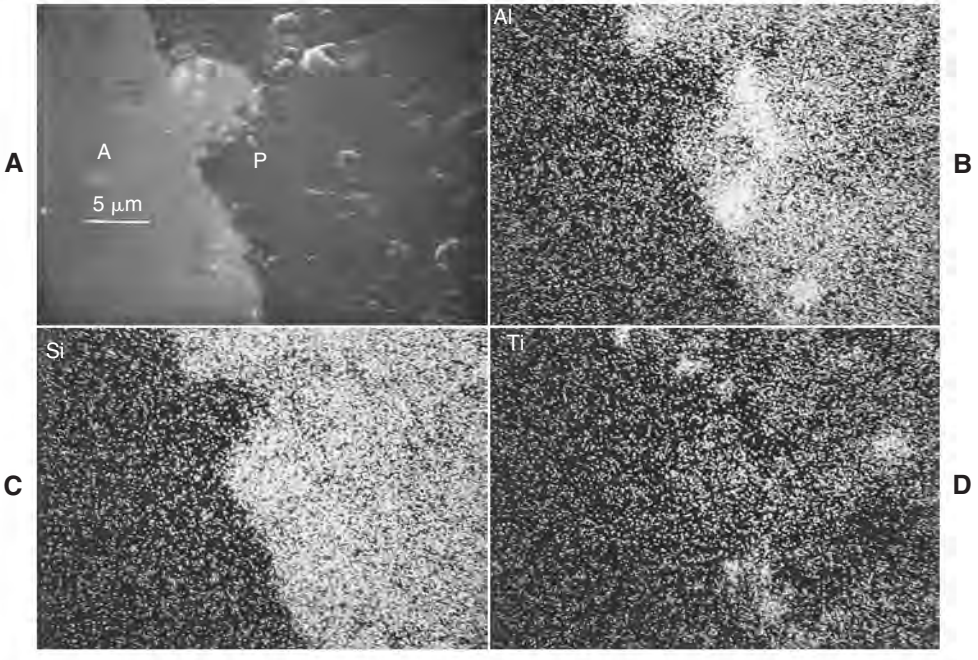

FIGURE 24-15 ■ Alloy-porcelain interface for an alloy with high noble metal content: Degudent U (DENTSPLY International Inc.) and VITA normal (VITA North America). **A,** Scanning electron microscopic view of the interface. **B** to **D,** Elemental maps of aluminum **(B),** silicon **(C),** and titanium **(D).** (From Laub LW, et al: The metal-porcelain interface of gold crowns [Abstract no. 874]. J Dent Res 57:A293, 1978.)

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around the interface is examined for specific elements (a technique known as *elemental mapping*), the concentrations of aluminum and titanium can be identified. These appear as dense regions in the figure, which indicates that discrete oxide particles of aluminum and titanium are in the opaque porcelain, probably just beneath the surface. When the elemental map is compared with the photomicrograph of the interface, it is possible to identify the distribution and size of the subsurface opacifying oxide particles. Silicon also demonstrates a uniform porcelain distribution, which is to be expected.

Body Porcelain

Body porcelain is fired onto the opaque layer, usually in conjunction with the incisal porcelain. It provides some translucency and contains metallic oxides that aid in shade matching. Body porcelains are available in a wide selection of shades to match adjacent natural teeth. Most porcelain manufacturers provide an opaque shade for each body shade. Although porcelains of different manufacturers are given the same nominal shade (e.g., the popular VITA classical shade guide [VITA North America]), there is significant color variation among manufacturers,[17,18] and a dentist should know which system the technician uses.

Incisal Porcelain

Incisal porcelain is usually translucent. As a result, the perceived color of the restoration is significantly influenced by the color of the underlying body and opaque porcelain.

• • •

Porcelain-Alloy Bonding

A. Brantley • Leon W. Laub • Carl J. Drago

The formation of a strong bond between the opaque porcelain layer and the cast alloy is essential for longevity of the metal-ceramic restoration. Extensive research since the 1970s has provided insight into the important factors for achieving metal-ceramic bonding. Early work[19] established the importance of wetting the alloy surface by the porcelain at the firing temperature. Although similar measurements of contact angles have not been reported for current dental porcelains and casting alloys, good wetting is essential for minimizing porosity at the metal-ceramic interface. A detailed relationship between the elevated-temperature contact angle and metal-ceramic bonding has not been established, but the research by O'Brien and Ryge[19] indicated that perfect wetting (a contact angle of 0 degrees) does not occur.

In the model by Borom and Pask,[20] an idealized continuous lattice structure is considered across the metal-ceramic interface for chemical bonding. This would be achieved in principle by incorporating certain oxidizable elements in the porcelain composition that (1) can diffuse into the casting alloy at the elevated temperatures of the porcelain firing cycles and (2) have the same equilibrium chemical potentials in both the metal and ceramic. In reality, however, the situation at the dental metal-ceramic interface does not fit this idealized model. Research on gold[21] and high-palladium[22,23] alloys used for ceramic veneering has shown that the structure of oxidized regions is highly complex; similar results would be anticipated for detailed studies of other types of oxidized dental casting alloys. The existence of multiple phases in the oxidized region of the alloy indicates that the proposed continuity[20] of atomic bonds cannot generally be achieved across the metal-ceramic interface, except possibly at sites where the glass matrix of the porcelain is in contact with the solid solution matrix of the alloy.

In casting alloy compositions, manufacturers incorporate small amounts of certain base metals that form oxides[24,25] and contribute chemical bonding to the metal-ceramic adherence. Investigators using the electron microprobe and SEM[16,26-31] have shown that these elements accumulate at the metal-ceramic interface and form an interfacial oxide layer. For noble-metal alloys, elements that have a major role for porcelain adherence are iron (alloys with high gold content), tin and indium (alloys with lower gold content, palladium-silver alloys, silver-palladium alloys, and alloys with high palladium content), and gallium (alloys with high palladium content). For base metal alloys in which the principal elements are nickel and cobalt, chromium oxidation provides chemical bonding for porcelain adherence; titanium oxidation fulfills this role for titanium casting alloys.

Figure 24-16, *A*, is an SEM photomicrograph of the interface for a high-palladium alloy bonded to dental porcelain. This alloy undergoes complex external and internal oxidation during porcelain firing cycles. The internal oxide particles in the palladium solid solution grains are too small (less than 1 to 2 μm in diameter) for accurate compositional determinations by x-ray energy-dispersive spectroscopic analysis with the SEM. X-ray diffraction[22] has shown that $CuGa_2O_3$ and SnO_2 are present in the oxidation region when the alloy surface receives standard airborne-particle abrasion with 50 μm of aluminum oxide before oxidation. Figure 24-16, *B*, shows line scans obtained with the SEM for major elements in the metal and ceramic near the interface. Variations in the x-ray counts occurred when the line scan crossed a region of internal oxidation.

Factors Affecting the Bond

Most metal-ceramic systems require that the cast alloy be subjected to an initial oxidation step before the several layers of dental porcelain are fired. (A notable exception is the palladium-copper-gallium [Pd-Cu-Ga] high-palladium alloy Freedom Plus [Jelenko Dental Alloys], in which the oxidation step does not need to be performed before firing the opaque porcelain layer.) This step has also been called a *conditioning bake* or *degassing*. The latter term, which is frequently used in the dental laboratory industry, is inaccurate because this procedure's purpose is to oxidize the metal surface for subsequent adherence to the fired porcelain. Historically, some clinicians thought that the heating cycle might result in loss of gases incorporated in the alloy during melting. However, this occurs during solidification because of the much greater

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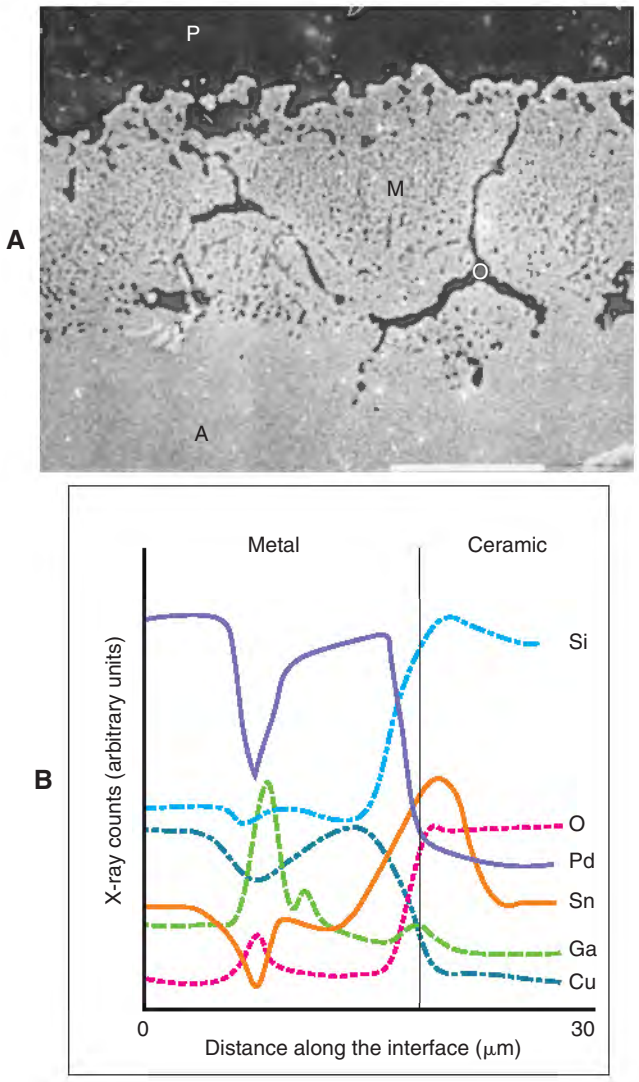

FIGURE 24-16 ■ **A,** Secondary electron (scanning electron microscope [SEM]) photomicrograph of the metal-ceramic interface for Liberty (Jelenko Dental Alloys) palladium-copper-gallium (Pd-Cu-Ga) high-palladium alloy *(A)* bonded to VITA VMK 68 (VITA North America) dental porcelain *(P).* The grain boundaries of the alloy *(M)* have been widened by the formation of oxide *(O)* deposits, and there are numerous very small oxide particles within the grains. Scale bar = 10 μm. **B,** Elemental line scans perpendicular to the metal-ceramic interface obtained by x-ray energy-dispersive spectroscopic analyses for the Liberty alloy. Because the raw SEM data have not undergone matrix corrections, the relative elemental concentrations (x-ray counts) are qualitative, but the indicated trends are appropriate. *O,* Oxygen; *Si,* silica; *Sn,* tin. (From Papazoglou E, et al: New high-palladium casting alloys. Studies of the interface with porcelain. Int J Prosthodont 9:315, 1996.)

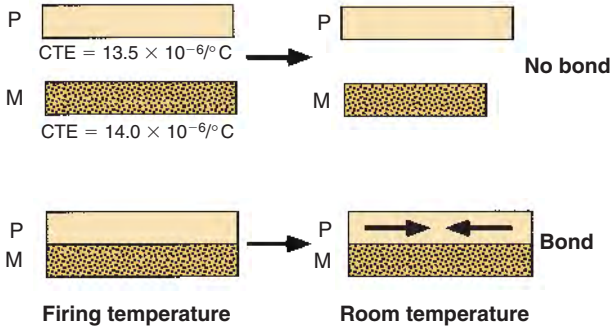

FIGURE 24-17 ■ The ceramic-metal bond at the firing temperature and at room temperature when the coefficient of thermal expansion of the metal is 0.5×10^{-6}/degree Celsius (°C) greater than that of the ceramic, which thus places the ceramic in compression at room temperature. (Adapted from Craig RG, et al: Dental materials: properties and manipulation, 7th ed. St. Louis, Mosby, 2000.)

solubility of atmospheric gases in the molten alloy than in the solidified alloy; it results in the formation of microscopic porosity[32] in the casting.

The oxide layer between the metal and ceramic should have an optimum thickness for a strong metal-ceramic interfacial bond. This was demonstrated in the 1970s for selected noble and base metal alloys.[33] Research has shown that with base metal casting alloys, particular care is needed to avoid excessively thick oxide layers.[34] Beryllium is added to some nickel-chromium (Ni-Cr) alloy compositions to lower the melting range; beryllium also has an effect on thickness of the oxide layer.[35] Some systems require the application of a bonding agent before the opaque porcelain is fired. Certain formulations consist of colloidal gold suspensions that are fired on silver-colored, gold-based ceramic alloys for esthetic purposes. SEM examination of the interfaces has shown that in Ni-Cr alloys, bonding agents may increase or decrease the width of the interaction zone between the metal and ceramic.[30] An analysis of bonding agents for several Ni-Cr alloys indicates that they contain elements found in porcelain (e.g., aluminum, tin, and silicon).[35] For certain specific brands of Ni-Cr alloys, the bonding agent appears to increase the adherence between the alloy and the opaque porcelain. The manufacturer indicates whether a bonding agent is necessary or beneficial.

Airborne-particle abrasion with aluminum oxide (alumina) is routinely performed on alloy castings to create surface irregularities and to provide mechanical interlocking with the opaque dental porcelain. The viscosity of opaque dental porcelain is low enough in the firing temperature range that the material can flow into these microscopic openings. Early studies found no effect of such surface roughening in the interfacial resistance of gold-platinum-palladium (Au-Pt-Pd),[36] gold-palladium-silver (Au-Pd-Ag), and Ni-Cr[37] systems to shear loading. In more recent research with a Pd-Cu-Ga high-palladium alloy, the metal-ceramic bond strength was increased by controlled amounts of mechanical surface roughening that yielded greater notch depth for the irregularities; greater improvements were noted with coarse roughening.[38]

The linear coefficients of thermal expansion for the metal (α_M) and ceramic (α_C) must closely match to achieve a strong interfacial bond. Typically, α_M values range from 13.5×10^{-6}/degree Celsius to 14.5×10^{-6}/degree Celsius; α_C values range from 13.0×10^{-6}/degree Celsius to 14.0×10^{-6}/degree Celsius.[39] The slightly higher coefficient for the metal causes the ceramic to be in a beneficial state of residual compressive stress at room temperature (Fig. 24-17). (Thermal contraction and expansion

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coefficients are assumed to be equal, and residual stress is developed in the ceramic only below its glass transition temperature, at which time viscous flow is no longer possible.) Porcelain is much stronger in compression than in tension, and to prevent fracture of the restoration, residual tensile stress in the porcelain must be avoided.

Adherence between the alloy casting and porcelain is very important in fixed prosthodontics; investigators have used a variety of test configurations with shear, tensile, flexural, and torsional loading to determine metal-ceramic bond strength. Ideally, the interfacial bond is strong enough that fracture of the test specimen occurs entirely within the porcelain (cohesive failure). In one early study,[40] no significant difference was found in the diametral tensile strength of commercial dental porcelains for air firing and vacuum firing. Lower tensile strength values of 28 MPa (4061 psi) for opaque porcelain, in comparison with 42 MPa (6092 psi) for gingival porcelain, were attributed to compositional differences for the two types of porcelain.[40] In addition, vacuum firing appeared to have little effect on the porosity of opaque porcelain. On the basis of these findings, tensile strength of the metal-ceramic bond should exceed 28 MPa to have cohesive failure through the porcelain rather than failure at the interface. Measurement of the shear strength of dental porcelain[41] allows a similar prediction of the minimum interfacial shear strength required for cohesive shear failure through the ceramic. Results from several studies[35,42,43] in which researchers measured the tensile bond strength of metal-ceramic systems were consistent with these concepts. Cohesive failure within the porcelain occurred at 15 to 39 MPa (2176 to 5656 psi), whereas shear bond strengths ranged from 55 to 103 MPa (7977 to 14,938 psi). For many of the shear bond strength determinations, a mixed mode of failure was observed, in which adhesive failure at the metal-ceramic interface extended into the porcelain, which fractured cohesively.

Subsequently, the focus for evaluating the metal-ceramic interfacial bond was on measurement of porcelain adherence rather than determination of bond strength. Anusavice and associates[44] reported a finite element analysis of the tests that had been used to measure metal-ceramic bond strength (i.e., pull-shear, three-point bending, and four-point bending). Two major problems were revealed for all bond strength tests: The stress varied with position along the metal-ceramic interface (particularly near porcelain termination sites), and there was a lack of pure shear stress conditions that were considered necessary to simulate the loading generally expected to cause clinical failure. Furthermore, the small mismatch between the thermal contraction coefficients of the metal (α_M) and ceramic (α_C) results in an unknown amount of residual stress at the interface, and an idealized value of metal-ceramic bond strength is based on an assumed presence of a residual stress-free interface.

To avoid these problems, O'Brien[45,46] proposed a completely different approach, focusing on the mode of failure of metal-ceramic specimens or restorations rather than measurement of bond strength. Adhesive or cohesive failure can occur at six possible sites or combinations of those sites (Fig. 24-18). Adhesive failure can occur (1) at the porcelain-metal interface if no oxide layer is present; (2) at the metal oxide–metal interface; and (3) at the porcelain–metal oxide interface. Cohesive failure can occur (4) through the porcelain, which is the desirable mode; (5) through the metal oxide layer; and (6) through the metal. (Metal fracture is highly unlikely but is described in this model for completeness.) This approach for evaluating metal-ceramic bonds by determining the area fraction of adherent porcelain on fractured test specimens was adopted in the American National Standards Institute/American Dental Association (ANSI/ADA) Specification No. 38 for metal-ceramic systems.[47] The method of microscopic measurement was not specified.

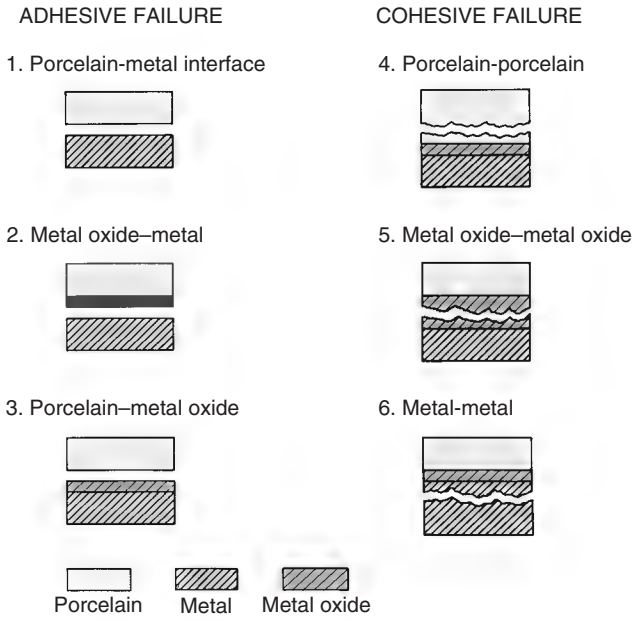

FIGURE 24-18 ■ Possible modes of failure of alloy-porcelain restorations. (Modified from O'Brien WJ: Evolution of dental casting. In Valega TM Sr, ed: Alternatives to gold alloys in dentistry [DHEW Publication No. (NIH) 77-1227, p 5]. Washington, DC, U.S. Government Printing Office, 1977.)

A quantitative x-ray spectrometric method was developed by Ringle and coworkers[48] to measure porcelain adherence. The fracture surfaces of metal-ceramic specimens loaded to failure in biaxial flexure are examined with the SEM, with x-ray energy-dispersive spectroscopic analysis. This method is based on the principle that silicon is a major element in dental porcelain but is largely absent in dental alloys (except as contaminants from investments or polishing abrasives used to prepare specimens). The amount of dental porcelain remaining on the metal surface of the fractured specimen is readily determined by measuring the silicon Kα signal, with necessary calibration measurements on the oxidized alloy surface before porcelain application, and on the porcelain surface before testing the specimen. This technique has been used to measure oxide adherence to a variety of ceramic alloys,[49] porcelain adherence to high-palladium alloys,[50,51] and to titanium and an alloy of titanium-aluminum-vanadium (Ti-6Al-4V).[52-55]

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Another philosophic change in the recommended method for evaluating the metal-ceramic bond occurred with the introduction of International Organization for Standardization (ISO) Standard No. 9693 for dental porcelain-fused-to-metal restorations,[56] which contains a three-point bending test. Lenz and colleagues[57,58] performed a finite element analysis for this test and considered the effects of thermal stresses in the metal-ceramic specimens arising from the mismatch between α_M and α_C. Investigators using several Pd-Ga high-palladium alloys with identical values of elastic modulus found no correlation[59] between porcelain adherence measured by the x-ray spectrometric method[50,51] and the force to failure by the three-point bending test in ISO Standard No. 9693.[56] These experimental results cast doubt on the effectiveness of the x-ray spectrometric technique[48,50] in measuring porcelain adherence. A possible explanation is that the metal is forced to undergo a small amount of permanent flexural deformation with the porcelain adherence test[50] that does not occur with the measurement of force to failure (shear bond strength) of the metal-ceramic bond in the ISO standard.[56]

Other important factors that affect the metal-ceramic bond are the surface treatment of the alloy before porcelain is fired and the atmosphere of the porcelain furnace during firing. As previously mentioned, airborne-particle abrasion of the cast alloy is typically performed before the oxidation step to help remove surface contaminants that remain from devesting and to help clean the casting and provide microscopic surface irregularities for mechanical retention of the ceramic. The oxidation step for the alloy can be performed in air or with the use of the reduced atmospheric pressure (approximately 0.1 atm) available in dental porcelain furnaces. A much thinner oxide layer is formed if the alloy is oxidized at this reduced atmospheric pressure, in comparison with the thickness for oxidation in air. Manufacturers' recommendations for oxidation of the alloy and porcelain firing cycles must be followed. An early study[60] showed that the shear bond strength of porcelain-gold alloy specimens was 60% greater when air firing was employed; another study at that time[61] revealed that the tensile bond strength varied according to the furnace atmosphere used. The shear bond strength of porcelain-nickel alloy specimens was greater when firing was performed in oxidizing atmospheres than in nonoxidizing or reducing atmospheres.[62] More recently, Wagner and associates[38] found that the use of a reducing atmosphere severely reduced the bond strength of a Pd-Cu-Ga high-palladium alloy, which confirmed the role of alloy oxidation during the standard porcelain firing cycles.

Since 2005, there has been considerable research on bonding between titanium/titanium alloy and dental porcelain. Zinelis and colleagues[63] reported substantial differences in bond strength for eight different porcelains bonded to commercially pure titanium and a lack of correlation between measurements of porcelain adherence[53,59] and metal-ceramic bond strength with the ISO three-point bending test.[56] An excellent review article critically summarized the results from numerous studies of bonding between titanium and dental porcelain.[64] Excessive oxidation during porcelain firing and the very hard α case surface layer (see Chapter 19) cause difficulty with porcelain bonding to cast titanium/titanium alloys. Another factor is the need for low-fusing porcelains to minimize elevated-temperature reaction with titanium; these porcelains have lower bond strengths than do traditional medium-fusing porcelains.[65,66]

Strategies for titanium surface modification before porcelain firing include roughening,[65-68] use of acidic and caustic solutions,[53,69,70] and deposition of special layers or coatings.[54,55,71-75] Clinical investigation has revealed that the prevalence of cohesive fracture within porcelain is greater than adhesive failure at the titanium-porcelain interface; it is suggested that an important concern is inadequate furnace control at the low temperatures employed with veneering porcelains for titanium.[64] Although values of bond strength for dental porcelain bonded to cast titanium in current studies meet the minimum value of 25 MPa in ISO Standard No. 9693,[56] higher bond strengths are observed for conventional nickel-chromium alloys than for titanium.[64,65,69] For noncast titanium, in which surfaces were prepared by electrical discharge machining, porcelain bond strengths were not significantly different from those of bonds to cast surfaces when α case was removed.[65,76]

A concluding area of research that has attracted interest is the effect on metal-ceramic bond strength from the use of recycled metals. This is of practical interest in dental laboratories for expensive gold and palladium alloys. High-gold, gold-palladium, and palladium-silver alloys were melted up to three times without reduction in bond strength to porcelain.[77] In contrast, melting of used metal with fresh metal for a conventional nickel-chromium alloy yielded significant reduction in bond strength in comparison with that for entirely new metal.[78]

• • •

SELECTION CRITERIA

Most manufacturers of modern dental porcelains specify the alloy systems with which a material is compatible. Usually *compatibility* refers to the relative coefficients of thermal expansion. The clinically selected shade determines which powders to combine. Depending on the characteristics of the color to be matched, several powders can be combined for the desired esthetic result. Commercially available porcelains can be divided into fine-grain and coarse-grain types. The typical particle size of a fine-grain porcelain ranges from 5 to 110 μm; the particle size for a coarse-grain porcelain can be as large as 200 μm.

Opaque Porcelain

For a proper mechanical bond and chemical interaction at the interface, opaque porcelain must wet the surface easily. It becomes the primary source of color of the restoration and must mask the color of the metal, even in thin layers. Opaque thickness generally should not exceed 0.1 mm; otherwise, achieving an esthetic result without overcontouring the restoration becomes

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FIGURE 24-19 ■ **A** to **C,** Types of metal-ceramic porcelain. Porcelains are available as powders or pastes. (Courtesy Ivoclar Vivadent, Amherst, New York.)

impossible, although a greater opaque thickness may be necessary to mask the darker oxide of some alloys.[79] Small amounts of zirconium oxide and titanium oxide, in conjunction with alumina, act as the opacifying agents to block the darker color of the oxidized metal. Some of these oxides are also present in the body porcelain. Manufacturers supply opaque porcelains in paste and powder form (Fig. 24-19).

Body and Incisal Porcelains

As with opaque porcelain, the selection of body and incisal porcelains is based largely on their esthetic properties. However, the amount of shrinkage that occurs when these powders are fired must also be considered. The volume of body and incisal porcelains usually shrinks as much as 27% to 45% during a first firing[15]; opaque porcelain, on the other hand, may exhibit some cracking during an initial bake, but it remains relatively stable dimensionally. Low-fusing metal-ceramic porcelains (Finesse, Dentsply Prosthetics; Omega 900, VITA North America) have become popular.[80] When opposing enamel wear is likely to be a problem, these materials should be considered because in vitro they tend to exhibit lower abrasiveness than do conventional formulations.[81]

FABRICATION

For optimum esthetics, custom-mixing body and enamel powders to achieve desired color variations is recommended.

Porcelain Application

Armamentarium

The following equipment is needed (Fig. 24-20):

- Porcelain modeling liquid
- Paper napkin
- Glass slab or palette
- Tissues or gauze squares
- Two cups of distilled water
- Glass spatula
- Serrated instrument
- Porcelain tweezers or hemostat
- Ceramist's sable brushes (Nos. 2, 4, and 6) and whipping brush
- Razor blade or modeling knife
- Cyanoacrylate resin
- Colored pencil or felt-tip marker
- Articulating tape
- Ceramic-bound stones
- Flexible thin diamond disk (about 20 mm in diameter)

Step-by-Step Procedure

After the metal substructure has been oxidized, it must be inspected carefully. An uninterrupted oxide layer should cover the entire surface to be veneered.

Opaque Porcelain. This technique is illustrated in Figure 24-21.

1. After selecting the opaque bottle, shake it to mix the powder thoroughly. Then place it on the bench to allow the smaller pigment particles to settle. Over time, all porcelain powders segregate into layers of different particle size if left undisturbed.
2. Dispense a small amount of powder on a glass slab or palette. Add some modeling liquid and mix it with the spatula. Metal instruments should not be used in mixing because metal particles could rub off and act as contaminants. The proper opaque consistency should "hold an edge" for a few seconds.

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FIGURE 24-20 ■ **A,** Armamentarium for porcelain application. **B,** Whip Mix Pro Press 200 *(left)* and Pro 200 *(right)* porcelain furnaces. **C,** Dentsply NeyFire T porcelain furnace. (**B,** Courtesy Whip Mix Corporation, Louisville, Kentucky. **C,** Courtesy Dentsply International, York, Pennsylvania.)

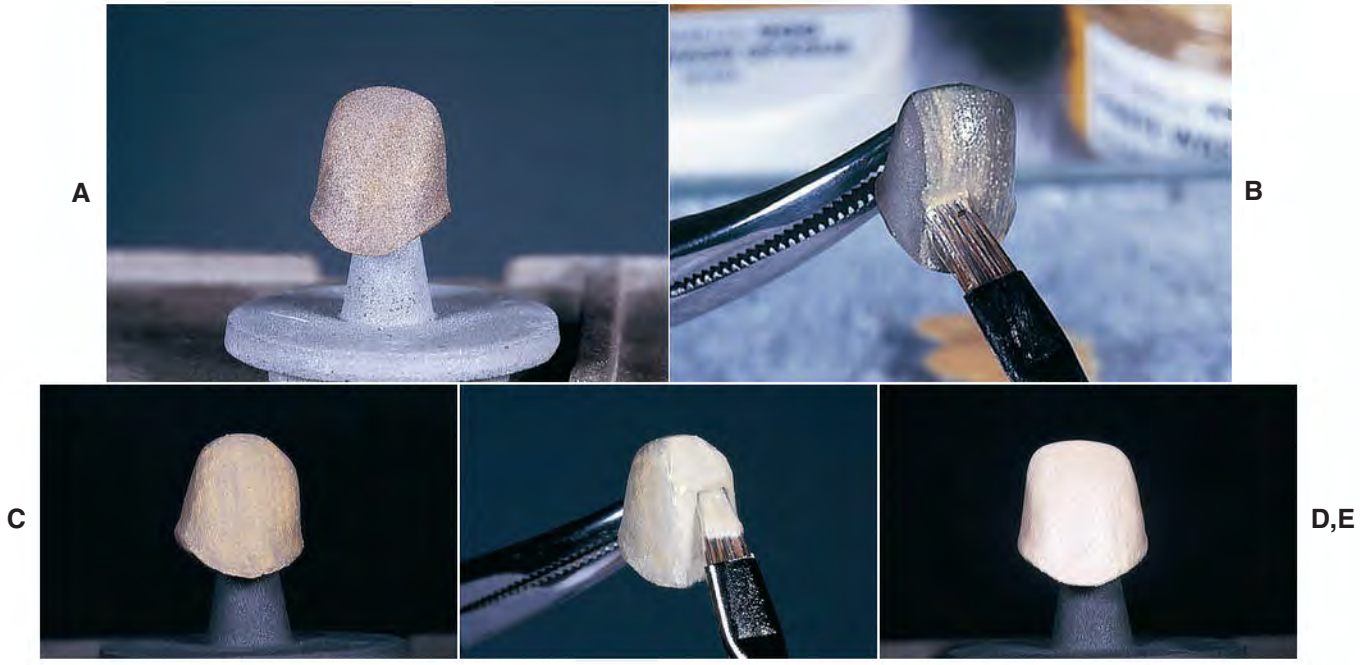

FIGURE 24-21 ■ Opaque porcelain application. **A,** Substructure is oxidized. **B,** Porcelain is applied. Vibration can be used to help spread the opaque porcelain into an even, thin film **(C). D,** Application of additional opaque porcelain. **E,** After drying in front of the furnace, the opaque layer should have a uniform matte-white appearance. Excess powder must be removed before firing.

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3. Moisten the substructure with some of the liquid, and pick up a small bead of opaque porcelain with the tip of the brush or spatula. Apply it to the coping, which should be held with the porcelain tweezers.
4. Use light vibration to spread the material thinly and evenly. Moving the serrated instrument back and forth over the handle of the tweezers creates the necessary disturbance. Excess moisture that comes to the surface can be blotted off with a clean tissue. Vibration may not be as necessary with the so-called paint opaque materials.
5. Apply a second bead on top of the first, and spread it in a similar manner. To minimize the entrapment of air when the two masses meet, do not apply opaque porcelain adjacent to the initial mass. If the moisture content is properly controlled, condensing poses little difficulty. A mix that is too wet will slump and produce too thick a layer on the substructure, especially in the concave areas near the porcelain-metal junction.
6. Once the veneering surface is covered, add more material to a dry base. Wetting the initial application before adding more porcelain may be necessary. If not, the moisture will be absorbed immediately by the dry base layer before a new material can be properly condensed and distributed, which results in a porous and weakened application (similar to constructing a sand castle with wet sand on a dry beach). The addition of more liquid and further vibration will resolve the problem.
7. When the entire veneering surface has been covered, remove any excess material from other surfaces with the side of a slightly moistened brush. If the metal immediately adjacent to the veneer has been properly prepared and smoothed, it is not difficult to remove the excess porcelain. However, this crucial task is often overlooked, and its omission can make metal polishing much more difficult.
8. After removing any excess porcelain, carefully inspect the inside of the restoration for porcelain particles. A stiff, dry, short-bristle brush can be used to remove the particles.
9. Before firing, inspect the opaque application to see that it satisfies the following criteria:
   - The entire veneering surface is evenly covered with a smooth layer that masks the color of the metal.
   - There is no excess anywhere on the veneering surface.
   - There is no opaque material on any external surface adjacent to the veneer.
   - There is no opaque material on the internal aspect of the substructure.

   If these criteria have been met, the coping is transferred to a sagger tray and placed near the open muffle of the porcelain furnace for several minutes. This allows moisture to evaporate. When drying is completed (this varies according to specific manufacturer's recommendations), reinspect the work for any residual excess opaque powder. Material that was previously overlooked is clearly visible because the chalky white porcelain contrasts with the darker oxidized metal. A stiff, short-bristle brush can again be used to remove any remaining porcelain powder. The opaque layer is then fired according to manufacturer's recommendations.
10. After the first firing, remove the work from the muffle, and set it aside to cool to room temperature.
11. At this time, inspect the opaque veneer for cracks, thin spots, and general adequacy of coverage. When the veneer is removed from the furnace, it appears yellow; however, when it has cooled, the color is the more representative matte white. Fired opaque material should have an eggshell appearance. If necessary, a second application of opaque material can be made. Small cracks and fissures are common after the first firing. This problem can be resolved by application of moisture, followed by a thin mix of opaque material carefully condensed into the fissures. When correcting a thin area where the color of the metal has not been masked completely, moisten the surface before applying a second coat (to facilitate wetting).
12. After firing, check that the opaque application (Fig. 24-22) meets the following criteria:
    - Relatively smooth, even layer masking the color of the framework
    - Eggshell appearance
    - No excess on any external or internal surface of the restoration (which would prevent it from seating fully on the die)

FIGURE 24-22 ■ Appearance of the opaque porcelain.

Body and Incisal Porcelains. When an opaque layer has been fired satisfactorily, the body and incisal porcelains (Fig. 24-23) can be applied. The use of several porcelains in one restoration is common. Body porcelains with increased opacity (often called *opacious dentins*) may be used in areas where less translucency is required (e.g., the gingival area of the pontic, incisal

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FIGURE 24-23 ■ Body and incisal porcelain application. **A** to **E,** Development of incisal mamelons with opacious dentin. The incisal plaster or silicone putty index is made from the anatomic contour wax patterns (see Chapter 18) and serves as a guide to developing proper incisal edge position. **F** and **G,** Cervical and body powders are added to the contour. **H,** Alternatively, the incisal index can be used to establish incisal edge position. This is especially helpful for extensive restorations. **I,** Restorations are slightly overbuilt. **J,** The buildup is smoothed with a whipping brush. **K,** Restorations are separated with a razor blade before firing. Additional porcelain is added to the proximal contacts. **L** and **M,** Restorations after firing of the first body bake. **N,** Porcelain is added in areas of deficient contour. **O,** After firing, the proximal contacts are carefully adjusted, and the restorations are seated on the cast. **P** to **S,** Restorations are contoured by grinding. Careful attention is paid to the shape and position of line angles and incisal edges. When completed, the restorations are ready for clinical evaluation and final contouring intraorally (see Chapter 29).

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mamelons) to mimic existing anatomic features of adjacent natural teeth. Special neck powders can be applied on the cervical third, and incisal powders on the incisal edge, to simulate natural enamel. In general, the restoration is built to anatomic contour; when it is acceptable, a cutback similar to that made during the waxing stage allows for a veneer of the more translucent incisal porcelain.

1. Dispense the neck, body, incisal, and other powders on a glass slab or palette. If the same slab was used for the opaque porcelain, any opaque residue must be removed.
2. Mix the powders with the recommended liquid or distilled water. The moisture content for these powders should be the same as for opaque porcelain. Specially formulated liquids that allow longer manipulation than is possible with conventional glycerin-containing liquids are available.
3. Wet the previously fired opaque layer with a small amount of the liquid, and place a bead of neck powder on the cervical portion of the veneering surface. Gentle patting with a brush and light tapping on the cast produces adequate vibration during the preliminary stage of condensation. Hold a tissue close for removal of excess surface moisture. During the entire buildup procedure, the facial surface should not be blotted with tissue because the smaller pigment particles might be removed. Blotting consistently from the lingual aspect is recommended and results in superior esthetics.
4. After placing the neck powder and sculpting it, build the veneer to anatomic contour with body porcelain. Use the adjacent and opposing teeth as a guide. Where contact is anticipated between the wet buildup and stone cast, the cast can be coated with a small amount of cyanoacrylate resin, immediately blown into a thin layer. This seals the surface and prevents the absorption of moisture from the buildup.
5. To compensate for the firing shrinkage that results when the particles fuse, slightly overbuild the porcelain. A typical metal-ceramic anterior crown shrinks 0.6 mm at the incisal edge and 0.5 mm midfacially[82] (Fig. 24-24).
6. When the body buildup is completed, assess it for proper mesiodistal, faciolingual, and incisogingival contour.
7. Depending on the desired appearance, make a cutback for the more translucent incisal powder. Some manufacturers recommend carrying the incisal veneer all the way to the cervical portion of the restoration; others suggest limiting it to the incisal third. The possibilities are almost infinite, and only with experience can the dentist predict the finished product's appearance. Whether the cutback is made with a razor blade, scalpel, or modeling instrument, condensing the body buildup well before cutting back is necessary. This minimizes the risk of fracture during the process. Furthermore, to minimize the chance of damaging the unsupported incisal portion of the buildup, the cutback should be made from incisal to cervical aspects. Space for the incisal veneer must be adequate in the interproximal area.
8. Apply the incisal powder in the same manner, and overbuild the restoration as described for body porcelain. The remaining body powder must be wet before application of the incisal powder, and, again, intermittent light vibration helps achieve an acceptable level of condensation. Prolonged condensation should be avoided; it does not reduce porosity[83] or increase fracture toughness[84] and may lead to unwanted redistribution of the pigmented particles.
9. Mark the opposing teeth on the stone cast with a red or green felt-tip marker. These markings are not absorbed if the cast first has been coated with cyanoacrylate resin. The articulator can then be closed to allow the antagonists to contact the wet porcelain. If this is done carefully, the markings are transferred onto the buildup without fracturing, and the buildup can be modified to the necessary occlusal scheme. Only red or green dyes, which burn off without leaving a residue, should be used for these markings. Blue or black pigments usually contain metal oxides or carbon, which after firing can discolor the porcelain.
10. Moisten the proximal contact areas immediately before removing the completed buildup from the cast. This reduces the risk of fracturing that portion of the buildup.
11. After the restoration has been removed from the cast, fill in the proximal contact areas. At this time, the work should be reinspected for any excess

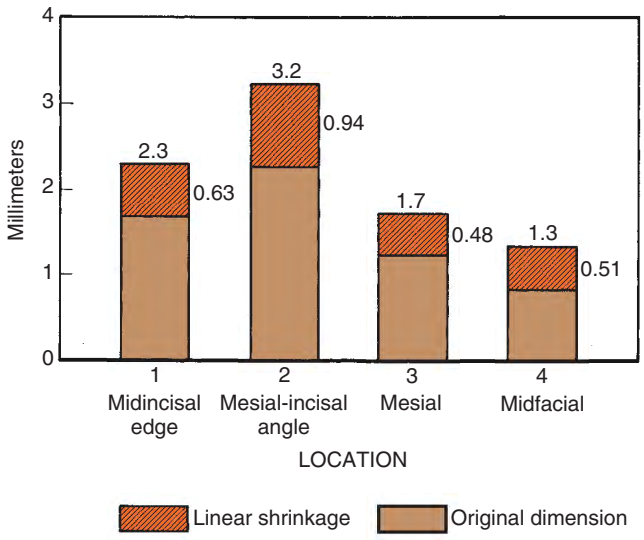

FIGURE 24-24 ■ Mean shrinkage values from firing of a typical maxillary central incisor metal-ceramic crown. (From Rosenstiel SF: Linear firing shrinkage of metal-ceramic restorations. Br Dent J 162:390, 1987.)

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material beyond the veneering area (which, as before, must be removed before firing). The internal aspect of the coping should be reinspected even more carefully because enamel powders are quite transparent in thin layers and are not easily detected after firing.

12. Place the restoration on a sagger tray close to the open muffle at the drying temperature recommended by the manufacturer. A drying time of 6 to 10 minutes is usually sufficient. If a restoration is fired prematurely, the residual moisture in the buildup may generate steam, and the accompanying vapor pressure causes the buildup to explode. After the drying process, once it has been determined that no undesired excess material remains, proceed with firing. When the firing is completed, allow the work to cool to room temperature before further handling. Follow the manufacturer's recommendations concerning the cooling rate after firing. Incorrect cooling rates may lead to residual stresses that eventually result in porcelain fracture during function. Thermal expansion increases after slow cooling, because additional (high-expansion) leucite crystallizes.[85] In general, alloys with high thermal expansion coefficients require more rapid cooling than do alloys with low coefficients.[86]
13. Be especially critical when evaluating the first (or low-bisque) bake. If the surface is fissured, grind the porcelain before adding any more (Fig. 24-25). The shape of the restoration should conform to the standards set by dental anatomy and the predetermined occlusal scheme for the patient.
14. Remove all excess material with ceramic-bound stones. A flexible diamond disk is imperative for proper shaping of the embrasure spaces. To extend its usefulness, the disk should be kept moist.
15. When the restoration has been contoured and all the necessary areas reduced, certain portions probably require a second application of porcelain.
16. Before a second corrective bake (also referred to as a *patch bake*), clean the restoration ultrasonically to remove any grinding debris.
17. Place the second body and incisal layers directly on the slightly moistened low-bisque bake. Evaluate the color at this time, keeping the restoration moist. Sometimes another bake is needed, particularly for an extensive prosthesis. However, multiple firings lead to devitrification of the porcelain, with a loss of translucency and a decrease in the restoration's fracture resistance.[87]

Internal Characterization

Internal or intrinsic characterization or staining may be accomplished by incorporating colored pigments in the opaque, body, or incisal powder. These pigments are ceramic in nature, and their physical properties are similar to those of the porcelain powders.

Most commercially available porcelains have colored opaque modifiers that can be selectively mixed with the opaque to increase the saturation of the desired pigment.

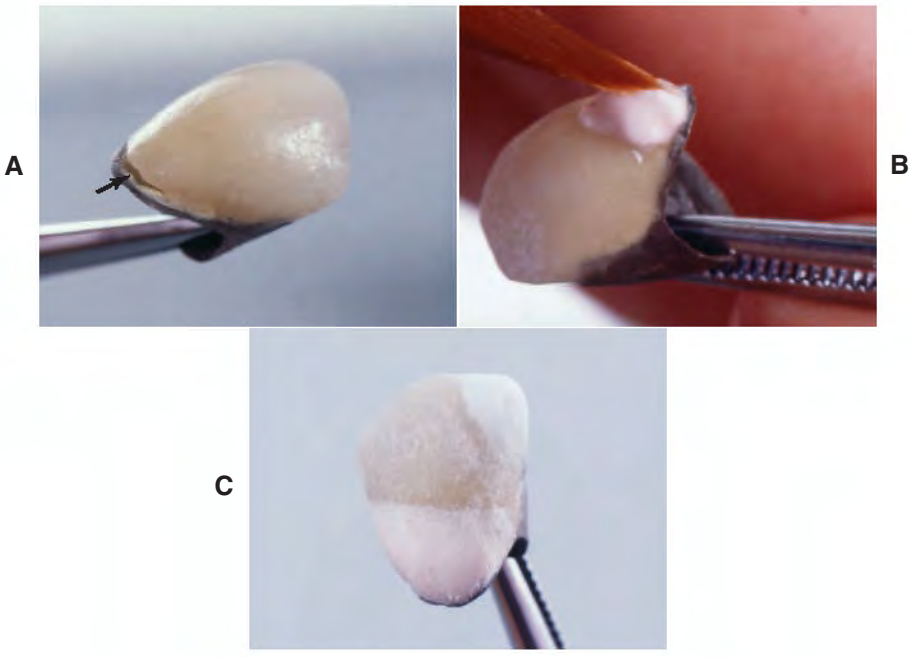

FIGURE 24-25 ■ **A,** This restoration had a defect *(arrow)* at the gingival margin after the first firing. Access for repair is made by grinding out such cracks. **B,** Additional porcelain is applied after the area is moistened. **C,** The porcelain has been added, and the restoration is ready for a second firing.

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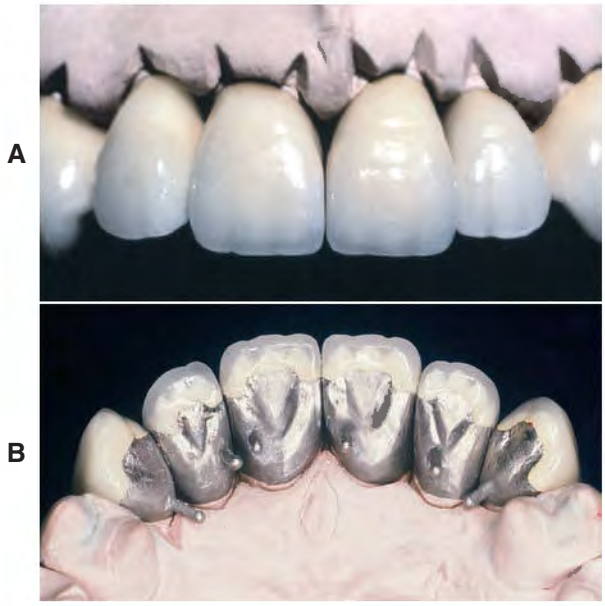

FIGURE 24-26 ■ **A** and **B,** Natural incisal appearance has been achieved through subtle layering of porcelains of different translucencies.

FIGURE 24-27 ■ Porcelain stain was applied intrinsically to create the effect of discolored dentin in these mandibular incisors, seen before firing.

A variation of this approach is to use opacified dentin powders that produce a finished restoration with a slightly higher chroma than one prepared with the more translucent dentin powders. Similarly, a translucent powder can be used to enhance incisal translucency (Fig. 24-26). Highly colored glazes, commonly used as surface stains, may be layered within the buildup powders to create special effects (Fig. 24-27).

The use of internal stains presents little technical difficulty for operators familiar with metal-ceramic procedures. Because the pigment is built into the material, however, if the desired effect is not obtained through internal staining, the porcelain must be stripped from the substructure.

Another technique for internal characterization is to fire the body powders initially, carve them into the desired mamelon shape, and then apply the subsequent enamel powders. A disadvantage of this approach is that an additional firing is needed.

Contouring

The appearance of the finished restoration depends on its color, shape, and surface texture, which can be altered by shaping and characterizing dental porcelain to mimic the appearance of natural teeth (see Fig. 24-23, *P* to *S*).

The appearance of restorations can be influenced considerably through the selected use of optical illusion (see Chapter 20). The human eye is capable of discerning differences in height and width, but its depth perception is far less developed. Even trained observers experience difficulty when attempting to recognize subtle differences in the third dimension.

Through selective contouring, the apparent shape of a restoration can be made to look quite different from its actual configuration. The perceived size of a tooth depends on the reflection of its line angles and the relative position and spacing of these reflections. Even though an edentulous area on one side may be slightly larger than a space occupied by the corresponding tooth on the contralateral side, a restoration can be made to appear similar (or even identical) through careful mimicking of the line angle distribution and contours immediately adjacent to the line angles. The clinician can create an illusion that the restoration is narrower than it really is (Fig. 24-28). In addition, by simulating the normal distance between line angles superimposed on a pontic in an edentulous area that is otherwise too narrow, it is possible to create the illusion that teeth are of normal size but merely crowded. Careful application of these principles may trick the casual observer into concluding that the teeth overlap and that a portion of the tooth (or restoration) is behind an adjacent tooth although, in reality, the overlap does not exist.

The surface texture of a metal-ceramic restoration should resemble that of the adjacent teeth, including selected characterizing irregularities that exist on those teeth. Several rules of light reflection must be remembered when the clinician attempts to accomplish this:

- A flat surface reflects primarily parallel light bundles.
- A convex surface results in divergence of reflected light, whereas a concave surface creates a convergent light bundle.
- Sharp transitions (e.g., geometric line angles) result in line reflections, but smooth, gently flowing curved surfaces create a reflection pattern with greater surface area.

Thus a smooth restoration can appear larger than one of identical size that has been characterized or textured. Careful study of adjacent teeth and an understanding of how their reflective patterns should be simulated before characterization are essential. Care must also be taken not to "overcharacterize," which

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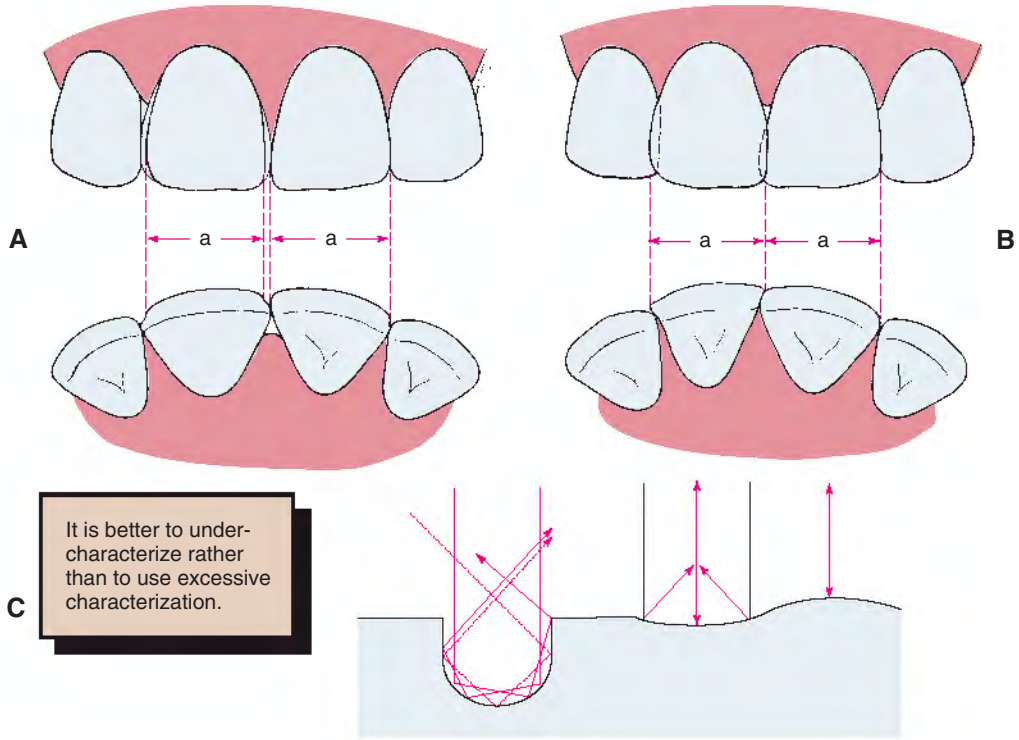

FIGURE 24-28 ■ **A** and **B,** The esthetics of an abnormally sized restoration can be improved by matching the location of the line angles and adjusting the interproximal areas. **C,** The pattern of light reflection depends on the surface texture of the restoration. (**A** and **B** redrawn from Blancheri RL: Optical illusions and cosmetic grindings. Rev Asoc Dent Mex 8:103, 1950.)

would draw attention to the restoration and reveal that it is artificial.

Glazing and Surface Characterization

Metal-ceramic restorations are glazed to create a shiny surface similar to that of natural teeth (Fig. 24-29). (An acceptable alternative is to polish the ceramic [see Chapter 29].) The glazing cycle can be performed concurrently with any necessary surface characterization (see Chapter 29).

In *autoglazing*, the contoured bisque bake is raised to its fusion temperature, which is maintained for a time before cooling. A pyroplastic surface flow occurs, and a vitreous layer or surface glaze is formed. Sharp angles and edges are rounded slightly during this process. Consequently, occlusal contact in porcelain is altered slightly during glazing.

In contrast, in *overglazing*, a separate mix of powder and liquid is applied to the surface of a shaped restoration, and the restoration is subsequently fired. The firing procedure is similar to that for autoglazing, although there are variations among brands. Because most metal-ceramic restorations include low-fusing porcelain, overglazing is not currently in widespread use.

FIGURE 24-29 ■ **A** and **B,** Glazed and polished restorations.

External Characterization

Surface stains are highly pigmented glazes, which can be mixed with glycerin and water (supplied with most commercially available staining kits).

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By moistening the bisque firing, the dentist can cause the restoration to appear as if it is glazed. After the desired effect has been obtained by placing selected stains on the surface, the restoration is held outside the open muffle of the glazing furnace, and the stain is allowed to dry.

When it turns white and chalky, any excess that may have been accidentally applied to the metal surface is removed, and the restoration is fired. During this staining and glazing bake, a pyroplastic surface flow occurs, and a glassy layer (or autoglaze) forms on the surface in which the stains are incorporated.

PORCELAIN LABIAL MARGINS

Many patients object to the grayness at the margin associated with metal-ceramic restorations. However, hiding the margin subgingivally may not be possible. If esthetics is of prime importance, a collarless metal-ceramic crown (Fig. 24-30) or an all-ceramic crown (Chapter 25) should be considered. On collarless crowns, the facial margin is porcelain, and the lingual and proximal margins are metal (Fig. 24-31).

Some technicians fabricate a 360-degree porcelain margin to optimize light transmission in the gingival area and provide optimal esthetics. That technique is quite demanding. Preparation for these restorations is similar to that for an all-ceramic crown [see Chapter 11] with a circumferential shoulder margin with rounded internal line angles.

Advantages and Disadvantages

The collarless crown's most obvious advantage is the esthetic superiority over the conventional metal-ceramic restoration. Plaque removal also is easier when gingival tissues are in contact with vacuum-fired glazed porcelain than when they are contacting highly polished gold. Therefore, porcelain appears to be the material of choice for restorations that will be in contact with gingival tissues.

The difficulties encountered during fabrication, however, limit its application. Although a technically comparable result is feasible,[88,89] the marginal adaptation of these restorations (as currently produced by most commercial laboratories) is slightly inferior to that of cast metal. Because of careless handling, fracture of the unsupported margin is sometimes a problem during evaluation or cementation. Fracture during function is rarely a problem because the labial margin is not subjected to high tensile stresses.[90] In addition, the collarless metal-ceramic restoration is more time consuming and therefore more costly to make.

Indications and Contraindications

A porcelain labial margin is indicated when a conventional metal-ceramic restoration will not create the desired esthetic result. It is contraindicated when an extremely smooth, 1-mm-wide shoulder margin cannot be prepared in the area of the ceramic veneer. (In this regard, the conventional metal-ceramic restoration is somewhat more forgiving.) Although multiple porcelain

FIGURE 24-30 ■ **A** and **B,** Metal-ceramic restorations with porcelain labial margins combine the excellent esthetics of all-ceramic restorations with the strength of the metal-ceramic technique.

FIGURE 24-31 ■ Schematic of a collarless restoration fabricated with the platinum foil technique. To support the foil during burnishing, a "skirt" of a suitable blockout material has been added to the facial aspect of the die adjacent to the proposed porcelain labial margin. This prevents distortion of the foil upon removal from the die. Alternatively, a blocked-out die can be duplicated in epoxy resin or electroplated.

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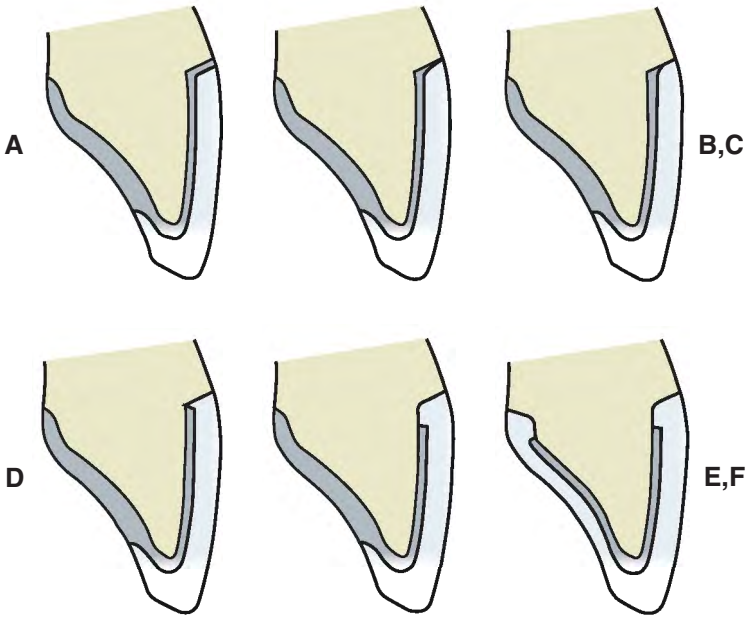

FIGURE 24-32 ■ Labial margin designs for metal-ceramic restorations. **A,** A thin metal band provides excellent adaptation but is very unesthetic unless it can be hidden subgingivally. For esthetic reasons, this design is rarely used for anterior teeth. **B,** A "disappearing" margin, sometimes called a *conventional margin,* is commonly used and is esthetically acceptable to some patients. However, the metal often causes unacceptable grayness of the gingival tooth surface. **C** to **E,** Various cutback designs for labial porcelain margin restorations. Reducing the metal provides better esthetics but makes the laboratory phase more demanding and may result in margin chipping. **F,** A 360-degree porcelain margin provides excellent light transmission in the gingival area and optimal esthetics; however, the laboratory fabrication is very demanding. This design requires a preparation design that is similar to that for an all-ceramic crown (see Chapter 11) with a circumferential rounded shoulder margin. Close cooperation between dentist and technician is essential in determining the best labial margin design.

margins may be used in one fixed dental prosthesis without sacrifice of marginal adaptation, the limitations of the operator and the technical auxiliary staff should be carefully and objectively assessed before the dentist and patient commit themselves to a fixed prosthesis consisting of multiple collarless retainers.

Framework Design for Labial Margin

Various framework designs have been proposed with different facial framework reductions[91] (Fig. 24-32). In general, the more metal reduction, the better the esthetic result; however, the technical procedures become more demanding. Removal of up to 2 mm of the labial framework has been shown not to decrease the fracture resistance of the restoration.[92,93]

Step-by-Step Procedure

This procedure is illustrated in Figure 24-33.

1. Apply cyanoacrylate resin to the labial margin area of the die. This acts as a sealant of the porous stone. Compressed air should be used to minimize the thickness of the film.
2. Apply porcelain release agent to the shoulder margin of the prepared die.
3. Seat the opaque porcelain–coated casting on the die.
4. Mix porcelain for the shoulder margin, and apply it directly to the die and the opaque porcelain. Light tapping assists in condensation and should be done before the dry buildup is separated from the die.
5. After the first firing of the shoulder margin porcelain, reseat the crown on the die. At this time, the restoration should be examined for margin discrepancies. A second firing of the shoulder margin porcelain is usually necessary.
6. Relubricate the die, reseat the crown, and apply a thinner mix of porcelain powder to the shoulder margin. Vibration helps the porcelain fill the defect completely. After blotting, the restoration can be separated from the die.
7. When the firing is completed, use a water-soluble marking agent to detect premature contacts. The marking agent is applied to the shoulder margin, and the restoration is then gently tried on the die. The markings will be visible on the porcelain and the inner aspect of the casting.
8. Adjust any areas of contact of the restoration, and proceed with the conventional buildup of body and incisal porcelains, followed by glazing of the final restoration.

TROUBLESHOOTING

Technical failures can occur in the complex metal-ceramic system and are difficult to detect. Different errors may lead to problems that appear similar. Table 24-2 summarizes some of these.

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FIGURE 24-33 ■ The direct lift (cyanoacrylate resin) technique for a porcelain labial margin. **A,** Armamentarium. **B,** Cyanoacrylate resin (e.g., Krazy Glue) serves as a sealant of the porous stone die. **C,** The resin is applied to the area of the die where it will be in direct contact with the porcelain. Compressed air is used to minimize film thickness. **D,** Recommended separating medium. **E,** The separating liquid is applied to the shoulder margin of the prepared die. **F,** The opaque porcelain–covered casting is seated on the prepared die. **G,** Mixing the porcelain for the shoulder margin. **H,** Shoulder margin porcelain is applied in direct contact with the die and opaque porcelain. **I,** Light tapping is used to assist in condensation. **J,** The dry buildup is separated from the die. **K,** The buildup before firing. **L,** First firing of the shoulder margin porcelain is completed. **M,** The fixed restoration is reseated on the die. Note the minor marginal discrepancy. **N,** Before additional porcelain application, the die is relubricated. **O,** Second application of shoulder margin porcelain. **P,** Vibration. **Q,** Separating from the die after the second application of shoulder margin porcelain.

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FIGURE 24-33, cont'd ■ **R,** Water-soluble marking agent for detecting premature contact. **S,** The marking agent is applied to the shoulder margin. **T,** The fired restoration is gently tried on the die. **U,** Markings are visible on the porcelain and on the internal aspect of the casting. **V,** Excess porcelain is removed. **W,** The seated restoration. **X,** Internal view of the completed shoulder margin. **Y,** Conventional buildup with body and incisal powders.

TABLE 24-2 **Common Reasons for Failure of Metal-Ceramic Restorations**

Failure	Reason
Fracture during bisque bake	Improper condensation
	Improper moisture control
	Poor framework design
	Incompatible metal-porcelain combination
Bubbles	Too many firings
	Air entrapment during buildup of restoration
	Improper moisture control
	Poor metal preparation
	Poor casting technique
Unsatisfactory appearance	Poor communication with technician
	Inadequate tooth reduction
	Excessive thickness of opaque porcelain
	Excessive firing
Clinical fracture	Poor framework design
	Centric stops too close to metal-ceramic interface
	Improper metal preparation

Cracks

Surface cracks and fractures in the opaque porcelain are usually of little concern. They can be patched before the body firing begins. Fractures during the bisque bake, however, often are the result of improper condensation, overly rapid drying, or haphazard moisture control. Poor substructure design, resulting in areas of unsupported porcelain, also can lead to porcelain failure (see Chapter 19). After cementation, pinpointing the cause of failure may be difficult. If the substructure is properly designed and the porcelain-metal interface is kept away from direct occlusal contact, cracks and fractures should not develop during normal function.

Bubbles

Even the most experienced ceramist sometimes traps air between the metal and the opaque porcelain. Usually this is of little concern. However, if a restoration is fired too many times, the trapped air may appear as blisters that rise to the surface. If this occurs, the porcelain must be stripped, and the procedure must start over.

If bubbles appear after only a few firings, improper casting technique, insufficient metal preparation, or haphazard moisture control can usually be isolated as the cause (Fig. 24-34).

Unsatisfactory Appearance

Poor esthetic results often result from poor communication between the operator and the dental technician (see Chapter 16). An opaque application that is too thick can result in opacity of the veneer. Inadequate tooth reduction, especially in the cervical third and the interproximal areas, is one of the more common causes of a poor esthetic result. Careful communication, based on a thorough understanding and knowledge of relevant laboratory procedures and color science, is essential.

PRESS-TO-METAL TECHNIQUE

Press-to-metal porcelain systems (Fig. 24-35) allow metal-ceramic restorations to be fabricated with the lost-wax

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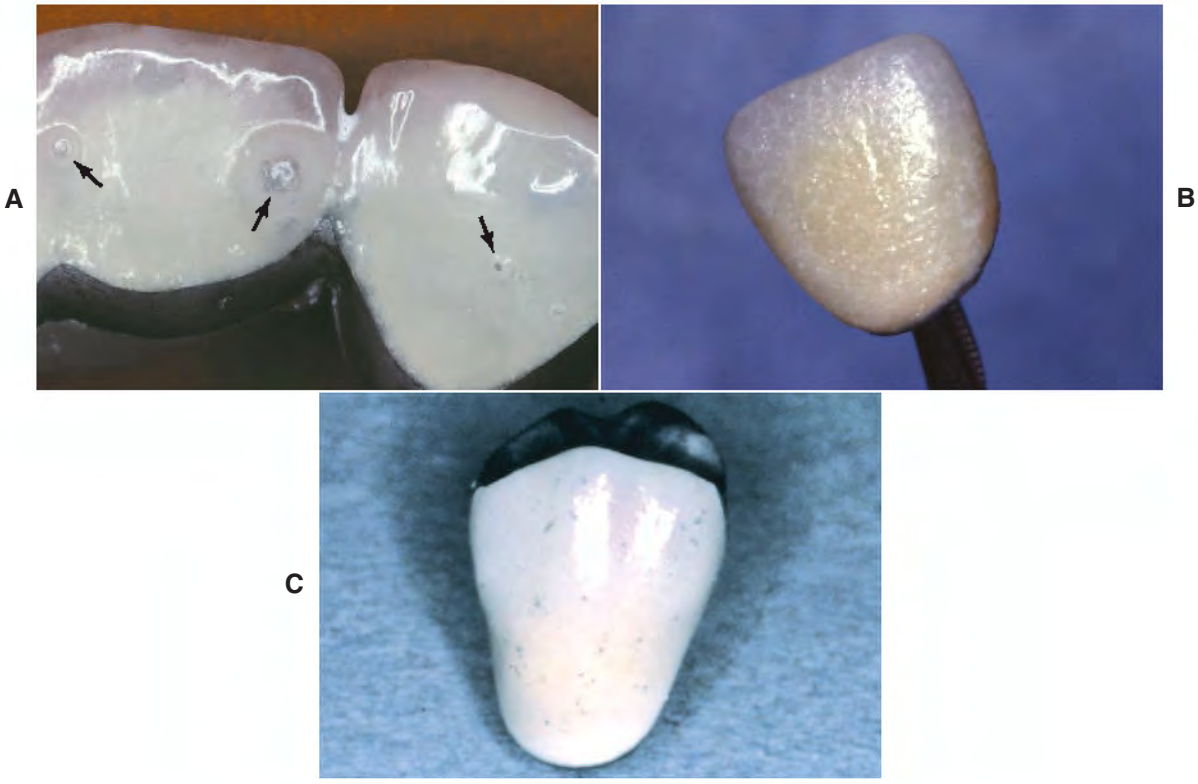

FIGURE 24-34 ■ **A,** Bubbles *(arrows)* have made this metal-ceramic restoration unacceptable. **B,** Devitrified porcelain on a metal-ceramic restoration is the result of an excessive number of firings. **C,** Contamination of the porcelain surface has made this prosthesis unacceptable.

process. The porcelain is applied to an opaque framework is a similar manner as the fabrication of heat-pressed dental ceramics for all-ceramic restorations (see Chapter 25). The metal-ceramic bond in the press-to-metal technique is similar to that in traditional powder application.[94]

REVIEW OF TECHNIQUE

Fabricating a metal-ceramic restoration involves the following steps:

1. Patterns are waxed to anatomic contour.
2. The cutback is completed and verified with an index made from the anatomic waxing.
3. The patterns are cast (see Chapter 22) and seated on the die.
4. After finishing (and clinical evaluation if desired; see Chapter 29), the substructures are coated with opaque porcelain to mask the metal color.
5. Body powders are added to build to contour and cut back to standardize the amount of enamel powder that is added.
6. Enamel powder is added, and the buildup is slightly overcontoured to compensate for firing shrinkage.
7. After preliminary contouring, the bisque bake can be evaluated clinically. The incisal edge position is adjusted for function, esthetics, and phonetics.
8. After contouring, the restorations are glazed, and the metal is polished before cementation.

SUMMARY

Substructure design for metal-ceramic restorations must be based on an understanding of fundamental material properties. Restorations should be waxed to anatomic contour and then cut back in the area that is to be veneered. This allows porcelain thickness to be even, which not only is a means of obtaining superior mechanical properties in the completed restoration but also simultaneously helps standardize shade matching.

Metal-ceramic restorations with excellent appearance and good mechanical properties are obtainable if the techniques of metal preparation, framework design, porcelain manipulation, drying, and firing are carefully followed. Lifelike effects can be achieved by layering cervical, body, and incisal porcelains and by the judicious use of internal characterization and special dentin powders with relatively higher concentrations of opacifiers. Although it may create esthetic problems in many patients, the simplest way to obtain good marginal fit is to use a narrow, 0.2- to 0.3-mm facial collar.

Whenever optimum appearance is desired, the procedures described in this chapter for fabricating a labial porcelain margin should be considered. However, the level of expertise needed to produce excellent marginal adaptation with these techniques is higher than that needed to use a cast margin; this should be considered in treatment planning. When failure occurs, all technical steps and materials should be reevaluated.

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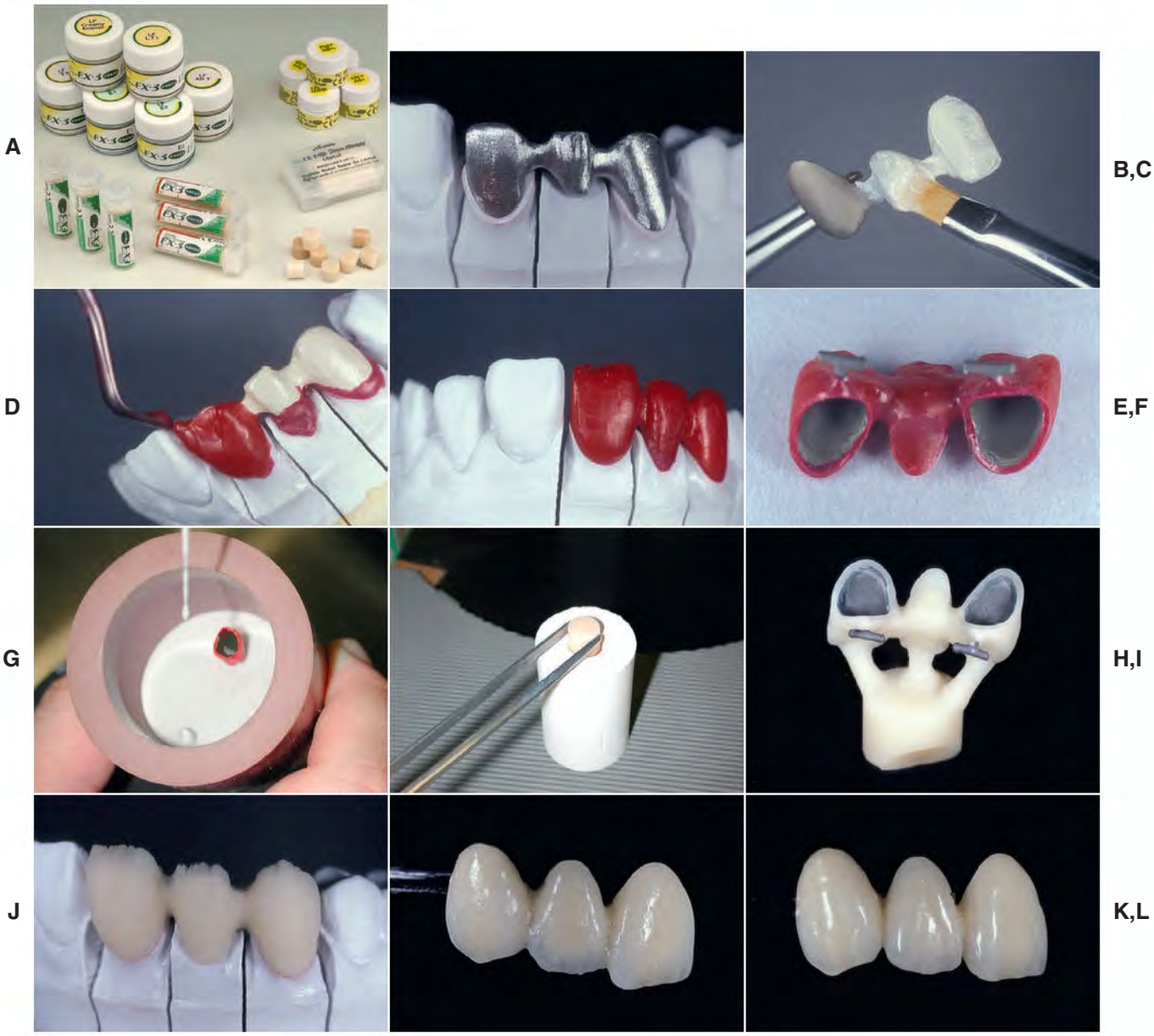

FIGURE 24-35 ■ Press-to-metal technique. **A,** Press-on-metal porcelain system. **B,** Metal-framework before oxidation. **C,** Special opaque porcelain is applied and fired. **D** to **F,** The opaque framework is waxed to the contour of the body porcelain. **G,** Investing the waxed framework. **H,** After wax elimination the porcelain is pressed. **I,** Pressed body porcelain. **J,** The incisal mamelons have been created by grinding the pressed porcelain. **K,** The incisal porcelain is added with special powders in the conventional manner. **L,** The completed restoration. (Courtesy Kuraray Noritake Dental Inc., Tokyo, Japan).

REFERENCES

1. Ernsmere JB: Porcelain dental work. Br J Dent Sci 43:547, 1900.
2. Johnston JF, et al: Porcelain veneers bonded to gold castings: a progress report. J Prosthet Dent 8:120, 1958.
3. Reitemeier B, et al: A prospective 10-year study of metal ceramic single crowns and fixed dental prosthesis retainers in private practice settings. J Prosthet Dent 109:149, 2013.
4. MacEntee MI, Belser UC: Fixed restorations produced by commercial dental laboratories in Vancouver and Geneva. J Oral Rehabil 15:301, 1988.
5. Goodacre CJ, et al: The collarless metal-ceramic crown. J Prosthet Dent 38:615, 1977.
6. Toogood GD, Archibald JF: Technique for establishing porcelain margins. J Prosthet Dent 40:464, 1978.
7. Warpeha WS, Goodkind RJ: Design and technique variables affecting fracture resistance of metal-ceramic restorations. J Prosthet Dent 35:291, 1976.
8. Moore PA, Manor RC: Hydrofluoric acid burns. J Prosthet Dent 47:338, 1982.
9. Felton DA, et al: Effect of air abrasives on marginal configurations of porcelain-fused-to-metal alloys: an SEM analysis. J Prosthet Dent 65:38, 1991.
10. Hamaguchi H, et al: Marginal distortion of the porcelain-bonded-to-metal complete crown: an SEM study. J Prosthet Dent 47:146, 1982.
11. Richter-Snapp K, et al: Change in marginal fit as related to margin design, alloy type, and porcelain proximity in porcelain-fused-to-metal restorations. J Prosthet Dent 60:435, 1988.
12. Weinstein M, et al: Fused porcelain-to-metal teeth. Washington, D.C., U.S. Patent Office, Publication No. US3052982 A, September 11, 1962.
13. Weinstein M, Weinstein AB: Porcelain-covered metal-reinforced teeth. Washington, D.C., U.S. Patent Office, Publication No. US3052983 A, September 11, 1962.

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همیار دندانسازان و دندانپزشکان

14. Barreiro MM, et al: Phase identification in dental porcelains for ceramo-metallic restorations. Dent Mater 5:51, 1989.
15. Rasmussen ST, et al: Optimum particle size distribution for reduced sintering shrinkage of a dental porcelain. Dent Mater 13:43, 1997.
16. Laub LW, et al: The metal-porcelain interface of gold crowns [Abstract no. 874]. J Dent Res 57:A293, 1978.
17. Seghi RR, et al: Spectrophotometric analysis of color differences between porcelain systems. J Prosthet Dent 56:35, 1986.
18. Rosenstiel SF, Johnston WM: The effects of manipulative variables on the color of ceramic metal restorations. J Prosthet Dent 60:297, 1988.
19. O'Brien WJ, Ryge G: Contact angles of drops of enamels on metals. J Prosthet Dent 15:1094, 1965.
20. Borom MP, Pask JA: Role of "adherence oxides" in the development of chemical bonding at glass-metal interfaces. J Am Ceram Soc 49:1, 1966.
21. Ohno H, Kanzawa Y: Structural changes in the oxidation zones of gold alloys for porcelain bonding containing small amounts of Fe and Sn. J Dent Res 64:67, 1985.
22. Brantley WA, et al: X-ray diffraction studies of oxidized high-palladium alloys. Dent Mater 12:333, 1996.
23. Kerber SJ, et al: The complementary nature of x-ray photoelectron spectroscopy and angle-resolved x-ray diffraction. II. Analysis of oxides on dental alloys. J Mater Eng Perform 7:334, 1998.
24. Cascone PJ: The theory of bonding for porcelain-metal systems. In Yamada HN, Grenoble PB, eds: Dental porcelain: the state of the art—1977, p. 109. Los Angeles, University of Southern California School of Dentistry, 1977.
25. Cascone PJ: Oxide formation on palladium alloys and its effects on porcelain adherence [Abstract no. 772]. J Dent Res 62:255, 1983.
26. Lautenschlager EP, et al: Microprobe analyses of gold-porcelain bonding. J Dent Res 8:1206, 1969.
27. Payan J, et al: Changes in physical and chemical properties of a dental palladium-silver alloy during metal-porcelain bonding. J Oral Rehabil 13:329, 1986.
28. Hong JM, et al: The effect of recasting on the oxidation layer of a palladium-silver porcelain alloy. J Prosthet Dent 59:420, 1988.
29. Anusavice KJ, et al: Adherence controlling elements in ceramic-metal systems. I. Precious alloys. J Dent Res 56:1045, 1977.
30. Anusavice KJ, et al: Adherence controlling elements in ceramic-metal systems. II. Nonprecious alloys. J Dent Res 56:1053, 1977.
31. Papazoglou E, et al: New high-palladium casting alloys. Studies of the interface with porcelain. Int J Prosthodont 9:315, 1996.
32. Anusavice KJ: Phillips' science of dental materials, 11th ed, p. 342. Philadelphia, Elsevier Science/Saunders, 2003.
33. Caputo AA: Effect of surface preparation on bond strength of nonprecious and semi-precious alloys. J Calif Dent Assoc 6:42, 1978.
34. Baran GR: The metallurgy of Ni-Cr alloys for fixed prosthodontics. J Prosthet Dent 50:639, 1983.
35. Laub LW, et al: The tensile and shear strength of some base metal/ceramic interfaces [Abstract no. 504]. J Dent Res 56:B178, 1977.
36. Shell JS, Nielsen JP: Study of the bond between gold alloys and porcelain. J Dent Res 41:1424, 1962.
37. Carpenter MA, Goodkind RJ: Effect of varying surface texture on bond strength of one semiprecious and one nonprecious ceramo-alloy. J Prosthet Dent 42:86, 1979.
38. Wagner WC, et al: Effect of interfacial variables on metal-porcelain bonding. J Biomed Mater Res 27:531, 1993.
39. Powers JM, Sakaguchi RL, eds: Craig's restorative dental materials, 12th ed, p. 468. St. Louis, Elsevier Health Sciences/Mosby, 2006.
40. Meyer JM, et al: Sintering of dental porcelain enamels. J Dent Res 55:696, 1976.
41. Johnston WM, O'Brien WJ: The shear strength of dental porcelain. J Dent Res 59:1409, 1980.
42. Nally JN: Chemico-physical analysis and mechanical tests of the ceramo-metallic complex. Int Dent J 18:309, 1968.
43. Kelly M, et al: Tensile strength determination of the interface between porcelain fused to gold. J Biomed Mater Res 3:403, 1969.
44. Anusavice KJ, et al: Comparative evaluation of ceramic-metal bond tests using finite element stress analysis. J Dent Res 59:608, 1980.
45. O'Brien WJ: Cohesive plateau theory of porcelain-alloy bonding. In Yamada HN, Grenoble PB, eds: Dental porcelain: the state of the art—1977, p. 137. Los Angeles, University of Southern California School of Dentistry, 1977.
46. O'Brien WJ: The cohesive plateau stress of ceramic-metal systems [Abstract no. 501]. J Dent Res 56:B177, 1977.
47. American National Standards Institute/American Dental Association: Metal-ceramic dental restorative systems [ANSI/ADA Standard No. 38]. Chicago, American Dental Association, 2000.
48. Ringle RD, et al: An x-ray spectrometric technique for measuring porcelain-metal adherence. J Dent Res 62:933, 1983.
49. Mackert JR, et al: Measurement of oxide adherence to PFM alloys. J Dent Res 63:1335, 1984.
50. Papazoglou E, et al: Porcelain adherence to high-palladium alloys. J Prosthet Dent 70:386, 1993.
51. Papazoglou E, et al: Effects of dental laboratory processing variables and in vitro testing medium on the porcelain adherence of high-palladium casting alloys. J Prosthet Dent 79:514, 1998.
52. Adachi M, et al: Oxide adherence and porcelain bonding to titanium and Ti-6Al-4V alloy. J Dent Res 69:1230, 1990.
53. Cai Z, et al: Porcelain adherence to dental cast CP titanium: effects of surface modifications. Biomaterials 22:979, 2001.
54. Sadeq A, et al: Effects of interfacial variables on ceramic adherence to cast and machined commercially pure titanium. J Prosthet Dent 90:10, 2003.
55. Lee KM, et al: SEM/EDS evaluation of porcelain adherence to gold-coated cast titanium. J Biomed Mater Res B Appl Biomater 68B:165, 2004.
56. International Organization for Standardization: Dental porcelain fused to metal restorations [ISO Standard No. 9693]. Geneva, Switzerland, International Organization for Standardization, 2000 (updated and approved 2012).
57. Lenz J, et al: Bond strength of metal-ceramic systems in three-point flexure bond test. J Appl Biomater 6:55, 1995.
58. Lenz J, Kessel S. Thermal stresses in metal-ceramic specimens for the ISO crack initiation test (three-point flexure bond test). Dent Mater 14:277, 1998.
59. Papazoglou E, Brantley WA: Porcelain adherence vs. force to failure for palladium-gallium alloys: critique of metal-ceramic bond testing. Dent Mater 14:112, 1998.
60. Leone EF, Fairhurst CW: Bond strength and mechanical properties of dental porcelain enamels. J Prosthet Dent 18:155, 1967.
61. Knap FJ, Ryge G: Study of bond strength of dental porcelain fused to metal. J Dent Res 45:1047, 1966.
62. Sced IR, McLean JW: The strength of metal/ceramic bonds with base metals containing chromium. Br Dent J 13:232, 1972.
63. Zinelis S, et al: Bond strength and interfacial characterization of eight low fusing porcelains to cp Ti. Dent Mater 26:264, 2010.
64. Haag P, Nilner K: Bonding between titanium and dental porcelain: a systematic review. Acta Odontol Scand 68:154, 2010.
65. İnan Ö, et al: Effects of sandblasting and electrical discharge machining on porcelain adherence to cast and machined commercially pure titanium. J Biomed Mater Res B Appl Biomater 78:393, 2006.
66. Kim JT, Cho SA: The effects of laser etching on shear bond strength at the titanium ceramic interface. J Prosthet Dent 101:101, 2009.
67. Li JX, et al: Effects of micro-arc oxidation on bond strength of titanium to porcelain. Surf Coat Technol 204:1252, 2010.
68. Mohsen CA: Effect of surface roughness and thermal cycling on bond strength of C.P. titanium and Ti-6Al-4V alloy to ceramic. J Prosthodont Res 56:204, 2012.
69. Acar A, et al: Effects of airborne-particle abrasion, sodium hydroxide anodization, and electrical discharge machining on porcelain adherence to cast commercially pure titanium. J Biomed Mater Res B Appl Biomater 82:267, 2007.
70. Troia MG Jr, et al: The effect of surface modifications on titanium to enable titanium-porcelain bonding. Dent Mater 24:28, 2008.
71. Özcan I, Uysal H: Effects of silicon coating on bond strength of two different titanium ceramic to titanium. Dent Mater 21:773, 2005.
72. Papadopoulos TD, Spyropoulos KD: The effect of a ceramic coating on the cpTi-porcelain bond strength. Dent Mater 25:247, 2009.
73. Guo L, et al: Effect of oxidation and SiO_2 coating on the bonding strength of Ti-porcelain. J Mater Eng Perform 19:1189, 2010.
74. Xia Y, et al: Effect of ZrN coating by magnetron sputtering and sol-gel processed silica coating on titanium/porcelain interface bond strength. J Mater Sci Mater Med 22:317, 2011.

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75. Lim HP, et al: Fracture load of titanium crowns coated with gold or titanium nitride and bonded to low-fusing porcelain. J Prosthet Dent 105:164, 2011.
76. Atsü S, Berksun S: Bond strength of three porcelains to two forms of titanium using two firing atmospheres. J Prosthet Dent 84:567, 2000.
77. Liu R, et al: The effect of metal recasting on porcelain-metal bonding: a force-to-failure study. J Prosthet Dent 104:165, 2010.
78. Ucar Y, et al: Metal ceramic bond after multiple castings of base metal alloy. J Prosthet Dent 102:165, 2009.
79. Wang RR, et al: Silicon nitride coating on titanium to enable titanium-ceramic bonding. J Biomed Mater Res 46:262, 1999.
80. Terada Y, et al: The masking ability of an opaque porcelain: a spectrophotometric study. Int J Prosthodont 2:259, 1989.
81. McLaren EA: Utilization of advanced metal-ceramic technology: clinical and laboratory procedures for a lower-fusing porcelain. Pract Periodont Aesthet Dent 10:835, 1998.
82. Metzler KT, et al: In vitro investigation of the wear of human enamel by dental porcelain. J Prosthet Dent 81:356, 1999.
83. Rosenstiel SF: Linear firing shrinkage of metal-ceramic restorations. Br Dent J 162:390, 1987.
84. Evans DB, et al: The influence of condensation method on porosity and shade of body porcelain. J Prosthet Dent 63:380, 1990.
85. Rosenstiel SF, Porter SS: Apparent fracture toughness of metal ceramic restorations with different manipulative variables. J Prosthet Dent 61:185, 1989.
86. Mackert JR Jr, Evans AL: Effect of cooling rate on leucite volume fraction in dental porcelains. J Dent Res 70:137, 1991.
87. Asaoka K, Tesk JA: Transient and residual stress in a porcelain-metal strip. J Dent Res 69:463, 1990.
88. Barghi N, et al: Comparison of fracture strength of porcelain–veneered–to–high noble and base metal alloys. J Prosthet Dent 57:23, 1987.
89. Abbate MF, et al: Comparison of the marginal fit of various ceramic crown systems. J Prosthet Dent 61:527, 1989.
90. Belser UC, et al: Fit of three porcelain-fused-to-metal marginal designs in vivo: a scanning electron microscope study. J Prosthet Dent 53:24, 1985.
91. Anusavice KJ, Hojjatie B: Stress distribution in metal-ceramic crowns with a facial porcelain margin. J Dent Res 66:1493, 1987.
92. Touati B, Miara P: Light transmission in bonded ceramic restorations. J Esthet Dent 5:11, 1993.
93. O'Boyle K, et al: An investigation of new metal framework design for metal ceramic restorations. J Prosthet Dent 78:295, 1997.
94. Ishibe M, et al: Shear bond strengths of pressed and layered veneering ceramics to high-noble alloy and zirconia cores. J Prosthet Dent 106:29, 2011.

STUDY QUESTIONS

1. Discuss the types of dental porcelains used in the fabrication of a metal-ceramic restoration. What are the composition differences among the various powders? How does the handling differ?

2. What are the prerequisites for casting preparation before the initial firing?

3. What is the role of a vacuum in firing a metal-ceramic restoration? Which procedures require a vacuum, and which are performed without it?

4. How do firing schedules vary as a function of the alloy used?

5. What is vitrification? What is devitrification?

6. Discuss the porcelain-metal bond. Which components of the alloy are involved? Which components of the dental porcelain are involved?

7. Discuss two different techniques for fabricating a porcelain labial margin.

8. Describe the causes of fractures and air bubbles during the bisque bake.

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CHAPTER 25

All-Ceramic Restorations

Isabelle L. Denry, Contributing Author

All-ceramic inlays, onlays, veneers, and crowns can be some of the most esthetically pleasing restorations currently available. They can be made to match natural tooth structure accurately in terms of color, surface texture, and translucency. Well-made all-ceramic restorations can be virtually indistinguishable from unrerestored natural teeth (Fig. 25-1).

Traditionally, ceramic crowns have been made on a platinum matrix and were referred to as *porcelain jacket crowns*. More recently, improved materials and techniques have been introduced in an attempt to overcome disadvantages inherent in that traditional method. These improvements, particularly the use of higher strength ceramics and adhesives for bonding the ceramic restoration to tooth structure, have led to a resurgence of interest in all-ceramic restorations, including the more conservative inlays and veneers (Fig. 25-2). With increasing esthetics demand, all-ceramic restorations are an important part of contemporary dental practice.

In this chapter, the historical background of all-ceramic restorations and more recent developments is reviewed. The laboratory procedures necessary for the fabrication of all-ceramic inlays, veneers, and crowns are reviewed, and the alternatives are compared.

The importance of the design of the tooth preparation to the success of ceramic restorations cannot be overemphasized (see Chapter 11).

HISTORICAL BACKGROUND

The first attempt to use ceramics for making denture teeth was made by Alexis Duchateau in 1774. More than a hundred years later, C. H. Land made the first ceramic crowns and inlays with a platinum foil matrix technique in a gas-powered furnace and was granted a patent in 1887.[1] As this method was fraught with a number of risks, it did not become popular until electric furnaces were introduced a number of years later.[2] The popularity of ceramic restorations declined with the introduction of acrylic resin in the 1940s and continued to be low until the disadvantages of resin veneering materials (increased wear, high permeability leading to discoloration and leakage) were realized.[3-5] In 1962, Weinstein and Weinstein[6] patented a leucite-containing porcelain frit for use in metal-ceramic restorations. The presence of leucite, an aluminosilicate with high thermal expansion, allowed a match between the thermal expansion of the ceramic and that of the metal (see Chapter 24). The appearance of ceramic restorations was improved by the introduction of vacuum firing, which considerably reduced the amount of porosity and therefore resulted in restorations that were denser, stronger, and more translucent than could be achieved with air firing.[7]

HIGH-STRENGTH CERAMICS

The chief disadvantage of the early restorations was their low strength, which limited their use to low-stress situations, such as those encountered by anterior teeth. Thus fracture was a fairly common occurrence, which prompted the development of higher strength materials.[8,9] These developments have followed two paths. One approach is to use two ceramic materials to fabricate the restoration. A high-strength but nonesthetic ceramic core material is veneered with a lower strength, esthetic porcelain. This approach is similar to the metal-ceramic technique (see Chapter 24), although the color of the ceramic core is more easily masked than that of a metal substructure. The other approach is the development of a ceramic that combines good esthetics with high strength. This has the obvious attraction of not needing the additional thickness of material to mask a high-strength core.

Monolithic zirconia restorations[10,11] provide a good compromise of outstanding strength and esthetics that are acceptable for posterior restorations. The restorations are generally colored by dipping of the presintered material in special colorants,[12] although the process has drawbacks, including nonuniformity of the coloring[13] and color change after adjustment.[14] Because of their high strength, less tooth reduction is needed than for other all-ceramic or metal-ceramic systems.[15] Wear of opposing enamel appears to be less with monolithic zirconia than other dental ceramics,[16] although the restoration must be carefully polished because a rough surface will lead to increased wear of the opposing tooth.[17]

STRENGTHENING MECHANISMS OF DENTAL CERAMICS

In spite of their excellent esthetic qualities and outstanding biocompatibility, dental ceramics, like all ceramic materials, are brittle. They are susceptible to fracture at the time of placement and during function. Brittle materials such as ceramics always contain at least two types of flaws from which fracture can initiate: fabrication defects and surface cracks. Methods used to improve the strength and clinical performance of dental ceramics include crystalline reinforcement, chemical strengthening, and stress-induced transformation.

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FIGURE 25-1 ■ **A,** All-ceramic crown restoring the right maxillary central incisor. **B** and **C,** Maxillary anterior teeth restored with facial veneers and an all-ceramic fixed dental prosthesis. (**B** and **C,** Courtesy Dr. D.H. Ward.)

FIGURE 25-2 ■ **A,** Mandibular molar prepared for conservative ceramic onlay after cuspal fracture. **B,** Lithium disilicate evaluated intraorally before firing. **C,** Completed restoration.

Fabrication Defects

Fabrication defects are created during processing and consist of voids or inclusions generated during sintering. Condensation of a ceramic slurry by hand before sintering may introduce porosity. Sintering under vacuum reduces the porosity in dental ceramics from 5.6 to 0.56 volume percent.[18] Porosity on the internal side of clinically failed glass-ceramic restorations has been shown to be a fracture initiation site.[19] Also, microcracks develop within the ceramic upon cooling in leucite-containing ceramics and are caused by thermal contraction mismatch between the crystals and the glassy matrix.[20-22]

Surface Cracks

Surface cracks are induced by machining or grinding. The average natural flaw size varies from 20 to 50 μm.[23] Usually, fracture of the ceramic material originates from the most severe flaw, which effectively determines the fracture resistance of the restoration. Ceramic engineers analyze failure with a statistical approach, assessing flaw size and spatial distribution.[24]

Crystalline Reinforcement

Strengthening by crystalline reinforcement involves the introduction of a high proportion of crystalline phase into the ceramic material to improve the resistance to crack propagation. The crystals can deflect the advancing crack front to increase the fracture resistance of two-phase materials. Microstructural features that typically lead to crack deflection include (1) weakened interfaces between grains in single-phase materials that may be caused by incomplete sintering and (2) residual strains in two-phase materials.[25] The latter constitutes a major issue in dental ceramics.

A crystalline phase whose thermal expansion coefficient is *greater* than that of the matrix produces tangential *compressive* stress (and radial tension) near the crystal-matrix interface. Such tangential stresses tend to divert the crack around the particle. Leucite particles have a

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greater thermal expansion coefficient than does the surrounding glassy matrix. Upon cooling, compressive stresses develop at the leucite crystal–matrix interface.[21]

Chemical Strengthening

Chemical strengthening is another method used to increase the strength of glass and ceramics. Chemical strengthening relies on the exchange of small alkali ions for larger ions below the strain point of the ceramic material. Because stress relaxation is not possible in this temperature range, the exchange leads to the creation of a compressive layer at the surface of the ceramic.[26] Finally, any applied load must first overcome this built-in compression layer before the surface can be placed into tension; this results in an increase in fracture resistance. This technique involves the use of alkali salts with a melting point lower than the glass transition temperature of the ceramic material. Ion exchange strengthening has been reported to increase the flexural strength of feldspathic dental porcelain up to 80%, depending on the ionic species involved and the composition of the porcelain.[27,28] The depth of the ion-exchanged layer can be as high as 50 μm.[29] However, this technique is diffusion driven, and its kinetics are limited by time, temperature, and ionic radius of the exchanged ions.

In the glass industry, thermal tempering (fast cooling) is also used as a strengthening method.[30]

Stress-Induced Transformation

In some ceramic materials, such as polycrystalline zirconia, strengthening can be obtained through a stress-induced transformation. Zirconia is monoclinic at room temperature and tetragonal between about 1170°C (≈2140°F) and 2370°C (≈4300°F). The transformation between tetragonal and monoclinic zirconia is accompanied by an increase in volume. The tetragonal form can be retained at room temperature by addition of various oxides such as yttrium oxide. Stress can trigger the transformation from tetragonal to monoclinic zirconia, thereby leading to strengthening as a result of an increase in grain volume in the vicinity of the crack tip.[31]

Glazing

The addition of a surface glaze can also be used to strengthen ceramics. The principle is the formation of a low-expansion surface layer formed at a high temperature. Upon cooling, the low-expansion glaze places the surface of the ceramic in compression and reduces the depth and width of surface flaws.[32]

With contemporary dental ceramics, self-glazing is the standard technique. This consists of an additional firing in air after the original firing, without application of a low-expansion glaze. However, self-glazing does not significantly improve the flexure strength of feldspathic dental porcelain.[33,34]

Prevention of Stress Corrosion

The strength of ceramics is reduced in moist environments. This weakening is caused by a chemical reaction between water and the ceramic at the tip of the strength-controlling crack, which results in an increase in the crack size—a phenomenon called *stress corrosion* or *static fatigue*.[35] According to Michalske and Freiman,[36] the reaction steps involve the following:

1. The adsorption of water to a strained silicon-oxygen-silicon (Si-O-Si) bond
2. A concerted reaction involving simultaneous proton and electron transfer
3. The formation of surface hydroxyls

Sherrill and O'Brien[37] reported a reduction in fracture strength of about 30% when dental porcelains were fractured in water, and other authors[38,39] have concluded that stress corrosion is important in the performance of dental ceramic restorations.

Ceramic systems such as Captek (The Argen Corporation) that are baked on a metal foil may reduce fracture incidence by reducing moisture exposure to the internal surface of the ceramic material, from where the fracture is thought to initiate.[19] In industry, coatings such as optical fibers are used to reduce stress corrosion of glass and ceramics. Similar coatings have been tried experimentally for their effect on dental ceramics.[40]

ALL-CERAMIC SYSTEMS

The microstructure of some ceramic systems discussed in this chapter is illustrated in Figure 25-3, and their properties are summarized in Table 25-1.

Aluminous Core Ceramics

The high-strength ceramic core was first introduced to dentistry by McLean and Hughes[41] in 1965. They advocated using aluminous porcelain, which is composed of aluminum oxide (alumina) crystals dispersed in a glassy matrix. Their recommendation was based on the use of alumina-reinforced porcelain in the electrical industry[42] and the fact that alumina has high fracture toughness and hardness.[43]

The technique devised by McLean[44] involved the use of an opaque inner core containing 50% by weight alumina for high strength. This core was veneered by a combination of esthetic body and enamel porcelains with 15% and 5% crystalline alumina, respectively[45] (Fig. 25-4) and matched thermal expansion. The resulting restorations were approximately 40% stronger than those with traditional feldspathic porcelain.[35]

High-strength core frameworks for all-ceramic restorations were later produced with a slip-casting procedure[46] such as the VITA In-Ceram (VITA North America). Slip-casting is a traditional technique in the ceramic industry and is used to make sanitary ware. The starting medium in slip-casting is a slip that is an aqueous suspension of fine ceramic particles in water with dispersing agents. The slip is applied onto a porous refractory die, which absorbs the water from the slip and leads to the condensation of the slip on the die. The piece is then fired at a high temperature (1150°C [≈2100°F]). The refractory die shrinks more than the condensed slip, which allows easy separation after firing. The fired porous

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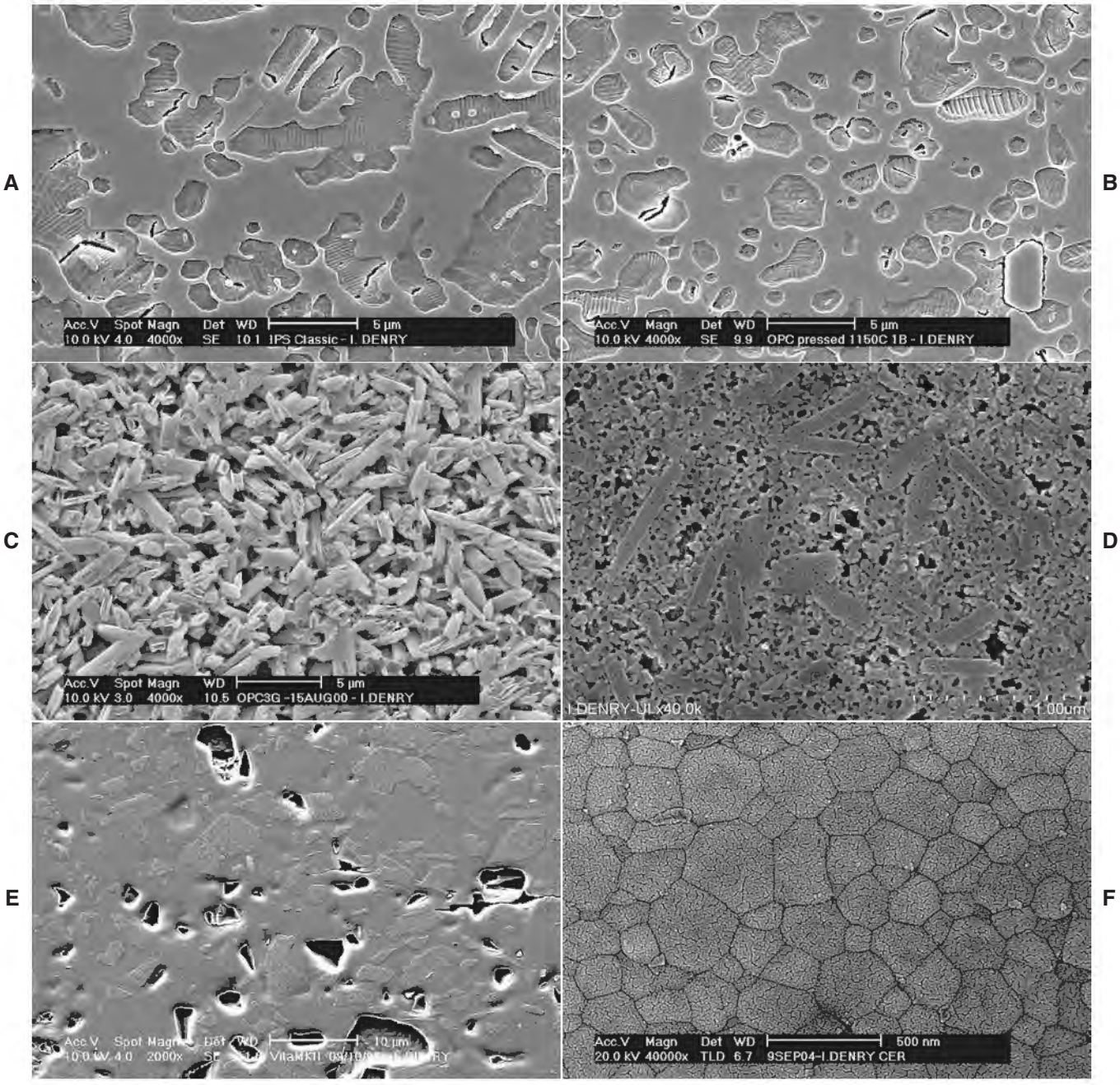

FIGURE 25-3 ■ Representative dental ceramics etched to reveal microstructure. **A,** A feldspathic porcelain (IPS Classic, Ivoclar Vivadent). **B,** A leucite-reinforced Optimal Pressable Ceramic (OPC, Pentron Clinical). **C,** A lithium disilicate Optimal Pressable Ceramic (OPC 3G, Pentron Clinical). **D,** A zirconia-reinforced lithium silicate ceramic (Suprinity, VITA North America). **E,** A feldspathic machinable (VITA Mark II, VITA North America). **F,** A machined and sintered zirconia ceramic (Cercon, DeguDent/Dentsply International).

core is then glass infiltrated, a unique process in which molten glass is drawn into the pores by capillary action at a high temperature.[47] Materials processed by slip-casting tend to exhibit lower porosity and fewer processing defects than do traditionally sintered ceramic materials. The strength of In-Ceram is about three to four times greater than that of earlier alumina core materials.[48,49] Subsequently, modified porcelain compositions for the In-Ceram technique were introduced: In-Ceram Spinell* contains a magnesium spinel ($MgAl_2O_4$) as the major crystalline phase, which improves the translucency of the definitive restoration (Fig. 25-5). In-Ceram Zirconia contains zirconium oxide (ZrO_2) and is said to provide the highest strength.[50,51] Marginal fit of In-Ceram has been reported as very good[52] or good[53] but also poor,[54]

*Note: "Spinell" in this product name is spelled differently from the mineral spinel.

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TABLE 25-1 **Comparison of Available All-Ceramic Systems**

	Brand						
Information	CAPTEK	CERAMCO 3	CERINATE	IPS EMPRESS	IPS E.MAX PRESS	BRUXZIR	IPS EMPRESS COSMO
Manufacturer	The Argen Corporation	Dentsply	DenMat	Ivoclar Vivadent	Ivoclar Vivadent	Glidewell Laboratories	Ivoclar Vivadent
Crystalline phase	Leucite	Leucite	Leucite	Leucite	Lithium disilicate	Zirconia	Lithium phosphate
Recommended usage	Crowns	Inlays, onlays, veneers	Inlays, onlays, crowns, veneers	Inlays, onlays, crowns, veneers	Anterior three-unit FDPs, crowns	Posterior crowns and FDPs	Endodontic foundation
Fabrication	Sintered on metal foil	Sintered	Sintered	Heat-pressed	Heat-pressed	CAD/CAM	Heat-pressed
Strength	Low	Low	Medium/low	Medium/low	High	Very high	Medium
Fracture toughness	Medium/low	Medium/low	Medium/low	Medium/low	High	Very high	Medium
Translucency	Opaque	Medium	Medium	Medium	Medium	Low	Medium
Enamel abrasiveness	Medium	Medium	High	Medium	Low	Low	Not tested
Marginal fit	Good	Fair	Fair	Fair	Fair	Good	Not tested

CAD/CAM, Computer-aided design/computer-aided manufacturing; *FDP,* fixed dental prosthesis.

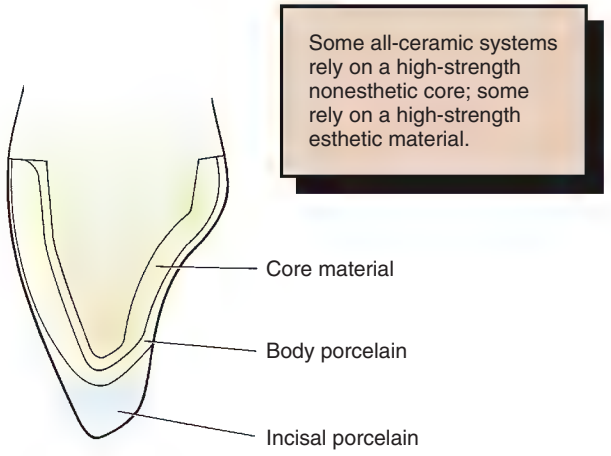

FIGURE 25-4 ■ The strength of a veneered zirconia crown is derived from its high strength zirconia core, onto which esthetic body and incisal porcelains are fired. This is analogous to the metal-ceramic crown, whose strength is derived from a metal substructure.

which emphasizes the technique sensitivity of the process and the need to select a skilled dental laboratory.

Heat-Pressed Ceramics

Leucite Based

Heat-pressed ceramics have been popular in restorative dentistry since the early 1990s. The restorations are waxed, invested, and pressed in a manner somewhat similar to that for gold casting. Marginal adaptation seems to be better with heat pressing than with the high-strength alumina core materials,[54] although the results from individual dental laboratories may not support the research findings. Most heat-pressed materials contain leucite as a major reinforcing crystalline phase, dispersed in a glassy matrix. The crystal size varies from 3 to 10 μm, and the leucite content varies from approximately 35% to approximately 50% by volume, depending on the material. Research has shown that residual tangential stresses remain around the leucite crystals after cooling.[21] Ceramic ingots are pressed at a high temperature (≈1165°C [≈2130°F]) into a refractory mold made by the lost-wax technique. The ceramic ingots are available in different shades.

Two finishing techniques can be used: a characterization technique (surface stain only) and a layering technique, involving the application of a veneering porcelain (Fig. 25-6, *G* and *H*). The two techniques lead to comparable mean flexural strength values for the resulting porcelain composite.[55] The thermal expansion coefficient of the core material for the veneering technique is usually lower than that of the material for the staining technique, to be compatible with the thermal expansion coefficient of the veneering porcelain. Among the currently available leucite-containing materials for heat-pressing are IPS Empress (Ivoclar Vivadent); Optimal Pressable Ceramic (OPC, Pentron Clinical); and two lower fusing materials: Cerpress (ADS, Inc) and Finesse (Dentsply Prosthetics).

Lithium Silicate Based

IPS e.max* is an example of the second generation of heat-pressed dental ceramics. The major crystalline phase

*Ivoclar Vivadent, Inc, Amherst, New York

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	Brand					
FINESSE	VITA SUPRINITY	VITA IN-CERAM ALUMINA	MARK II	PROCAD	LAVA	METAL-CERAMIC
Dentsply Ceramco	VITA North America	VITA North America	VITA North America	Ivoclar Vivadent	3M ESPE Dental	Various
Leucite	Zirconia lithium silicate	Alumina	Feldspar	Leucite	Zirconia	Leucite
Inlays, onlays, crowns, veneers	Crowns, veneers	Crowns, veneers	Inlays, onlays, crowns	Inlays, onlays, crowns	Crowns, FDPs	Crowns, FDPs
Heat-pressed	CAD/CAM	CAD/CAM	CAD/CAM	CAD/CAM	CAD/CAM and sintered	Cast framework, sintered porcelain
Medium/low	High	High	Medium/low	Medium/low	Very high	Very high
Medium/low	High	High	Medium/low	Medium/low	Very high	Medium
Medium	Medium	Medium	Medium	Medium	Opaque	Opaque
Medium	Medium	Medium	Medium	Not tested	Not tested	Medium
Not tested	Good	Good	Fair	Fair	Not tested	Good

FIGURE 25-5 ■ **A,** Defective maxillary metal-ceramic crowns. Esthetic problems included high value and opacity. **B,** Crowns removed. The preparations are not discolored and thus allow a translucent all-ceramic crown system. **C,** Maxillary all-ceramic crowns with a translucent slip-cast spinel core material. (Courtesy Dr. R.B. Miller.)

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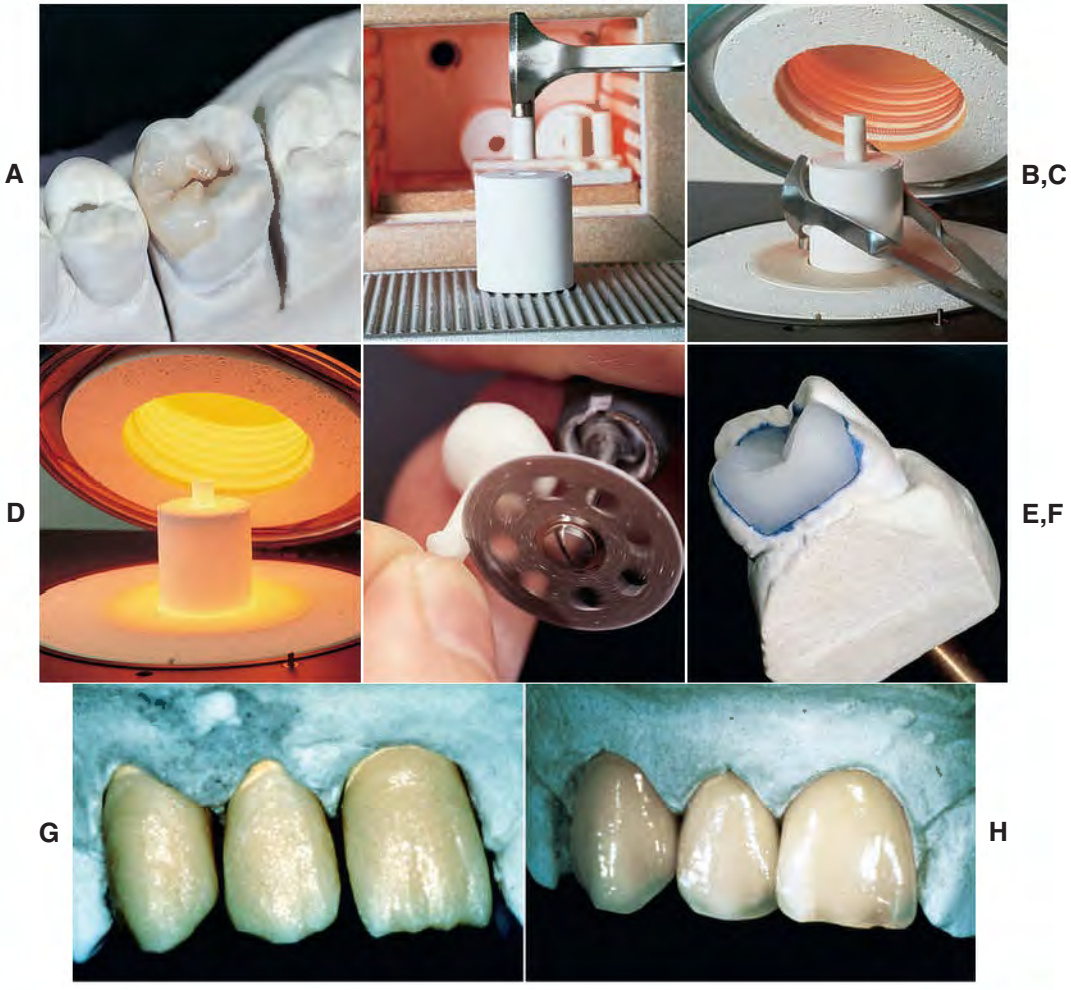

FIGURE 25-6 ■ Heat-pressed ceramic technique. **A,** Ceramic inlay restoration for a maxillary molar. A wax pattern is made in a manner similar to that for conventional gold castings. **B,** After the pattern is invested, it is burned out, and a ceramic ingot and an alumina plunger are placed in the heated mold. **C** and **D,** The pressing is done under vacuum pressure at 1165°C. **E,** The sprue is removed. **F,** The pressed restoration is seated on the die. **G** and **H,** For esthetic anterior restorations, only the dentin-colored ceramic is pressed. The incisal porcelain is applied by brush in the conventional manner.

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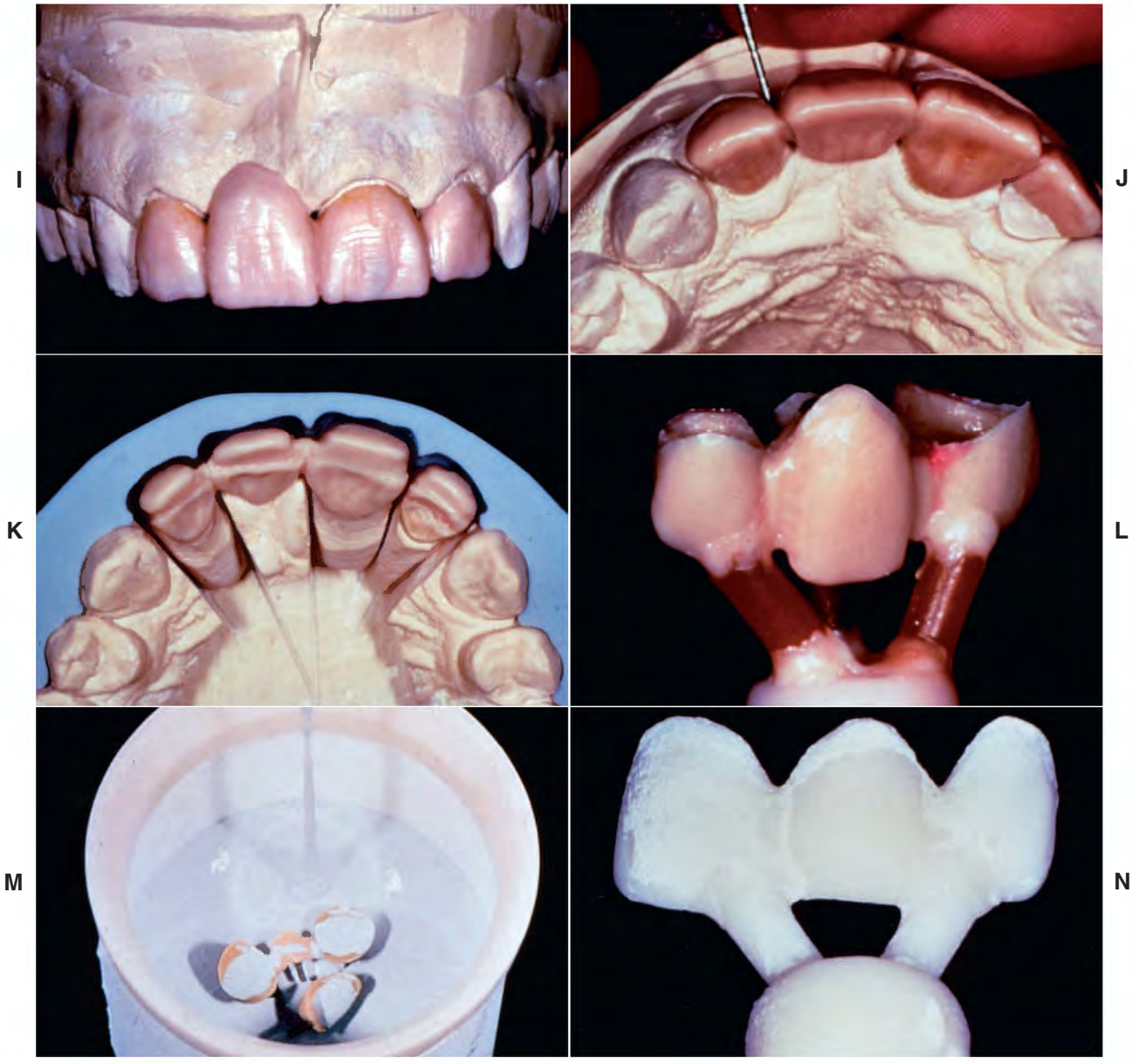

FIGURE 25-6, cont'd ■ **I,** Three-unit fixed dental prosthesis and veneer waxed to anatomic contour. **J,** The technician ensures that the connector size is adequate (4 × 4 mm). **K,** A silicone putty matrix is used to aid in cutback of the wax pattern. The sprue is inserted into the framework **(L),** the framework is invested **(M),** and the lithium-silicate ceramic is pressed into the mold. **N,** The pressed restoration.

Continued

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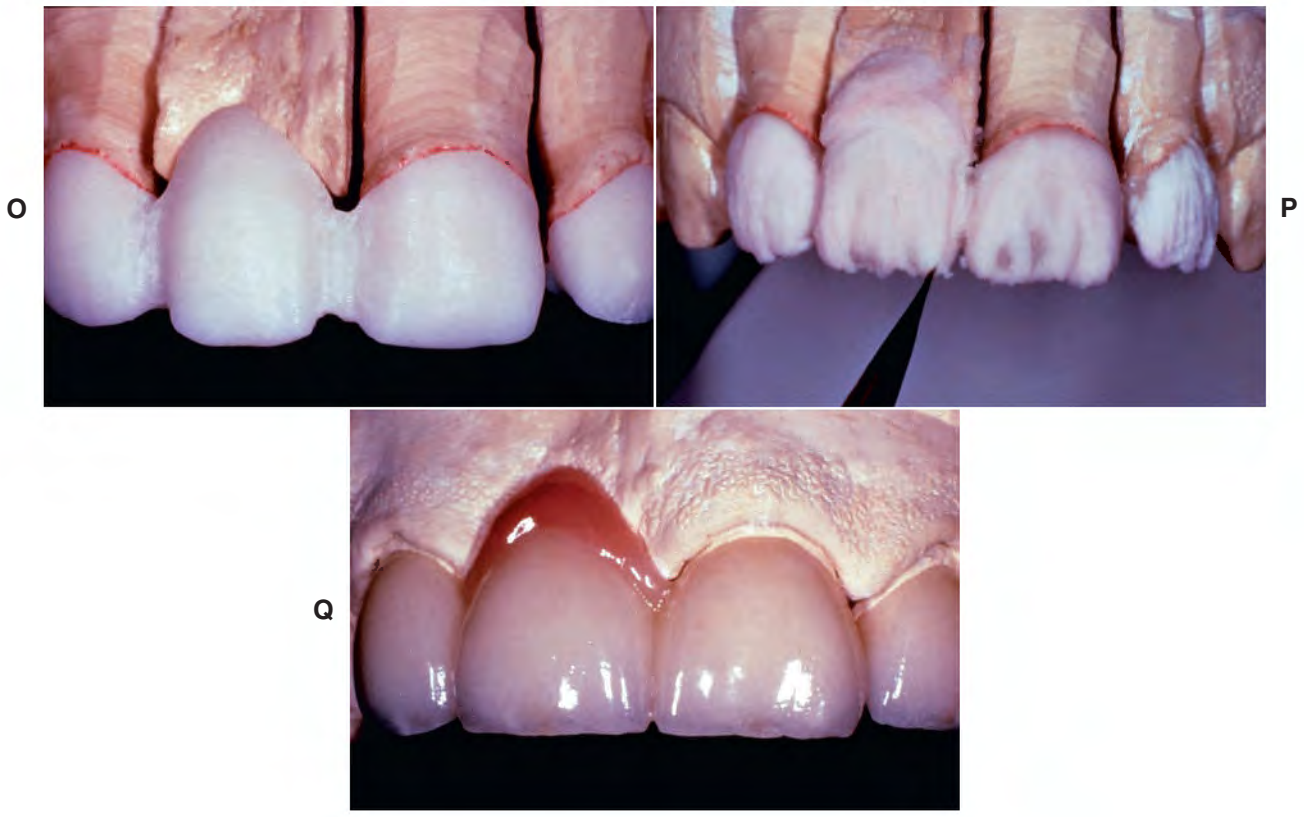

FIGURE 25-6, cont'd ■ O, Framework on definitive cast. **P,** Applying veneering porcelain. **Q,** Completed restorations. (Courtesy Ivoclar Vivadent, Amherst, New York.)

of the core material is a lithium disilicate. The material is pressed at 920°C (≈1690°F) and layered with a glass containing some dispersed apatite crystals.[56,57]

The indications for higher-strength pressable dental ceramics include crowns and anterior three-unit fixed dental prostheses (FDPs).

Fabrication Procedure

1. Wax the restoration to anatomic contour, insert sprue, and invest as with conventional gold castings (see Fig. 25-6, *A*). If the veneering technique is used, only the body porcelain shape is waxed.
2. Heat the investment to 800°C (or recommended temperature) to burn out the wax pattern.
3. Insert a ceramic ingot of the appropriate shade and alumina plunger in the sprue (see Fig. 25-6, *B*), and place the refractory cast in the special pressing furnace (see Fig. 25-6, *C*).
4. After heating to 1165°C, the softened ceramic is slowly pressed into the mold under vacuum (see Fig. 25-6, *D*).
5. After pressing, recover the restoration from the investment by airborne-particle abrasion, remove the sprue (see Fig. 25-6, *E*), and refit the pressed restoration to the die (see Fig. 25-6, *F*). Esthetics can be enhanced by applying an enamel layer of matching porcelain (see Fig. 25-6, *G* and *H*) or by adding surface characterization. The procedure for an FDP is similar (see Fig. 25-6, *I* to *Q*).

Machined Ceramics

The evolution of computer-assisted design/computer-assisted manufacturing (CAD/CAM) systems for the production of machined inlays, onlays, veneers, and crowns led to the development of a new generation of ceramics that are machinable.

Cerec System

The Cerec system (Sirona Dental Systems, LLC) has been marketed since the 1980s; improved systems were introduced as advances in scanning and milling machines were developed. The current Omnicam intraoral scanning wand with upgraded software is a significant improvement over earlier versions. The equipment consists of a computer-integrated imaging and milling system, with the restorations designed on the computer screen (Fig. 25-7, *A*). Several materials can be used with this system: VITA Mark II (VITA North America), IPS Empress CAD (Ivoclar Vivadent), IPS e.max CAD (Ivoclar Vivadent), CEREC Blocs C (Cerec 3D, Sirona Dental Systems, Inc.), and In-Ceram Alumina and Spinell (Dentsply Prosthetics). VITA Mark II contains a feldspar (sanidine, $KAlSi_3O_8$) as a major crystalline phase within a glassy matrix. IPS Empress CAD is a leucite-containing ceramic designed for making machined restorations. In-Ceram Alumina and Spinell are machined before the infiltration and veneering stages. Composite resin blocks are also available. Weaknesses of the earlier Cerec systems

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FIGURE 25-7 ■ Cerec Omnicam computer-assisted design/computer-assisted manufacturing (CAD/CAM) system. **A,** The Cerec Omnicam system consists of an imaging system, a computer, and a milling system. **B,** Making an optical impression. **C,** A number of computer-assisted designs for extracoronal restorations are available. **D,** The software enables simulated mandibular movements to help evaluate that the desired occlusal structure is approximated. **E-G,** Blocks are available in different ceramic systems, as is composite resin. **H,** Milling of a blue, translucent-state lithium disilicate crown in progress. *Continued*

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FIGURE 25-7, cont'd ■ **I,** Completely milled extracoronal restoration. **J,** Restoration on firing tray before firing to transform the lithium metasilicate into lithium disilicate. On firing, the restoration achieves its desired appearance. **K** and **L,** Completed crown. (**A** to **D** and **H** to **L,** Courtesy Dr. R. Fox, Sirona Dental Systems, Inc., Charlotte, North Carolina. **E,** Courtesy VITA North America, Yorba Linda, California. **F,** Courtesy Ivoclar Vivadent, Amherst, New York. **G,** Courtesy 3M ESPE Dental, St. Paul, Minnesota.)

included poor marginal fit of the restorations[58] and the lack of sophistication in machining of the occlusal structure. The marginal adaptation of Cerec 3 was improved,[59] and achieving improved occlusal anatomy became feasible. The most recently introduced version of the CAD/CAM software (Cerec 3D, Sirona Dental Systems, Inc.) allows complete three-dimensional visualization of the designed restoration with "virtual seating" capabilities. The various surfaces of the virtual restoration can be modified in all three dimensions before machining.

Fabrication Procedure

1. Tooth preparation follows typical all-ceramic guidelines.
2. Coat the preparation with opaque powder.
3. Use the optical scanner to obtain an image of the preparation, aligning the camera with the path of insertion of the restoration (see Fig. 25-7, *B*). When the best view is obtained, store it in the computer.
4. Identify and mark the margins and contours on the computer screen. The computer software assists with this step (see Fig. 25-7, *C*).
5. Manipulate the design software to simulate excursive movements and adjust restoration design accordingly (see Fig 25-7, *D*).
6. Select the appropriate size block of the selected material from which the restoration is to be milled (see Fig. 25-7, *E* to *G*), and insert the appropriate shade of ceramic block in the milling machine. Fabrication time for a crown varies (see Fig. 25-7, *H* and *I*). Lithium disilicate crowns can be machined from blocks that have been fired only to achieve an intermediate level of crystallization, enabling more efficient milling with less wear on the cutting tools. Specifically, the metasilicate crystals allow for good edge stability and machinability. Subsequent firing converts the BlueBlock lithium metasilicate crystals to their final crystallized state to achieve significantly higher strength. After crystallization, IPS e.max CAD lithium disilicate reportedly consists of up to 70% lithium disilicate crystals in a glassy matrix (see Fig. 25-7, *J* and *K*).
7. Additional characterization can be achieved with surface stains incorporated into an overglaze (see Fig. 25-7, *L*).
8. Evaluate the restoration in the patient's mouth, etch, and silanate and lute it to place as described in Chapter 30.

Machined and Sintered Ceramics

Zirconia Ceramics

Extensive research in the field of zirconia ceramics and CAD/CAM technology has led to the development of

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zirconia ceramics for dental restorations.[60] The material used is tetragonal zirconia stabilized with 3 mol% yttrium oxide. Enlarged zirconia copings are machined from presintered zirconia blocks to compensate for the sintering shrinkage. The restorations are later sintered at a high temperature (1350°C to 1450°C [≈2460°F to ≈2640°F], depending on the manufacturer) for several hours. Matching veneering ceramics are available to achieve an esthetic restoration for an anterior tooth (Figs. 25-8 and 25-9). For posterior teeth, anatomic-contour (monolithic) restorations in which the color is imparted with an intrinsic dye[12,13] (Fig. 25-10) are used. Zirconia materials exhibit very high strength and high fracture toughness. Long-term data are needed to assess the clinical performance of these ceramics. The concern is that the restorations may be susceptible to low-temperature degradation,[10] particularly if lower-grade powders and high sintering temperatures are used. Nevertheless, medium-term clinical performance has been acceptable.[61]

Zirconia-Reinforced Lithium Silicate Ceramics

Lithium silicate-based glass-ceramics have been introduced as machinable materials (Celtra, Dentsply Prosthetics; Vita Suprinity, VITA North America) for CAD-CAM techniques, with claimed mechanical properties comparable with those of lithium disilicate glass-ceramics.[62] The technology relies on the addition of 10 mass percent zirconium oxide to lithium silicate glass compositions.[10] Zirconia acts as nucleating agent but remains in solution in the glassy matrix, with two main consequences: A dual microstructure consisting of very fine lithium metasilicate (L_2SiO_3) and lithium disilicate ($Li_2Si_2O_5$) crystals is obtained, with a glassy matrix reinforced by the presence of zirconium oxide in solution.[63] The microstructure is achieved in two stages. The glass-ceramic in the first precrystallized stage contains only lithium metasilicate crystals and is easy to machine. The final crystallization stage, leading to the dual lithium silicate microstructure, is obtained after a short heat treatment at 840°C (1544°F) for 8 minutes. The main difference between zirconia-reinforced lithium silicate ceramics and lithium disilicate glass-ceramics in their final stage of crystallization concerns the nature of the crystalline phases: lithium metasilicate plus lithium disilicate for zirconia-reinforced lithium silicate ceramics and only lithium disilicate for lithium disilicate ceramics.[10] The zirconia-containing lithium silicate glass-ceramic material illustrates the ongoing quest for ceramic materials that offer adequate translucency combined with superior mechanical properties. These stable ceramics may offer better reliability than do zirconia ceramics but may not represent the endpoint for this quest.

FIGURE 25-8 ■ The Procera AllCeram system. **A,** Tooth preparations for Procera crown on the maxillary anterior teeth. **B,** Completed restorations. **C,** Tooth preparations for Procera fixed dental prosthesis. **D,** High-strength framework. Body and incisal porcelains will be subsequently applied. (**A** and **B,** Courtesy Dr. E. van Dooren. **C** and **D,** Courtesy Dr. E. Hagenbarth.)

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FIGURE 25-9 ■ The Lava system. **A,** Lava computer-assisted design/computer-assisted manufacturing (CAD/CAM) designing and milling machine. **B,** Computer design of framework. **C** and **D,** Framework milled from zirconia block.

Interpenetrating Phase Composites

Interpenetrating phase composites (IPCs) are characterized by two phases that are each intact three dimensionally (intertwined) throughout the fully dense material. Such composites are formed by infiltration of a porous structure (first phase) with a liquid to form the second interpenetrating phase. Melt-infiltration of glasses followed by solidification and monomer infiltration followed in turn by thermoset polymerization is a common fabrication method.[64] IPCs are often tougher and stronger and display a higher damage tolerance (R-curve behavior) than either pure phase.

Because of esthetic needs, only ceramic-glass and ceramic-polymer IPCs have been developed for dentistry. The first (In-Ceram Alumina, VITA North America) is based on alumina (68%) infiltrated with a lanthanum-containing glass.[65] Fabrication of porous alumina is achieved by initial sintering characterized by surface diffusion without shrinkage. In-Ceram Alumina was the first fully dense net-shape ceramic available for dental restorations, and it performed very well (91.5% to 100% success) in at least eight clinical trials of between 5 and 7 years.[66]

The second IPC for dental restorations was introduced in 2013 (VITA Enamic, VITA North America). This IPC is based on initial sintering of porcelain powder to approximately 70% of full density, followed by infiltration with dental monomers.[67] Whereas the porous ceramic network has a strength of 135 MPa and the polymer below 30 MPa, the infiltrated IPC has a strength of 160 MPa.[68] As would be expected, many bulk and elastic properties are intermediate between those of particle-filled resins and ceramics. In fatigue testing, VITA ENAMIC performed as well as lithium disilicate.[69] This IPC has three additional advantages over other CAD/CAM and pressable ceramics: (1) reasonable brittleness index; (2) lower hardness; and (3) similar creep response to enamel (lower contact stress development and good stress redistribution).[67]

Metal-Reinforced Systems

High-gold substructure systems are designed to overcome some of the disadvantages inherent in the porcelain jacket crown technique. The systems rely on different ways of creating a thin coping onto which the ceramic is

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FIGURE 25-9, cont'd ■ **E,** Veneering porcelain. **F,** Teeth prepared for posterior all-ceramic partial fixed dental prosthesis. **G,** Completed restoration. **H,** Framework evaluation for anterior partial fixed dental prosthesis. **I,** Completed anterior partial fixed dental prosthesis. (**A** to **E,** Courtesy 3M ESPE Dental, St. Paul, Minnesota. **F** and **G,** Courtesy Dr. L. Jones and M. Roberts, CDT. **H** and **I,** Courtesy Dr. V. Bonatz.)

fired. In strictest terms, therefore, they are metal-ceramic crowns, as opposed to all-ceramic crowns.

The Captek System

In the Captek (The Argen Corporation) system, the coping is produced from two metal-impregnated wax sheets that are adapted to a die and fired. The first sheet forms a porous gold-platinum-palladium layer that is impregnated with 97% gold when the second sheet is fired.[70] Advantages of the system include excellent esthetics and marginal adaptation.[71]

Fabrication Procedure

1. Duplicate the working die in the special refractory material (Fig. 25-11, *A*).
2. Cut a piece of the gold-platinum-palladium impregnated wax sheet (see Fig. 25-11, *B*).
3. Adapt the foil to the die (see Fig. 25-11, *C*). Then fire it to 1075°C (≈1965°F), so that it forms a porous metal coping.
4. Adapt the second gold-impregnated wax (see Fig. 25-11, *D*) and refire (see Fig. 25-11, *E*). Capillary action draws the gold into the porous gold-platinum-palladium structure to form the finished coping.
5. Build up the opaque body and incisal porcelains in a manner similar to that for a conventional metal-ceramic crown (see Fig. 25-11, *F*).
6. Glaze the completed restoration, and polish the metal foil at the margin (see Fig. 25-11, *G* and *H*). The procedure has been adapted for FDPs (see Fig. 25-11, *I*).

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FIGURE 25-10 ■ **A,** Patient was unhappy with the appearance of the gold crown on the mandibular first molar. **B,** Monolithic zirconia crown. **C,** The contour of the existing crown was scanned and replicated in the esthetic replacement.

SELECTION OF ALL-CERAMIC SYSTEMS

The primary purpose in recommending an all-ceramic restoration is to achieve the best possible esthetic result. Typically this is at the risk of reduced restoration longevity because of the potential for fracture of the ceramic material, and the restoration may have a slightly inferior marginal adaptation than does a metal-ceramic crown.

Fracture Resistance

Long-term performance of all-ceramic restorations has long been hampered by problems with restoration fracture, and these restorations were mainly confined to lower stress anterior teeth; their greatest benefit was the improved esthetics. However, the newer materials, particularly the monolithic zirconias and lithium disilicates, have much higher strength (see Table 25-1), and medium-term clinical performance is promising. The materials are still relatively new, and long-term data to determine whether they are satisfactory, particularly for FDPs, remains lacking.

Esthetics

A knowledge of the available ceramic systems is needed to select a material that will provide the best esthetics for a particular patient. This is especially important when a single maxillary incisor is matched to an adjacent tooth, undoubtedly still the most difficult challenge in fixed prosthodontics. Careful consideration should also be given to the availability of laboratory support because no dental laboratory invests in the expensive equipment needed for all the various systems. The marginal adaptation of the system is very important, even when resin bonding is used. When selecting a system, the dentist should carefully evaluate the internal and marginal adaptation, using an elastomeric detection paste (this must be thoroughly removed before the restoration is bonded). Although research studies have identified differences among the various systems[54] (see Table 25-1), these results may not represent an individual laboratory's results.

The translucency of the adjacent teeth and discoloration of the tooth being restored also must be considered when the most appropriate system is selected.[72] A more opaque, high-strength core, ceramic system (e.g., Procera [Nobel Biocare]) would not be a good choice for highly translucent teeth. However, such a system might be a good choice if the tooth exhibits discoloration that would not be well masked by a more translucent material. Conversely, when fracture is a concern, the higher strength materials should normally be given preference (see Table 25-1).

Abrasiveness

One concern with ceramic restorations is the potential for abrasion of the opposing enamel, particularly in patients with parafunctional habits. Whenever possible, a low-abrasion material should be considered. Abrasiveness has been studied in vitro,[16,73-81] and the results are summarized in Table 25-1.

INLAYS AND ONLAYS

Refractory Dies

Ceramic restorations can be made through the use of the heat-pressed systems or with the CAD/CAM process, but some technicians prefer a refractory die (Fig. 25-12). Marginal adaptation can be excellent, depending more on the technician's skill than on the ceramic material used.[82]

Step-by-Step Procedure

1. Pour an elastomeric impression of the prepared teeth in type IV or V stone; then repour it or duplicate it in ceramic refractory material, using an appropriate removable die system. The Di-Lok (see Chapter 17) or a similar system is convenient for this technique. The dies need to be separated very carefully because the refractory material is friable and breaks if mishandled.
2. Trim the refractory cast as far as possible to minimize the quantity of ammonia released during decontamination.
3. Mark the margins lightly with a special pencil (V.H.T., Whip Mix Corporation)
4. Decontaminate the cast by firing according to the manufacturer's instructions. This is normally done in two stages: the first in a burnout furnace, the second under vacuum pressure in a porcelain furnace.

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FIGURE 25-11 ■ The Captek system. **A,** Duplicated refractory die. **B,** Cutting the metal-impregnated wax sheet. **C,** Adapting the first sheet to the die. The first layer is fired to form a porous coping. **D,** Adapting the second metal-impregnated wax sheet. **E,** Fired framework. **F,** Sectioned Captek crown showing coping design. Defective metal-ceramic crown on the maxillary incisors **(G),** replaced with Captek crowns **(H). I,** Partial fixed dental prosthesis frameworks can be fabricated with special pontic components. (Courtesy The Argen Corporation, Altamonte Springs, Florida.)

5. Allow the cast to cool, and then soak it in soaking liquid or distilled water for 5 minutes. This seals the die and prevents moisture from being drawn out of the porcelain buildup.
6. Apply an initial layer of porcelain to the refractory cast, and fire the cast according to the manufacturer's directions. With some systems, a higher strength core material is used as the initial coat.
7. Build up the restorations onto moist dies; for inlays, leave short of the margins.
8. Make a relieving cut through the central fossa, and fire the porcelain.
9. Fill in the central fossa area, and build up to the margins.
10. Contour and refine occlusion and proximal contacts. Glaze according to the manufacturer's instructions.
11. Remove the investment with a bur and 50-µm alumina in an airborne-particle abrasion unit. Transfer the restorations to the master dies on the mounted cast.
12. If necessary, adjust the restoration margins and occlusion with fine-grit diamond stones. Polish with diamond polishing paste.

ALL-CERAMIC PARTIAL FIXED DENTAL PROSTHESES

All-ceramic FDPs have a checkered history. Researchers attempted to fabricate them with aluminous porcelain by connecting alumina cores with pure alumina rods. These restorations were usually unsuccessful; either they fractured or the restorations encroached excessively into the embrasures, resulting in hygiene deficiencies. Leucite-containing heat-pressed ceramics do not appear to possess adequate strength for FDPs, except in very low-stress situations. Clinical trials of posterior ceramic FDPs have yielded disastrous results.[42,83] More recently introduced anatomic-contour zirconia has much higher laboratory strength than these materials and might be suitable for posterior FDPs. The newer lithium disilicate

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FIGURE 25-12 ■ Fabrication of facial veneers and ceramic onlay with the refractory die technique. **A,** A surfactant "de-bubbleizer" is used to spray the impression, after which it is lightly blown dry. **B,** The impression is poured with die stone. The preparation margins are marked before die spacing **(C),** and the cast is duplicated with an elastomeric duplicating material **(D). E,** The mold is filled with the refractory investment. A die-lock system can be used **(F);** alternatively, a reverse dowel pin can be used with the dowel pin remaining in the cast base **(G). H,** As another alternative, special high-heat dowel pins (High Temp Ceramic Dowel Pins, Dental Ventures of America, Inc.) can be used. **I,** Margins are marked with a special pencil (V.H.T., Whip Mix). **J,** The investment is decontaminated. **K,** The blue margin marking turns red during this firing. **L,** The dies are soaked in distilled water until bubbling disappears. **M,** Adjacent proximal areas are coated with die hardener to prevent moisture from being absorbed into the cast.

heat-pressed ceramic and the veneered zirconia systems have also been recommended as suitable for anterior FDPs. Although the newer materials might be successful for FDPs, their manufacturers recommend a design with substantial connectors (typically 4 × 4 mm, as opposed to 2 × 3 mm recommended for metal connectors). These dimensions can lead to problems with adequate access for cleaning and poor esthetics.

ALL-CERAMIC FOUNDATION RESTORATIONS

All-ceramic materials have been used as foundation restorations for endodontically treated teeth[81,84] to overcome esthetic problems associated with metal post and core systems (see Chapter 12). The post is made of zirconia (CosmoPost, Ivoclar Vivadent; ER C-Post,

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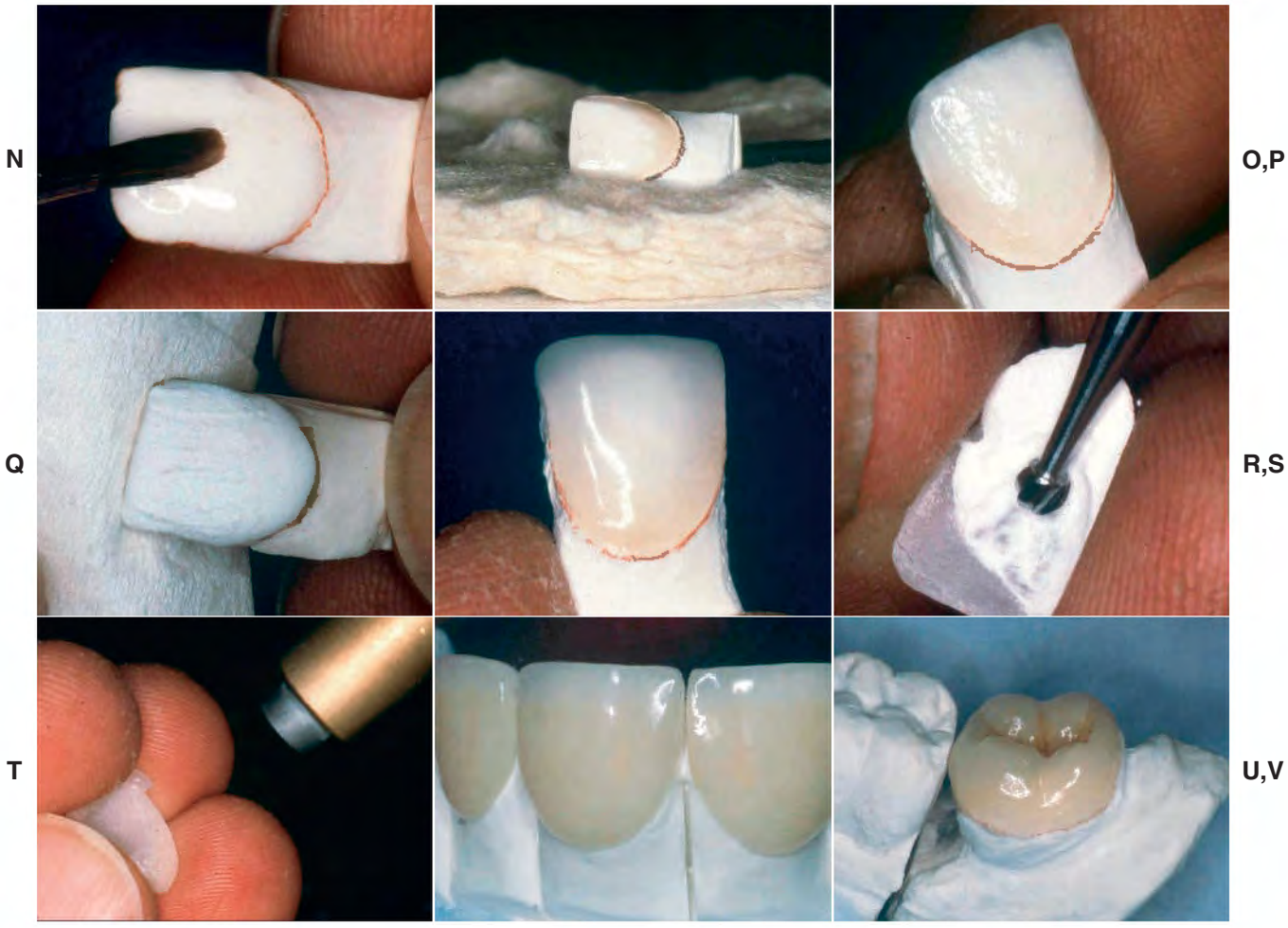

FIGURE 25-12, cont'd ■ **N,** The initial porcelain application. **O** and **P,** The first application is fired. **Q,** Additional firing is needed to compensate for shrinkage. **R,** The veneer is built up to final contour and glazed. The investment is removed with a bur **(S)** and an airborne-particle abrasion unit **(T). U,** Finished veneer on definitive cast. **V,** Inlays and onlays are made in a similar manner. (Courtesy Whip Mix, Louisville, Kentucky.)

Komet USA; TZP-post, Maillefer) chosen for its excellent strength,[85] and, depending on the system, the core material can be composite resin or a pressable ceramic (IPS Empress Cosmo, Ivoclar Vivadent). Alternatively, a custom post and core can be milled from zirconia with a CAD/CAM system.[86]

RESIN-BONDED CERAMICS

The performance of all-ceramic restorations has been enhanced by the use of resin bonding. This technique was first devised for the porcelain laminate veneer technique[87,88] and has been applied to other ceramic restorations. The technique entails the use of hydrofluoric acid or a less toxic substitute to etch the ceramic and a silane (silicon compounds, hydrogen compounds, and other monomeric compounds that are used as coupling agents to bond inorganic materials to organic resins) coupling agent to bond a resin luting agent to the ceramic. The luting agent is bonded to enamel after etching with phosphoric acid, as with resin-retained FDPs (see Chapter 26), and bonded to dentin with a dentin-bonding agent. Significant reduction in the fracture incidence of some types of ceramic crowns has been reported when an adhesive cement has been used,[89] although one retrospective study failed to reveal an improvement in comparison with traditional cements.[90] Resin bonding does not appear to improve the fracture resistance of the high-strength alumina core materials such as In-Ceram and Procera. Nevertheless, for feldspathic and leucite-reinforced ceramics, resin bonding is now the recommended procedure and is also used extensively for luting ceramic inlays and onlays.[91]

Etching and Silanating the Restoration

1. Support the restoration in soft wax with the fitting surface uppermost.
2. Apply a 1-mm coat of the etching gel (Ceram-Etch gel [9.5% hydrofluoric acid], Gresco Products, Inc., or the ceramic manufacturer's recommended product) to the fitting surface only.
3. The etching time depends on the ceramic material. Feldspathic porcelain is typically etched for 5 minutes.

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4. Very carefully rinse away the gel under running water. The gel is very caustic; it should not be allowed to contact skin or eyes.
5. Continue to rinse until all the gel color has been removed.
6. Dry the ceramic with oil-free air. A hair dryer is recommended to ensure that the ceramic is not contaminated.
7. Apply the silane according to the manufacturer's recommendations. Some manufacturers recommend a heat-polymerized silane coupling agent for increased bond strength, rather than a chemically activated silane. Heat polymerizing is normally done by the laboratory, and care must be taken to clean the fitting surface thoroughly with alcohol before cementation.

The cementation procedures are presented in Chapter 30.

SUMMARY

For many years, porcelain jacket crowns have been the most esthetic of fixed restorations. Unfortunately, they have a number of disadvantages in comparison with the more popular metal-ceramic crowns, including inferior mechanical properties and increased technical difficulties associated with obtaining adequate margin fit.

Improved materials and the bonded ceramic technique have renewed interest in all-ceramic restorations. Porcelain laminate veneers have proved to be conservative and esthetic alternatives to complete coverage. Porcelain inlays and onlays may provide a durable alternative to posterior composite resins without the extensive tooth preparation needed for crowns. The highest-strength materials may be suitable for high-stress applications, including FDPs. However, they are relatively new and still lack the support of long-term clinical experience and research.

REFERENCES

1. Ernsmere JB: Porcelain dental work. Br J Dent Sci 43:547, 1900.
2. Custer LE: A system of making jacket porcelain crowns without fusing. Dent Cosmos 57:1356, 1915.
3. Ehrlich A: Erosion of acrylic resin restorations [Letter]. J Am Dent Assoc 59:543, 1959.
4. Söremark R, Bergman B: Studies on the permeability of acrylic facing material in gold crowns, a laboratory investigation using Na. Acta Odontol Scand 19:297, 1961.
5. Lamstein A, Blechman H: Marginal seepage around acrylic resin veneers in gold crowns. J Prosthet Dent 6:706, 1956.
6. Weinstein M, Weinstein AB: Fused porcelain-to-metal teeth. Washington, D.C., U.S. Patent Office, Publication No. US3052982 A, September 11, 1962.
7. Vines RF, Semmelman JO: Densification of dental porcelain. J Dent Res 36:950, 1957.
8. Hondrum SO: A review of the strength properties of dental ceramics. J Prosthet Dent 67:859, 1992.
9. Denry IL: Recent advances in ceramics for dentistry. Crit Rev Oral Biol Med 7:134, 1996.
10. Denry I, Kelly JR: Emerging ceramic-based materials for dentistry. J Dent Res 93:1235, 2014.
11. Mehra M, Vahidi F: Complete mouth implant rehabilitation with a zirconia ceramic system: a clinical report. J Prosthet Dent 112:1, 2014.
12. Suttor D, et al: Coloring ceramics by way of ionic or complex-containing solutions. Washington, D.C., U.S. Patent Office, Publication No. US6709694 B1, March 23, 2004.
13. Shah K, et al: Effect of coloring with various metal oxides on the microstructure, color, and flexural strength of 3Y-TZP. J Biomed Mater Res B Appl Biomater 87:329, 2008.
14. Oh G-J, et al: Effect of metal chloride solutions on coloration and biaxial flexural strength of yttria-stabilized zirconia. Metals Mater Int 18:805, 2012.
15. Jang GW, et al: Fracture strength and mechanism of dental ceramic crown with zirconia thickness. Procedia Eng 10:1556, 2011.
16. Sripetchdanond J, Leevailoj C: Wear of human enamel opposing monolithic zirconia, glass ceramic, and composite resin: an in vitro study. J Prosthet Dent 112:1141, 2014.
17. Mitov G, et al: Wear behavior of dental Y-TZP ceramic against natural enamel after different finishing procedures. Dent Mater 28:909, 2012.
18. Jones DW, Wilson HJ: Some properties of dental ceramics. J Oral Rehab 2:379, 1975.
19. Kelly JR, et al: Fracture surface analysis of dental ceramics: clinically failed restorations. Int J Prosthodont 3:430, 1990.
20. Mackert JR Jr: Isothermal anneal effect on microcrack density around leucite particles in dental porcelain. J Dent Res 73:1221, 1994.
21. Mackert JR Jr: Effect of thermally induced changes on porcelain-metal compatibility. In Preston JD, ed: Perspectives in dental ceramics, Proceedings of the Fourth International Symposium on Ceramics, pp 53-64. Chicago, Quintessence Publishing, 1988.
22. Mackert JR Jr, Williams AL: Microcracks in dental porcelain and their behavior during multiple firing. J Dent Res 75:1484, 1996.
23. Anusavice KJ, et al: Influence of initial flaw size on crack growth in air-tempered porcelain. J Dent Res 70:131, 1991.
24. Weibull W: A statistical theory of the strength of material. Ing Vetensk Akad Proc 151:1, 1939.
25. Davidge RW, Green TJ: The strength of two-phase ceramic/glass materials. J Mater Sci 3:629, 1968.
26. Dunn B, et al: Improving the fracture resistance of dental ceramic. J Dent Res 56:1209, 1977.
27. Seghi RR, et al: The effect of ion-exchange on the flexural strength of feldspathic porcelains. Int J Prosthodont 3:130, 1990.
28. Denry IL, et al: Enhanced chemical strengthening of feldspathic dental porcelain. J Dent Res 72:1429, 1993.
29. Anusavice KJ, et al: Strengthening of porcelain by ion exchange subsequent to thermal tempering. Dent Mater 8:149, 1992.
30. Anusavice KJ, Hojjatie B: Effect of thermal tempering on strength and crack propagation behavior of feldspathic porcelains. J Dent Res 70:1009, 1991.
31. Garvie RC, et al: Ceramic steel? Nature 258:703, 1975.
32. Denry IL, et al: Effect of heat treatment on microcrack healing behavior of a machinable dental ceramic. J Biomed Mater Res 48:791, 1999.
33. Fairhurst CW, et al: The effect of glaze on porcelain strength. Dent Mater 8:203, 1992.
34. Griggs JA, et al: Effect of flaw size and auto-glaze treatment on porcelain strength [Abstract 1658]. J Dent Res 74:219, 1995.
35. McLean JW, Kedge MI: High-strength ceramics. Quintessence Int 18:97, 1987.
36. Michalske TA, Freiman SW: A molecular interpretation of stress corrosion in silica. Nature 295:511, 1982.
37. Sherrill CA, O'Brien WJ: Transverse strength of aluminous and feldspathic porcelain. J Dent Res 53:683, 1974.
38. Morena R, et al: Fatigue of dental ceramics in a simulated oral environment. J Dent Res 65:993, 1986.
39. Rosenstiel SF, et al: Stress-corrosion and environmental aging of dental ceramics [Abstract 823]. J Dent Res 71:208, 1992.
40. Rosenstiel SF, et al: Fluoroalkylethyl silane coating as a moisture barrier for dental ceramics. J Biomed Mater Res 27:415, 1993.
41. McLean JW, Hughes TH: The reinforcement of dental porcelain with ceramic oxides. Br Dent J 119:251, 1965.
42. Batchelor RW, Dinsdale A: Some physical properties of porcelain bodies containing corundum. In Transactions, Seventh International Ceramics Congress, p 31. London, British Ceramic Society, 1960.
43. Dinsdale A, et al: The mechanical strength of ceramic tableware. Trans Br Ceram Soc 66:367, 1967.
44. McLean JW: A higher strength porcelain for crown and bridge work. Br Dent J 119:268, 1965.

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45. Jones DW: Ceramics in dentistry. II. Dent Techn 24:64, 1971.
46. Claus H: VITA In-Ceram, a new procedure for preparation of oxide-ceramic crown and bridge framework. Quintessenz Zahntech 16:35, 1990.
47. Pröbster L, Diehl J: Slip-casting alumina ceramics for crown and bridge restorations. Quintessence Int 23:25, 1992.
48. Seghi RR, et al: Flexural strength of new ceramic materials. J Dent Res 69:299, 1990.
49. Wolf WD, et al: Mechanical properties and failure analysis of alumina-glass dental composites. J Am Ceram Soc 79:1769, 1996.
50. McLaren EA: All-ceramic alternatives to conventional metal-ceramic restorations. Compend Contin Educ Dent 19:307, 1998.
51. Sorensen JA, et al: Core ceramic flexural strength from water storage and reduced thickness [Abstract 906]. J Dent Res 78:219, 1999.
52. Shearer B, et al: Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. Biomaterials 17:1891, 1996.
53. Pera P, et al: In vitro marginal adaptation of alumina porcelain ceramic crowns. J Prosthet Dent 72:585, 1994.
54. Sulaiman F, et al: A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. Int J Prosthodont 10:478, 1997.
55. Lüthy H, et al: Effects of veneering and glazing on the strength of heat-pressed ceramics. Schweiz Monatssch Zahnmed 103:1257, 1993.
56. Höland W, et al: A comparison of the microstructure and properties of the IPS Empress® 2 and the IPS Empress® glass-ceramics. J Biomed Mater Res 53:297, 2000.
57. Culp L: Empress 2. First year clinical results. J Dent Technol 16:12, 1999.
58. Anusavice KJ: Recent developments in restorative dental ceramics. J Am Dent Assoc 124:72, 1993.
59. Estafan D, et al: Scanning electron microscope evaluation of CEREC II and CEREC III inlays. Gen Dent 51:450, 2003.
60. Filser F, et al: Net-shaping of ceramic components by direct ceramic machining. Assembly Autom 23:382, 2003.
61. Dhima M, et al: Practice-based clinical evaluation of ceramic single crowns after at least five years. J Prosthet Dent 111:124, 2014.
62. ElBatal FH, et al: Preparation and characterization of some multi-component silicate glasses and their glass–ceramics derivatives for dental applications. Ceram Int 35:1211, 2009.
63. Kruger S, et al: Nucleation kinetics of lithium metasilicate in ZrO_2-bearing lithium disilicate glasses for dental ppplication. Int J Appl Glass Sci 4(1):9, 2013.
64. Wegner LD, Gibson LJ: The fracture toughness behaviour of interpenetrating phase composites. Int J Mech Sci 43:1771, 2001.
65. Guazzato M, et al: Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part I. Pressable and alumina glass-infiltrated ceramics. Dent Mater 20:441, 2004.
66. Della Bona A, Kelly JR: The clinical success of all-ceramic restorations. J Am Dent Assoc 139(Suppl 4):8S, 2008.
67. He L-H, Swain M: A novel polymer infiltrated ceramic dental material. Dent Mater 27:527, 2011.
68. Coldea A, et al: Mechanical properties of polymer-infiltrated-ceramic-network materials. Dent Mater 29:419, 2013.
69. Kelly JR, et al: Development of a clinically validated bulk failure test for ceramic crowns. J Prosthet Dent 104:228, 2010.
70. Shoher I: Vital tooth esthetics in Captek restorations. Dent Clin North Am 42:713, 1998.
71. Zappala C, et al: Microstructural aspects of the Captek alloy for porcelain-fused-to-metal restorations. J Esthet Dent 8:151, 1996.
72. Holloway JA, Miller RB: The effect of core translucency on the aesthetics of all-ceramic restorations. Pract Periodontics Aesthet Dent 9:567, 1997.
73. Seghi RR, et al: Abrasion of human enamel by different dental ceramics in vitro. J Dent Res 70:221, 1991.
74. Hacker CH, et al: An in vitro investigation of the wear of enamel on porcelain and gold in saliva. J Prosthet Dent 75:14, 1996.
75. Metzler KT, et al: In vitro investigation of the wear of human enamel by dental porcelain. J Prosthet Dent 81:356, 1999.
76. Ramp MH, et al: Evaluation of wear: enamel opposing three ceramic materials and a gold alloy. J Prosthet Dent 77:523, 1997.
77. Wall JG, et al: Cement luting thickness beneath porcelain veneers made on platinum foil. J Prosthet Dent 68:448, 1992.
78. Dietschi D, et al: In vitro evaluation of marginal fit and morphology of fired ceramic inlays. Quintessence Int 23:271, 1992.
79. Amer R, et al: Three-body wear potential of dental yttrium-stabilized zirconia ceramic after grinding, polishing, and glazing treatments. J Prosthet Dent 112(5):1151, 2014.
80. Burgess JO, et al: Enamel wear opposing polished and aged zirconia. Oper Dent 39:189, 2014.
81. Preis V, et al: Wear performance of monolithic dental ceramics with different surface treatments. Quintessence Int 44:393, 2013.
82. Christensen R, Christensen G: Service potential of all-ceramic fixed prostheses in areas of varying risk [Abstract 1716]. J Dent Res 71:320, 1992.
83. Kakehashi Y, et al: A new all-ceramic post-and-core system: clinical, technical, and in vitro results. Int J Periodont Restor Dent 18:586, 1998.
84. Zalkind M, Hochman N: Esthetic considerations in restoring endodontically treated teeth with posts and cores. J Prosthet Dent 79:702, 1998.
85. Asmussen E, et al: Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 27:275, 1999.
86. Bittner N, et al: Evaluation of a one-piece milled zirconia post and core with different post-and-core systems: an in vitro study. J Prosthet Dent 103:369, 2010.
87. McLaughlin G: Porcelain fused to tooth—a new esthetic and reconstructive modality. Compend Contin Educ Gen Dent 5:430, 1984.
88. Calamia JR: Etched porcelain veneers: the current state of the art. Quintessence Int 16:5, 1985.
89. Malament KA, Grossman DG: Bonded vs. non-bonded DICOR crowns: four-year report [Abstract 1720]. J Dent Res 71:321, 1992.
90. Sjögren G, et al: Clinical evaluation of all-ceramic crowns (Dicor) in general practice. J Prosthet Dent 81:277, 1999.
91. Schaffer H, Zobler C: Complete restoration with resin-bonded porcelain inlays. Quintessence Int 22:87, 1991.

STUDY QUESTIONS

1. Discuss the advantages and disadvantages, indications, and contraindications of all-ceramic crowns.

2. Which all-ceramic system might be considered for a partial fixed dental prosthesis? What are the limitations with all-ceramic restorations in this application?

3. Compare the fabrication steps for a slip-cast system with those of a heat-pressed ceramic system. What are the advantages of each?

4. Describe the fabrication steps for laminate veneers.

5. What are the currently available computer-assisted design/computer-assisted manufacturing (CAD/CAM) systems? What are the advantages and limitations of these restorations?

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CHAPTER 26

Resin-Bonded Fixed Dental Prostheses

Van P. Thompson

OVERVIEW

Resin-bonded fixed dental prostheses (FDPs) have had variable popularity since the technique for splinting mandibular anterior teeth with a perforated metal casting was described by Rochette in 1973.[1] His work suggested an alternative to conventional metal-ceramic FDPs and the associated substantial removal of tooth structure needed to create strong, anatomically contoured, and esthetic restorations (see Chapter 7). An FDP that requires only minimal removal of tooth structure is appealing, particularly for intact, caries-free abutment teeth. The primary goal of the resin-bonded FDP is the replacement of missing teeth while conserving maximal tooth structure.

The advent of electrolytic etching of metal surfaces to provide micromechanical retention for bonding of metal to enamel led to the technique's broad application.[2] The restoration is simple in concept and consists of one or more pontics supported by thin metal retainers bonded lingually and proximally to the enamel of the abutment teeth (Fig. 26-1). The success of these conservative FDPs depends on bonding between etched enamel and the metal casting, and precise and defined metal engagement of the abutment is required. Early bonded retainers tested the limits of this application. Understanding of treatment planning limitations was minimal, and the necessity of incorporating appropriate resistance and retention form in the preparation was poorly understood. In general use, poor design of the early retainers (with some bonded only to lingual enamel) was compounded by the challenge of properly etching the metal. As a result, several failures occurred, and the technique was used more conservatively from 1986 to 1996. During and since that period, design parameters have been enumerated and tested clinically.[3-6] Such designs, combined with new technologies for adhesive bonding of resin to most alloys, have led to a simpler, more reliable prosthetic procedure that complements the dentist's prosthodontic armamentarium.

DEVELOPMENT OF RESIN-BONDED FIXED DENTAL PROSTHESES

Bonded Pontics

The earliest resin-bonded prostheses were extracted natural teeth or acrylic teeth used as pontics that were bonded to the proximal and lingual surfaces of abutment teeth with composite resin.[7,8] The composite resin connectors were brittle and required supporting wire or a stainless steel mesh framework. These bonded pontics were limited to short anterior spans and had a limited lifetime, with degradation of the composite resin bond to the wire or mesh and subsequent fracture. Such restorations should be offered to patients only as short-term replacements.[9-11]

Cast Perforated Resin-Bonded Fixed Dental Prostheses (Mechanical Retention)

In 1973, Rochette[1] introduced the concept of bonding metal to teeth by using flared perforations of the metal casting to provide mechanical retention. He used the technique principally for periodontal splinting but also included pontics in his design. Howe and Denehy[12] recognized the metal framework's improved retention (over bonded pontics) and began using FDPs with cast-perforated metal retainers bonded to abutment teeth and metal-ceramic pontics to replace missing anterior teeth. Their design recommendation, extending the framework to cover a maximum area of the lingual surface, suggested little or no tooth preparation. Use of these FDPs was limited to mandibular teeth or situations with minimal occlusal contact. The restorations were bonded with a heavily filled composite resin as a luting medium.

Livaditis[13] expanded this concept to replacement of posterior teeth. Perforated retainers were used to increase resistance and retention. Cast retainers were extended interproximally into the edentulous areas and onto occlusal surfaces. The design included a defined occlusogingival path of placement by tooth modification, which involved lowering the proximal and lingual height of contour of the enamel on the abutment teeth. These restorations were placed in normal occlusion; many have survived and have been seen on recall for up to 13 years (Fig. 26-2). Despite this success, the perforation technique presents the following limitations:

- Weakening of the metal retainer by the perforations
- Exposure to wear of the resin at the perforations
- Limited adhesion of the metal provided by the perforations[14]

Clinical results with the perforated technique were monitored for 15 years in a study at the University of Iowa.[15] The results from this well-controlled study suggest that for anterior FDPs, the perforated retainers have a failure rate of 50% at 110 months and 63% at about 130 months (Table 26-1).

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FIGURE 26-1 ■ **A,** Facial view of resin-bonded retainer replacing the right central incisor, which was lost as a result of trauma. **B,** Lingual view of the retainer. Note the extension of the retainer over the marginal ridges of both abutment teeth, which is an aspect of all designs for anterior retainers.

FIGURE 26-2 ■ Lingual view of an early perforated resin-bonded fixed dental prosthesis that replaced a premolar, photographed at the 13-year recall. Note the loss of resin from the perforations, the poor gingival embrasures, and the generalized wear of the occlusal composite resin restoration on the molar abutment.

Etched-Cast Resin-Bonded Fixed Dental Prostheses (Micromechanical Retention: "Maryland Bridge")

A technique for the electrolytic etching of cast base metal retainers was developed at the University of Maryland by Thompson and Livaditis.[2,16] Etched-cast retainers have definite advantages over cast-perforated restorations:

- Retention is improved because the resin-to-etched metal bond can be substantially stronger than the resin-to-etched enamel. The retainers can be thinner yet still resist flexing.
- The oral surface of the cast retainers is highly polished and resists plaque accumulation.

TABLE 26-1 **Estimated Time to 50% Failure (Debondings) in Studies with 10-Year Mean Service Time**

Study	Months to 50% Failure
Boyer et al (1993)[15]	
Perforated design	110
Etched metal*	250
de Rijk et al (1996)[74]	
Etched metal†	190

*At the University of Iowa; 143 anterior and 30 posterior fixed dental prostheses (FDPs).
†At the University of Maryland; 61 anterior and 84 posterior FDPs.

During the course of this work, the need for a composite resin with a low film thickness for luting the casting became apparent. This led to the first generation of resin cements, which allowed micromechanical bonding into the undercuts in the metal casting created by etching and simultaneously provided adequate strength and allowed complete seating of the cast retainers. Comspan (Dentsply Caulk), the first of these cements, was moderately filled (60% by weight) with a film thickness of approximately 20 μm.[17] Such cements do not adhere chemically to the metal.

Electrolytic etching of base metal alloys proved to be critically dependent on the base metal alloy and attention to detail in the laboratory. Initial etching methods were developed for a nickel-chromium (Ni-Cr) alloy (Biobond C & B Flux, Dentsply International) and a nickel-chromium-molybdenum-aluminum-beryllium (Ni-Cr-Mo-Al-Be) alloy (Rexillium III, Pentron Clinical).[18] These methods were followed by simplified techniques,[19] chemical etching,[20] or gel etching.[21] They all yield similar results, provided that the technique is optimized for a specific alloy.[22] Proper etching requires evaluation of the alloy surface with a scanning electron microscope. The degree of undercut created by this etching process is shown in Figure 26-3. Lack of attention to detail can result in electropolishing or surface contamination.[23] Over time, both techniques severely degrade bond strengths in a moist environment.

Highly variable results have been reported from dental laboratories in which the same alloy is etched.[24] Etching and bonding techniques were adopted on the basis of bond strength testing of specimens subjected to only 24 hours or 7 days of water exposure. When resin-to-metal test specimens were aged for 6 months in water and then thermally stressed by 10,000 or more thermal cycles, large reductions in bond strengths were recorded.[25,26] Therefore, data from specimens that have not been aged and thermally stressed should be viewed skeptically. Even particle abrasion provides initially high resin-to-metal bonds, which can degrade to almost zero with time.[27]

Well-researched and tested resin systems for direct adhesion to metal surfaces have now completely

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supplanted metal etching as retention mechanisms.[28] This is discussed subsequently.

Ceramic Retainers

High-strength ceramics, particularly zirconia (see Chapter 25), have been used as retainers for resin-bonded FDPs.[29,30] These restorations exhibit better esthetics (Fig. 26-4) than do metal retainers, which can discolor, particularly with thin abutment teeth. Good medium-term clinical performance has been demonstrated.[31]

Chemical-Bonding Resin-Bonded Fixed Dental Prostheses (Adhesion Bridges)

During the 1980s and early 1990s, when etched castings were the method of choice for retention of resin-bonded FDPs, extensive research was under way in Japan to develop adhesive systems for direct bonding of metal for this application. The first of these resin systems (Super-Bond C&B, Sun Medical Co., Ltd.; C&B MetaBond, Parkell, Inc.) is based on a formulation of a methyl methacrylate polymer powder and methyl methacrylate liquid modified with the adhesion promoter 4-methacryloxyethyl-trimellitic anhydride (4-META).[32] It was developed with a unique tri-n-butylborane catalyst system that is added to the liquid before combining with the powder. On base metal alloys, Super-Bond C&B has the highest initial bond strength of any adhesive resin system. Unfortunately, the hydrolytic stability of these bonds over time depended on the alloy's Ni-Cr ratio.[33,34] Its advantages include its lower elastic modulus and higher fracture toughness in comparison with bisphenol-A-glycidylether methacrylate (bis-GMA)–based resin cements,[35,36] yielding better clinical results with less well-adapted castings.[37] This system had yielded poor clinical results when retainers made of alloy with high gold content were bonded to abutment teeth.[38] However, alloy primers have been developed that provide a more stable bond to noble alloy surfaces,[39,40] which has been confirmed in a clinical study.[41]

The advent of Super-Bond C&B was followed by a bis-GMA–based composite resin luting cement (Panavia, Kuraray America, Inc.) that is modified with the adhesion promoter 10-methacryloxydecyl dihydrogen phosphate (MDP). MDP's chemical structure and use are described in the literature.[42]

Panavia resin luting agent has shown excellent bonds to particle-abraded Ni-Cr and cobalt-chromium (Co-Cr) alloys,[43,44] as well as tin-plated gold and gold-palladium alloys.[22,45]

Panavia has a tensile bond to etched enamel (10 to 15 MPa) comparable with that of the traditional bis-GMA composites with low film thickness (e.g., Comspan

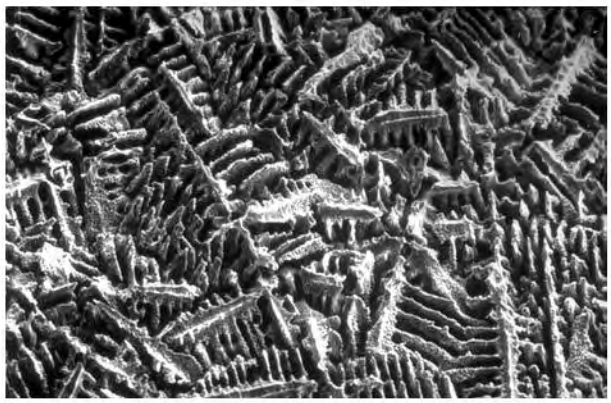

FIGURE 26-3 ■ Scanning electron micrograph (SEM) at 1000× magnification of a nickel-chromium-molybdenum-aluminum-beryllium (Ni-Cr-Mo-Al-Be) alloy electrolytically etched. The microstructure is selectively removed to create a highly undercut surface that can be wetted by hydrophobic composite resins.

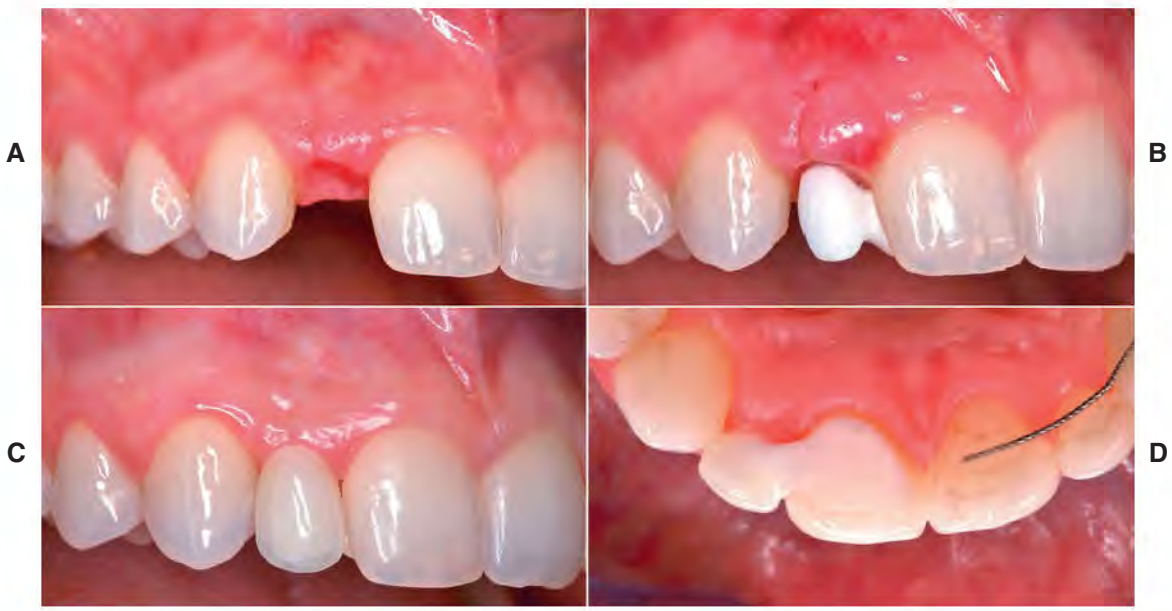

FIGURE 26-4 ■ All-ceramic resin-retained fixed dental prosthesis. **A,** Missing maxillary lateral incisor. **B,** Zirconia framework evaluated intraorally. **C** and **D,** Completed prosthesis. (Courtesy Dr. M. Kern.)

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[Dentsply Caulk]). The combination of metal electrolytic etching, followed by application of an adhesive such as Panavia, does not improve the tensile bond to the alloy, and its strength is actually slightly lower than that of the bond of Panavia to base metal alloys abraded with airborne particles (sandblasted).[46] The most recent versions are Panavia 21 and Panavia F 2.0, the latter being a dual polymerizing system (chemical and visible light) that releases fluoride. Both incorporate a self-etching primer system (ED Primer) for bonding to enamel and dentin.

Tin plating of noble alloys allows resin-to-metal tensile bond strengths only slightly lower than those for either the electrolytically etched or particle abraded nickel-chromium-beryllium alloys (18 to 30 MPa). However, tensile bond strengths are certainly greater than the bond to etched enamel.[47,48] Tin plating of the metal surface also requires particle abrasion of the alloy surface just before bonding for adequate tin nucleation sites (Fig. 26-5).[49,50] Tin plating can be completed in the dental laboratory or at chairside to achieve metal bonding. One tin-plating system (MicroTin, Materials) (Fig. 26-6, *A*) involves the use of a tin amide solution, which is applied to the metal surface with a saturated cotton pledget held on the end of a 4-V battery-powered probe. The probe is grounded elsewhere on the metal (see Fig. 26-6, *B*). Tin-plating times are usually 5 to 10 seconds, and a light gray surface is produced. Plating is followed by copious rinsing with water and drying; the adhesive resin is then applied.

Particle abrasion of the alloy surface with 50-µm alumina before bonding or tin plating not only creates a roughened, higher surface area substrate for bonding but also creates a molecular coating of alumina.[51] The alumina on the surface aids in oxide bonding of the phosphate-based adhesive systems (e.g., Panavia to alloy surfaces). Studies of this bonding mechanism are also reinforced by laboratory data on bonding to alumina and zirconia surfaces.[52-54]

These adhesive systems have shown nearly the same degree of long-term clinical bonding (since 1983 in Japan) as the conventional composites on etched base metal (since 1981 in the United States).[16] Laboratory data confirm their efficacy. The favorable findings for direct adhesion to base metal have rendered alloy etching and macroscopic retention mechanisms obsolete.[55] This simplifies the laboratory and clinical procedures for placement of resin-bonded FDPs.

A laboratory method for resin bonding to both base and noble metal is the Rocatec system (3M ESPE Dental). In this method, the metal surface is initially particle abraded with 120-µm alumina particles. This is followed by abrasion with a special silicate particle–containing alumina (Fig. 26-7). In this second particle abrasion step, a molecular coating of silica and alumina is deposited on the alloy surface. Silane is then applied to the surface, which makes it adhesive to composite resin. Norling and colleagues[56] compared various silane application techniques. The Rocatec system has been compared with Panavia for

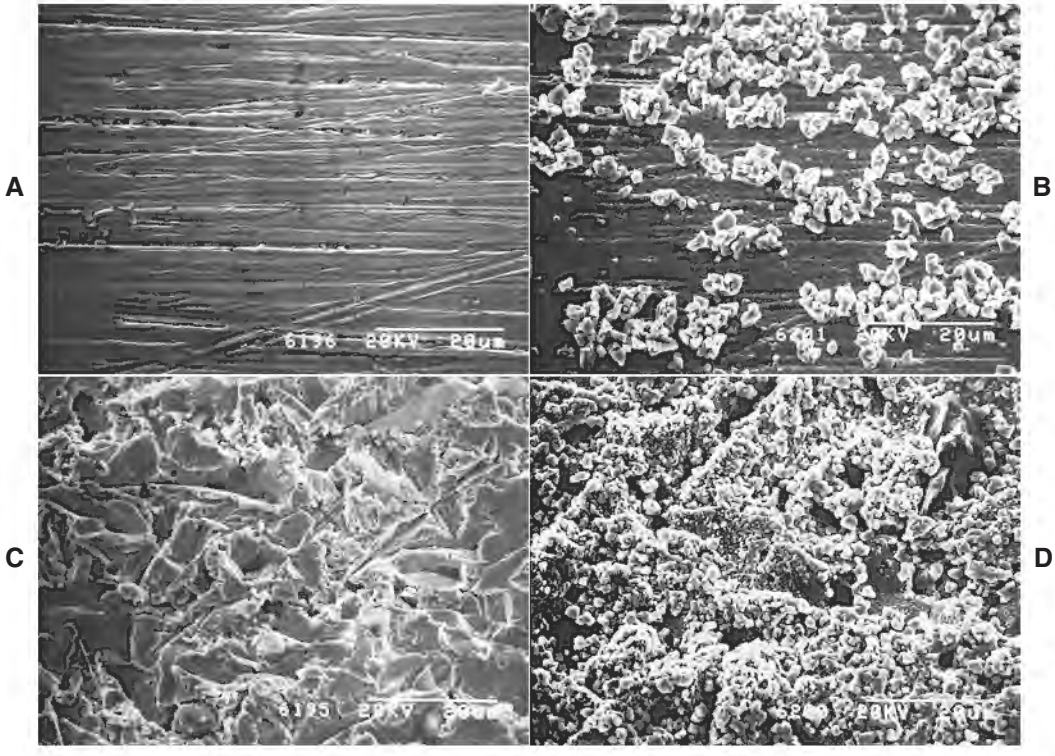

FIGURE 26-5 ■ Variations in tin-plating patterns with two surface treatments. **A,** Gold alloy (Firmilay, Jelenko Dental Alloys) surface prepared with sandpaper (600 grit). **B,** Tin plating exhibiting local clumping and random distribution of tin particles. **C,** Gold alloy surface after 50-µm alumina particle abrasion. **D,** Particle-abraded gold alloy surface after tin plating with an even distribution of fine tin particles.

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FIGURE 26-6 ■ Intraoral tin plating. **A,** Tin-plating system in which direct current is used to deposit tin from an amide solution (Micro-Tin Materilas). **B,** The system in use intraorally. Note the gray color change. The tin is being deposited from the solution and carried to the metal in the cotton pledget affixed to one electrode of the plater; the circuit is completed with the alligator clip, which is in electrical contact with the prosthesis.

FIGURE 26-7 ■ Scanning electron micrograph of airborne abrasion particles (Rocatec Special, 3M ESPE Dental, Norristown, Pennsylvania) composed of a mixture of 50-µm alumina particles *(dark irregular particles)* and smaller silicate particles *(light color)* used for final abrasion of metals, during which a molecular coating of silicate is tribochemically deposited on the metal. This silicate layer on the metal allows reaction with a silane-priming solution for subsequent bonding of resin to the metal.

bonding to a range of surfaces and is adequate in this regard.[26,28,51] However, it requires careful laboratory technique and is generally confined to bonding composite resin veneers to alloy castings because of the concern that the silane-treated surface may become contaminated before or during the clinical bonding procedures.

Since the mid-1990s, several competing primer and cement systems for direct adhesive bonding to noble alloys have evolved (Table 26-2). All entail particle abrasion of the alloy surface, followed by application of a primer and then the resin cement. These primers have been studied in the laboratory[57-61] and evaluated clinically.[41,62] Their usage is justified and simplifies bonding to both gold- and palladium-based alloys.

Changing the method of attachment of the resin to the metal framework does not change the design of the framework itself because the limiting factor in the system is still the bond of resin to enamel. The evolution of

TABLE 26-2 **Adhesive Resin Cements and Primers for Noble Alloys**

Cement	Primer	Manufacturer
Non–Self-adhesive Systems		
Bistite II DC	Metaltite	Tokyuyama Dental Corp.
C&B Metabond	MTL-V Primer	Parkell Inc.
Linkmax	Metal Primer II	GC America
Multilink	Multilink Primer	Ivoclar Vivadent
Panavia F 2.0	Alloy Primer	Kuraray America Inc.
Self-adhesive Systems		
Maxcem		Kerr Corp.
RelyX Unicem		3M ESPE Dental

Japanese designs for resin-bonded FDPs[63] has paralleled that in North America and Europe. There is an almost universal agreement concerning the need for mechanical retention of the framework to limit the stress on the bond interfaces (resin-to-metal and resin-to-enamel) and in the composite resin, which can become fatigued with time.[64-66]

DESIGN CONCEPTS

The guidelines for optimum design of resin-retained FDPs have been empirically derived. The principle underlying these restorations has always been that it is necessary to cover as much enamel surface as possible, as long as occlusion, esthetics, or periodontal health is not compromised. To emphasize the significance of maximum enamel coverage, Crispin and associates[67] reported 3-year failure rates of up to 50% with the use of small bonded areas and minimal retention designs.

The initial designs of etched-cast retainers included an "interproximal wraparound" concept developed to resist occlusal forces and provide a broader area for bonding. Enamel preparations consisted of creating occlusal

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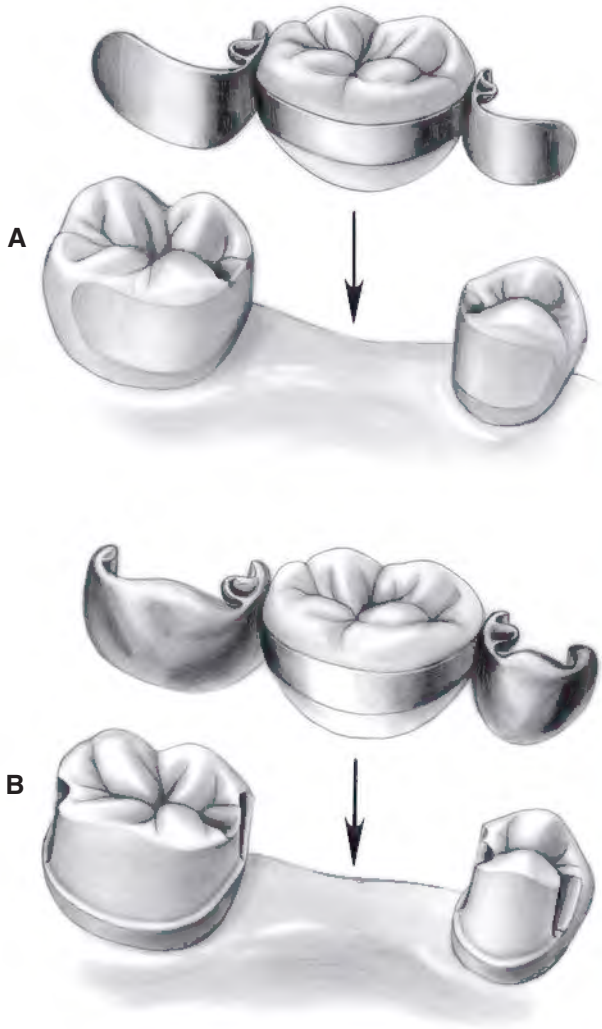

FIGURE 26-8 ■ Comparison of initial and contemporary posterior resin-bonded fixed dental prosthesis designs. **A,** Original design. Minimal modification of lingual and proximal enamel allowed sufficient buccal extension of the metal. Once seated, the retainer could not be displaced from buccal to lingual. **B,** More extensive enamel preparation is now used with proximal grooves at the buccal-proximal line angles of the edentulous space. Note that with this design, the abutment teeth cannot be displaced from the retainer.

clearance, placing occlusal/cingulum rests, and lowering the lingual and proximal height of contour, thus creating proximal extensions.

Frameworks should seat in an occlusogingival direction and should have no facial-lingual displacement (Fig. 26-8, A). The contemporary design has improved retention with well-placed and precise grooves on abutment teeth (see Fig. 26-8, *B*). It is detailed in the following sections. Contemporary mouth preparations, in an effort to minimize failures, do not preserve as much tooth structure as did their predecessors; nevertheless, they are still limited to enamel and conform to conservative design principles. The new designs have been tested in laboratory studies.[68,69]

Three principles are fundamental to achieve predictable results with resin-bonded FDPs: proper patient selection, correct enamel modification, and framework design. The treatment is not a panacea, and if any contraindications are present, the patient should be treated with a conventional FDP or an implant-supported prosthesis.

BOX 26-1 Resin-Bonded Fixed Dental Prostheses: Advantages, Disadvantages, Indications, and Contraindications

ADVANTAGES
- Minimal removal of tooth structure
- Minimal potential for pulpal trauma
- Anesthesia not usually required
- Supragingival preparation
- Easy impression making
- Interim restoration not usually required
- Reduced chair time
- Reduced patient expense
- Rebonding possible

DISADVANTAGES
- Reduced restoration longevity
- Enamel modifications: required
- Space correction: difficult
- Good alignment of abutment teeth: required
- Esthetics compromised on posterior teeth

INDICATIONS
- Replacement of missing anterior teeth in children and adolescents
- Short edentulous span
- Unrestored abutments
- Single posterior tooth replacement
- Significant clinical crown length
- Excellent moisture control

CONTRAINDICATIONS
- Parafunctional habits
- Long edentulous span
- Restored or damaged abutments
- Compromised enamel
- Significant pontic width discrepancy
- Deep vertical overlap
- Nickel allergy

ADVANTAGES

When used appropriately, resin-bonded FDPs offer several advantages over conventional FDPs (Box 26-1). Because of the unique preparation design, minimal tooth structure needs to be removed. In general, the preparation is confined to enamel only. Because of the conservative nature of the preparation, the potential for pulpal trauma is minimized. Anesthetics are not routinely used during tooth preparation (without anesthesia, it is possible to monitor the proximity of the preparation to the dentoenamel junction by the patient's comfort level). The prosthesis can often be kept entirely supragingival; as a result, periodontal irritation is kept to a minimum. In a periodontal evaluation of restorations that averaged 10

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years in service, the periodontal response was not significantly different from that for unrestored contralateral teeth.[70] Only when the retainer gingival margins were less than 0.5 mm from the gingival crest was there a correlation with a detrimental gingival response. Concurrently, impression making is simplified because of the supragingival margins. Because the abutment teeth are, in addition to being nonsensitive, maintained with normal proximal contacts, fabrication of traditional interim restorations (see Chapter 15) is usually not required except for selected patients. However, judicious placement of composite resin is important for maintaining occlusal clearances after the final impression and until the final restoration is bonded[71] (see Fig. 26-16). Chair time is significantly reduced in comparison with that for conventional fixed prosthodontic treatment, and the cost incurred by the patient is lower. Both may be reduced by as much as 50%.[72]

The restoration can be rebonded, in which case particle abrasion and adhesive resin systems are used (as long as the debonding occurred with no sequelae involving the abutment teeth). If a two-retainer design is used and one retainer remains bonded, it can be gently loosened with a monobevel, single-ended instrument and a soft mallet. Any deformation of the metal framework in relation to the tooth structure can cause a crack to propagate through the luting composite resin. The monobevel chisel is positioned at an incisal or occlusal edge at an oblique angle to the long axis of the tooth along a mesial or distal line angle. The mallet should be used lightly (limited by patient response); repeated tapping causes debonding. However, with mechanically retentive designs, which include grooves and slots, the framework may require sectioning and removal of the individual sections (Fig. 26-9). As an alternative, ultrasonic scalers have been proposed to help remove partially debonded FDPs.[71] Ultrasonic scalers with special tips are available for this specific purpose. They are applied at the incisal and gingival margins, but the procedure requires a high-power setting and can take considerable time. The debonding rate with rebonded restorations is high,[73] and preparation design modifications and a new or alternative restoration should be considered.

DISADVANTAGES

The primary disadvantage associated with resin-bonded FDPs concerns their longevity, which is less than that of conventional FDPs. This has been the subject of considerable investigation. Studies of first-generation etched metal FDPs at the University of Iowa (more anterior FDPs than posterior) and at the University of Maryland (more posterior FDPs than anterior), with an average service time of more than 10 years, have revealed relative success. According to the results, an estimated 50% fail after 250 months and 190 months, respectively (see Table 26-1).[15,74,75] These studies also indicate that the rate of debondings does not increase with time.

In a study conducted in a private practice setting, contemporary designs with a mean service time of 6 years achieved a 93% success rate.[3] This result differs from the findings in a multicenter study in Europe, in which debonding rates increased with time after placement (almost 50% at 5 years) and were related to preparation design, luting agent selection, and the area of placement within the dental arch.[76] Another European study revealed retention rates of 60% at 10 years for early designs. In one study, posterior and mandibular resin-bonded FDPs demonstrated higher rates of dislodgment,[77] which may have resulted from occlusal forces (see Chapter 4) and increased difficulty in isolation during the bonding procedure.[73,78] In view of these studies, the likelihood of eventual debonding should be discussed with the patient before treatment. In comparison, a meta-analysis of clinical studies of conventional FDPs indicated a doubling of the failure rate for every 5 years of service from 0 to 15 years.[79] When these results are projected from 15 years to 20 years, the failure rate for conventional FDPs would reach 50% in about 20 years.[75]

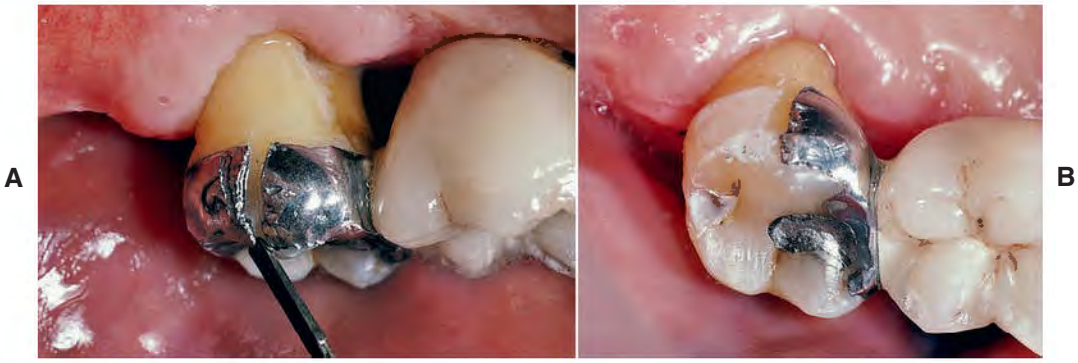

FIGURE 26-9 ■ Removal of a retainer with a contemporary design. **A,** The retainer has been sectioned with a tungsten carbide bur to allow separation of the mesial and distal retentive features. The monobevel chisel is oriented to provide a wedging action between the metal and the enamel, which allows a crack to propagate through the brittle resin. **B,** The cracking of the resin has enabled debonding between the metal and the resin. The mesial retainer half can now be removed in a similar manner. This retainer was removed because of fatigue fracture of the metal at the junction of the pontic metal with the premolar retainer arm (not shown), where the retainer was thinner than 1 mm. The poor periodontal support of the molar abutment allowed large lateral movements of the pontic and molar during function.

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Extensive enamel modifications are required with retentive design to the proximal and lingual surfaces of the abutment teeth (see Fig. 26-8, *B*). If the restoration is removed, composite resin bonding could restore the enamel contours, but transition to a more traditional FDP is likely. Because enamel is limited in thickness, precision and attention to detail are necessary in design and preparation.[80] Enamel lingual surfaces of anterior teeth are almost always thinner than 0.9 mm.[81]

Space correction is difficult with resin-bonded FDPs. When the pontic space is greater or less than the dimensions of a normal tooth, achieving an esthetic result with this restoration is difficult. As with conventional FDPs, treatment of diastemata is demanding, although a cantilever option may be appropriate.

Good alignment of abutment teeth is required because the FDP's path of placement is limited by potential penetration of the enamel thickness. However, some posterior teeth, which are mesially or mesiolingually tilted, can receive an onlay that consists of a bonded retainer (see Figs. 26-18 and 26-20).

Esthetics is compromised on posterior teeth. Posterior resin-bonded FDP design requires the extension of the metal framework onto the occlusal surface of posterior teeth. These occlusal rests and occasional onlaying of cusps are visible, which might be objectionable to some patients (see Fig. 26-18).

Clinical indications and contraindications are quite specific. In the presence of any contraindications, a conventional FDP or an implant-supported crown should be considered.

FIGURE 26-10 ■ Resin-bonded fixed dental prostheses are particularly useful in the treatment of congenitally missing teeth in young patients. Note the unusual tooth pattern with the first premolar in the canine space and the absence of lateral incisors.

FIGURE 26-11 ■ **A,** Preparation for resin-bonded fixed dental prosthesis incorporating an existing amalgam restoration by use of a shallow inlay preparation, in which the amalgam reduction is short of the depth of the dentoenamel junction (with current dentin-bonding technology, a composite resin base would be substituted for the amalgam). Note the shallow distal rest on the premolar and the lack of mesiolingual slot/groove preparation on the premolar abutment. **B,** Appearance of the restoration at 9-year recall appointment, in which luting resin is still present as a sealant in the molar lingual groove.

INDICATIONS

In the treatment plan for any FDP, the patient's individual needs must be properly identified. The presence of any existing disease, its causes, and how it relates to the treatment prognosis must be assessed. Periodontal and general dental health must be reestablished, and the proposed abutment teeth should not exhibit mobility; however, periodontal splinting of teeth with a resin-retained FDP has been successful with strict provision of mechanical retention of each tooth within the alloy framework.

Resin-bonded restorations have been used for many years to replace missing anterior teeth in children (Fig. 26-10).[12] Conventional fixed prosthodontic techniques are generally contraindicated in young patients because of management problems, inadequate plaque control, the large size of the pulps, and the fact that children routinely participate in sports. One or two anterior teeth with mesial and distal abutments can generally be replaced with a resin-bonded FDP. Depending on circumstances, a greater number of teeth can be involved.

Sound teeth or those with minimal restorations are suitable as abutments with resin-bonded retainers. For bonding to anterior teeth, the presence of interproximal restorations is not a contraindication to a bonded retainer. However, large multiple restorations or a restoration involving the incisal edge would limit the resulting bond and the abutment's mechanical integrity. In the posterior region, existing interproximal lesions adjacent to the edentulous space can be incorporated into the retainer design. Minimal or moderate alloy restorations in the abutment teeth should be replaced with dentin bonding and composite resin, or they can sometimes be incorporated into the preparation design. The incorporation of a mesio-occlusal amalgam into the retainer design, shown in Figure 26-11, was placed before the advent of high-strength dentin-bonding systems. The appearance of the restoration at the 9-year recall appointment is also shown.

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As demonstrated in clinical studies, single posterior teeth can be replaced with resin-bonded FDPs.[3,74] Significant clinical crown length should be present to maximize retention and resistance form. In addition to replacing missing teeth, the resin-bonded FDP can be used for periodontal splinting and postorthodontic fixation.

The restorations may be used both anteriorly and posteriorly. However, excellent moisture control must be practiced during cementation.

Proper patient selection also requires an aggressive and ongoing follow-up program to detect debonding and the presence of caries resulting from debonding. However, caries rates on bonded retainers are low.[82,83]

FIGURE 26-12 ■ Minimal clinical crown length is available for adequate retention as a result of hyperplastic gingival tissue on the maxillary canines. Surgical crown lengthening is indicated.

CONTRAINDICATIONS

Because of the apparent advantages of resin-retained restorations, they have been used in inappropriate circumstances, which led to failures that reduced patients' (and dentists') confidence in the technique. Fortunately, these failures were usually correctable by more conventional methods. If any of the following contraindications exist in a particular clinical situation, an alternative approach to treatment should be selected.

In patients with parafunctional habits, the use of resin-bonded FDPs should be considered cautiously because these retainers are less resistant to displacement than are conventional FDPs. They should be used judiciously when above-average lateral forces are likely to be applied (e.g., in a patient with parafunctional habits or in a patient who requires an anterior tooth replacement in the presence of an unstable or nonexistent posterior occlusion). In these instances, all possible means to enhance the mechanical retention of the framework (grooves, occlusal rests, interproximal extension of metal; see Fig. 26-8, *B*) should be used. The patient should be cautioned about the possibility of debonding. Bonded periodontal splints can also be fabricated, but they necessitate strict attention to mechanical retention.[84,85]

Long edentulous spans should be avoided because they place excessive force on the metal retention mechanism; with repeated loading, fatigue of the bonding interfaces or even the metal is possible.

Retention is dependent on an adequate surface area of enamel and clinically sufficient crown length for proximal contouring and placement of grooves. This can be difficult if the abutment teeth have short clinical crowns (Fig. 26-12). Surgical crown lengthening may therefore be necessary to increase the bondable surface area and because subgingival margins must be avoided.

Extensively restored or damaged teeth are unsuitable as abutments. One sound abutment and one extensively restored abutment can be incorporated into a combination FDP. In one retrospective clinical study with restorations in function for an average of more than 10 years, combination FDPs with one conventional retainer and one bonded retainer were very successful.[86]

Compromised enamel on abutment teeth as a result of hypoplasias, demineralizations, or congenital problems (e.g., amelogenesis imperfecta or dentinogenesis imperfecta) adversely affects resin bond strength.

As previously mentioned, edentulous spaces that are larger or smaller than normal tooth size or diastemata are not easily accommodated. The labiolingual thickness of anterior abutment teeth and translucency of the enamel should be evaluated to determine if the shade of the abutment teeth will be changed (i.e., reduced tooth translucency caused by the metal retainer[87,88]). Graying of the abutments can be minimized through the use of opaque bonding resins and by limiting the incisal extent of the metal on the lingual surface. Translucent resins cause optical coupling of the metal to the tooth; appreciable graying of the enamel results. A trial insertion of the metal with water between the metal and the tooth provides a preview of potential graying. Similarly, when the pontic of a resin-bonded FDP is custom stained, a trial resin that does not polymerize should be used to visualize the final shade of the abutment teeth with the metal backing (Fig. 26-13).

The presence of a deep vertical overlap prevents adequate enamel reduction and can place excessive forces on resin-bonded FDPs; this situation should be approached cautiously.

Nickel-based alloys have been the primary metal for resin-bonded FDPs. Allergy to nickel should be identified, and an affected patient should be offered an alternative.[89] Tin plating and laboratory-applied bonding systems allow the use of noble alloys. However, the lower elastic modulus of most noble alloys requires that the metal thickness should be increased by approximately 30% to 50% so that the rigidity of the noble metal framework is equal to that of base metal.[90] This is an important factor in treatment planning and can influence the amount of occlusal clearance required for the metal (which is critical in patients with an increased vertical overlap).

FABRICATION

In the fabrication of resin-bonded FDPs, attention to detail in the following three phases is necessary for predictable success:

1. Preparation of the abutment teeth
2. Design of the restoration
3. Bonding

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FIGURE 26-13 ■ **A,** Evaluation of resin-bonded fixed dental prosthesis for characterization of the pontic. Graying of the central incisor abutment is extensive when translucent resin optically couples the dark metal to the tooth. **B,** Use of opaque resin prevents the darkening of the abutment and raises the value slightly. Opaque and translucent resins can be combined to provide the correct shade for the abutment; the pontic can then be characterized accordingly.

Preparation of the Abutment Teeth

John Locke

On anterior teeth, the procedure is similar in many ways to the lingual reduction needed for a pinledge preparation (see Chapter 10), but the amount of reduction is significantly less because the enamel must not be penetrated. Nonnoble alloys are usually used because they provide a strong framework in thin metal sections. Nonnoble metal also provides a strong margin, and so there is no need to prepare the tooth with a distinct margin; thus the enamel is preserved in this area. If necessary, the opposing teeth can be recontoured to increase interocclusal clearance. There must be sufficient enamel area for successful bonding, and the metal retainers must encompass enough tooth structure and have sufficient resistance form to prevent the individual abutment tooth from being displaced in any direction out of the framework.

Where possible, the casting can extend onto both the mesial and distal surfaces to improve resistance and retention. This is usually possible on mandibular incisors because of open embrasures and the shape of the teeth. Wraparound castings are less applicable to maxillary incisors because less tooth is exposed, especially in younger patients, and because such teeth are not shaped appropriately. The solution is the use of narrow-diameter, lingual surface grooves, which can be used on most teeth.

Step-by-Step Procedure

1. Retainer retention can be substantially improved by the placement of additional strategically placed grooves. Two additional grooves are placed on the lingual surface of the abutment tooth. These grooves run in the incisogingival direction. They do not need to be parallel and are usually positioned on mesiolingual and distolingual aspects of the tooth, just inside the marginal ridges on the incisors. Some teeth have rather prominent mesial and distal marginal ridges, which will enhance the depth and effectiveness of the grooves. The grooves look like railroad tracks, and they do not need to be parallel. However, the depth and width are critical for clinical success. They should be 0.75 mm wide, 1 mm deep, and approximately 5 mm long. They should be started with a new ½ round tungsten carbide bur (0.5 mm in diameter) in a high-speed handpiece, and then the sides and base should be squared with a new small, tapered fissured (No. 168) bur (Fig. 26-14). The diameter of the tip of this bur is also 0.5 mm. Always use new tungsten carbide burs because they blunt quickly when cutting enamel. See Figure 26-14 for correct groove placement.
2. An additional groove is placed on the interproximal surface next to the pontic space. This groove extends vertically from the gingival margin and exits on the lingual side of the incisal edge. The groove is shaped with a No. 168 bur. The length of this groove can vary considerably, depending on the size of the interproximal surface. The position of this groove is usually more lingual to avoid involving or undermining the incisal enamel (Fig. 26-15).

   The size and shape of the grooves are critical for retention. Large grooves are less effective. All grooves should be narrow and have flat parallel sides. They are placed with burs of very narrow diameter. The interproximal groove resists displacement in the buccolingual direction, and the lingual (railroad-track) grooves resist displacement in the incisogingival direction.
3. Make an accurate impression. Marginal fit is as crucial for a resin-bonded restoration as for a conventional FDP. Bond strengths are reduced with thick resin layers.[37]
4. Provide temporary occlusal stops. Significant supraocclusion of the abutment teeth can occur rapidly, particularly in younger patients and in patients with reduced periodontal support. This can be avoided on anterior teeth by placement of a small amount of composite resin on the opposing mandibular teeth. This is rarely needed for posterior teeth unless significant onlays are planned for

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FIGURE 26-14 ■ The longevity of resin-bonded retainers can be substantially improved with the use of narrow, strategically placed grooves. **A,** Armentarium. **B** and **C,** Suggested groove placements for maxillary central incisor and canine. **D,** Definitive cast showing narrow groove placement. **E,** Base metal casting should accurately reproduce the prepared grooves.

FIGURE 26-15 ■ Replacement of congenitally missing lateral incisors with resin-retained fixed dental prostheses. For this patient, the maxillary central incisors were indicated for the abutment teeth because of the occlusal relationship.

FIGURE 26-16 ■ Temporary replacement of occlusal stops is crucial whenever they have been removed as a result of enamel recontouring. The composite resin stops shown here were removed when this posterior inlay/onlay resin-bonded fixed dental prosthesis was bonded.

the abutment (in which case small composite resin stops can be bonded to the enamel; Fig. 26-16). The resin is removed just before placement of the resin-bonded FDP.

A cantilever pontic design for resin-bonded FDPs is recommended. This has been successful in the anterior region[91] and is particularly useful for replacement of lateral incisors, for which cantilevers from either the central incisor or canine are possible. The choice is based on providing the best retention and the best esthetics (Fig. 26-17). When properly designed, the cantilever approach has been shown to have better fatigue bond strength than a two-abutment design.[92]

Cantilevered designs have significant advantages:

- The preparation is simplified.
- The problems associated with the occlusion and differing mobilities of abutment teeth, which tend to place excessive stresses on the cement and retentive features, are avoided. Cantilevered resin-bonded FDPs work well on mobile teeth.
- If a cantilevered resin-bonded FDP with a single abutment becomes loose, it falls out of the mouth.

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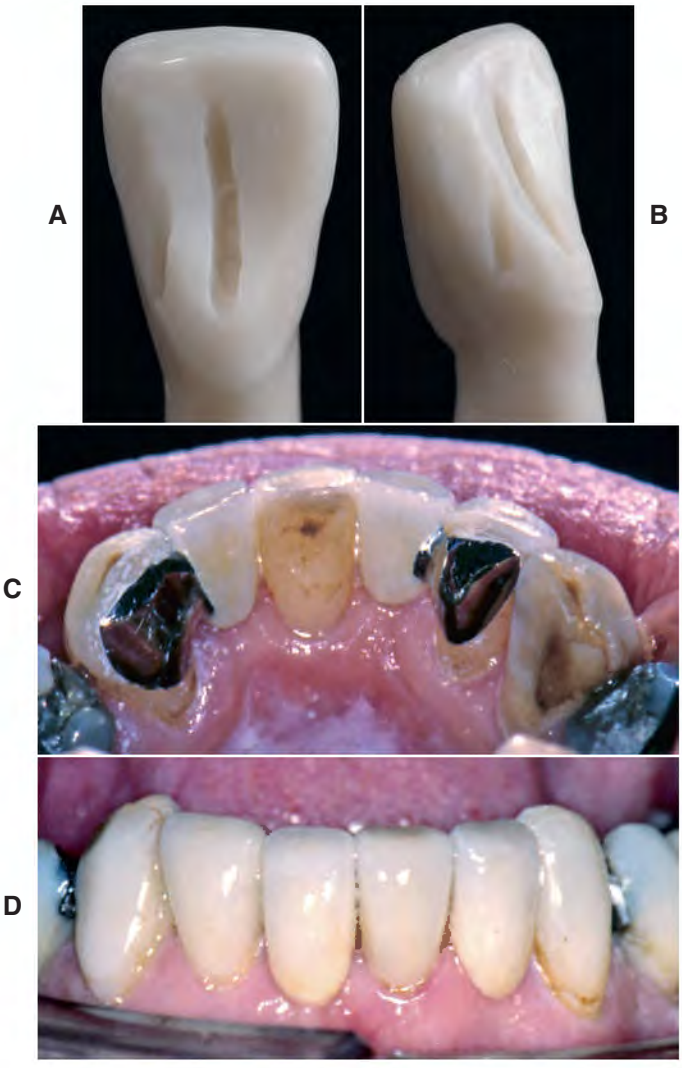

FIGURE 26-17 ■ Replacement of missing mandibular incisors. **A** and **B,** Groove placement for mandibular incisor abutments. **C** and **D,** Completed prostheses.

The dentist can then reassess the situation in terms of occlusion, retentive features, and cementation. A much more difficult situation is if a resin-bonded FDP becomes loose at one end. Many patients return to the dentist only when caries are established under the loose abutment. A cantilevered resin-bonded FDP either is cemented or falls out. The risk to the patient of caries under a loose retainer is eliminated.

The most effective way to replace a missing mandibular incisor with a resin-bonded FDP is an FDP cantilevered from the adjacent tooth. If two mandibular incisors are being replaced, it is recommended that two separate FDPs are made. Connecting the pontics increases the risk of failure (see Fig. 26-17).

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Posterior Tooth Preparation and Framework Design

The basic framework for the posterior resin-bonded FDP consists of three major components: the occlusal rest (for resistance to gingival displacement), the retentive surface (for resistance to occlusal displacement), and the proximal wrap and proximal slots (for resistance to torquing forces; see Fig. 26-8, *B*).

FIGURE 26-18 ■ **A,** Preparation for large premolar pontic. The first premolar has been prepared with mesial and distal rests and a distobuccal groove. **B,** The definitive restoration displays extensive metal on the occlusal surface of the premolar. This may be esthetically unacceptable to some patients.

A spoon-shaped occlusal rest seat, similar to that described for a partial removable dental prosthesis (see Chapter 21), is placed in the proximal marginal ridge area of the abutments adjacent to the edentulous space. An additional rest seat may be placed on the opposite side of the tooth (Fig. 26-18). The rest is an important retention feature and simultaneously provides resistance to both occlusal and lateral forces. It should be designed to function as a shallow "pin."

To resist occlusal displacement, the restoration is designed to maximize the bonding area without unnecessarily compromising periodontal health or esthetics. Proximal and lingual axial surfaces are reduced to lower their height of contour to approximately 1 mm from the crest of the free gingiva. The proximal surfaces are prepared so that parallelism results without undercuts. In the interproximal area, a gingival chamfer margin is not desirable; a knife-edge margin is better for avoiding enamel penetration. Occlusally, the framework should be extended high on the cuspal slope, well beyond the actual area of enamel recontouring (provided that it does not interfere with the occlusion; Fig. 26-19).

Resistance to lingual displacement is more easily managed in the posterior region of the mouth. A single path of placement should exist. The alloy framework should be designed to engage at least 180 degrees of

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FIGURE 26-19 ■ **A,** Preparation for a maxillary premolar prosthesis. A groove has been placed at the mesial extension of the premolar retainer arm to eliminate the use of a mesio-occlusal rest. This could compromise esthetics. Note that the lingual groove preparation on the molar extends gingivally as the preparation is carried down the buccal slope of the groove, which adds mechanical retention. **B,** The completed prosthesis.

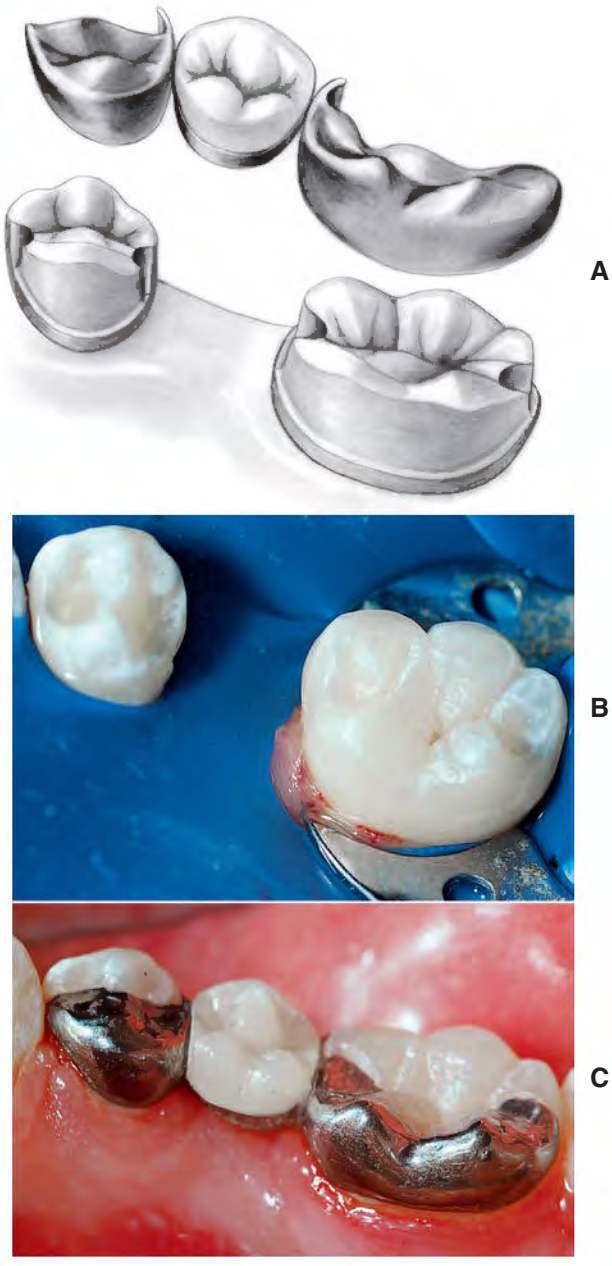

FIGURE 26-20 ■ **A,** Schematic of a resin-bonded onlay design in a fixed dental prosthesis. A thin veneer of metal is extended onto the occlusal surface of the teeth with approximately 0.5 mm reduction of the enamel where necessary. **B,** Preparation of molar and premolar. The lingual cusp of the premolar is covered to add additional mechanical retention on this short clinical crown. **C,** Completed restoration. Onlays also could have been placed on the lingual cusps of the molar; however, the mesial and distal rests were deemed sufficient in this situation.

tooth structure when viewed from the occlusal aspect. This proximal wrap enables the restoration to resist lateral loading by engaging the underlying tooth structure and is assisted in this regard by grooves in the proximal surface just lingual to the buccal line angle. Distal to the edentulous space, the retainer resistance is augmented by a groove at the linguoproximal line angle. Moving a properly designed resin-bonded FDP in any direction except parallel to its path of placement should not be possible, nor should it be possible to displace any tooth to the buccal aspect from the framework (see Figs. 26-8, *B*; 26-18; and 26-19).

In general, preparation differences between maxillary and mandibular molar teeth exist only on the lingual surfaces. The lingual wall of the mandibular tooth may be prepared in a single plane. The lingual surface of the maxillary molars requires a two-plane reduction because of occlusal function and the curvature of these functional cusps in the occlusal two thirds. However, the mandibular lingual retainer may be carried over the lingual cusps to augment resistance and retention form, which is particularly helpful on short clinical crowns of mesially and lingually inclined molars (this extension may necessitate a two-plane modification[80,93]; Fig. 26-20).

A wide range of extensions of the casting onto the occlusal surfaces of posterior teeth is possible. They include shoeing of cusps, encircling of cusps, and extensions of metal through the central fossa in a mesial-to-distal direction with the lingual cusps exposed. The clinician is limited only by imagination, available enamel, occlusion, and the display of metal tolerated by the patient. Several examples of preparations and restorations are presented in Figures 26-21 and 26-22.

On occasion, a combination restoration can be used. This type of FDP includes a resin-bonded retainer on

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one of the abutment teeth and a conventional cast restoration on the other. As previously noted, this type of FDP has been very successful in clinical studies.[86] Periodontal splinting is the most demanding of the restoration designs; splints and splint-FDP combinations necessitate care in designing adequate mechanical retention. An example of a multiple-rest design with interproximal extension of the metal is shown in Figure 26-23. The posterior splint-FDP combination entails the use of multiple rests and distinct mechanical retention of the abutment in the retainer, which can be important when the abutment is the most distal tooth in the arch (Fig. 26-24). The anterior splint must engage as much enamel as possible to aid in retention (Fig. 26-25), and achieving this is more demanding with regard to tooth alignment and preparation design.

FIGURE 26-21 ■ **A,** Preparations for a premolar resin-bonded fixed dental prosthesis. The distal aspect of the canine had a small class III composite resin restoration. This has been replaced and modified to create a distal slot for the retainer. The premolar has both mesial and distal occlusal rest preparations. **B,** Bonded prosthesis. The gingival margin of the restoration is very close to the free gingival crest (the ideal is 1 mm above the gingival crest). Meticulous plaque control is essential.

Laboratory Procedures

1. Wax the framework, invest and cast it in a Ni-Cr or Co-Cr alloy. Different alloys necessitate different surface preparation or tin plating; the dentist should use an alloy that has been well tested with the adhesive composite resin of choice (see later discussion).
2. Build up the pontic in porcelain, fire it, and contour it.
3. Evaluate the restoration clinically; when the fit is satisfactory, characterize and glaze it. As previously noted, opaque resins are necessary to prevent metal from graying the abutment teeth. Depending on the opacity of the resin and tooth translucency, the value of the abutment may be increased. Evaluation for anterior teeth should involve a try-in paste for proper characterization of the pontic. Any try-in paste remaining on the pontic will be eliminated during the glaze firing. After this is completed, the restoration can be polished. Regular finishing compound is suitable.
4. Clean the fitting surface with a particle-abrasion unit, using aluminum oxide (50 μm at a minimum of 0.3 MPa [40-psi] pressure); rinse thoroughly with water, and dry. If the restoration is evaluated again, particle abrasion should be repeated just before bonding.

Bonding the Restoration

Cements (Bonding Agents)

Composite resins play an important role in bonding the metal framework to etched enamel. A variety of resin

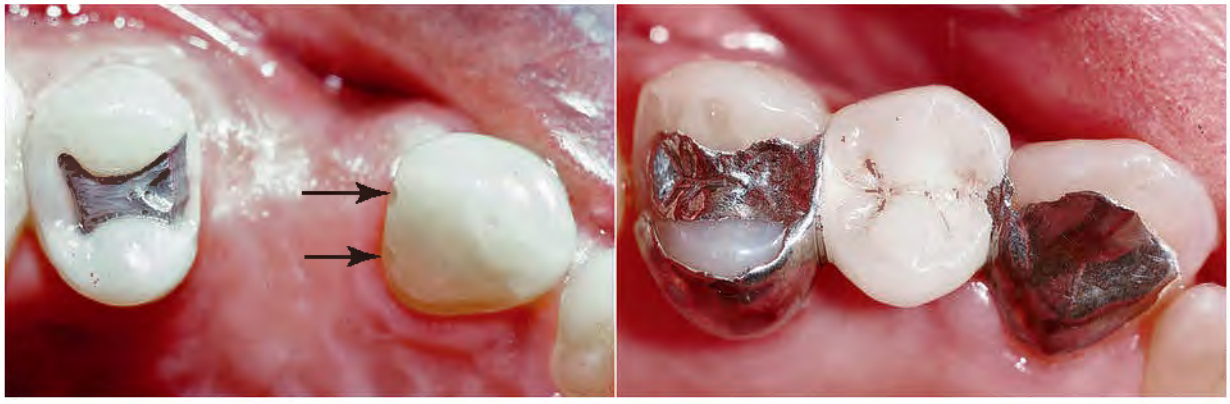

FIGURE 26-22 ■ **A,** Incorporation of an amalgam restoration into a resin-bonded fixed dental prosthesis (FDP). Note the margin placement at the gingival level, the use of two distal grooves *(arrows)*, and a distinct gingival finish line on the canine abutment. **B,** Another completed resin-bonded FDP with an inlay component.

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FIGURE 26-23 ■ **A,** One portion of the mandibular arch with teeth prepared as abutments for a resin-bonded splint replacing the mandibular incisors. Here both mesial and distal rests are used, in addition to extending the preparation into the proximal contact area. **B,** A bonded restoration. The extension to the second premolar was intended to help stabilize these mobile teeth, on the basis of a consultation with the periodontist. **C,** The completed restoration. The use of multiple rests on each posterior abutment is evident.

FIGURE 26-24 ■ Long-term recall of a resin-bonded fixed dental prosthesis. Particular care has been exercised in providing mechanical engagement of the second premolar, which is the most distal abutment in the arch.

FIGURE 26-25 ■ Anterior splint, viewed at 12-year recall appointment. Note the extension of the metal to engage as much lingual enamel as possible, extending over marginal ridges and into the interproximal areas wherever possible.

adhesives have been introduced specifically for this purpose. Conventional bis-GMA–type resins (e.g., Comspan, Dentsply Caulk) originally used for luting resin-bonded FDPs have been replaced by these more recently developed resin-metal adhesives, which continue to improve.

As mentioned earlier in this chapter, Panavia 21 (Kuraray America, Inc.) is an adhesive monomer (MDP), a glass-filled bis-GMA composite with a long history of successful application (Fig. 26-26, *B*). Panavia 21 exhibits excellent bond strengths with base metal alloys and tin-plated noble metals. It has an anaerobic setting reaction and thus does not set in the presence of oxygen. To ensure complete polymerization the manufacturer provides a polyethylene glycol gel (Oxyguard II) that can be placed over the restoration margins. The gel creates an oxygen barrier and can be washed away after the material has completely set. The latest version of this luting agent

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FIGURE 26-26 ■ Bonding procedures with an adhesive resin. **A,** Preparation of an anterior resin-bonded fixed dental prosthesis with mesial and distal groove retention, which was based on the presence of incisal wear facets. Note the use of rubber dam for moisture control. **B,** Dispensing system for anaerobic-setting adhesive composite resin paste. **C,** Use of both opaque and translucent composite resin with the opaque resin on the lingual aspect and the translucent resin in the interproximal aspect for esthetics. **D,** The restoration has been seated, and the excess resin has been removed while the resin between the retainers and the enamel sets anaerobically. The margin resin and excess remain nonsetting. **E,** Oxygen-barrier gel is applied for margin resin setting. **F,** The final restoration, which was cast from a high–gold content alloy and then tin plated. To provide good mechanical retention, the casting is increased in thickness by 50%, in comparison with a higher stiffness (elastic modulus) base metal alloy.

(Panavia F 2.0) is both chemically and light polymerized; as an alternative to the gel, a polymerization light can be used to polymerize the margins. This adhesive is supplied in opaque and tooth-colored forms. Because of the anaerobic setting reaction, both types can be mixed and do not set until air is excluded (as in seating of the restoration). This allows the application of opaque porcelain to the lingual aspect of an anterior retainer and the translucent tooth color to the interproximal aspect so that an opaque line will not be visible from the facial aspect. Both types can be mixed ahead of time and applied to the bonding surfaces of the retainer at a convenient time (see Fig. 26-26, *C*). This method makes it possible to mask the unesthetic metallic gray retainer, thus preventing it from showing through translucent enamel.[94]

Step-by-Step Bonding Procedures with Panavia Resin Adhesive Cement

As for any adhesive luting system, the manufacturer's instructions must be closely followed to maximize the cemented restoration's physical properties (see Fig. 26-26).

1. Clean the teeth with pumice and water. Isolate them with the rubber dam, and acid etch with 37% phosphoric acid for 30 seconds. Rinse, dry, and maintain air drying until the primer is applied (see Fig. 26-26, *A*). The assistant should dispense and mix the Panavia cement during the etching process and set it aside until step 3. The assistant should then mix the Panavia ED Primer

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and give it to the operator, who is keeping the etched teeth dry.
2. Apply the Panavia ED Primer to the etched surface. Although Panavia ED Primer is a "self-etching" primer, it should not be used without enamel etching because bonded retainer surfaces are not "freshly prepared enamel." After preparation, they acquire a salivary pellicle, which limits the self-etching capabilities of this type of product.[95]
3. Apply the premixed Panavia 21 cement (both opaque and tooth-colored if it is an anterior retainer) to the inner surface of the casting (see Fig. 26-26, *C*).
4. Dry the Panavia ED Primer to ensure evaporation of the solvent (this should remain on the enamel surface for 30 seconds before drying).
5. Seat the casting firmly, and maintain pressure while removing the excess resin cement with a brush or pledget. The cement sets within 60 to 90 seconds under the casting but not at the margins, which are exposed to air (see Fig. 26-26, *D*).
6. Light-polymerize the margins or apply Oxyguard II to exclude air (see Fig. 26-26, *E*).
7. Rinse away Oxyguard II after 2 minutes, and remove residual cement with a sharp hand instrument (see Fig. 26-26, *F*). Major finishing, polishing, and occlusal adjustments should be performed before the restoration is bonded. The tensile strength of the bonded FDP can be adversely affected by the heat or vibrations produced with rotary instruments.[96] However, minor adjustments and removal of excess resin can be accomplished with judicious use of these instruments.

Occlusion

The occlusion is adjusted so that there is a centric stop on the pontic and no other contacts on the pontic in all excursive movements. The abutment tooth has normal occlusal contacts on enamel or the metal casting. Contact on the metal casting is in the direction of seating the casting rather than dislodging it.

POSTOPERATIVE CARE

All resin-bonded restorations should be scrutinized at the regular recall examinations (see Chapter 31). Because debonding or partial debonding can occur without complete loss of the prosthesis, visual examination and gentle pressure with an explorer should be performed to confirm such a complication. Because debonding is most commonly associated with biting or chewing hard food,[96] patients should be warned about this danger. If the patient perceives any changes in the restoration, he or she should seek early attention. Early diagnosis and treatment of a partially debonded FDP can prevent significant caries (Fig. 26-27).[96]

The restoration can usually be rebonded successfully. The bonding surface should be cleaned with airborne-particle abrasion and the enamel surface refreshed by careful removal of the remaining resin with rotary instruments, followed by etching. If a prosthesis debonds more than once, reevaluating the preparation and remaking the prosthesis are probably necessary.

FIGURE 26-27 ■ Maxillary three-unit, resin-bonded fixed dental prosthesis. The distal retainer became debonded, but this was not detected promptly; as a result, a carious lesion developed.

Attention to periodontal health is crucial because this retainer design has the potential to accumulate excess plaque as a result of lingual overcontouring and the gingival extent of the margins.[70] The patient should be taught appropriate plaque-control measures (see Chapter 31). Calculus removal is recommended with hand instruments over ultrasonic scalers to reduce the risk of debonding.

REVIEW OF TECHNIQUE

The following list summarizes the steps involved in preparation and placement of a resin-bonded FDP:

- Eligible patients are those with sound abutments with minimal or no restorations. Occlusion must be stable.
- Tooth preparations consist of creating a large lingual bonding area with proximal wrap; a definite, single path of insertion; occlusal, incisal, or cingulum rest seats; and proximal grooves/slots.
- An accurate elastomeric impression material should be used.
- Careful laboratory technique is necessary to ensure a well-fitting and esthetic casting.
- Specially formulated resin-luting agents that are capable of adhering to the prescribed alloy should be used to bond the prosthesis.

SUMMARY

One of the biologic principles of tooth preparation for fixed prosthodontics is conservation of tooth structure. This is the primary advantage of resin-bonded FDPs. Precision and attention to detail are just as important for resin-bonded FDPs as for conventional FDPs. To provide a long-lasting prosthesis, the practitioner must plan and fabricate a resin-bonded restoration with the same diligence used for conventional restorations. The techniques can be very rewarding but must be approached carefully. Careful patient selection is an important factor in predetermining clinical success.

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REFERENCES

1. Rochette A: Attachment of a splint to enamel of lower anterior teeth. J Prosthet Dent 30:418, 1973.
2. Livaditis G, Thompson VP: Etched castings: an improved retentive mechanism for resin-bonded retainers. J Prosthet Dent 47:52, 1982.
3. Barrack G, et al: A long-term prospective study of the etched-cast restoration. Int J Prosthodont 6:428, 1993.
4. Brabant A: Indication and design: the key to successful resin-bonded fixed partial dentures. In Degrange M, Roulet J-F, eds: Minimally invasive restorations with bonding, pp 201-210. Chicago, Quintessence Publishing, 1997.
5. Marinello CP, et al: Resin-bonded fixed partial dentures and extracoronal attachments for removable partial dentures. In Degrange M, Roulet J-F, eds: Mininally invasive restorations with bonding, pp 221-240. Chicago, Quintessence Publishing, 1997.
6. Minami H, et al: Twelve-year results of a direct-bonded partial prosthesis in a patient with advanced periodontitis: a clinical report. J Prosthet Dent 108:69, 2012.
7. Ibsen R: Fixed prosthetics with a natural crown pontic using an adhesive composite. J South Calif Dent Assoc 41:100, 1973.
8. Portnoy J: Constructing a composite pontic in a single visit. Dent Surv 39:30, 1973.
9. Heymann H: Resin-retained bridges: The natural-tooth pontic. Gen Dent 31:479, 1983.
10. Heymann H: Resin-retained bridges: The acrylic denture-tooth pontic. Gen Dent 32:113, 1984.
11. Jordan R, et al: Temporary fixed partial dentures fabricated by means of the acid-etch resin technique: a report of 86 cases followed for up to three years. J Am Dent Assoc 96:994, 1978.
12. Howe D, Denehy GE: Anterior fixed partial dentures utilizing the acid-etch technique and a cast metal framework. J Prosthet Dent 37:28, 1977.
13. Livaditis G: Cast metal resin-bonded retainers for posterior teeth. J Am Dent Assoc 101:926, 1980.
14. Williams VD, et al: The effect of retainer design on the retention of filled resin in acid-etched fixed partial dentures. J Prosthet Dent 48:417, 1982.
15. Boyer DB, et al: Analysis of debond rates of resin-bonded prostheses. J Dent Res 72:1244, 1993.
16. Thompson VP, et al: Resin bond to electrolytically etched non-precious alloys for resin bonded prostheses. J Dent Res 60:377, 1981.
17. Levine W: An evaluation of the film thickness of resin luting agents. J Prosthet Dent 62:175, 1989.
18. Livaditis GJ, et al: Etched casting resin bonded retainers, part 1: resin bond to electrolytically etched non-precious alloys. J Prosthet Dent 50:771, 1983.
19. McLaughlin G, et al: Comparison of bond strengths using one-step and two-step alloy etching techniques. J Prosthet Dent 53:516, 1985.
20. Livaditis G: A chemical etching system for creating micromechanical retention in resin-bonded retainers. J Prosthet Dent 56:181, 1986.
21. Doukoudakis A, et al: A new chemical method for etching metal frameworks of the acid-etched prosthesis. J Prosthet Dent 58:421, 1987.
22. Re G, et al: Shear bond strengths and scanning electron microscope evaluation of three different retentive methods for resin-bonded retainers. J Prosthet Dent 59:568, 1988.
23. Wiltshire WA: Tensile bond strengths of various alloy surface treatments for resin bonded bridges. Quintessence Dent Technol 10:227, 1986.
24. Sloan KM, et al: Evaluation of laboratory etching of cast metal resin-bonded retainers [Abstract 1220]. J Dent Res 63:305, 1983.
25. Kern M, et al: Influence of prolonged thermal cycling and water storage on the tensile bond strength of composite to NiCr alloy. Dent Mater 10:19, 1994.
26. Kern M, et al: Durability of resin bonds to a cobalt-chromium alloy. J Dent 23:47, 1995.
27. Thompson VP, et al: [Bonded bridge technics: electrolytic etching of NiCr alloy]. Dtsch Zahnarztl Z 41:829, 1986.
28. Ozcan M, et al: A brief history and current status of metal- and ceramic surface-conditioning concepts for resin bonding in dentistry. Quintessence Int 29:713, 1998.
29. Kern M: Clinical long-term survival of two-retainer and single-retainer all-ceramic resin-bonded fixed partial dentures. Quintessence Int 36:141, 2005.
30. Kern M, Sasse M: Ten-year survival of anterior all-ceramic resin-bonded fixed dental prostheses. J Adhes Dent 13:407, 2011.
31. Sasse M, Kern M: Survival of anterior cantilevered all-ceramic resin-bonded fixed dental prostheses made from zirconia ceramic. J Dent 42:660, 2014.
32. Masuhara E: A dental adhesive and its clinical application. Vol 1, Tokyo, Quintessence, 1982.
33. Ohno H, et al: The adhesion mechanism of dental adhesive resin to alloy—relationship between Co-Cr alloy surface structure analyzed by ESCA and bonding strength of adhesive resin. Dent Mater 5:46, 1986.
34. Salonga JP, et al: Bond strength of adhesive resin to three nickel-chromium alloys with varying chromium content. J Prosthet Dent 72:582, 1994.
35. Asmussen E, et al: Adherence of resin-based luting agents assessed by the energy of fracture. Acta Odontol Scand 51:235, 1993.
36. Northeast SE, et al: Tensile peel failure of resin-bonded Ni/Cr beams: an experimental and finite element study [see comments]. J Dent 22:252, 1994.
37. Degrange M, et al: Bonding of luting materials for resin-bonded bridges: clinical relevance of in vitro tests. J Dent 22(Suppl 1):S28, 1994.
38. Hannsson O: Clinical results with resin-bonded prostheses and an adhesive cement. Quintessence Int 25:125, 1994.
39. Matsumura H, et al: Adhesive bonding of noble metal alloys with a triazine dithiol derivative primer and an adhesive resin. J Oral Rehabil 26:877, 1999.
40. Matsumura H, et al: Bonding of silver-palladium-copper-gold alloy with thiol derivative primers and tri-n-butylborane initiated luting agents. J Oral Rehabil 24:291, 1997.
41. Hikage S, et al: Clinical longevity of resin-bonded bridges bonded using a vinyl-thiol primer. J Oral Rehabil 30:1022, 2003.
42. Yamashita A: A dental adhesive and its clinical application. Vol 2, Tokyo, Quintessence, 1983.
43. Omura I, et al: Adhesive and mechanical properties of a new dental adhesive. J Dent Res 63:233, 1984.
44. Tjan A, et al: Bond strength of composite to metal mediated by metal adhesive promoters. J Prosthet Dent 57:550, 1987.
45. Imbery TA, et al: Tensile strength of three resin cements following two alloy surface treatments. Int J Prosthodont 5:59, 1992
46. Thompson V: Cast-bonded retainers. In Wei SHY, ed: Textbook of pediatric dentistry: total patient care, pp 233-245. Philadelphia, Lea & Febiger, 1988.
47. Breeding LC, et al: The effect of metal surface treatment on the shear bond strengths of base and noble metals bonded to enamel. J Prosthet Dent 76:390, 1996.
48. Dixon DL, et al: Shear bond strengths of a two-paste system resin luting agent used to bond alloys to enamel. J Prosthet Dent 78:132, 1997.
49. Bertolotti RL, et al: Intraoral metal adhesion utilized for occlusal rehabilitation. Quintessence Int 25:525, 1994.
50. Wood M, et al: Repair of porcelain/metal restoration with resin bonded overcasting. J Esthet Dent 4:110, 1992.
51. Kern M, et al: Effects of sandblasting and silica-coating procedures on pure titanium. J Dent 22:300, 1994.
52. Kern M, et al: Bonding to alumina ceramic in restorative dentistry: clinical results over up to 5 years. J Dent 26:245, 1998.
53. Kern M, et al: Sandblasting and silica-coating of dental alloys: volume loss, morphology and changes in the surface composition. Dent Mater 9:151, 1993.
54. Kern M, et al: Bonding to zirconia ceramic: adhesion methods and their durability. Dent Mater 14:64, 1998.
55. Barrack G: A look back at the adhesive resin-bonded cast restoration. J Esthet Dent 7:263, 1995.
56. Norling B, et al: Resin-metal bonding via three silica deposition processes [Abstract 993]. J Dent Res 70:390, 1991.
57. Yoshida K, et al: Effects of adhesive primers on bond strength of self-curing resin to cobalt-chromium alloy. J Prosthet Dent 77:617, 1997.
58. Aguilar LT, et al: Tensile bond strength of adhesive systems—effects of primer and thermocycling. Pesqui Odontol Bras 16:37, 2002.

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59. Matsumura H, et al: Evaluation of two thione primers and composite luting agents used for bonding a silver-palladium-copper-gold alloy. J Oral Rehabil 29:842, 2002.
60. Shimizu H, et al: Use of metal conditioners to improve bond strengths of autopolymerizing denture base resin to cast Ti-6Al-7Nb and Co-Cr. J Dent 34(2):117, 2006.
61. Watanabe I, et al: Shear bond strengths of laboratory-cured prosthetic composite to primed metal surfaces. Am J Dent 16:401, 2003.
62. Chadwick RG, et al: A retrospective observational study of the effect of surface treatments and cementing media on the durability of gold palatal veneers. Oper Dent 29:608, 2004.
63. Yamashita A, et al: Adhesion bridge background and clinical procedure. In Gettleman L, et al, eds: Adhesive prosthodontics: adhesive cements and techniques, pp 61-76. Nijmegen, The Netherlands, Eurosound, 1988.
64. Aquilino S, et al: Tensile fatigue limits of prosthodontic adhesives. J Dent Res 70:208, 1991.
65. Saunders W: The effect of fatigue impact forces upon the retention of various designs of resin-retained bridgework. Dent Mater 3:85, 1987.
66. Zardiakas L, et al: Tensile fatigue of resin cements to etched metal and enamel. Dent Mater 4:163, 1988.
67. Crispin B, et al: Etched metal bonded restoration: three years of clinical follow-up. J Dent Res 65:311, 1986.
68. el Salam Shakal MA, et al: Effect of tooth preparation design on bond strengths of resin-bonded prostheses: a pilot study. J Prosthet Dent 77:243, 1997.
69. Pegoraro LF, et al: A comparison of bond strengths of adhesive cast restorations using different designs, bonding agents, and luting resins. J Prosthet Dent 57:133, 1987.
70. Romberg E, et al: 10-Year periodontal response to resin bonded bridges. J Periodontol 66:973, 1995.
71. Krell KV, et al: Ultrasonic debonding of anterior etched-metal resin bonded retainers. Gen Dent 34:378, 1986
72. Creugers NH, et al: A method to compare cost-effectiveness of dental treatments: adhesive bridges compared to conventional bridges. Community Dent Oral Epidemiol 20:280, 1992.
73. Creugers NH, et al: Risk factors and multiple failures in posterior resin-bonded bridges in a 5-year multi-practice clinical trial. J Dent 26:397, 1998.
74. de Rijk WG, et al: Maximum likelihood estimates for the lifetime of bonded dental prostheses. J Dent Res 75:1700, 1996.
75. Thompson VP, et al: Longevity of resin-bonded fixed partial dentures: better than conventional fixed restorations? In Degrange M, Roulet J-F, eds: Minimally invasive restorations with bonding, pp 185-200. Chicago, Quintessence Publishing, 1997.
76. Creugers NH, et al: Long-term survival data from a clinical trial on resin-bonded bridges. J Dent 25:239, 1997.
77. De Kanter RJ, et al: A five-year multi-practice clinical study on posterior resin-bonded bridges. J Dent Res 77:609, 1998.
78. Olin PS, et al: Clinical evaluation of resin-bonded bridges: a retrospective study. Quintessence Int 22:873, 1991.
79. Creugers NHJ, et al: A meta-analysis of durability on conventional fixed bridges. Community Dent Oral Epidemiol 22:448, 1994.
80. Eshleman J, et al: Tooth preparation designs for resin-bonded fixed partial dentures related to enamel thickness. J Prosthet Dent 60:18, 1988.
81. Shillingburg HT, et al: Thickness of enamel and dentin. J South Calif Dental Assoc 41:33, 1973.
82. Djemal S, et al: Long-term survival characteristics of 832 resin-retained bridges and splints provided in a post-graduate teaching hospital between 1978 and 1993. J Oral Rehabil 26:302, 1999.
83. Wood M, et al: Resin-bonded fixed partial dentures. II. Clinical findings related to prosthodontic characteristics after approximately 10 years. J Prosthet Dent 76:368, 1996.
84. Marinello CP, et al: Experiences with resin-bonded bridges and splints—a retrospective study. J Oral Rehabil 14:251, 1987.
85. Marinello CP, et al: First experiences with resin-bonded bridges and splints—a cross-sectional retrospective study, Part II. J Oral Rehabil 15:223, 1988.
86. Wood M, et al: Ten-year clinical and microscopic evaluation of resin-bonded restorations. Quintessence Int 27:803, 1996.
87. Simonsen R, et al: Etched cast restorations: clinical and laboratory techniques. Chicago, Quintessence Publishing, 1983.
88. Wood M, et al: Adhesive resin bonded cast restorations. In Dale BG, Aschheim KW, eds: Esthetic dentistry: a clinical approach to techniques and materials, pp 151-162. Philadelphia, Lea & Febiger, 1992.
89. Blanco-Dalmau L: The nickel problem. J Prosthet Dent 48:99, 1982.
90. Nakabayashi N, et al: Relationship between the shape of adherend and the bond strength. Jpn J Dent Mater 6:422, 1987.
91. Briggs P, et al: The single unit, single retainer, cantilever resin-bonded bridge. Br Dent J 181:373, 1996.
92. Wong TL, Botelho MG: The fatigue bond strength of fixed-fixed versus cantilever resin-bonded partial fixed dental prostheses. J Prosthet Dent 111:136, 2014.
93. Simonsen R, et al: Posterior design principles in etched cast restorations. Quintessence Int 3:311, 1983.
94. Caughman WF, et al: A double-mix cementation for improved esthetics of resin-bonded prostheses. J Prosthet Dent 58:48, 1987.
95. Caughman W, et al: The effect of finishing resin-bonded fixed partial dentures on postcementation tensile strength. J Prosthet Dent 59:149, 1988.
96. Gilmour ASM: Resin bonded bridges: a note of caution. Br Dent J 167:140, 1988.

STUDY QUESTIONS

1. Discuss the indications and contraindications of resin-bonded FDPs.

2. When the replacement of a congenitally missing lateral incisor with a resin-bonded fixed dental prosthesis (FDP) is planned, a cantilevered design is considered. Is a single-abutment design better or worse than a two-abutment design? Why?

3. List the various bonding techniques used for resin-bonded FDPs. Which one is currently recommended? Why?

4. Discuss the tooth preparations needed for anterior resin-bonded FDPs. How does the preparation differ for posterior abutments?

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CHAPTER 27

Connectors for Partial Fixed Dental Prostheses

Connectors are the components of a partial fixed dental prosthesis (FDP) or splint that join the individual retainers and pontics together. Usually this is accomplished with rigid connectors (Fig. 27-1), although nonrigid connectors are occasionally used. The latter are usually indicated when it is impossible to prepare a common path of placement for the abutment preparations for a partial FDP (Fig. 27-2, *A* and *B*). Their use has been reported to be associated with significantly reduced failure rates.[1]

RIGID CONNECTORS

Rigid connections in metal can be made by casting, milling, laser sintering, soldering, or welding. Cast connectors are shaped in wax as part of a multiunit wax pattern. Milled or laser-sintered connectors are shaped in the computer processing when computer-assisted design/computer-assisted manufacturing (CAD/CAM) is used.[2] Cast connectors are convenient and minimize the number of steps involved in the laboratory fabrication. However, the fit of the individual retainers may be adversely affected because distortion more easily results when a multiunit wax pattern is removed from the die system. Soldered connectors involve the use of an intermediate metal alloy whose melting temperature is lower than that of the parent metal (Fig. 27-3). The parts being joined are not melted during soldering but must be thoroughly wettable by liquefied solder.[3] Dirt or surface oxides on the connector surfaces can interfere with wetting and impede successful soldering; for example, the solder may melt but does not flow into the soldering gap. Welding is another method of rigidly joining metal parts. In welding, the connection is created by melting adjacent surfaces that are often in contact with each other, with heat or pressure. A filler metal whose melting temperature is about the same as that of the parent metal can be used during welding.

In industrial metalworking, a distinction is made between *soldering*, in which the filler metal has a melting point below 450°C (842°F), and *brazing*, in which the filler has a melting point above 450°C.[4] Rigid connections in dentistry are generally fabricated at temperatures above 450°C, but the process has almost always been referred to in the dental literature as *soldering*. However, in a proposed international standard, the term *brazing* is used. With time, the latter term may become more generally accepted. In this text, however, the term *soldering* is used.

NONRIGID CONNECTORS

Nonrigid connectors are indicated when it is not possible to prepare two abutments for a partial FDP with a common path of placement. Segmenting the design of large, complex FDPs into shorter components that are easier to replace or repair individually is advisable. This can be helpful if an abutment's prognosis is uncertain. If the abutment fails, only a portion of the FDP may need to be remade. In the mandibular arch, nonrigid connectors are indicated when a complex FDP consists of anterior and posterior segments. During the mandibular opening and closing stroke, the mandible flexes mediolaterally.[5,6] Rigid FDPs have been shown to inhibit mandibular flexure, and extensive splints have been shown to flex during forced opening.[7,8] The associated stresses can cause dislodgment of complex FDPs. Segmenting complex mandibular FDPs can minimize this risk (Fig. 27-4).

Nonrigid connectors are generated through incorporation of prefabricated inserts in the wax pattern or through custom milling procedures after the first casting has been obtained. The second part is then custom fitted to the milled retainer and cast. They are often made with prefabricated plastic patterns. The retainers are then cast separately and fitted to each other in metal.

CONNECTOR DESIGN

The size, shape, and position of connectors all influence the success of the prosthesis. Connectors must be sufficiently large to prevent distortion or fracture during function but not too large; otherwise, they interfere with effective plaque control and contribute to periodontal breakdown over time. Adequate access (i.e., embrasure space) must be available for oral hygiene aids cervical to the connector. If a connector is too large incisocervically, hygiene is impeded, and over time, periodontal failure will result (Fig. 27-5, *A*). For esthetic FDPs, a large connector or inappropriate shaping of the individual retainers may result in display of the metal connector, which may compromise the appearance of the restoration and cause patient dissatisfaction (see Fig. 27-5, *B*).

In addition to being highly polished, the tissue surface of connectors is curved faciolingually to facilitate cleansing. Mesiodistally, it is shaped to create a smooth transition from one partial FDP component to the next. A properly shaped connector has a configuration similar to a meniscus formed between the two parts of the prosthesis.

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FIGURE 27-1 ■ Rigid connectors: a three-unit partial fixed dental prosthesis (FDP) replacing the maxillary second premolar. **A**, The anterior abutment and the pontic are connected with a rigid cast connector. These two partial FDP components are fabricated separately from the posterior abutment, which is cast in gold. **B,** The components are placed in relation to one another by a soldering assembly. **C,** The connected components. **D,** The FDP in place.

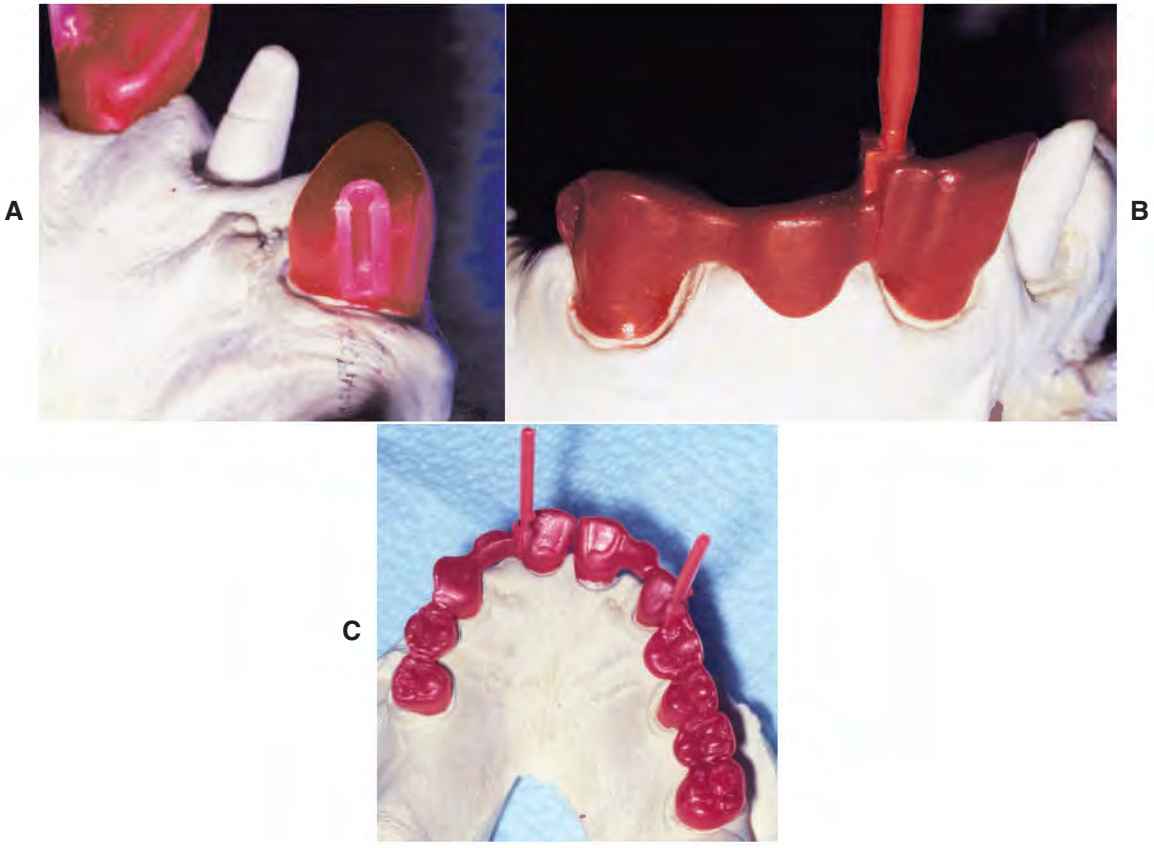

FIGURE 27-2 ■ Partial fixed dental prosthesis (FDP) with nonrigid connector. **A,** Mortise pattern ("female" component) positioned on the distal surface of the canine retainer. **B,** Partial FDP assembled with prefabricated resin tenon ("male" component) on the mesial surface of the pontic. **C,** Nonrigid connectors used to allow the fabrication of an extensive FDP having abutments prepared with divergent paths of placement. (Courtesy Dr. M. Chen.)

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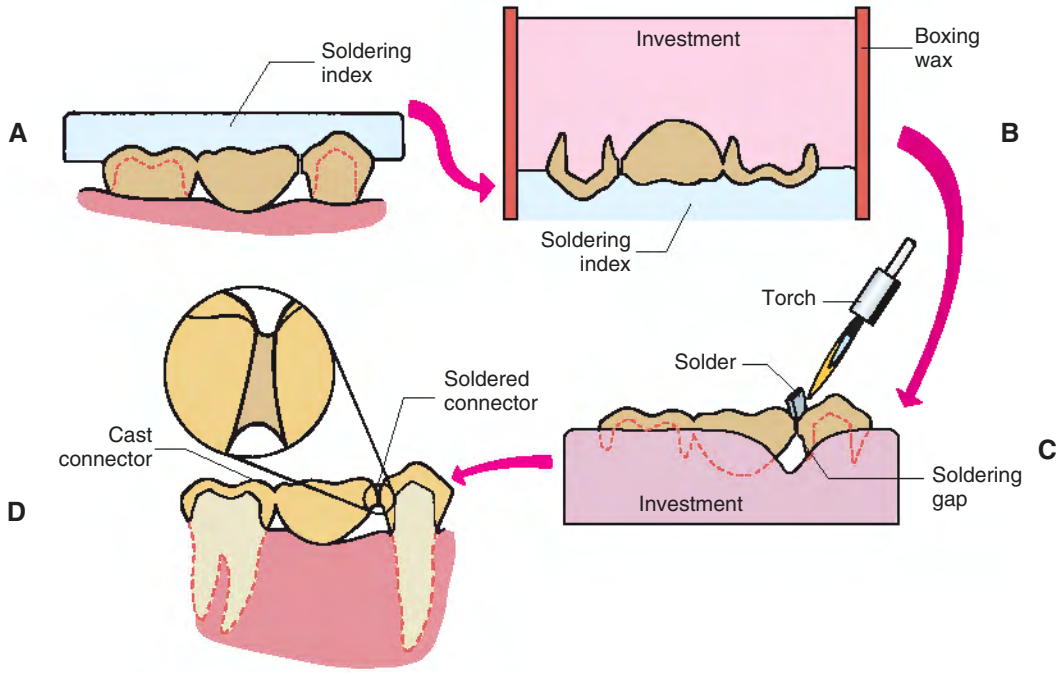

FIGURE 27-3 ■ The soldering process. **A,** Fabrication of occlusal soldering index. **B,** Investment of fixed dental prosthesis components. **C,** Torch soldering. **D,** Clinical evaluation.

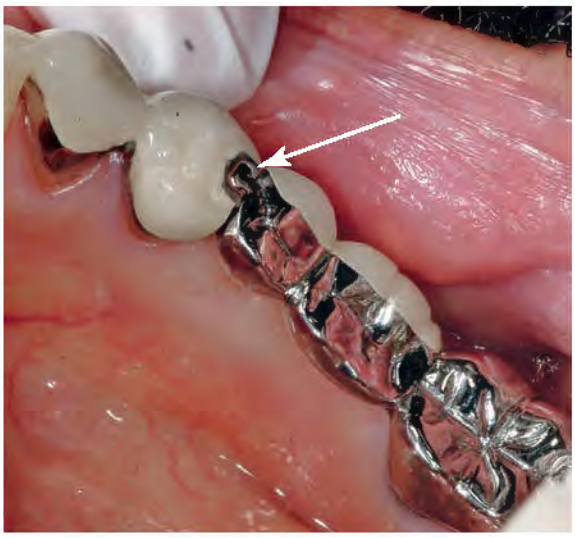

FIGURE 27-4 ■ This complex fixed dental prosthesis has been segmented through the use of a nonrigid connector *(arrow)* on the distal surface of the canine.

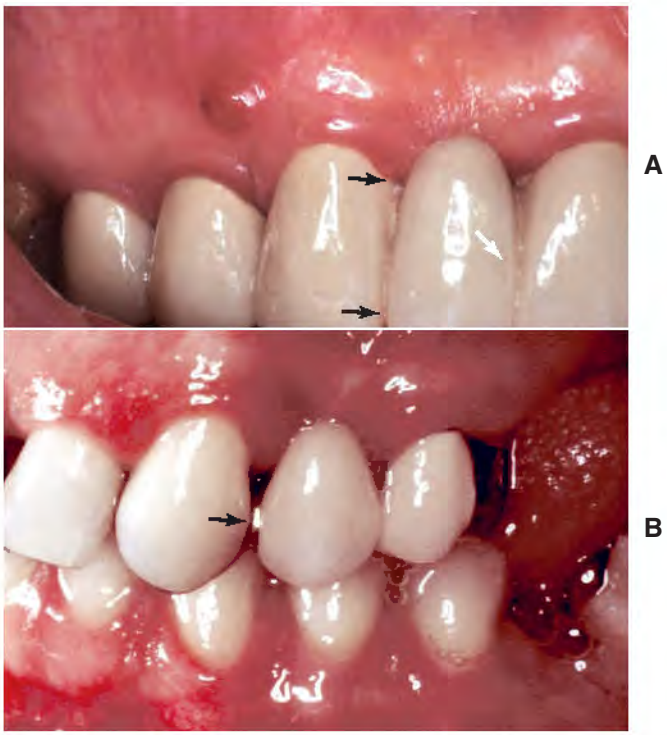

FIGURE 27-5 ■ Restorative failure. **A**, An excessively large Incisocervical connector *(arrows)* impedes proper plaque control, which has led to periodontal breakdown. **B,** A connector *(arrow)* that displays metal, although perhaps acceptable from a biologic and mechanical perspective, can prove to be esthetically unacceptable.

In a buccolingual cross section, most connectors are somewhat elliptical. Elliptical connectors are strongest if the major axis of the ellipse parallels the direction of the applied force. Unfortunately, because of anatomic considerations, this cannot always be achieved. In fact, because of space constraints, the greatest dimension of most connectors is perpendicular to the direction of applied force, which tends to weaken the connectors. For ease of plaque control, the connectors should occupy the normal anatomic interproximal contact areas because encroaching on the buccal, gingival, or lingual embrasure restricts access. However, to improve appearance without significantly affecting plaque control, anterior connectors are normally placed toward the lingual embrasure. Figure 27-6 depicts typical locations for connectors on selected teeth.

Pulp size and clinical crown height can be limiting factors in the design of nonrigid connectors. Most

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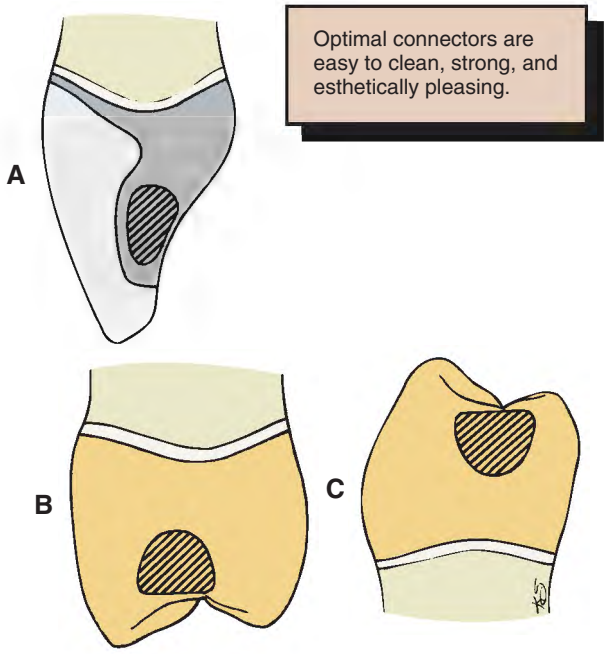

FIGURE 27-6 ■ Cross-sectional views through fixed dental prosthesis connectors. **A,** Maxillary anterior view. **B,** Maxillary posterior view. **C,** Mandibular posterior view. Note the convexity of the gingival surface of the connectors. To prevent excessive display of metal, anterior connectors should be placed toward the lingual embrasure.

prefabricated patterns require the preparation of a fairly sizable box. This allows incorporation of the mortise (see the section Nonrigid Connectors and Fig. 27-8) in the cast restoration without overcontouring of the interproximal emergence profile. Short clinical crowns do not provide adequate occlusocervical space to ensure adequate strength. Most manufacturers recommend 3 to 4 mm of vertical height, which is supported by empirical clinical findings.

TYPES OF CONNECTORS

Rigid Connectors

Rigid connectors must be shaped and incorporated into the wax pattern after the individual retainers and pontics have been completed to definitive contour but before reflowing of the margins for investing (see Chapter 18). When a CAD/CAM process is used, the connectors are designed as part of the framework with the computer software.[2]

Cast Connectors

Connectors to be cast are also waxed on the definitive cast before reflowing and investing of the pattern. The presence of a cast connector makes the process of investing somewhat more awkward: Access to the proximal margin is impeded, and the pattern cannot be held proximally during removal from the die. Restricting cast connectors to complete coverage restorations, which can be gripped buccolingually, is therefore advisable. Partial-coverage wax patterns are easily distorted, particularly when they are part of a single-cast partial FDP. One-piece castings often appear to simplify fabrication but tend to create more problems than do soldered connectors, especially as pattern complexity increases.

Soldered Connectors

As with cast connectors, connectors to be soldered are waxed to final shape but are then sectioned with a thin ribbon saw (Fig. 27-7, *A* and *B*); therefore, when the components are cast, the surfaces to be joined are flat, parallel, and a controlled distance apart. This allows accurate soldering with a minimum of distortion.[9] Molten solder flows toward the location where the temperature is highest. In metal, the two flat surfaces previously created in wax retain heat, which ensures that the highest temperature is in the connector area.

Soldering Gap Width. As gap width increases, soldering accuracy decreases.[10] Extremely small gap widths can prevent proper solder flow and cause the joint to be incomplete or weak.[11] An even soldering gap of about 0.25 mm is recommended. If a connector area has an uneven soldering gap width, obtaining a connector of adequate cross-sectional dimension without resulting distortion is more difficult.

Nonrigid Connectors

The design of nonrigid connectors that are incorporated in the wax pattern stage consists of a mortise (also referred to as the *"female" component*) prepared within the contours of the retainer and a tenon *("male" component)* attached to the pontic (Fig. 27-8). The mortise is usually placed on the distal surface of the anterior retainer. Accurate alignment of the dovetail or cylindrically shaped mortise is crucial; it must parallel the path of placement of the distal retainer (see Fig. 27-2). Paralleling is normally accomplished with a dental surveyor. When the cast is aligned, the path of placement of the retainer that will be contiguous with the tenon is identified. The mortise in the other retainer is then shaped so that its path of placement allows concurrent seating of the tenon and its corresponding retainer.

The mortise can be prepared freehand in the wax pattern or with a precision milling machine. Another approach is to use prefabricated plastic components for the mortise and tenon of a nonrigid connector (Fig. 27-9).

MATERIALS SCIENCE

M.H. Reisbick

Solder

Dental gold solders are given a fineness designation to indicate the proportion of pure gold contained in 1000 parts of alloy. For example, a 650-fine solder contains 65% gold. In an earlier designation,[12] the solder was

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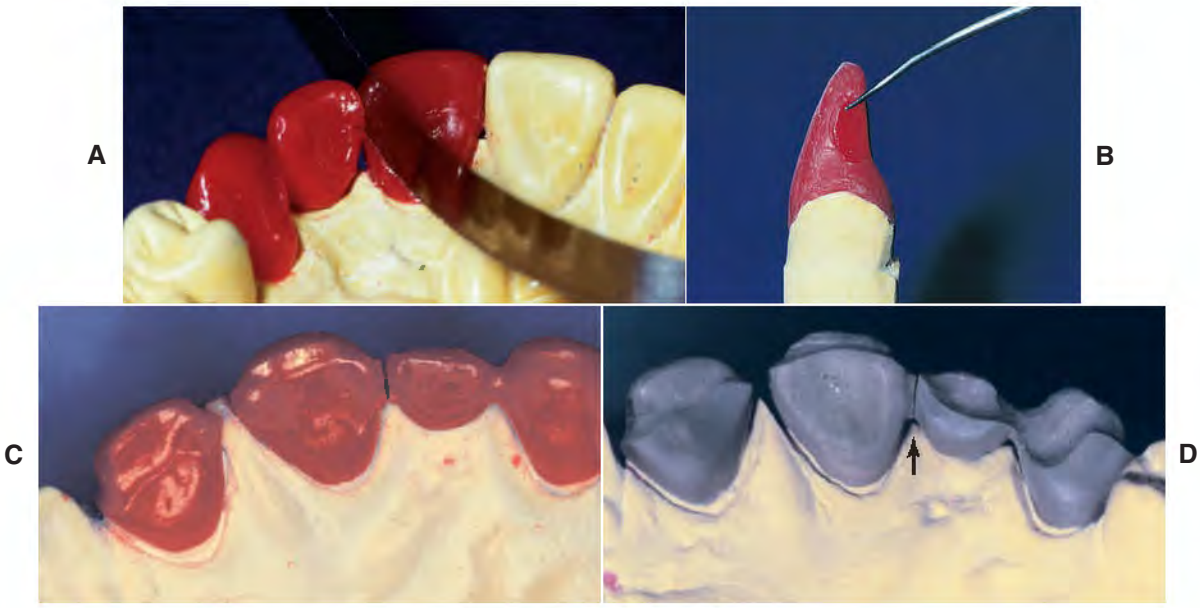

FIGURE 27-7 ■ Connector design. **A,** A ribbon saw is used to section the wax pattern. **B**, The sectioned surface should be flat and located far enough incisally and lingually to allow adequate hygiene and esthetics of the completed partial fixed dental prosthesis (FDP). **C,** A three-unit FDP after sectioning. **D,** Framework ready for porcelain application. Note the uniform gap width *(arrow).*

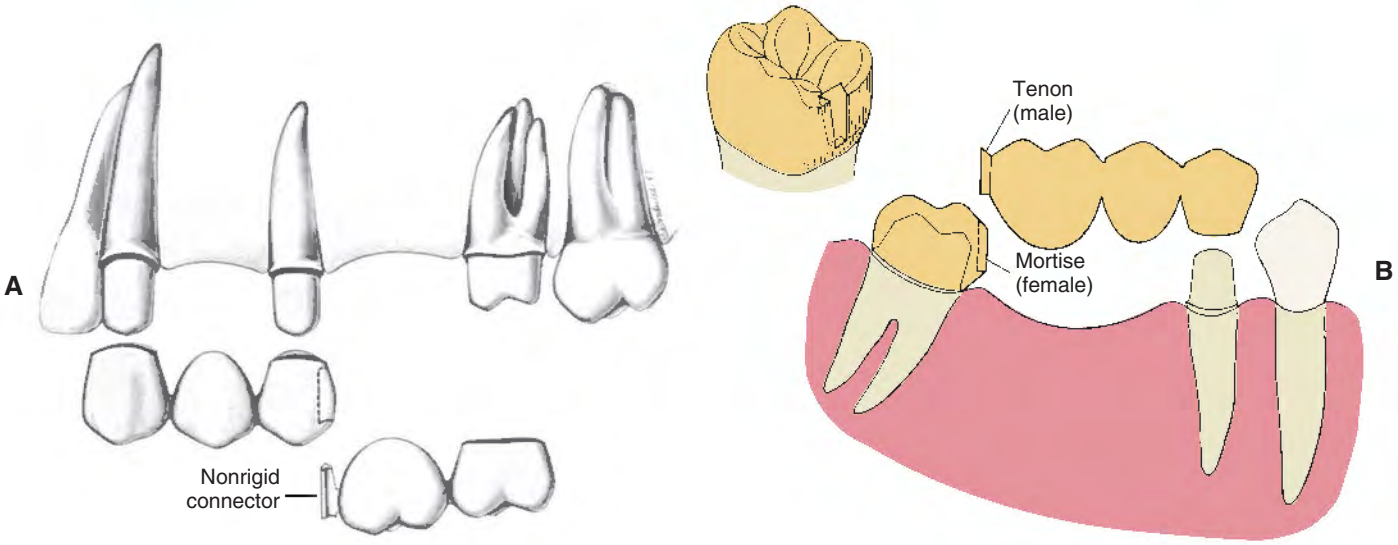

FIGURE 27-8 ■ Illustrations of partial fixed dental prostheses with nonrigid connectors. This type of connector may be indicated to overcome problems with intermediate or pier abutments **(A)** and abutment alignment **(B).**

assigned a carat number, which indicated the gold content of the castings that were to be joined with the solder; an 18-carat solder could be used to solder castings fabricated of an alloy containing 75% gold. Because numerous alloys other than type IV gold are available today, many of which contain platinum-group metals, the carat designation is of little value.

Modern casting alloys have become so metallurgically complex that most manufacturers now recommend specifically formulated solders. One manufacturer (Heraeus Kulzer) classifies traditional gold-containing solders as group I and others (termed *special solders*) as group II. Most of these have the brand name with a "pre" or "post" designation to indicate whether the solder is to be used for joining the components before or after porcelain application. The so-called preceramic solders are obviously high-fusing alloys, sometimes fusing only slightly beneath the softening point of the parent alloy to be joined. Ideally, they flow well above the fusion range of the subsequently applied porcelain. Postceramic solders must flow well below the pyroplastic range of the porcelain. For example, one popular silver-palladium (Ag-Pd) casting alloy has a specified melting range between 1232°C and 1304°C (2250°F to 2380°F). The recommended special presolder melts at 1110°C to 1127°C (2030°F to 2061°F), whereas the postsolder melts at

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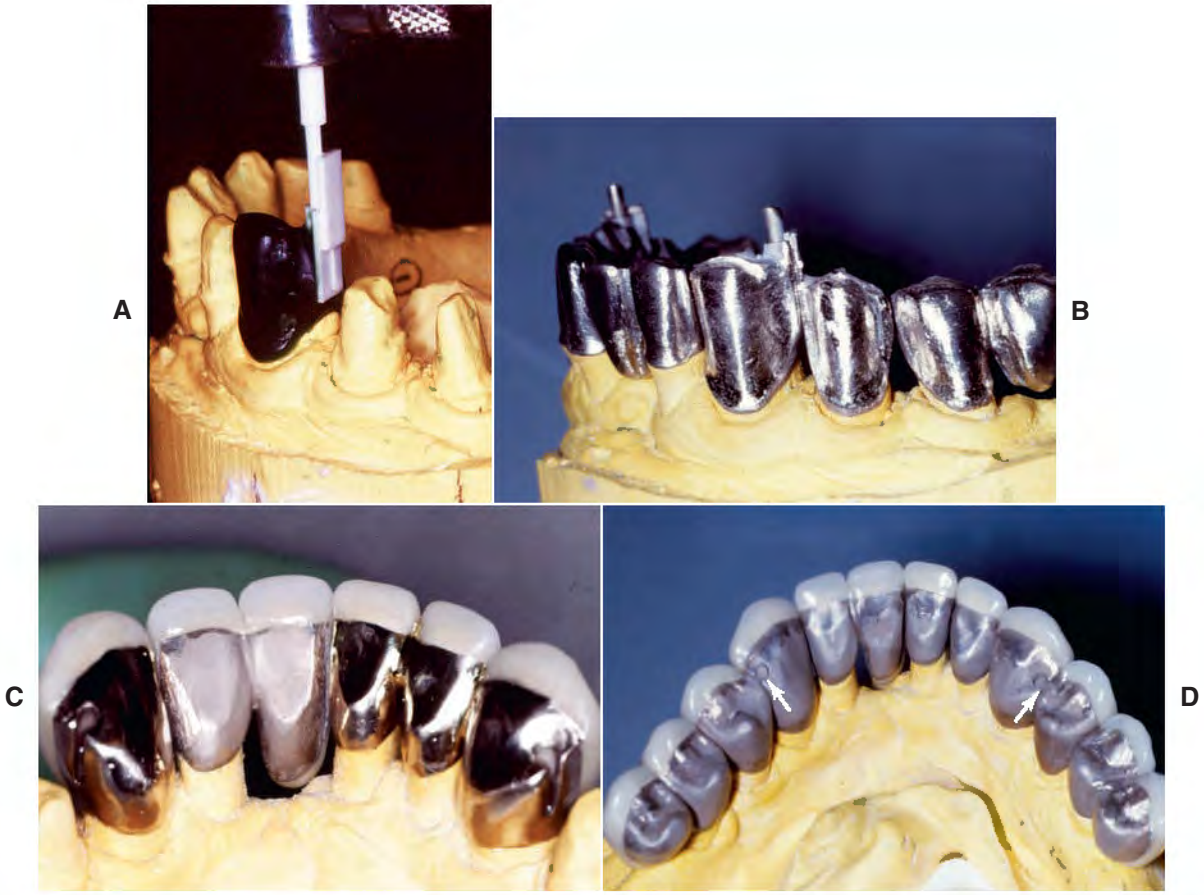

FIGURE 27-9 ■ **A,** Prefabricated plastic patterns are available for incorporation in the wax pattern. **B,** The metal substructure. **C** and **D,** The completed prosthesis incorporates bilateral nonrigid connectors *(arrows).* (Courtesy Dr. F. Hsu.)

TABLE 27-1 **Composition and Flow Temperatures of Dental Solders**

	Metal					
Fineness	GOLD	SILVER	COPPER	TIN	ZINC	**Flow Temperature (°C)**
490	49.0%	17.5%	23.0%	4.5%	6.0%	780
585	58.5%	14.0%	19.0%	3.5%	4.5%	780
615	61.5%	13.0%	17.5%	3.5%	4.5%	790
650	65.0%	12.0%	16.0%	3.0%	4.0%	790
730	73.0%	9.0%	12.5%	2.5%	3.0%	830

Courtesy Ivoclar Vivadent, Amherst, New York.

710°C to 743°C (1310°F to 1369°F). The porcelain fuses at about 982°C (1800°F), depending on time and temperature.

The composition of the solder determines its melting range, among other things. Some typical compositions and melting ranges are given in Table 27-1. The main requirement in soldering is to fuse safely below the sag or creep temperature of the casting to be soldered. Newer palladium casting alloys, by virtue of their higher melting ranges, have somewhat increased the reliability of the presoldering technique.[13]

However, preceramic soldering is relatively difficult and can be structurally hazardous (Fig. 27-10). This may be because base metal solder constituents volatilize with overheating,[14] which then results in microporosity, or pitting. The melting range of presolders is quite narrow because silver and copper (the usual modifiers of temperature range) cannot be used in the alloy; these elements discolor porcelain on contact. Another consideration is the oxide necessary for the chemical adherence of porcelain. Porcelain does not chemically bond equally well to all solders.

Other requirements of solders are their ability to resist tarnish and corrosion, to be free flowing, to match the color of the units that will be joined, and to be strong. These factors also depend on the chemical composition of the solder.

Resistance to tarnish and corrosion is determined by a solder's noble or precious metal content and its silver-to-copper (Ag/Cu) ratio.[15] In addition, if the

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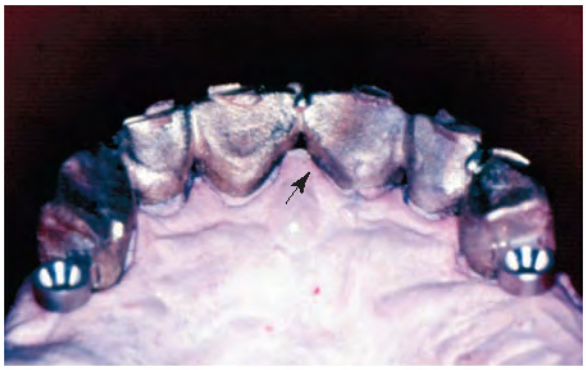

FIGURE 27-10 ■ Metal substructure for an anterior prosthesis. The preceramic soldering procedure in this case led to partial melting of the framework *(arrow),* which can result in distortion, premature failure, or both.

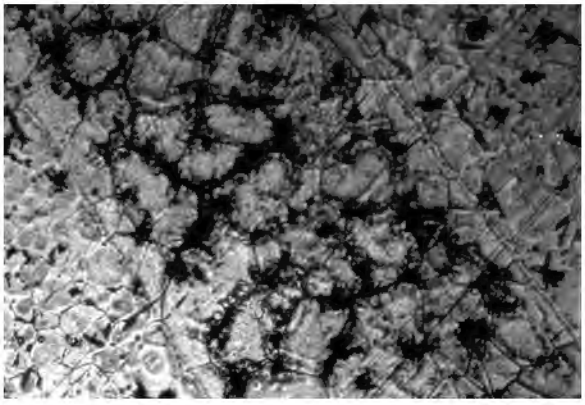

FIGURE 27-11 ■ Photomicrograph of a properly made solder joint connecting two castings.

compositions of the solder and work piece differ, galvanic corrosion may occur.

During the soldering procedure, the solder must flow freely over clean and smooth surfaces. These surfaces should be smoothed with abrasive disks, not with rubber wheels or polishing compounds. The phenomenon of free flow is termed *wetting*, during which remelting or realloying of the surface of the units to be joined must not occur.[16] Solder flow is increased by the addition of silver and decreased by the presence of copper. Figure 27-11 depicts a properly made solder joint. Note that the filler metal has joined the surfaces of the two castings without penetrating either one.

Lower-fineness gold solders are often more fluid and are generally chosen for joining castings. If necessary, proximal contacts with a solder of higher fineness can also be added because this tends to flow less freely. However, the exact minimally acceptable fineness necessary for resisting tarnish and corrosion has not been conclusively established; 615 or 580 fineness is probably the lower limit of clinical acceptability.

The last requirement, strength, is easily satisfied by most solders and is usually greater than that of the soldered parent metal, provided that the procedure is followed carefully.[10] In addition, most solders harden during cooling because of the "order-disorder" transformation and the formation of other intermetallic phases, which occur at grain boundaries. Brittleness is frequently encountered with gold-based copper-containing solders. As with type III and type IV gold casting alloys, the gold-copper order-disorder (or discontinuous phase-hardening) mechanism causes similar changes in the solder's microstructure.[17] Simply stated, with these solders, cooling to room temperature results in a brittle joint. The joints are strong but have no ductility. Some solder joints are weakened by notches.[18] This means that soldered connectors should be well polished to prevent fracture.

Partial FDPs fabricated with type III gold alloys and joined interproximally with traditional gold-based solders are usually water quenched 4 to 5 minutes after soldering is complete. Quenching immediately after soldering causes the partial FDP to warp; failure to quench results in a joint with little or no ductility. A brittle joint may easily fracture. Thus a disadvantage of postceramic soldering is the loss of joint ductility. Because the components are partially porcelain, quenching is not done, because porcelain fracture would occur.

Soldering Flux and Antiflux

Soldering Flux

Soldering flux is applied to a metal surface to remove oxides or prevent their formation. When the oxides are removed, the solder is free to wet the clean metal surface.

Borax glass ($Na_2B_4O_7$) is frequently used with gold alloys because of its affinity for copper oxides. An often-cited soldering flux formula[19] is borax glass (55 parts), boric acid (35 parts), and silica (10 parts). These ingredients are fused together and then ground into a powder.

Fluxes are available in powder, liquid, or paste form. The paste is popular because it can be easily placed and confined. To make pastes, the flux powder is mixed with petrolatum. The petrolatum excludes oxygen during heating and eventually carbonizes and then vaporizes.

New fluxes are available for use with non–gold-based alloys. Their formulas are not generally published. At present, none of the new fluxes are totally capable of preventing oxide formation during heating of the base metal or nonnoble alloys. An example of a rapidly forming oxide on a base metal occurring during a simulated post-soldering is shown in Figure 27-12. Soldering of base metal alloys is still unpredictable.[20]

All fluxes should be prevented from contacting porcelain-veneered surfaces. The contact causes pitting and porcelain discoloration.

Soldering Antiflux

Antiflux is used to limit the spreading of solder. It is placed on a casting before the flux application to limit the flow of molten solder. When the metal surfaces are clean, any excess solder introduced into the work gap tends to flow into undesirable areas. The antiflux helps prevent this.

Graphite (from a pencil) is often used as an antiflux. However, the carbon easily evaporates at higher

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FIGURE 27-12 ■ Simulated base metal–to–base metal postceramic soldering procedure. Excessive oxide formation prevented wetting by the solder. (From Sloan RH, et al: Post-ceramic soldering of various alloys. J Prosthet Dent 48:686, 1982.)

FIGURE 27-13 ■ Extensive fixed prosthesis indexed for postsoldering with autopolymerizing resin and a gypsum index.

temperatures, leaving the work piece unprotected. A more reliable antiflux is iron oxide (rouge) in a suitable solvent such as turpentine, which can be painted on the casting with a small brush.

Soldering Investment

Soldering investments are similar in composition to casting investments (see Chapter 22). Casting investments, both gypsum and phosphate bonded, mixed with water only, have been used for soldering. However, the refractory component in casting investments usually creates unwanted thermal expansion and therefore excessively separates the units to be joined. Soldering investments ideally contain fused quartz (the lowest thermally expanding form of silica) as their refractory component.

Invested units expand during heating, and they should do so at the same rate as the castings. The units must be correctly gapped so that they do not touch. When the work units are allowed to touch, distortion and porous, inadequate joints result.[12] Alternatively, excessive gap spaces cause undersized mesiodistal partial FDP widths because of solder solidification shrinkage. However, Ryge[12] showed that the gap space closes somewhat during heating, and so it is doubtful that the alloy and investment truly expand equally or at the same rates. Several commercial soldering investments are available; these should be used whenever possible. A list of reliable investments appears in Appendix A.

Joining Base Metals

Titanium and Titanium Alloys

The advent of titanium and its alloys, as with cobalt-chromium-nickel, has brought a new challenge to joining cast units. Titanium also responds to high heat with an increased oxide formation, which results in a poor union between components to be joined. A reasonable solution has proved to be welding, by either laser or plasma. Advantages include less heat distortion and a compositionally uniform joint. Joining with the same chemical element or elements thus minimizes detrimental galvanic degradation. Much work yet remains to render titanium a suitable replacement for noble casting alloys.

• • •

SELECTION OF SOLDERING TECHNIQUE

When partial FDPs are assembled by soldering, the relative position of the components is recorded with a soldering index (Fig. 27-13) on the definitive cast or intraorally (Fig. 27-14). If pontics are made individually, they can be difficult to position properly in relation to the abutment teeth. Although a positioning index made previously upon completion of the wax pattern can be helpful (Fig. 27-15), the pontics should be connected to one of the retainers with a cast connector because this stabilizes them and makes accurate positioning in relation to the other retainer much easier. To understand the selection of soldering technique, a thorough knowledge of the fusing ranges of all materials involved in the FDP is essential (Fig. 27-16).

Soldering of all-metal FDPs consisting of type III or IV gold units requires the use of a low-fusing solder. The procedure is referred to as *conventional soldering*. Through the use of the same low-fusing solder, regular gold retainers can also be connected with metal-ceramic components. A gas-air torch is used for either of these procedures.

For FDPs consisting of metal-ceramic units, the soldered connectors may be made either before the ceramic application with high-fusing solder (≈1100°C [2012°F]) or after the ceramic application with lower-fusing solder (750°C [1382°F]). Soldering before ceramic application is called *pre–ceramic application soldering* or *presoldering*. Soldering of metal-ceramic crowns after their completion is referred to as *postsoldering*. Many alloys can be combined by means of either presoldering or postsoldering. However, presoldering has been found to be less

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FIGURE 27-14 ■ Indexing a metal-ceramic fixed dental prosthesis before soldering. **A,** Incomplete abutment seating was detected during the clinical evaluation of this maxillary three-unit prosthesis. **B,** Sectioning with a thin separating disk. **C,** Adjusting the connector area to optimum gap distance. **D,** Surfaces to be soldered should be clean and free of debris. **E,** The restoration is indexed intraorally with autopolymerizing resin.

reliable,[10] with a number of apparently sound connectors exhibiting negligible tensile strength. Considerable variation in solder joint strength has also been recorded after laboratory testing,[21] which emphasizes the special care needed to avoid defective connectors.

Base metal alloys can be difficult to solder because they oxidize; oxidation must be controlled with special fluxes, although excessive fluxing can lead to undesirable inclusions and weak connectors. In one study,[22] investigators found that 20% of postsoldered joints involving base metal alloys had to be resoldered because they were so weak that they broke with finger pressure. In another study, Anusavice and colleagues[23] demonstrated great variability in solder joint quality with these alloys, with no consistent relationship of strength to gap width. These authors found that most failures occurred through the solder and were attributable to voids caused by gas entrapment or localized shrinkage. With experience and careful adherence to the manufacturer's recommended techniques and materials, soldered connectors made of base metal alloy can be reliable.[24] However, because of the problems of soldering base metal alloys, various alternative procedures have been advocated. These include making the soldered joint through the center of the pontic to increase the area soldered[25] and connecting the parts by a second casting procedure, with the molten metal flowing into undercuts in the sectioned pontic.[26]

Soldering All-Metal Partial Fixed Dental Prostheses

Type III and type IV gold retainers of partial FDPs are soldered with gold solder with fineness ranging from 615 to 650. An occlusal plaster index or autopolymerizing resin index is fabricated intraorally or in the dental laboratory; after investment, a gas-air torch can be used to solder the components. A disadvantage of the soldering procedure is that it requires an additional step, in comparison with a one-piece casting. However, soldering simplifies the manipulation of wax patterns. For instance, when a three-abutment FDP with two splinted abutments (e.g., two premolars) is fabricated, access to the interproximal margins of the two splinted abutments is often very difficult during the reflowing and finishing steps. Soldering such retainers enables the dentist to shape and adjust the retainers individually, with improved access for finishing procedures. Conventional soldering requires a gas-air torch; soldering can also be performed in a furnace.

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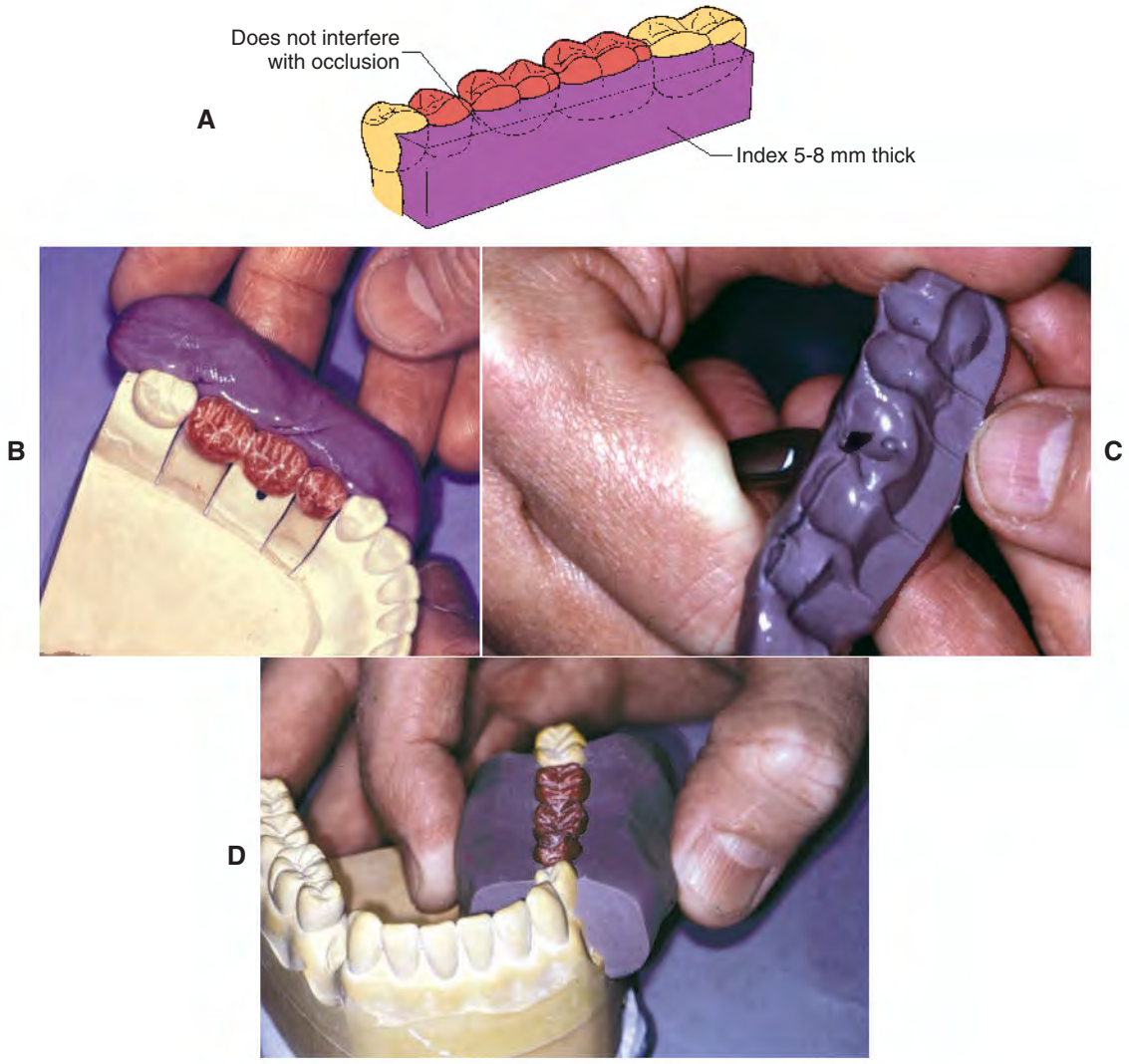

FIGURE 27-15 ■ Once the fixed dental prosthesis has been waxed to anatomic contour, a silicone putty buccal index **(A)** can be made. This can be helpful for relating the castings. **B,** Putty is applied to the buccal surface of the completed waxing. **C,** Excess is trimmed away with a scalpel blade. **D,** The flat surface makes verification of accurate reseating of the index much easier.

Soldering Metal-Ceramic Partial Fixed Dental Prostheses

Presoldering

Once a metal-ceramic framework has been assembled by presoldering, the subsequent procedures are the same as if it had been cast in one piece. This has the advantage of allowing the connected prosthesis to be tried in the mouth in the unglazed state. Any necessary adjustments can be made to the porcelain, which fuses at a lower temperature than does the presoldered connector. However, with presoldering, contouring the proximal embrasures so that the units resemble natural teeth may be more difficult. A very thin diamond disk is helpful in such contouring.

A disadvantage results from having to apply the porcelain to a longer structure, which needs support during firing to prevent high-temperature deformation or sag. Sag can be a particular problem with the high–gold content ceramic alloys because they have a lower melting range. High–palladium content or base metal alloys exhibit little sag during firing. Presoldering requires a gas-oxygen torch.

Postsoldering

Postsoldering is necessary when regular gold and metal-ceramic units are being combined in a partial FDP. The regular gold melts if it is subjected to the high temperatures needed for porcelain application; therefore, all porcelain adjustment and firing, including that for the final characterization and glazing, must be completed before the soldering. If further corrective adjustment is needed after soldering, the porcelain must be polished, or the joint must be separated, after which additional porcelain can be added as needed, the restorations can be reglazed, a new index can be made, and the FDP can be resoldered.

Because the proximal areas are shaped before soldering, a postsoldered connector can often be made to look more

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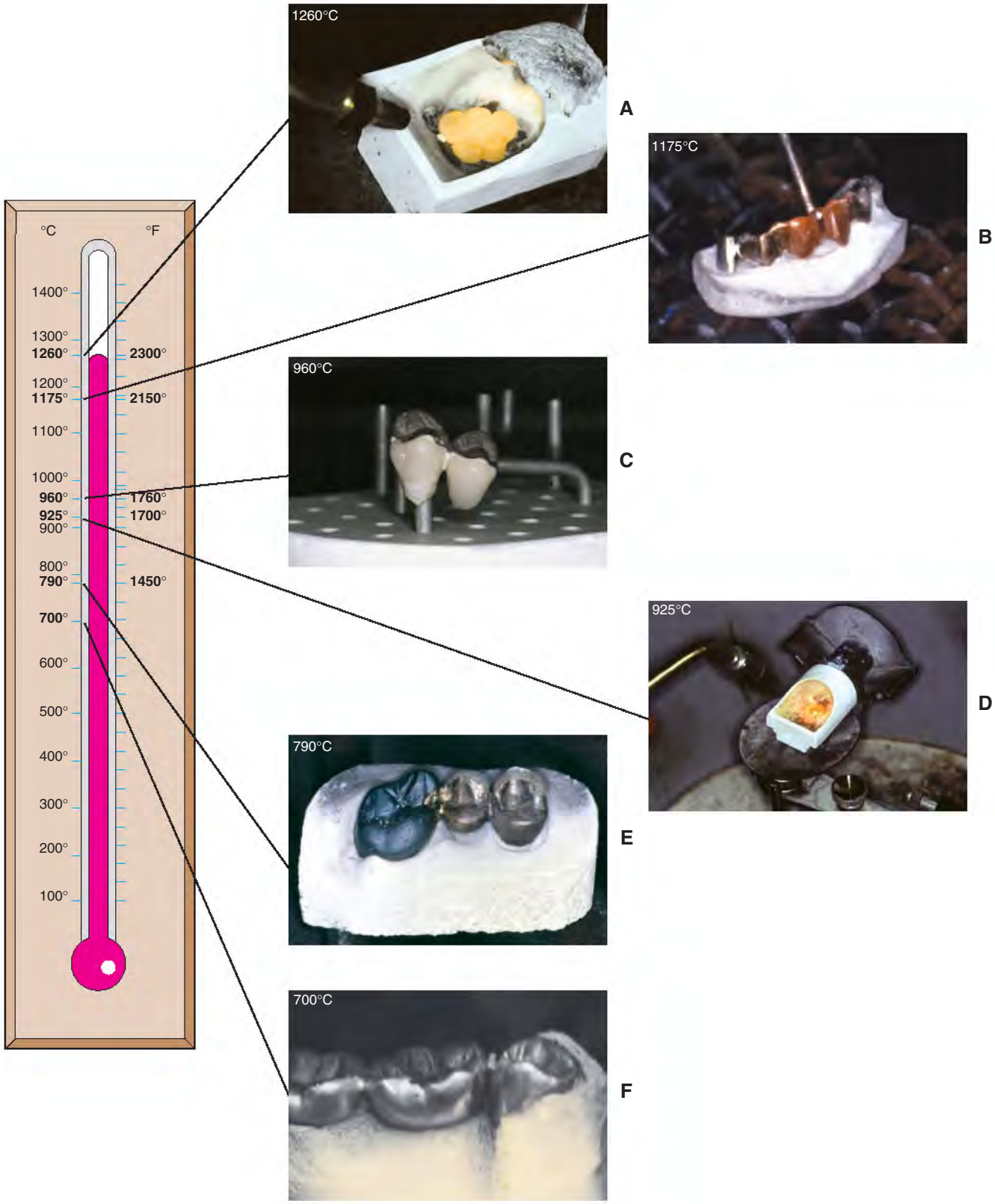

FIGURE 27-16 ■ **A,** Casting metal-ceramic alloys. **B,** Presoldering. **C,** Porcelain firing. **D,** Casting type III and type IV gold alloys. **E,** Postceramic soldering. **F,** Conventional soldering.

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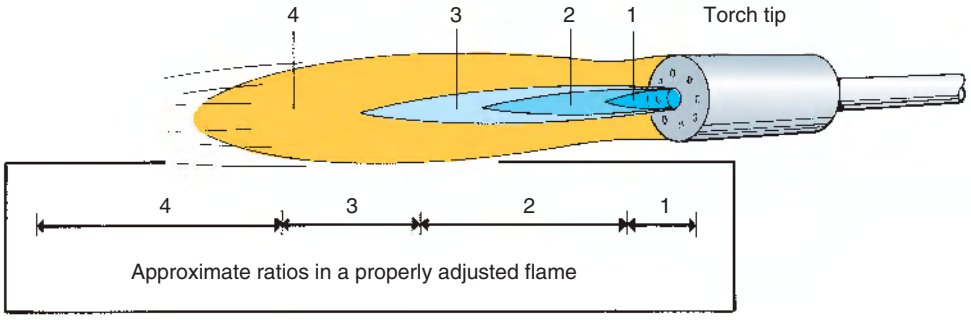
FIGURE 27-17 ■ Postceramic soldering of an anterior fixed dental prosthesis (FDP). **A,** The prosthesis has been assembled with a plaster index. **B,** After heating in a porcelain furnace, the solder is applied from the lingual. Complete flow of the solder into the connector area. **C,** Accuracy of the soldering procedure is verified by reseating the FDP into the index. **D,** Completed restoration with highly polished connectors. **E** and **F,** The assembled FDP. The connector is designed to be invisible from the facial view.



Zones:
1. Mixing zone
2. Combustion zone
3. Reducing zone
4. Oxidizing zone

FIGURE 27-18 ■ Illustration of gas-air torch adjusted for soldering.

natural than a presoldered or cast connector (Fig. 27-17). In addition, customized firing supports are not needed because sag is not a problem (the lengths of the individual components are shorter). Postsoldering is performed either in a porcelain furnace or with a gas-air torch.

HEAT SOURCES

Torch Soldering

When a gas-air torch is used as the heat source to melt the solder, metal-ceramic restorations are preheated in an oven to minimize the risk of cracking of the porcelain veneer. To prevent oxidization of the joint surfaces, the reducing (non-oxidizing) portion of the flame is used (Fig. 27-18) and an appropriate flux is applied (some soldering fluxes are unsuitable because they discolor the porcelain). To prevent uneven heat distribution, which could result in fracture, the flame is never concentrated in one area but is kept in constant motion.

Some dental technicians believe that the flow of solder is more controllable during torch soldering than during oven soldering because a slight temperature differential can be created and the solder always flows toward the hotter point. This makes torch soldering useful when the connector has not been well designed in wax, and a minor temperature difference can deliberately be created in the assembly to help direct the flow of the molten solder to ensure adequacy of the connector.

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FIGURE 27-19 ■ Oven soldering a three-unit fixed dental prosthesis. **A,** Prosthesis invested. **B,** Furnace temperature raised to the solder's melting range. **C** and **D,** Oven-soldered prosthesis.

Oven Soldering

Furnace or oven soldering is performed under vacuum pressure or in air. A piece of solder is placed at the joint space, and the casting and solder are heated simultaneously.

Criticism of this technique has been based on earlier observations[27] that less porosity resulted when castings were brought to soldering temperature before the solder was applied. The method does not allow the moment of solder fusion to be observed. (Some porcelain furnaces have an observation window for postsoldering.) This may be important because the longer the solder remains molten, the more it dissolves the parent metal and consequently weakens the joint.[11] Nevertheless, joints with strength similar or superior to that of the parent metal have been demonstrated[10] when oven soldering was used.

A different technique may be appropriate if the porcelain furnace has a horizontal muffle with a fixed floor. The soldering assembly is heated above the fusion point of the solder, the muffle door is opened, and the solder is fed into the joint space (Fig. 27-19).

Microwave Soldering

Microwave heating has been used for dental soldering on an experimental basis.[28,29] The process has the advantage of using less energy than conventional oven soldering, and joint strength has been found to be comparable with that produced by traditional methods.[28,29]

Laser Welding

Laser energy is extensively used for welding (Fig. 27-20) in many industries and has been described in dentistry since the 1970s.[30,31] Laser assembly of FDPs has been reported to have higher strength[32] and reduced corrosion[33] in comparison with conventional soldering, although laser-welded connectors seem as susceptible to fatigue failure[34] and may be less suitable for joining noble-metal alloys than for base-metal alloys.[28] Laser welding is a practical way to join cast or milled titanium or cobalt-chromium components (i.e., if these are to be used for implant-supported prosthesis frameworks[35-38]).

FIGURE 27-20 ■ Laser welding. Individual titanium components are carefully aligned in the laser welding unit. The joining procedure is monitored with high-magnification video. (Courtesy Crafford-LaserStar Technologies, Riverside, Rhode Island.)

SOLDERING ACCURACY

Controversy exists as to the relative accuracy of partial FDPs that are cast in one piece, presoldered, or postsoldered. Individual laboratory technicians often obtain

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consistently better results with one particular technique, but scientific evidence is conflicting.[39-42] In evaluating clinical work to determine whether cast or soldered connectors provide better results, the determining factor should be the fit of the individual retainers. This should be optimized through the investing and casting process (see Chapter 22) to minimize the risks of incomplete seating or excessive luting agent space. In some situations, it may be impossible to cast a long-span FDP with ideal retainer dimensions and ideal interabutment dimensions; the challenge lies in obtaining enough interabutment expansion without making the retainers too loose. In such circumstances, a soldered connector may provide better accuracy. The situation is reversed for fabricating frameworks for implant-supported prostheses (see Chapter 13): The fit of the individual units is determined by the implant manufacturer. Only the overall abutment-to-abutment fit is under the control of the technician. However, an accurate, passively fitting implant-supported framework is crucial for avoiding damaging forces. It is not yet clear whether accurate implant-supported frameworks are most effectively made with one-piece castings or as sectioned and soldered or laser-welded units.[41-43]

SOLDERING TECHNIQUE

Armamentarium

- Autopolymerizing acrylic resin
- Zinc oxide–eugenol (ZOE) paste
- Impression plaster
- Mixing bowl
- Spatula
- Small brush
- Waxing instrument
- Sticky wax
- Baseplate wax
- Sprue wax
- Soldering investment
- Glass slab
- Soldering tripod
- Flux
- Solder
- Tongs
- Pickling solution

Step-by-Step Procedure

Occlusal Soldering Index

Intraoral plaster or ZOE is used to make an impression of the occlusal surfaces of the partial FDP to capture the relative relationship of the individual FDP components and transfer this to the laboratory. This procedure can also be performed in the laboratory if the technician is satisfied that the individual components are seated completely on an accurate definitive cast. An advantage of an occlusal index (Fig. 27-21; see also Fig. 27-3) is that after the soldering procedure has been completed, the FDP can be reseated in the index, and soldering accuracy can be verified (sometimes a small amount of plaster must be removed in the area where the solder has been added, to ensure seating).

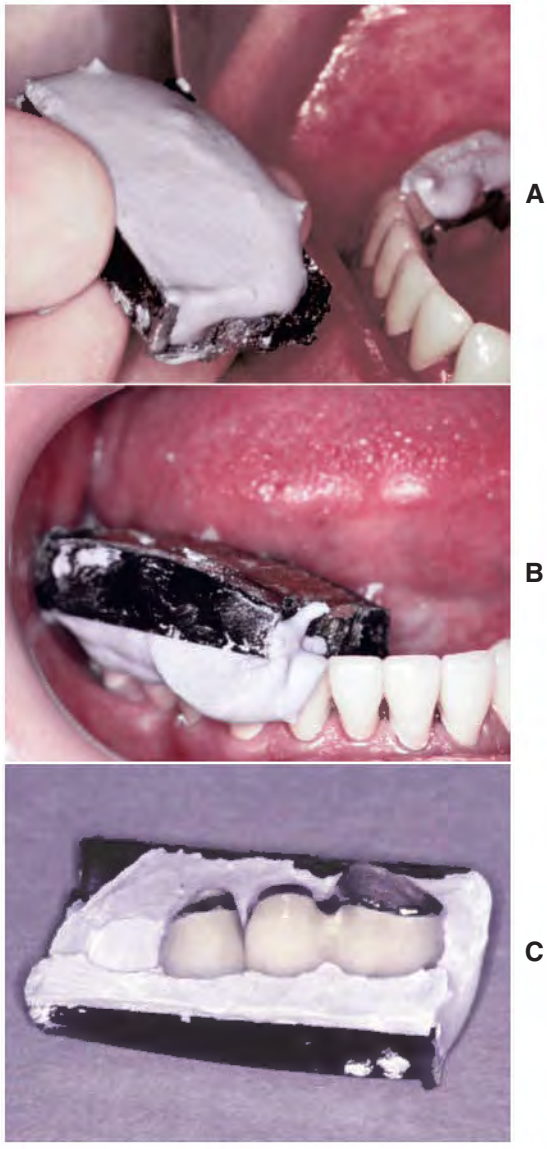

FIGURE 27-21 ■ Soldering index (plaster) for posterior fixed dental prostheses. **A,** A suitable carrier (e.g., baseplate wax) is trimmed to proper shape before a registration is made with impression plaster **(B). C,** The plaster occlusal registration.

1. Grind the connector surfaces of the finished castings with a stone or disk to remove surface oxides. Then fully seat the castings on the definitive cast or in the patient's mouth. Postsoldering connectors are best indexed intraorally after the contour and appearance have been perfected. If necessary, the soldering gap can be adjusted at this time (gap distance, 0.25 mm). The castings can be seated intraorally with a small quantity of low-viscosity impression material to ensure that they are not disturbed during the indexing.[44]
2. Make an impression plaster registration in a small tray or on a sheet of baseplate wax for the occlusal index. As an alternative, an index can be made with ZOE paste, a technique that has yielded[45]

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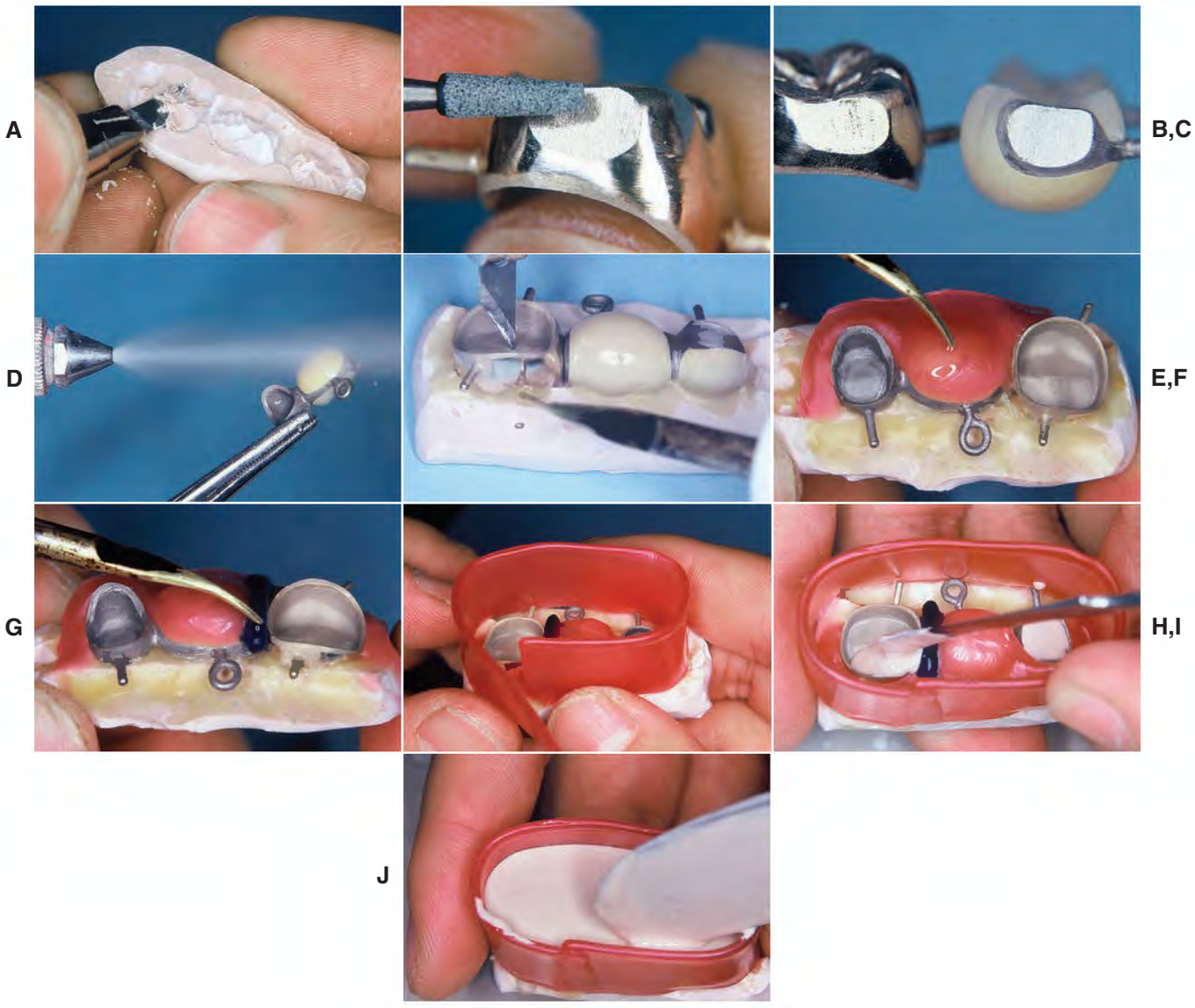

FIGURE 27-22 ■ Investing procedure (occlusal index). **A,** The index is trimmed to ensure complete seating of the castings. **B** and **C,** The connector area is ground with a noncontaminating stone. **D,** The restorations are steam cleaned. (Alternatively, they can be cleaned ultrasonically.) **E,** The castings are seated firmly and luted into place with sticky wax. **F,** Because glazed porcelain is damaged by contact with the investment, the porcelain is protected with a layer of wax. **G,** The wax flows into the connector areas and is adapted below each connector to create an airway. **H,** The soldering assembly is boxed. **I** and **J,** When the assembly is filled with soldering investment, great care is taken to ensure that there are no air bubbles in the investment.

consistent and accurate recordings. The index should not cover the margins of regular gold retainers because these are to be embedded in the investment to prevent their accidental melting during soldering.

3. Trim the index to fully expose the margins before investing (Fig. 27-22).

Investing

4. Seat each casting into the index, and lute it into place with sticky wax.
5. Have wax flow into the connector area to prevent the investment from entering.
6. To create a space that will help the solder spread, adapt sprue wax gingival to the solder joint. Burying the units completely in the investment makes soldering difficult because the unnecessary bulk of the investment prevents rapid heating of the castings.
7. Protect any glazed porcelain from contacting the investment by coating it with wax before investing. To protect regular gold margins from the soldering flame, they should be embedded in the investment; otherwise, they may become overheated and melt. For the same reason, all margins should be embedded in the investment before presoldering.
8. Box the assembly with suitable sheet wax.
9. Mix the investment carefully, and have it flow into the castings without trapping any air. Use only

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slight vibration so that the castings are not displaced from the index.

10. Allow the invested block to bench set before removing the wax and preheating.

Autopolymerizing Resin Soldering Index

A plaster or ZOE occlusal index is less suitable for the registration of anterior restorations. Because of the thinness of their incisal edges, these units are less stable, and accurate repositioning is more difficult. For this reason, autopolymerizing resin (Fig. 27-23) is recommended, although the resin burns off during the procedure. Therefore, the accuracy of the soldering procedure can be verified only intraorally.

1. Join the completed units together with autopolymerizing resin. The resin will later burn out, leaving no residue that could interfere with the casting.
2. Apply the resin with a bead technique. This minimizes the distortion from polymerization shrinkage. Excessive bulk of resin reduces the accuracy of the technique,[46] but sufficient material must be present to ensure that the components do not break (because they cannot then be accurately reseated in the index). The resin should extend onto the incisal edges of the retainers.
3. When the resin has fully hardened, carefully loosen the prosthesis from the abutments. Then replace it and check whether distortion has occurred. This is done in the same way as the evaluation of a finished FDP. It must be stable with no marginal discrepancies (see Fig. 27-23, *C*). The prosthesis should be invested without delay; otherwise, the resin index will become distorted.[47]

Investing. This process is illustrated in Figure 27-24.

4. Warm a sheet of wax, and push the cervical margins of the restorations through it. Then seal it along the axial wall with a warmed instrument. This protects the porcelain from contact with the soldering investment.
5. Fill the castings with soldering investment, and blot excess water from the remaining investment, forming it into a patty on a slab or tile.
6. Seat the restorations on the patty. When a joint is to be oven-soldered, the restoration should be angled forward so that the solder can be placed above the joint before the block is set inside the furnace.

FIGURE 27-23 ■ Soldering index (autopolymerizing resin). **A,** Armamentarium. **B,** A small brush dipped in resin monomer is touched to the polymer powder. This forms a bead. **C,** The restorations are thus connected, with resin extending onto the incisal edges of all the retainers.

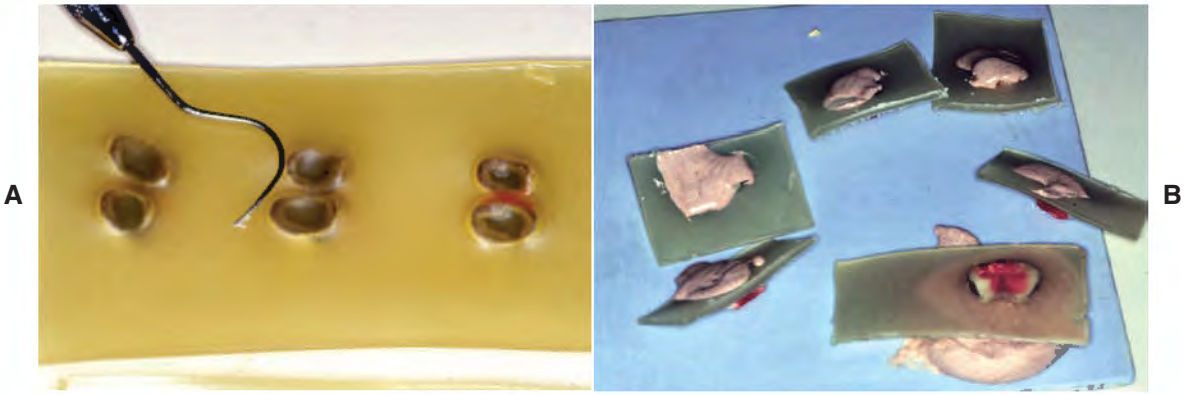

FIGURE 27-24 ■ Investing procedure (autopolymerizing resin). **A,** The castings are pressed firmly into a sheet of softened wax. Note that the internal walls of the castings are exposed; the wax seals them. **B,** Castings are filled with soldering investment and then inverted onto a patty of investment.

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Wax Removal and Preheating

This process is illustrated in Figure 27-25.

1. If a plaster or ZOE index was used, remove it after the investment has fully set. This separation is most effectively accomplished after the wax is removed with boiling water. The joint space must be free of investment. Flowing of a little flux into the joint space while the soldering block is still warm from wax removal is recommended. This prevents small particles from inadvertently falling into the gap. Be aware that many special soldering investments have low strength, and the assembly is easily broken at this stage.
2. Preheat the investment in a burnout furnace to 650°C (1202°F) for low-heat soldering or 850°C (1562°F) for presoldering. Acrylic resin indexes are removed by heating slowly to 300°C (572°F), at which time most of the resin will have burned away.
3. Heat the block to 650°C (1202°F) until all traces of wax and resin have vaporized, and then transfer it to the soldering stand or porcelain furnace.

Torch Soldering (Low Heat)

This process is illustrated in Figure 27-26.

1. Transfer the assembly to a soldering stand over a Bunsen burner, and place a piece of solder above the gap. Adjust the gas-air torch to produce a sharp blue cone (as for casting), and then reduce the air for a softer or less pointed "brush" flame. The reducing zone of the flame is used to heat the investment

FIGURE 27-25 ■ Wax removal and preheating. **A** and **B,** Boxing material is removed, and the wax residue is flushed out with boiling water or an organic solvent. **C,** The connector area must be free of contaminants. **D,** A small amount of soldering flux is applied while the assembly is still warm. **E,** The flux is carried into the connector area by capillary action. Then the assembly is placed in the burnout furnace. **F** and **G,** Autopolymerizing resin indexes. These are burned off directly in the furnace after wax elimination. **H,** The soldered restorations.

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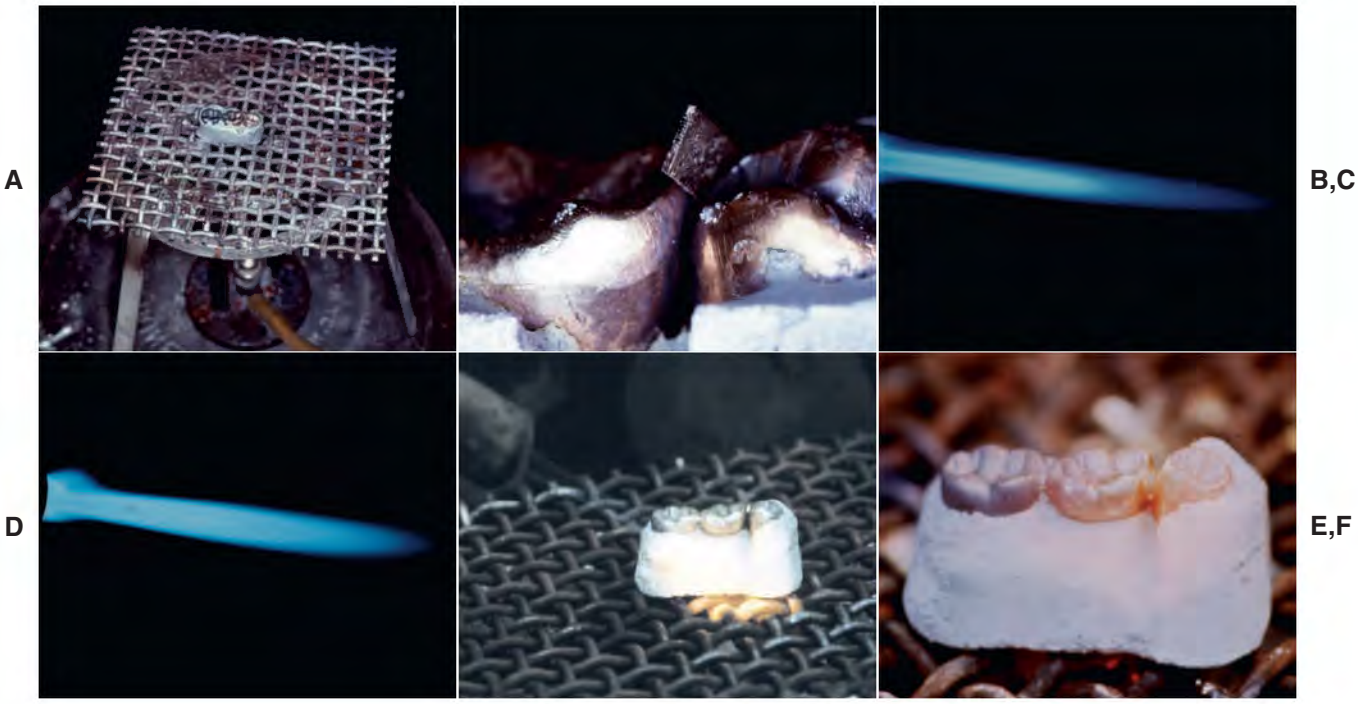

FIGURE 27-26 ■ Low-heat torch soldering. **A,** The assembly positioned on a wire mesh over a Bunsen burner. **B,** A flexed piece of solder is placed into the connector area. **C,** A sharply defined flame is preferable for casting procedures. **D,** A brush flame is more suitable for soldering. This can be obtained by slight reduction in the amount of air. **E,** The assembly is heated evenly until the solder melts. The solder must "spin" in the connector area to form a complete connection **(F).**

block. The flame is directed at the lingual surface of the block rather than at the casting.

2. Heat evenly and slowly, moving the tip of the flame constantly. This is particularly important in post-soldering because the porcelain may easily crack. When the metal glows brightly, the solder melts and flows into the joint space.
3. Quickly move the flame to the facial. When the solder "spins" in the joint, remove the flame.
4. Extinguish the flame, and let the soldered prosthesis cool for 4 or 5 minutes before quenching (unless there is porcelain on the restoration, in which case it should cool to room temperature). Earlier quenching may lead to distortion, whereas prolonged bench cooling increases the brittleness of the joint.

Torch Soldering (High Heat)

This process is illustrated in Figure 27-27.

1. Wear dark glasses for eye protection (Fig. 27-28). Gas-oxygen torches for high-heat presoldering have a miniature needle tip so that the flame can be pinpointed on the joint space.
2. Place the solder above the gap, and concentrate the reducing zone of the flame on the joint space.
3. When the solder melts, draw it into the joint and quickly "chase" it around with the flame (Fig. 27-29). The presolder may have a melting point close to that of the parent metal, and there is danger of melting a thin framework unless the flame is concentrated on the joint space (see Fig. 27-10).

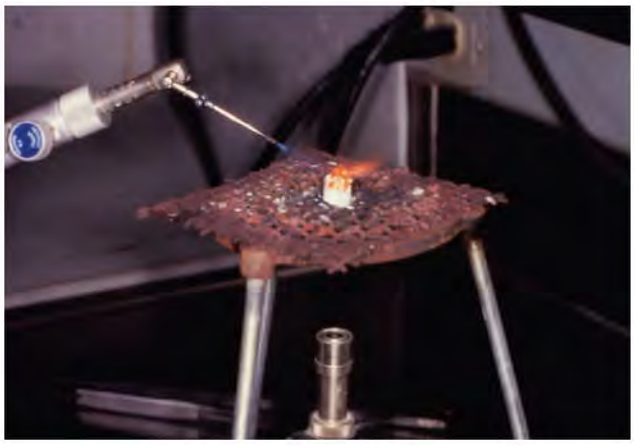

FIGURE 27-27 ■ High-heat (before ceramic application) torch soldering with a gas-oxygen torch and a miniature needle tip.

FIGURE 27-28 ■ Eye protection is essential for high-heat soldering and casting of high-fusing alloys.

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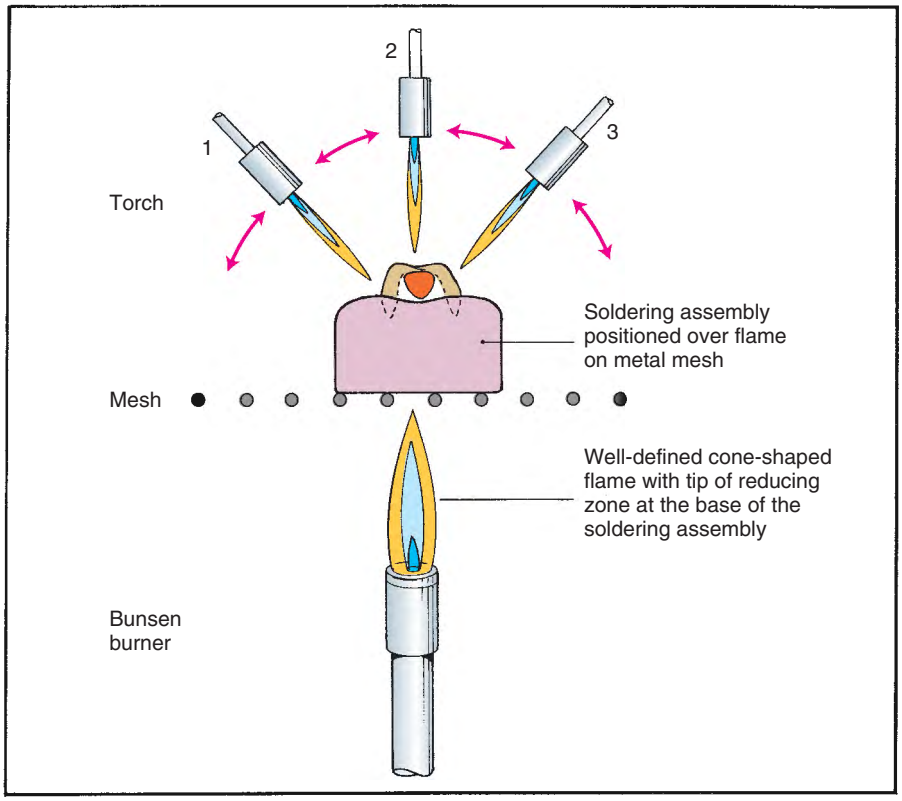

FIGURE 27-29 ■ The flame is directed at the connector immediately when the solder melts and is moved around from position *1* to positions *2* and *3*. This ensures that a complete meniscus is formed.

Oven Soldering

This process is illustrated in Figure 27-30.

1. Prepare a piece of solder by dipping it in liquid flux and melting it in a Bunsen flame to form a ball. The size of the ball is determined by the connector size and the joint gap.
2. Leave a short tail attached to the ball to help position it above the joint space. As an alternative, the solder can be fed into the joint area as shown in Figure 27-19.
3. Put the assembly in the furnace, and increase the temperature to melt the solder. A vacuum is not needed for oven soldering of noble-metal alloys. Air firing is preferred by some technicians because in a vacuum, there is always the chance of drawing entrapped gases to the surface of glazed porcelain, causing localized swelling or bloating.

Evaluation

If the solder fails to flow during torch soldering but forms a ball above the joint area, heating should be discontinued. The solder has oxidized, and further heating will melt the castings. If the solder has flowed properly, the completed joint can be evaluated for size before removal of the investment and, if necessary, reheated while still hot, with additional solder added. Excessive solder must be ground away during the finishing procedure.

If the connector has been designed properly and the solder has been properly positioned, no solder should run onto the occlusal surface or cover the margins. To prevent stray flow, a small amount of antiflux (rouge dissolved in turpentine) can be painted on critical areas before the assembly is heated. After bench cooling for about 5 minutes, the assembly is quenched (postsoldered metal-ceramic prostheses are always allowed to cool to room temperature), and the investment is broken away (Fig. 27-31). The connector is then carefully inspected. If signs of an incomplete joint are evident (i.e., visible porosity in the solder), they are removed by grinding with a fine disk; the units are then reinvested and resoldered.

The joints must be tested for strength (Fig. 27-32). Any connector that can be broken by force of hand will not serve adequately in the mouth. Because broken connectors cannot be easily repaired intraorally once the prosthesis has been cemented, the entire restoration usually must be remade.

REVIEW OF TECHNIQUE

Figure 27-33 summarizes the steps involved in partial FDP connector fabrication and should be referred to when the material is reviewed.

1. The design of connectors is determined in the wax pattern (see Fig. 27-33, *A*).

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FIGURE 27-30 ■ Oven soldering procedure. **A,** The invested partial fixed dental prosthesis (FDP) before soldering. **B,** A small amount of flux is added to the clean joint area. **C** and **D,** Solder is added, and the assembly placed in the oven. **E,** The soldered FDP. **F,** The soldering index is used to assess soldering accuracy. **G,** Oven-soldered connector before finishing.

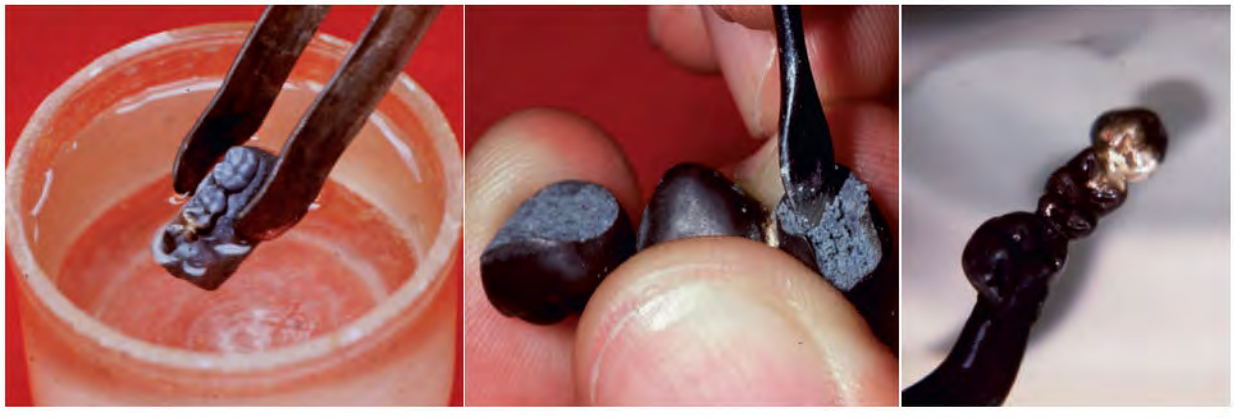

FIGURE 27-31 ■ **A,** After bench cooling for approximately 5 minutes, the assembly is quenched. **B,** The investment is removed from the castings. **C,** Surface oxides are dissolved in a pickling solution.

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2. All soldered connections require clean parallel surfaces. Gap width should be 0.25 mm (see Fig. 27-33, *B*).
3. The units are indexed either from the definitive cast or in the patient's mouth (see Fig. 27-33, *C*).
4. Wax is added to the indexed restorations to shape the soldering assembly. For metal-ceramic restorations, it is added to protect the porcelain (see Fig. 27-33, *D*).
5. The units are invested, and the investment is allowed to bench set (see Fig. 27-33, *E*).
6. If a plaster or ZOE index is used, wax is eliminated with boiling water or an organic solvent, the joint is fluxed, and the assembly is preheated in a burnout furnace (see Fig. 27-33, *F*).
7. If a resin index has been used, it is placed directly in the burnout furnace (see Fig. 27-33, *G*).
8. The connectors are soldered with a torch or in a porcelain furnace (see Fig. 27-33, *H*).

FIGURE 27-32 ■ Solder joints should always be tested for strength.

SUMMARY

Connectors join individual retainers and pontics. Rigid or nonrigid connectors can be used. Connector size, shape, and position influence the success of a partial FDP. The use of soldered connectors can simplify the fabrication of larger FDPs, which may be cast separately in groups of one or two units and assembled after their individual fit has been verified. The technical procedures involved in soldering are not difficult. If the joint surfaces have been correctly designed and soldering gap width has

FIGURE 27-33 ■ Technique review. **A,** The design of connectors is determined in the wax pattern. **B,** All soldered connections require clean parallel surfaces. Gap width should be 0.25 mm. **C,** The units are indexed either from the definitive cast or in the patient's mouth. **D,** Wax is added to the indexed restorations to shape the soldering assembly. For metal-ceramic restorations, it is added to protect the porcelain. **E,** The units are invested, and the investment is allowed to bench set. **F,** If a plaster or zinc oxide–eugenol index is used, wax is eliminated with boiling water or an organic solvent, the joint is fluxed, and the assembly is preheated in a burnout furnace. **G,** If a resin index has been used, it is placed directly in the burnout furnace. **H,** The connectors are soldered with a torch or in a porcelain furnace.

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been carefully controlled, the procedures are routine. All debris must be removed from the connector area because it interferes with surface wetting.

Conventional soldering involves the assembly of type II, III, or IV gold castings. Presoldering is the assembly of metal ceramic substructures before porcelain application. Postsoldering is the assembly of metal ceramic units after porcelain application. Heat sources used for soldering procedures include gas-air torches, gas-oxygen torches, furnaces, and laser units.

If the basic principles are understood and the technique has been mastered, these procedures are entirely reliable.

REFERENCES

1. Walton TR: An up to 15-year longitudinal study of 515 metal-ceramic FPDs: part 2. Modes of failure and influence of various clinical characteristics. Int J Prosthodont 16:177, 2003.
2. Stapleton BM, et al: Application of digital diagnostic impression, virtual planning, and computer-guided implant surgery for a CAD/CAM-fabricated, implant-supported fixed dental prosthesis: a clinical report. J Prosthet Dent 112:402, 2014.
3. Anusavice KJ: Phillips' science of dental materials, 11th ed, p 608. Philadelphia, WB Saunders, 2003.
4. British Standard Institute: British Standard glossary of dental terms. London, British Standard Institute, 1983.
5. Goodkind RJ, Heringlake CB: Mandibular flexure in opening and closing movements. J Prosthet Dent 30:134, 1973.
6. Al-Sukhun J, et al: Biomechanics of the mandible part I: measurement of mandibular functional deformation using custom-fabricated displacement transducers. J Oral Maxillofac Surg 64:1015, 2006
7. Fischman BM: The influence of fixed splints on mandibular flexure. J Prosthet Dent 35:643, 1976.
8. Law C, et al: Influence of implant framework and mandibular flexure on the strain distribution on a Kennedy class II mandible restored with a long-span implant fixed restoration: a pilot study. J Prosthet Dent 112:31, 2014.
9. Steinman RR: Warpage produced by soldering with dental solders and gold alloys. J Prosthet Dent 4:384, 1954.
10. Willis LM, Nicholls JI: Distortion in dental soldering as affected by gap distance. J Prosthet Dent 43:272, 1980.
11. Stade EH, et al: Preceramic and postceramic solder joints. J Prosthet Dent 34:527, 1975.
12. Ryge G: Dental soldering procedures. Dent Clin North Am 2:747, 1958.
13. Rasmussen EJ, et al: An investigation of tensile strength of dental solder joints. J Prosthet Dent 41:418, 1979.
14. Craig RG, Powers J: Restorative dental materials, 11th ed. St. Louis, Mosby, 2002.
15. Tucillo JJ: Compositional and functional characteristics of precious metal alloys for dental restorations. In Valega TM, ed: Alternatives to gold alloys in dentistry [U.S. DHEW Publication No. (NIH) 77-1227], p 40. Washington, D.C., U.S. Deptartment of Health, Education, and Welfare, Public Health Service, National Institutes of Health, 1977.
16. El-Ebrashi MK, et al: Electron microscopy of gold soldered joints. J Dent Res 47:5, 1968.
17. Leinfelder KF, et al: Hardening of dental gold-copper alloys. Dent Res 51:900, 1972.
18. Chaves M, et al: Effects of three soldering techniques on the strength of high-palladium alloy solder. J Prosthet Dent 79:677, 1998.
19. Phillips RW: Skinner's science of dental materials, 8th ed. Philadelphia, WB Saunders, 1982.
20. Sloan RM, et al: Postceramic soldering of various alloys. J Prosthet Dent 48:686, 1982.
21. Beck DA, et al: A quantitative study of preporcelain soldered connector strength with palladium-based porcelain bonding alloys. J Prosthet Dent 56:301, 1986.
22. Staffanou RS, et al: Strength properties of soldered joints from various ceramic-metal combinations. J Prosthet Dent 43:31, 1980.
23. Anusavice KJ, et al: Flexure test evaluation of presoldered base metal alloys. J Prosthet Dent 54:507, 1985.
24. Sobieralski JA, et al: Torch versus oven preceramic soldering of a nickel-chromium alloy. Quintessence Int 21:753, 1990.
25. Ferencz JL: Tensile strength analysis of midpontic soldering. J Prosthet Dent 57:696, 1987.
26. Fehling AW, et al: Cast connectors: an alternative to soldering base metal alloys. J Prosthet Dent 55:195, 1986.
27. Saxton PL: Post-soldering of nonprecious alloys. J Prosthet Dent 43:592, 1980.
28. Ghadhanfari HA, et al: Effects of soldering methods on tensile strength of a gold-palladium metal ceramic alloy. J Prosthet Dent 112:994, 2014.
29. Kim H, et al: Strength properties of preceramic brazed joints of a gold-palladium alloy with a microwave-assisted oven and gas/oxygen torch technique. J Prosthet Dent 112:606, 2014.
30. Gordon TE, Smith DL: Laser welding of prostheses—an initial report. J Prosthet Dent 24:472, 1970.
31. Preston JD, Reisbick MH: Laser fusion of selected dental casting alloys. J Dent Res 54:232, 1975.
32. Kasenbacher A, Dielert E: Tests on laser-welded or laser-soldered gold and Co/Cr/Mo dental alloys. Dtsch Zahnarztl Z 43:400, 1988.
33. Van Benthem H, Vahl J: Corrosion behavior of laser-welded dental alloys. Dtsch Zahnarztl Z 43:569, 1988.
34. Wiskott HW, et al: Mechanical and elemental characterization of solder joints and welds using a gold-palladium alloy. J Prosthet Dent 77:607, 1997.
35. Sjögren G, et al: Laser welding of titanium in dentistry. Acta Odontol Scand 46:247, 1988.
36. Ortorp A, et al: Clinical experiences with laser-welded titanium frameworks supported by implants in the edentulous mandible: a 5-year follow-up study. Int J Prosthodont 12:65, 1999.
37. Prasad S, Monaco EA Jr: Repairing an implant titanium milled framework using laser welding technology: a clinical report. J Prosthet Dent 101:221, 2009.
38. Barbi FC, et al: Comparative analysis of different joining techniques to improve the passive fit of cobalt-chromium superstructures. J Prosthet Dent 108:377, 2012.
39. Gegauff AG, Rosenstiel SF: The seating of one-piece and soldered fixed partial dentures. J Prosthet Dent 62:292, 1989.
40. Sarfati E, Harter J-C: Comparative accuracy of fixed partial dentures made as one-piece castings or joined by solder. Int J Prosthodont 5:377, 1992.
41. Kwon JY, et al: Three-dimensional accuracy of different correction methods for cast implant bars. J Adv Prosthodont 6:39, 2014.
42. Abduo J, et al: Fit of screw-retained fixed implant frameworks fabricated by different methods: a systematic review. Int J Prosthodont 24:207, 2011.
43. Wee AG, et al: Strategies to achieve fit in implant prosthodontics: a review of the literature. Int J Prosthodont 12:167, 1999.
44. Lynch CD, McConnell RJ: Accurately locating the components of a fixed partial denture prior to soldering the connector: an intraoral technique. J Prosthet Dent 87:460, 2002.
45. Harper RJ, Nicholls JI: Distortions in indexing methods and investing media for soldering and remount procedures. J Prosthet Dent 42:172, 1979.
46. Moon PC, et al: Comparison of accuracy of soldering indices for fixed prostheses. J Prosthet Dent 40:35, 1978.
47. McDonnell T, et al: The effect of time lapse on the accuracy of two acrylic resins used to assemble an implant framework for soldering. J Prosthet Dent 91:538, 2004.

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STUDY QUESTIONS

1. Contrast soldering, brazing, and welding.

2. Discuss how biologic, mechanical, and esthetic considerations affect connector size and position for each of the following classes of teeth: incisors, premolars, and molars.

3. When and why would a nonrigid connector be used? A loop connector?

4. Discuss fineness and carat. What is their importance in dental soldering?

5. How do soldering investments differ from conventional casting investments? Why?

6. What is flux? Antiflux? How do they work? Give several examples of each.

7. What are the fundamental differences among conventional soldering, postsoldering, and presoldering? When contrasting the last two techniques, identify the advantages and limitations associated with their use.

8. Describe the step-by-step procedures for two techniques to make a soldering index for a partial fixed dental prosthesis. What are the respective advantages and limitations?

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CHAPTER 28

Finishing the Cast Restoration

A cast metal restoration is not ready for evaluation and cementation merely because it has been stripped of its investment. The unpolished surface is relatively rough, and a series of finishing procedures are needed to produce highly polished axial surfaces. Such surfaces limit the accumulation[1,2] and retention[3] of plaque and facilitate maintenance of health of the supporting periodontal tissues. The sprue needs to be removed, and the area of its attachment needs to be recontoured. Any nodules or other minor irregularities remaining on the cast surface must be eliminated.

Metal finishing for metal-ceramic restorations is similar to that for cast metal crowns. The discussion in this chapter is applicable to both restoration types. In practice, the final polishing of metal-ceramic restorations is not done until after characterization and glazing (see Chapter 29). Cast titanium restorations require special polishing techniques.[4]

OBJECTIVES AND PROCEDURES

The objectives and procedures for finishing are different for each part of the cast restoration. The following discussion is sequentially divided into corresponding phases; each is identified as a zone (Fig. 28-1).

Zone 1: Internal Margin

Objective

To minimize any dissolution of the luting agent, a 1-mm-wide band of metal must be closely adapted to the tooth surface.[5] A discrepancy within this zone can significantly reduce a restoration's longevity. Good adaptation is obtained by careful reflowing of the wax pattern (Fig. 28-2). With careful standardization of technique, the dental technician can achieve predictable and consistent results.

Procedure

If a defect occurs in the marginal area, the restoration must be remade. This may necessitate an additional patient visit to make the new impression. Defects can be prevented or minimized by paying particular attention to reflowing the margins of the wax pattern and through careful investing (see Chapter 22).

Even small nodules can prevent a casting from seating completely. Careful examination under ample magnification helps identify interferences. Small nodules, if far enough away from the margin itself, can be removed under a binocular microscope with exceptionally cautious use of small rotary instruments (e.g., a No. ½ round bur). However, great care is needed to avoid damage to the margin and costly remakes.

Zone 2: Internal Surface (Intaglio)

Objective

No contact should exist between the die and the internal surface (intaglio) of the casting. A uniform space of 25 to 35 μm is necessary for the luting agent to spread evenly. Any contacts must be identified and relieved by careful selective grinding of the internal surface.

Procedure

Under normal circumstances, a casting's internal surface does not require finishing. It should, however, be examined for nodules (Fig. 28-3) before the restoration is seated on the die. Nodules can be removed with a small round tungsten carbide bur, which can be time consuming because it may need to be repeated several times. If the internal surface needs to be adjusted more than occasionally, the investing procedure should be reexamined for flaws.

Even a very small nodule can result in significant increase of the marginal gap width (Fig. 28-4). A binocular microscope is especially helpful in identifying nodules. High-quality loupes can also be used. Great care should be exercised when a casting is seated on its die. Any significant force will abrade or chip the die, so that the casting will seat on the die but will not seat fully on the prepared tooth. Overlooking this at the cementation appointment will result in a restoration with open margins and a poor prognosis. If a casting does not seat, a nodule may have been overlooked and may have scratched the die, or a little stone may have been picked up in the process. Close examination of the internal surface of the casting or the axial walls of the die (Fig. 28-5) will reveal this. Corrective action is often relatively simple, and the casting may be acceptable. Care must be taken not to seat a faulty casting repeatedly, thereby abrading the die. After a die has been abraded by a casting, it should not be used for rewaxing a restoration. If rewaxing is necessary, a new impression is required.

When a nodule is removed from the internal aspect of a casting, deliberately removing a slightly greater amount of alloy in the area is recommended. Once the casting has been adjusted, determining the exact location of the nodule is no longer possible. Therefore, the nodule should be removed entirely in one step, rather than through sequential relief of the internal surface (Fig. 28-6).

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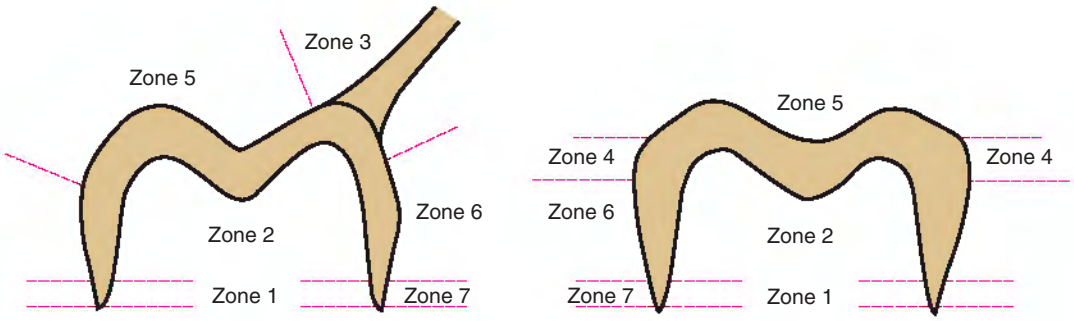

FIGURE 28-1 ■ Recommended sequence for finishing of a cast restoration. All procedures for a zone should be completed before the next zone is started. *Zone 1* is the internal margin; *Zone 2,* the internal surface; *Zone 3,* the sprue; *Zone 4,* the proximal contacts; *Zone 5,* the occlusal surface; *Zone 6,* the axial walls; and *Zone 7,* the external margins.

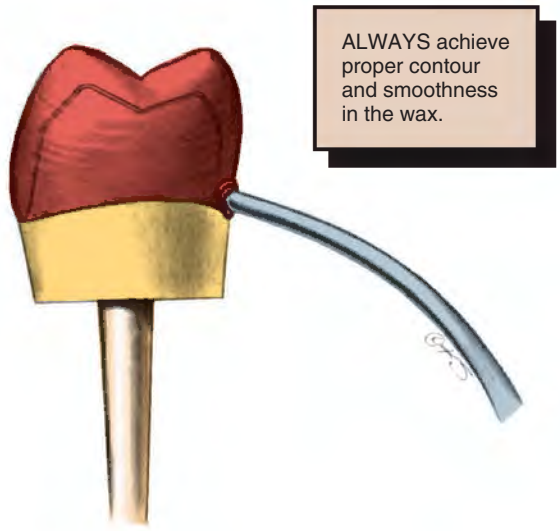

FIGURE 28-2 ■ Reflowing of the wax pattern. The objective is to create a well-adapted 1-mm zone to prevent cement dissolution. Proper reflowing before investing is essential.

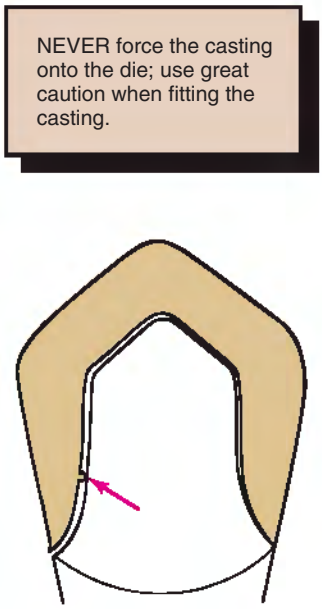

FIGURE 28-4 ■ A relatively small nodule *(arrow)* results in a substantial marginal gap width.

FIGURE 28-3 ■ Nodules on this casting have resulted from improper investing. To enable complete seating of the casting, even small ones such as these must be removed entirely.

FIGURE 28-5 ■ **A,** Internal surface of a casting. Note the stone *(arrow)* adhering where the die has been abraded by the casting. **B,** A suitable marking agent (e.g., rouge and turpentine) can be used to detect areas that must be relieved to allow complete seating.

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Indiscriminately removing material from the internal aspect of any casting is not an acceptable alternative. This results in excessive loss of retention and resistance form, and the restoration must be remade.

Marking Agents. Several agents are commercially available to facilitate identification of the seating interference between the casting and the die. These include water-soluble (e.g., Liqua-Mark, American Dental Supply, Inc.) and solvent-based dyes (e.g., AccuFilm IV, Parkell, Inc.). Powdered sprays (e.g., Occlude, Pascal Company, Inc.) have been shown to built up into an excessively thick film and are best avoided for the evaluation of seating.[6] A suspension of rouge in turpentine or an elastomeric detection paste (e.g., Fit Checker, GC America, Inc.) can also be used as an alternative.[7] These agents should be applied as a thin film to the internal surface of the casting. High magnification of the casting after seating reveals initial contact for grinding (Fig. 28-7). Regardless of the method used, the internal surface of the casting should always be thoroughly cleaned before the luting procedure (see Chapter 30).

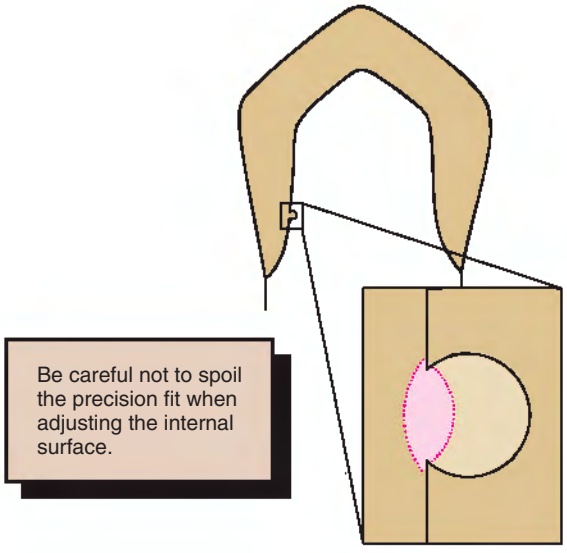

FIGURE 28-6 ■ When a nodule is removed, removal of slightly more than the defect ensures complete seating of the restoration.

Zone 3: The Sprue

Objective

To reestablish proper coronal structure and function, the sprue must be sectioned, and the casting must be recontoured in the area of its attachment.

Procedure

Once the fit of the casting has been verified on the die and it has been found to be acceptable, the sprue is sectioned, and the area of its attachment to the casting (Fig. 28-8) is reshaped.

A carborundum separating disk is used to cut through the sprue. Cutting should be performed circumferentially, with a small area maintained in the center of the sprue. To break this last connection, it is twisted and separated from the casting. Wire cutters are not recommended because they may lead to distortion of the casting. Any excess in the area of the sprue attachment is removed with the disk, and the area is refined with stones and sandpaper disks.

FIGURE 28-7 ■ Liquid marking agents can be helpful if the internal surface of a casting has a nodule. **A,** Incomplete seating. **B,** Liquid marking agent. **C,** A thin coat is applied to the internal surface and air dried. **D,** The casting is gently returned to the die. **E,** The area of interference is identified. **F,** Nodules are best removed with a small round bur. **G,** Seated casting.

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FIGURE 28-8 ■ The most effective way to remove the area of attachment **(A)** is to cut around the sprue and then twist it off **(B)**. **C,** With multiple castings made simultaneously, access is more difficult. When it is necessary to sever a sprue completely, care must be taken not to damage the margin inadvertently. **D,** Disks and stones are used for gross recontouring.

Zone 4: Proximal Contacts

Objective

The proximal contact areas are adjusted in the laboratory so that they will be correct (or slightly too tight) when the casting is evaluated in the patient's mouth.

Procedure

Special care is needed to prevent the finishing procedures from producing an overreduced and, consequently, inadequate proximal contact. Although this can be corrected with solder (see Chapter 29), it is a time-consuming and unnecessary procedure.

A slightly excessive contact, however, may be corrected easily during clinical evaluation. The proximal contacts on the stone cast can be minimally relieved by careful scraping with a scalpel (Fig. 28-9). The casting is then adjusted until it just seats. When adjacent castings are made, they should not be simultaneously adjusted to seat on the definitive cast. Under these circumstances, the proximal contacts should be left slightly too tight in the dental laboratory. Such multiple castings are clinically evaluated done sequentially and on an individual basis. Adjustments are made for each casting independently.

When proximal contacts are adjusted, placing a thin articulating film (Mylar) between adjacent castings or between the casting and the adjacent tooth is helpful (Fig. 28-10). Doing this allows the areas where binding contact occurs to be adjusted through selective adjustment where markings result.

FIGURE 28-9 ■ Rather than risk a deficient proximal contact at evaluation, the technician may reduce the cast slightly by scraping the adjacent teeth with a blade.

Connectors

When a partial fixed dental prosthesis is being finished, the connectors require special attention. Unless they are properly contoured and highly polished, periodontal health is invariably adversely affected, even in the presence of the most meticulous oral hygiene. Mesiodistally, a properly finished connector has a parabolic configuration (Fig. 28-11). Rotary instruments such as rubber wheels, which allow access to the cervical aspect of the connector for finishing while not jeopardizing the margin, are essential in these situations. In cases of root proximity between adjacent teeth, this can be quite problematic. After preliminary finishing with rubber wheels, a piece of twine impregnated with polishing compound can be used

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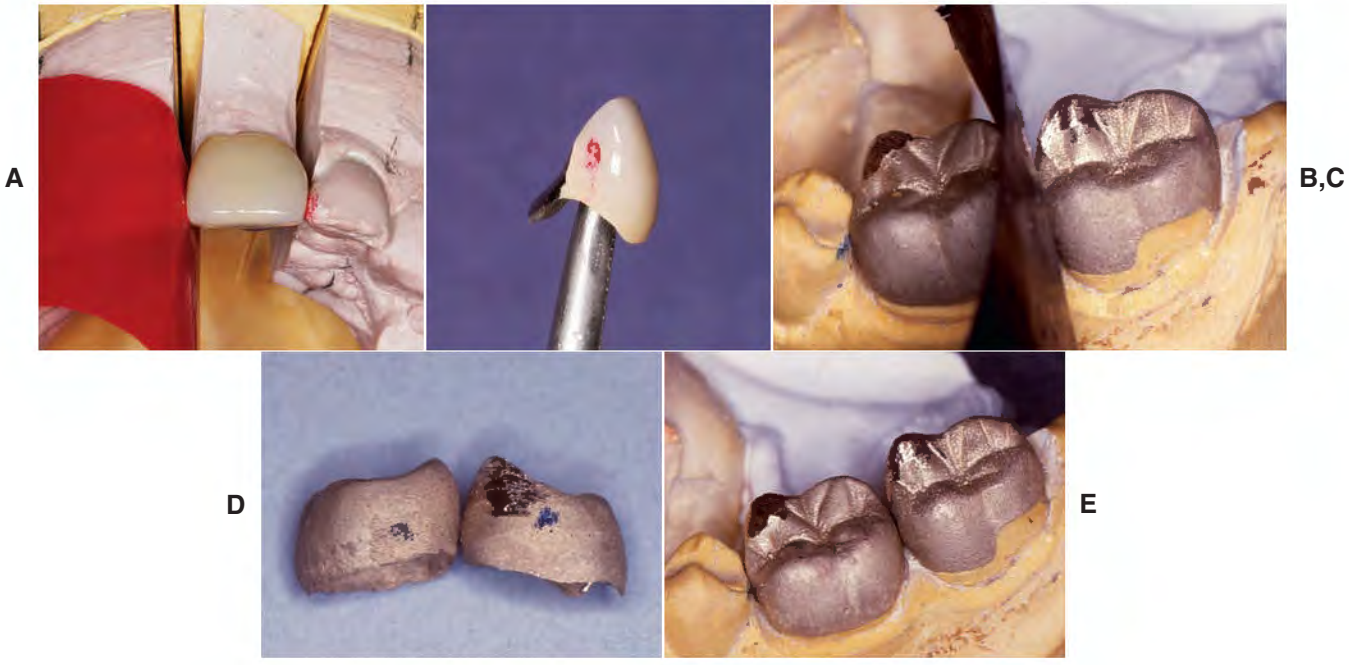

FIGURE 28-10 ■ **A,** Thin articulating film interposed between a metal-ceramic restoration and the adjacent tooth. **B,** The area of contact that prevents complete seating is readily apparent. **C** to **E,** Articulating film is used to detect the location of an excessive proximal contact on cast metal.

FIGURE 28-11 ■ Cross-sectional illustration of properly finished connectors.

to achieve the final polish to the cervical aspect of the connector (Fig. 28-12).

Zone 5: Occlusal Surface

Objective

Occlusal contacts are reestablished in static and dynamic relationships to the opposing arch. Obtaining accurate and stable contacts does not require highly polished metal occlusal surfaces; a satin finish is acceptable. Occlusal form must ensure positional stability and satisfy all functional requirements (see Chapter 4).

Procedure

The occlusal contacts are checked with thin articulating film (Mylar; Fig. 28-13) to ensure that they match the design in the waxing stage. If they do not, the occlusion must be adjusted. Wax is subject to elastic recovery. If an occlusal contact is heavy in wax, it springs back slightly when the articulator is opened and produces an occlusal prematurity in the casting (Fig. 28-14). If tiny contact points are established carefully during the waxing phase, significant occlusal adjustment should not be necessary.

Occlusal adjustments can be performed with flame-shaped finishing burs or diamonds (Fig. 28-15). A large stone creates unwanted concavities in the occlusal surface. The correct technique for occlusal adjustment is to redevelop the anatomy of the entire ridge or cusp rather than grinding only the point of interference. Simultaneously, any nodules can be removed, and grooves can be defined with a finishing bur or a small round bur.

Before starting any adjustment, the practitioner should use a thickness gauge on the metal. If only minimum clearance was established at the tooth preparation stage, indiscriminate adjustment leads to inadequate thickness of the casting (Fig. 28-16) and possible perforation. Although soldering such a hole in a casting is possible, the occurrence of this complication usually indicates an earlier error that must be corrected (e.g., inadequate clearance necessitates additional reduction of the tooth preparation).

After the occlusal contacts have been refined, they must not be altered by extensive polishing. A high polish may be essential for plaque control on axial surfaces (zones 6 and 7), but its benefit on the occlusal surface of metal castings is questionable. In fact, an accurate

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FIGURE 28-12 ■ Polishing connector areas. **A** and **B,** Twine impregnated with polishing compound is an efficient way to polish this hard-to-reach area.

FIGURE 28-13 ■ After complete seating is verified, the initial point of contact is marked.

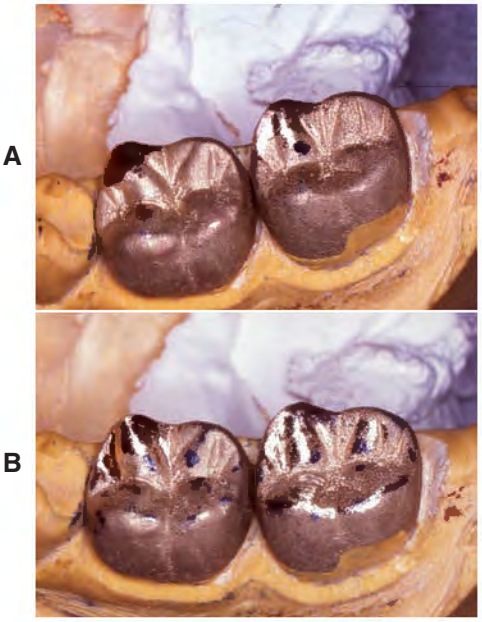

FIGURE 28-14 ■ **A** and **B,** Occlusal prematurities are generally the result of excessively heavy contact on the wax pattern.

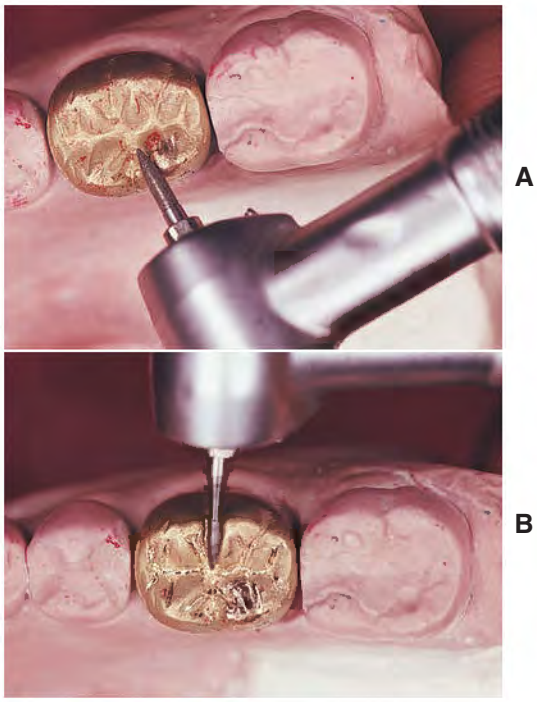

FIGURE 28-15 ■ **A,** Occlusal adjustment is readily accomplished with a pointed diamond or carbide bur. **B,** The grooves and fissures are concurrently refined.

occlusion so painstakingly established in wax can be rapidly destroyed by overzealousness to make a casting look "shiny."

If the wax pattern has been carefully finished, a smooth casting results, and removing surface oxides with a soft wire brush wheel is sufficient. The surface can then be polished with rouge on a soft brush wheel (which removes only 5 µm from the surface of the casting[8]; see Fig. 28-19).

Some authorities[9] recommend producing a matte finish on the occlusal surfaces to aid in the initial

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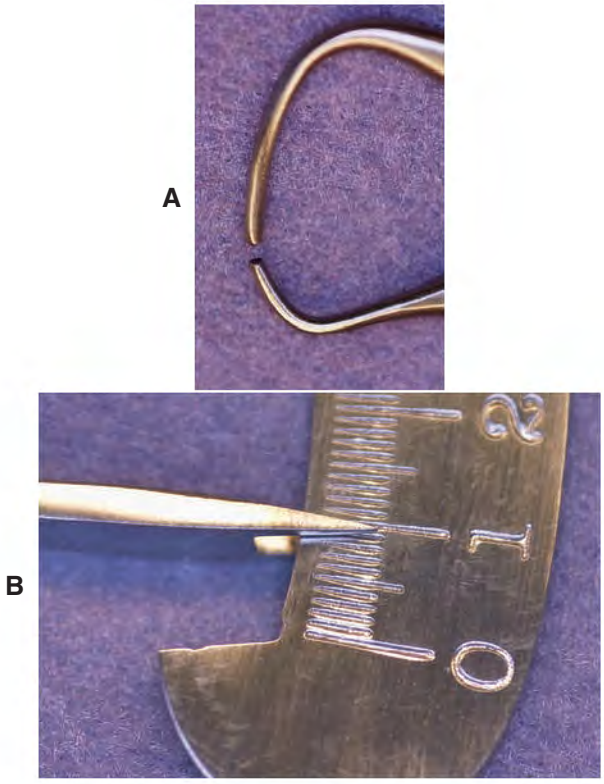

FIGURE 28-16 ■ As occlusal adjustments are made **(A)**, the residual thickness is continually monitored with an appropriately designed thickness gauge **(B)**. For structural durability, metal thickness of less than 1.0 mm is inadequate and is the result of insufficient occlusal reduction.

identification of wear facets during function, which show up as shiny marks on an otherwise dull surface. This type of finish is usually achieved with an airborne-particle abrasion unit and 25- to 50-µm Al_2O_3 (alumina) particles. However, a 5-second blast with 50-µm alumina at 0.5 MPa (73 psi) pressure removes about 20 µm of metal from the abraded surfaces[10]; therefore, the margins should be protected.[11] An exposure of about 1 second usually produces a smooth satin finish. If this cannot be accomplished, it is likely that the preparation before this step was deficient, and further refinement is necessary.

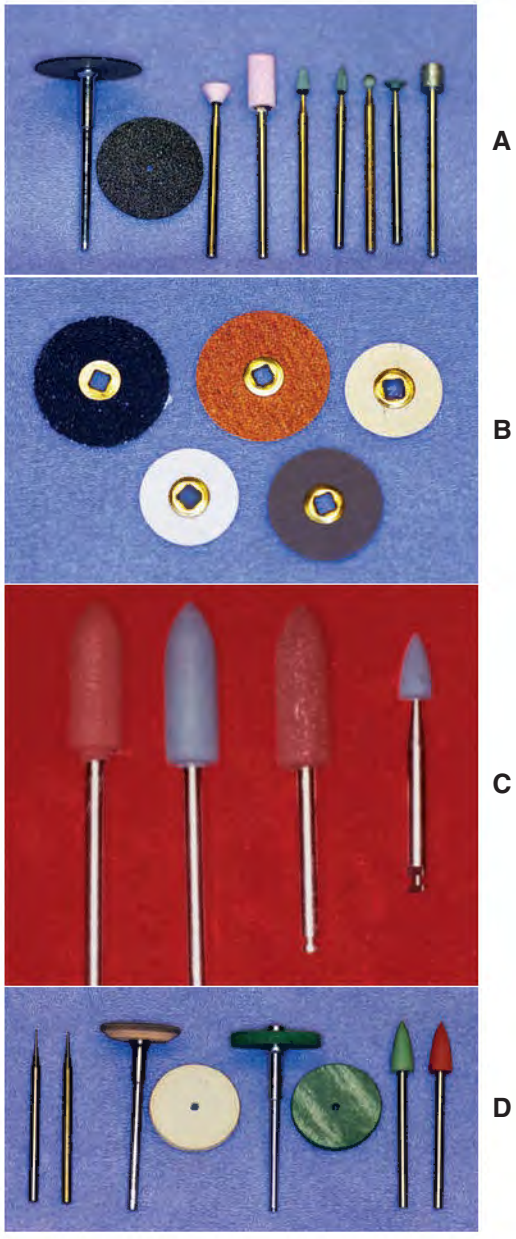

FIGURE 28-17 ■ Abrasives for finishing. A sequence of progressively finer grades is used to attain the desired surface. Carborundum disks and stones of varying degrees of coarseness **(A)** are typically used first; these are followed by garnet paper and sandpaper disks **(B)**, rubber points and white Arkansas stones **(C)**, and rubber wheels and points, along with small carbide burs for removing nodules **(D)**.

Zone 6: Axial Walls

Objective

When axial wall finishing is completed, the walls should be smoothly contoured and highly polished, enabling the patient to perform optimum plaque control.

Procedure

Surface defects are removed by grinding with abrasive particles bound into a grinding stone or rubber wheel, on a paper disk, or applied as an abrasive paste (Fig. 28-17). Each particle acts as a cutting tool on the metal surface.

The most efficient method of polishing[12] is to use a sequence of progressively finer abrasives (Fig. 28-18), each removing the scratches made by the previous grade. Time is wasted if the progression to a finer grade abrasive is too rapid because the coarser grits remove material much more efficiently.

Light pressure is applied when abrasives are used, and the instrument must be kept rotating; otherwise, the surface of the casting is ground into a series of facets that

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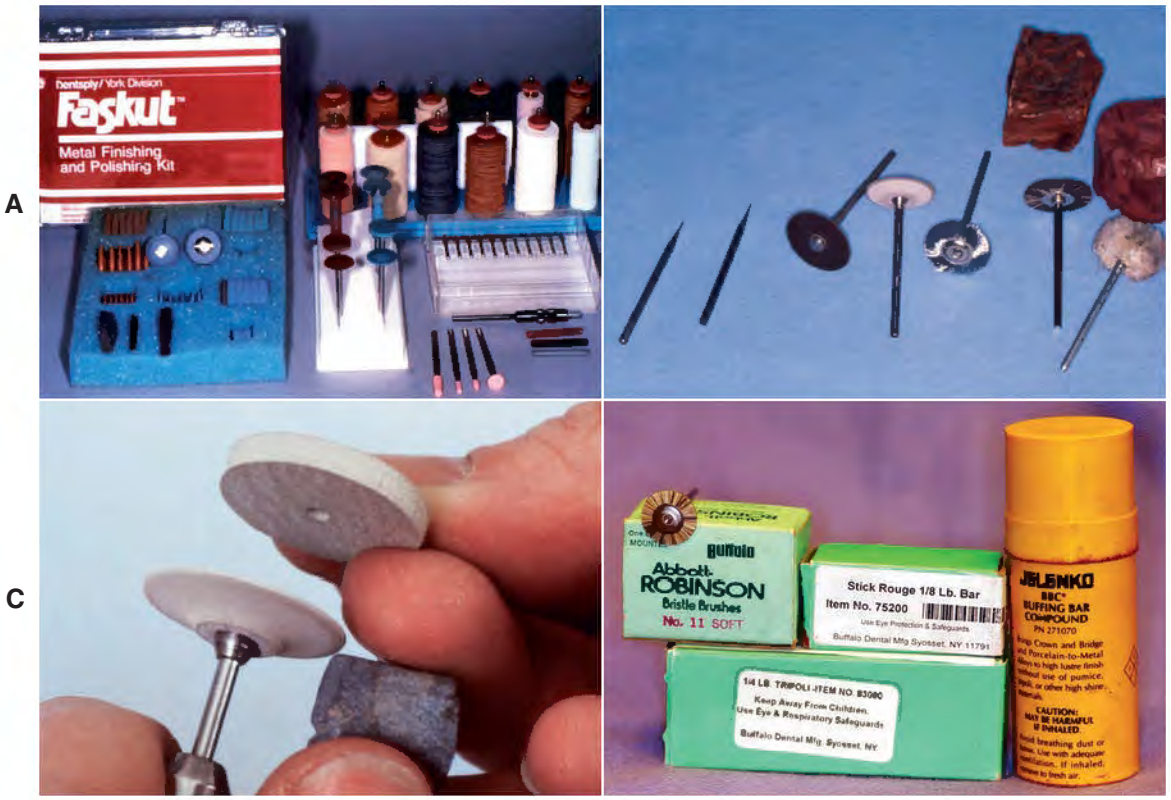

FIGURE 28-18 ■ Finishing armamentarium. **A,** Assorted abrasives, sandpaper disks, rubber points, and polishing wheels. **B,** Instruments used range from small carbides (for removing nodules) and a steel wire brush (for occlusal surface smoothing) to buffing wheels and compounds. **C,** A coarse wheel is used to true and thin the edge of a rubber wheel. **D,** Buffing compounds applied on a felt wheel or bristle brush.

ultimately impede plaque control. When all surface irregularities have been removed and the progression through the series of abrasives has left a finish with only minute scratches, the axial surfaces of the restoration are polished. Jeweler's rouge rapidly produces a high polish on a well-prepared surface of a dense casting (Fig. 28-19, *K*). This is carried on a wheel or brush, with heavier pressures and higher rotational speeds than were used in finishing (see Fig. 28-19).

Zone 7: External Margins

Objective

Margin finishing is crucial for a restoration's longevity and therefore merits special attention. The objective of all cast restoration finishing is a highly polished metal surface without ledges or steps as the transition is made from restoration to unprepared tooth. Failure to accomplish this leads to compromised plaque control.

Procedure

Where access allows, cavosurface margins should be finished directly on the tooth (see Fig. 29-10). Unfortunately, the areas where access for finishing is restricted (i.e., proximally or subgingivally) are precisely where plaque control presents the most problems. Therefore, only the least crucial areas can be finished intraorally. An advantage of partial-coverage restorations over complete crowns is that they allow better access for finishing margins and for subsequent plaque control.

The parts of the margin that cannot be finished on the tooth are finished on the die (Fig. 28-20). Care must be taken not to remove more metal than is strictly necessary. Excessive finishing creates problems similar to those caused by incomplete polishing. This raises the issue of how much material can be removed from the surface of a casting without compromising the ultimate fit and emergence profile of the finished restoration.

A stone die from a polysulfide impression is approximately 25 μm wider than the tooth because of polymerization and thermal shrinkage of the impression material and expansion of the gypsum.[13] In theory, therefore, if 12.5 μm is removed during finishing, the casting will be flush with the tooth surface. Although these values cannot be measured on a day-to-day basis in a dental office, they illustrate the tolerances of, and restrictions imposed by, the materials that are currently in use.

The edge of the margin must not be distorted during finishing, although carefully rubbing a smooth instrument along the length of the margin (burnishing;

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FIGURE 28-19 ■ Finishing and polishing. **A,** Initially a wire brush is used on the occlusal surfaces. **B,** A fine-grit sandpaper disk is applied for removing pits and irregularities from the axial walls. Note that the margin is not touched at this time. **C** and **D,** Rubber points and small carbides are used for selective finishing of the occlusal structure. **E,** A rubber wheel is then used on the axial walls. **F,** Castings, after polishing with buffing compound, immediately before clinical evaluation. **G,** When the fit has been verified clinically, the margins are polished. **H** and **I,** The completed castings immediately before cementation. **J,** Scanning electron micrograph of a gold alloy in the "as-cast" state. **K,** The same casting after finishing and polishing with a series of abrasives, culminating in rouge. (**J** and **K,** Courtesy Dr. J.L. Sandrik.)

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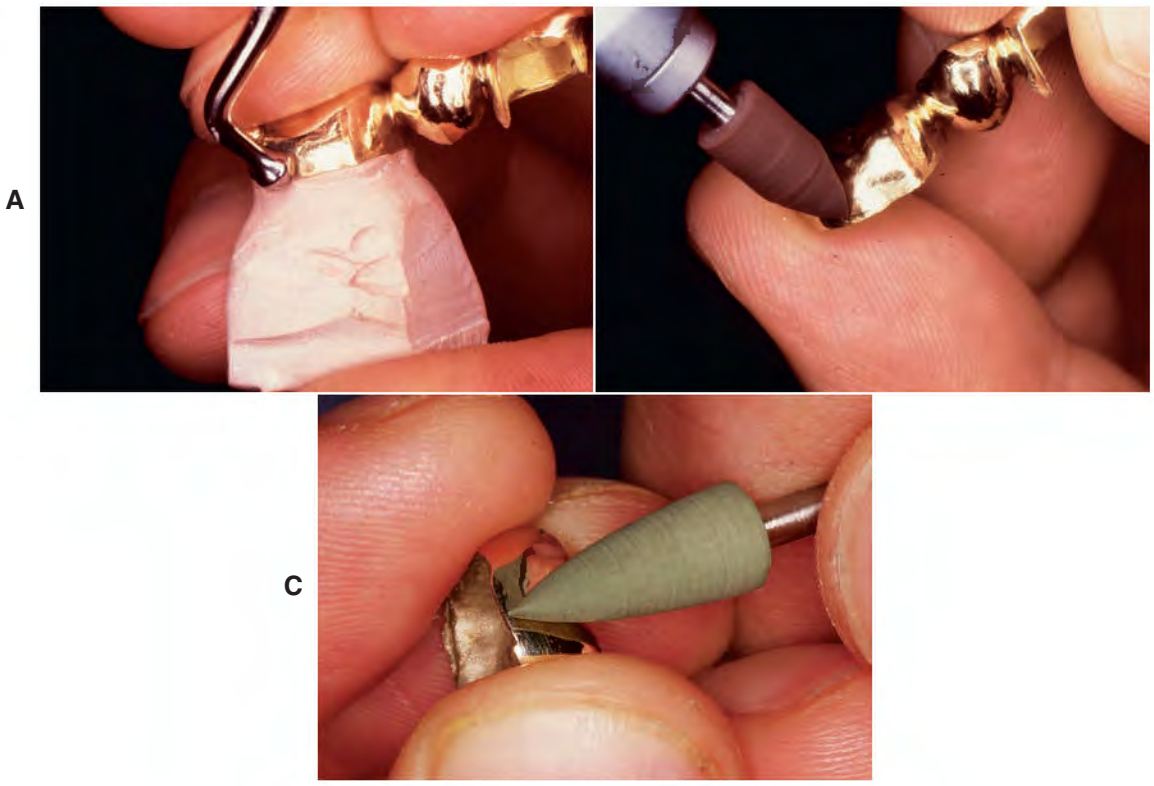

FIGURE 28-20 ■ When subgingival margins do not allow access, final finishing is performed on the die. During final polishing, the margin is carefully supported with a finger. **A,** Carefully rubbing a smooth instrument along the length of the margin (burnishing). **B,** Gently brushing a fine-grit stone over the surface to remove casting roughness. **C,** Using a soft rubber wheel or point.

see Fig. 28-20, *A*) may improve the margin,[14,15] but only when softer alloys are used.[16] Unfortunately, burnishing does not make a poorly fitting margin acceptable.

To perform finishing, a fine-grit stone should be brushed gently over the surface to remove casting roughness (see Fig. 28-20, *B*). This is followed by brushing with a soft rubber wheel or point (see Fig. 28-20, *C*) and finally by rouge on a brush. The margin should be supported with a finger during final polishing.

When the casting is smooth on all critical surfaces, any remaining polishing compound can be removed with a soft toothbrush, by ultrasonic cleaning in an appropriate solution, or by steam cleaning.

REVIEW OF TECHNIQUE

Figure 28-21 presents the steps involved in finishing a restoration and should be consulted when techniques are reviewed.

1. The internal margin is inspected to confirm that the casting accurately reproduces the prepared tooth and is intimately adapted to the prepared surfaces adjacent to the margin (see Fig. 28-21, *A*).
2. The internal surface is inspected under magnification and adjusted as necessary with small stones and tungsten carbide burs. Adjustments are restricted to areas where binding contacts occur (see Fig. 28-21, *B*).
3. The casting should seat completely without force and without noticeable rocking or instability (see Fig. 28-21, *C*).
4. The sprue is removed (see Fig. 28-21, *D*).
5. The area of its attachment is reshaped (see Fig. 28-21, *E*).
6. The proximal contact areas are identified (see Fig. 28-21, *F*).
7. On the cast, proximal contacts can be left slightly tight before the clinical evaluation appointment (see Fig. 28-21, *G*).
8. The occlusal surfaces are evaluated and adjusted. No centric or excursive interferences should remain (see Fig. 28-21, *H*).
9. The axial surfaces are finished and polished (see Fig. 28-21, *I*). Finishing the cervical aspect of axial walls on metal-ceramic restorations is postponed until after final glazing and characterization. In addition, if a soldering procedure is anticipated, the marginal area is left unfinished until the soldering has been completed and the fit of the assembled prosthesis is acceptable.
10. The polished restoration is cleaned. A steam cleaner or ultrasonic cleaner (with the appropriate solutions) can be used (see Fig. 28-21, *J*). The cleaned castings are seated on the definitive cast.

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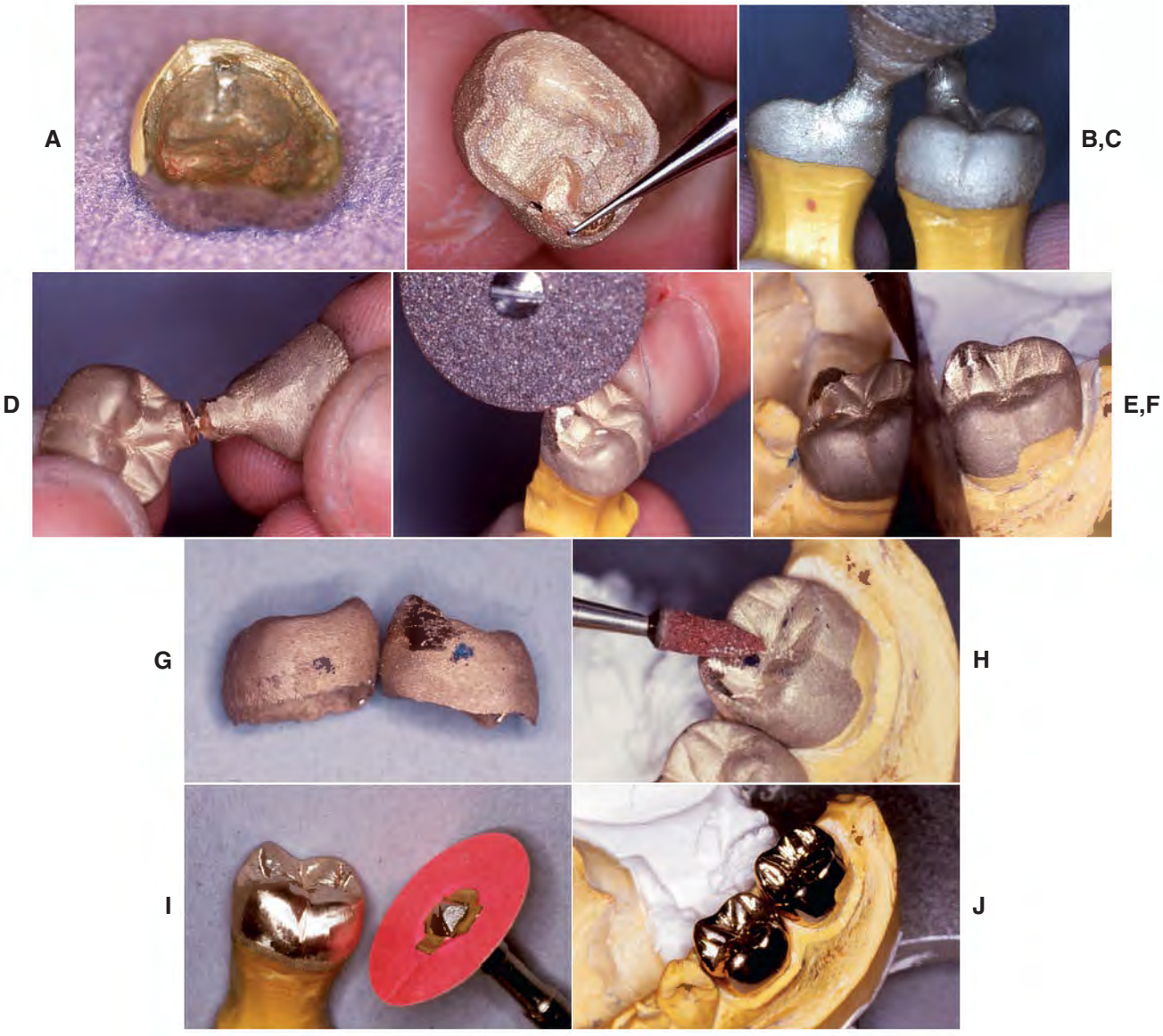

FIGURE 28-21 ■ Technique review. **A,** The internal margin is inspected to confirm that the casting accurately reproduces the prepared tooth and is intimately adapted to the prepared surfaces adjacent to the margin. **B,** The internal surface is inspected under magnification and adjusted as necessary with small stones and carbide burs. **C,** The casting should seat completely without force and without noticeable rocking or instability. **D,** The sprue is removed. **E,** The area of its attachment is reshaped. **F,** The proximal contact areas are identified. **G,** On the cast, proximal contacts can be left slightly tight before the clinical evaluation appointment. **H,** The occlusal surfaces are evaluated and adjusted. **I,** The axial surfaces are finished and polished. **J,** The polished restoration is cleaned.

REFERENCES

1. Gildenhuys RR, Stallard RE: Comparison of plaque accumulation on metal restorative surfaces. Dent Surv 51:56, 1975.
2. Shafagh I: Plaque accumulation on cast gold complete crowns polished by a conventional and an experimental method. J Prosthet Dent 55:339, 1986.
3. Keenan MP, et al: Effects of cast gold surface finishing on plaque retention. J Prosthet Dent 43:168, 1980.
4. Reddy ES, et al: Effect of different finishing and polishing agents on the surface roughness of cast pure titanium. J Prosthodont 16:263, 2007.
5. Mesu FP: Degradation of luting cements measured in vitro. J Dent Res 61:665, 1982.
6. Kious AR, et al: Film thickness of crown disclosing material and its relevance to cementation. J Prosthet Dent 112:1246, 2014.
7. White SN, et al: Improved marginal seating of cast restorations using a silicone-disclosing medium. Int J Prosthodont 4:323, 1991.
8. Anusavice KJ, et al: Phillips' science of dental materials, 12th ed. St. Louis, Elsevier, 2013.
9. Shillingburg HT, et al: Fundamentals of fixed prosthodontics, 4th ed. Chicago, Quintessence Publishing, 2012.
10. Adams HF: Effect of abrasive blasting on castings of gold alloys. Op Dent 6:11, 1981.
11. Felton DA, et al: Effect of air abrasives on marginal configurations of porcelain-fused-to-metal alloys: an SEM analysis. J Prosthet Dent 65:38, 1991.
12. Troxell RR: The polishing of gold castings. J Prosthet Dent 9:668, 1959.
13. Rosenstiel SF: The marginal reproduction of two elastomeric impression materials [Master's thesis]. Bloomington, Indiana University, 1977.

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14. Eames WB, Little RM: Movement of gold at cavosurface margins with finishing instruments. J Am Dent Assoc 75:147, 1967.
15. Goretti A, et al: A microscopic evaluation of the marginal adaptation of onlays in gold. Schweiz Monatsschr Zahnmed 102:679, 1992.
16. Sarrett DC, et al: Scanning electron microscopy evaluation of four finishing techniques on margins of gold castings. J Prosthet Dent 50:784, 1983.

STUDY QUESTIONS

1. What is the purpose of finishing and polishing the margin of a cast restoration? The occlusal surface? The proximal contact area?
2. What is the recommended procedure for severing a sprue?
3. What is the recommended procedure for removing a nodule?
4. What is the recommended procedure for shaping and finishing a connector for a partial fixed dental prosthesis?
5. Discuss the uses and limitations of air-particle abrasion in finishing cast restorations (gold and metal-ceramic).

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PART IV

CLINICAL PROCEDURES: SECTION 2

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CHAPTER 29

Evaluation, Characterization, and Glazing

EVALUATION

When the laboratory procedures have been completed, the restoration is ready to be evaluated intraorally before final finishing and cementation. The completed prosthesis is cleaned either ultrasonically or with a steam cleaner to remove any residual polishing compound and is then disinfected. Metal and all-ceramic restorations need to be evaluated in terms of proximal contacts, margin integrity, stability, internal fit, external contours, occlusion, and surface finish.

Metal-ceramic prostheses often require two evaluations: a metal evaluation stage, followed by reevaluation after the esthetic veneer has been applied. At the metal evaluation appointment, the dentist assesses the margin integrity, stability, occlusion, and substructure design. Especially important at this appointment is the assessment of the veneering area: specifically, the location of the metal-ceramic junction in relation to the location of the occlusal contacts. Adjustments are easily made at this time: for instance, by extending the veneering surface slightly interproximally to improve the appearance of the completed prosthesis. After porcelain has been applied, a second evaluation occurs in the bisque stage. At that time, the dentist reassesses marginal integrity and stability to determine whether any distortion has occurred during porcelain firing. Proximal contacts are also evaluated at this time, as are porcelain contours, stability, the shade match, surface texture, and glaze. For fixed dental prostheses (FDPs), tissue contact of the pontics and the location and shape of connectors must be assessed carefully; adaptation must be passive, to prevent tissue irritation. Primarily because of the inevitable inaccuracies that result from the indirect technique and the high degree of precision required for a successful FDP, restorations almost inevitably require some chairside adjustment before cementation.

Interim Restoration and Luting Agent

To remove the interim restoration, hemostats or a Backhaus towel clamp are positioned carefully on the buccal and lingual surfaces, and it is rocked gently in a buccolingual direction to break the seal of the interim luting agent. Special band removers (Fig. 29-1) may also be used. Most of the luting agent or interim cement adheres to the interim restoration when it is taken out of the patient's mouth. Any remaining cement should be loosened from the prepared tooth surface with an explorer, followed by careful application of a water-pumice mixture* in a prophylaxis cup. Low-speed mixing and relatively light pressure are essential. Polishing the preparation is undesirable because it may lessen retention.[1] The preparations are rinsed with water and air spray, and after drying, the area is inspected. All residual luting material must have been removed because even a very small particle of interim cement can prevent a casting from seating completely.

Evaluation Sequence

Following a logical sequence during the evaluation procedures is important if mistakes are to be avoided. The recommended sequence is as follows:

1. Proximal contacts
2. Marginal integrity
3. Stability
4. Occlusion
5. Characterization and glazing

The proximal contacts are evaluated first because excessive contact there prevents the restoration from seating, which leads to a marginal discrepancy. If a restoration is not seating completely, then assessing stability and sectioning, or adjusting the occlusion, is premature.

Proximal Contacts

The location, size, and tightness of a restoration's proximal contacts should resemble those of the natural teeth. Typically, textbooks refer to contacts that allow unwaxed floss to "snap" through "relatively easily." Although this is not a very scientific definition, the use of floss is a convenient method for comparing the tightness of the proximal contacts with other contacts between adjacent teeth in the arch. If the floss does not pass, the contact is excessively tight; if it goes through too easily, food impaction may result (Fig. 29-2). The use of shim stock (thin Mylar film) is a more reliable indicator of proximal contact than floss. A passive contact allows the Mylar film to be pulled from the interproximal with some slight resistance. If the strip tears, the contact is too tight. The ideal contact allows for positional stability of the abutments and adjacent teeth, as well as easy maintenance of the supporting structures. Most patients give reliable information as to a tight proximal contact when asked whether they "feel as though they have a seed between

*As an alternative, the pumice can be mixed with an antimicrobial such as chlorhexidine (Consepsis, Ultradent Products, Inc.), which may reduce postcementation sensitivity.

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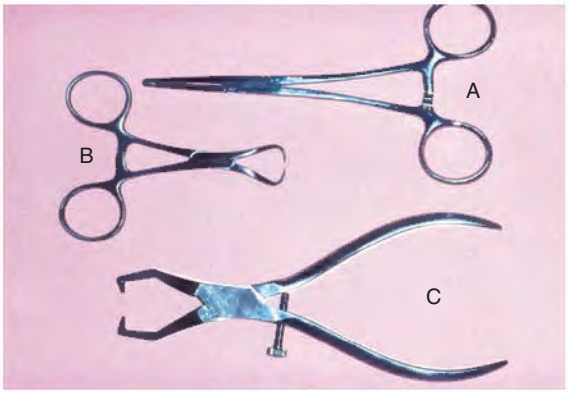

FIGURE 29-1 ■ Hemostat *(A)*, Backhaus towel clamp forceps *(B)*, and Baade-type band remover *(C)*.

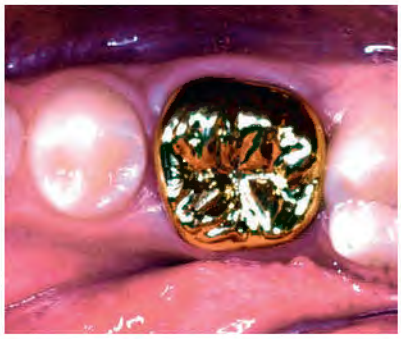

FIGURE 29-2 ■ Deficient mesial contact, which could allow food to become impacted.

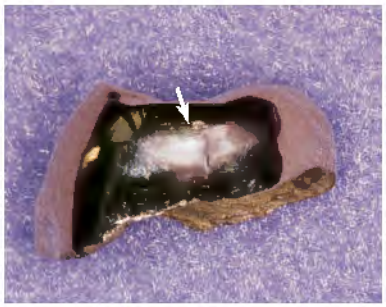

FIGURE 29-3 ■ Identifying the location of a tight proximal contact. The metal is given a matte finish by grinding with a rubber wheel. A shiny mark *(arrow)* is formed where the contact is excessive.

their teeth," provided that a local anesthetic has not been administered. A deficient contact is easily overlooked but invariably results in discomfort as food becomes impacted.

Excessive Tightness

All-Metal Restorations. If a tight contact prevents the seating of an all-metal restoration, adjustments are readily made with a rubber wheel. The matte finish produced helps identify where binding occurs because a shiny spot (Fig. 29-3) appears where adjustment is necessary.

When a contact is too tight, the restoration is removed from the patient's mouth, adjusted, and then reevaluated

FIGURE 29-4 ■ The location of tight porcelain contacts can be identified with thin marking tape.

intraorally. The dentist must remember to allow a small degree of excessive tightness for polishing. When both proximal contacts of a crown are excessively tight, the dentist should make adjustments on an alternating basis, verifying whether additional material needs to be removed before proceeding with further adjustments.

Ceramic Restorations. A tight proximal contact in unglazed or unpolished ceramic is easily adjusted with a cylindrical stone. The area of contact (Fig. 29-4) can be identified with thin marking tape.

After glazing, a slight change in the contact may be observed because of the pyroplastic surface flow that occurs during firing. If adjustment of a glazed restoration is needed, it should be repolished with diamond-impregnated silicone wheels and points, pumice, or diamond-polishing paste.

Deficiency

All-Metal Restorations. A gold casting with a deficient proximal contact can usually be corrected by soldering (Fig. 29-5). The procedure is simple and can be performed in the dental office in a matter of minutes. However, soldering a proximal contact should not be routinely necessary. After soldering, the restoration requires pickling and repolishing.

Armamentarium. The equipment needed is shown in Figure 29-5, *A*.

- Soldering tweezers
- Gold solder
- Paste flux
- Bunsen burner
- Antiflux
- Polishing armamentarium

Step-by-Step Procedure

1. Roughen the deficient area with a disk (see Fig. 29-5, *B*).
2. Protect the margin of the casting with a graphite pencil (or another suitable antiflux; see Fig. 29-5, *C*).
3. Coat a small piece of solder with flux, and position it on the previously roughened surface (see Fig. 29-5, *D*).

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FIGURE 29-5 ■ Adding a proximal contact with gold solder. **A,** Armamentarium. *1,* Soldering tweezers. *2,* Gold solder. *3,* Paste flux. *4,* Antiflux. *5,* Finishing disk. **B,** The deficient proximal surface is roughened. **C,** Antiflux (graphite or rouge/turpentine) is added to the margin. **D,** A segment of solder is positioned with paste flux. **E,** The solder is heated over a Bunsen burner flame until just when it melts. **F,** Proximal contact is readjusted.

4. Hold the casting with the soldering tweezers in a properly adjusted flame of the Bunsen burner to position the solder at the height of the reducing portion of the flame (see Fig. 29-5, *E*, see also Fig. 27-18).
5. Observe the solder carefully as it heats up. As the solder starts to fuse, it spreads rapidly. With a little practice, the casting can be tipped to help the solder flow in the desired direction. The casting is then immediately removed from the flame.
6. Pickle the casting, and adjust the proximal contours with disks (see Fig. 29-5, *F*) before repolishing and cleaning.

Ceramic Restorations. A deficient ceramic proximal contact necessitates additional firing. At the bisque stage, this is time consuming, but adding additional porcelain is not a problem. However, if a restoration has been completely finished, glazed, and characterized at the time the deficient contact is discovered, a lower fusing "add-on" or correction porcelain can be used to solve the problem (Fig. 29-6).

These correction porcelains are a mixture of body porcelain and overglaze with additional modifiers to produce a maturation temperature as low as 850°C (1562°F). Minor corrections can thus be made with little risk of dimensional change in any other part of the restoration. Major corrections should be made by means of an additional firing with the conventional body and incisal powders, although there are limits to the number of times a restoration can be fired if devitrification is to be avoided (see Fig. 24-34, *B*).

Margin Integrity

The completed restoration should go into place without binding of its internal aspect against the occlusal surface

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FIGURE 29-6 ■ Correction of a defective proximal contour with porcelain. **A,** A low-fusing add-on porcelain is used. **B,** Applying the porcelain. **C,** Corrected proximal contours. **D,** Fired restoration.

FIGURE 29-7 ■ Water-soluble marking agent.

or the axial walls of the tooth preparation; in other words, the best adaptation should be at the margins. If the indirect procedure is handled properly, there should be no noticeable difference between the fit of a restoration on the die and the intraoral fit.

Several techniques have been used to detect where a casting binds against an occlusal or axial wall, including disclosing waxes, painting the inside of the restoration with a suspension of rouge in turpentine or acetic acid, airborne-particle abrasion to form a matte finish surface, powdered sprays, water-soluble marking agents (Fig. 29-7), and special elastomeric detection pastes. However, none has proved to be entirely satisfactory. Most techniques are rather messy and time consuming and should not be needed on a routine basis.

Powdered sprays (originally designed to facilitate seating of frameworks of removable dental prostheses), can build into a layer of excessive thickness on the restoration's internal surface, interfering with seating the crown.[2] Nevertheless, elastomeric paste (Fig. 29-8) has some advantages. The material is similar to a silicone impression material and is obtained as a two-paste system. Its viscosity is similar to that of the definitive luting agents, and so it can be used not only to identify unwanted internal contacts but also to assess adequate marginal fit. The degree of clinically acceptable marginal opening (i.e., the discrepancy unlikely to have an adverse effect on the prognosis) is hard to define. Margin integrity has been the subject of many laboratory and clinical evaluations. To minimize dissolution of the luting agent, the thickness of the cement film at the margins should be kept minimal. Through careful technique, a marginal gap width of less than 30 µm can be obtained consistently.[3,4]

Assessment

Figure 29-9 illustrates the possibilities that may be encountered in verifying margin integrity. The presence of a small overhang or ledge (see Fig. 29-9, *A* and *B*) does not necessarily mean that the restoration must be remade. It may merely require additional finishing where accessibility allows.

A sharp explorer moved from restoration to tooth and from tooth to restoration can be used in evaluating the marginal adaptation. If resistance is encountered in both directions, a gap or open margin exists, and its cause must be determined. If the gap is the result of an excessive proximal contact or of residual interim luting agent that prevents the casting from being seated, the situation is easily remedied. However, an obviously inaccurate restoration should be quickly rejected. Trying to "make it fit" is wasted effort, and making a new impression is a better use of time.

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FIGURE 29-8 ■ **A,** Elastomeric detection paste, recommended for evaluating the internal surface of a restoration. **B,** The interference is seen as a perforation in the film of silicone material, which can be marked with a colored pencil. The residual film of silicone should be thoroughly removed before the restoration is cemented. (**B,** Courtesy Dr. J.H. Bailey.)

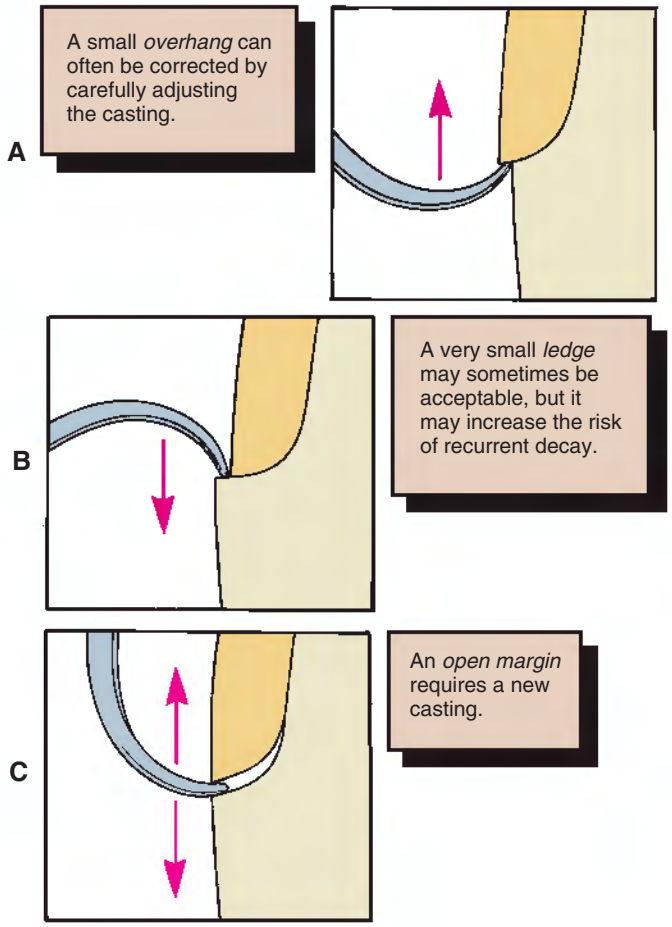

FIGURE 29-9 ■ Assessing margin integrity with an explorer. **A,** An overhang. **B,** A ledge. **C,** An open margin.

Finishing

Subgingival margins are not accessible for finishing in the mouth. They must be finished on the die. Because clinical examination of subgingival margins is not always easy, a precementation radiograph may be justified.

Supragingival margins are generally finished with the restoration seated on the tooth. White stones and cuttle disks rotating from restoration to tooth structure should result in a suitably finished margin (Fig. 29-10), which, if the restoration is properly adapted, is virtually undetectable with the tip of a sharp explorer.[5]

The accessible margins of cast-metal restorations can also be burnished during the cementation procedure before initial setting of the cement.[6] However, the less accessible proximal margins are the critical ones in terms of prognosis. They are the most common site of recurring caries and periodontal disease, and intraorally neither can be evaluated readily or finished easily. It has also been shown[7,8] that correcting a poorly fitting cast restoration with finishing procedures is not possible.

Stability

The restoration should then be assessed for stability on the prepared tooth. It should not rock or rotate when force is applied. Any degree of instability is likely to cause failure during function. If instability is caused by a small positive nodule, this can usually be corrected; if it is caused by distortion, however, a new casting is necessary.

Occlusion

After the restoration has been seated and the margin integrity and stability are acceptable, the occlusal contact with the opposing teeth is carefully checked. The criteria for these relationships, both static and dynamic, are discussed in Chapters 4 and 18. Any undesirable eccentric contacts, as well as centric interferences, must be identified. Adjustment of eccentric contacts is often needed if the restoration was made from a closed-mouth impression.

Evaluation and Adjustment

Armamentarium

- Hemostats
- Miller forceps
- Marking ribbon or tape
- Thin Mylar shim stock

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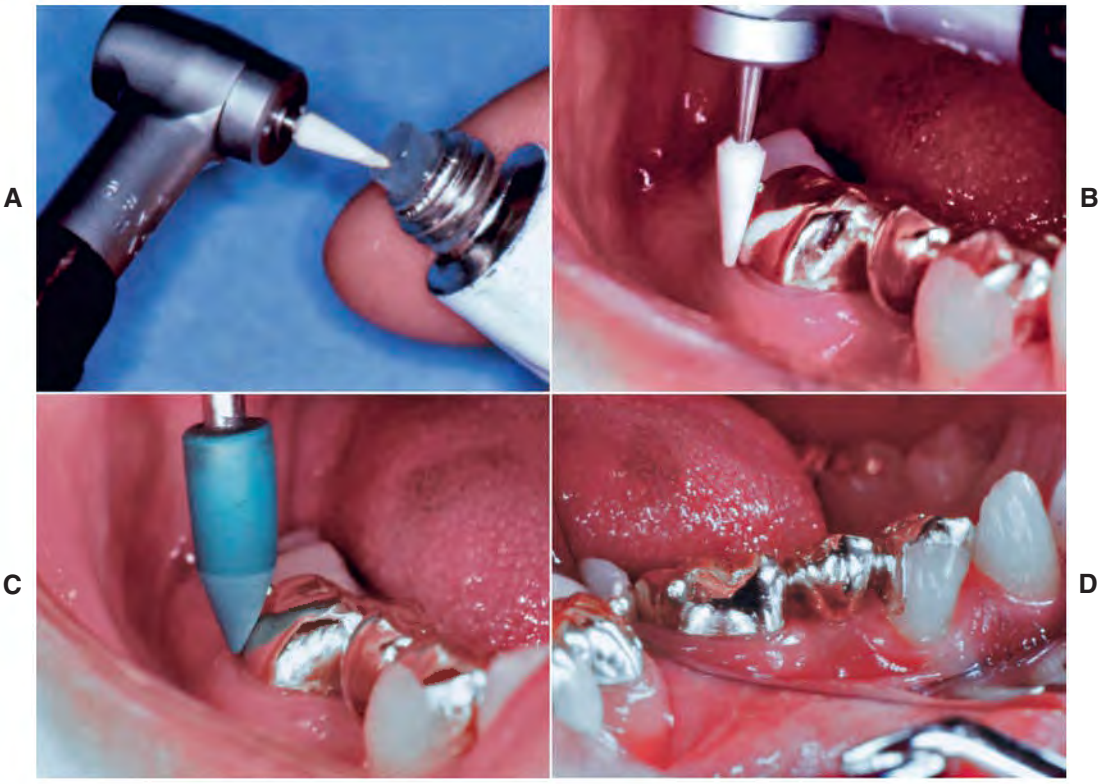

FIGURE 29-10 ■ Supragingival margins allow access for finishing the restoration directly on the tooth. **A** and **B,** Fine-grit white stone lubricated with petroleum jelly. **C,** Rubber point. **D,** Completed restoration.

- Diamond rotary instruments
- White stones

Only restorations in supraocclusion can be adjusted. For those that are out of occlusion, there is no satisfactory solution other than remaking (if in metal or monolithic ceramic) or adding porcelain and refiring (if the restoration is metal-ceramic or all-ceramic with a high-strength core).

Step-by-Step Procedure. This process is shown in Figure 29-11.

1. Before seating the casting, assess the contact relationship between maxillary and mandibular teeth. The most convenient way to do this is to cut a narrow strip of Mylar shim stock, hold it in hemostats or forceps, and have the patient open and close the jaws with the strip between opposing teeth. A tug felt on the strip indicates occlusal contact (Fig. 29-12). Ideally, contact should be as evenly distributed as possible, but it is not uncommon to find one or more areas of relatively light contact between opposing teeth.
2. Seat the restoration, have the patient close the jaws, and reassess the contacts. The new restoration should hold the shim stock and yet not alter the existing tooth relationships. If a discrepancy is detected, a decision must be made whether this can be adjusted intraorally or whether a remount procedure is necessary.
3. Mark any interferences that are detected. Have the patient close the jaws on articulating film.
4. Adjust the marked interferences with the diamond rotary instrument or white stone, always checking the thickness of the restoration with calipers before an adjustment is made. On occasion, adjusting an opposing cusp rather than cementing a restoration that is too thin may be the preferred method, although performing such adjustment at the tooth preparation stage is recommended. Explaining the procedure and its rationale to the patient before grinding an opposing tooth is essential. Options, such as increasing occlusal clearance by repreparing the tooth, should be presented to the patient before the procedure continues.
5. Be careful not to misinterpret occlusal markings. Note that a true interocclusal contact leaves a mark with a clean center (like a bull's-eye), but a false contact leaves a smudge. Marking ribbon or tape is useful for helping determine the location of an interference. Shim stock, however, is a more reliable indicator than ribbon or tape for confirming the presence or absence of an occlusal contact and should be used to evaluate the result.
6. Use two colors of ribbon for the different types of movement. Excursive movements and interferences are first marked in one color (e.g., green). Then a different color (e.g., red) is inserted for centric contacts. Any excursive interferences (in this example, green marks not covered by red) are adjusted with the diamond or white stone.

An alternative technique for metal restorations requires the use of an airborne-particle abrasion unit

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FIGURE 29-11 ■ Evaluating and adjusting the occlusion. **A,** Refinement on the articulator before evaluation. **B,** Testing the occlusal relationship with shim stock and marking with tape. Typically, some adjustment is needed, especially in more complex treatments, but this should not be extensive unless an error has been made. **C,** After adjustment, the occlusal contacts should always be verified with shim stock because ribbon markings can be misinterpreted.

FIGURE 29-12 ■ **A,** Use shim stock (Mylar) to identify presence or absence of occlusal contacts. **B,** Use articulating tape to identify the location of occlusal contact.

with aluminum oxide (Fig. 29-13). A matte finish is obtained on the occlusal surfaces of the casting in question, and the patient is asked to close the jaws. Where shiny marks appear, an adjustment is made. This technique, however, has the following disadvantages:

1. Differentiating between centric and excursive contacts is not possible.
2. The technique is more time consuming.
3. It is applicable only to cast-metal occlusal surfaces.

Gross occlusal adjustment involving dental ceramics is better done in the bisque stage because interferences are more easily marked on a bisque surface than on glazed porcelain. Minor adjustments may be needed after glazing because of the pyroplastic flow of the porcelain.[9] After adjustment, the ceramic can be polished with silicon-impregnated wheels or diamond-polishing paste.

Remount

If clinical evaluation reveals a need for significant occlusal adjustment of multiple restorations, a remount procedure[10] may be indicated. When extensive restorative dentistry is undertaken, the remount serves to convey the relationships of the restorations and teeth to the dental laboratory (Fig. 29-14). Detailed adjustments can then be made in an organized manner. Any inaccuracy (e.g., slight tooth movement, previous mounting discrepancies, or small dimensional change inherent with the indirect process) can be compensated for with relative ease, which thus reduces the amount of chair time needed for intraoral precementation adjustment.

Intraoral occlusal refinement is limited because of visibility and access difficulties. Laboratory adjustments offer far superior access and visibility and the opportunity to properly evaluate lingual contact relationships.

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FIGURE 29-13 ■ Occlusal prematurities can be identified by giving the casting a matte finish with an airborne-particle abrasion unit. **A** and **B,** The prematurities appear as shiny areas. (Courtesy Dr. M.T. Padilla.)

FIGURE 29-14 ■ **A** and **B,** Occlusal relationships transmitted to the laboratory should be accurate when a careful technique has been followed. Any discrepancies are often better corrected by a remount procedure in the laboratory.

The remount procedure consists of making an impression of the seated restorations in the patient's mouth, with an occlusal index in place. The index is made with reinforced resin or impression plaster and provides the opportunity to accurately reposition the castings back into the impression after it has been removed from the patient's mouth. A new definitive cast can then be fabricated. To enable easy removal of the castings from the newly fabricated definitive cast, resin is usually poured into the castings, after which the rest of the impression is poured in conventional type IV stone (Fig. 29-15). The cast can then be articulated with a

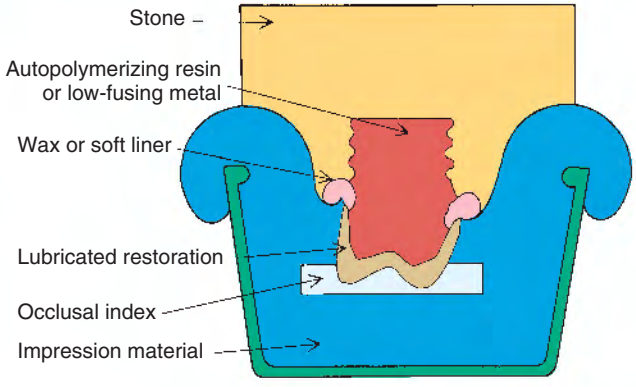

FIGURE 29-15 ■ Cross-sectional schematic of the remount procedure.

conventional facebow transfer and occlusal registration techniques (see Chapter 2).

Armamentarium. The equipment needed is shown in Figure 29-16.

- Impression trays
- Irreversible hydrocolloid
- Rubber bowl and spatula
- Interim luting agent
- Petrolatum
- Photopolymerizing resin
- Stiff wire (e.g., coat hanger wire)
- Zinc oxide–eugenol (ZOE) occlusal registration paste
- Inlay wax or light-bodied reversible hydrocolloid
- Facebow transfer equipment
- Centric relation recording

Step-by-Step Procedure. This process is shown in Figure 29-17.

1. Use photopolymerizing resin (e.g., custom tray resin) to make an occlusal index of the restorations on the definitive cast. The index will ensure that the restorations are accurately positioned on the remount cast. Reinforce the index with stiff wire. The index should not extend beyond the occlusal table of the restored teeth, and its

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FIGURE 29-16 ■ Armamentarium for a remount procedure: *A,* Impression trays; *B,* irreversible hydrocolloid; *C,* Rubber bowl and spatula; *D,* interim luting agent; *E,* petrolatum; *F,* photopolymerizing resin; *G,* stiff wire (e.g., coat hanger wire); *H,* zinc oxide–eugenol (ZOE) occlusal registration paste; *I,* inlay wax or light-bodied reversible hydrocolloid.

thickness should be less than 5 mm. It should fit the cast passively.

2. Adjust the occlusal surface of the index until only shallow indentations of the cusp tips remain.
3. Seat the restorations on the prepared teeth (see Fig. 29-17, *B*). To prevent dislodgment, use a small amount of interim luting agent mixed with petrolatum. FDPs that have yet to be assembled can be stabilized with autopolymerizing resin applied by the brush-bead technique (see Fig. 27-34).
4. After the fit of the index has been verified, cover the surfaces of the restorations with a thin coating of petrolatum, and apply ZOE registration paste to the occlusal surface of the index. Then seat it in the patient's mouth. As an alternative, impression plaster can be used (see Fig. 29-17, *C*).
5. Make an orientation impression over the index and the restorations with an elastomeric impression material in a stock tray, ensuring that the index is not displaced (see Fig. 29-17, *D*).
6. Make a conventional opposing impression if no restorations were made for that arch. If restorations have been made for both arches, repeat the procedure described for the opposing arch.
7. After an interocclusal record has been obtained, remove the restorations from the mouth, replace the interim restorations, and schedule a remount appointment for the patient.
8. Clean the internal surface of the restorations of all residual cement or debris, reseat the restoration in the index, and apply a thin coating of petrolatum to the intaglio of the crowns.
9. Cover any exposed margins of the restorations with wax or soft lining resin. As an alternative, reversible hydrocolloid impression material can be applied around them with a syringe. Note: Crowns with long retentive axial walls can be partially filled with reversible hydrocolloid to facilitate their subsequent removal.
10. Fill the internal surface of the castings with autopolymerizing resin, adding retention (see Fig. 29-17, *E*). Although type IV stone can be used, difficulty may be encountered retrieving the castings from the model because of the setting expansion of the stone. If stone is to be used, the castings must be lubricated carefully, and special care must be taken to prevent fracture when they are removed.
11. Complete the maxillary cast (see Fig. 29-17, *F*).
12. Use the newly obtained centric relation record at the occlusal vertical dimension and articulate the cast (see Fig. 29-17, *G*).
13. Save the index to verify accuracy after the remount cast is poured.

This completes the remount procedure. The restorations can now be reassessed and adjusted in the dental laboratory. Although a remount procedure is not routinely needed, it may be advantageous when extensive treatment is undertaken to reduce the amount of chair time required for occlusal adjustment.

Ceramic Restorations

During evaluation of ceramic restorations, certain additional steps are necessary to satisfy esthetic, biologic, and mechanical requirements. Achieving an esthetic result depends on the contour of the restoration, surface characterization, and color match.

Contouring

Armamentarium. The equipment needed is shown in Figure 29-18.

- Flexible diamond disk
- Porcelain grinding wheel
- Ceramic-bound stones
- Diamonds

When a restoration that is to be evaluated during the bisque stage is contoured, it should be moistened first with water or saliva. The moist surface reflects light in the same manner as the glazed restoration.

Step-by-Step Procedure

1. Check the proximal contact relationship (adjust as necessary), and verify the marginal fit of the restoration.
2. Verify the contour of the gingival third, and make any necessary adjustments to the emergence profile. Excessive bulk in this area is a common fault and is often associated with periodontal disease (Fig. 29-19). When adjustment of a metal-ceramic restoration is needed, the porcelain and metal should not be ground simultaneously because small metal particles may be transferred to the porcelain, causing discoloration and a black spotty appearance after glazing. If grinding both porcelain and metal simultaneously is absolutely necessary, the direction of grinding should parallel the metal-ceramic junction (Fig. 29-20). A thin, flexible disk provides good access to reduce any overcontoured interproximal area (Fig. 29-21).

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FIGURE 29-17 ■ Remount technique. **A,** A maxillary arch is prepared for metal-ceramic crowns and fixed dental prostheses. **B,** The metal framework is evaluated clinically; a remount procedure is needed. **C,** Impression plaster can be used to register the location of each unit. **D,** The registration is picked up with an elastomeric material. **E,** Restorations are lubricated, and soft lining resin is painted around them. Their internal surfaces are filled with hard resin. Acrylic chips provide retention for the soft resin. Small wood screws are inserted into the hard acrylic, which are also for retention. The remainder of the cast is poured **(F)** and articulated **(G)** in the usual way. (Courtesy Dr. J.H. Bailey.)

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FIGURE 29-18 ■ Armamentarium for porcelain adjustment. **A,** Pink aluminum oxide stones *(left)*. Thin diamond disk *(center)*. Green silicon carbide stones *(right)*. **B,** Shofu Porcelain Adjustment Kit with white aluminum oxide stones *(left)* and silicon carbide impregnated polishers *(right)*. **C,** Brasseler Porcelain Adjustment Kit with diamond impregnated rubber polishers in three grits. *Blue,* Course; *pink,* medium; *grey,* fine.

FIGURE 29-19 ■ **A,** Periodontal disease associated with excessively contoured restorations. **B** and **C,** Teeth reprepared to allow appropriate facial contours. **D,** Correct emergence profile established in restoration. **E,** Clinical adaptation verified. **F,** Note tissue response to new restorations. **G,** Appropriate embrasure form allows plaque control.

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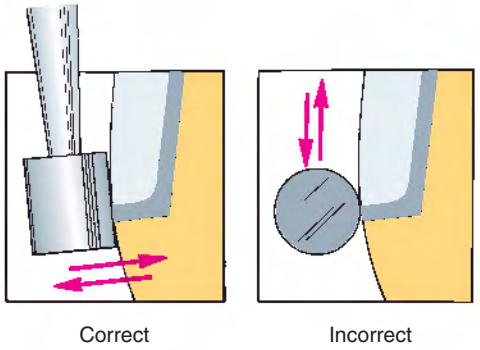

FIGURE 29-20 ■ If it is necessary to grind at the metal-porcelain junction, the stone should be held so that the direction of grinding is parallel to the metal-ceramic junction. Otherwise, metal particles may contaminate the porcelain.

FIGURE 29-22 ■ Typical incisal edge position. (From Monteith BD: A cephalometric method to determine the angulation of the occlusal plane in edentulous patients. J Prosthet Dent 54:81, 1985.)

FIGURE 29-21 ■ Adjusting the interproximal area.

3. Identify and adjust any occlusal interferences on the posterior teeth. Porcelain occlusal contacts may need minor readjustment after glazing because of the pyroplastic flow of porcelain.
4. On anterior teeth, establish the proper position and shape of the incisal edge. This is a key step in achieving good esthetics and function. Unfortunately, achieving proper position and shape are challenging in the laboratory because the soft tissues of the patient's lips and cheeks are not present on the articulator. A solid cast of a well-adjusted interim restoration (made from the diagnostic cast or waxing procedure) helps the technician because it can be duplicated when the restoration is shaped. Alternatively, an optical capture of satisfactory interim restorations may be used as a reference. However, it may be advantageous to evaluate the restoration in the patient's mouth with the incisal edges very slightly longer than intended; their shape should be refined in the mouth.

Excessive adjustment will result in removal of the translucent incisal porcelain, spoiling the esthetics. Incisal edge position is crucial for obtaining good esthetics and function. Specific criteria for what constitutes "normal" are hard to define, but an average of 1 to 2 mm of the clinical crown should be visible on maxillary central and lateral incisors when the upper lip is relaxed. Additional help in contouring the incisal edges can be obtained by looking at the patient's smile and listening to speech characteristics. Ideally, the incisal edges of the maxillary anterior teeth follow the curvature of the lower lip when the patient smiles.[11] Ordinarily, the incisal edges of the lateral incisors (Fig. 29-22) are 0.5 to 2 mm shorter than the central incisors, which may touch the internal border of the lower lip when it is relaxed. This lateral incisor offset is important for natural esthetics[12] and also prevents interference from the mandibular canine during protrusive mandibular movement.

5. Evaluate the *negative space:* the shape of the incisal embrasures[13] (see Chapter 1). Properly shaped embrasures (Fig. 29-23, *A* and *B*) significantly enhance the apparent separation between restorations, whereas their absence draws attention to the prosthesis and reveals its artificial nature (see Fig. 29-23, *C*). Similarly, when viewed from the incisal aspect, interproximal embrasures should be as narrow and deep as possible to enhance the shadows between components of the FDP. If these are absent, even the casual observer will recognize the teeth as artificial.
6. Have the patient enunciate the consonants. *F* sounds are particularly helpful because they are made with the incisal edge of the maxillary central incisors touching at the junction of the moist and dry surfaces of the vermilion border of the lower lip ("wet-dry line").[14]
7. Mark the line angles directly on the porcelain restoration in the bisque stage with a colored pencil, and compare these to the line angles of adjacent and contralateral teeth. Red pencil is preferred because blue or black pencil may discolor the porcelain. Correct line angle delineation is one of the more critical procedures for achieving good esthetics because the line angles define the shape of the tooth to an observer. (Line angles on wax patterns are discussed in Chapter 18.) By superimposing normal line angle distribution over teeth that are otherwise too large or too narrow,[15] creating the

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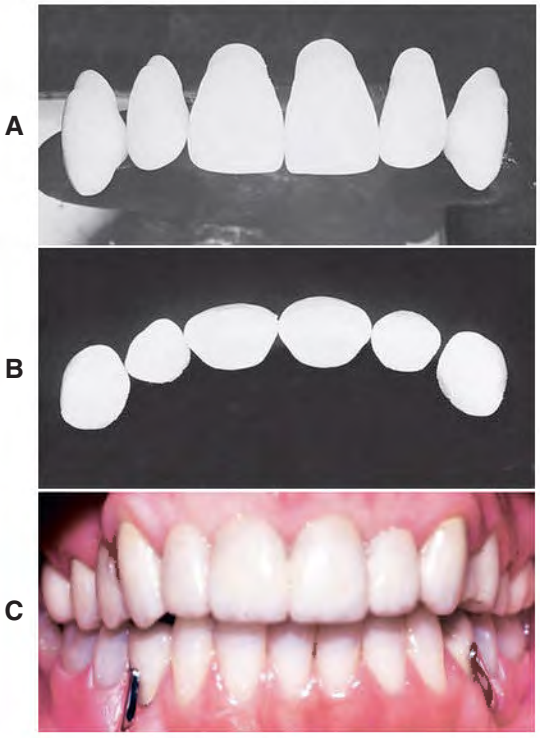

FIGURE 29-23 ■ **A** and **B,** Properly shaped incisal embrasures. **C,** Inadequate embrasures. Note the unnatural look.

FIGURE 29-24 ■ Insufficient mesiodistal space is available for the right maxillary lateral incisor. By creation of an apparent overlap, the pontic is given the illusion of normal anatomic proportions.

impression that the left and right sides are identical is possible (Fig. 29-24; see Chapter 23).

8. Evaluate the overall contour to see that it matches the shape of the adjacent teeth. With experience, most operators quickly develop an appreciation for evaluating "normal" contours and detecting areas that need correction. Moistening the teeth and observing light reflections may help. It also helps to have the patient stand up to be checked at normal conversational distance, as opposed to the extreme closeup of a dental examination.

Anatomically contoured ceramic restorations, including those made with lithium disilicate and zirconia, need special consideration when being evaluated before seating. Any necessary proximal or occlusal adjustment must be followed up by a careful and thorough polishing protocol to prevent the surface from being rough and abrasive. An appropriate finishing protocol for lithium disilicate and zirconia ceramics is presented in Figures 29-25 and 29-26. Note the differences in the final polishing sequence.

Surface Texture Characterization

When the contour of the restoration has been finalized, the next goal is to duplicate the surface detail of the patient's natural teeth.

Armamentarium

- Diamond disk
- Carborundum stones
- Diamond stones

Step-by-Step Procedure

1. Dry the teeth, and examine their surfaces carefully. Perikymata and other defects can be simulated by grinding the porcelain with a diamond stone of appropriate texture. (Be careful not to overemphasize such details.) Flat or concave areas reflect light in a characteristic manner, producing highlights (Fig. 29-27).
2. Copy the details, and carefully blend them to mimic adjacent teeth. In general, the effort should aim at generating textures that follow the principal curvatures of the normal anatomic form of the tooth, in order to result in optimal perception of the characterized surface.
3. Similarly, mimic any vertical defects with careful grinding.
4. Be careful to avoid "overcharacterizing" restorations, which is a common error (Fig. 29-28).

On occasion, altering the apparent size of a restoration by these techniques may be possible. A smooth tooth appears larger than one that is identical in size but has intensive surface texture characterization.

CHARACTERIZATION AND GLAZING

The surface luster or degree of gloss of a porcelain restoration depends on the autoglazing procedure

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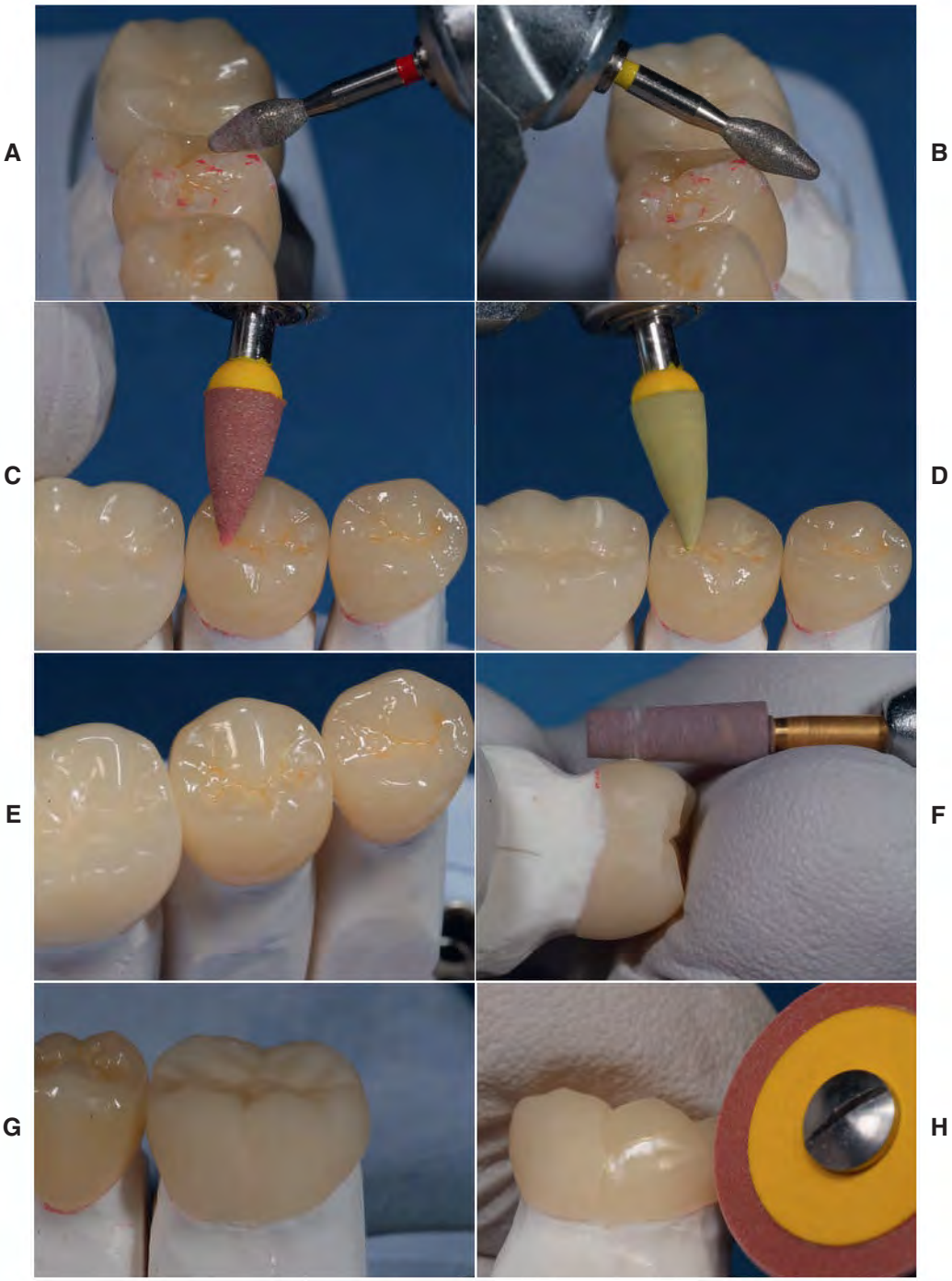

FIGURE 29-25 ■ Finishing protocol for lithium disilicate ceramics. **A,** Intraoral occlusal adjustment of LD2 with red-band fine Dialite finishing diamond 8369DF. **B,** Intraoral occlusal adjustment of LD2 with yellow-band extra-fine Dialite finishing diamond 369DEF. **C,** Intraoral polishing of LD2 with intraoral red medium polishing Dialite LD point W16MLD. **D,** Intraoral fine polishing of LD2 with intraoral yellow fine polishing Dialite LD point W16FLD. **E,** Completely polished LD2 crown with no stain or glaze. **F,** Grinding off positioning sprue with LD Grinder LD13M, which minimizes heat generation. **G,** Devested IPS e.max Press LD crown. Because occlusion can be precisely waxed there is no need to grind-in anatomy. Only polishing is necessary. **H,** Dialite LD red medium polishing wheel R17MLD for establishing shine on lithium disilicate (note right side polished and left side untreated airborne-particle abraded surface).

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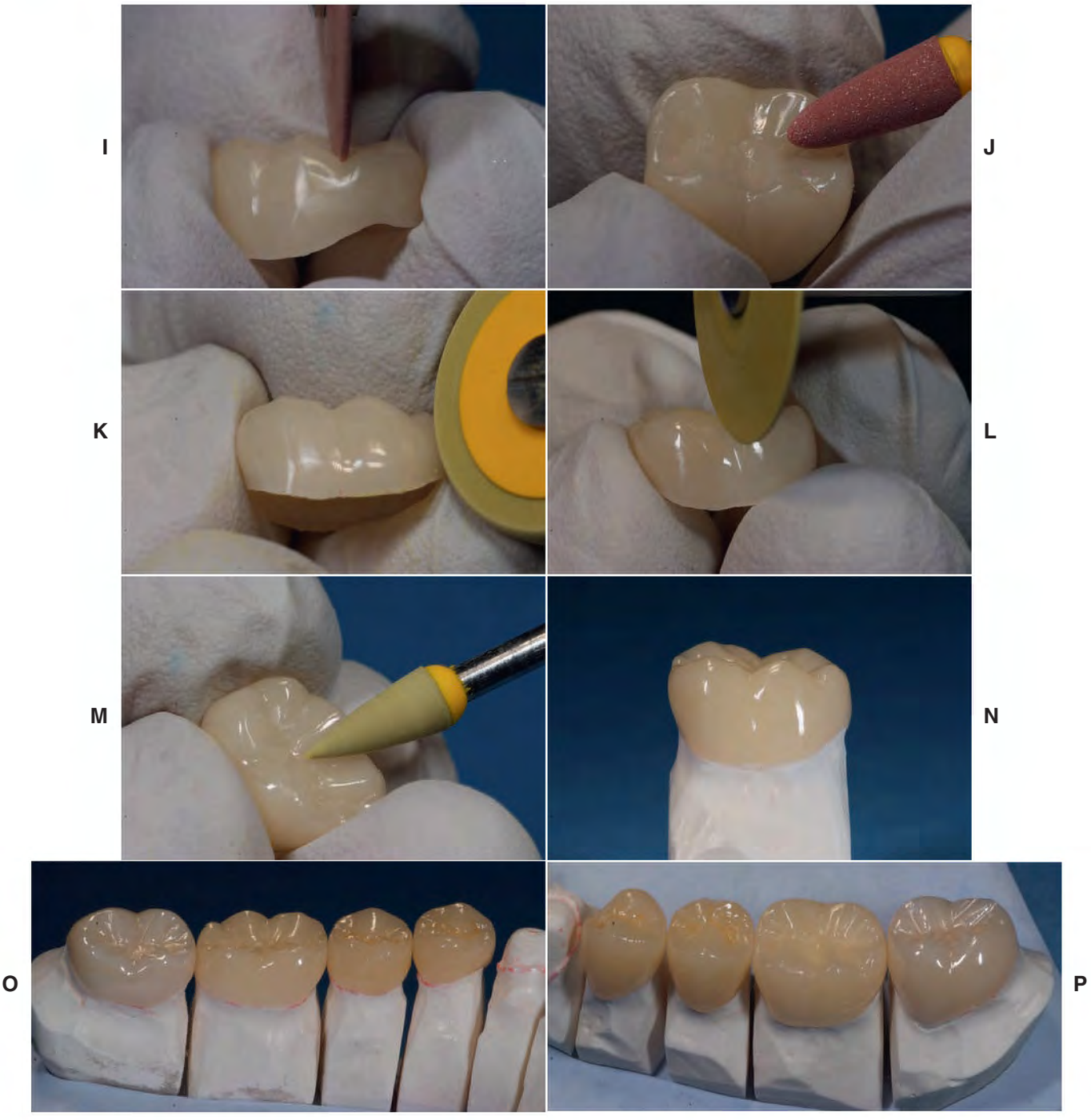

FIGURE 29-25, cont'd ■ **I,** Dialite LD red medium thin polishing disk L20MLD for polishing grooves. **J,** Dialite LD red medium polishing point H2MLD for crafting a shine in the occlusal grooves. **K,** Dialite LD yellow fine polishing wheel R17FLD for establishing high shine and luster on lithium disilicate (note right side with finish polish). **L,** Dialite LD yellow fine thin polish disk L20FLD for polishing grooves. **M,** Dialite LD yellow fine polishing point H2FLD for creating a shine in the occlusal grooves. **N,** Completed lithium disilicate crown only polished with Dialite LD kit and no stain or glaze. **O,** Comparison of LD stain and glazed premolar crowns, Dialite LD kit polished LD 1st molar crown and Dialite ZR polished ZrO_2 2nd molar crown (lingual view). **P,** Comparison of 1st premolar stained and glazed, 2nd premolar and 1st molar polished only. Dialite ZR polished ZrO_2 2nd molar crown (buccal view). (Courtesy Dr J.A. Sorensen.)

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FIGURE 29-26 ■ Finishing protocol for zirconia ceramics. **A,** Adjustment of occlusion on anatomic contour ZrO_2 crown using football-shaped red-band Dialite finishing diamond 8369DF. **B,** Grinding in anatomy of ZrO_2 crown using football-shaped red-band Dialite finishing diamond 8369DF. **C,** Primary and secondary anatomy ground in anatomic contour ZrO_2 crown. **D,** Small round red-band Dialite finishing diamond 8801LDF grinding in grooves and refining secondary anatomy in ZrO_2. **E,** Gross contouring of complete ZrO_2 crown with green coarse LD Grinder LD13C. **F,** Refining adjustment of complete ZrO_2 crown with pink medium LD Grinder LD13M. **G,** Dialite ZR green medium polishing wheel R17MZR for establishing shine on ZrO_2 (note right side with high polish even with Medium Fine polishing only). **H,** Dialite ZR green medium polishing point H2MZR for crafting a shine in the occlusal grooves. **I,** Dialite ZR orange fine polishing point H2FZR for high shine in the occlusal grooves. **J,** Dialite ZR orange fine thin polishing disk L20FZR for high shine in grooves. **K,** Completed polished anatomic contour ZrO_2 crown.

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FIGURE 29-26, cont'd ■ **L,** Completed anatomic contour ZrO_2 crown mandibular second molar and lithium disilicate crowns mandibular first molar and mandibular second premolar with durable high shine and luster (occlusal view). **M,** Completed anatomic contour ZrO_2 cown mandibular second molar and lithium disilicate crowns mandibular first molar and mandibular second premolar with durable high shine and luster (buccal view). **N,** The Lava Plus All-Zirconia Monolithic system achieves esthetic results that match the VITA Shade Guide. **O,** Lava Plus monolithic translucent ZrO_2 crown differentially colored with incisal and dentin internally, then polished with Dialite ZR system (buccal view). **P,** Lava Plus monolithic translucent ZrO_2 crown polished with Dialite ZR system (palatal view). (Courtesy Dr J.A. Sorensen.)

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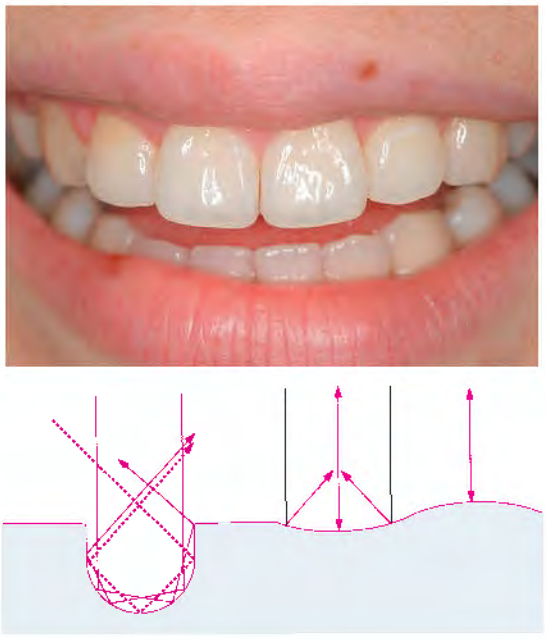

FIGURE 29-27 ■ **A,** Restoration texture should closely match natural enamel. **B,** Sharp grooves should not be cut into the ceramic surface because these "trap" light. A curved surface looks more natural and results in either converging or diverging reflections. (Courtesy Dr. D. Ketteman.)

FIGURE 29-28 ■ The texture of these metal-ceramic units has been overemphasized, which has led to an artificial appearance.

(see Chapter 24). Both time and temperature must be carefully controlled. During the glazing firing, the surface layers of porcelain melt slightly, causing the particles to coalesce and thereby fill in surface defects.

Restorations should not be glazed in a vacuum because included air may be drawn to the surface and result in bubbling (Fig. 29-29). Because air-fired glazing furnaces are relatively compact and inexpensive, some dentists prefer to glaze porcelain restorations in the office. This is particularly convenient if surface stains are to be used. Glazing is straightforward; the degree of glaze depends on furnace temperature and how long the restoration is held at the firing temperature. Excessively glazed anterior teeth look unnatural. During the clinical evaluation, the patient should be instructed to moisten the restoration because saliva affects its appearance. A dry crown looks misleadingly underglazed. However, underglazing and refiring a restoration is better than overglazing it. If a restoration is not sufficiently glazed, it will retain more plaque and may be more liable to fracture. After glazing, the metal surfaces of the restoration, which have oxidized during firing, are polished.

FIGURE 29-29 ■ A bubble that surfaced immediately before the evaluation stage. Such a defect must be addressed before delivery of the prosthesis.

An alternative to glazing is to polish the porcelain surfaces of the restoration.[16] This provides greater control of the surface luster and distribution than glazing.[17] For example, having a higher gloss on the cervical area and a lower gloss on the incisal area is possible. This is not possible with glazing because the entire crown is subjected to the same time-temperature combination.

Polishing dental ceramics has long been advocated as an expedient way of restoring luster after adjusting by grinding. A number of commercially available polishing kits are available for this purpose. If used correctly (i.e., without omitting the successively finer grits), most are capable of producing smooth porcelain surfaces.[18,19] As an alternative, the use of finishing wheels followed by pumice is satisfactory.[20] Ceramists have advocated polishing as a way to improve luster control. To achieve the precise degree and distribution of luster required, the porcelain is polished rather than glazed.

Despite the esthetic advantages of polishing, there is concern whether the strength of a polished restoration might be reduced or its abrasiveness increased. Glazing has been cited as strengthening a dental restoration,[21] presumably because it causes a reduction of the flaws that initiate fracture. However, polishing also reduces flaws, and in laboratory studies, polishing has not been found to reduce physical properties, in comparison with glazing.[22-26] Laboratory studies have shown that polished porcelain is no more abrasive than glazed porcelain.[27] However, unpolished porcelain is much more abrasive on opposing enamel and is more plaque retentive than is polished or glazed porcelain.[28]

External Color Modification and Characterization

Stuart H. Jacobs

The goal of all dental ceramists is to accomplish a perfect color match by using the basic shades supplied in the porcelain kits, without the need for chairside modification.

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FIGURE 29-30 ■ Ney Miniglaze/2 glazing furnace. (Courtesy Dentsply International, York, Pennsylvania.)

However, there are difficulties and inaccuracies inherent in the technique. There are also difficulties in duplicating the appearance of a patient's tooth without the patient's actually being present in the dental laboratory. These problems make perfect shade matching very difficult to achieve routinely. In many situations, a restoration that does not blend well with the adjacent teeth can be improved by simple chairside color modification or characterization procedures.[29] These are done concurrently with final glazing, and it is therefore recommended that restorations be tried in the patient's mouth when contoured but unglazed (at the bisque stage).

Armamentarium

- Porcelain furnace (a small air-fired furnace is suitable for the operatory; Fig. 29-30).
- Clean glass slab
- Sable hair brush
- Distilled water
- Tissue
- Stain kit

A number of stain kits are available from porcelain manufacturers, and most contain a fairly wide range of colors. The stains themselves are highly pigmented surface colorants that contain a small amount of glass, which allow the color to fuse into the porcelain surface. All-ceramic systems generally have dedicated surface colorants that are normally applied by the dental technician in accordance with the dentist's shade prescription. However, some dentists like to apply these surface stains clinically to obtain an improved shade match (Fig. 29-31).

Available characterization kits are illustrated in Figure 29-32. Various colors are available. To make additional colors, the stains can be mixed with each other; the color intensity can also be toned down with a colorless porcelain.

FIGURE 29-31 ■ The appearance of these veneered zirconia crowns has been enhanced with custom staining. (From Freedman G: Contemporary Esthetic Dentistry, St. Louis, 2012, Mosby.)

Step-by-Step Procedure

The application of stain has advantages and disadvantages. One advantage is that the dentist or technician can modify the shade after a restoration is completed, with the patient present. The greatest disadvantage is that the color can be applied only to the surface, and so it is ineffective in producing characterizations that look realistic (i.e., deep within the tooth). Also, excessive surface characterization[30] can cause a loss of fluorescence in the finished restoration and an increase in the metameric effect (shade mismatch is more apparent under some lighting conditions). Furthermore, a characterized crown is slightly rougher than an autoglazed one,[31] and the stain will eventually (in 10 to 12 years) wear away with normal toothbrushing.[32,33]

Three aspects of characterization may be used singly or in combination to achieve a natural appearance: shade modification (increasing the chroma, changing the hue, or reducing the value); specific characterization (e.g., hypocalcified areas or cracks); and special illusions of form or position (Fig. 29-33).

1. Mix the stain with the liquid provided in the kit (normally a glycerin-water mixture) to a creamy, stiff consistency (see Fig. 29-33, *A*). If the mixture is too thin, it runs over the restorations and pools in certain areas. An even coat is essential for producing the best results.
2. Before applying the stain, thoroughly clean the restoration with steam. Apply stain to the restorations with the clean moist sable brush (see Fig. 29-33, *B*). When moist, the brush becomes easier to draw to a point, and application of the stain is greatly facilitated.
3. When the effect has been created, make a note of which stain was used and where. This procedure usually must be duplicated because absolute cleanliness is essential; in addition, placing a unit in the mouth without some contamination is difficult. Removing the restorations without smudging is also challenging.
4. Take the restorations out of the mouth, wash them, and re-create the characterization (see Fig. 29-33, *C* to *E*).
5. After the characterization is complete, transfer the restorations to a firing tray, and place it in front of

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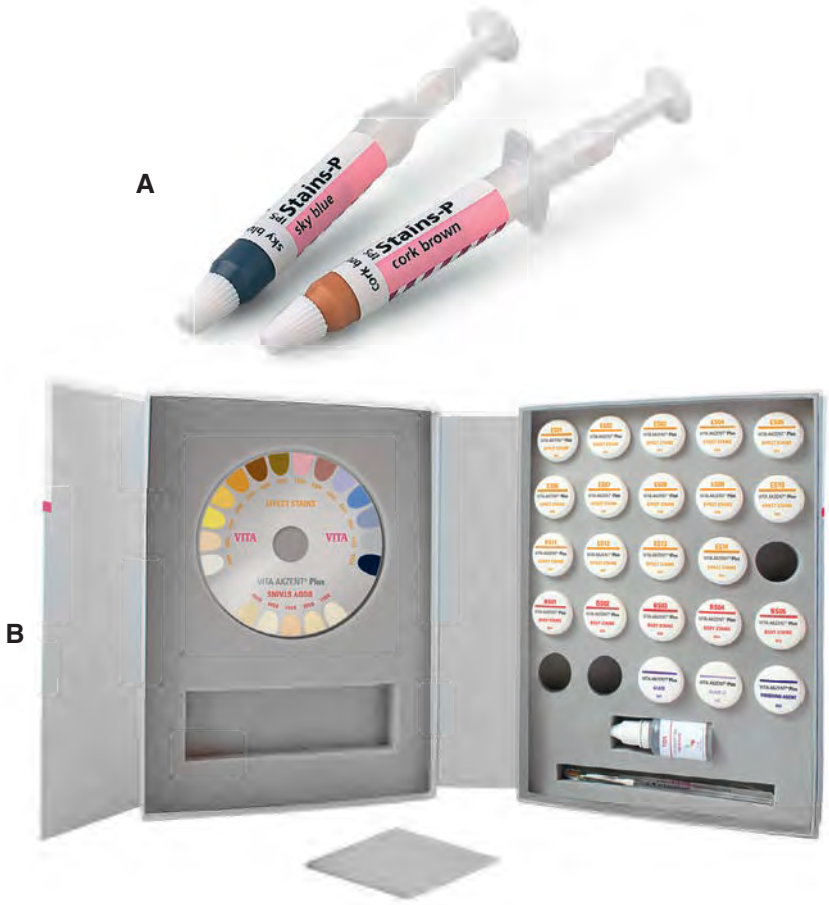

FIGURE 29-32 ■ **A,** Representative IPS stains. **B,** The VITA Akzent Stain Kit. (**A,** Courtesy Ivoclar Vivadent, Amherst, New York; **B,** Courtesy VITA North America, Yorba Linda, California.)

the muffle of the furnace until the stain is dry and the surface appears chalky white (see Fig. 29-33, *F* and *G*).

6. Remove the prosthesis, and examine it to ensure that no stain has run inside.
7. Remove any excess with a dry brush, and place the crown in the furnace.
8. Increase the heat to the maturation temperature of the porcelain, and hold it there according to the degree of glaze desired (see Fig. 29-33, *H*).
9. Remove the restorations, allow them to cool, and reevaluate them in the patient's mouth.

Shade Modification

When a porcelain shade is altered with external stain (see Chapter 23), certain limitations must be considered, particularly because use of surface stains causes a loss of fluorescence and increases the effect of metamerism. It cannot be used to make major corrections or compensate for gross shade mismatches.

When the shade match is evaluated, the appearance of glazed porcelain is necessary. To simulate this appearance, some of the liquid provided in the stain kit is painted onto the porcelain. It may also help to coat the adjacent natural tooth to prevent dehydration during the characterization procedure, which will increase the value of the tooth.

Chroma and Hue Adjustment. Increasing the chroma (saturation) is one of the simplest shade alterations to achieve.[34] The addition of yellow stain increases the chroma of a basically yellow shade, whereas adding orange has the same effect on a yellow-red shade. When an alteration in hue is necessary, pink-purple moves yellow toward yellow-red, whereas yellow decreases the red content of a yellow-red shade. These are the only two modifications that should be necessary because the hue of a natural tooth always lies in the yellow-red to yellow range.

A metal-ceramic restoration that has too high a chroma is difficult to modify. Choosing a shade with a lower chroma is always better because a lower chroma can be altered easily. Using the complementary color of a restoration reduces its chroma: For yellow, purple-blue is used, and for orange, blue or blue-green is necessary. However, the addition of these stains lowers the value of the restoration and increases the metameric effect; it is rarely successful.

Value Adjustment. Value can be reduced by adding a complementary color (see Fig. 23-1). Violet is used on

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FIGURE 29-33 ■ Characterization and glazing technique. **A,** The colored stains are mixed to a stiff consistency on a suitable palette. **B,** Applying the stain. Often the procedure is repeated, or modifications are made after removal from the patient's mouth. **C,** White stain is used to mimic hypocalcification. **D,** Stain with increased chroma is used for proximal coloration. **E,** A thin brown check line is made by painting a line of stain on the porcelain. To reduce this to the desired width, a clean brush is used to wipe on each side of it. **F** and **G,** Stain is dried to a chalky consistency in front of the furnace muffle. **H,** Characterized and glazed restorations after firing. (**A,** Courtesy Dr. G.W. Sheen.)

yellow restorations and has the added effect of increasing apparent translucency. Use of gray stains is not encouraged because it tends to reduce translucency and makes the surface cloudy.

Attempting to increase the value is generally less successful, although value can be increased if the dominant color added has a higher lightness ranking. For example, a crown can be stained with white, but opacity will be greatly increased.

Characterization. Characterization is the art of reproducing natural defects, and it can be particularly successful in making a crown blend with the adjacent natural teeth. In general, defects should be reproduced to a slightly lesser extent on the restoration than as they appear on the natural teeth. The temptation to overcharacterize is strong but must be resisted.

Characterization looks slightly more natural and is more permanent if applied intrinsically during the buildup of the restoration (see Chapter 24) rather than by subsequent extrinsic application.[35] However, communicating the exact characterization needed to the laboratory may be difficult; therefore, copying natural defects at chairside may be more successful.

Hypocalcified Areas. These are produced with white stain and may be some of the easiest and most commonly made modifications.

Proximal Coloration. Many natural teeth exhibit proximal characterization. By reproducing this in the restoration, the dentist is able to create the illusion of depth and separation and is also able to tone down excessive opacity at the cervical area. The stains used are brown and orange. They are applied lightly to the proximal area and extended slightly onto the buccal surface apical to the contact. Proximal coloring is particularly useful in creating the illusion of separate units of an FDP.

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Enamel Cracks. This characterization is better if done intrinsically, although it can be added extrinsically. A linear vertical crack interrupts the light transmission across the tooth surface, causing a shadow. Thus, both the highlight and the shadow of the crack must be simulated for an authentic result.

The highlight is developed with white and yellow mixed in the ratio of 4:1, and gray stain is used for the shadow. A thin line is drawn with a brush in the desired area with the white and yellow stains. Then a thin line of gray is placed distal to the first line to create the illusion of a shadow.

Stained Crack Line. Cracked enamel stains quickly on natural teeth (Fig. 29-34). An orange-brown mixture applied in as thin a line as possible will effectively simulate a crack.

Exposed Incisal Dentin. This is usually seen on the mandibular incisors of older patients and is caused by enamel wear. The incisal edge should be "cupped out," with orange and brown colorants used to reproduce the dentinoenamel junction.

FIGURE 29-34 ■ Thin brown check lines have been added to enhance the appearance of this prosthesis.

Incisal Halo. Translucent incisal edges are more common on the incisors of younger patients. Often, although the incisal area is translucent, the edge is totally opaque. This may be difficult to reproduce internally. A mixture of white and yellow stains in the ratio of 4:1 is placed in the linguoincisal area, with an extension just onto the labial area, to produce the halo effect.

Translucency. Translucency can be mimicked with violet stain, although the results are usually disappointing in comparison with those achieved with correct application of the incisal porcelain. For optimum results, both labial and lingual surfaces should be coated. Decreasing the translucency is accomplished by adding the dominant hue over the labiolingual surface.

Special Illusions. Form and position are undoubtedly the most important factors in achieving an attractive result. However, restoring the original form may not always be possible. Loss of supporting tissue, the size of a pontic space, or a poor occlusal position may impede the attempt.

An FDP pontic may be very long because of loss of supporting bone. Simulating a root surface can partially improve the appearance. The root extension is contoured for length and width, and then an orange-brown mixture is placed over the extension. Pink stain can be used to simulate gingival tissue, but results are better with pink body porcelain.

Recommended characterization procedures are summarized in Table 29-1.

• • •

TABLE 29-1 **Characterization Procedures**

Characteristic	Basic Colors	Ivoclar IPS Stain	VITA Akzent Stain No.
Chroma increase	Yellow and yellow-red	Caramel brown, orange	See Fig. 29-29, *A*
Chroma decrease	Violet and blue-green	Sky blue + basic red, sky blue	See Fig. 29-29, *A*
Hue adjustment	Pink-purple or yellow	Basic red + basic blue, basic yellow	12 (Redwood) + 17 (Niagara), 03 (Sun Kiss)
Value adjustment	Violet and (white)*	Sky blue + basic red, white	See Fig. 29-29 *A*
Hypocalcification	White	White	01 (Birch)
Proximal coloration	Brown and orange	Cork brown, orange	Use increased chroma (see Fig. 29-29, *A*)
Enamel cracks	White-yellow and gray	Bamboo beige	01 (Birch) + 03 (Sun Kiss)
Stained crack line	Orange-brown	Cork brown + orange	01 (Birch) with 13 (Shak)
Exposed incisal dentin	Orange and brown	Orange, cork brown	Use increased chroma (see Fig. 29-29, *A*)
Incisal halo	White-yellow	Bamboo beige	02 (Mellow Yellow)
Translucency	(Violet)*	Sky blue + basic red	13 (Shak)
Cervical staining			
A shades	Orange-browns	A1, A2/A3, A4†	Use increased chroma (see Fig. 29-29, *A*)
B shades	Greenish-browns	B1, B2/B3/B4†	Use increased chroma (see Fig. 29-29, *A*)
C shades	Greenish-browns	C1/C2, C3/C4†	Use increased chroma (see Fig. 29-29, *A*)
D shades	Greenish-browns	D2/D3, D4†	Use increased chroma (see Fig. 29-29, *A*)

*Modification may not be successful.
†IPS Shade V.

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SUMMARY

When a restoration is evaluated in the mouth, the proximal contacts are assessed first, followed by margin integrity, stability, and occlusion. Minor occlusal discrepancies can usually be adjusted intraorally. For extensive prosthodontic treatment, a remount procedure may be needed, which will reduce the chair time needed to achieve an optimum occlusal scheme in the restoration.

With a metal-ceramic restoration, proper contouring of the porcelain in the cervical third is crucial for facilitating maintenance of health of the supporting structures. Proper shaping of the gingival and incisal embrasures, along with contouring and characterization, significantly improves the esthetic result. Small corrections and subtle changes can be made with surface stains. Certain all-ceramic restorations may be luted before final adjustment of the occlusion.

REFERENCES

1. Li YQ, et al: Effect of different grit sizes of diamond rotary instruments for tooth preparation on the retention and adaptation of complete coverage restorations. J Prosthet Dent 107:86, 2012.
2. Kious AR, et al: Film thickness of crown disclosing material and its relevance to cementation. J Prosthet Dent 112:1246, 2014.
3. Byrne G, et al: Casting accuracy of high-palladium alloys. J Prosthet Dent 55:297, 1986.
4. Schilling ER, et al: Marginal gap of crowns made with a phosphate-bonded investment and accelerated casting method. J Prosthet Dent 81:129, 1999.
5. Christensen GJ: Marginal fit of gold inlay castings. J Prosthet Dent 16:297, 1966.
6. Goretti A, et al: A microscopic evaluation of the marginal adaptation of onlays in gold. Schweiz Monatsschr Zahnmed 102:679, 1992.
7. Lofstrom LH, Asgar K: Scanning electron microscopic evaluation of techniques to extend deficient cast gold margins. J Prosthet Dent 55:416, 1986.
8. Eames WB: Movement of gold at cavosurface margins with finishing instruments [Letter]. J Prosthet Dent 56:516, 1986.
9. Hobo S: Distortion of occlusal porcelain during glazing. J Prosthet Dent 47:154, 1982.
10. Huffman RW, Regenos JW: Principles of occlusion, 4th ed. London, Ohio, H & R Press, 1973.
11. Monteith BD: A cephalometric method to determine the angulation of the occlusal plane in edentulous patients. J Prosthet Dent 54:81, 1985.
12. Sharma N, et al: Smile characterization by U.S. white, U.S. Asian Indian, and Indian populations. J Prosthet Dent 107:327, 2012.
13. Matthews TG: The anatomy of a smile. J Prosthet Dent 39:128, 1978.
14. Rahn AO, Heartwell CM: Textbook of complete dentures, 5th ed. Philadelphia, BC Decker, 1993.
15. Blancheri RL: Optical illusion and restorative dentistry. Rev Asoc Dent Mex 8:103, 1950.
16. al-Wahadni A, Martin DM: Glazing and finishing dental porcelain: a literature review. J Can Dent Assoc 64:580, 1998.
17. Hubbard JR: Natural texture and lustre in ceramics. In Preston JD, ed: Perspectives in dental ceramics. Chicago, Quintessence Publishing, 1988.
18. Goldstein GR, et al: Profilometer, SEM, and visual assessment of porcelain polishing methods. J Prosthet Dent 65:627, 1991.
19. Fuzzi M, et al: Scanning electron microscopy and profilometer evaluation of glazed and polished dental porcelain. Int J Prosthodont 9:452, 1996.
20. Newitter DA, et al: An evaluation of adjustment and postadjustment finishing techniques on the surface of porcelain-bonded-to-metal crowns. J Prosthet Dent 48:388, 1982.
21. Binns DB: The physical and chemical properties of dental porcelain. In Yamada HN, ed: Dental porcelain: the state of the art 1977. A compendium of the colloquium held at the University of Southern California School of Dentistry on Feb. 24-26, 1977, p 25. Los Angeles, University of Southern California, 1977.
22. Levy H: Effect of laboratory finishing technics and the mechanical properties of dental ceramic. Inf Dent 69:1039, 1987.
23. Rosenstiel SF, et al: Comparison of glazed and polished dental porcelain. Int J Prosthodont 2:524, 1989.
24. Brackett SE, et al: An evaluation of porcelain strength and the effect of surface treatment. J Prosthet Dent 61:446, 1989.
25. Fairhurst CW, et al: The effect of glaze on porcelain strength. Dent Mater 8:203, 1992.
26. Giordano R, et al: Effect of surface finish on the flexural strength of feldspathic and aluminous dental ceramics. Int J Prosthodont 8:311, 1995.
27. al-Hiyasat AS, et al: The abrasive effect of glazed, unglazed, and polished porcelain on the wear of human enamel, and the influence of carbonated soft drinks on the rate of wear. Int J Prosthodont 10:269, 1997.
28. Preis V, et al: Wear performance of dental ceramics after grinding and polishing treatments. J Mech Behav Biomed Mater 10:13, 2012.
29. Abadie FR: Porcelain surface characterization and staining in the office. J Prosthet Dent 51:181, 1984.
30. Weiner S: Staining porcelain veneer restorations. J Prosthet Dent 44:670, 1980.
31. Cook PA, et al: The effect of superficial colorant and glaze on the surface texture of vacuum-fired porcelain. J Prosthet Dent 51:476, 1984.
32. Aker DA, et al: Toothbrush abrasion of color-corrective porcelain stains applied to porcelain-fused-to-metal restorations. J Prosthet Dent 44:161, 1980.
33. Bativala F, et al: The microscopic appearance and effect of toothbrushing on extrinsically stained metal-ceramic restorations. J Prosthet Dent 57:47, 1987.
34. Lund TW, et al: Spectrophotometric study of the relationship between body porcelain color and applied metallic oxide pigments. J Prosthet Dent 53:790, 1985.
35. Winings JR: A method of making decalcifications in the porcelain build up. J Dent Technol 15:13, 1998.

STUDY QUESTIONS

1. What is the recommended sequence for the clinical evaluation of a gold crown? Why? Which additional steps are necessary for a metal-ceramic restoration?
2. How is a tight proximal contact most effectively identified and corrected?
3. Discuss the addition of a proximal contact for a gold crown and a metal-ceramic crown.
4. What is a remount procedure? Discuss the steps involved.
5. What is the “negative space”?
6. When shade modification is desired, how is chroma increased? What hue adjustments are feasible? How is value adjusted?

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CHAPTER 30

Luting Agents and Cementation Procedures

Luting agents are used to ensure the stability of fixed prostheses throughout their serviceable lifespan. They can be interim luting agents, or definitive luting agents. Definitive luting agents are either water or polymer based.

INTERIM CEMENTATION

On occasion, cementing a restoration on an interim basis may be advised so that the patient and dentist can assess its appearance and function over a time longer than during a single visit. However, such trial cementations should be managed cautiously. On one hand, removing the restoration for definitive cementation may be difficult, even when temporary zinc oxide–eugenol (ZOE) cement is used. To avoid this problem, the interim cement can be mixed with a little petrolatum. The modified luting agent is applied only to the margins of the restoration to seal them and yet allow subsequent removal without difficulty. However, an interim cemented restoration may come loose during function. If a single unit is displaced, it can be embarrassing or uncomfortable for the patient. If one abutment of a partial fixed dental prosthesis (FDP) becomes loose, the consequences can be more severe. If the patient does not return promptly for recementation, caries can develop very rapidly.

Interim cementation should not be undertaken unless the patient is given clear instructions about the objectives of the procedure, the intended duration of the trial cementation, and the importance of returning promptly if an abutment loosens. If removing an interim cemented FDP is difficult, the use of a crown-removal device such as the CORONAflex (KaVo Dental Corporation) or the Crown Tractor (Practicon Inc.; see Chapter 31) is recommended.

DEFINITIVE CEMENTATION

Conventional Cast Restorations

Definitive cementation often does not receive the same attention to detail as do other aspects of restorative dentistry. Careless luting agent selection can result in margin discrepancies and improper occlusion and may even necessitate cutting the restoration from the patient's mouth and making a new one. The choice of luting agent depends first on whether a conventional casting or an adhesively bonded restoration, such as a ceramic inlay or resin-bonded partial FDP, is to be cemented. Traditional water-based dental cements can be used for cast crowns and FDPs, but not where adhesion is needed. Adhesive resins are necessary for some restorations, but, unless the newer self-etch formulations are chosen, they are technique sensitive and can be difficult to use; in addition, long-term data justifying their more general use with conventional cast restorations are limited.

Dental Cements

Most luting agents traditionally used for cast restorations are dental cements (Fig. 30-1). These consist of an acid combined with a metal oxide base to form a salt and water cement. The setting mechanism results from the binding of unreacted powder particles by a matrix of salt to harden the mass. However, because they are ionic, these agents are susceptible to acid attack and are therefore somewhat soluble in oral fluids.[1-4] Traditionally, the success of restorations cemented with these luting agents has been attributed to excellent adaptation between the casting and the prepared tooth. In vitro, however, cement dissolution is independent of the marginal width up to a certain critical value. After that, it increases only slightly, which is explained by Fick's first law of diffusion[5]: The flux of a component of concentration across a membrane of unit area, in a predefined plane, is proportional to the concentration differential across that plane. Dupuis and colleagues,[6] and other researchers, identified dissolution (rather than physical disintegration) as the mechanism for cement erosion. Such helps understand the success of cast restorations, despite the prevalence of relatively large subgingival marginal discrepancies, which are difficult to detect even at 0.1 mm.[7]

Zinc Phosphate Cement

Traditional zinc phosphate cement continues to be used for cast restorations. It has adequate strength, a film (layer) thickness of approximately 25 μm (Fig. 30-2) (which is within the tolerance limits required for making cast restorations),[8] and a reasonable working time. After setting, excess material can be easily removed with a sharp explorer.

The toxic effects of zinc phosphate, or, more specifically, phosphoric acid, are well documented.[9] However, the success of the use of this material over many years suggests that its effect on the dental pulp is clinically acceptable as long as normal precautions are taken and the preparation is not too close to the pulp.

Zinc Polycarboxylate Cement

One advantage of zinc polycarboxylate is its relative biocompatibility,[10] which may stem from the fact that the polyacrylic acid molecule is large and therefore does not

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penetrate into the dentinal tubule. Zinc polycarboxylate cement exhibits specific adhesion to tooth structure because it chelates the calcium (although it has no adhesion to gold castings). Because of its high viscosity, this cement can be difficult to mix, but that problem can be overcome by using encapsulated products (Durelon Maxicap, 3M ESPE Dental).

In clinical trials, polycarboxylate performs as well as or slightly better than zinc phosphate.[11,12] However, dentists have reported varying success rates and inferior long-term retention. These problems may be related to use of an incorrect powder-to-liquid ratio. At manufacturers' recommended powder-to-liquid ratios, mixed polycarboxylate cement is initially quite viscous. Some dentists may prefer a more fluid working consistency for reliable seating during cementation. However, the rheologic or flow properties of polycarboxylate cements are different from those of zinc phosphate; polycarboxylate cements exhibit thinning with increased shear rate.[8] This means that they are capable of forming low film thicknesses despite their viscous appearance. When the dentist unnecessarily reduces the powder-to-liquid ratio, the solubility (how susceptible something is to being dissolved) of the cement increases dramatically (as much as threefold).[13] This may be the cause of increased clinical failures. By fabricating luting agents, including polycarboxylate in encapsulated form, manufacturers have reduced problems arising from manipulative variables.

The working time of polycarboxylate is much shorter than that of zinc phosphate (≈2.5 minutes, in comparison with 5 minutes). This may be a problem when multiple units are being cemented. Residual zinc polycarboxylate is more difficult to remove than zinc phosphate, and there is some evidence[14,15] that it provides less crown retention than zinc phosphate (Fig. 30-3). Its selection therefore should probably be limited to restorations with good retention and resistance form for which minimum pulp irritation is desired, e.g., in children with large pulp chambers. Its use as a base material and to block out minor undercuts in preparations on vital teeth may also be worth considering. Because of a chemical interaction between zinc polycarboxylate and titanium, it is contraindicated when cementing implant crowns on titanium abutments.[16]

FIGURE 30-1 ■ Representative cement-based luting agents.

Glass Ionomer Cement

Glass ionomer cement adheres to enamel and dentin and exhibits good biocompatibility. In addition, because it releases fluoride,[17,18] it may have an anticariogenic effect, although this has not been documented clinically.[19] The set cement is somewhat translucent, which is an advantage when it is used with the porcelain labial margin design (see Chapter 24).

The mechanical properties of glass ionomer cement are generally superior to those of the zinc phosphate or polycarboxylate cements (Fig. 30-4). A disadvantage is that during setting, glass ionomer is particularly susceptible to moisture contamination[20] and should be protected with a foil or resin coat, or a band of cement should

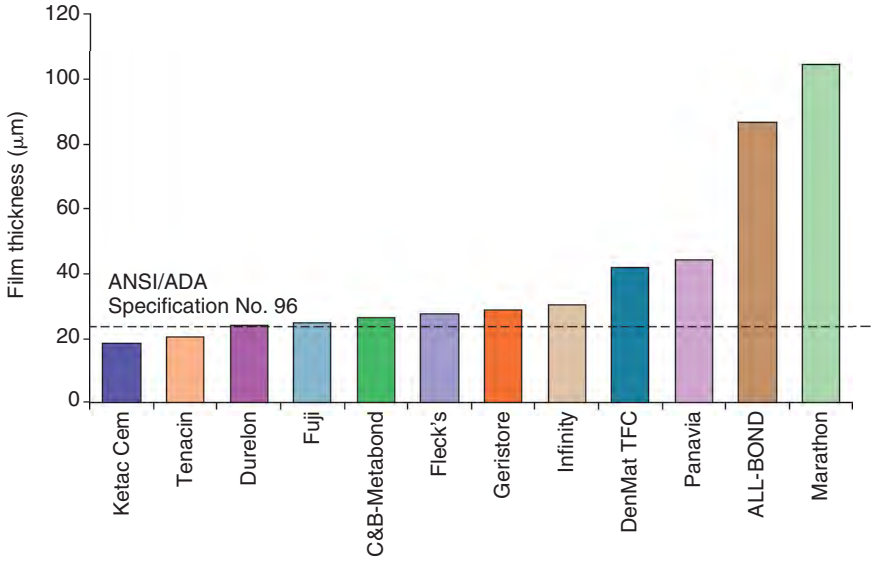

FIGURE 30-2 ■ The film thickness of a range of luting agents was tested according to American Dental Association (ADA) specification No. 8 for zinc phosphate cement (now American National Standards Institute [ANSI]/ADA Specification No. 96) by White and Yu.[57] Some of the adhesive materials possessed unacceptably high film thicknesses, which may translate into clinical problems for complete restoration seating. (From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80: 280, 1998.)

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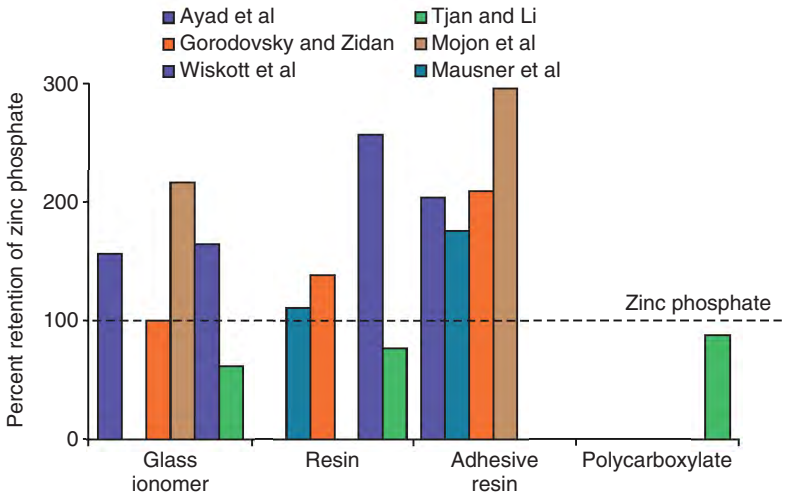

FIGURE 30-3 ■ Crown retention studies: effect of luting agent. In the six in vitro studies cited, researchers evaluated the effect of luting agent on crown retention. The data were normalized as percentages of the retention value with zinc phosphate cement. Adhesive resins had consistently greater retention than did zinc phosphate. Conventional resins and glass ionomers yielded less consistent results. (From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)

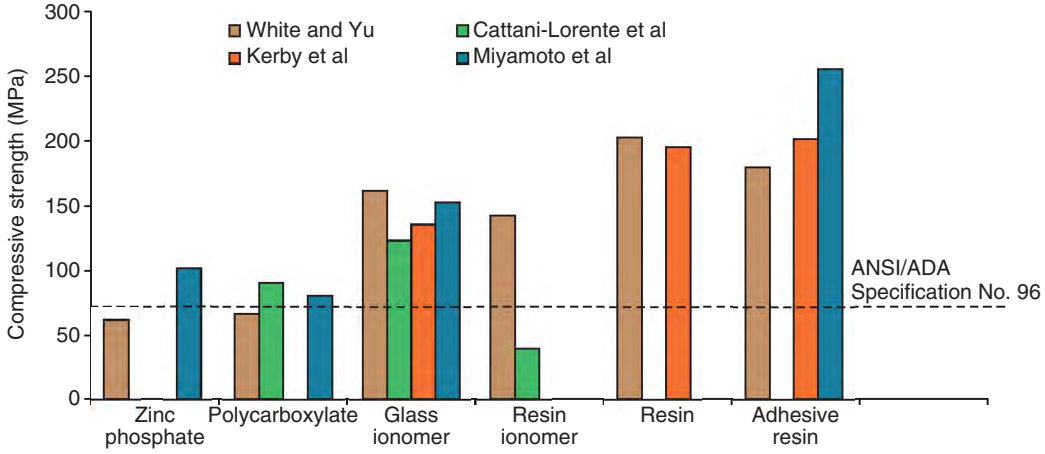

FIGURE 30-4 ■ Compressive strength of luting agents. In the studies cited, higher strength values were reported with the resin cements and glass ionomers than with zinc phosphate or polycarboxylate. Resin-modified glass ionomer exhibited greater variation than did other cements. *ANSI/ADA,* American Dental Association/American National Standards Institute. (From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)

be left undisturbed for 10 minutes.[21] The water changes the setting reaction of the glass ionomer as cement-forming cations are flushed away and water is absorbed, which leads to erosion.[22] However, zinc phosphate has also demonstrated significant early erosion when exposed to moisture.[18] Glass ionomers should not be allowed to desiccate during this critical initial setting period. The newer resin-modified glass ionomers are less susceptible to early moisture exposure.[23]

Although glass ionomers have been reported to cause sensitivity,[24] there appears to be little pulpal response at the histologic level,[25] particularly if the remaining dentin thickness exceeds 1 mm.[26] Side effects such as posttreatment sensitivity thought to result from a lack of biocompatibility may actually be a result of desiccation or bacterial contamination[27] of the dentin rather than irritation by the cement. Anecdotal findings that glass ionomer causes more posttreatment sensitivity have not been replicated in clinical trials. Authors have reported little association between the choice of zinc phosphate or glass ionomer cement and increased pulpal sensitivity, provided that manufacturers' recommendations were followed[28-30] (Fig. 30-5). If postcementation sensitivity becomes a problem, dentists should carefully evaluate their technique, particularly avoiding desiccation of the prepared dentin surface.[31] Resin-modified glass ionomer materials and self-adhesive resins have been reported to provoke less posttreatment sensitivity.[32] A desensitizing agent may prevent sensitivity, although it may also reduce retention, at least with some luting cements.[15,33] Some formulations of glass ionomer and resin cements are radiolucent (Fig. 30-6), which may prevent the practitioner from distinguishing a cement line from recurrent caries, as well as detecting cement overhangs.[34] The use of a glass ionomer luting agents in general practice has been favorable[35]; however, any reduction in caries activity that might be anticipated by the fluoride content has not been demonstrated by clinical research.[36]

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Zinc Oxide–Eugenol with and without Ethoxybenzoic Acid

Reinforced ZOE cement is extremely biocompatible and provides an excellent seal. However, its physical properties are generally inferior to those of other cements, which limits its use.[37] In terms of compressive strength, solubility, and film thickness, another luting agent (e.g., zinc phosphate) should be used. The ethoxybenzoic acid (EBA) modifier replaces a portion of the eugenol in conventional ZOE cement; although the change improves compressive strength without affecting its resistance to deformation; the cement should be used only in restorations with good inherent retention form in which emphasis is on biocompatibility and pulpal protection.

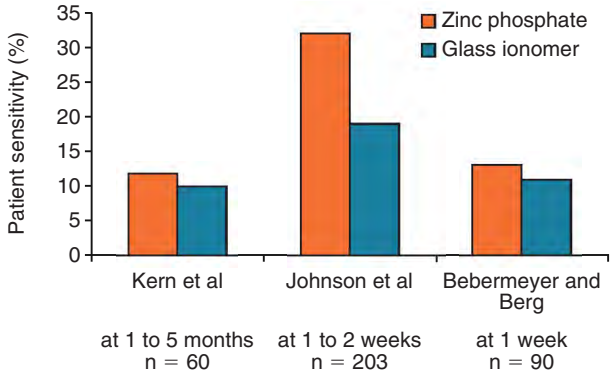

FIGURE 30-5 ■ Postcementation sensitivity of patients with crowns cemented with zinc phosphate or glass ionomer cement, as evaluated in three clinical trials.[28-30] Contrary to anecdotal evidence, patients with glass ionomer–cemented crowns did not exhibit increased postcementation sensitivity. (From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)

The EBA cement has a relatively short working time, and excess material is difficult to remove.

Resin-Modified Glass Ionomer Luting Agents

Resin-modified glass ionomers were introduced in the 1990s in an attempt to combine some of the desirable properties of glass ionomer (i.e., fluoride release and adhesion) with the higher strength and low solubility of resins. (The terminology for some of the newer glass ionomer/resin combinations is rather confusing. In this textbook, the term *resin-modified glass ionomer* has been used. Other terms used for luting agents and restorative materials with a combination of glass ionomer and resin chemistries include *compomer* [mostly composite with some glass ionomer chemistry], *hybrid ionomer* [now considered obsolete], and *resin-reinforced glass ionomer*.) These materials are less susceptible to early moisture exposure[23] than is glass ionomer and are currently among the most popular materials in general practice. Empirically, postcementation sensitivity resulting from their use is minimal. They exhibit higher strength than the conventional cements; strength values are similar to those of the resin luting agents.[38]

Resin Luting Agents

Unfilled resins have been used for cementation since the 1950s. Because of their high polymerization shrinkage and poor biocompatibility, these early products were unsuccessful, although they had very low solubility. Composite resin cements with greatly improved properties were developed for resin-bonded prostheses (see Chapter 26) and are used extensively for the bonded ceramic

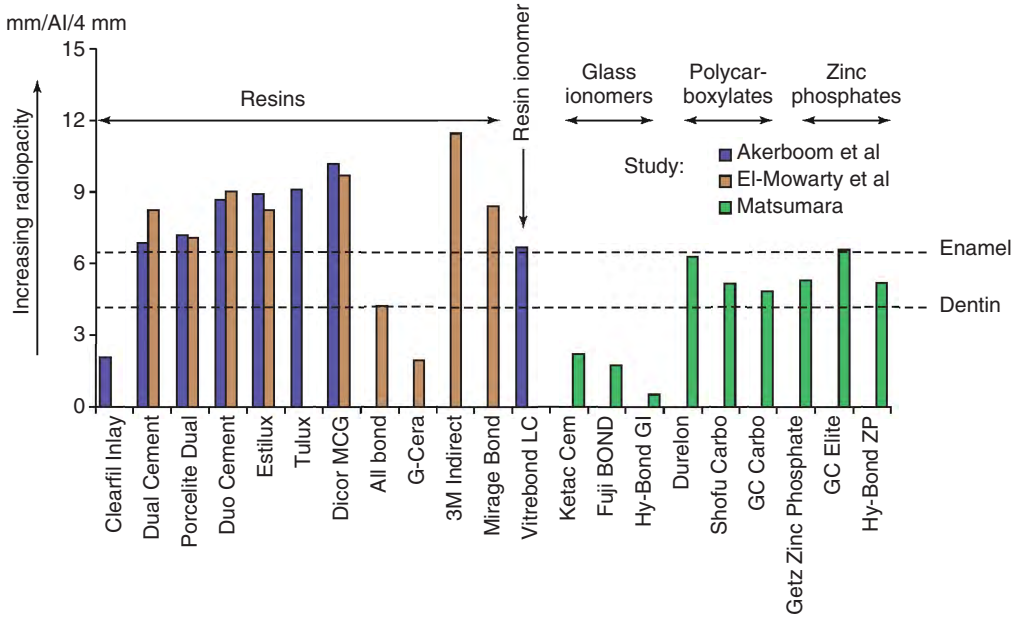

FIGURE 30-6 ■ Radiopacity of luting agents. In three in vitro studies, investigators compared the radiographic appearance of various luting agents to aluminum. The data were normalized to account for different specimen thicknesses used by the investigators. Excess luting agent is more difficult to detect if materials with lower values are chosen. In addition, margin gaps and recurrent caries are more difficult to diagnose. (From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80: 280, 1998.)

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technique (see Chapter 25). Resin cements with adhesive properties (i.e., capable of bonding chemically to dentin) are available.[39] Bonding is usually achieved with organophosphonates, hydroxyethyl methacrylate (HEMA), or 4-methacryloxyethyl trimellitic anhydride (4-META).[40] These developments, and their lack of solubility, have rekindled an interest in the use of resin cements, particularly self-etching systems[41] for crowns and conventional FDPs (Fig. 30-7). Resin luting agents are less biocompatible than cements such as glass ionomer, especially if they are not fully polymerized. The self-adhesive resins have been showed to have the lowest incidence of postcementation sensitivity.[42]

Choice of Luting Agent

An ideal luting agent has a long working time, adheres well to both tooth structure and restorative materials, provides a good seal, is nontoxic to the pulp, has adequate strength properties, is compressible into thin layers, has low viscosity and solubility, and exhibits good working and setting characteristics. In addition, any excess can be easily removed. Unfortunately, no such product exists (Tables 30-1, 30-2, and 30-3).

Zinc Phosphate Cement

Despite its limited biocompatibility in terms of pulp irritation, zinc phosphate has a long history, and its limitations are well documented. This factor is important for cast restorations, which should be designed for long-term service. Zinc phosphate cement remains an excellent choice for luting restorations on otherwise normal, conservatively prepared teeth. Incremental mixing is necessary because exothermic heat, resulting from the chemical reaction, would cause the mix to set too rapidly. Cavity varnish can be used to protect the pulp against irritation by phosphoric acid and appears to have little effect on the amount of retention of the cemented restorations.[43] In addition, crowns cemented with zinc phosphate displayed increased resistance to dislodgment on preparations that lack resistance form.[31]

Zinc Polycarboxylate Cement

Zinc polycarboxylate cement is recommended on retentive preparations when minimal pulp irritation is important (i.e., in children with large pulp chambers).

Glass Ionomer Cement

Glass ionomer cement has become a popular cement for luting cast restorations. It has good working properties and is more translucent than zinc phosphate. The material sets more rapidly than does zinc phosphate cement and is easily mixed.

Resin-Modified Glass Ionomer Luting Agents

Currently among the most popular luting agents, resin-modified glass ionomer luting agents have low solubility, adhesion, and low rates of microleakage (the seepage of

FIGURE 30-7 ■ Representative resin luting agents. **A,** RelyX Unicem 2. **B,** PANAVIA F 2.0. **C,** C&B-Metabond Quick. (**A,** Courtesy 3M ESPE Dental, St. Paul, Minnesota. **B,** Courtesy Kuraray America, Inc., New York, New York. **C,** Courtesy Parkell Inc., Edgewood, New Jersey.)

fluids and microorganisms at the interface between a restoration and the walls of a cavity preparation; Fig. 30-8). The popularity of these materials is derived mainly from the perceived benefit of reduced postcementation sensitivity.[44,45]

Adhesive Resins

Adhesive resin luting agents are indicated for all-ceramic and laboratory-processed composite restorations. Laboratory testing yields high retention strength values,[46]

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TABLE 30-1 Comparison of Available Luting Agents

Property	Ideal Material	Zinc Phosphate	Poly-carboxylate	Glass Ionomer	Resin Ionomer	Composite Resin	Adhesive Resin	Self-Etch Adhesive Resin
Film thickness (μm)*	Low	≤25	<25	<25	>25	>25	>25	>25
Working time (min)	Long	1.5 to 5	1.75 to 2.5	2.3 to 5	2 to 4	3 to 10	0.5 to 5	2 to 2.5
Setting time (min)	Short	5 to 14	6 to 9	6 to 9	2	3 to 7	1 to 15	5 to 6
Compressive strength (MPa) (see Fig. 30-4)	High	62 to 101	67 to 91	122 to 162	40 to 141	194 to 200	179 to 255	195 to 240
Elastic modulus (GPa)†	Dentin = 13.7 Enamel = 84 to 130‡	13.2	Not tested	11.2	Not tested	17	4.5 to 9.8	Not tested
Pulp irritation	Low	Moderate	Low	High	High	High	High	Low
Solubility	Very low	High	High	Low	Very low	High to very high	Very low to low	Very low
Microleakage (see Fig. 30-8)	Very low	High	High to very high	Low to very low	Very low	High to very high	Very low to low	Very low
Ease of removal of excess	Easy	Easy	Medium	Medium	Medium	Medium	Difficult	Difficult
Retention (see Fig. 30-3)	High	Moderate	Low/ moderate	Moderate to high	High§	Moderate	High	Very high

*From White SN, Yu Z: Film thickness of new adhesive luting agents. J Prosthet Dent 67:782, 1992; see also Figure 30-2.
†From Rosenstiel SF, et al: Strength of dental ceramics with adhesive cement coatings. J Dent Res 71:320, 1992.
‡From O'Brien WJ: Dental materials and their selection, 2nd ed, p 351. Chicago, Quintessence Publishing, 1997.
§From Cheylan JM, et al: In vitro push-out strength of seven luting agents to dentin. Int J Prosthodont 15:365, 2002.

TABLE 30-2 Indications for and Contraindications to Luting Agent Types

Restoration	Indication	Contraindication
Cast crown, metal-ceramic crown, partial FDP	1, 2, 3, 4, 5, 6, 7	—
Crown or partial FDP with poor retention	1, 2	3, 4, 5, 6, 7
MCC with porcelain margin	1, 2, 3, 4, 5, 6, 7	—
Casting on patient with history of post-treatment sensitivity	Consider 4 or 7	2
Pressed, high-leucite, ceramic crown	1, 2	3, 4, 5, 6, 7
Slip-cast alumina crown	1, 2, 3, 4, 6, 7	5
Ceramic inlay	1, 2	3, 4, 5, 6, 7
Ceramic veneer	1, 2	3, 4, 5, 6, 7
Resin-retained partial FDP	1, 2	3, 4, 5, 6, 7
Cast post-and-core	1, 2, 3, 5, 6	4, 7

Key

LUTING AGENT TYPE	CHIEF ADVANTAGES	CHIEF CONCERNS	PRECAUTIONS
1. Adhesive resin	Adhesive, low solubility	Film thickness, history of use	Moisture control
2. Self-etch adhesive resin	Low solubility, ease of use, bonding to dentin	Film thickness	Moisture control
3. Glass ionomer	Translucency	Solubility, leakage	Avoid early moisture exposure
4. Reinforced ZOE	Biocompatible	Low strength	Only for very retentive restorations
5. Resin ionomer	Low solubility, low microleakage	Water sorption, history of use	Avoid with ceramic restorations
6. Zinc phosphate	History of use	Solubility, leakage	Use for "traditional" cast restorations
7. Zinc polycarboxylate	Biocompatible	Low strength, solubility	Do not reduce powder-to-liquid ratio

FDP, Fixed dental prosthesis; *MCC,* metal-ceramic crown; *ZOE,* zinc oxide–eugenol.

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TABLE 30-3 Product Information

Cement Products

Conventional (Water-based) Weak Cements

ZINC PHOSPHATE CEMENT	ZINC POLYCARBOXYLATE CEMENT	GLASS-IONOMER CEMENT	RESIN IONOMER CEMENTS*
Fleck's Zinc (Mizzy) Hy-Bond Zinc Phosphate (Shofu) Modern Tenacin (LD Caulk)	Durelon (3M ESPE Dental) Fleck's PCA (Mizzy) Liv Carbo (GC America) Hy-Bond Polycarboxylate (Shofu) Tylok-Plus (LD Caulk)	Fuji I (GC America) Ketac Cem (3M ESPE Dental) CX-Plus (Shofu)	FujiCEM (GC America) RelyX Luting (3M ESPE Dental)

Composite (Resin-based) Strong Cements

DUAL POLYMERIZED (WITH ADHESIVE)	AUTOPOLYMERIZED (WITH ADHESIVE)	LIGHT/DUAL POLYMERIZED (WITH ADHESIVE)	DUAL POLYMERIZED (SELF-ADHESIVE)
Panavia F 2.0 (Kuraray) RelyX ARC (3M ESPE Dental) Duo-Link (Bisco) LinkMax (GC America)	Panavia 21† (Kuraray) C&B-Metabond (Parkell) Multilink† (Ivoclar Vivadent) C&B Cement (Bisco)	Insure (Cosmedent) Nexus 2 (Kerr) Variolink II (Ivoclar Vivadent) Appeal (Ivoclar Vivadent) RelyX Veneer (3M ESPE Dental)	RelyX Unicem† (3M ESPE Dental) MaxCem† (Kerr) MonoCem (Shofu) Dyract CEM† (DENTSPLY)

Ceramic Products

Silica-based Weaker Ceramics (Require Silane Coupler and Resin Cements)

FELDSPATHIC PORCELAINS	LEUCITE-REINFORCED PORCELAINS	LITHIUM DISILICATE GLASS-CERAMICS
Ceramco 3 (DENTSPLY) VITA VMK, Omega 900 (VITA North America) IPS dSIGN (Ivoclar Vivadent) Numerous products for metal veneering	IPS Empress Esthetics (Ivoclar Vivadent) OPC (Pentron) Finess (DENTSPLY) ProCAD, IPS Empress CAD (Ivoclar Vivadent) Cerinate (DenMat)	IPS Empress 2 (Ivoclar Vivadent) G3 (Pentron) IPS e.max CAD (Ivoclar Vivadent)

Non–silica-based Oxides (Stronger Ceramics Can Be Used with Any Cements Except RMGIs)

GLASS-INFILTRATED OXIDES	DENSE SINTERED ALUMINUM OXIDES	DENSE SINTERED ZIRCONIA OXIDES
VITA In-Ceram ALUMINA, VITA In-Ceram ZIRCONIA, VITA In-Ceram SPINELL (VITA North America) Wol-Ceram (Electro Phorectic Ceramic)	NobelProcera (Nobel Biocare)	LAVA (3M ESPE Dental) Cercon (DENTSPLY) IPS e.max ZirCAD (Ivoclar Vivadent) Procera Crown Zirconia (Nobel Biocare) Anatomic-contour zirconia crowns (all brands)

Which Cement Should I Use?

CERAMIC TYPE	SURFACE PREPARATION	COUPLING AGENT	CEMENT TYPE	USES
Silica-based (Weaker)				
Feldspathic porcelain	Hydrofluoric acid etch	Yes (silane)	Composite resin only Adhesive assisted preferred	Veneers, inlays
Leucite-reinforced porcelain	Hydrofluoric acid etch	Yes (silane)	Composite resin only Adhesive assisted preferred	Veneers, inlays, onlays, anterior and premolar crowns
Lithium disilicate glass-ceramics				Anterior and posterior crowns; anterior FPDs (large connectors needed)
Option 1 (preferred)	Hydrofluoric acid etch	Yes (silane)	Composite resin	
Option 2	None	None	Conventional	
Non–silica-based (Stronger)				
Glass-infiltrated oxides				Anterior and posterior crowns; three-unit FPDs
Option 1 (preferred)	None	NA	Composite resin‡	
Option 2 (easiest)	None	NA	Conventional	
Option 3 (limited at laboratories)	Rocatec (silica coat)	Yes (silane)	Composite resin	
Option 4	Air-particle abrasion‖	NA	Composite resin‡	

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TABLE 30-3 **Product Information—cont'd**

Which Cement Should I Use?

CERAMIC TYPE	SURFACE PREPARATION	COUPLING AGENT	CEMENT TYPE	USES
Dense sintered oxides				Anterior and posterior crowns and FDPs
Option 1 (with retentive prep)	Air abrade[‖] or Ivoclean	NA	Composite resin[‡]	Cement clean up can be difficult
Option 2 (with retentive prep)	Same	NA	Conventional	Cement clean up easier
Option 3 (for nonretentive prep)	Same	Metal/zr primer	Composite resin[‡]	Improved cement bond to zirconia
Option 4 (for nonretentive prep)	Rocatec (silka coat)	Yes (silane)	Composite resin	Improved cement bond to zirconia

Courtesy Dr. R.R. Seghi.
FDP, Fixed dental prosthesis; *NA,* not applicable; *RMGI,* resin-modified glass ionomer.
*This category is not recommended for silica-based ceramics; stresses are generated from expansion.
[†]Phosphate ester–modified; best on non–silica-based oxide ceramics.
[‡]Phosphate ester–modified composite resin cements.
[§]Airborne-particle abrasion in general and internal grinding of the ceramic introduces surface flaws (roughness) that can lead to improved bonding but can weaken ceramic.
[‖]In general air abrasion and internal grinding of the ceramic introduces surface flaws (roughness) that can lead to improved bonding but weaken ceramic. Air abrasion on dense sintered zirconia surfaces may not be as detrimental as it can be with other weaker ceramic materials.

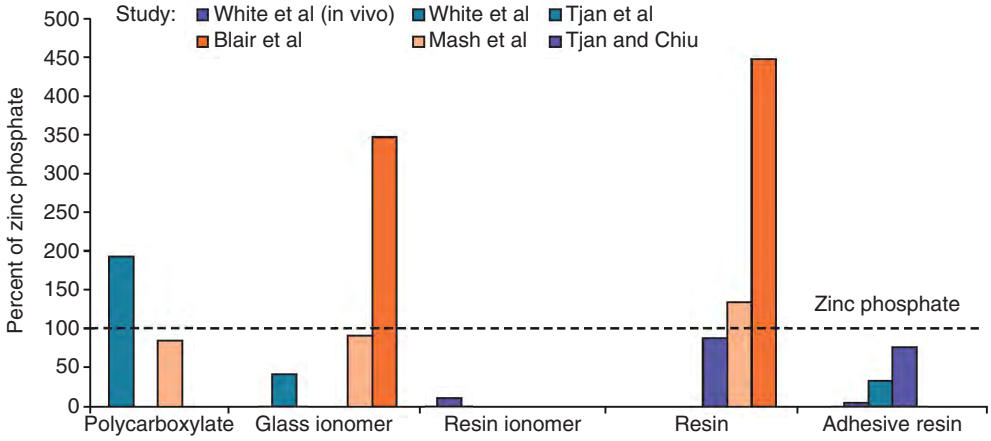

FIGURE 30-8 ■ Microleakage of luting agent. A comparison of data from one clinical study and five laboratory studies, expressed as percentages of the value obtained for zinc phosphate cement. Considerable variation was reported; adhesive resins and resin-modified glass ionomer agents exhibited low microleakage values. (From Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.)

but there is concern that stresses caused by polymerization shrinkage, magnified in thin films,[47] lead to marginal leakage. Adhesive resin may be indicated when a casting has become displaced through lack of retention, and resins are recommended for all-ceramic restorations.[48]

The self-etching systems have become increasingly popular because they combine the simplicity of traditional cements with the reduced solubility of traditional adhesive resins. Patients appear to experience the lowest incidence of post-treatment sensitivity with self-etch resin cements.[42] They also show good bond strength to dentin, which was not affected by storage up to 2 years or mechanical load cycling.[49]

Preparation of the Restoration and Tooth Surface for Cementation

The performance of all luting agents is degraded if the material is contaminated with water, blood, or saliva. Therefore, the restoration and tooth must be carefully cleaned and dried after the evaluation procedure, although excessive drying of the tooth must be avoided to prevent damage to the odontoblasts (Fig. 30-9). Cast restorations are best prepared by airborne-particle abrasion of the fitting surface with 50-µm alumina particles. This should be done carefully to avoid abrading the polished surfaces or margins. Airborne-particle abrasion has increased the in vitro retention of castings by 64%.[50] Alternative cleaning methods include steam cleaning, the use of ultrasonic units, and the use of organic solvents.

Before the selected cement is mixed, the area of cementation must be isolated, and the tooth must be cleaned and dried. However, the tooth should never be excessively desiccated; overdrying the prepared tooth leads to postoperative sensitivity. (The techniques for moisture control, essential to proper cementation, are described in Chapter 14.) If a nonadhesive cement (e.g., zinc phosphate, glass ionomer) is to be used, the tooth should be cleaned, gently dried, and coated with cavity varnish or dentin-bonding resin. (Pumice or a chlorhexidine preparation such as Consepsis [Ultradent Products, Inc.] is recommended.)

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FIGURE 30-9 ■ Teeth and restorations must be carefully prepared immediately before cementation. **A,** These preparations need to be cleaned of interim luting agent and dried but not excessively desiccated. **B** and **C,** A steam cleaner is convenient for removing traces of polishing compound from the restorations. **D** and **E,** Airborne-particle abrasion of internal restoration surface.

Armamentarium

The following equipment is needed (Fig. 30-10):

- Mirror
- Explorer
- Dental floss
- Cotton rolls
- Prophylaxis cup
- Flour of pumice
- Cement
- White stones
- Cuttle disks
- Local anesthetic (if needed)
- Saliva evacuator
- Forceps
- Thick glass slab (chilled)
- Cement spatula
- Gauze squares
- Adhesive foil
- Plastic instrument

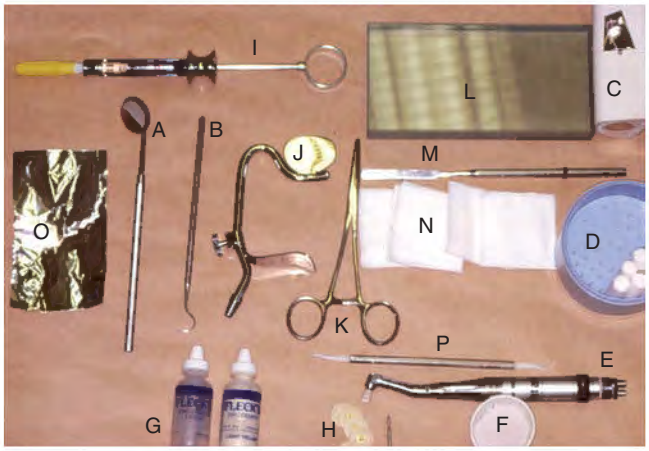

FIGURE 30-10 ■ Armamentarium for definitive cementation. *A,* Mirror; *B,* explorer; *C,* dental floss; *D,* cotton rolls; *E,* prophylaxis cup; *F,* flour of pumice; *G,* cement; *H,* white stones and cuttle disks; *I,* local anesthetic; *J,* saliva evacuator; *K,* forceps; *L,* thick glass slab; *M,* cement spatula; *N,* gauze squares; *O,* adhesive foil; *P,* plastic instrument.

Step-by-Step Procedure

Self-etch resin cement is used to illustrate a typical procedure with ceramic restorations, but the steps may vary

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FIGURE 30-11 ■ Cementation technique with self-adhesive resin. Demonstration of the use of a self-adhesive composite resin cement with alumina core ceramic crowns (NobelProcera, Nobel Biocare, Göteborg, Sweden). Preoperative facial **(A)** and lingual **(B)** views of the teeth 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, Schaumburg, Illinois) being placed into the all-ceramic crown with an automixing tip. **F,** Completed all-ceramic crowns for the maxillary lateral and central incisors. **G,** When a posterior restoration is seated, an orangewood stick is applied with a rocking motion against the restoration to ensure that all excess cement is expressed. (**A** to **F,** From Freedman G: Contemporary esthetic dentistry. St. Louis, Mosby, 2012. **G,** From Campagni WV: The final touch in the delivery of a fixed prosthesis. CDA J 12[2]:21, 1984.)

slightly, depending on the restorations and the cement chosen (Fig. 30-11).

1. Immediately before cementation, inspect all preparation surfaces for cleanliness. Remove any interim luting agent with a pumice wash or hydrogen peroxide. A eugenol-free interim luting agent should be used with resin cements, because eugenol inhibits the polymerization of the resin. Because the restoration-cement interface is where failure occurs when a crown is displaced, the intaglio of the restoration must be clean and prepared to maximize the bond between the restoration surface and the luting agent. Cast metal restorations should be airborne-particle abraded, steam cleaned, or cleaned ultrasonically and washed with alcohol to remove any remaining polishing compound that might interfere with retention of the finished restoration (see Fig. 30-9, *B* to *E*).
2. Isolate the area with cotton rolls and place the saliva evacuator. On occasion, a rubber dam can be used, but only rarely for extracoronal restorations. Avoid using cavity cleaners to aid in drying the preparation, because they may adversely affect pulpal health.
3. Dispense the cement into the clean internal surface of the restoration (see Fig. 30-11, *E*). To extend working time, the cement should be applied to a cool restoration rather than to a warm tooth.

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4. Dry the tooth again with a light blast of air and push the restoration into place (see Fig. 30-11, *F*). The final seating of posterior restorations is achieved by rocking with an orangewood stick until all excess cement has escaped. Seating the restoration firmly with a rocking, dynamic seating force is important (see Fig. 30-11, *G*). Using a static load may cause binding of the restoration and lead to incomplete seating. If the casting is not rocked, increasing the load seems only to increase the binding reaction.[51] Excessive force during seating should be avoided, especially with metal-ceramic or all-ceramic restorations, which may fracture.
5. After the crown is seated, check the margins to verify that the restoration is fully in place. Protect the setting cement from moisture by covering it with an adhesive foil (e.g., Dryfoil, Jelenko Dental Alloys; Heraeus Kulzer, Inc.).
6. When it is fully set, remove excess cement with an explorer. Early cement removal may lead to early moisture exposure at the margins with increased solubility. Some cements, such as polycarboxylate or resin, tend to pull away from the margins if excess cement is removed too early, and the integrity of many contemporary cements is disturbed if finished in the first 24 hours.[52] Dental floss with a small knot in it can be used to remove any irritating residual cement interproximally and from the gingival sulcus. The sulcus should contain no cement. After the excess has been removed, the occlusion can be checked once more with Mylar shim stock.
7. Cements take at least 24 hours to develop their final strength. Therefore, the patient should be cautioned to chew carefully for a day or two.

Resin Luting Agents

Resin luting agents are available in a wide range of formulations. These can be categorized on the basis of polymerization method (chemical-polymerization, light-polymerization, or dual-polymerization), the presence of dentin-bonding mechanisms, and whether they incorporate the acid etchant. A chemically polymerized system is appropriate with metal restorations, whereas a light- or dual-polymerized system is appropriate with ceramics. Resins formulated for cementing conventional castings must have lower film thickness than materials designed for ceramics or orthodontic brackets. However, this may be achieved at the expense of filler particle content and will adversely affect other properties, such as polymerization shrinkage.

Manipulative techniques vary widely, depending on the brand of resin cement. For example, Panavia EX (Kuraray America Inc.) sets very rapidly when air is excluded. The directions call for the material to be spatulated in a thin film. It sets rapidly if piled up on the mixing pad. Another material, C&B-Metabond (Parkell Inc.), is mixed in a ceramic well that must be chilled to prevent premature setting. The self-etching dual polymerizing resin RelyX UniCEM (3M ESPE Dental) is a two-paste system that is delivered in appropriate proportions via a dispensing system or in capsules. Mixing techniques for these materials are illustrated in Figures 30-12 and 30-13.

CEMENTATION PROCEDURES FOR CERAMIC VENEERS AND INLAYS

These restorations rely on resin bonding for retention and strength (Fig. 30-14). The cementation steps are crucial for the restoration's success; careless handling of the resin luting agent may adversely affect their longevity. Bonding is achieved with the following steps:

1. Etching the fitting surface of the ceramic with hydrofluoric acid
2. Applying a silane coupling agent to the ceramic material
3. Etching the enamel with phosphoric acid
4. Applying a resin-bonding agent to etched enamel and silane[53]
5. Seating the restoration with a composite resin luting agent

The etching and silanating steps are described in Chapter 25.

Selection of Resin Luting Agent

Composite resin luting agents are available in a range of formulations. For veneers, a light-polymerized material can be used. For inlays, a chemical-polymerized material is preferred, to ensure maximum polymerization of the resin in the less accessible proximal areas. In clinical testing, restorations luted with chemically polymerized materials have performed better than dual-polymerized luted restorations.[54]

The shade of veneers can be modified by the shade of the luting agent. To facilitate shade selection, color-matched try-in pastes are available from some manufacturers (e.g., NX3 Nexus, Kerr Corporation).

Bonding the Restoration

Armamentarium

The equipment needed is shown in Figure 30-15.

- Mirror
- Explorer
- Periodontal probe
- Rubber dam kit
- Local anesthetic
- Saliva evacuator
- Cotton pliers
- Scalpel
- Curette
- Dental tape
- Mylar strips
- Cotton rolls
- Prophylaxis cup
- Flour of pumice paste

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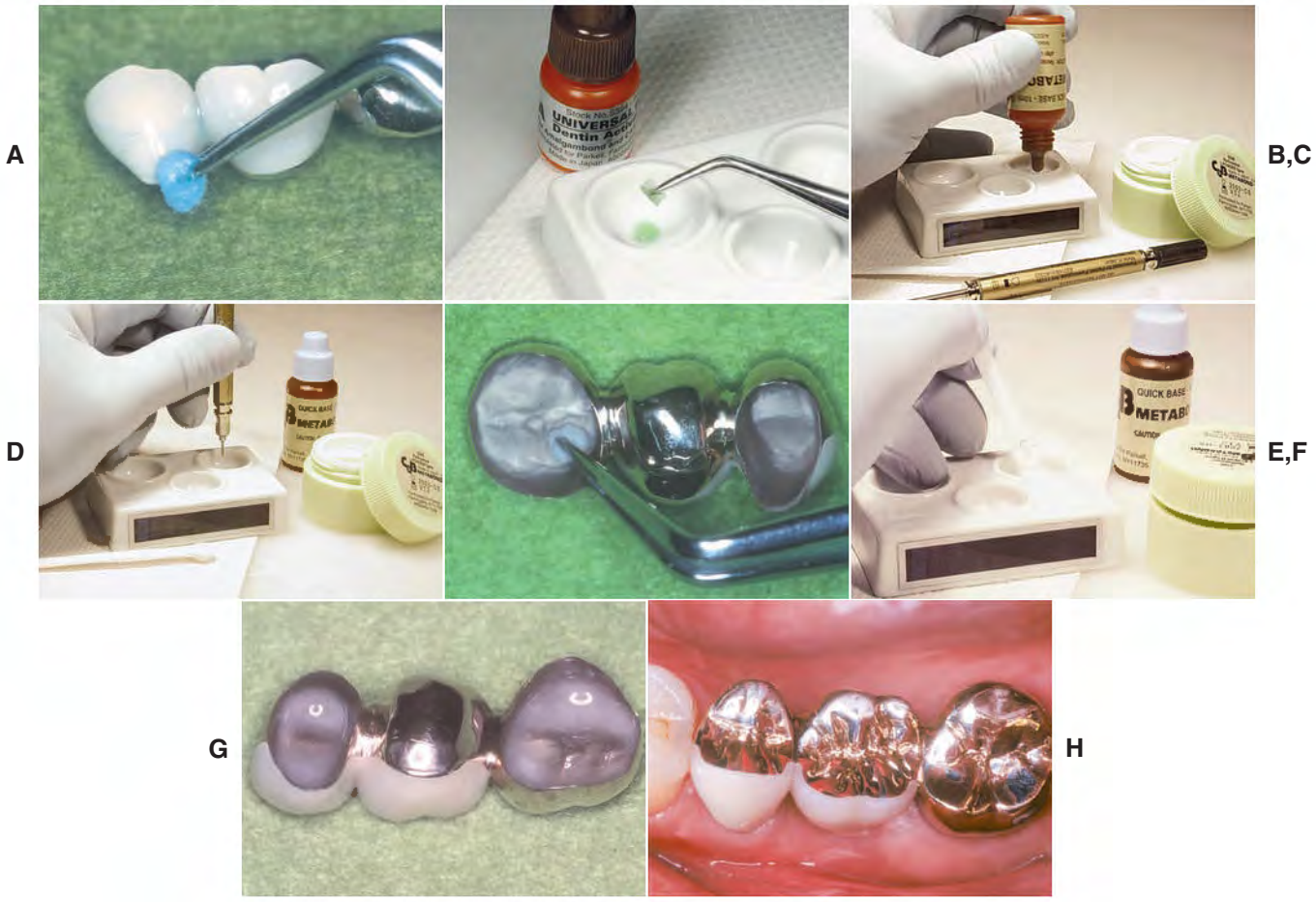

FIGURE 30-12 ■ Cementation with C&B-Metabond resin cement. **A,** The brush-on separating film is applied to the prosthesis, the proximal teeth, in order to prevent the adhesive from bonding where it is not wanted. **B,** The recommended dentin conditioner is applied for 10 seconds and rinsed off, and the tooth is dried. **C** and **D,** Four drops of base and one drop of catalyst are mixed for each crown. After the preparation and interior of the crown are wetted with this mixed liquid **(E),** the powder is added **(F). G,** The casting is painted, and the crown is seated. **H,** Excess resin is removed after it has completely set. Cleanup is greatly facilitated when the separating film is used. It is important not to remove resin before it has fully set because the rubbery material will pull away from the margins. (Courtesy Parkell Inc., Edgewood, New Jersey.)

- Acid etchant
- Porcelain etchant
- Silane coupling agent
- Acetone
- Glycerin or try-in paste
- Bonding agent
- Brush
- Resin luting agent
- Polymerization light
- Fine-grit diamonds
- Porcelain polishing kit

Step-by-Step Procedure

This process is illustrated in Figure 30-16.

1. Remove any interim restorations (see Fig. 30-16, *A*), and clean the teeth with pumice and water (or a chlorhexidine preparation). A luting agent that contains ZOE should be avoided for cementing interim restorations before resin bonding because eugenol inhibits the polymerization of the resin. Cleansing with pumice leaves a ZOE residue mixed with pumice, which can inhibit bonding.[55] Etching with 37% phosphoric acid after cleaning with pumice may be the best way to remove ZOE.[56]
2. Evaluate the restorations with glycerin or a try-in paste (see Fig. 30-16, *B*). Verify fit, shade, and insertion sequence.
3. Clean the restorations thoroughly in water with ultrasonic agitation. Use acetone if luting resin was used to verify the shade at evaluation. (This technique requires care. The restoration should not be exposed to the unit light; otherwise, the resin polymerizes prematurely.) Dry the restorations.
4. Etch and silanate the restorations as described in Chapter 25.

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FIGURE 30-13 ■ **A,** Panavia resin cement. **B,** Measured powder and liquid are spatulated for 60 to 90 seconds. The mix becomes creamier as it is mixed. The cement sets if oxygen is excluded, and so the cement should not be piled up; instead, it should be spread out over a large surface area. **C,** A thin coat of the cement is applied, the restoration is seated, and excess cement is removed. **D,** The cement is coated with oxygen-inhibiting gel to promote polymerization. (Courtesy J. Morita USA, Inc., Irvine, California.)

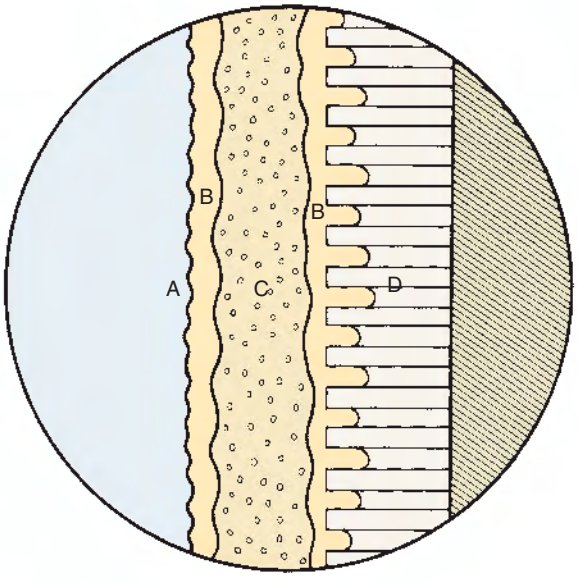

FIGURE 30-14 ■ Schematic of resin-bonding technique. *A,* Ceramic surface (etched and silanated); *B,* unfilled resin; *C,* resin luting agent; *D,* etched enamel.

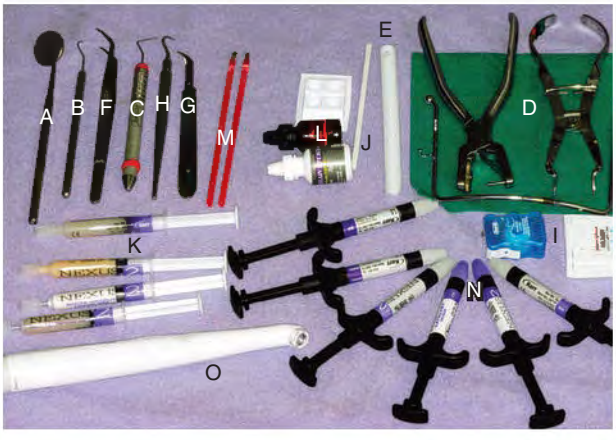

FIGURE 30-15 ■ Armamentarium for bonding procedure. *A,* Mirror. *B,* Explorer. *C,* Periodontal Probe. *D,* Rubber dam kit. *E,* Saliva evacuator. *F,* Cotton pliers. *G,* Scalpel. *H,* Curette. *I,* Dental tape. *J,* Mylar strips. *K,* Try-in paste. *L,* Bonding agent. *M,* Brush. *N,* Resin luting agent. *O,* Polymerization light.

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FIGURE 30-16 ■ **A,** Interim restorations removed. **B,** Evaluating the porcelain veneers. **C,** Matrix bands in place. **D,** Acid etching the enamel. **E,** Rinsing off the etching gel. **F,** Applying the bonding agent. **G,** Air thinning the bonding agent. **H,** Applying the luting composite resin. **I,** Placing the first veneer. **J,** Placing the second veneer.

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FIGURE 30-16, cont'd ■ **K,** Removing excess unpolymerized luting composite resin. **L,** Tack polymerizing each veneer. **M,** Cleaning excess unpolymerized luting composite resin. **N,** Light polymerizing the material to completion. **O,** Removing excess polymerized luting composite resin with a finishing tungsten carbide bur. **P,** Using an polishing cup to remove excess luting composite resin. **Q,** Removing excess luting composite resin on the lingual surface. **R,** Using a diamond strip to finish the interproximal area. **S,** Using an aluminum oxide strip to polish the interproximal area.

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FIGURE 30-16, cont'd ■ **T,** Ten porcelain veneers in place, facial view. **U,** Lateral view of definitive result. **V,** Incisal view of definitive result. **W,** Patient's new smile. (From Freedman G, Contemporary esthetic dentistry, St. Louis, 2012, Mosby.)

5. Isolate the adjacent teeth with matrix bands (see Fig. 30-16, *C*). Acid etch the enamel; 37% phosphoric acid is generally used and is applied for 20 seconds (see Fig. 30-16, *D*). Rinse thoroughly and dry (see Fig. 30-16, *E*).
6. Apply a thin layer of bonding resin to the preparation (see Fig. 30-16, *F* and *G*). Do not polymerize this layer because it might interfere with complete seating.
7. Apply composite resin luting agent to the restoration (see Fig. 30-16, *H*); be especially careful to avoid trapping air.
8. Position the restoration gently (see Fig. 30-16, *I* and *J*), removing excess luting agent with an instrument or a microbrush (see Fig. 30-16, *K*).
9. Hold the restoration in place while briefly tack polymerizing the resin. Do not press on the center of veneers; they may flex and break (see Fig. 30-16, *L*).
10. Use dental tape to remove resin flash from the interproximal margins (see Fig. 30-16, *M*).
11. Complete the polymerization of the luting agent (see Fig. 30-16, *N*). Do not underpolymerize the resin cement. Allow at least 40 seconds for each area.
12. Remove resin flash with a scalpel, sharp curette, or finishing tungsten carbide bur (see Fig. 30-16, *O*).
13. Finish facial margins with a polishing cup (see Fig. 30-16, *P*). Finish the lingual margins with a finishing tungsten carbide bur (see Fig. 30-16, *Q*). Use diamond and aluminum oxide finishing strips to finish and polish the interproximal margins (see Fig. 30-16, *R* and *S*).
14. The completed restorations and the patient's new smile can be seen in Figure 30-16, *T* to *W*).

REVIEW OF TECHNIQUE

Figure 30-17 illustrates the cementation of six maxillary anterior metal-ceramic crowns.

1. The preparations are thoroughly cleaned; the clinician makes sure all interim luting agent is removed (see Fig. 30-17, *A*).
2. The restorations are seated, and a readily accessible area of the margin is examined with an explorer (see Fig. 30-17, *B*); this evaluation provides a reference for complete seating during cementation.
3. The restorations are thoroughly cleaned with airborne-particle abrasion, steam cleaning, or an ultrasonic unit (see Fig. 30-17, *C*).
4. The luting agent is mixed according to the manufacturer's recommendations (see Fig. 30-17, *D*).
5. The restorations are seated to place with a firm rocking pressure (see Fig. 30-17, *E*).
6. The accessible margin area is quickly reexamined to ensure complete seating (see Fig. 30-17, *F*).
7. Once the luting agent has completely set, all excess is removed (see Fig. 30-17, *G* and *H*).

SUMMARY

Proper moisture control is critical for the cementation step. Tooth and restoration must be carefully prepared for cementation; such preparation includes the removal of any residual polishing compounds. Airborne-particle abrasion of the fitting surface is recommended. The selected luting agent is mixed according to the manufacturer's recommendations, and the restoration is seated, with the use of a rocking action. The luting agent must be protected from moisture during its initial set. Removal

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FIGURE 30-17 ■ Technique review. **A,** The preparations are thoroughly cleaned; all interim luting agent should be removed. **B,** The restorations are seated, and a readily accessible area of the margin is examined with an explorer. **C,** The restorations are thoroughly cleaned with airborne-particle abrasion, steam cleaning, or an ultrasonic unit. **D,** The luting agent is mixed according to the manufacturer's recommendations. **E,** The restorations are seated to place with a firm rocking pressure. **F,** The accessible margin area is quickly reexamined to ensure complete seating. **G** and **H,** Once the luting agent has completely set, all excess is removed.

of excess luting agent from the gingival sulcus is crucial for continued periodontal health.

Additional steps are necessary for adhesively bonded restorations. These steps must be carefully sequenced and timed, in accordance with the manufacturer's directions.

REFERENCES

1. Swartz ML, et al: In vitro degradation of cements: a comparison of three test methods. J Prosthet Dent 62:17, 1989.
2. Stannard JG, Sornkul E: Demineralization resistance and tensile bond strength of four luting agents after acid attack. Int J Prosthodont 2:467, 1989.
3. Dewald JP, et al: Evaluation of the interactions between amalgam, cement and gold castings. J Dent 20:121, 1992.
4. Knibbs PJ, Walls AW: A laboratory and clinical evaluation of three dental luting cements. J Oral Rehabil 16:467, 1989.
5. Jacobs MS, Windeler AS: An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent 65:436, 1991.
6. Dupuis V, et al: Solubility and disintegration of zinc phosphate cement. Biomaterials 13:467, 1992.
7. Dedmon HW: Ability to evaluate nonvisible margins with an explorer. Oper Dent 10:6, 1985.
8. Anusavice KJ, et al: Phillips' science of dental materials, 12th ed, St. Louis, Elsevier, 2013.
9. Langeland K, Langeland LK: Pulp reactions to crown preparation, impression, temporary crown fixation, and permanent cementation. J Prosthet Dent 15:129, 1965.
10. Going RE, Mitchem JC: Cements for permanent luting: a summarizing review. J Am Dent Assoc 91:107, 1975.
11. Dahl BL, et al: Clinical study of two luting cements used on student-treated patients: final report. Dent Mater 2:269, 1986.
12. Black SM, Charlton G: Survival of crowns and bridges related to luting cements. Restorative Dent 6:26, 1990.
13. Osborne JW, Wolff MS: The effect of powder/liquid ratio on the in vivo solubility of polycarboxylate cement. J Prosthet Dent 66:49, 1991.
14. Øilo G, Jørgensen KD: The influence of surface roughness on the retentive ability of two dental luting cements. J Oral Rehabil 5:377, 1978.
15. Mausner IK, et al: Effect of two dentinal desensitizing agents on retention of complete cast coping using four cements. J Prosthet Dent 75:129, 1996.
16. Wadhwani C, Chung K-H: Bond Strength and interactions of machined titanium-based alloy with dental cements. J Prosthet Dent, In Press.

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17. Swartz ML, et al: Long-term F release from glass ionomer cements. J Dent Res 63:158, 1984.
18. Muzynski BL, et al: Fluoride release from glass ionomers used as luting agents. J Prosthet Dent 60:41, 1988.
19. Rosenstiel SF, et al: Dental luting agents: a review of the current literature. J Prosthet Dent 80:280, 1998.
20. Um CM, Øilo G: The effect of early water contact on glass-ionomer cements. Quintessence Int 23:209, 1992.
21. Curtis SR, et al: Early erosion of glass-ionomer cement at crown margins. Int J Prosthodont 6:553, 1993.
22. McLean JW: Glass-ionomer cements. Br Dent J 164:293, 1988.
23. Cho E, et al: Moisture susceptibility of resin-modified glass-ionomer materials. Quintessence Int 26:351, 1995.
24. Council on Dental Materials, Instruments, and Equipment, American Dental Association: Reported sensitivity to glass ionomer luting cements. J Am Dent Assoc 109:476, 1984.
25. Heys RJ, et al: An evaluation of a glass ionomer luting agent: pulpal histological response. J Am Dent Assoc 114:607, 1987.
26. Pameijer CH, et al: Biocompatibility of a glass ionomer luting agent. II. Crown cementation. Am J Dent 4:134, 1991.
27. Torstenson B: Pulpal reaction to a dental adhesive in deep human cavities. Endod Dent Traumatol 11:172, 1995.
28. Johnson GH, et al: Evaluation and control of post-cementation pulpal sensitivity: zinc phosphate and glass ionomer luting cements. J Am Dent Assoc 124:38, 1993.
29. Bebermeyer RD, Berg JH: Comparison of patient-perceived post-cementation sensitivity with glass-ionomer and zinc phosphate cements. Quintessence Int 25:209, 1994.
30. Kern M, et al: Clinical comparison of postoperative sensitivity for a glass ionomer and a zinc phosphate luting cement. J Prosthet Dent 75:159, 1996.
31. Rosenstiel SF, Rashid RG: Postcementation hypersensitivity: scientific data versus dentists' perceptions. J Prosthodont 12:73, 2003.
32. Chandrasekhar V: Post cementation sensitivity evaluation of glass Ionomer, zinc phosphate and resin modified glass Ionomer luting cements under class II inlays: An in vivo comparative study. J Conserv Dent 13:23, 2010.
33. Pameijer CH, et al: Influence of low-viscosity liners on the retention of three luting materials. Int J Periodontics Restorative Dent 12:195, 1992.
34. Goshima T, Goshima Y: Radiographic detection of recurrent carious lesions associated with composite restorations. Oral Surg 70:236, 1990.
35. Brackett WW, Metz JE: Performance of a glass ionomer luting cement over 5 years in a general practice. J Prosthet Dent 67:59, 1992.
36. Moura JS, et al: Effect of luting cement on dental biofilm composition and secondary caries around metallic restorations in situ. Oper Dent 29:509, 2004.
37. Silvey RG, Myers GE: Clinical study of dental cements. VI. A study of zinc phosphate, EBA-reinforced zinc oxide eugenol and polyacrylic acid cements as luting agents in fixed prostheses. J Dent Res 56:1215, 1977.
38. Piwowarczyk A, et al: Laboratory strength of glass ionomer cement, compomers, and resin composites. J Prosthodont 11:86, 2002.
39. Cheylan J-M, et al: In vitro push-out strength of seven luting agents to dentin. Int J Prosthodont 15:365, 2002.
40. Anusavice KJ, et al: Phillips' science of dental materials, 12th ed. St. Louis, Elsevier, 2013.
41. Swift EJ Jr, Cloe BC: Shear bond strength of new enamel etchants. Am J Dent 6:162, 1993.
42. Blatz MB et al: Postoperative tooth sensitivity with a new self-adhesive resin cement—a randomized clinical trial. Clin Oral Investig 17:793, 2013.
43. Felton DA, et al: Effect of cavity varnish on retention of cemented cast crowns. J Prosthet Dent 57:411, 1987.
44. Hilton T, et al: A clinical comparison of two cements for levels of post-operative sensitivity in a practice-based setting. Oper Dent 29:241, 2004.
45. Chandrasekhar V: Post cementation sensitivity evaluation of glass Ionomer, zinc phosphate and resin modified glass Ionomer luting cements under class II inlays: an in vivo comparative study. J Conserv Dent 13:23, 2010.
46. Tjan AHL, Tao L: Seating and retention of complete crowns with a new adhesive resin cement. J Prosthet Dent 67:478, 1992.
47. Feilzer AJ, et al: Setting stress in composite resin in relation to configuration of the restoration. J Dent Res 66:636, 1987.
48. Malament KA, Socransky SS: Survival of Dicor glass-ceramic dental restorations over 16 years. Part III: effect of luting agent and tooth or tooth-substitute core structure. J Prosthet Dent 86:511, 2001.
49. Aguiar TR, et al: Effect of storage times and mechanical load cycling on dentin bond strength of conventional and self-adhesive resin luting cements. J Prosthet Dent 111:404, 2013.
50. O'Connor RP, et al: Effect of internal microblasting on retention of cemented cast crowns. J Prosthet Dent 64:557, 1990.
51. Rosenstiel SF, Gegauff AG: Improving the cementation of complete cast crowns: a comparison of static and dynamic seating methods. J Am Dent Assoc 117:845, 1988.
52. Irie M, et al: Marginal and flexural integrity of three classes of luting cement, with early finishing and water storage. Dent Mater 20:3, 2004.
53. Della Bona A, et al: Effect of ceramic surface treatment on tensile bond strength to a resin cemen. Int J Prosthodont 15:248, 2002.
54. Sjögren G, et al: A 10-year prospective evaluation of CAD/CAM-manufactured (Cerec) ceramic inlays cemented with a chemically cured or dual-cured resin composite. Int J Prosthodont 17:241, 2004.
55. Mojon P, et al: A comparison of two methods for removing zinc oxide–eugenol provisional cement. Int J Prosthodont 5:78, 1992.
56. Schwartz R, et al: Effect of a ZOE temporary cement on the bond strength of a resin luting cement. Am J Dent 3:28, 1990.
57. White SN, Yu Z: Film thickness of new adhesive luting agents. J Prosthet Dent 67:782, 1992.

STUDY QUESTIONS

1. Discuss the principal differences in chemistry, physical properties, and manipulative variables for three different types of luting agents. How do the differences affect their clinically indicated use?

2. What are properties of the "ideal" luting agent?

3. Compare the recommended technique for mixing zinc phosphate cement with that for mixing Panavia EX.

4. Describe how the tooth and the restoration are prepared before a metal-ceramic crown is cemented with glass ionomer cement. How does this change when a different luting agent is selected?

5. Discuss the steps involved in cementation of two laminate veneers on the maxillary central incisors.

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CHAPTER 31

Postoperative Care

After placement and cementation of a fixed dental prosthesis (FDP), patient treatment continues with a carefully structured sequence of postoperative appointments designed to monitor the patient's dental health (Fig. 31-1), ensure meticulous plaque control habits, identify any incipient disease, and introduce any corrective treatment that may be needed before irreversible future damage occurs.

Patients should be instructed in special plaque-control measures, especially around pontics and connectors, and the use of special oral hygiene aids such as floss threaders (Fig. 31-2). If pontics are properly designed (see Chapter 20), floss can be looped through the embrasure spaces on each side, and the loop can be pulled tightly against the convex pontic tissue surface. A sliding motion is then used to remove dental plaque (Fig. 31-3). Flossing under pontics is essential for improving prosthesis longevity. When dental floss is used, the mucosa beneath pontics remains healthy; without its use, mild or moderate inflammation results.[1] Tissue response has been shown to be independent of the pontic material.[2]

Recall examinations are especially important for patients with extensive restorations and should be carried out by the dentist. Responsibility for follow-up care should not be delegated to auxiliary personnel (although good cooperation with a dental hygienist is beneficial for success).

Detecting disease around an FDP can be extremely difficult at a stage when corrective treatment is still relatively simple. For instance, partial dissolution of the luting agent may be difficult to diagnose with a subgingival margin. Caries is often detected only after irreversible pulp involvement has resulted. Caries under a crown is more difficult to detect radiographically, although bitewing images provide some interproximal information. Follow-up studies on patients with FDPs reveal that identifying risk factors and predicting the development of caries in any particular patient are complicated. However, there is no indication that caries is more likely to occur in association with prostheses than on unrestored teeth.[3]

If caries is overlooked, disease may rapidly progress to the point at which the fabrication of a new prosthesis becomes inevitable or, even worse, tooth loss results.

POSTCEMENTATION APPOINTMENTS

To enable the dentist to monitor the function and comfort of the prosthesis and to verify that the patient has mastered proper plaque control (Fig. 31-4), an appointment is generally scheduled within a week to 10 days after the cementation of an FDP. The dentist should check carefully that the gingival sulcus is clear of any residual luting agent that may have been overlooked previously and that all aspects of the occlusion remain satisfactory.

Radiolucent cements should be avoided because detecting excess luting agent radiographically is impossible if that material is effectively radiolucent. With luting agents of greater radiopacity, excess cement is spotted more easily on routine radiographs; therefore, the dentist should choose a luting agent that is as radiopaque as possible. In practice, luting agents are available in a wide range of radiopacities.[4-6] Figure 31-5 summarizes data from these studies.

The presence of fremitus (see Chapter 1), or "polished" facets, on the occluding surfaces of cast restorations at the postcementation appointment should prompt a careful reassessment and correction of the occlusion. If any minor shift in tooth position has occurred, some occlusal adjustment may be necessary. If so, the patient is rescheduled to visit the following week to confirm that no further correction is needed.

PERIODIC RECALL

Patients with cast restorations should attend recall visits at least every 6 months. If recall is less frequent, recurrent caries or the development of periodontal disease may go undetected. Patients who have been provided with extensive FDPs (Fig. 31-6) need more frequent recall appointments, particularly when advanced periodontal disease is present. The restorative dentist or the periodontist can coordinate these appointments. To ensure treatment continuity, it is imperative to establish in advance who will assume primary responsibility for coordinating recall appointments.

History and General Examination

The patient's medical history should be reviewed and updated at least annually. The patient should be examined according to the principles introduced in Chapter 1. Particular attention is paid to the soft tissues because early signs of oral cancer may be detected at a recall appointment.

Oral Hygiene, Diet, and Saliva

Patients tend to become somewhat less diligent in their plaque control efforts when the active phase of their treatment is completed. The dentist should look carefully for any signs of deterioration in oral hygiene and assess the general effectiveness of plaque control at every recall with an objective index (Fig. 31-7). Deficiencies must be identified early, and corrective therapy should be initiated. The dentist should ask about changes in diet,

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FIGURE 31-1 ■ Treatment after placement of multiple restorations. To ensure tissue health and long-term success, proper oral hygiene is mandatory.

FIGURE 31-2 ■ Oral hygiene aids designed to maintain partial fixed dental prostheses.

FIGURE 31-3 ■ The patient should be instructed in the use of floss to clean partial fixed dental prostheses.

particularly increased sugar consumption or "fad" diets. Excessive weight loss or gain should also be investigated. For instance, a patient who has recently stopped smoking may start ingesting large amounts of candy, which can result in an increase in dental caries.

FIGURE 31-4 ■ Postcementation monitoring of plaque control is necessary around recently cemented restorations. In this patient, poor oral hygiene has led to gingival inflammation *(arrows)*.

Saliva plays an important role in caries development. Patients with xerostomia can rapidly develop extensive carious lesions.[7] Diagnosing the cause of reduced saliva is imperative; the origin is often a drug side effect.[8] Patients with dry mouth should be on a more frequent recall schedule (e.g., every 3 months), and fluoride varnish may be applied. A protocol of a chlorhexidine 0.12% 10-mL rinse for 1 minute daily for one week each month, in combination with xylitol gum or candies and high-fluoride toothpaste, has been advocated.[9]

Dental Caries

Dental caries (Fig. 31-8) is the most common cause of failure of a cast restoration.[10-13] Detection can be very difficult,[14] particularly where complete coverage is used. At each appointment, the teeth should be thoroughly dried and visually inspected (Fig. 31-9). The explorer must be used very carefully when early enamel lesions are assessed because a heavy-handed examination may damage the fragile demineralized enamel matrix. An intact enamel matrix is essential for procedures that induce remineralization[15] (e.g., improved plaque control, dietary changes, topical fluoride applications).

Conservative treatment of caries at the cavosurface margin is especially problematic. The lesion can spread rapidly, particularly if the restoration has a suboptimal marginal fit. Use of a small restoration made with amalgam, composite resin, or glass ionomer sometimes corrects the problem (Fig. 31-10). If the cast restoration is supported by an amalgam or composite resin core, the extent of the caries may be difficult to determine. When there is doubt that all carious dentin has been removed, replacing the entire restoration is recommended.

Root Caries

Caries of exposed root surfaces (Fig. 31-11) can be a severe problem in patients older than 50 (the age group of patients who most commonly seek fixed prosthodontic care).[16-18] In the classic Vipeholm study,[19] root caries accounted for more than 50% of new lesions in patients in that age group. Root caries incidence increased considerably with age.[20] In the caries examination from phase

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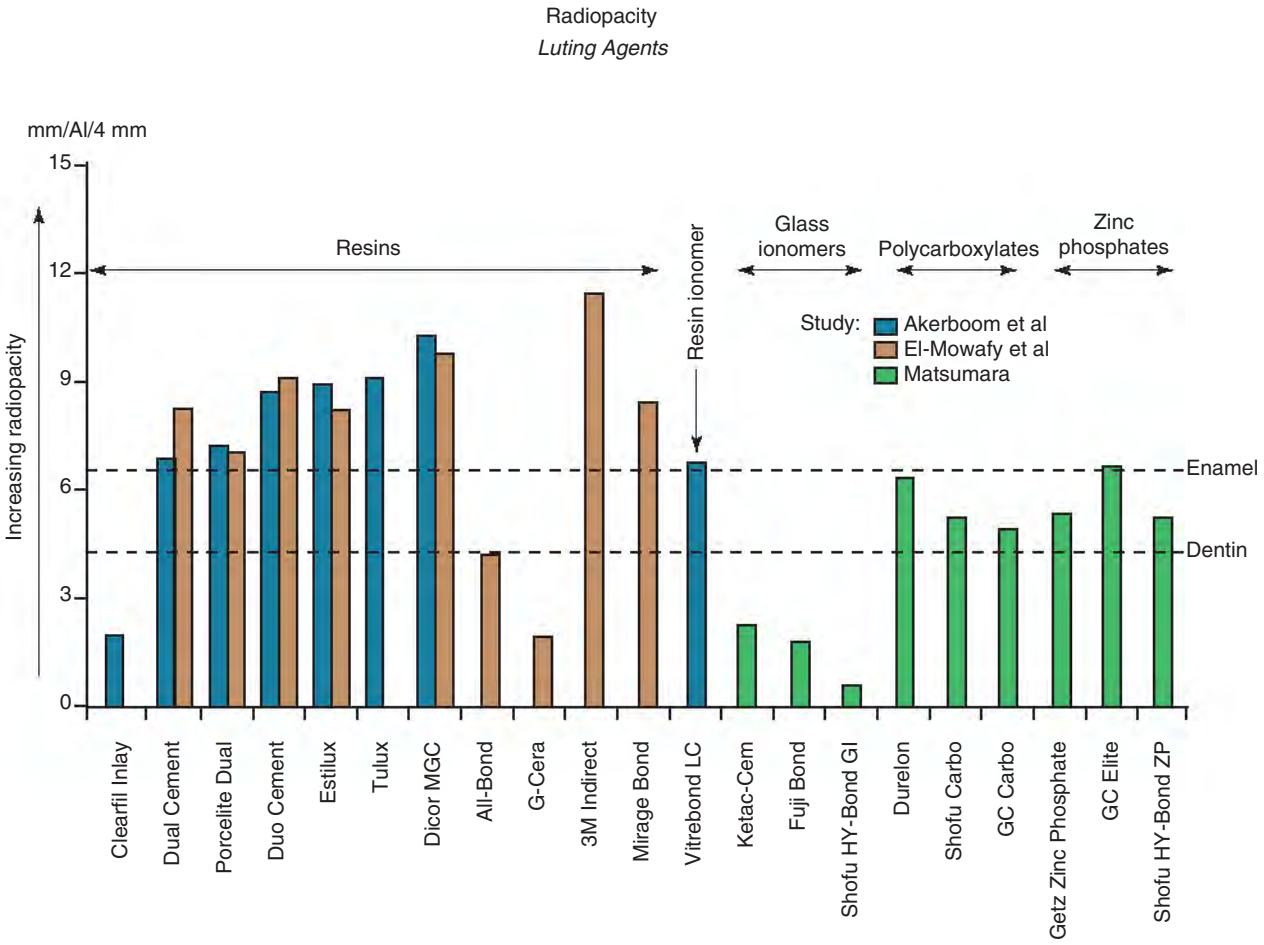

FIGURE 31-5 ■ Radiopacity of luting agents. In three in vitro studies,[4-6] investigators compared the radiographic appearance of various luting agents with that of aluminum. The data were normalized to account for different specimen thicknesses used by the investigators. Excess luting agent is more difficult to detect if materials have lower radiopacity values. In addition, margin gaps and recurrent caries are more difficult to diagnose.

FIGURE 31-6 ■ Patients who have received extensive treatment of this nature require frequent follow-up care.

1 of the Third National Health and Nutrition Examination Survey, root caries affected 22.5% of the dentate population.[21] Root caries seems to be associated with individual dental plaque scores and high counts of salivary *Streptococcus mutans*.[22] Xerostomia that is age-related or caused by medication or radiation treatment has been implicated in the origin of rampant caries.[23-25] Other factors include the patient's economic status, diet, oral hygiene, and ethnic background.[26] Only a most vigorous effort on the part of the dentist and patient leads to resolution of the problem. Prevention is focused on diet counseling and fluoride treatment. Treatment often requires the placement of large cervical glass ionomer or amalgam restorations that wrap around the periphery of previously placed cast restorations. Such restorations are difficult to place. However, in view of the constraints, they are a preferred alternative to comprehensive re-treatment with elaborate FDPs.

Periodontal Disease

Unfortunately, periodontal disease often occurs after placement of FDPs,[27] especially where the cavosurface margin has been placed subgingivally[28-30] or if the prosthesis is overcontoured.[31] Inflammation is more severe with poorly fitting restorations[32] (Fig. 31-12), but even "perfect" margins have been associated with periodontitis.[33] At recall appointments, the dentist should be particularly alert for sulcular hemorrhage, furcation

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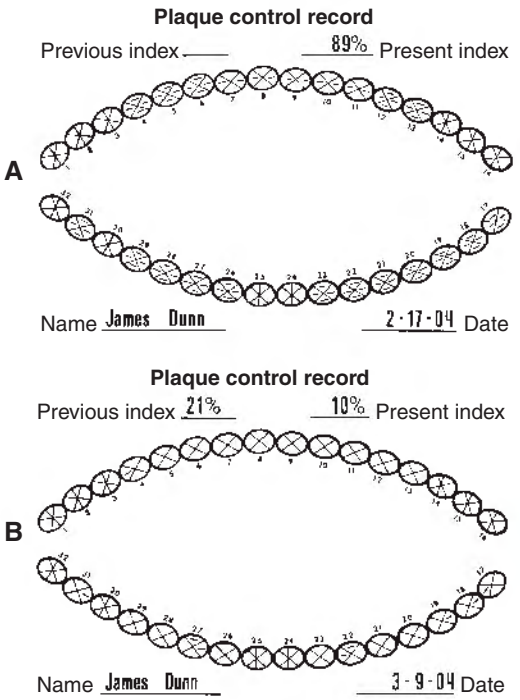

FIGURE 31-7 ■ **A,** Plaque control record filled out at the first appointment for teaching proper oral hygiene measures. **B,** Plaque control record after four sessions of instruction. This patient's plaque level is such that definitive treatment can begin. This level of plaque control needs to be maintained during the postoperative phase of treatment. (Modified from Goldman HM, Cohen DW: Periodontal therapy, 5th ed. St. Louis, Mosby, 1973.)

FIGURE 31-8 ■ Undetected caries beneath this partial fixed dental prosthesis resulted in serious complications.

FIGURE 31-9 ■ Drying the teeth facilitates assessment of the margin integrity of a cemented prosthesis.

FIGURE 31-10 ■ Occasionally, cervical glass ionomer or amalgam restorations *(arrows)* can extend the useful life of a previously placed cast restoration and postpone complicated replacement of the prosthesis.

FIGURE 31-11 ■ Extensive root caries beneath a cemented partial fixed dental prosthesis. (Courtesy Dr. J. Keene.)

involvement, and calculus formation as early signs of periodontal disease. Improperly contoured restorations should be recontoured or replaced.

Occlusal Dysfunction

At each recall appointment, the patient is examined for signs of occlusal dysfunction. The patient should be asked about any noxious habits such as bruxism. An examination of the occlusal surfaces may reveal abnormal wear facets (Fig. 31-13). In particular, the canines should be inspected because wear in this area soon leads to other excursive interferences. If parafunctional activity is a cause of tooth wear, the progression of facet formation often begins on the canines. In a slightly more advanced state of wear, additional facets can be observed on the

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FIGURE 31-12 ■ Periodontal failure resulting from defective fixed dental prostheses. **A,** Inadequate margins and contour. **B,** Appearance before surgery. **C,** Flap reflected. **D,** Appearance after surgical recontouring. **E,** Radiograph of new cast restorations. **F,** Replacement restorations. (Courtesy Dr. C.L. Politis.)

FIGURE 31-13 ■ If a cast restoration is not designed according to neuromuscular and temporomandibular controls, extensive wear can result after a relatively short time.

incisor teeth, after which excursive interfering contacts result in wear facets on the posterior teeth. Abnormal tooth mobility is investigated, as is muscle and joint pain. A standardized muscle-and-joint palpation technique (see Chapter 1) is helpful. Articulated diagnostic casts should be periodically remade (Fig. 31-14) and compared with previous records so that any occlusal changes can be monitored and corrective treatment initiated.

A small number of patients may not have responded well to previous occlusal treatment or may resume parafunctional activity some time after completion of the active phase of fixed prosthodontic treatment. Although resolving the underlying cause is preferable, prescribing a night guard is occasionally helpful (Fig. 31-15). Its design is identical to that of the occlusal device described in Chapter 4 for treating neuromuscular symptoms resulting from malocclusion. However, the device is worn only at night. If the patient primarily clenches, the dentist should consider a slightly flatter anterior ramp than is ordinarily incorporated in the conventional device.

Pulp and Periapical Health

At the recall appointment, the patient may describe one or more episodes of pain during the previous months. This could indicate the loss of vitality of an abutment tooth and should be investigated. Appropriate corrective measures can then be made.

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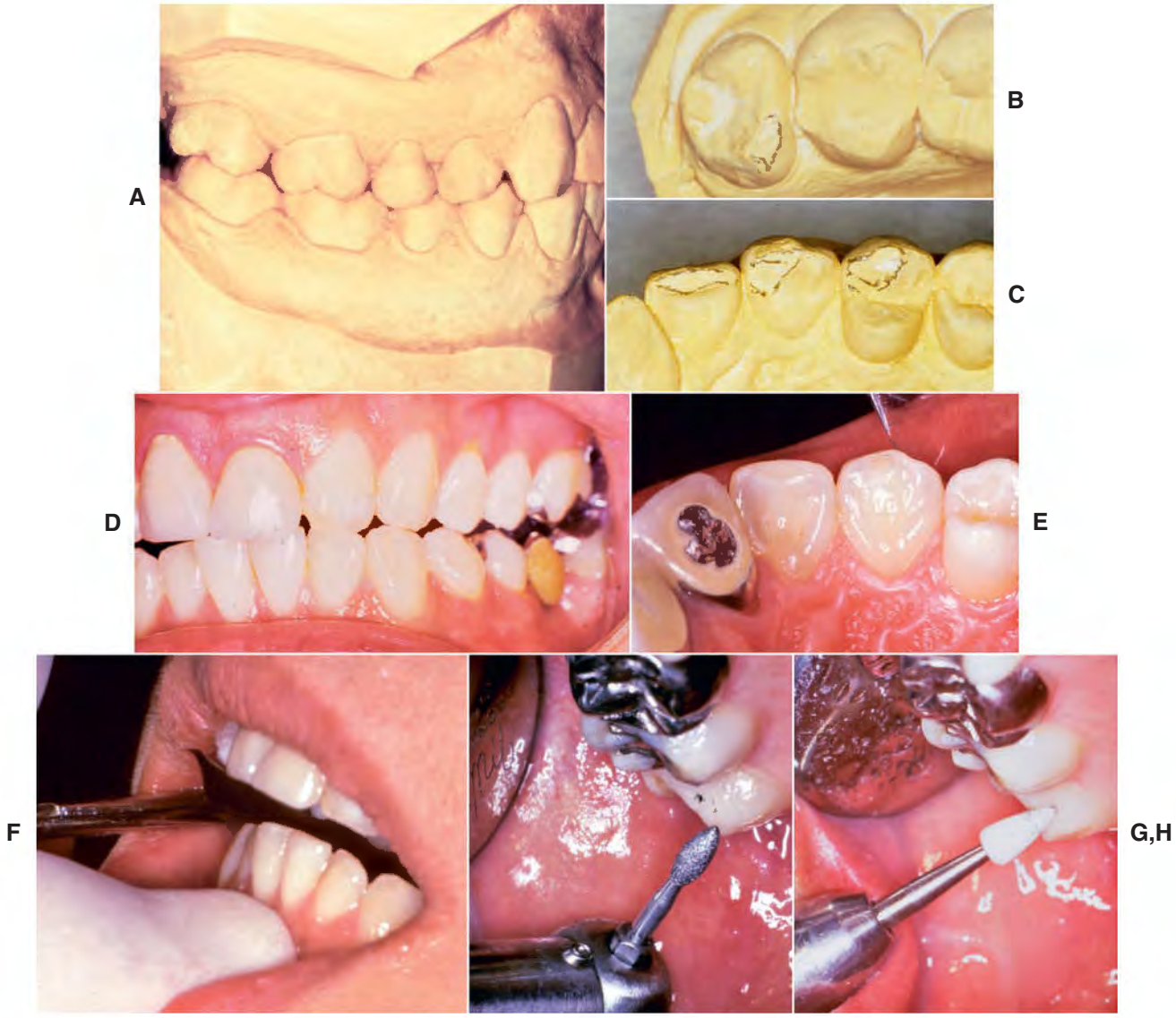

FIGURE 31-14 ■ Posttreatment occlusal analysis. **A,** Diagnostic casts should be articulated periodically. **B** and **C,** Nonworking wear facets on the maxillary molar correspond with wear on the premolar, canine, and lateral incisor. **D** and **E,** Mandibular excursion corresponding to the observed wear patterns. **F** and **G,** After marking, the newly detected interferences can be easily removed. **H,** The adjusted surfaces are polished.

FIGURE 31-15 ■ **A** and **B,** It may be essential to prescribe an occlusal device after extensive fixed prosthodontic treatment has been provided, especially if occlusal porcelain is used or the patient has a bruxism habit.

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One advantage of partial-coverage restorations is that pulp health can be monitored with an electric pulp tester (Fig. 31-16), although the vitality of any tooth with a complete crown can still be assessed by thermal means. Correlating the histologic condition of a pulp directly with the patient's response to pulp testing is difficult.[34] Therefore, such results should be combined with other clinical data that result from careful patient history documentation and examination. Consultation with an endodontist is often advisable (Fig. 31-17). Radiographs provide useful information about the presence of periapical pathosis. Teeth with fixed restorations should be reviewed radiographically every few years. The use of a standardized technique enables the dentist to make an objective comparison with previous films. Although the incidence of periapical disease in association with FDPs is high in some studies,[35,36] it is low in others.[30,37,38]

EMERGENCY APPOINTMENTS

On occasion, patients have an emergency between routine recall visits. With carefully planned and executed treatment, however, these should be rare (although problems can still develop even with the best treatment). Patients should be taught to notice small changes in their oral health and to report them without delay. For instance, the porcelain veneer of a metal-ceramic restoration may be shielded from further fracture when a small chip is promptly rounded off and the occlusion adjusted immediately after it is first noticed. All-ceramic crowns are subject to fracture, which often necessitates their replacement (Fig. 31-18). Postponement of corrective treatment can be especially costly, necessitating a remake of a complex prosthesis that could have been saved with prompt attention.

Pain

A patient presenting with pain should be asked about its location, character, severity, timing, and onset. Factors that precipitate, relieve, or change the pain should be investigated, and appropriate treatment measures should be initiated (see Chapter 3).

Although most oral pain is of pulpal origin, such an origin should never be assumed. A detailed investigation is always recommended. In difficult or questionable situations, the diagnosis should be confirmed by an appropriate specialist.

If the patient has several endodontically treated teeth that have been restored with posts and cores and with FDPs, the possibility of root fracture should be considered, especially for teeth that were internally weakened as a result of endodontic treatment in conjunction with oversized posts of suboptimal length. If a fracture has occurred, the tooth is almost invariably lost, which can

FIGURE 31-16 ■ **A** and **B,** Partial-coverage restorations offer the advantage of convenient vitality assessment with an electric pulp tester.

FIGURE 31-17 ■ Endodontic treatment after crown cementation. **A,** Symptomatic maxillary molar with a metal-ceramic crown. **B,** Access cavity prepared through the crown. **C,** Endodontic therapy in progress. (Courtesy Dr. D.A. Miller.)

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significantly complicate follow-up treatment, especially if it involves an abutment tooth for an FDP (Fig. 31-19). Fracture of a tooth that has not been endodontically treated can be confirmed by sequential loading of individual cusps (Fig. 31-20). Pain on release, the neural signal for which is transmitted by Aδ fibers, can be indicative of radicular fracture. Sophisticated electronic testing to determine whether teeth have been fractured has also been reported.[39]

Loose Abutment Retainer

Looseness of a retainer (Fig. 31-21) may not be easily perceived by the patient, especially if it is part of an FDP supported by several abutment teeth. The patient may have noticed a bad taste or smell rather than detecting movement.

Unless appropriate instrumentation is available, removing the prosthesis intact for recementation is often difficult or impossible. The more recently developed devices shown in Figures 31-22 to 31-24 have been successful, but they are expensive. The devices shown in Figure 31-25 are less reliable and can be quite intimidating and uncomfortable for the patient. On occasion, a direct pull with hemostat forceps or special crown-removal forceps (Trial Crown Remover, Hu-Friedy Mfg.

FIGURE 31-18 ■ Clinical example of a fracture in an all-ceramic restoration. (Courtesy Dr. D. Ketteman.)

FIGURE 31-20 ■ A tooth Sleuth can be used to selectively load individual cusps of teeth that are suspected of having a radicular fracture. Pain on release is indicative of fracture.

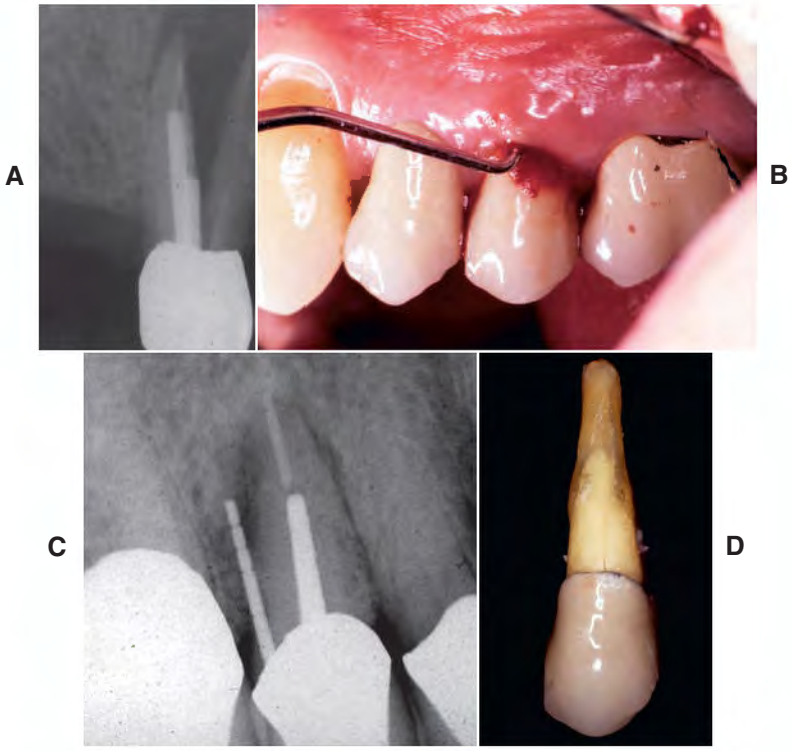

FIGURE 31-19 ■ **A,** Longitudinal root fracture of an abutment tooth for a partial removable dental prosthesis necessitated removal of the abutment tooth. **B** and **C,** Longitudinal fracture with resulting periodontal defect. **D,** Fracture is clearly visible after removal. (Courtesy Dr. D.A. Miller.)

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FIGURE 31-21 ■ **A,** Severe tooth destruction may result when looseness of a retainer goes undetected. **B,** Looseness of one retainer is occasionally observed directly *(arrow)* when force is exerted in an occlusal direction. Water is then applied to the cervical area **(C),** and the diagnosis is confirmed if bubbles appear *(arrow)* when pressure is exerted **(D).**

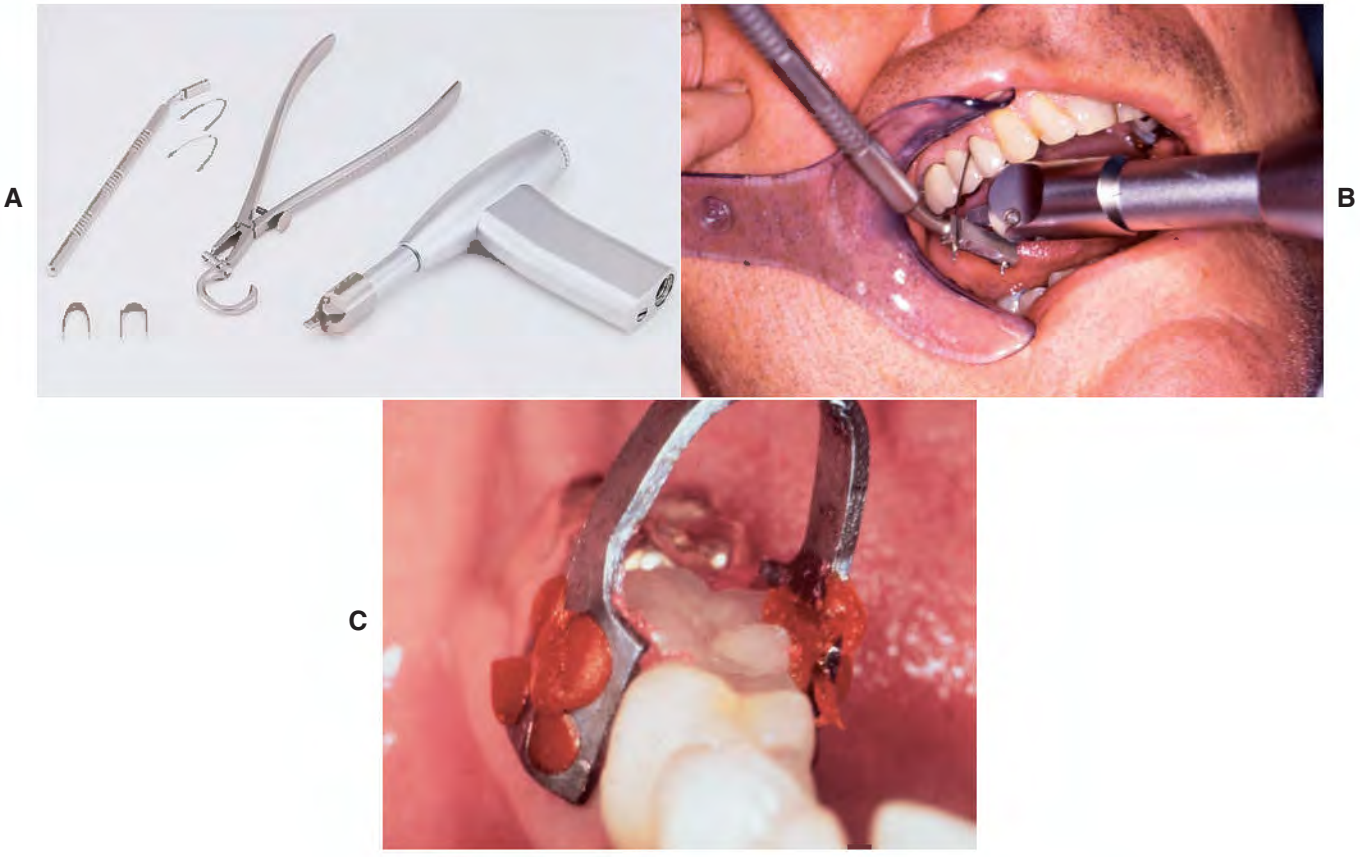

FIGURE 31-22 ■ CORONAflex crown remover. This is an air-driven device that connects to standard dental handpiece hoses via KaVo's MULTIflex coupler. The crown remover delivers a controlled low-amplitude impact at its tip. The device works well on partial fixed dental prostheses (FDPs) and is well tolerated by patients. **A,** The kit includes calipers, loops to thread under FDP connectors that attach to a holder, and an adhesive clamp to obtain purchase on single crowns. The goal is to deliver the impact in the long axis of the abutment tooth. **B,** The loop is threaded under the connector. The tip of the crown remover is placed on the bar, and the impact is activated by releasing the index finger from the air valve. **C,** The adhesive clamp is attached with autopolymerizing resin used to remove a single crown. (**A** and **C,** Courtesy KaVo Dental, Charlotte, North Carolina.)

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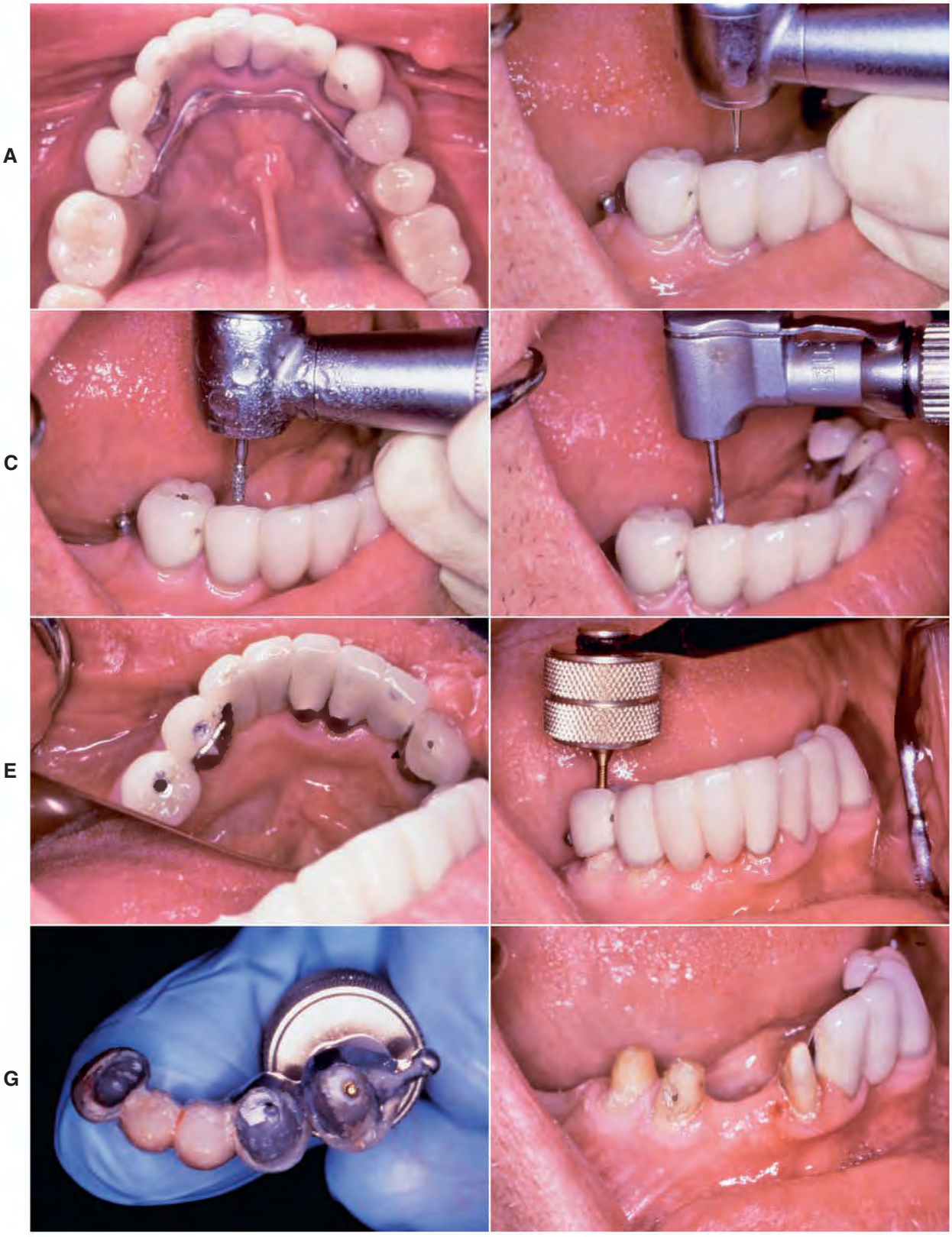

FIGURE 31-23 ■ The Metalift Crown and Bridge Removal System (Classic Practice Resources, Inc.). **A,** Five-unit partial fixed dental prosthesis (FDP) supporting a partial removable dental prosthesis. The anterior abutment (right mandibular central incisor) is loose; the posterior abutments (both right mandibular premolars) are firmly cemented. **B,** To obtain access to the metal on each abutment, a diamond is used to drill through the porcelain. **C,** The metal is penetrated with a No. 1 round bur to create a pilot channel in each abutment. **D,** The special drill is inserted into the pilot hole. **E,** The holes should just penetrate the metal, as indicated by the visible cement. **F,** The Metalift instrument is threaded into both crowns, breaking the cement seal. The partial FDP is removed **(G),** and if the abutments are satisfactory, as seen here **(H),** it can be recemented for further service. The manufacturer supplies threaded keys that can be used to seal the occlusal holes. To facilitate recovery, they can also be incorporated in crowns before cementation. (Courtesy Dr. R.D. Westerman.)

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FIGURE 31-24 ■ Removal devices. **A,** GC Pliers. This device has specially rasped finish with small sharp pins and is designed to grip a crown or partial fixed dental prosthesis and to deliver a removal force along the long axis. Grip can be enhanced with emery powder. **B,** Easy Pneumatic Crown and Bridge Remover II. With this device, compressed air is used to deliver a controlled, adjustable force to remove the restoration. (**A,** Courtesy GC America, Inc., Alsip, Illinois. **B,** Courtesy Dent Corp Research and Development, White Plains, New York.)

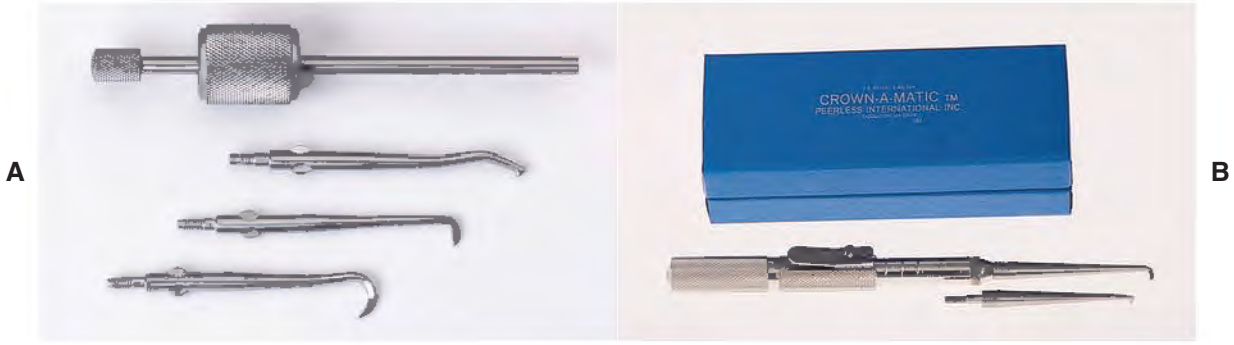

FIGURE 31-25 ■ Crown removers. **A,** Back-action. **B,** Spring-activated. (**A,** Courtesy Henry Schein Inc., Melville, New York. **B,** Courtesy Peerless International Inc., North Easton, Massachusetts.)

FIGURE 31-26 ■ Richwil Crown and Bridge Remover (Almore International, Inc., Portland, Oregon). This adhesive resin tablet is softened in warm water for 1 to 2 minutes, and the patient is instructed to close into it **(A);** the manufacturer recommends tying a length of floss to the tablet to prevent aspiration. The resin is cooled with water. A sharp opening action should remove the crown **(B).** Care is needed to avoid removing a restoration in the opposing jaw.

Co.) succeeds. (Metal-ceramic crowns should first be coated with autopolymerizing acrylic resin to prevent chipping or cracking.) Applying the tip of an ultrasonic scaler to the restoration is recommended because prolonged ultrasonic vibration can decrease crown retention.[40] A procedure for removing crowns and FDPs with a strongly adhesive resin[41] has been used successfully in certain situations[42] (Fig. 31-26). When trying to remove a definitively cemented prosthesis, the dentist must use great caution. Unless force is applied in the path of withdrawal, an abutment tooth may fracture and be lost.

Looseness of a retainer usually indicates inadequate tooth preparation, poor cementation technique, or caries. In this situation, the tooth requires repreparation and a

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new prosthesis. Sectioning the prosthesis rather than attempting to remove it intact is often the best procedure (Fig. 31-27).

Fractured Connector

An improperly fabricated connector may fracture under functional loading (Fig. 31-28). Depending on the design and location of the FDP, the degree of pain may vary. Because the load is no longer shared between the abutment teeth, extra force is typically transmitted to the abutment tooth, and discomfort from overloading the periodontal ligament may draw attention away from the location of the actual problem. If the abutment teeth have good bone support and minimal mobility, fractures of connectors can be very difficult to detect clinically. Wedges can sometimes be positioned to separate the individual FDP components enough to confirm the correct diagnosis.

Fractured Porcelain Veneer

Mechanical failure of a metal-ceramic restoration (Fig. 31-29) is not uncommon. It is usually related to

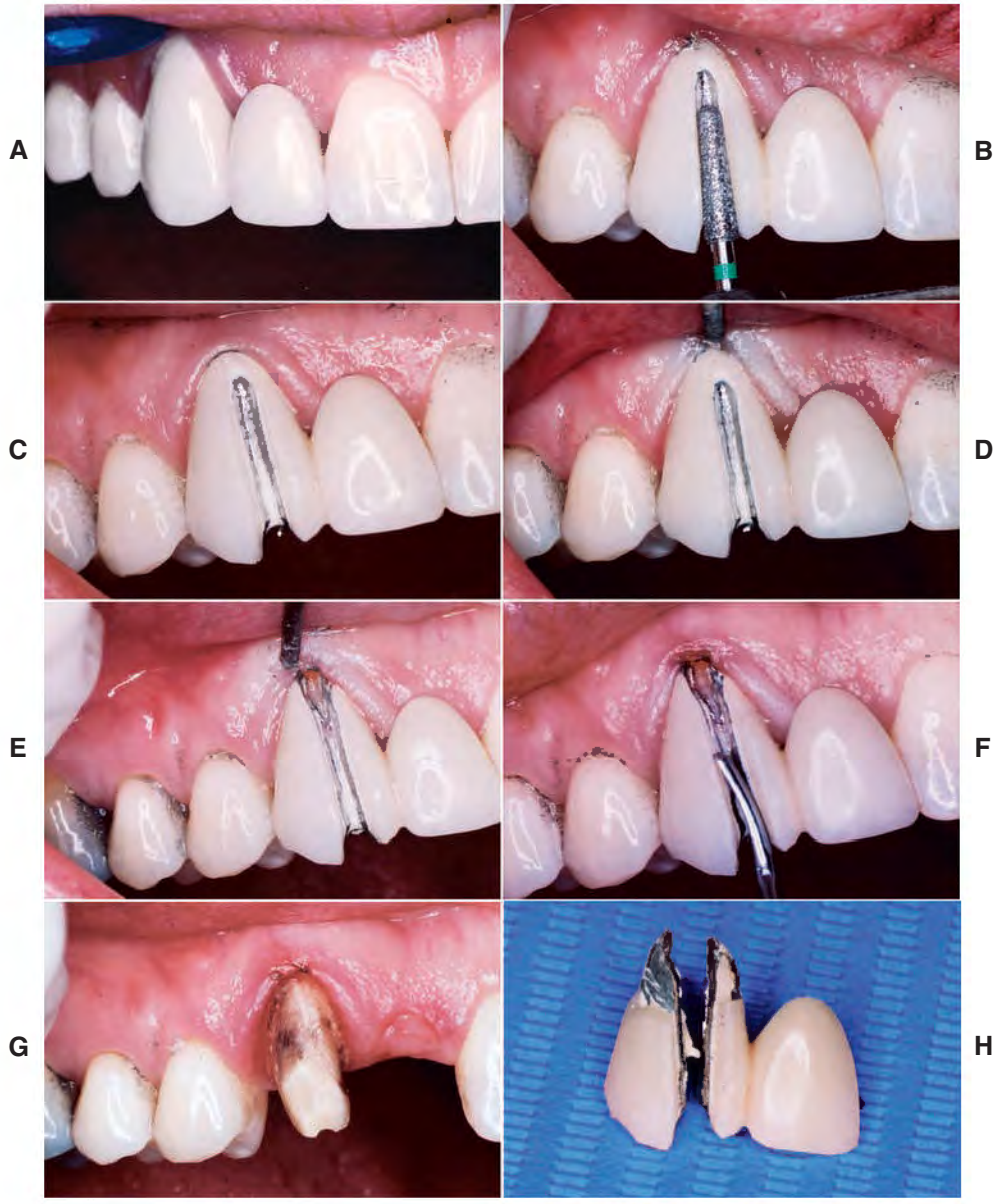

FIGURE 31-27 ■ Removal of an existing crown by sectioning. **A,** This cantilevered partial fixed dental prosthesis had to be replaced for esthetic and periodontal reasons. **B,** The restoration is carefully sectioned, with the initial cut through the ceramic just to the metal. It is easiest to do this on the facial and incisal surfaces. **C,** The goal is to cut through the metal just to the cement and follow the cement toward the gingival margin. The gingiva is displaced with an instrument **(D),** and the crown is carefully sectioned to the gingival margin **(E). F,** A suitable instrument (e.g., a cement spatula or sterilized screwdriver) is placed in the cut and gently rotated to force the halves of the crown apart. It may be necessary to section part of the lingual surface to facilitate this step. **G,** The abutment. Additional incisal reduction was necessary; the notch in the incisal edge is of no concern. **H,** Removed prosthesis.

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FIGURE 31-27, cont'd ■ I, A cut has been made through the mesiobuccal and occlusal surfaces of the defective metal-ceramic crown. An elevator is used to bend the crown open, initially from the buccal surface **(J),** and then the occlusal aspect **(K).** Note that gauze is used to capture any metal-ceramic shards that may chip off. **L,** On removal of the crown, the residual tooth structure can be assessed for further modification. (**A-H,** Courtesy Dr. D.H. Ward.)

FIGURE 31-28 ■ A, The soldered connector *(arrow)* of a four-unit partial fixed dental prosthesis fractured during function. **B,** The soldering gap was too narrow; as a result, the connector was incomplete, which eventually caused the clinical failure. The long lever arm, which consisted of the two "cantilevered" pontics that resulted after fracture, caused the pulpal irritation to arise.

FIGURE 31-29 ■ The incisal edge of the maxillary lateral incisor metal-ceramic pontic has fractured.

faults in framework design, improper laboratory procedures, excessive occlusal function, or trauma (e.g., an automobile or sports accident). All-ceramic crowns are also susceptible to fracture after extended use (Fig. 31-30).

If the porcelain has fractured on an otherwise satisfactory multiunit prosthesis, an attempt at repair rather than a remake may be justified to save the patient additional discomfort, time, and expense. When the fractured porcelain is not missing and there is little or no functional loading on the fracture site, it can sometimes be bonded in place with a porcelain repair system (Fig. 31-31) with the use of silane coupling agents or

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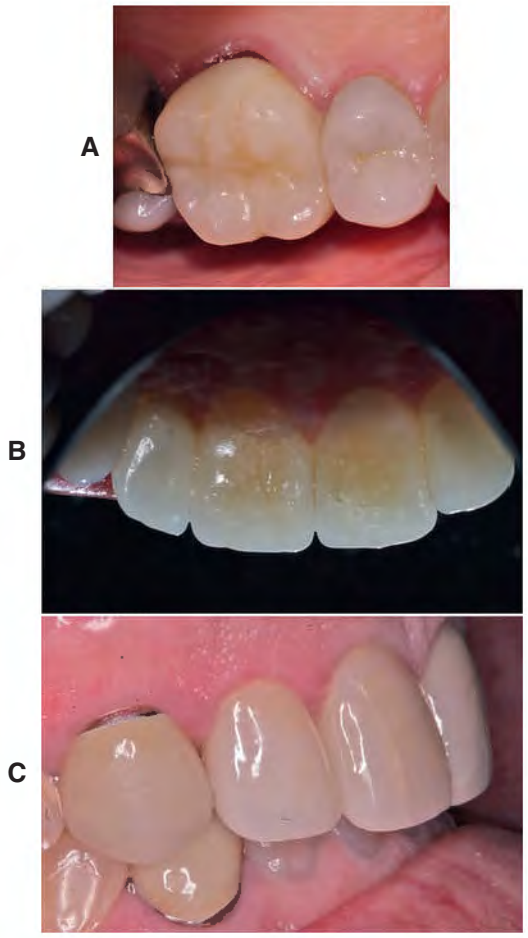

FIGURE 31-30 ■ **A,** In this monolithic zirconia molar crown, a crack extended from the central fossa to the mesiolingual surface. **B,** The lingual surfaces of veneered zirconia crowns on both central incisors exhibit cracking. These crowns had been in service for approximately 7 years before failure occurred. **C,** Fractures in pressed lithium-disilicate crowns. (**A** to **C,** Courtesy Dr. D. Ketteman.)

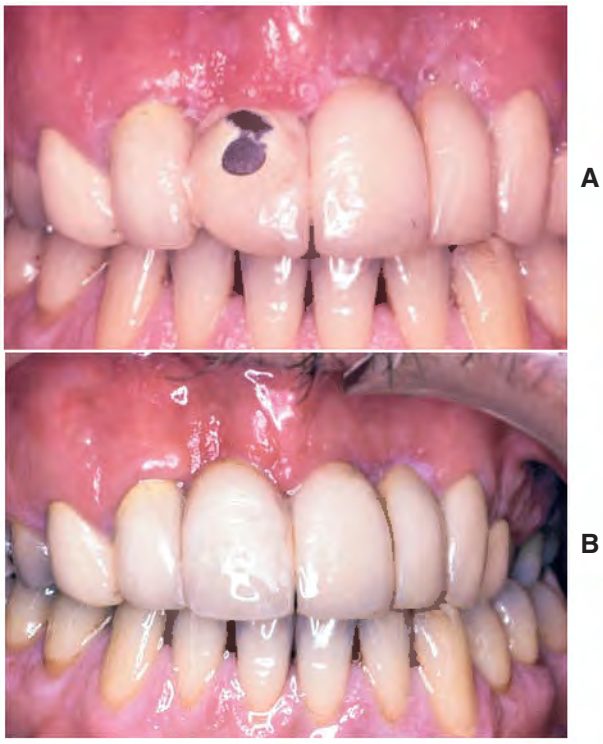

FIGURE 31-31 ■ On occasion, repairing a fractured metal-ceramic veneer is more advantageous than replacing the entire fixed dental prosthesis. **A,** Fractured central incisor pontic of an extensive prostheses. **B,** The porcelain surface has been etched; a resin repair system has been used.

4-methacryloxyethyl-trimellitic anhydride (4-META) to promote bonding with acrylic or composite resin.[43-46] Unfortunately, the strength of joints made this way seems to diminish with changes in temperature[47] and with prolonged water storage.[48] Benefits from such repair are considered temporary, but it may be preferable to periodically perform a repair than to dismantle and remake a complex FDP. In other circumstances, the fractured area may be repaired with composite resin retained by means of mechanical undercuts in the metal framework.[49] The use of a silane coupling agent is also recommended for these repairs.

A metal-ceramic restoration made to fit over the fractured original sometimes provides a more permanent repair. This technique is appropriate when the pontic rather than an abutment retainer has fractured. A little ingenuity is needed to produce a suitable design.[50,51] The most common difficulty encountered when such a repair is attempted is weakening of the connectors during the preparation, with the associated risk of subsequent prosthesis fracture (Fig. 31-32).

RE-TREATMENT

FDPs do not last forever; however, with good plaque removal, patient motivation, and average or above-average resistance to disease, a well-designed and well-fabricated restoration can provide many years of service. With poor care and neglect, even the "perfect" prosthesis or restoration can fail rapidly (Fig. 31-33). Because of exceptional host resistance, long-term success is sometimes possible with obviously defective restorations (Fig. 31-34).

Nevertheless, at some stage, the decision about re-treatment must be made. Much depends on whether the re-treatment is part of an ongoing program of comprehensive care or whether the existing prosthesis has been subjected to years of neglect.

Planned Re-treatment

At the original treatment planning stage, the need for future re-treatment should be considered. This consideration may need to be general rather than specific because of difficulties in accurately predicting the pattern of future dental disease. On occasion, however, a prosthesis is designed to accommodate the eventual failure of a doubtful abutment (Fig. 31-35). With a little foresight, survey contours can already be incorporated in the retainers of an FDP to accommodate a future partial removable

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FIGURE 31-32 ■ Repair of a fractured metal-ceramic pontic. **A,** Pretreatment appearance. **B,** The ceramic veneer is removed with diamond rotary instruments. **C,** Appearance after porcelain removal. **D,** Special impression tray. **E,** Pinholes are placed in the substructure. **F,** Cast of the substructure. **G** and **H,** Waxed overlay. Note the plastic pins used **(H). I,** Cast overlay. **J,** Facial view. **K,** Proximal view. **L,** Facial view after the porcelain application. **M,** Lingual view after firing (cast relieved). **N,** Appearance after cementation. **O** and **P,** The finished repair. (Courtesy Dr. A.G. Gegauff.)

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dental prosthesis in the event of loss of a terminal abutment. Similarly, accommodations can be made for future occlusal rests by intentionally increasing occlusal reduction during tooth preparation and using metal occlusal surfaces. Furthermore, proximal boxes can be incorporated to achieve extra metal thickness if it is anticipated that a nonrigid (dovetail) rest could simplify future re-treatment (see Fig. 31-35).

When tooth preparations are conservative, when preparation margins are supragingival, and when complicated FDP designs are avoided, subsequent re-treatment and replacement of failed work can be performed in a predictable manner, provided that plaque control and follow-up care are maintained.

The key to successful fixed prosthodontic treatment planning (see Chapter 3) lies in anticipating potential areas of future failure. Ideally, the design of a prosthesis should incorporate an escape mechanism to allow simple and convenient alteration to accommodate future treatment needs.

Neglect

An extensive FDP that has been neglected is much more difficult to treat. Considerable expertise is needed to perform the lengthy and demanding procedures successfully. Specialized treatment is almost always necessary and usually includes controlling mobility of the abutment teeth, improving support for removable appliances in the edentulous area, and creating a more favorable load distribution.

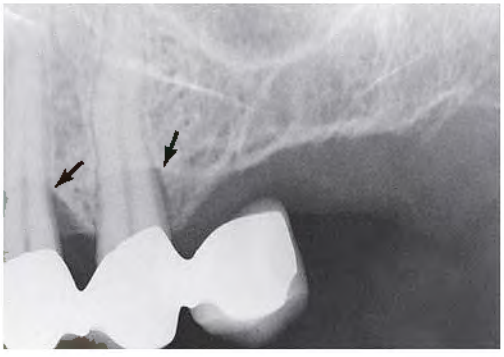

FIGURE 31-33 ■ Osseous defects *(arrows)* occurred within 2 years of the placement of this partial fixed dental prosthesis. (Courtesy Dr. J. Keene.)

TREATMENT PRESENTATIONS

Several treatment results are presented, including follow-up documentation as appropriate, in some cases over many years. The treatments demonstrate successful treatment approaches that are consistent with the principles discussed throughout this text.

- Treatment I (Fig. 31-36): simple cast restorations
- Treatment II (Fig. 31-37): single cast restorations
- Treatment III (Fig. 31-38): simple partial FDPs
- Treatment IV (Fig. 31-39): full-mouth rehabilitation with FDPs and removable prostheses
- Treatment V (Fig. 31-40): extensive fixed prosthodontic treatment
- Treatment VI (Fig. 31-41): extensive fixed and removable prosthodontic treatment
- Treatment VII (Fig. 31-42): anticipation of future needs
- Treatment VIII (Fig. 31-43): long-term evaluation of comprehensive rehabilitation with FDPs and removable dental prostheses
- Treatment IX (Fig. 31-44): long-term evaluation of comprehensive rehabilitation with FDPs
- Treatment X (Fig. 31-45): long-term evaluation of comprehensive rehabilitation of a periodontally compromised dentition
- Treatment XI (Fig. 31-46): long-term evaluation of FDPs

SUMMARY

Well-organized and efficient postoperative care is the chief mechanism for ensuring optimal longevity and success in fixed prosthodontics. A restoration that is cemented and then forgotten or ignored is likely to fail, regardless of how skillfully it was designed, created, and placed. Restored teeth require more assiduous plaque removal and maintenance than do healthy unrestored teeth, and, similarly, an FDP requires additional care and attention.

Common complications after completion of the active phase of treatment include caries, periodontal failure, endodontic failure, loose retainers, porcelain fracture, and root fracture.[52,53] If possible, the dentist should anticipate the long-term prognosis and treatment needs

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FIGURE 31-34 ■ **A,** A "saddle" pontic should not be fabricated because it makes plaque control impossible. This particular partial fixed dental prosthesis, however, served for 35 years. **B,** Despite poor pontic design, there are no significant signs of ulceration. This example illustrates the variability of tissue response as a result of differences in host resistance.

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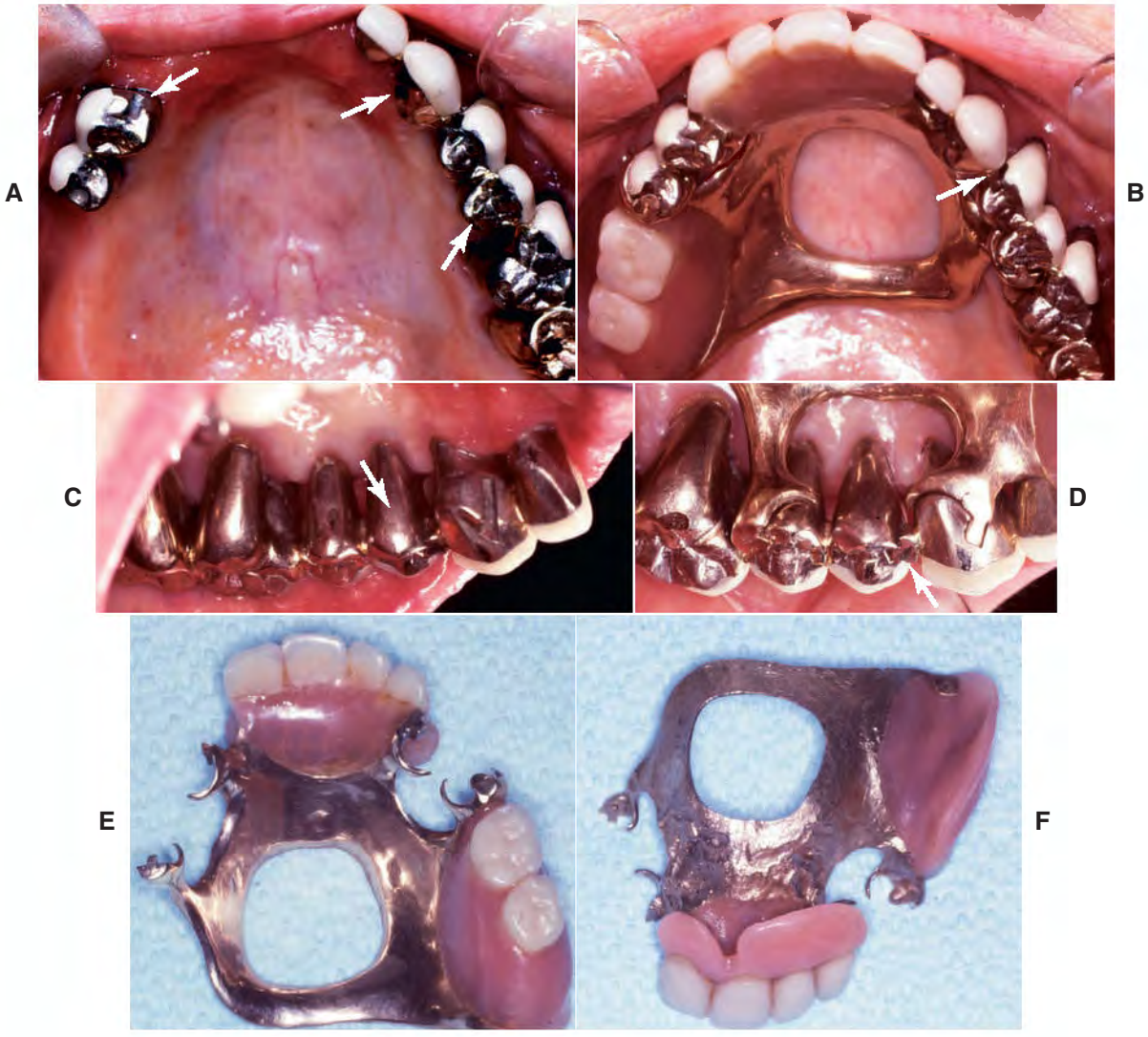

FIGURE 31-35 ■ Anticipation of future needs. **A,** Appearance 4 years after the restoration of an arch with periodontally compromised teeth. Three intracoronal rests *(arrows)* were fabricated to support a partial removable dental prosthesis (RDP). **B,** An additional rest *(arrow)* was included as a nonrigid connector for splinting the prostheses in the maxillary left quadrant. This rest is parallel to the others, and so it is available (if needed) for future support of a modified or new RDP. **C,** The lingual wall of the premolar incorporates the appropriate survey contour *(arrow)* to accommodate such a prosthesis. **D,** The RDP in place. Note the third intracoronal rest *(arrow).* **E** and **F,** External and internal views of the RDP. This was cast in type IV gold, which allows the relatively easy addition of a new minor connector with conventional soldering techniques.

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FIGURE 31-36 ■ Simple cast restorations (treatment I): a complete cast crown and an inlay used to restore the first molars. **A,** Wax patterns. **B,** Castings seated and adjusted for clinical evaluation. **C,** Cemented restorations. **D,** This two-surface intracoronal cast restoration served for 66 years.

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FIGURE 31-37 ■ Single cast restorations (treatment II) reestablish canine guidance and functional occlusion. **A,** Extensive anterior wear caused by prolonged parafunctional activity that resulted from malocclusion. **B,** Anterior pinledges are waxed concurrently with the molar castings. **C,** Anterior guidance and posterior occlusion are reestablished. Castings seated and adjusted **(D)** and at clinical evaluation **(E). F,** A normal canine-to-canine relationship has been reestablished. **G,** Working-side excursion.

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FIGURE 31-38 ■ Simple partial fixed dental prostheses (FDPs; treatment III). Long-term follow-up: These small FDPs remain serviceable after 7 and 13 years. **A** and **B,** Appearance at 7-year follow-up. **C** and **D,** Appearance at 13-year follow-up.

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FIGURE 31-39 ■ Full-mouth rehabilitation with fixed, implant-supported, and removable partial prosthodontics (treatment IV). Before treatment (**A** to **E**): Note the reverse smile line and discrepancy in the maxillary central incisor gingival tissue levels. The maxillary first molars had furcation involvement and poor prognosis as a result of periodontal bone loss. **A** and **B,** Occlusal views. **C,** Frontal view. **D** and **E,** Right and left views in maximum intercuspation. During treatment: **F,** Diagnostic waxing. **G,** Dental implants were placed to restore the mandibular arch and to provide retention and support for a maxillary partial removable dental prosthesis (RDP). **H,** The gingival tissue levels were corrected with periodontal surgery. **I** and **J,** Anterior teeth were prepared for fixed restorations.

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FIGURE 31-39, cont'd ■ After treatment: Occlusal views of maxillary arch without **(K)** and with **(L)** partial RDP. **M,** Occlusal view of restored mandibular arch. Views in maximum intercuspation: right **(N)** and left **(O)** mirror views and frontal view **(P).** (Courtesy Dr. B.A. Purcell.)

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FIGURE 31-40 ■ Extensive fixed prosthodontic treatment (treatment V): teeth with advanced periodontal disease restored with fixed dental prostheses. **A,** Initial presentation. The patient required extraction of the right maxillary incisor and surgical correction of the periodontal defects. **B,** Maxillary teeth prepared for metal-ceramic restorations. **C,** Reversible hydrocolloid impression. **D,** Interim restorations. **E,** Definitive casts. **F,** Anatomic contour wax patterns.

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FIGURE 31-40, cont'd ■ **G,** Patterns cut back for porcelain application. **H,** Patterns with sprues inserted. **I,** Appearance of metal framework at evaluation. **J,** Opaque porcelain applied. **K,** Appearance of porcelain at bisque stage. **L,** Centric contacts are on metal. **M,** Finished restorations before cementation. The extensive prosthesis is segmented with intracoronal rests. **N** and **O,** Cemented prostheses. (Courtesy Dr. M.T. Padilla.)

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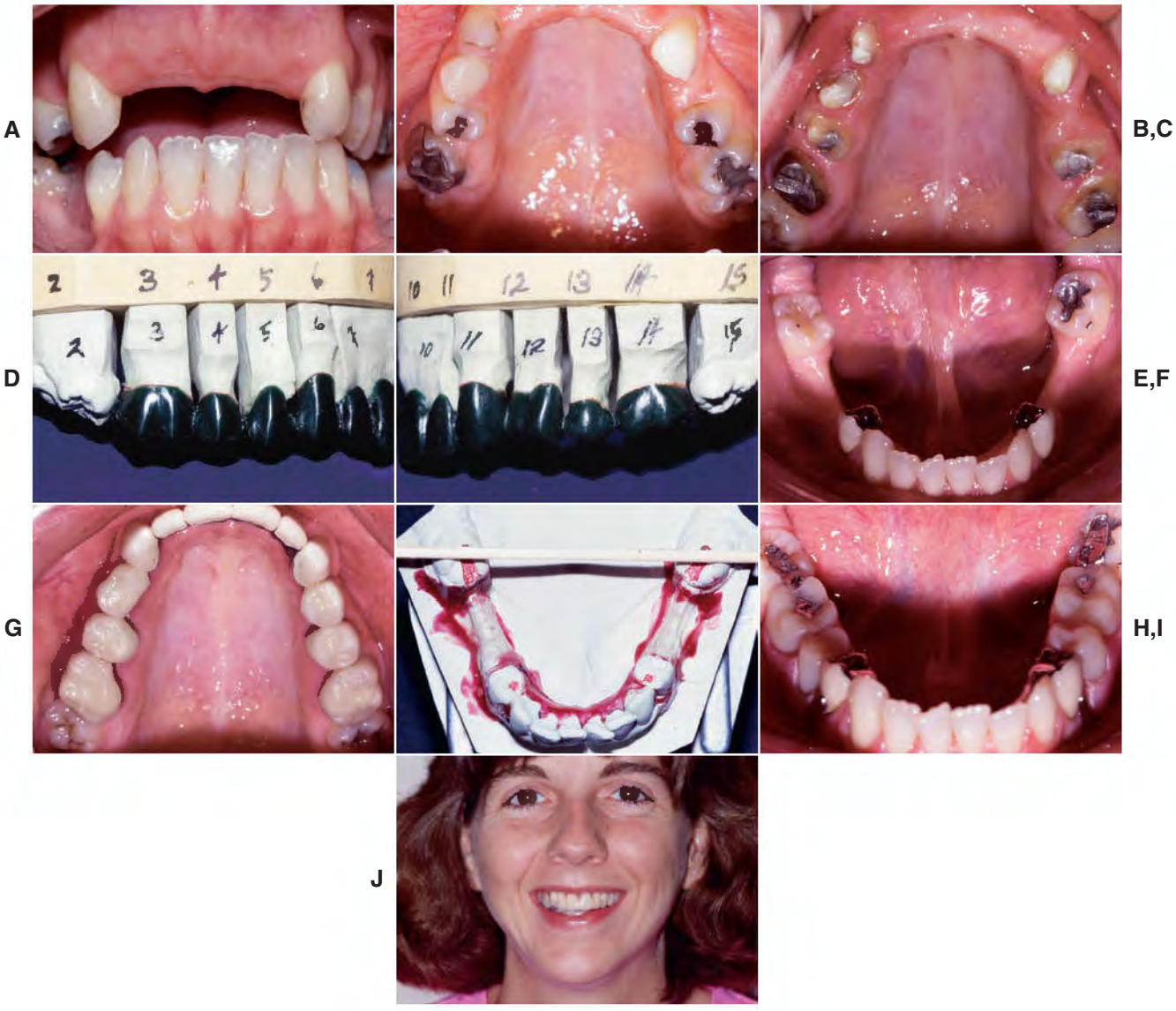

FIGURE 31-41 ■ Extensive fixed and removable prosthodontic treatment (treatment VI). The patient presented with missing maxillary anterior teeth **(A)** and missing mandibular posterior teeth **(B).** There was a significant slide from centric relation to maximum intercuspation. The patient was treated with a combination of fixed and removable prostheses. **C,** Maxillary teeth were prepared, and foundation restorations were placed. **D** and **E,** Maxillary teeth waxed to anatomic contour. **F** and **G,** Completed fixed restorations. **H,** Definitive cast for mandibular partial removable dental prosthesis (RDP) framework before duplication. A rotational path of placement was used to engage mesial undercuts in second molars. **I,** Completed mandibular RDP. Amalgam stops were placed in the first molars to prevent premature wear of the denture teeth. **J,** Appearance at completion of treatment.

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FIGURE 31-41, cont'd ■ K to O, Appearance 13 years after treatment. (Courtesy Dr. J.A. Holloway.)

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FIGURE 31-42 ■ Anticipation of future needs (treatment VII). Appearance of maxillary teeth **(A)** and mandibular teeth **(B)** before treatment. Appearance at bisque bake: buccal views **(C** and **D)** and labial view **(E). F,** Occlusal view before clinical evaluation. **G,** Occlusal view at clinical evaluation. Note the location of the occlusal rests to anticipate various future partial removable dental prosthesis designs. An intracoronal rest (dovetail) was incorporated in the left lateral incisor. It is filled with composite resin, which is easily removed if the need arises. **H,** Appearance at completion of treatment.

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FIGURE 31-43 ■ Long-term evaluation of comprehensive rehabilitation with fixed and removable dental prostheses (treatment VIII). The patient presented with multiple failing restorations and severely compromised function. **A** to **E,** Preoperative photographs. **F** to **J,** Posttreatment photographs. Where possible, I-bars were used to minimize clasp visibility. Also note the extensive use of metal occlusal surfaces. When prostheses are designed for dentitions with compromised crown-to-root ratios, the occlusion and anterior guidance components must be adjusted precisely.

Continued

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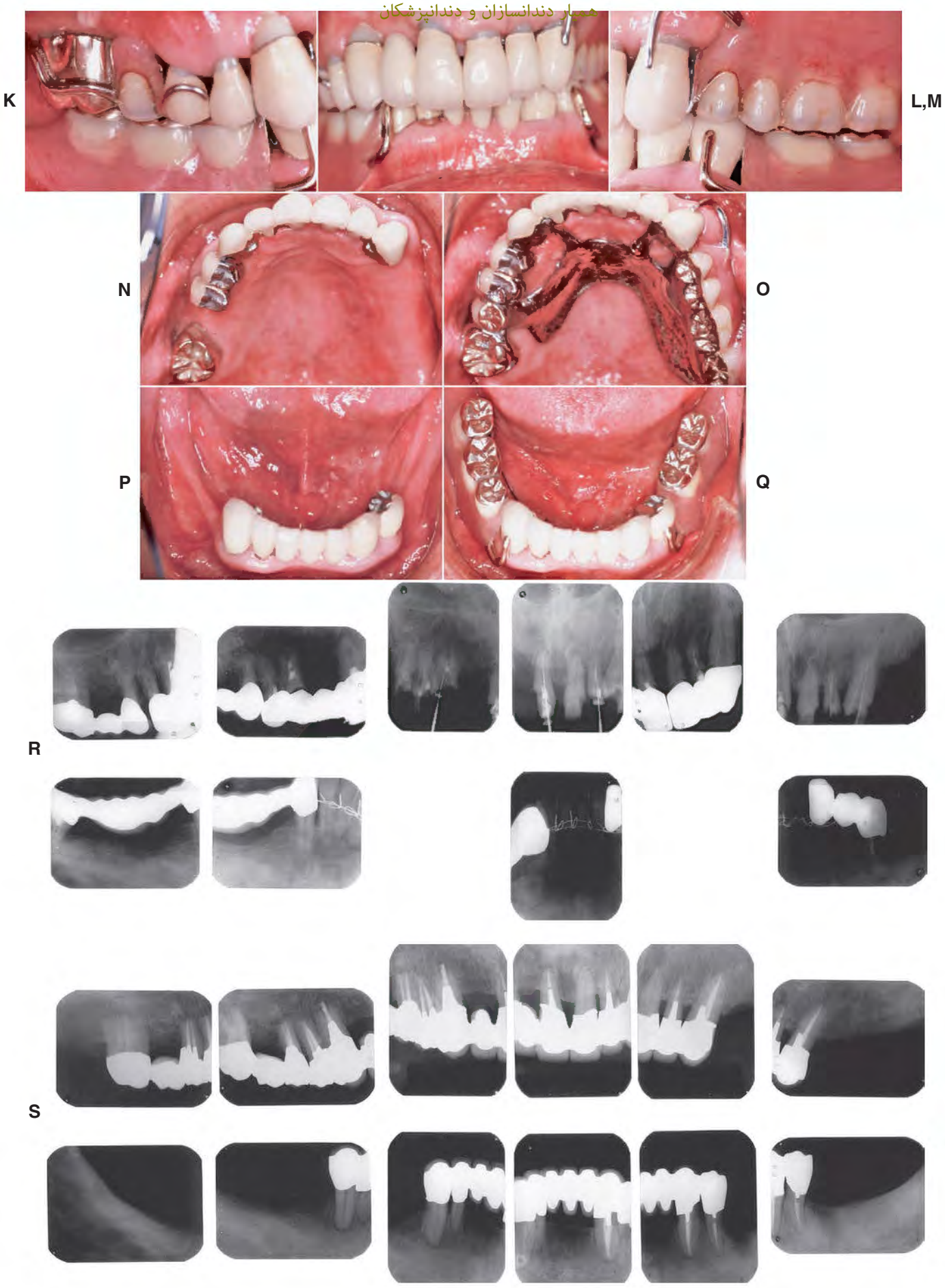

FIGURE 31-43, cont'd ■ **K** to **Q,** Seventeen-year follow-up photographs. Note that the maxillary canine was lost and the existing retainer was modified into a pontic through the addition of composite resin. Additional endodontic treatment was needed as time passed. **R,** Preoperative radiographs. **S,** Postoperative radiographs.

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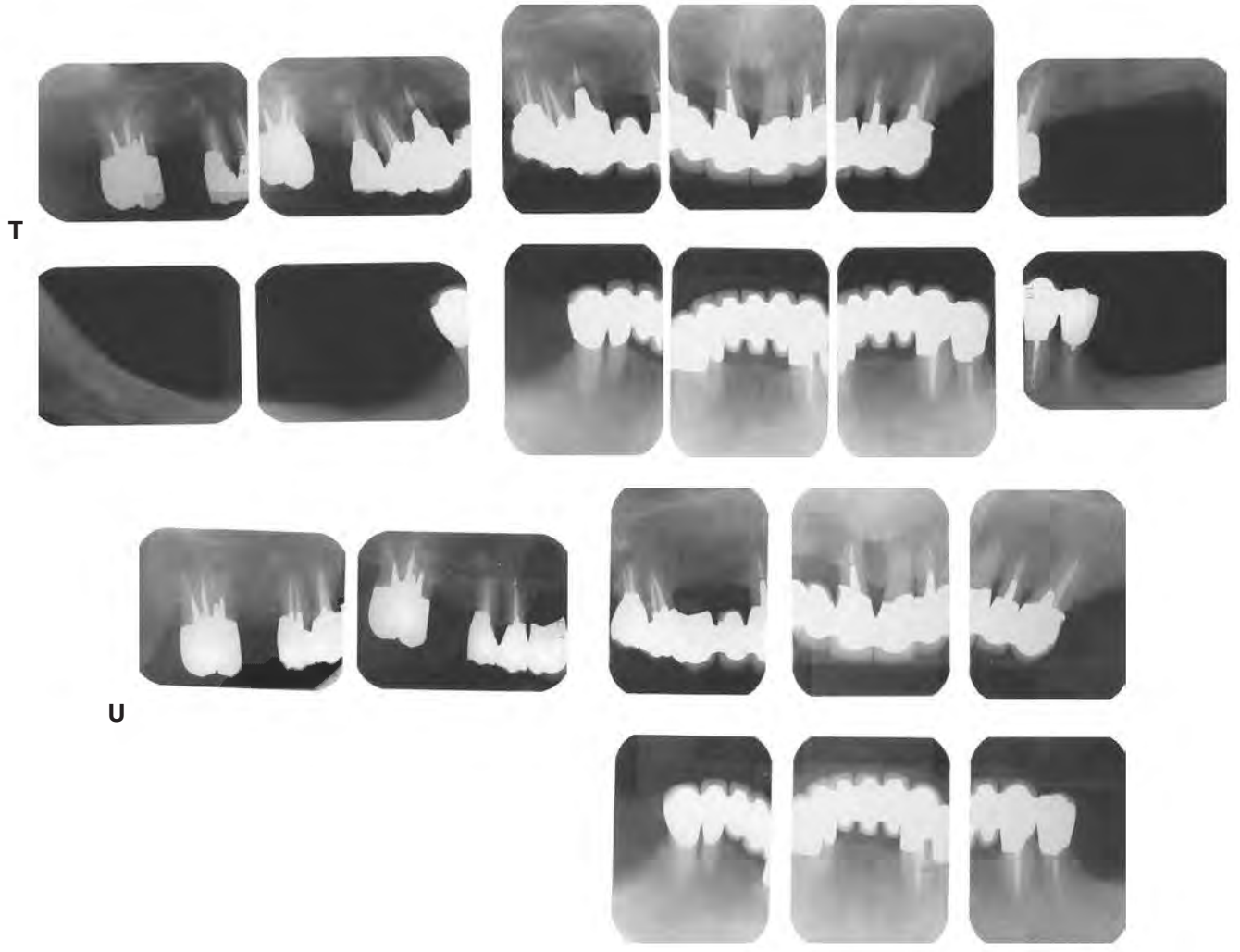

FIGURE 31-43, cont'd ■ **T,** Eight-year postoperative radiographs. **U,** Seventeen-year postoperative radiographs. A fixed dental prosthesis (FDP) was fabricated, replacing the missing tooth #3 with teeth #5, #4, and #2 as abutments. The teeth were prepared with minimal taper, and the castings exhibited good retention. After 10 years, the FDP failed when tooth #2 became dislodged, possibly as a result of the additional loading by the removable dental prosthesis (RDP). Tooth #2 and the pontic were removed, endodontic treatment was performed, a new crown was fabricated, and the #3 pontic was incorporated in a new RDP. Tooth #6 was lost as a result of internal resorption and caries. Initially, the tooth was discolored, but the lesion was inactive, and the attempt to save it failed after 8 years. Its guarded prognosis was discussed as a significant risk factor before treatment initiation. This suggests that teeth with a guarded prognosis can be maintained if attention is paid to the principles of casting adaptation and occlusion.

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FIGURE 31-44 ■ Long-term follow-up after comprehensive treatment with fixed dental prostheses (FDPs) of the patient in Fig. 31-42 (treatment IX). **A** to **E,** Preoperative photographs. **F** to **J,** Postoperative photographs.

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FIGURE 31-44, cont'd ■ **K,** Preoperative radiographs. **L,** Fourteen-year postoperative radiographs. If the FDPs have been designed carefully and the patient is cooperative and maintains excellent plaque control, FDPs can withstand the test of time. Today, these prostheses continue to provide excellent esthetics and function after more than 16 years of service. Note that no intervention was performed for the impacted canine. Initially, the patient presented with only posterior guidance on the left and right first molars. A gingival graft was performed on the left side before the fixed prosthodontic treatment. Fourteen years later, all teeth were stable without any clinically significant mobility, and the anterior guidance components exhibited no visible faceting. No significant change occurred in bone levels, whereas apparent radiographic bone densities appeared slightly increased. Meticulous attention to precise adjustment of the occlusion, especially the anterior guidance component, contributed to the long-term success of this treatment. The 14-year postoperative radiographs showed no signs of occlusal trauma. Also, note that three endodontically treated molars had very large access cavities. Such teeth had a guarded prognosis and were prone to fracture, but no fractures had occurred. Again, this suggests the importance of precise and optimal load distribution at the time of initial treatment and during periodic follow-up appointments. Recall visits were scheduled every 6 months.

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FIGURE 31-45 ■ Comprehensive rehabilitation of severely periodontally compromised dentition (treatment X). **A** to **C,** Preoperative photographs. **D** to **F,** Fourteen-year postoperative photographs. In the initial discussion of an extensive treatment plan with a patient with a severely compromised dentition, the many risks and possibilities of failure must be fully understood by all parties. This extremely complex rehabilitation continues to serve well today. A meticulous design and frequent recall appointments, combined with outstanding home care, enabled this patient to enjoy improved function 14 years later. Throughout the follow-up, the patient was seen at 1-month and periodic 3-month recall appointments, depending on pocket charting and patient motivation. At the 14-year evaluation, tooth #4 had no attached gingiva and little bone support, but no pocket formation. Initially, it was expected that this tooth would be the first to be lost. In conjunction with loss of tooth #1, this would have necessitated a partial removable dental prosthesis or implant-supported fixed dental prosthesis. Occlusal rests, undercuts, and guide planes had been incorporated in the initial prosthesis to anticipate such failure. After more than 14 years, the prostheses continued to serve satisfactorily. The anterior guidance component was starting to show some wear. Throughout the recall period, wherever posterior tooth contact was observed in excursive movements, they were eliminated as part of ongoing occlusal adjustment. Meticulous management of load distribution contributed to the long-term success of this very complex rehabilitation.

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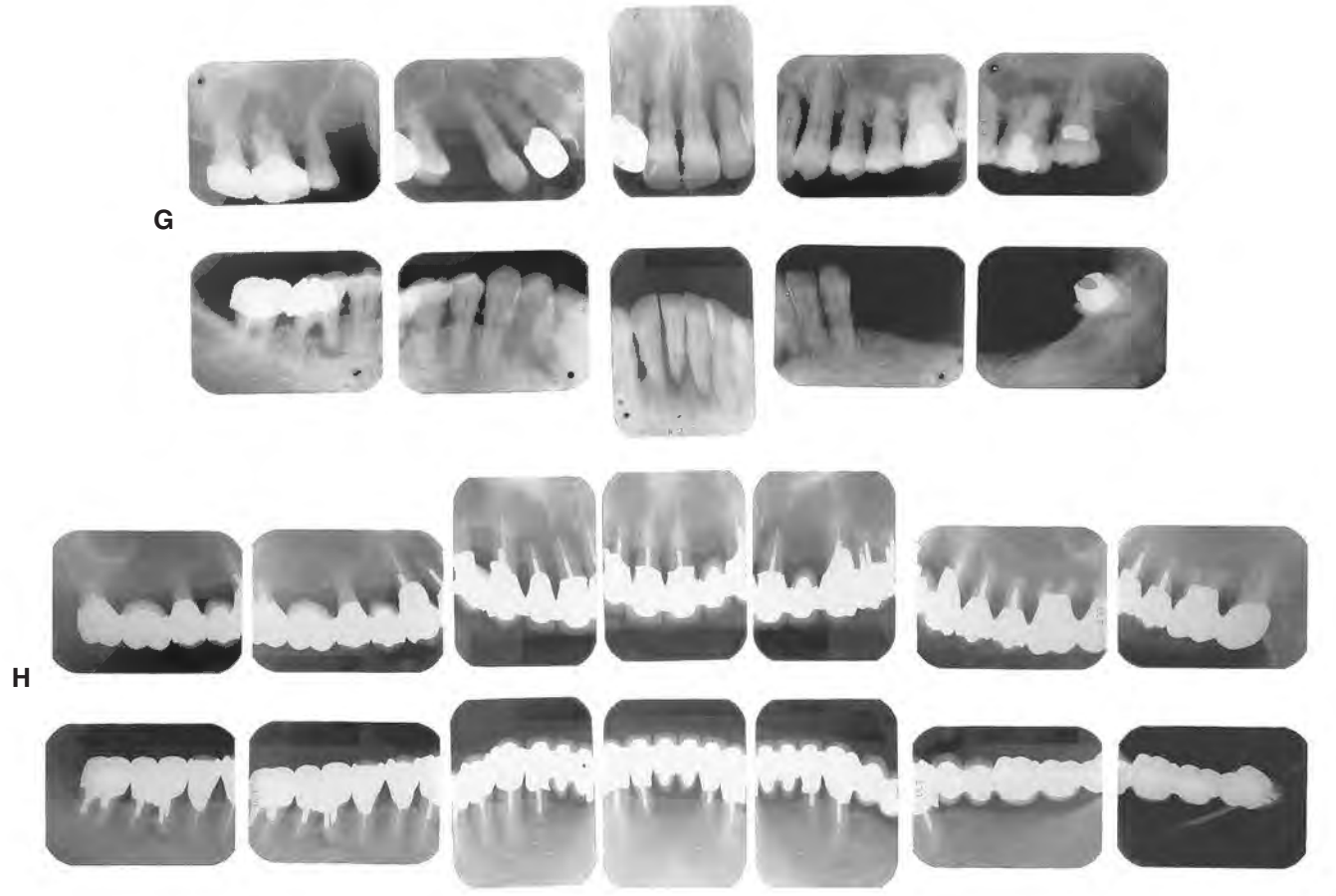

FIGURE 31-45, cont'd ■ **G,** Preoperative radiographs. **H,** Fourteen-year postoperative radiographs. This patient was referred initially for complete maxillary and mandibular denture fabrication. Before prosthodontic treatment, the periodontal condition was treated. Treatment included a modified Widman flap, performed throughout both arches. A root resection was performed for tooth #14, and tooth #30 was hemisected, which resulted in two premolar-like restorations. Use of the severely tilted tooth #17 as a single abutment to support a very long span posed a substantial risk to the long-term success of this treatment, and the tooth's future loss was anticipated in the design of the prostheses. Another risk was posed by the root structure of tooth #1, with a small, fused root. This tooth was lost after 14 years as a result of a periodontal defect that progressed along a vertical groove in the fused root.

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FIGURE 31-46 ■ Long-term evaluation of fixed dental prostheses (FDPs; treatment XI). **A** to **E,** Preoperative photographs. **F** to **J,** Eighteen-year posttreatment photographs. Three simple FDPs, combining conventional and metal-ceramic prostheses with post-soldered connectors, continue to serve 18 years after initial placement. Complications over the years included the reshaping of some restorations to correct occlusal discrepancies and the endodontic treatment of tooth #19 through the prosthesis (the access cavity was restored with amalgam). The patient presented with congenitally missing teeth #4 and #12. The maxillary canine was left in the premolar position for use as an abutment with posterior disocclusion resulting from guidance on the canine-shaped pontic. This is not ideal from the perspective of force distribution; however, the canine root successfully withstood the loading over time. Risk factors initially discussed with the patient included uncertainty regarding the effect of the crown-to-root ratios on the long-term prognosis. At the time of prosthetic treatment, more than 25 years before these pictures were taken, osseous integration was not the reliable treatment modality that it is today. The patient declined a removable prosthesis as an alternative to FDPs. A pinledge retainer was used on the small lateral incisor. Over time, not only was this esthetically effective, but it contributed to long-term maintenance of its periodontal health. Similarly, a pinledge was used on the left mandibular canine, a far more conservative option than a metal-ceramic restoration. If instead metal-ceramic retainers had been used, additional treatment needs and possibly the loss of the lateral incisor may have eventually resulted. Teeth #18, #19, and #3 were treated endodontically; cast posts and cores were used. Also, note that tooth #8 has served well over time. The conservative access cavity was restored, and the favorable position in the arch results in favorable loading. Recall appointments for the patient were scheduled at 6-month intervals throughout the evaluation period.

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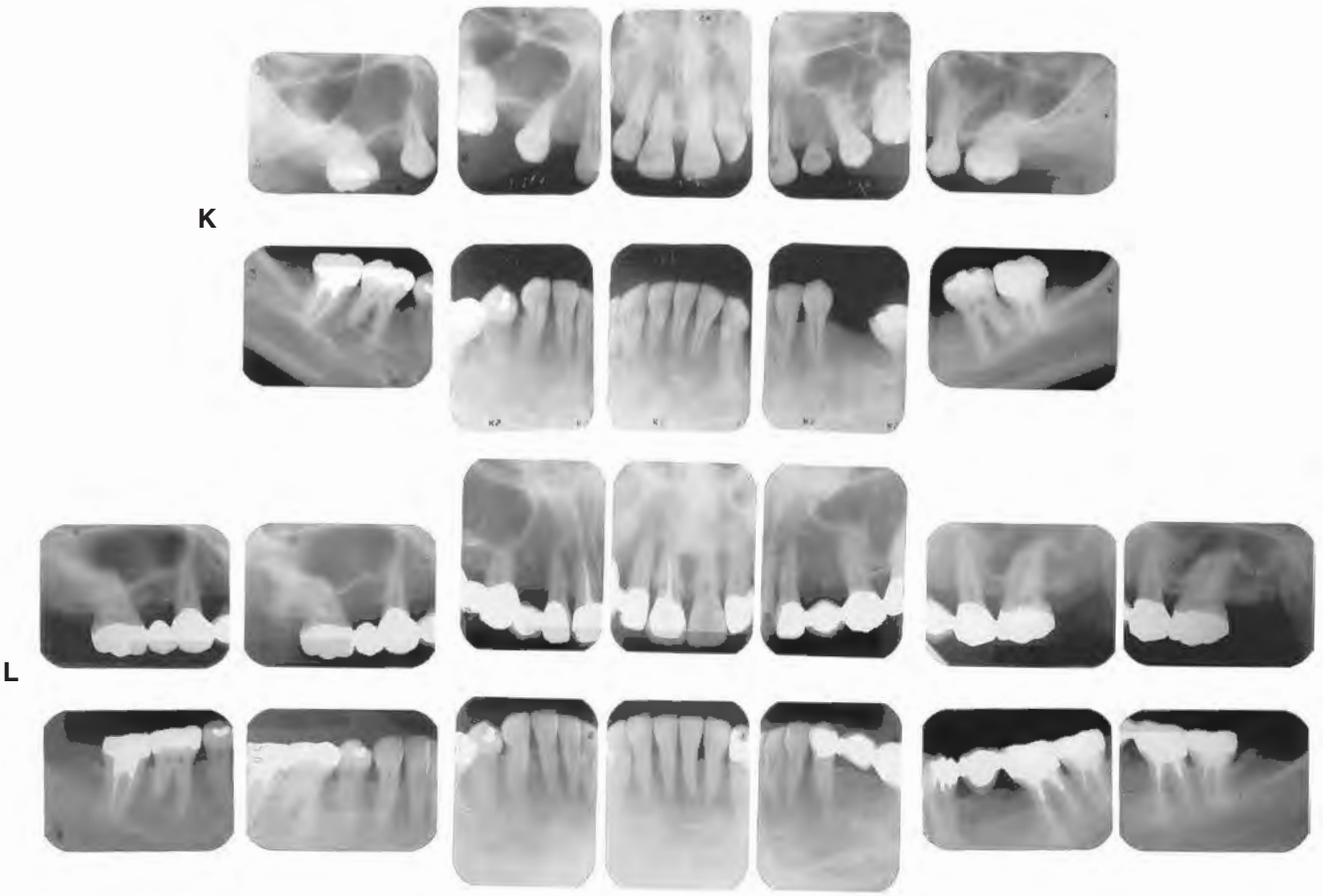

FIGURE 31-46, cont'd ■ **K,** Preoperative radiographs. **L,** Eighteen-year postoperative radiographs.

of the patient and attempt to design the treatment plan accordingly. On occasion, FDPs can be designed so that future re-treatment can be anticipated and simplified. However, it is impossible, even for the most experienced and talented clinicians, to anticipate every contingency and complication. The patient must understand the limitations of fixed prosthodontics before treatment begins.

REFERENCES

1. Tolboe H, et al: Influence of oral hygiene on the mucosal conditions beneath bridge pontics. Scand J Dent Res 95:475, 1987.
2. Tolboe H, et al: Influence of pontic material on alveolar mucosal conditions. Scand J Dent Res 96:442, 1988.
3. Ericson G, et al: Cross-sectional study of patients fitted with fixed partial dentures with special reference to the caries situation. Scand J Dent Res 98:8, 1990.
4. Akerboom HB, et al: Radiopacity of posterior composite resins, composite resin luting cements, and glass ionomer lining cements. J Prosthet Dent 70:351, 1993.
5. Matsumura H, et al: Radiopacity of dental cements. Am J Dent 6:43, 1993.
6. el-Mowafy OM, Benmergui C: Radiopacity of resin-based inlay luting cements. Oper Dent 19:11, 1994.
7. Gibson G: Identifying and treating xerostomia in restorative patients. J Esthet Dent 10:253, 1998.
8. Keene JJ Jr, et al: Antidepressant use in psychiatry and medicine: importance in dental practice. J Am Dent Assoc 134:71, 2003.
9. Jenson L, et al: Clinical protocols for caries management by risk assessment. CDA J 35:714, 2007.
10. Walton JN, et al: A survey of crown and fixed partial denture failures: length of service and reasons for replacement. J Prosthet Dent 56:416, 1986.
11. Libby G, et al: Longevity of fixed partial dentures. J Prosthet Dent 78:127, 1997.
12. Sundh B, Odman P: A study of fixed prosthodontics performed at a university clinic 18 years after insertion. Int J Prosthodont 10:513, 1997.
13. Priest GF: Failure rates of restorations for single-tooth replacement. Int J Prosthodont 9:38, 1996.
14. Bauer JG, et al: The reliability of diagnosing root caries using oral examinations. J Dent Educ 52:622, 1988.
15. Silverstone LM: Remineralization phenomena. Caries Res 11(Suppl 1):59, 1977.
16. Gordon SR: Older adults: demographics and need for quality care. J Prosthet Dent 61:737, 1989.
17. Hellyer PH, et al: Root caries in older people attending a general dental practice in East Sussex. Br Dent J 169:201, 1990.
18. Guivante-Nabet C, et al: Active and inactive caries lesions in a selected elderly institutionalised French population. Int Dent J 48:111, 1998.
19. Gustafsson BE, et al: The Vipeholm Dental Caries Study: the effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for 5 years. Acta Odontol Scand 11:232, 1954.
20. Fure S: Five-year incidence of caries, salivary and microbial conditions in 60-, 70- and 80-year-old Swedish individuals. Caries Res 32:166, 1998.
21. Winn DM, et al: Coronal and root caries in the dentition of adults in the United States, 1988-1991. J Dent Res 75(Spec. No.):642, 1996.
22. Reiker J, et al: A cross-sectional study into the prevalence of root caries in periodontal maintenance patients. J Clin Periodont 26:26, 1999.
23. Younger H, et al: Relationship among stimulated whole, glandular salivary flow rates, and root caries prevalence in an elderly population: a preliminary study. Spec Care Dentist 18:156, 1998.

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24. Powell LV, et al: Factors associated with caries incidence in an elderly population. Community Dent Oral Epidemiol 26:170, 1998.
25. Sorensen JA: A rationale for comparison of plaque-retaining properties of crown systems. J Prosthet Dent 62:264, 1989.
26. Alexander AG: Periodontal aspects of conservative dentistry. Br Dent J 125:111, 1968.
27. Valderhaug J: Gingival reaction to fixed prostheses. J Dent Res 50:74, 1971.
28. Reichen-Graden S, Lang NP: Periodontal and pulpal conditions of abutment teeth. Status after four to eight years following the incorporation of fixed reconstructions. Schweiz Monatsschr Zahnmed 99:1381, 1989.
29. Wagman SS: The role of coronal contour in gingival health. J Prosthet Dent 37:280, 1977.
30. Mojon P, et al: Relationship between prosthodontic status, caries, and periodontal disease in a geriatric population. Int J Prosthodont 8:564, 1995.
31. Rantanen T: A control study of crowns and bridges on root canal filled teeth. Suom Hammaslaak Toim 66:275, 1970.
32. Abou-Rass M: The stressed pulp condition: an endodontic-restorative diagnostic concept. J Prosthet Dent 48:264, 1982.
33. Saunders WP, Saunders EM: Prevalence of periradicular periodontitis associated with crowned teeth in an adult Scottish subpopulation. Br Dent J 185:137, 1998.
34. Karlsson S: A clinical evaluation of fixed bridges, 10 years following insertion. J Oral Rehabil 13:423, 1986.
35. Eckerbom M, et al: Prevalence of apical periodontitis, crowned teeth and teeth with posts in a Swedish population. Endod Dent Traumatol 7:214, 1991.
36. Valderhaug J, et al: Assessment of the periapical and clinical status of crowned teeth over 25 years. J Dent 25:97, 1997.
37. Olin PS: Effect of prolonged ultrasonic instrumentation on the retention of cemented cast crowns. J Prosthet Dent 64:563, 1990.
38. Oliva RA: Clinical evaluation of a new crown and fixed partial denture remover. J Prosthet Dent 44:267, 1980.
39. Sheets CG, et al: An in vitro comparison of quantitative percussion diagnostics with a standard technique for determining the presence of cracks in natural teeth. J Prosthet Dent 112:267, 2014.
40. Parreira FR, et al: Cast prosthesis removal using ultrasonics and a thermoplastic resin adhesive. J Endod 20:141, 1994.
41. Robbins JW: Intraoral repair of the fractured porcelain restoration. Oper Dent 23:203, 1998.
42. Chung KH, Hwang YC: Bonding strengths of porcelain repair systems with various surface treatments. J Prosthet Dent 78:267, 1997.
43. Kupiec KA, et al: Evaluation of porcelain surface treatments and agents for composite-to-porcelain repair. J Prosthet Dent 76:119, 1996.
44. Pameijer CH, et al: Repairing fractured porcelain: how surface preparation affects shear force resistance. J Am Dent Assoc 127:203, 1996.
45. Nowlin TP, et al: Evaluation of the bonding of three porcelain repair systems. J Prosthet Dent 46:516, 1981.
46. Gregory WA, et al: Composite resin repair of porcelain using different bonding materials. Oper Dent 13:114, 1988.
47. Barreto MT, Bottaro BF: A practical approach to porcelain repair. J Prosthet Dent 48:349, 1982.
48. Welsh SL, Schwab JT: Repair technique for porcelain-fused-to-metal restorations. J Prosthet Dent 38:61, 1977.
49. Miller TH, Thayer KE: Intraoral repair of fixed partial dentures. J Prosthet Dent 25:382, 1971.
50. Cardoso AC, Spinelli Filho P: Clinical and laboratory techniques for repair of fractured porcelain in fixed prostheses: a case report. Quintessence Int 25:835, 1994.
51. Westerman RD: A new paradigm for the construction and service of fixed prosthodontics. Dent Today 18:62, 1999.
52. Goodacre CJ, et al: Clinical complications in fixed prosthodontics. J Prosthet Dent 90:31, 2003.
53. Goodacre CJ, et al: Clinical complications with implants and implant prostheses. J Prosthet Dent 90:121, 2003.

STUDY QUESTIONS

1. What should be included in a typical posttreatment assessment once the previously rendered treatment has been completed? When and how often should the patient be reexamined? Provide examples of variables that influence this frequency.

2. What are typical complications for short-term post cementation? How can they be avoided? Once they have been identified, how can they be resolved?

3. How can advanced root caries be satisfactorily resolved?

4. How is looseness of a retainer confirmed? Once this has been confirmed, how is the FDP removed?

5. Give three examples of treatment planning in which future failure is taken into consideration.

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APPENDIX

Dental Materials and Equipment Index*

AIRBORNE-PARTICLE ABRASION UNITS

(Paasche Airbrush Company)

Recommended Use

Metal preparation before porcelain application (Chapter 24)
Identification of unwanted metal contact (Chapters 22 and 29)
Preparation of casting before cementation (Chapter 30)

Selected Suppliers

Hand-Held Clinical Units

Paasche Airbrush Company
Danville Materials
Henry Schein, Inc.
Buffalo Dental Manufacturing Co., Inc.

Laboratory Units

Bego USA
Comco, Inc.
Heraeus Kulzer GmbH
Buffalo Dental Manufacturing Co., Inc.
Integral Systems, Inc.
Denerica Dental Corporation
Renfert USA
Vaniman Manufacturing Co.
Worldent Group

*The authors thank all of the companies who provided images in this appendix

ARTICULATORS

Fully Adjustable

(Whip Mix Corporation)

Recommended Use

Complex prosthodontics

Selected Products

Denar D5A (Whip Mix Corporation)
Stratos 300 (Ivoclar Vivadent, Inc.)

Semiadjustable

(Whip Mix Corporation)

Recommended Use

Most prosthodontic diagnosis and treatment

Selected Products

Denar Mark 330 (Whip Mix Corporation)
Panadent Articulator (Panadent Corporation)

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Hanau Wide-Vue Arcon 183-2 (Whip Mix Corporation)
2000 Series Articulators (Whip Mix Corporation)

ASH'S METAL

See Soft Metal Sheet.

ATTACHMENTS

Bar Attachments

(Sterngold Dental, LLC)

Recommended Use

Support and retention of removable dental prostheses and overdentures

Selected Products

ABS Bar, CBS Bar, Dolder Bar, Hader Bar (Attachments International, Inc.)
Dolder bar (Sterngold Dental, LLC)

Extracoronal Attachments

(Sterngold Dental, LLC)

Recommended Use

Retention and support of removable dental prostheses (Chapter 21)

Selected Products

ERA-RV (Sterngold Dental, LLC)
CEKA (Alphadent NV)
Dalbo (Cendres+Métaux)

Intracoronal Rests

Recommended Use

Support of removable dental prostheses (Chapter 21)
Fixed dental prostheses connectors (Chapter 27)

Selected Products

Mandrels (CMP Industries LLC)
PD Attachments (Keystone Industries)

Intracoronal Slider Attachments

Recommended Use

Retention and support of removable dental prostheses (Chapter 21)

Selected Products

C&M McCollum (Sterngold Dental, LLC)
Stern Latch (Sterngold Dental, LLC)

Stud Attachments

(Sterngold Dental, LLC)

Recommended Use

Overdenture retention (Chapter 21)

Selected Products

Stern Root Anchor (Sterngold Dental, LLC)
Dalla Bona Spherical (Sterngold Dental, LLC)
ZAAG (Zest Anchors, LLC)
Flexi-Post (Essential Dental Systems, Inc.)

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BURS, DIAMONDS, AND STONES

High-Speed Diamonds

(Premier Dental Products Company)

Recommended Use

Extracoronal tooth preparation (Chapters 8 to 11)

Selected Products

Two Striper (Premier Dental Products Company)
Brasseler Diamonds (Brasseler USA)
BluWhite Diamonds (Kerr Corporation)

Tungsten Carbide Burs

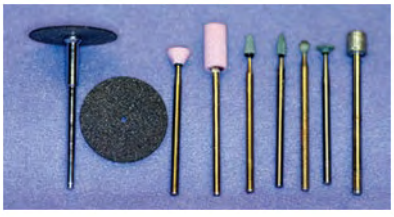
Recommended Use

Intracoronal tooth preparation
Retention features (Chapters 8 to 11)
Finishing preparations

Selected Products

Brasseler Burs (Brasseler USA)
Busch Burs (Pfingst & Co., Inc.)
Carbide Burs (Henry Schein Dental)

Laboratory Stones (for Metal)



Recommended Use

Grinding castings (Chapter 28)

Selected Suppliers

Dentsply Prosthetics
Brasseler USA
Shofu Dental Corporation
Heraeus Kulzer GmbH

Laboratory Stones (for Porcelain)

Recommended Use

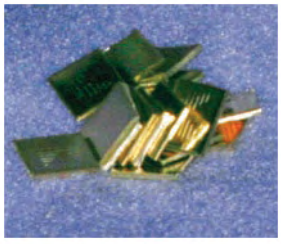
Grinding porcelain (Chapters 24 and 25)

Selected Products

Ceramiste Polisher (Shofu Dental Corporation)
Busch Silent; Horico Diamond (Pfingst & Co., Inc.)
Dura-Green Stones (Shofu Dental Corporation)
Green Mounted Points (Heraeus Kulzer GmbH)

CASTING ALLOYS

American Dental Association Type III Gold Casting Alloys



Recommended Use

Extracoronal and intracoronal restorations (Chapter 22)

Selected Products

Firmilay (Jelenko Dental Alloys)
Degulor C (DeguDent, A Dentsply Company)
Ney-Oro B-2 (Dentsply Prosthetics)
Harmony Line (Hard) (Ivoclar Vivadent, Inc.)

American Dental Association Type IV Gold Casting Alloys

Recommended Use

Extracoronal restorations (high stress)

Selected Products

Jelenko No. 7 (Jelenko Dental Alloys)
Ney-Oro G-3 (Dentsply Prosthetics)

Lower Gold Content Casting Alloys

Recommended Use

Extracoronal and intracoronal restorations

Selected Products

Midas (Jelenko Dental Alloys)
Midigold 50 (Ivoclar Vivadent, Inc.)

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Metal-Ceramic Alloys (Base Metal)

Recommended Use

Substructure for metal-ceramic restorations

Selected Products

See Table 19-2.

Metal-Ceramic Alloys (High Noble Metal)

Recommended Use

Substructure for metal-ceramic restorations (Chapter 19)

Selected Products

See Table 19-2.

CEMENTS/LUTING AGENTS

Glass Ionomer

(3M ESPE)

Recommended Use

Definitive cementation (especially with esthetic considerations)

Selected Products

Ketac-Cem, Ketac-Cem Aplicap (3M ESPE)
GC Fuji I (GC America, Inc.)
Vivaglass CEM PL (Ivoclar Vivadent, Inc.)

Interim

(Kerr Corporation)

Recommended Use

Luting interim restorations (Chapter 15)

Selected Products

Temp-Bond (Kerr Corporation)
Zone (DUX Dental)

Resin (Adhesive)

(Kuraray America, Inc.)

Recommended Use

Definitive cementation (Chapter 30)

Selected Products

Panavia F2.0 (Kuraray America, Inc.)
C&B-Metabond (Parkell, Inc.)

Resin (Autopolymerizing)

(Dentsply Caulk)

Recommended Use

Luting ceramic inlays and veneers (Chapter 25)

Selected Products

Calibra, Comspan (Dentsply Caulk)
C&B Cement (Bisco, Inc.)
Cement-It! (Pentron Clinical)
RelyX ARC (3M ESPE)

Resin (Photopolymerizing)

(Kerr Corporation)

Recommended Use

Luting ceramic inlays and veneers (Chapter 25)

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Selected Products

Nexus RMGI (Kerr Corporation)
Variolink II (Ivoclar Vivadent, Inc.)
DUO-LINK (Bisco, Inc.)
Lute-It! (Pentron Clinical)
RelyX Veneer (3M ESPE)
Ultra-Bond (DenMat)

Resin (Self-adhesive)

Recommended Use

Definitive cementation (Chapter 30)

Selected Products

RelyX Unicem 2 (3M ESPE)
Maxcem Elite (Kerr Corporation)
SpeedCEM (Ivoclar Vivadent, Inc.)
BisCem (Bisco, Inc.)

Resin-Modified Glass Ionomer

(3M ESPE)

Recommended Use

Definitive cementation (Chapter 30)

Selected Products

RelyX Luting Plus (3M ESPE)
GC Fuji Plus (GC America, Inc.)
Principle Self Adhesive Compomer Cement (Dentsply Caulk)

Zinc Phosphate

(Keystone Industries)

Recommended Use

Definitive cementation (Chapter 30)
Bases (Chapter 6)

Selected Products

Fleck's Zinc Phosphate Cement (Keystone Industries)
Hy-Bond Zinc Phosphate Cement (Shofu Dental Corporation)

Zinc Polycarboxylate

(3M ESPE)

Recommended Use

Definitive cementation (Chapter 30; especially with pulpal considerations)

Selected Products

Durelon (3M ESPE)
Hy-Bond Polycarboxylate Cement (Shofu Dental Corporation)
Tylok Plus (Dentsply Caulk)

CROWN AND FIXED DENTAL PROSTHESIS REMOVERS

(KaVo Dental)

Recommended Use

See Chapter 31.

Selected Products

CORONAflex Crown and Bridge Remover (KaVo Dental)
Metalift Crown and Bridge Removal System (Classic Practice Resources, Inc.)
Richwil Crown and Bridge Remover (Almore International, Inc.)
Atwood Crown and Bridge Remover (Atwood Industries)
Easy Pneumatic Crown and Bridge Remover II (Dent Corp.)

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CYANOACRYLATE RESIN

Recommended Use

Impregnating stone dies (Chapters 17, 18, 19, and 24)
Cementing Pindex dowel pins (Chapter 17)

Selected Products

Hot Stuff thin CA glue (Satellite City, Inc.)
Permabond 910 (Permabond Engineering Adhesives)
Krazy Glue (Krazy Glue)
DVA Rocket System (Dental Ventures of America, Inc.)

DENTURE TEETH

Selected Suppliers

Dentsply International,
American Tooth Industries, Inc.,
Ivoclar Vivadent, Inc.,
VITA North America

DIAMONDS

See Burs, Diamonds, and Stones.

DIE LUBRICANT

(Keystone Industries)

Recommended Use

Lubricating dies before waxing (Chapter 17)

Selected Products

Slaycris Slikdie Lubricant (Keystone Industries)
Gator Die Lube (Whip Mix Corporation)
Isolit (DeguDent, A Dentsply Company)

DIE MATERIALS (ALTERNATIVES TO GYPSUM)

(Keystone Industries)

Recommended Use

Dies for complete ceramic crowns (Chapter 25)

Electroplating Materials

Selected Suppliers

Baker Dental Corp.

Resins

Selected Products

AlphaDie MF (Schütz Dental GmbH)
Tri-Dynamics Tri-Epoxy (Keystone Industries)

DIE SAWS

Recommended Use

Sectioning definitive casts (Chapter 17)

Selected Products

Laboratory Saw (Dentsply Neytech)
Pindex Handsaw System (Coltène/Whaledent)

DIE SPACERS

Recommended Use

To increase space for luting agent (Chapter 17)

Selected Products

Classic Die Spacer Blue and Grey (Kerr Corporation)
Tru-Fit (Taub Products)

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DIE SYSTEMS

Recommended Use

Fabricating removable dies (Chapter 17)

Selected Products

(See Table 17-2.)
Pindex (Coltène/Whaledent)
EZ DI-LOK System (DentiFax/Di-Equi)
DVA Model System (Dental Ventures of America, Inc.)
Ceramco Dowel Pins (Dentsply Neytech)
V2 Straight Quadrant (Monotrac Articulation)

ELECTROPLATING MATERIALS

See Die Materials.

ELECTROSURGICAL EQUIPMENT

(Macan Engineering & Manufacturing Co.)

Recommended Use

Removal of hyperplastic tissue before impression making (Chapter 14)

Selected Products

Macan MC-4A, MC-6A (Macan Engineering & Manufacturing Co.)
Dento-Surg 90 F.F.P. (Ellman International, Inc.)
PerFect TCS II (Coltène/Whaledent)
Sensimatic 700SE Electrosurge (Parkell, Inc.)

EPOXY RESIN DIE MATERIALS

See Die Materials.

FACEBOWS

(Whip Mix Corporation)

Recommended Use

Articulator mounting casts (Chapters 2 and 17)

Selected Products

Denar Slidematic Facebow (Whip Mix Corporation)
QuickMount Facebow (Whip Mix Corporation)
Hanau Facebow (Whip Mix Corporation)
Hinge Axis Locator (Almore International, Inc.)

FIBER-REINFORCED COMPOSITES

Recommended Use

Alternative to metal ceramic restorations

Selected Products

Ribbond (Ribbond)
Construct (Kerr Corporation)
FibreKor (Pentron Clinical)

GINGIVAL DISPLACEMENT

Astringent Solutions

(Premier Dental Products Company)

Recommended Use

Gingival displacement before impression making (Chapter 14)

Selected Products

Hemodent (Premier Dental Products Company)
Gingi-Aid (Gingi-Pak, a division of Belport Co., Inc.)

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Astringedent; ViscoStat (Ultradent Products, Inc.)
Visine Eye Drops (Johnson & Johnson Services, Inc.)
Afrin [oxymetazoline] Nasal Spray (Bayer Group)

Displacement Cord

(Gingi-Pak, a division of Belport Co., Inc.)

Recommended Use

Gingival displacement before impression making (Chapter 14)

Selected Products

Gingi-Pak Original Retraction Cord (Gingi-Pak, a division of Belport Co., Inc.)
GingiBraid; GingiGel (DUX Dental)
Sil-Trax AS (Pascal International, Inc.)
Ultrapak (Ultradent Products, Inc.)

Displacement Putty and Foam

(Kerr Corporation)

Recommended Use

Gingival displacement before impression making (Chapter 14)

Selected Products

Expasyl (Kerr Corporation)
Astringent Retraction Paste (3M ESPE)
Magic FoamCord (Coltène/Whaledent)

GYPSUM PRODUCTS

American Dental Association Types IV and V Die Stones

(Whip Mix Corporation)

Recommended Use

Casts and dies (Chapters 2 and 17)

Selected Products

Silky-Rock; Prima-Rock; Jade Stone; ResinRock; Hard Rock (Whip Mix Corporation)
Vel-Mix Stone; Suprastone (Kerr Corporation)
Glastone, Glastone 3000 (Dentsply International)
Modern Materials Die-Keen; Modern Materials Die-Stone; Modern Materials Tru-Stone (Heraeus Kulzer GmbH)
Thixo Die Stone (Microstar Dental, LLC)

Impression Plaster

Recommended Use

Soldering index (Chapter 27)
Occlusal registration (Chapter 17)

Selected Products

Snow White Plaster #2 (Kerr Corporation)

Mounting Stone

Recommended Use

Articulator mounting casts (Chapters 2 and 17)

Selected Products

Mounting Stone (Whip Mix Corporation)
Castone Dental Stone (Dentsply International)

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IMPLANT MATERIALS

Selected Suppliers

Nobel Biocare
Zimmer Dental Inc.
Biomet 3i
Straumann AG
Attachments International, Inc.
Lifecore Biomedical, Inc.
Dentsply Implants

IMPRESSION MATERIALS

Addition Silicone

(GC America, Inc.)

Recommended Use

Impressions of preparations (Chapter 14)

Selected Products

Affinis; President (Coltène/Whaledent)
Extrude; Take 1 (Kerr Corporation)
Reprosil; Aquasil (Dentsply Caulk)
Exaflex; Examix (GC America, Inc.)
Imprint; Express (3M ESPE)

Irreversible Hydrocolloid (Alginate)

(Dentsply International)

Recommended Use

Impressions for diagnostic casts (Chapter 2)
Duplicating diagnostic waxing

Selected Products

Jeltrate Alginate Impression Material (Dentsply International)
Coe Alginate (GC America, Inc.)
Supergel Alginate Impression Material (Harry J. Bosworth Company)

Polyether

(3M ESPE)

Recommended Use

Impressions of preparations (Chapter 14)

Selected Products

Impregum, Impregum Penta, Permadyne (3M ESPE)
Polyjel NF (Dentsply Caulk)

Polysulfide Polymer

(GC America, Inc.)

Recommended Use

Impressions of preparations (Chapter 14)

Selected Products

Permlastic (Kerr Corporation)
COE-FLEX (GC America, Inc.)

Reversible Hydrocolloid (Agar)

DUX Dental

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Recommended Use

Impressions of preparations (Chapter 14)

Selected Products

Van R Heavy Bodied, Qwik CartriLoids (DUX Dental)
SuperBody (Gingi-Pak, a division of Belport Co., Inc.)

Silicone Putty

(Heraeus Kulzer GmbH)

Recommended Use

External mold for interim restorations (Chapter 15)
Preparation reduction guide (Chapters 8 to 11)

Selected Products

C-silicone (Zhermack SpA)
Coltoflax (Coltène/Whaledent)

Vinyl Polyether Silicone

(GC America Inc)

Recommended Use

Impressions of preparations (Chapter 14)

Selected Product

EXA'lence (GC America Inc.)

Zinc Oxide–Eugenol Occlusal Registration (Impression) Pastes

(GC America, Inc.)

Recommended Use

Occlusal records (Chapters 2 and 17)
Soldering records (Chapter 27)
Remount procedure (Chapter 29)

Selected Products

Superpaste (Harry J. Bosworth Company)
Opotow Standard Zinc Oxide Eugenol Impression Paste; Krex Zinc Oxide Eugenol Impression Corrective Paste (Waterpik, Inc.)
COE-FLO (GC America, Inc.)

IMPRESSION SYRINGES

(Kerr Corporation)

Recommended Use

Making elastomeric impressions (Chapter 14)

Selected Products

COE Aluminum Syringe; GC Plastic Syringe (GC America, Inc.)
Free-Flo Syringe (Kerr Corporation)
Penta Elastomer Syringe (3M ESPE)

INTERNAL FITTING AGENTS

(GC America, Inc.)

Recommended Use

Evaluating and refining internal fit of restoration (Chapter 29)

Selected Products

Fit Checker Advanced (GC America, Inc.)
Disclosing Wax (Kerr Corporation)
Mizzy Pressure Indicator Paste (Keystone Industries)

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INVESTING EQUIPMENT

Casting Rings, Liners, and Crucible Formers

Selected Suppliers

Whip Mix Corporation
Dentsply Prosthetics
Kerr Corporation
Buffalo Dental Manufacturing Co., Inc.

INVESTMENT MATERIALS

Gypsum Bonded

(Whip Mix Corporation)

Recommended Use

Conventional (low-heat) casting (Chapter 22)

Selected Products

Beauty-Cast (Whip Mix Corporation)
G-400 (Kerr Corporation)

Investments for Porcelain

(Whip Mix Corporation)

Recommended Use

Ceramic inlays and veneers (Chapter 25)

Selected Products

Note: some ceramic systems require manufacturer's specified material.
Polyvest; Formula 1 (Whip Mix Corporation)

Phosphate Bonded

(Whip Mix Corporation)

Recommended Use

Casting metal-ceramic alloys (Chapter 19)
Preceramic application soldering (Chapter 27)

Selected Products

Cera-Fina; Ceramigold; Hi-Temp; FastFire 15; PowerCast; Formula 1 (Whip Mix Corporation)
Deguvest SR; Deguvest Impact (Dentsply Prosthetics)

Soldering Investment

Recommended Use

Soldering (Chapter 27)

Selected Products

Soldering Investment (Whip Mix Corporation)
Snow White Plaster #2 (Kerr Corporation)

MAGNIFICATION EQUIPMENT

Laboratory Microscope

Selected Suppliers

Nikon Instruments Inc.
Olympus Corporation of the Americas
Zeiss United States

Loupes

(Vision USA, Dentrex Technologies)

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Selected Suppliers

Almore International, Inc.
Designs for Vision, Inc.
Orascoptic
General Scientific Corporation
Vision USA, Dentrex Technologies

MARKING AGENTS

(Pascal International, Inc.)

Recommended Use

Identifying unwanted contacts on the fitting surface of castings (Chapters 20 and 26)

Selected Products

AccuFilm IV (Parkell, Inc.)

MODELING COMPOUND

(GC America, Inc.)

Recommended Use

Modifying impression trays (Chapter 2)
Supporting rubber dam clamps, matrix bands (Chapter 6)
Transfer fork registration (Chapter 2)

Selected Products

Mizzy Compound Cakes & Sticks (Mizzy, Inc.)
Impression Compound (Kerr Corporation)
ISO Functional (Compound) (GC America, Inc.)

MOISTURE-CONTROL PRODUCTS

Saliva Ejectors

Recommended Use

Moisture and tongue control (Chapters 8 to 11 and 14)

Selected Products

Svedopter (Hager Worldwide)
DentaPops (Primotec, Inc.)
Hygoformic (Pulpdent Corporation)

OCCLUSAL CONTACT INDICATORS

Articulating Film

Recommended Use

Identifying the location of occlusal contacts (Chapters 4, 6, and 29)

Selected Products

AccuFilm II (Parkell, Inc.)
Wide Articulation Silk; Madame Butterfly Silk (Almore International, Inc.)
Articodent (Integra Miltex, Inc.)
Articu Film (Henry Schein Dental)

Powdered Wax

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Recommended Use

As an alternative to zinc stearate for identifying wax contacts (Chapter 18)

Selected Products

Powdered Wax (Almore International, Inc.)
Powdered Wax (DeLar Corporation)

Thin Mylar Film

(Almore International, Inc.)

Recommended Use

Identifying the presence of occlusal contact (Chapters 4, 6, and 29)

Selected Products

Plastic Shim Stock (.0005 inch) (Artus Corporation)
Shimstock Occlusion Foil (Almore International, Inc.)

PICKLING SOLUTION

Recommended Use

Removing oxides from castings (Chapter 22)

Selected Products

Pickle-It Compound (American Dental Supply, Inc.)

POLISHING MATERIALS

Acrylic Resins (Chapters 4 and 14)

Selected Products

Pumice (Whip Mix Corporation)

Castings (Chapter 28)

(Dedeco International, Inc.)

Selected Products

Moore's Discs (E. C. Moore Co.)
Classic White Flexies Rubber Wheels (Dedeco International, Inc.)
Tripoli, Red Rouge-XXG (Buffalo Dental Manufacturing Co., Inc.)
BBC (Heraeus Kulzer GmbH)

Porcelain (Chapter 29)

(Axis Dental Corporation)

Selected Products

Ceraglaze Ultimate Porcelain Polishing logic set (Axis Dental Corporation/SybronEndo)
Two-Striper; Luminescence Plus (Premier Dental Products Company)
Porcelain Adjustment Kit (Shofu Dental Corporation)
Diamond Restoration Polish (VITA North America)
Insta-Glaze (Taub Products)

PORCELAIN

Complete Ceramic

Recommended Use

Crowns, inlays, and veneers with high esthetic need (Chapter 25)

Selected Products

IPS Empress, IPS e.max (Ivoclar Vivadent, Inc.)
VITA VM9 (VITA North America)

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Metal-Ceramic

(Ivoclar Vivadent, Inc.)

Recommended Use

Esthetic crowns and fixed dental prostheses (Chapter 24)

Selected Products

IPS Classic (Ivoclar Vivadent, Inc.)
VITA VMK Master Porcelain; VITA VM13 (VITA North America)

PORCELAIN INSTRUMENTS

(KerrLab Corporation)

Selected Suppliers

VITA North America
Kerr Corporation
Heraeus Kulzer GmbH

PORCELAIN STAINS

(Ivoclar Vivadent, Inc.)

Recommended Use

Characterizing ceramic restorations (Chapter 29)

Selected Products

IPS Empress Universal Shade/Stains Kit (Ivoclar Vivadent, Inc.)
VITA Akzent Stains (VITA North America)

POST REMOVERS

Selected Products

Ruddle Post Removal System (SybronEndo)
Masserann Micro Kit (Micro-Mega)
Universal Post Remover (FFDM PNEUMAT)

POST SYSTEMS

(Integra Miltex, Inc.)

Post Preparation Drills

Recommended Use

Restoration of endodontically treated teeth (Chapter 12)

Selected Products

Gates Glidden drills (Quala Dental Products)
Gates Glidden drills (Integra Miltex, Inc.)

Posts

(Coltène/Whaledent)

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Recommended Use

Restoration of endodontically treated teeth (Chapter 12)

Selected Products

(See also Table 12-6.)
Endowel (DentalEZ Integrated Solutions)
ParaPost (Coltène/Whaledent)
Flexi-Post (Essential Dental Systems, Inc.)
Radix Fiber Posts (Dentsply International)

PREFABRICATED CROWN FORMS

Recommended Use

Interim restorations (Chapter 15)

Metal (Posterior Teeth)

Selected Products

(See also Table 15-2.)
Gold Anodized Crowns (3M ESPE)
Iso-Form Crowns (3M ESPE)

Resin (Anterior Teeth)

(3M ESPE)

Selected Products

(See also Table 15-2.)
Polycarbonate Crowns (3M ESPE)
Polycarbonate Crowns (Henry Schein Dental)
Protemp Temporary Crown (3M ESPE)

RESINS

Autopolymerizing Acrylic Resin Pattern Material

(GC America.)

Recommended Use

Direct patterns for posts and cores (Chapter 12)
Soldering index (Chapter 27)
Recording occlusal relationship (Chapter 17)

Selected Products

DuraLay (Reliance Dental Manufacturing Company)
Pattern Resin LS (GC America, Inc.)
Relate Liquid Monomer (Parkell, Inc.)
Palavit G (Heraeus Kulzer GmbH)

Autopolymerizing Clear Acrylic Resin

(Dentsply Caulk)

Recommended Use

Fabricating occlusal appliances (Chapter 4)

Selected Products

Orthodontic Resin (Dentsply Caulk)
GC Fuji ORTHO (GC America, Inc.)

Custom Tray Resin

(Dentsply Caulk)

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Recommended Use

Impression trays (Chapter 14)
Anterior guide table (Chapter 2)
Remount procedure (Chapter 29)

Selected Products

Trayresin Self-Curing Resin (Dentsply Caulk)
Instant Tray (Lang Dental Manufacturing Co., Inc.)
COE Tray Plastic (GC America, Inc.)

Heat-Polymerized Clear Acrylic Resin

Recommended Use

Fabricating occlusal appliances (Chapter 4)

Selected Products

Lucitone Clear Resin (Dentsply International)

Interim Resin

(GC America, Inc.)

Recommended Use

Fabricating interim restorations (Chapter 15)

Selected Products

Jet Tooth Shade (Lang Dental Manufacturing Co., Inc.)
Temporary Bridge Resin (Dentsply Caulk)
ALIKE (GC America, Inc.)
SNAP (Parkell, Inc.)
Trim (Harry J. Bosworth Company)
Protemp 3 Garant (3M ESPE)
Integrity Multi-Cure (Dentsply Caulk)
Temphase (Kerr Corporation)
Luxatemp Ultra (DMG America)

Thermoplastic Resin

Recommended Use

Anterior programming device fabrication (Chapter 2)
Exterior surface mold for interim restorations (Chapter 15)

Selected Products

Matrix Button (Advantage Dental Products, Inc.)

RESIN STAINS

(Taub Products)

Recommended Use

Characterizing interim restorations (Chapter 15)

Selected Products

Jet adjusters (Lang Dental Manufacturing Co., Inc.)
Minute Stains (Taub Products)

SEATING STICKS

(Temrex Corporation)

Recommended Use

Seating cast restorations (Chapter 30)

Selected Products

Aidaco Bite Sticks (Temrex Corporation)

SEPARATING FLUIDS

See also Die Lubricant.

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(Dentsply Caulk)

Recommended Use

Fabricating interim restorations (Chapter 15)
Fabricating occlusal appliances (Chapter 4)

Selected Products

Al-Cote (Dentsply Caulk)
COE-SEP (GC America, Inc.)

SOFT TISSUE LASER

Recommended Use

Removal of hyperplastic tissue before impression making (Chapter 14)

Selected Products

WaterLase iPlus (Biolase Technology, Inc.)

SOLDERING FLUX

(Nobilium)

Recommended Use

Preventing oxidation during soldering (Chapter 27)

Selected Products

Solder Flux High Fusing, Solder Flux Low Fusing, Flux Weld Paste (Nobilium)
High Fusing Solder/Flux Paste (Matech, Inc.)

SOLDERS

High-Heat

Recommended Use

Preceramic soldering (Chapter 27)

Selected Products

Use material recommended by alloy manufacturer.

Low-Heat

Recommended Use

Soldered connectors for conventional gold restorations (Chapter 27)
Postceramic soldered connectors (Chapter 27)

Selected Products

18-650 Solder (Jelenko Dental Alloys)
Balenced Line Solder (Dentsply Prosthetics)
Dental solders (Baker Dental Corp.)

STONES

See Burs, Diamonds, and Stones.

SURFACTANTS

(Whip Mix Corporation)

Recommended Use

Painting patterns before investing (Chapter 22)

Selected Products

Smoothex Debubbling Solution (Whip Mix Corporation)
DeBubblizer (Kerr Corporation)
DeLar Surfactant (DeLar Corporation)

THERMOPLASTIC RESIN SHEETS

Recommended Use

External mold for interim restorations (Chapter 15)
Matrix for occlusal appliance (Chapter 4)
Tooth-preparation reduction guides (Chapters 8 to 11)

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Selected Products

PolyShoK (Buffalo Dental Manufacturing Co., Inc.)
Thermo-Forming Sheets (Henry Schein Dental)

THICKNESS GAUGES

(Kerr Corporation)

Recommended Use

Measuring thickness of patterns and restorations

Selected Products

Iwansson Measuring Device (Almore International, Inc.)
Iwanson Spring Caliper (Hu-Friedy Mfg. Co., LLC)
Calipers (Kerr Corporation)
Iwanson Caliper Spring (Henry Schein Dental)

ULTRASONIC CLEANERS AND SOLUTIONS

Recommended Use

Cleaning restorations and interim restorations

Selected Suppliers

Heraeus Kulzer GmbH
L&R Manufacturing Company
Hu-Friedy Mfg. Co., LLC
Coltène/Whaledent

VACUUM FORMERS

(Buffalo Dental Manufacturing Co., Inc.)

Recommended Use

External molds for interim restorations (Chapter 15)
Tooth preparation reduction guides (Chapters 8 to 11)

Selected Suppliers

Buffalo Dental Manufacturing Co., Inc.
Ultradent Products, Inc.
Henry Schein Dental

WAXES

Boxing Wax

(Dentsply International)

Recommended Use

Boxing impressions (Chapter 14)
Boxing soldering assembly (Chapter 27)

Selected Products

Modern Materials Boxing Wax (Heraeus Kulzer GmbH)
Boxing Wax (Dentsply Prosthetics)
Magnetic Boxing Strips (Almore International, Inc.)
DeLar Magnetic Boxing Strip (DeLar Corporation)

Inlay Casting Wax

(Keystone Industries)

Recommended Use

Making wax patterns (Chapter 18)

Selected Products

Inlay Casting Wax (Kerr Corporation)
Casting Inlay Wax (MDL Dental Products, Inc.)
Slaycris Wax Regular Green (Keystone Industries)
Almore Margin and Inlay Wax (Almore International, Inc.)

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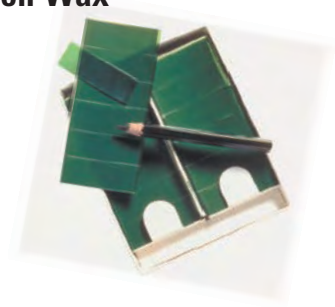
Occlusal Registration Wax



(Kerr Corporation)

Recommended Use

Centric recording for diagnostic casts (Chapter 2)

Selected Products

Aluwax (Aluwax Dental Products Company)
Occlusal Indicator Wax (Kerr Corporation)

Sprue Wax

Recommended Use

Sprue former (Chapter 22)

Selected Products

Sprue Wax (Keystone Industries)
Sprue Wax Coils (Ultimate Dental)
Success Injection System Sprue Wax Sticks (Dentsply International)

WAXING INSTRUMENTS

(Kerr Corporation)

Selected Suppliers

American Dental Manufacturing
Kerr Corporation
Hu-Friedy Mfg. Co.
Premier Dental Products Company
Henry Schein Dental

Electric Waxing Instrumentss

(Kerr Corporation)

Selected Products

Electra Waxer, Gemini Waxer (Almore International, Inc.)
Ultra-Waxer 2 (Kerr Corporation)

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