

Fig. 12.45 (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.)

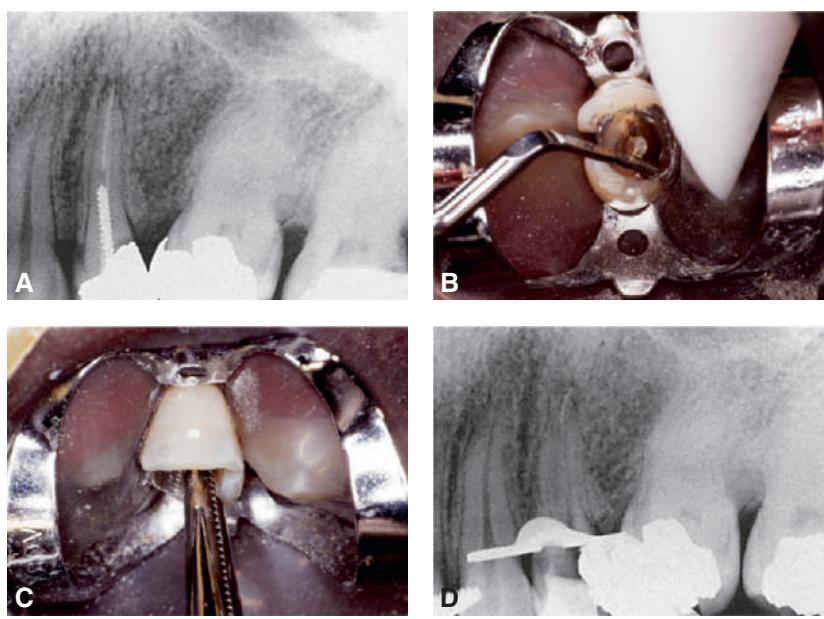


Fig. 12.46 Post removal by ultrasonic device. (A) Preoperative radiograph of the left maxillary first premolar with a parallel-sided threaded post that had to be removed for endodontic re-treatment. (B) After the coronal portion of the post has been well isolated, the tip of the ultrasonic device is 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.)

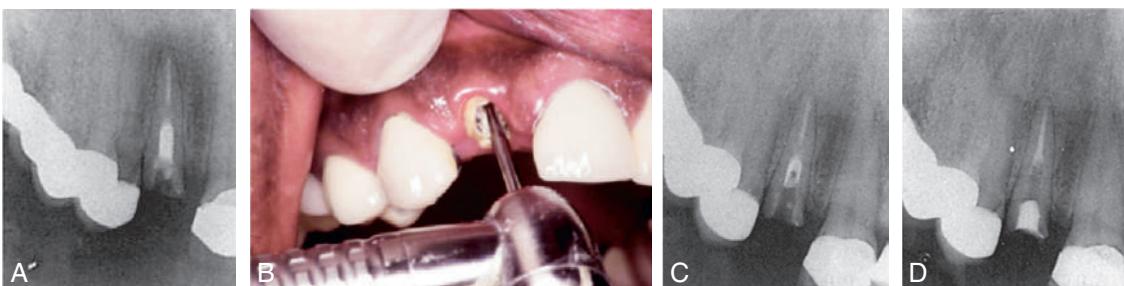


Fig. 12.47 Post removal by high-speed bur. (A) Preoperative radiograph of the right maxillary lateral incisor, in which both the crown and part of a post have been fractured off. A portion of the parallel-sided, threaded post remains within the canal. (B) Because of the large diameter of the post and 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.)

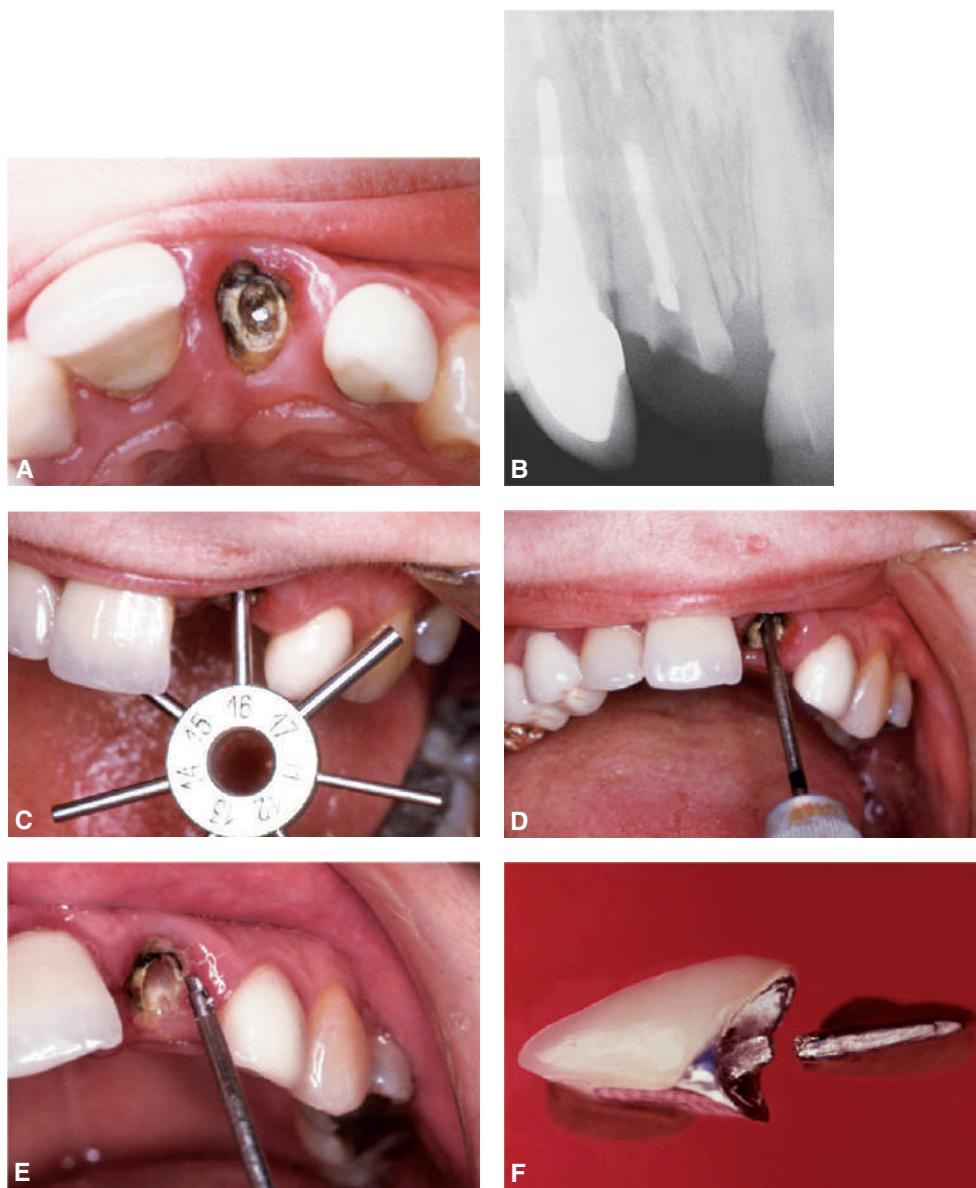


Fig. 12.48 Masserann technique for the removal of fractured posts. (A and B) Maxillary incisor with a post that has fractured inside the canal. (C) The diameter of the post is gauged with a sizing tool. (D) The selected trephine is carefully rotated counterclockwise to create a narrow channel around the post. (E) When the instrument has removed sufficient material, the post is recovered. (F) The fractured crown and post after removal.

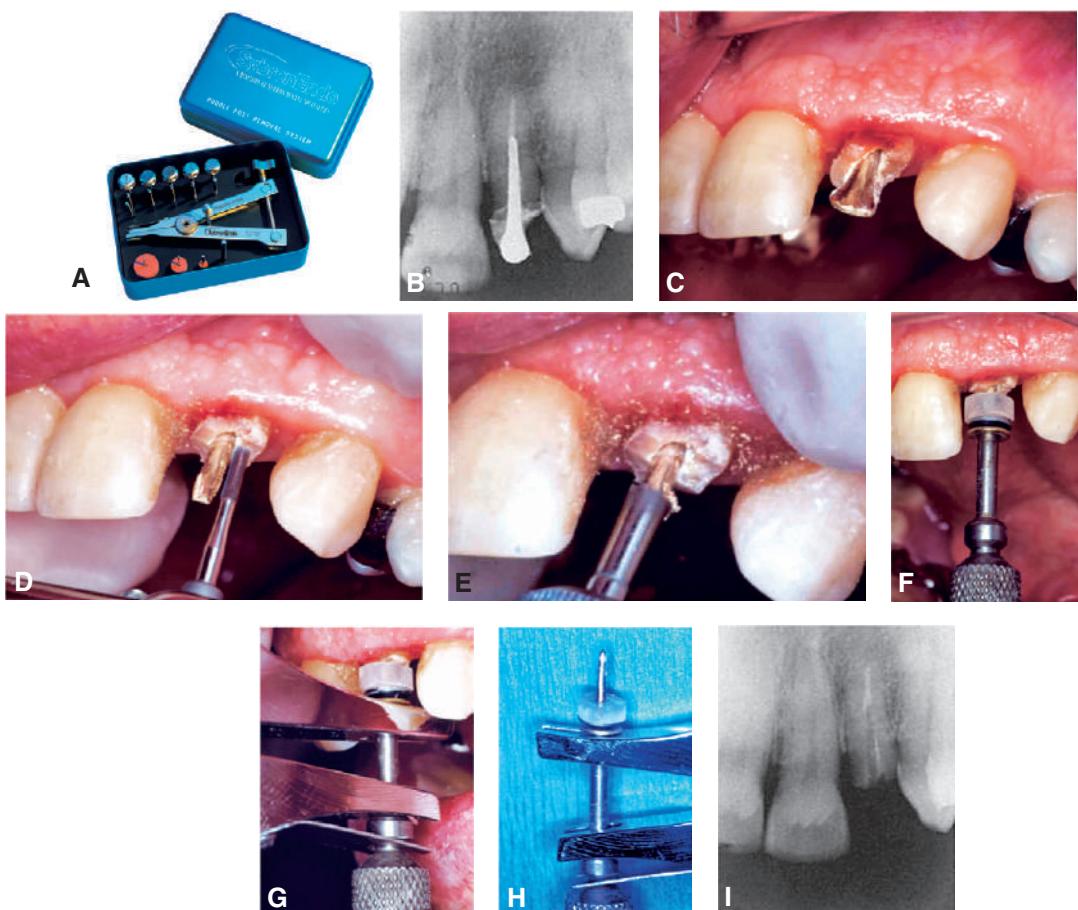


Fig. 12.49 Post removal by extractor. (A) Ruddle Post Removal System. It includes pliers, trephine burs, mandrels, and washers. (B) Preoperative radiograph of the left maxillary lateral incisor with a post. (C) Note the flared shape of the post in this preoperative view and the height of the surrounding 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–H, Courtesy Dr. D.A. Miller.)

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 plunger 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.

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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Implant-Supported Fixed Prostheses

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As a result of the continued high rate of success achieved with osseointegrated 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 patients with partial edentulism are the free-end distal extension removable partial prosthesis when no posterior abutment is available (Fig. 13.1), and long edentulous spans. In both these situations, the classic dental treatment plan would include a removable partial denture. However, with the advent of dental implants, the patient can benefit from fixed restorations. In addition, in the short edentulous span, single dental implants (Fig. 13.2) are a popular option to 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 the 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). Root form implants at this point in time are the primary type of implant in use. Root form dental implants are categorized as one-stage (tissue level) or two-stage (bone level). The tissue level dental implant is designed to be placed in the bone and to immediately project through the mucosa into the oral cavity. The bone-level dental implant necessitates two surgical procedures. First, the implant is placed in the 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 2 months in the mandible and 3 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 suggested⁶ 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, such as the 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

Advantages of root-form endosteal dental implants 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; these materials are perceived to have the highest biofunctionality. Both threaded and nontoothed 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 Conference¹ in 1988, root-form implants were reported to have already constituted 78% of the dental implant market. This trend is credited to the Bränemark 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. Bränemark were atraumatic implant placement and delayed implant loading. These factors contributed to a remarkably increased degree

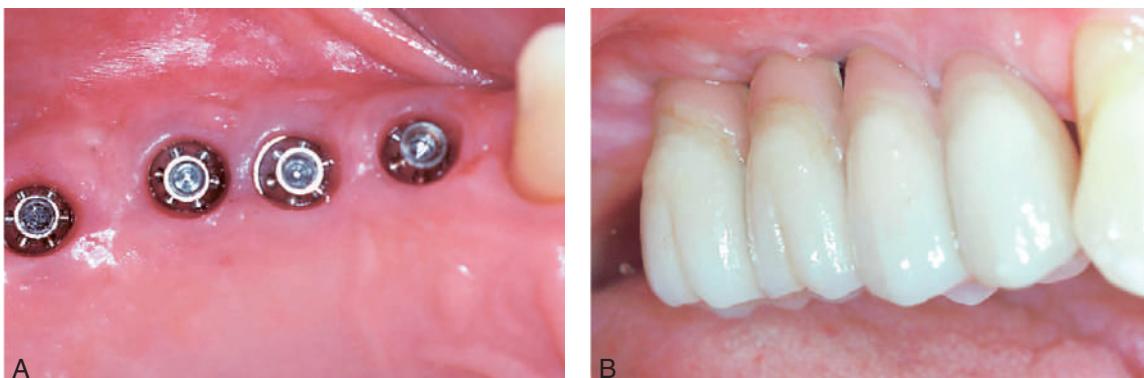


Fig. 13.1 Implant-supported fixed prosthesis. Four dental implants (A) supporting a fixed dental prosthesis (B).



Fig. 13.2 (A) Single-tooth implant with an internal antirotational feature. (B) Implant crown replacing a single missing tooth (cement-retained).

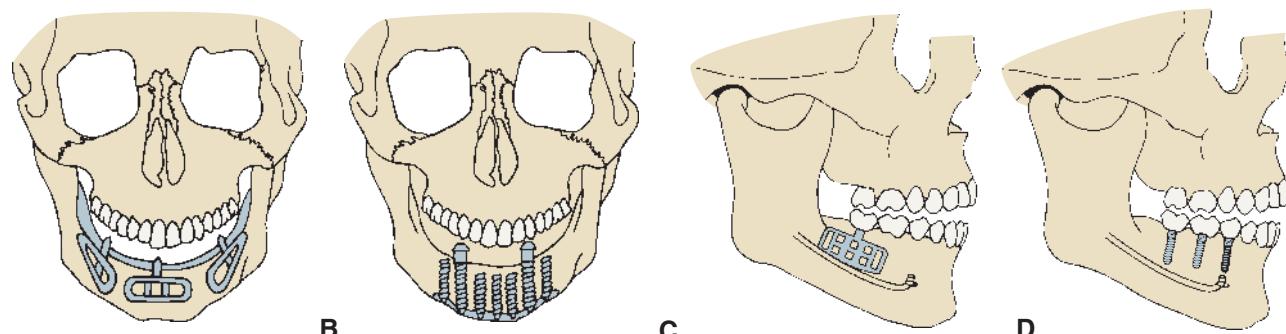


Fig. 13.3 The three major subgroups of dental implants. (A) Subperiosteal. (B) Transosteal. Endosteal implants can be further subdivided into plate form (C) and root form (D).

of implant predictability. Brånenmark and colleagues' original 15-year success rate of 91% in the mandible² 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

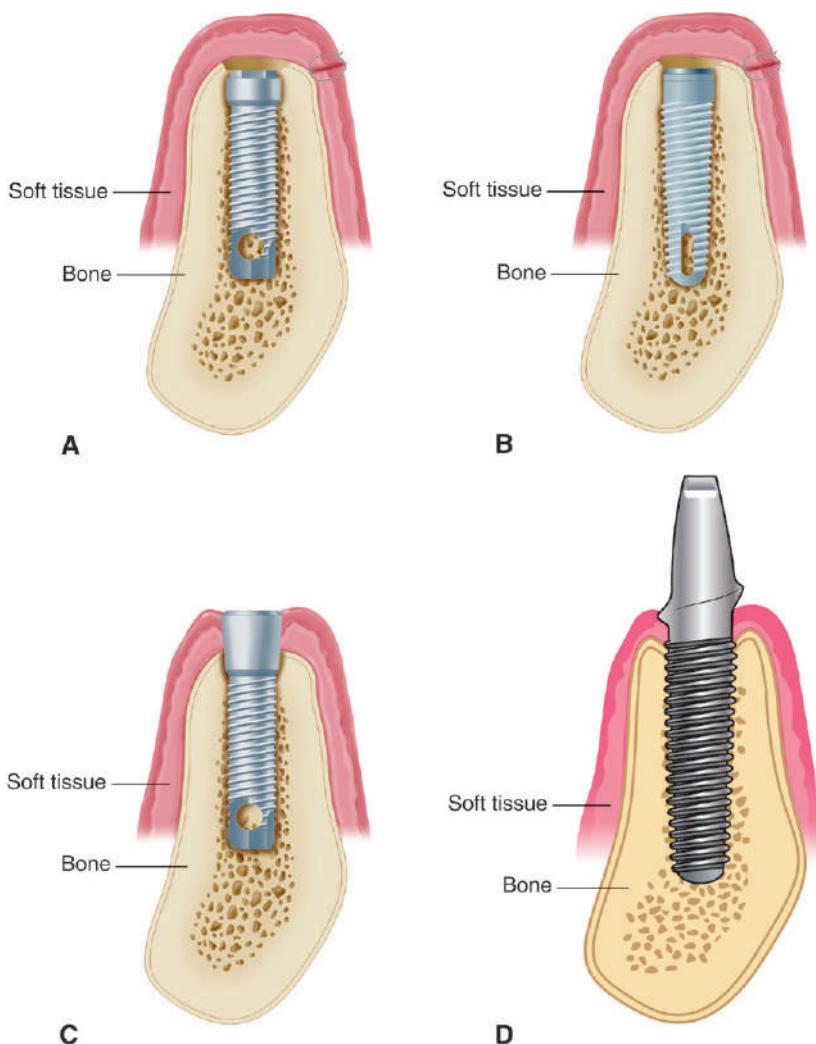


Fig. 13.4 (A) Straight-walled bone level implant. (B) Tapered bone level implant. (C) Tissue level implant. (D) One-piece implant.

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

limited to the presence of acute illness, uncontrolled metabolic disease, and pregnancy (these 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. The suspicion that hygiene will continue to be inadequate is a relative contraindication to implant placement. Patients must be motivated and

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

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 the 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 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 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. When the results of clinical and radiographic examinations are equivocal and additional information is needed, sounding of the bone with a probe has been used historically. 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. However, currently, specialized computed tomography (CT) scans provide necessary information for the available bone volume. Measurements can be performed on the CT image to determine the available bone size (Fig. 13.7). The location of the inferior alveolar canal and maxillary sinus can be determined by CT (Fig. 13.8), although comparatively high radiation exposure and cost may limit its routine use. However, significant advances being made in CT technology may reduce 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 a duplicate. Proposed implant 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 implants are planned as part of a complete-mouth reconstruction or when the anterior esthetic

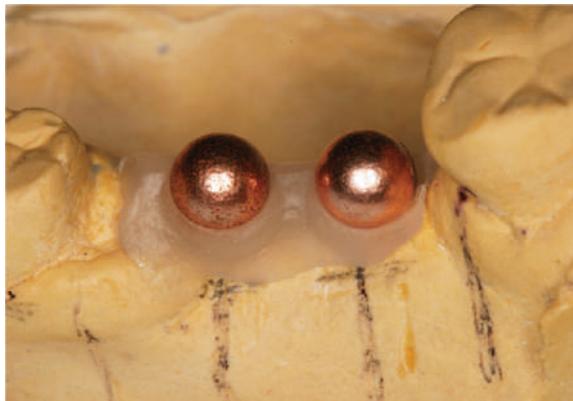


Fig. 13.5 Ball bearings (5-mm diameter) placed on the diagnostic cast at the proposed implant site.

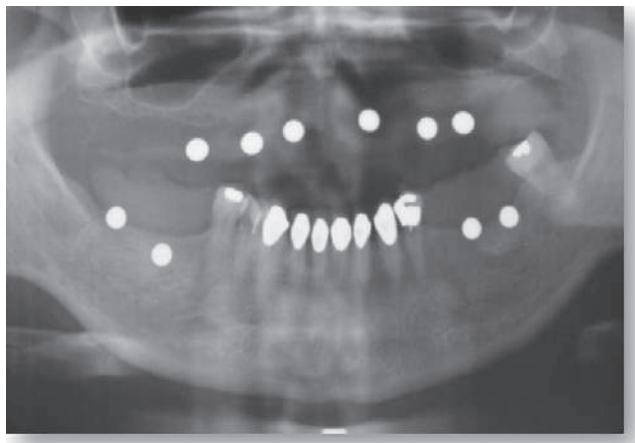


Fig. 13.6 A panoramic radiograph showing the ball bearings positioned intraorally with a wax or resin baseplate.

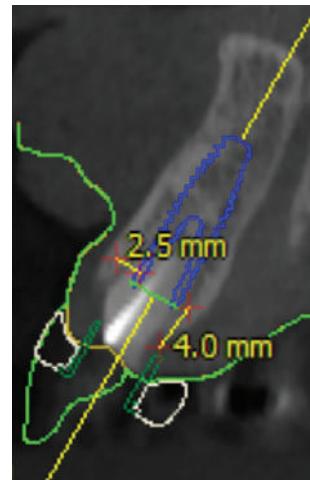


Fig. 13.7 Digital measurements can be made on computed tomography images.

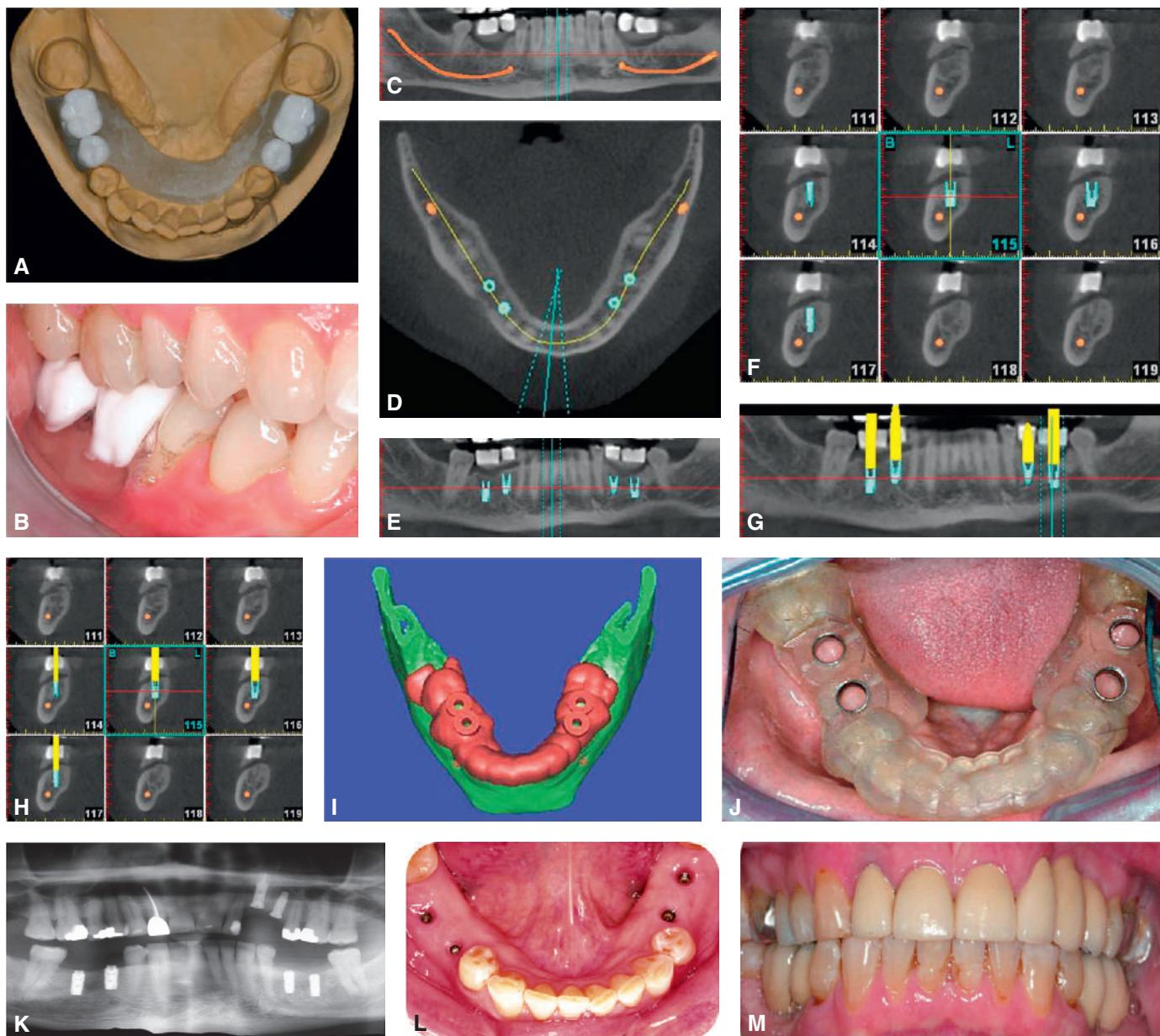


Fig. 13.8 Computed tomography (CT). (A) Scan guide with barium-impregnated teeth. (B) Scan guide positioned in the mouth. (C) Barium-impregnated teeth in the scan. (D) Scan with lines orienting the position of transverse mandibular cross-sections. (E and F) Reformatted cross-section of the posterior part of the mandible. Software program allows visualization of prospective implant placement. (G and H) The software program allows for placement of abutments for predictable prosthetic positioning. (I and J) CT-generated surgical guide design generated by software program (I) and the intraoral view (J). (K) Panoramic radiograph. (L) Intraoperative view of implants. (M) Intraoperative view of definitive restorations.

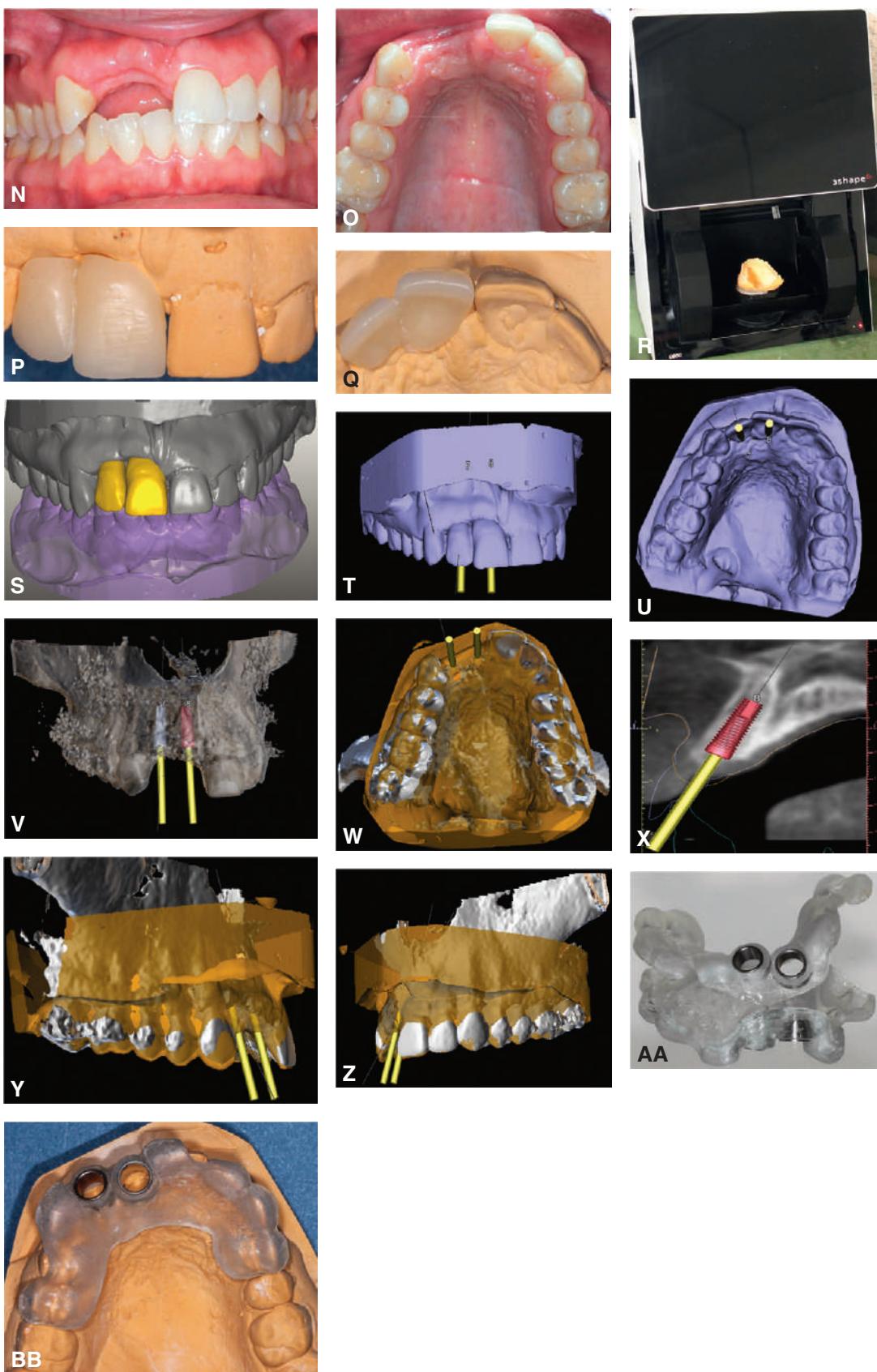


Fig. 13.8 Cont'd (N and O) Missing right lateral and central incisors to be restored with two implants. (P and Q) Diagnostic waxing. (R) Laboratory scanner. (S) Laboratory scan of the diagnostically waxed cast. (T–Z) Incorporation of software-generated views of the waxed diagnostic cast into CT for virtual treatment planning. (AA and BB) CT-generated surgical guide.

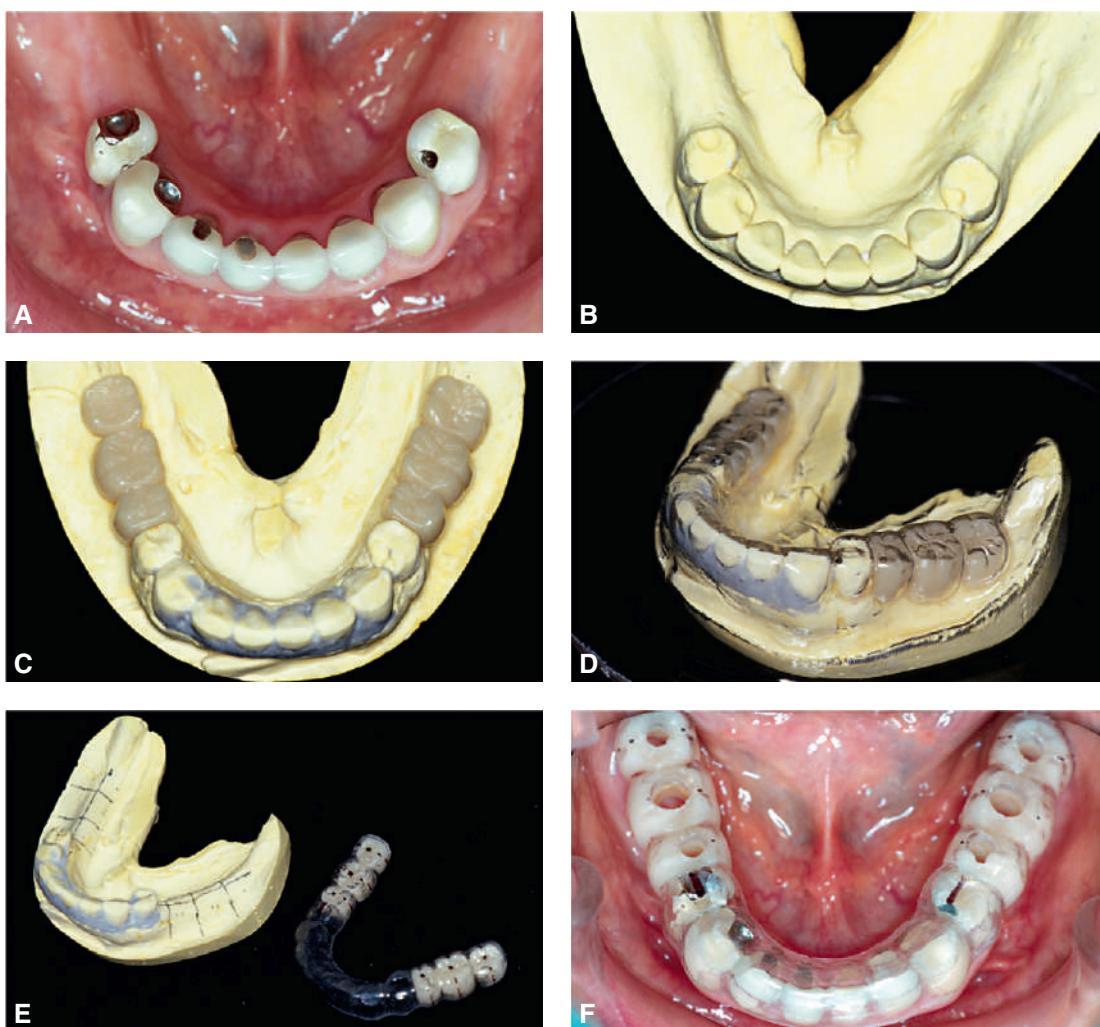


Fig. 13.9 (A) Bilateral missing posterior teeth to be replaced with implant-supported restorations. (B) Diagnostic cast. (C) Diagnostic denture tooth arrangement to simulate three-unit fixed prostheses on each side of the mandible. (D) Vacuumed matrix formed over the cast with 1.5-mm (0.060-inch) thermoplastic 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.

zone is restored (Fig. 13.10). With the advent of imaging technologies, the diagnostic waxing can be performed virtually on digitally scanned arches either with intraoral scanners or the scans of the casts with laboratory scanners. In completely edentulous situations, existing dentures or interim dentures can be used with scan markers for superimposition of CT images of the denture and the intraoral situation when the denture is in place, and the superimposed image of scans reveals the relationship of the bone to planned tooth positions (Fig. 13.11A–D).

PRINCIPLES OF IMPLANT LOCATION

Anatomic Limitations

To maximize success, the implant should be placed entirely within the 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. 13.12). 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.

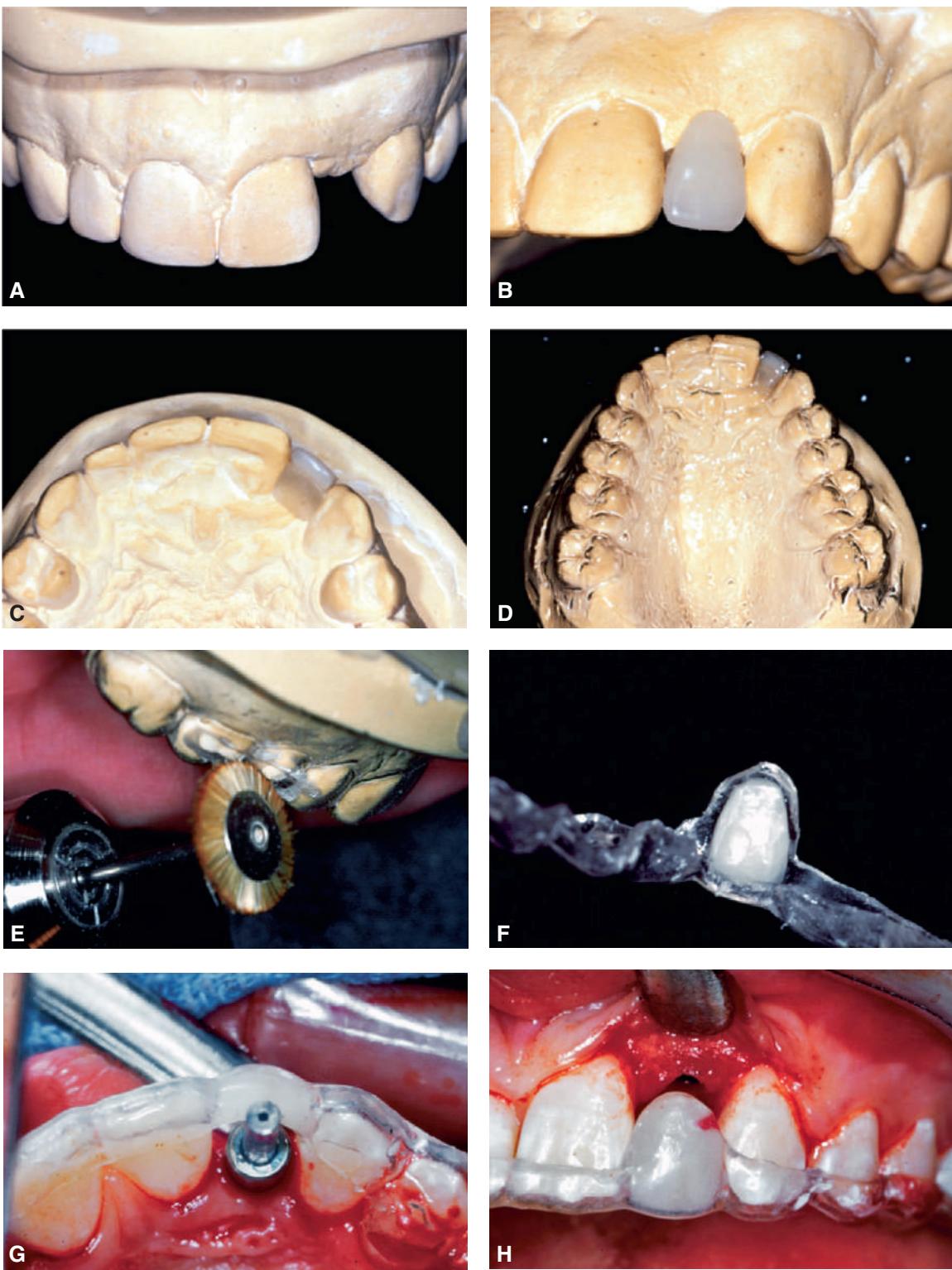


Fig. 13.10 (A) Diagnostic cast with missing maxillary left lateral incisor. (B) The denture tooth is positioned for optimum esthetics. (C) The denture tooth is trimmed from the lingual side until it is 2-mm thick. (D) If the denture tooth is held in position with a light-polymerized composite resin, 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.

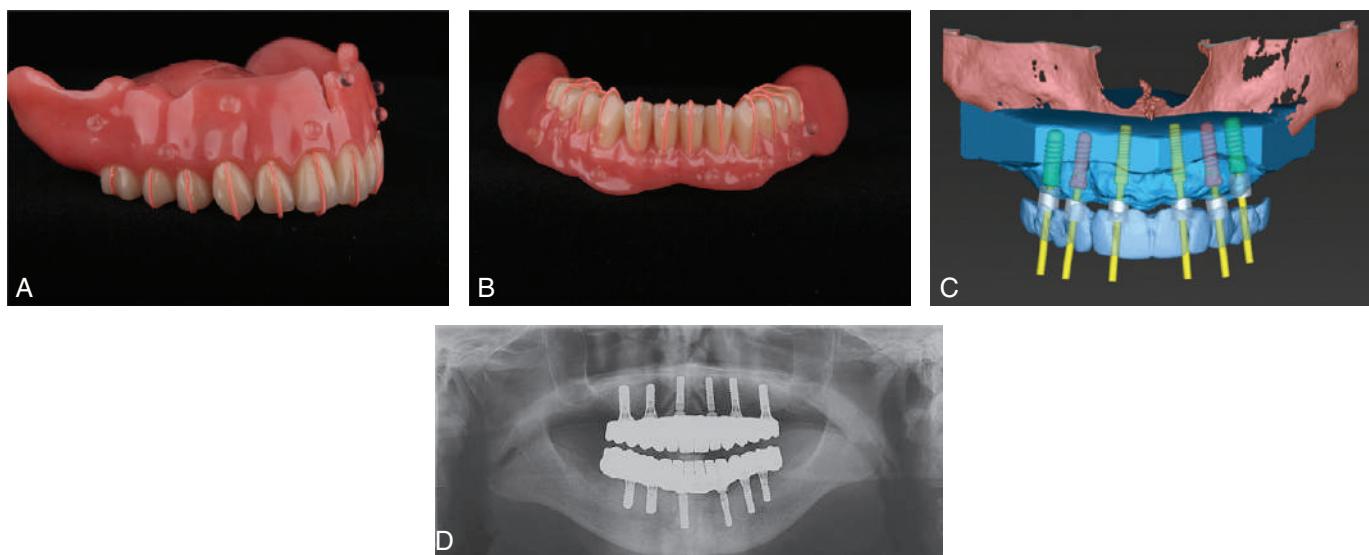


Fig. 13.11 (A and B) Complete dentures with radiographic markers. (C) Complete denture is computed tomography scanned when in patient's mouth and implants are virtually placed considering the marker locations. (D) Panoramic radiograph showing implants placed according to the virtual plan. (A–D, Courtesy Dr. Manrique Fonseca.)

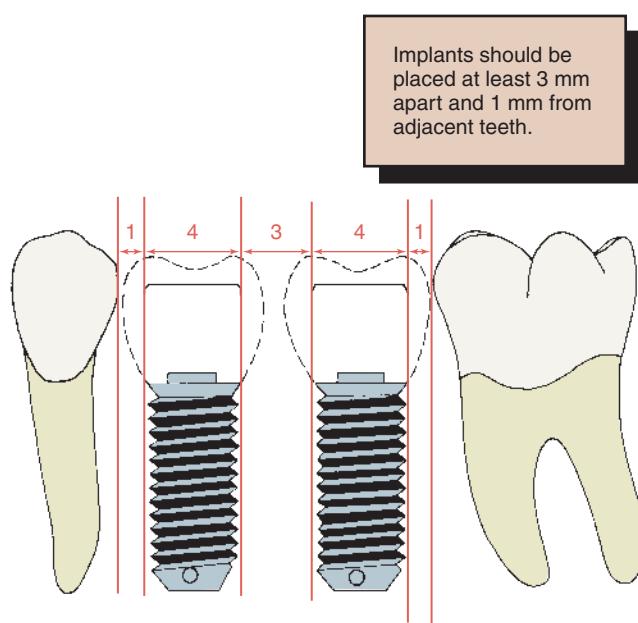


Fig. 13.12 Recommended minimum distances (in millimeters) between implants and between implants and natural teeth.

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.

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 3 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 if 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. 13.13). 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 the cortical bone of the sinus floor. Bone height between the nasal cavity and the maxillary sinus is usually adequate for implant stability. If the bone is not adequate for implant placement and support, bone augmentation through the sinus should be considered.

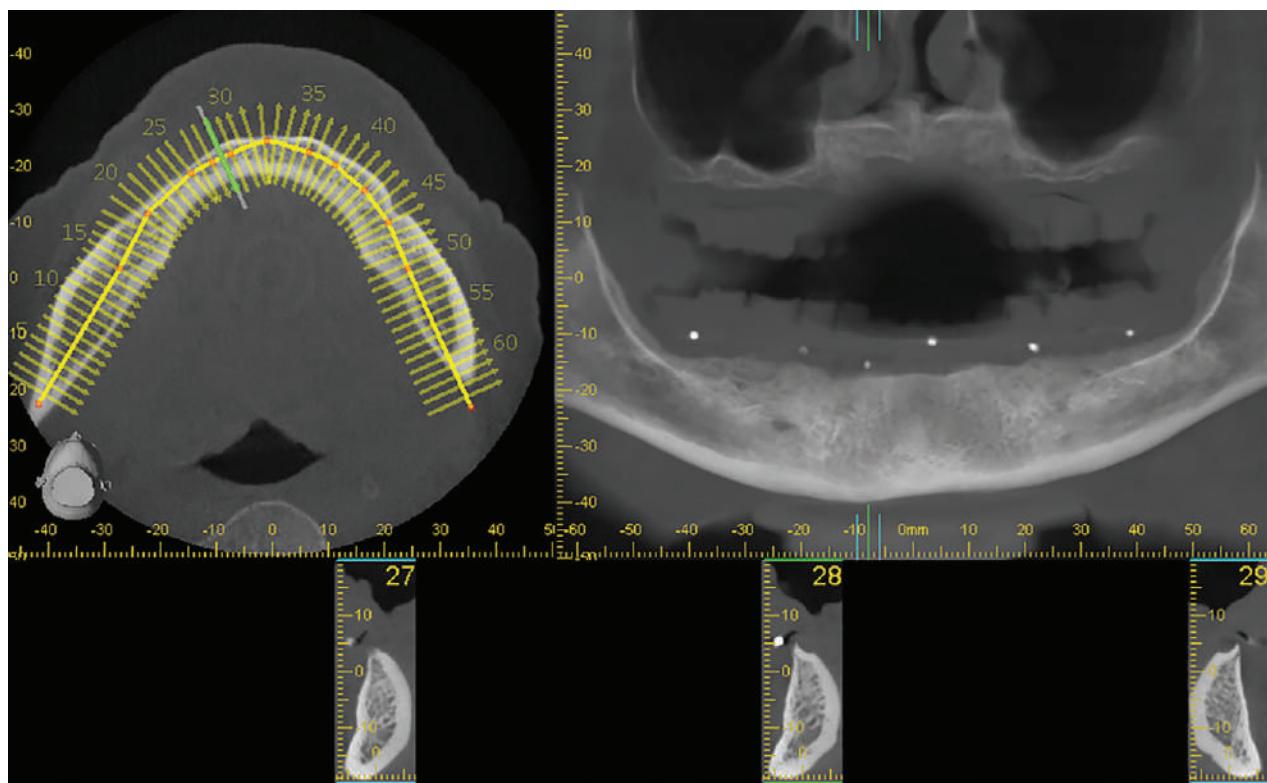


Fig. 13.13 Thin maxillary bone inferior to the sinus would be inadequate for implant placement without additional grafting procedures. (Courtesy Prof. Martin Schimmel.)

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. 13.14). 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 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.

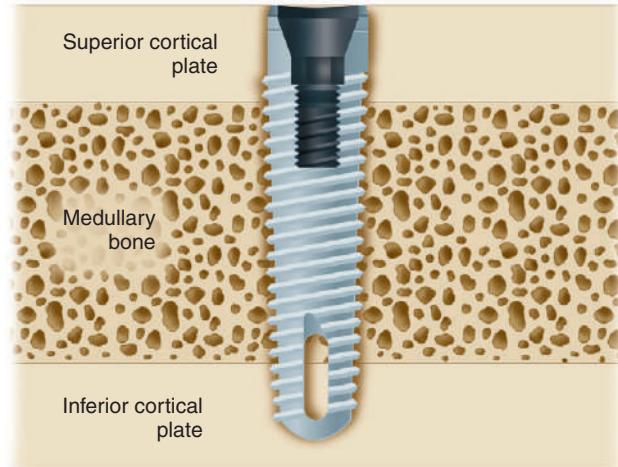


Fig. 13.14 Whenever possible, implants should engage two cortical plates of bone.

Implants placed in the posterior part of the mandible are usually shorter, do not engage the 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. 13.15).

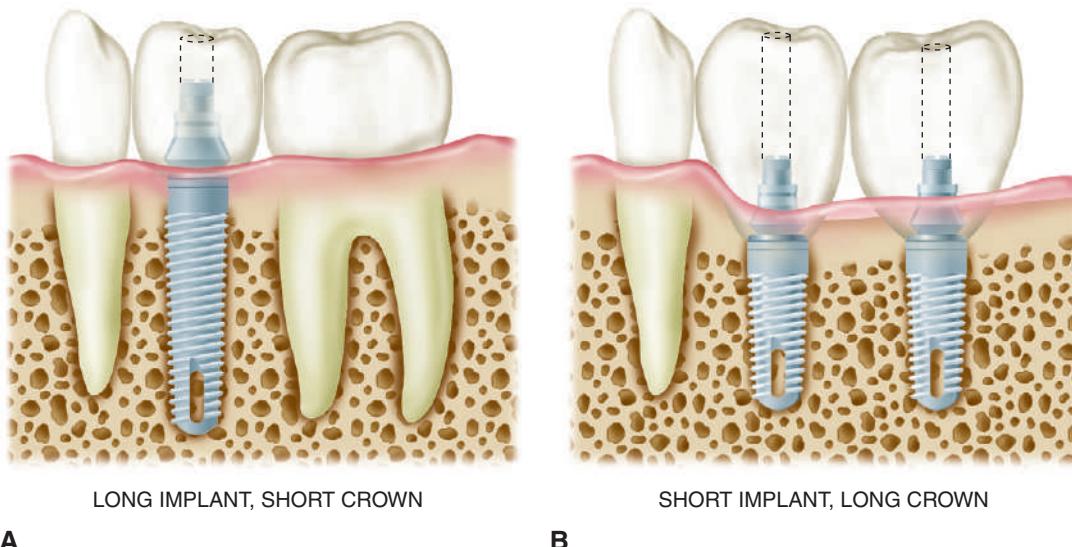


Fig. 13.15 Shorter implants usually have two problems: (1) less bone contact and (2) longer crowns, which increase the forces acting on the implant. Restorations with more favorable (lower) crown-to-implant ratios (A) have a better prognosis than those with less favorable (higher) ratios (B).

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.

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 since that permits the development of optimal restoration contours by the restorative dentist. For proper access during oral hygiene procedures, a minimum of 3.0 mm should be left between adjacent 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. 13.16).

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 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. 13.17).

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 eventual restoration will be over-contoured 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 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. 13.18).

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 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 built into the system (e.g., a spline or a hexagon) is essential (Fig. 13.19).

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

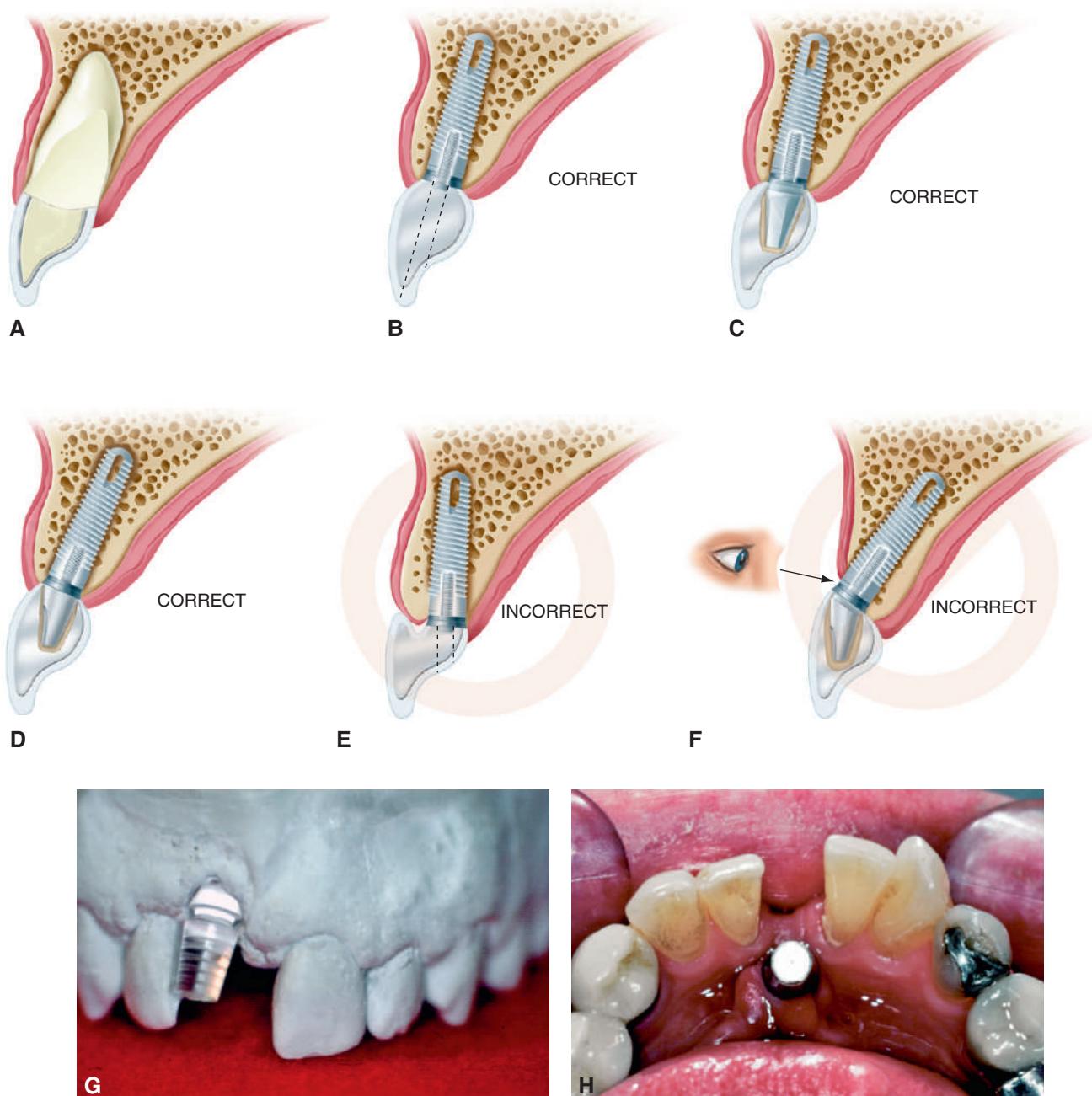


Fig. 13.16 Implant placement and angulation dictate the screw emergence position and crown contours. Esthetics and access to hygiene can be greatly affected. (A) A restored tooth. (B) Ideal implant location with acceptable crown contours and lingual screw emergence. (C) Acceptable implant location for 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.

contains guidelines that help predict whether adequate soft tissue contour can be maintained. As diagrammed (Fig. 13.20), the relationship of interdental bone to the interproximal contact seems correlated with the presence or absence of an interdental 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 implant restoration. A surgical guide template is extremely useful for anterior implants because slight variations in angulation can significantly affect the appearance of the definitive restoration. Fabrication of the surgical

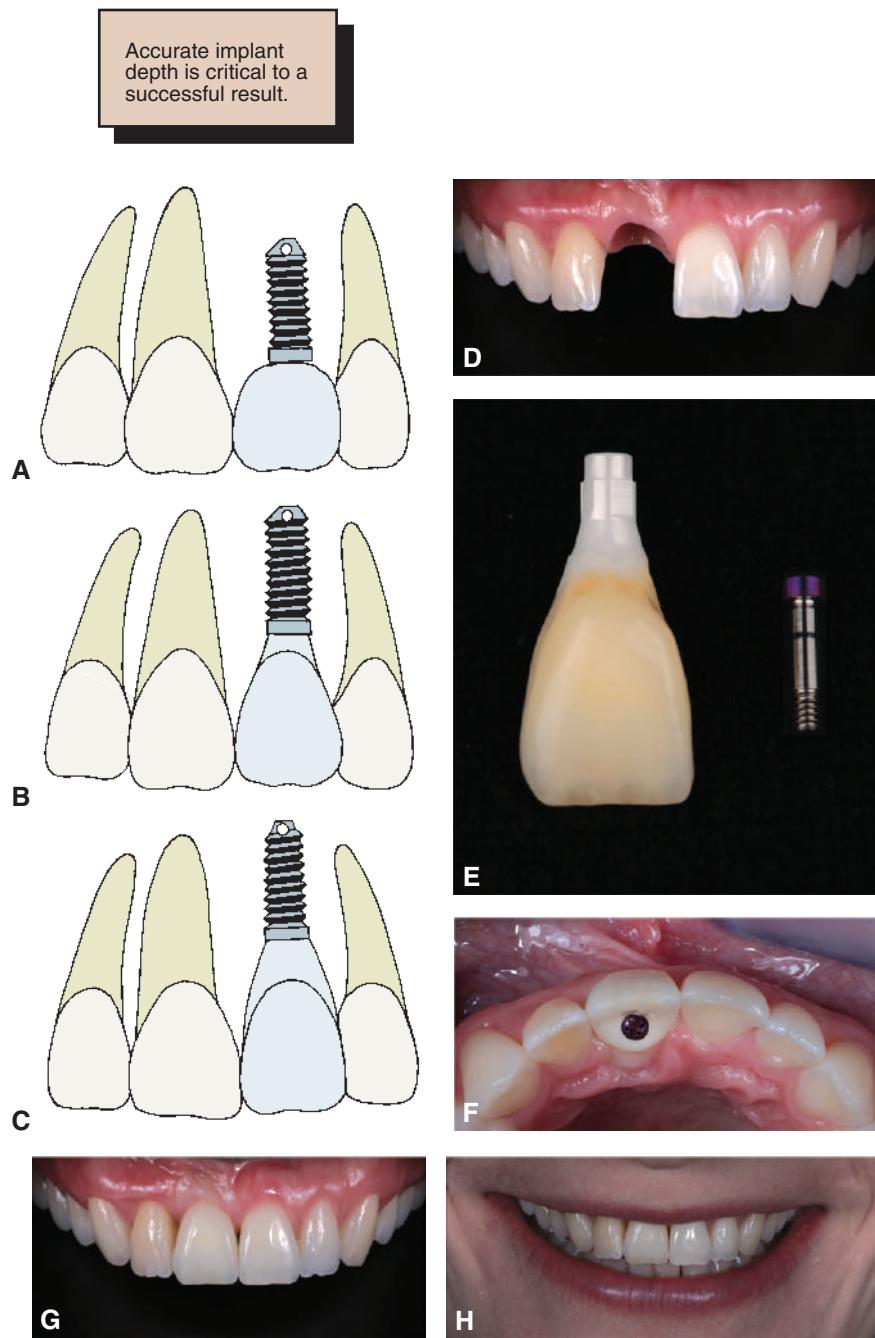


Fig. 13.17 Superior or inferior positioning may affect crown contours and pocket depth. (A) The implant is not placed deep enough. As a result, the crown will be short and over-contoured. (B) Placement 2 to 3 mm apical to the tooth emergence position is ideal. (C) Placing the implant 4 mm apical to the crown contours may result in an excessively deep gingival sulcus. (D) Contoured soft tissues. (E) Zirconia crown. (F) Occlusal view. (G) Intraoperative facial view. (H) Facial view. (A–C, Courtesy Dr. Luiz Daroz Diaz. D–H, Courtesy Dr. Manrique Fonseca.)

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 are 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 into quick-setting stone. Then 1.5-mm (0.060-inch)-thick vacuum-formed matrix material is adapted to the replicated

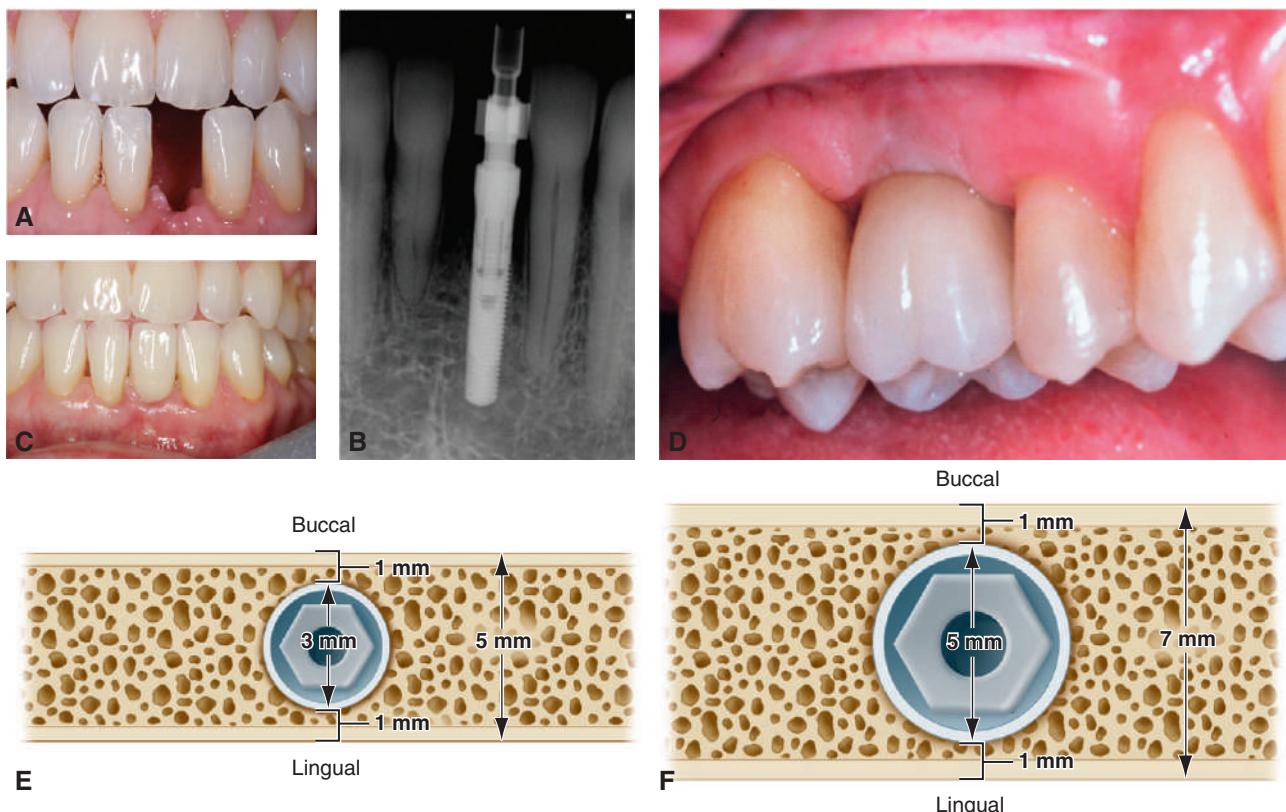


Fig. 13.18 (A) Missing mandibular central incisor. (B) Radiograph of narrow diameter 2-piece implant. (C) Completed screw-retained crown for mandibular central incisor. (D) Completed implant restoration of the maxillary first molar. (E) The minimum bone dimension for a small diameter implant is 5 mm. 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.

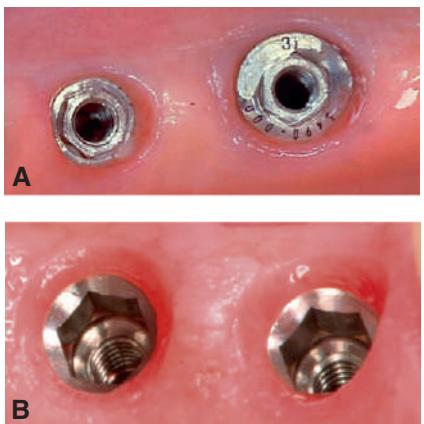


Fig. 13.19 (A) Implants with an antirotational feature (standard external hexagon). (B) Implants with internal hexagon connection.

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. 13.21). (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.

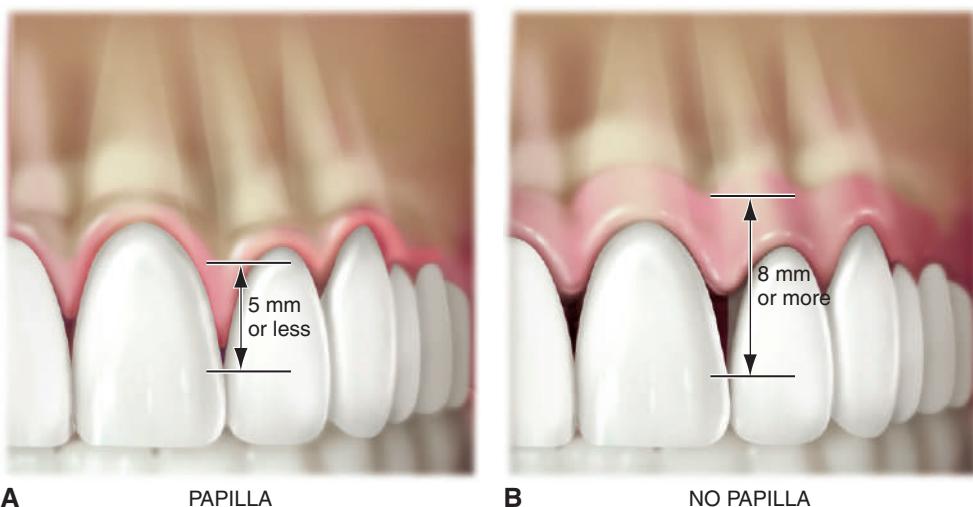


Fig. 13.20 Relationship of interdental bone to the position of interproximal contacts seems to predict whether interdental papilla will be present or not. If the distance between the bone and the contact is less than 5 mm (A), usually a papilla is present; if the distance is more than 8 mm (B), usually no interdental papilla is present.

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, 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, the 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.

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 the 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.

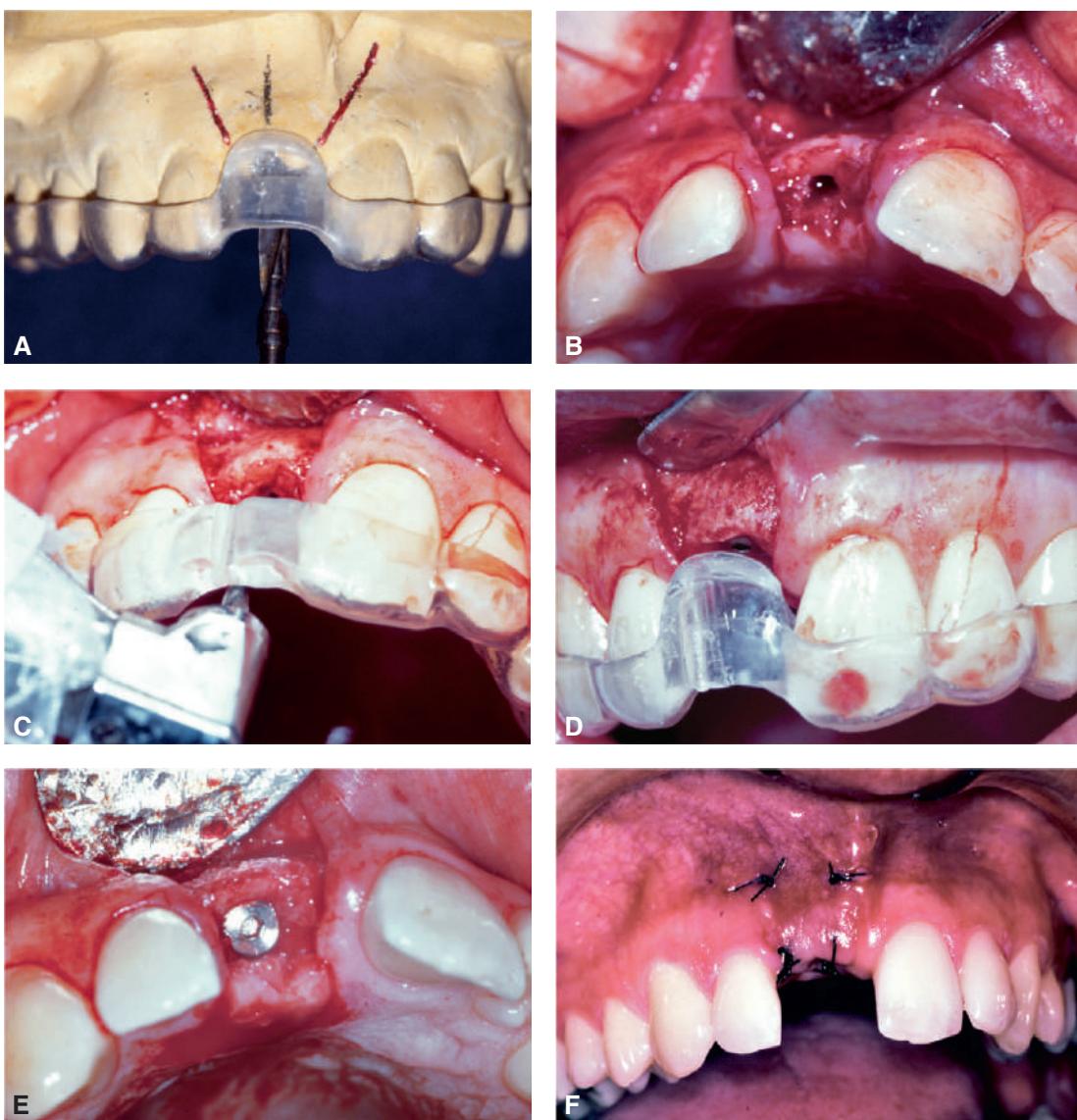


Fig. 13.21 Anterior implant placement with a surgical guide template. (A) The apical extent of the template is left in place, which allows the superoinferior orientation of implant placement to be determined. (B) Full-thickness flap incisions are made, preserving the interdental papilla. The flap is 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 2 to 6 months. (Courtesy Dr. J.A. Holloway.)

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 pre-threading 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 tissue level 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 3 months in the maxilla, 2 months in the mandible, which were historically 3 months for the mandible and 6 months for the maxilla.

The goals of surgical uncovering are to accurately attach the abutment to the implant, preserve attached tissue, and 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 to 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. 13.19), 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).

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 Fig. 13.22.

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 non-threaded root form and is ordinarily made of either titanium or a titanium alloy of varying surface roughnesses, or in zirconia (Fig. 13.23). In the past, some titanium or titanium alloys were coated with hydroxyapatite.³ 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 *tissue level* or *bone level*. Tissue level implants project through the soft tissue immediately after first-stage surgery. Bone level implants are typically covered with soft tissue at this point. Placement of a tall healing screw or cap on a bone level implant, to project it through the tissue at the time of placement, is referred to as “using a bone level 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 bone level implant or to minimize loading in the tissue level implant (Fig. 13.24). 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

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



Fig. 13.22 (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 profiles. (J) Abutment for cement-retained restoration selected. (K) Zirconia abutment seated on the cast and ready for the fabrication of ceramic restoration (see Chapter 25). (L) Zirconia abutment seated in the mouth. (M) Appearance of the ceramic restoration.

TABLE 13.1 Implant Terminology

Text Term	Also Known As	Function/Description
Implant body (see Fig. 13.23)	Implant fixture screw or cylinder	Portion of the implant system within the bone
Healing screw (see Fig. 13.24)	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. 13.25)	Temporary gingival cuff Healing collar Implant healing cap Healing abutment	A cover, attached to the implant, which 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. 13.25B)	Temporary screw Comfort cap Abutment healing cap	A cover that is attached to the top of a transmucosal abutment, protects the internal threads and interface surfaces of the abutment while the restoration is being completed
Standard abutment (see Fig. 13.26A)	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. 13.26D)	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. 13.36A)	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 inches)
Abutment driver or seating tool	The name of each driver/tool is specific, based on its use	Used to seat the abutment directly onto the implant
Impression coping (see Fig. 13.36A, 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. 13.36G)	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. 13.51H)	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. 13.26B 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. 13.41)	Plastic sheath Plastic sleeve Plastic coping Castable abutment Castable coping Gold sleeve Gold coping Gold cylinder	A castable plastic pattern usually attached to a pre-machined metal base used to form an abutment during the laboratory waxing procedure Placed directly onto the implant or the transmucosal abutment
Prosthesis-retaining screw (see Fig. 13.42)	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)

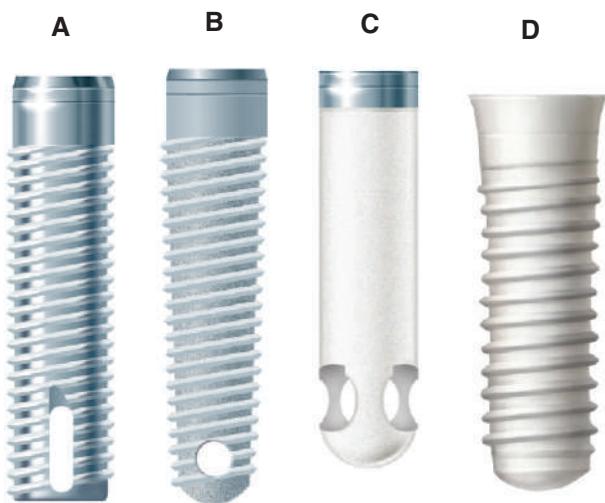


Fig. 13.23 Four main categories of osseointegrated implants. (A) Titanium screw. (B) Ti plasma-sprayed screw. (C) Titanium plasma-sprayed cylinder. (D) Zirconia.

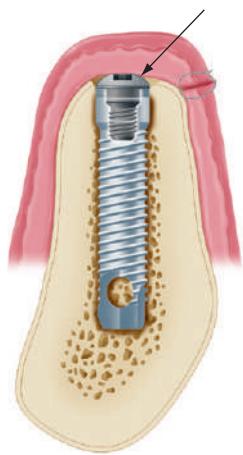


Fig. 13.24 Healing screw (arrow) in place during the initial healing phase of implant placement. Soft tissue is sutured over the implant. A removable prosthesis can be worn over this area during healing.

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. 13.25). 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-ceramic 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.

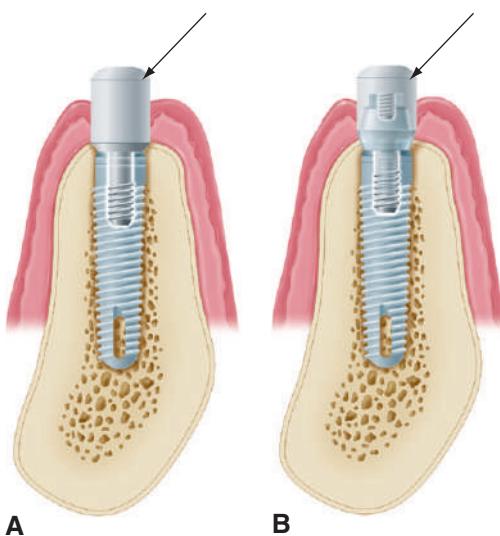


Fig. 13.25 Components that allow for soft tissue healing after second-stage surgery. (A) This interim abutment (arrow) screws into the implant. (B) The healing cap (arrow) screws into the abutment.

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. 13.26). 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. 13.27). In esthetic areas, an abutment can be selected to allow the porcelain to extend subgingivally for optimum esthetics (Fig. 13.28).

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. 13.29). With angled abutments, a similar technique is used to correct divergently placed implants (Fig. 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. Ceramic components onto which ceramic crowns can be cemented became popular for the anterior part of the mouth. The ceramic components are usually made of sintered alumina, zirconia, or a combination of the two. Ceramic components can be in one piece (see Fig. 13.17E) or cemented or friction-fitted on titanium components to form hybrid abutments (see Fig. 13.22).¹³ There

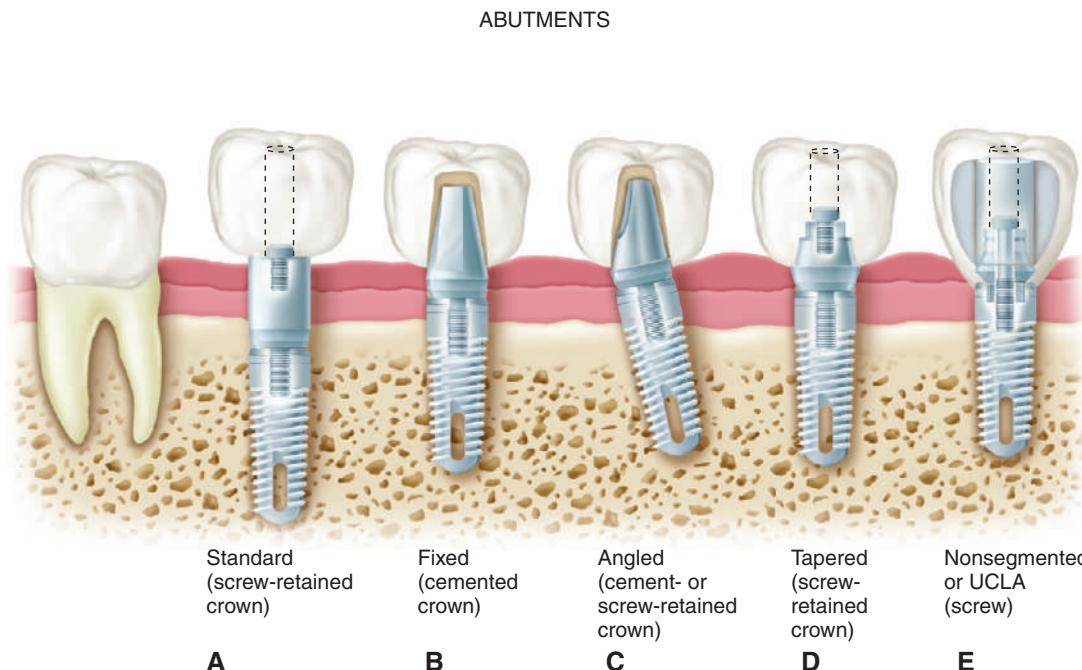


Fig. 13.26 Types of abutments. (A) Standard. Length can be selected to make the margin subgingival or supragingival. (B) Fixed. This abutment is much like a conventional post-and-core restoration. It is screwed into the implants, has a prepared finish line, and receives a cemented restoration. (C) Angled (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 onto 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.)

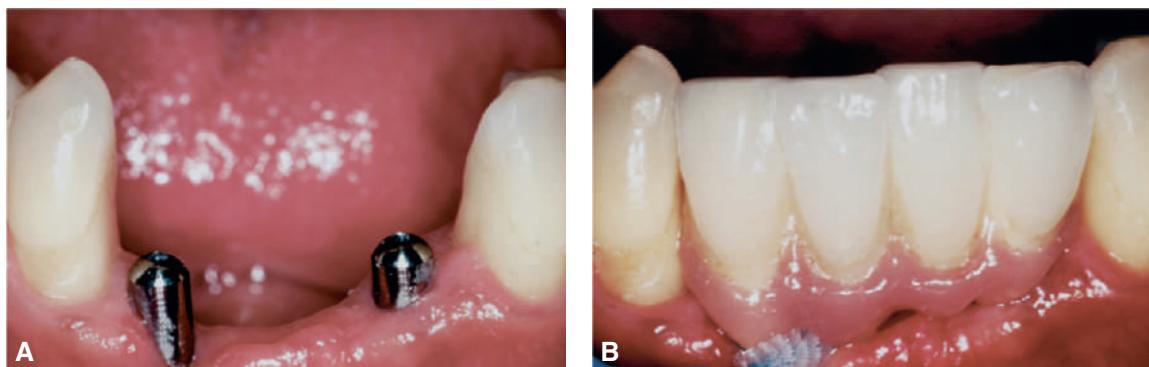


Fig. 13.27 (A) Interim abutments projecting through the soft tissue. (B) Implant restorations supported by standard abutments that allow easy access for oral hygiene.

have been some fractures reported when the ceramic abutment is used one-piece ([Fig. 13.31A and B](#)).

The recently introduced angled screw channel concept enables the fabrication of screw-retained crowns on misaligned implants changing the location of the access hole to a more lingual or palatal location ([Fig. 13.32A](#)). These systems have unique screwdrivers which allow the clinician to approach the screw head from a certain angle. These crowns can be made out of zirconia cemented or friction-fitted on titanium components.

A resin opaquer has also been recently introduced to be applied on metal abutments to mask the dark metal color, and these opaquer resins enable the delivery of ceramic crowns on metal abutments ([Fig. 13.33](#)).¹⁴

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,

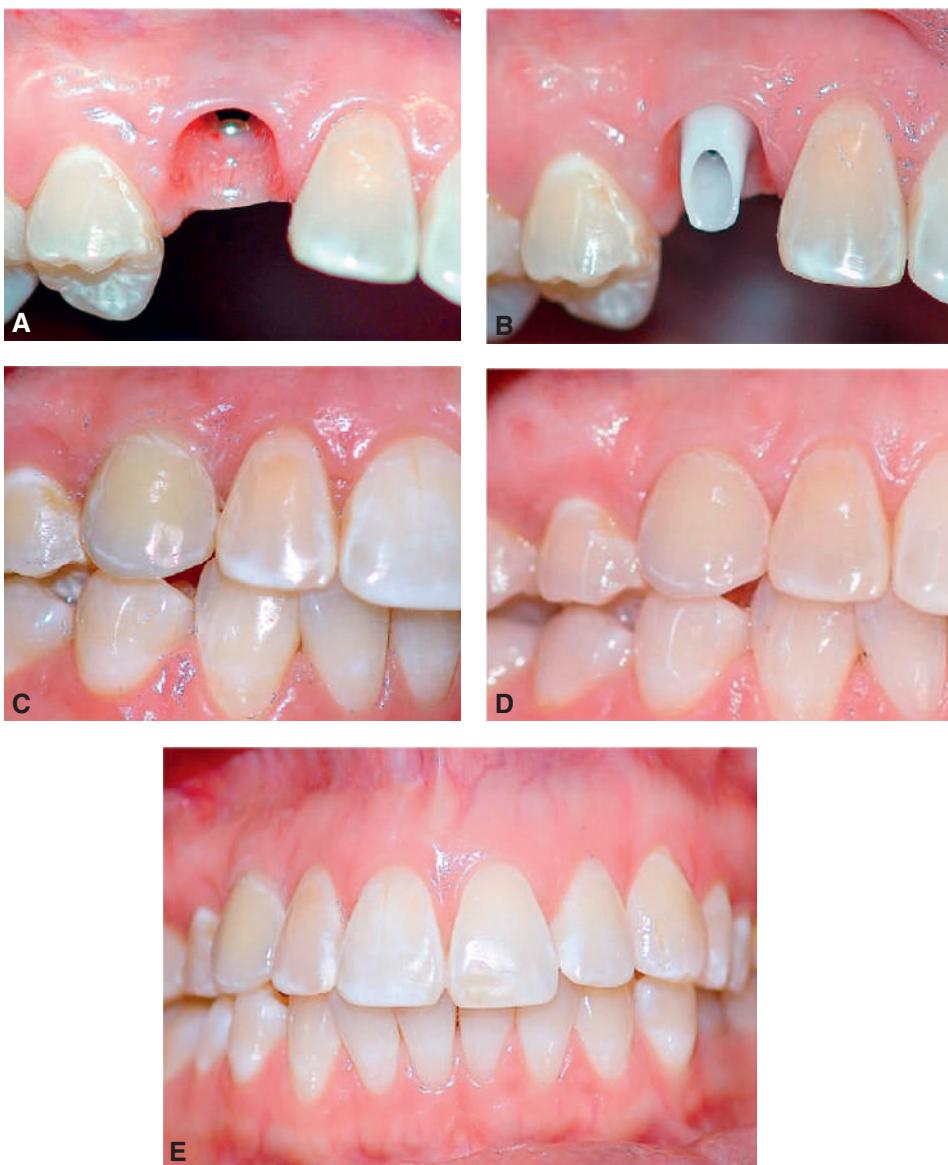


Fig. 13.28 (A) Contoured soft tissue for implant restoration of maxillary right canine. (B) Fixed zirconia abutment selected with margins 1 to 2 mm subgingival. (C) Completed, cemented restorations. (D) Five-year restoration result. (E) Overall 5-year result. Esthetic tissue contours are symmetric with those of the contralateral canine. (Courtesy Dr. Tuncer Burak Ozcelik.)

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. 13.34).

Impression Copings

Impression copings facilitate the 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. 13.35). 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 made to confirm the complete engagement. Heavier body impression materials (e.g., polyvinyl siloxane or 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 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

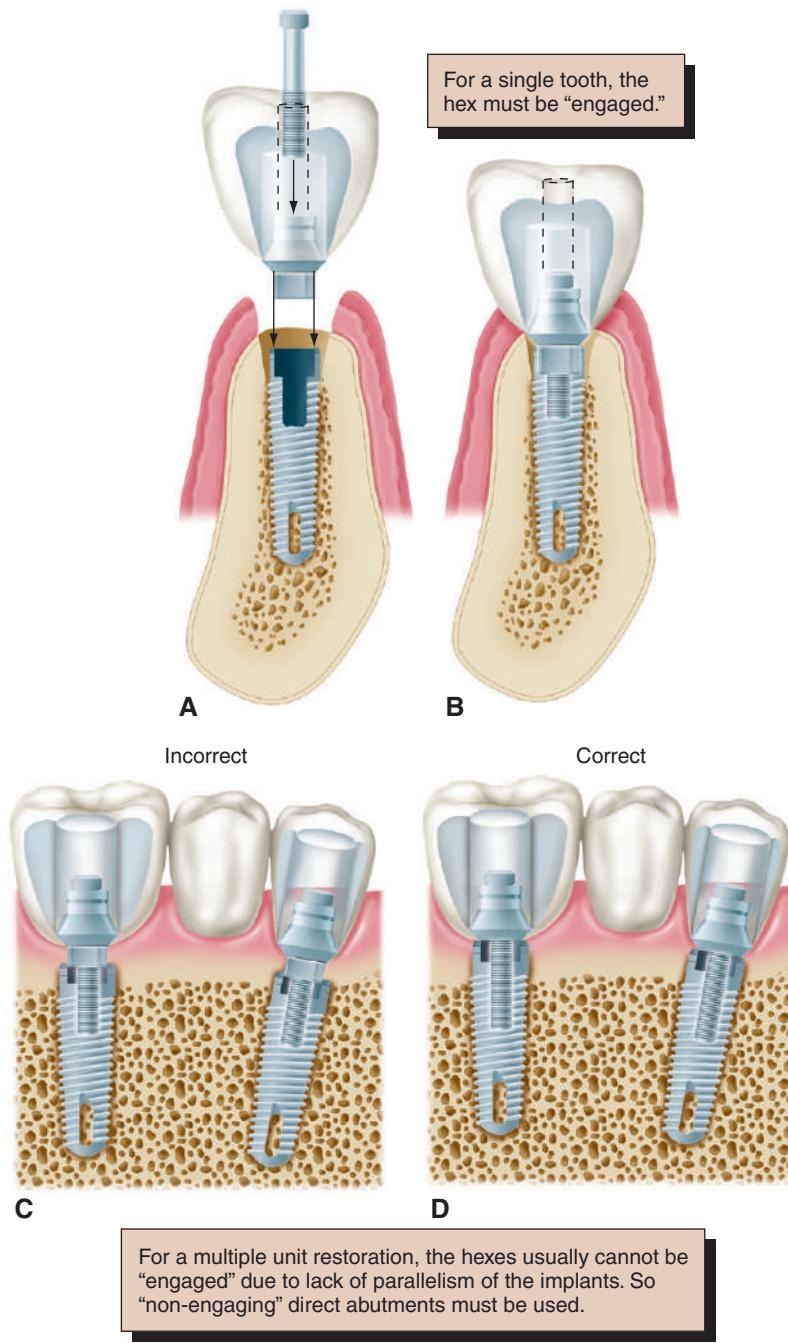


Fig. 13.29 (A–D) When an antirotational feature is to be engaged by the abutment, one component of the abutment (the sleeve) must fit the hexagon (“hex”), whereas the other (the screw) independently tightens the components together.

cast, a flat-sided impression coping that goes directly into the implant should be used (Fig. 13.36). 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 been set so that the copings can be picked up within the impression when it is removed from the mouth (Fig. 13.37). When implants are oriented at significantly divergent angles, the pickup technique is generally

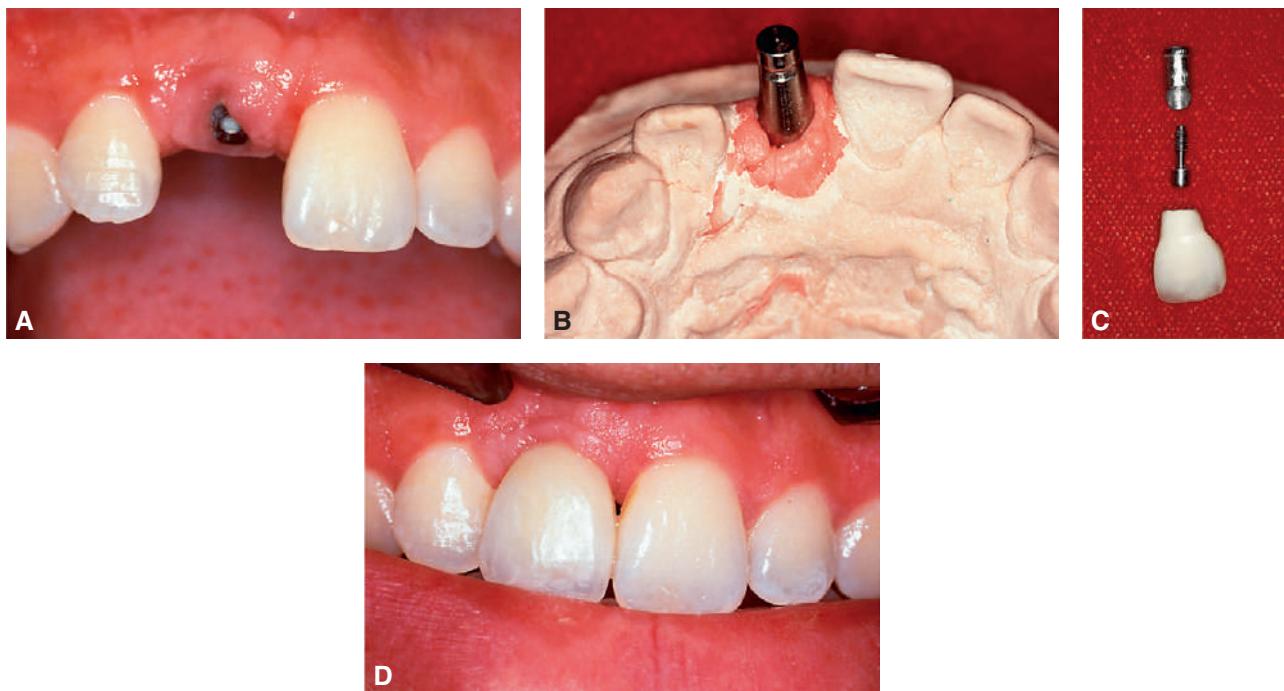


Fig. 13.30 (A and B) This implant in the maxillary central incisor position is angled too far facially to restore with a straight abutment. (C) An abutment angled 15 degrees with subgingival margins is chosen to rectify the situation. (D) The completed crown cemented onto the angled abutment. An interim 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.

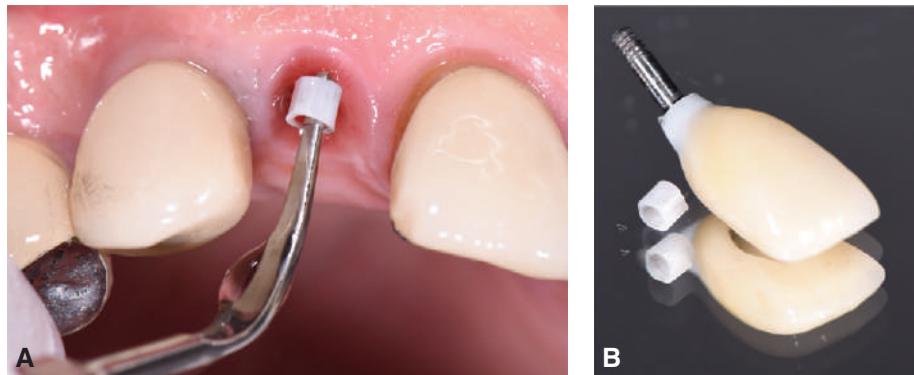


Fig. 13.31 (A) Fractured piece of the abutment at internal connection area being removed. (B) Screw-retained crown with one-piece zirconia abutment with fractured internal connection area. (Courtesy Prof. Dr. Julia Wittneben.)

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 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. 13.38). 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 definitive 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 the 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. 13.39).

Abutment analogs are generally attached to an implant impression coping. Implant body impression copings are normally attached to implant body analogs. The advantage of

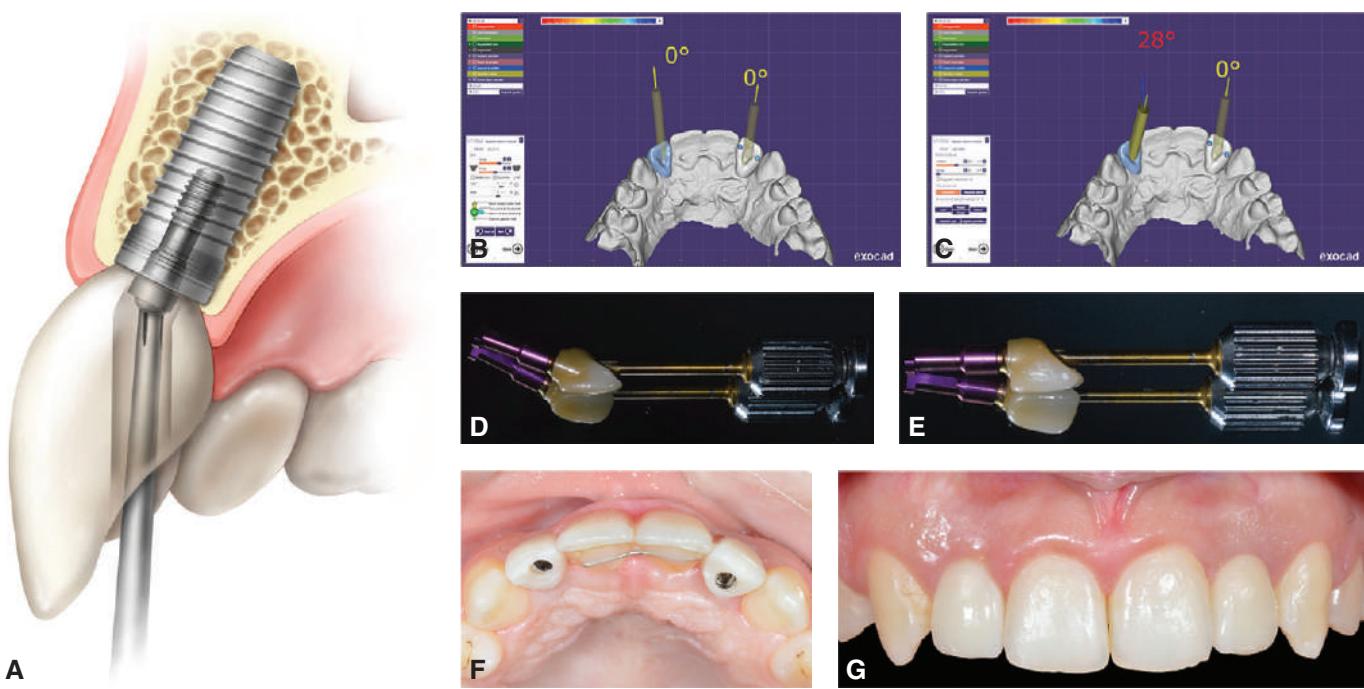


Fig. 13.32 (A) The angled screw channel concept enables the fabrication of screw-retained crowns on misaligned implants, changing the location of the access hole to a more lingual/palatal location. (B) Buccally placed right central incisor and optimal placement with left lateral incisor. (C) Virtually corrected angle with angulated screw channel on the right lateral incisor. (D) Straight channel crown for left central incisor. (E) Angulated channel for right lateral incisor. (F) Incisal view of the corrected angle of the right lateral incisor. (G) Frontal view. (B–G, Courtesy Dr. Oguz Ozan.)

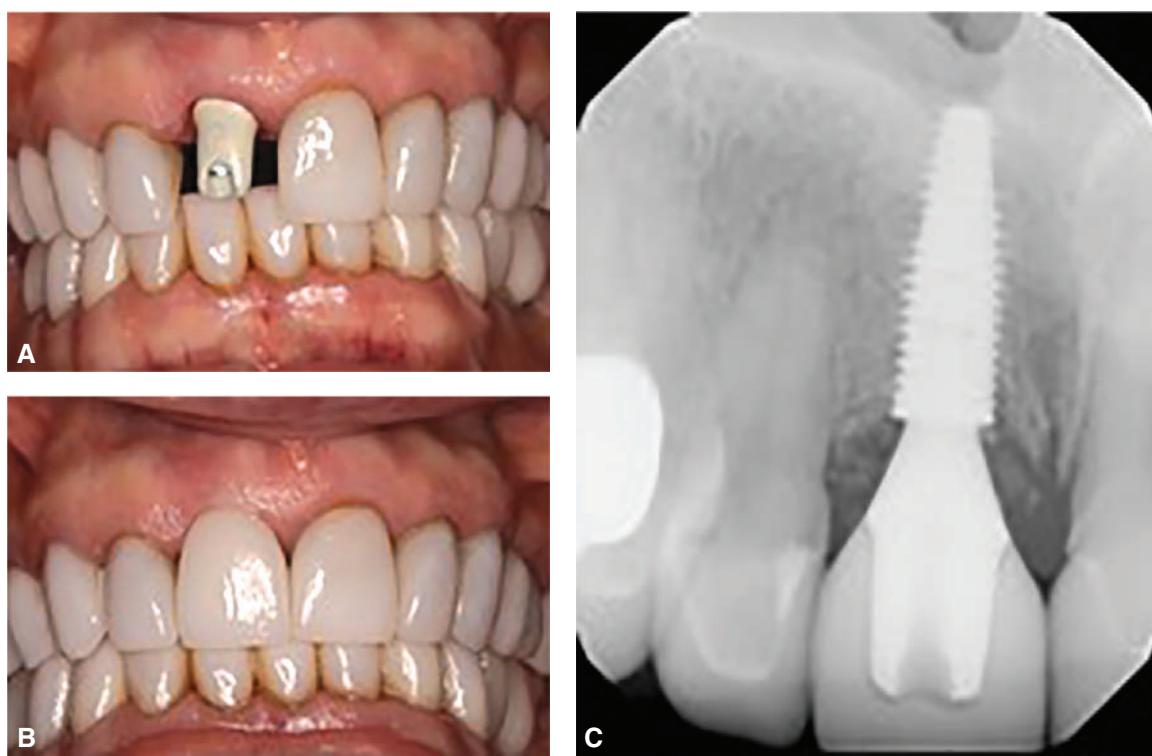


Fig. 13.33 (A) Opaqued titanium abutment. (B) Zirconia crown on the opaqued abutment. (C) Periapical radiograph.

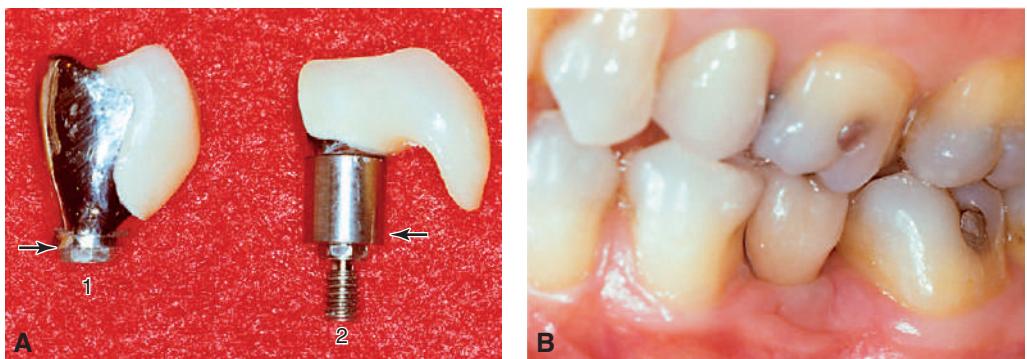


Fig. 13.34 (A) Two crowns fabricated for the same lingually tipped mandibular implant. The arrows denote the connection to the implant body for both units. Crown 2 is fabricated on a 4-mm abutment. Crown 1 is connected directly to the implant body, allowing the creation of more physiologic contours. (B) One-year follow-up of crown 1. The soft tissue response is excellent despite poor placement of the implant.

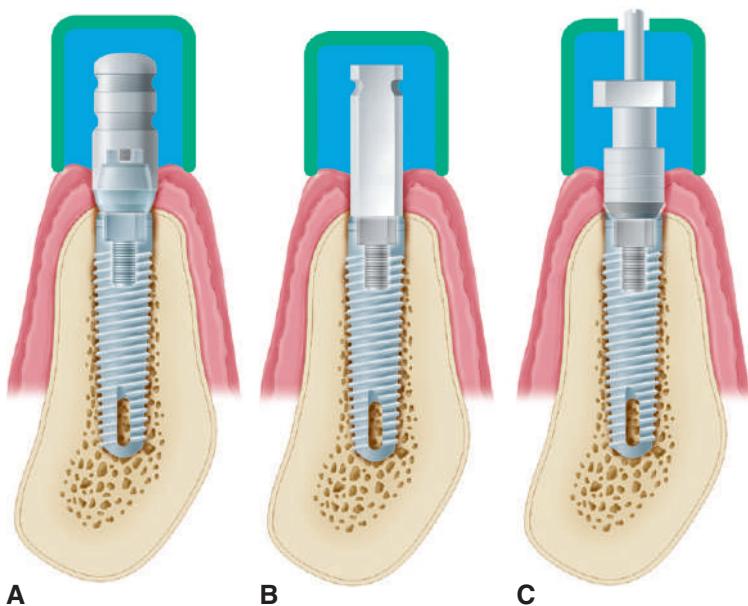


Fig. 13.35 Types of impression copings. (A) A one-piece coping (screws onto abutment) is used if the abutment does not need to be changed on the laboratory cast. (B) A two-piece coping (transfer/closed tray) is attached directly to the fixture if the abutment does need to be changed on the cast (it should 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.

using the implant analog is that the 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 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.

Intraoral Scan Bodies

With the advent of digital technologies, digital scans of the implants are possible, and impression copings that are used for digital scans are called scan bodies (Fig. 13.40).¹⁵ The position of

the implant can be digitized by using a scan body and an intra-oral scanner, and the scan file can be exported to a software program for a virtual analog to be placed in a virtual master model. Then, the program enables the placement of a virtual abutment and fabrication of the crown through computer-aided manufacturing (CAM) technology.

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 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

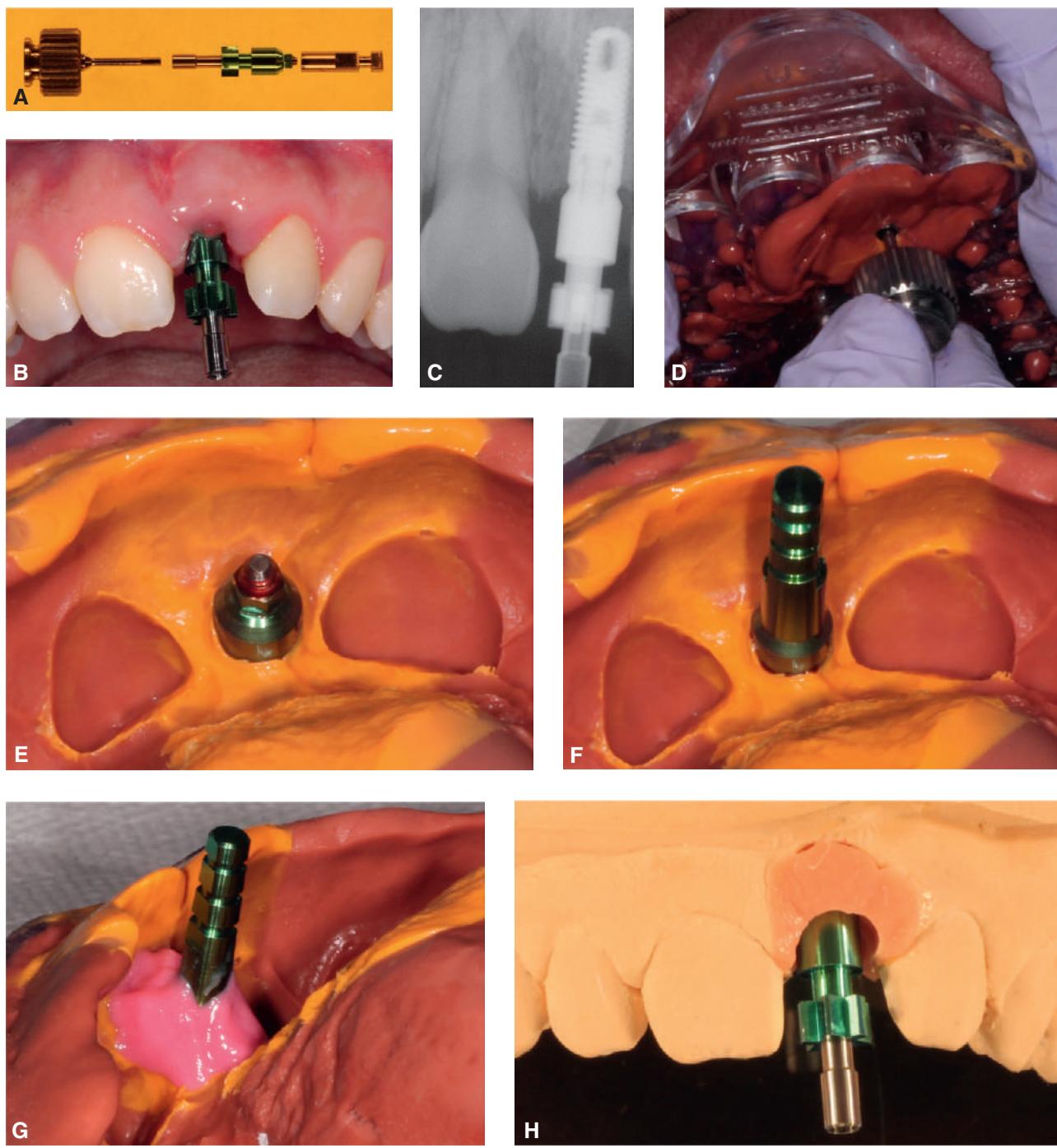


Fig. 13.36 (A) A standard open-tray transfer impression coping is a sleeve that matches the implant diameter. A screw penetrates through its center. The screw can be placed through the impression coping sleeve and carried to the mouth with the standard hexagonal driver. (B) Impression coping seated into 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) Implant analog screwed into the impression coping. (G) Polyether impression material is injected around the complex before the 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.)

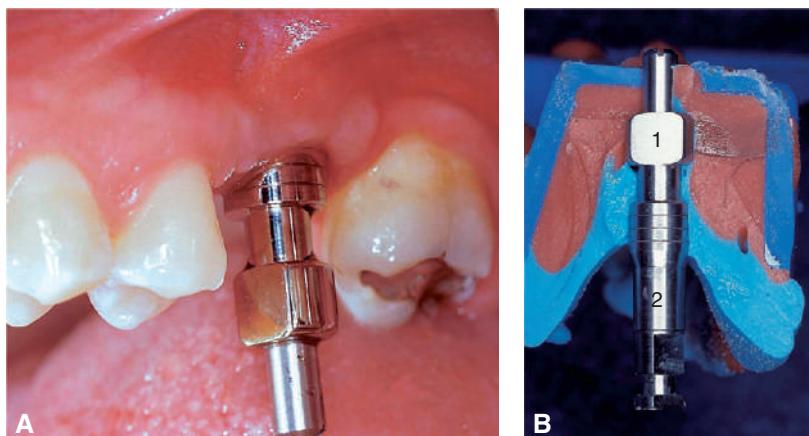


Fig. 13.37 (A) Two-piece impression coping and screw seated intraorally. (B) Cross-sectional view of the impression coping and screw (1) with the implant analog (2) attached. The impression coping remains within the impression material.

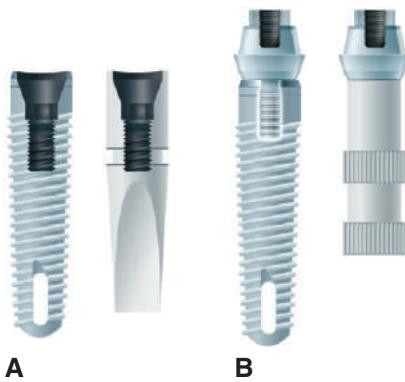


Fig. 13.38 Implant analogs. These represent either implants (fixture analogs) or abutments (abutment analogs). (A) Analog that duplicates the top of the implant. (B) Analog that duplicates the top of the abutment.

the precious alloy cylinder or a combination of each. The 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. 13.41). 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. 13.42). 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 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. 13.43).

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 dental treatment plan would include a partially 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 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. 13.44). 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).

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 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

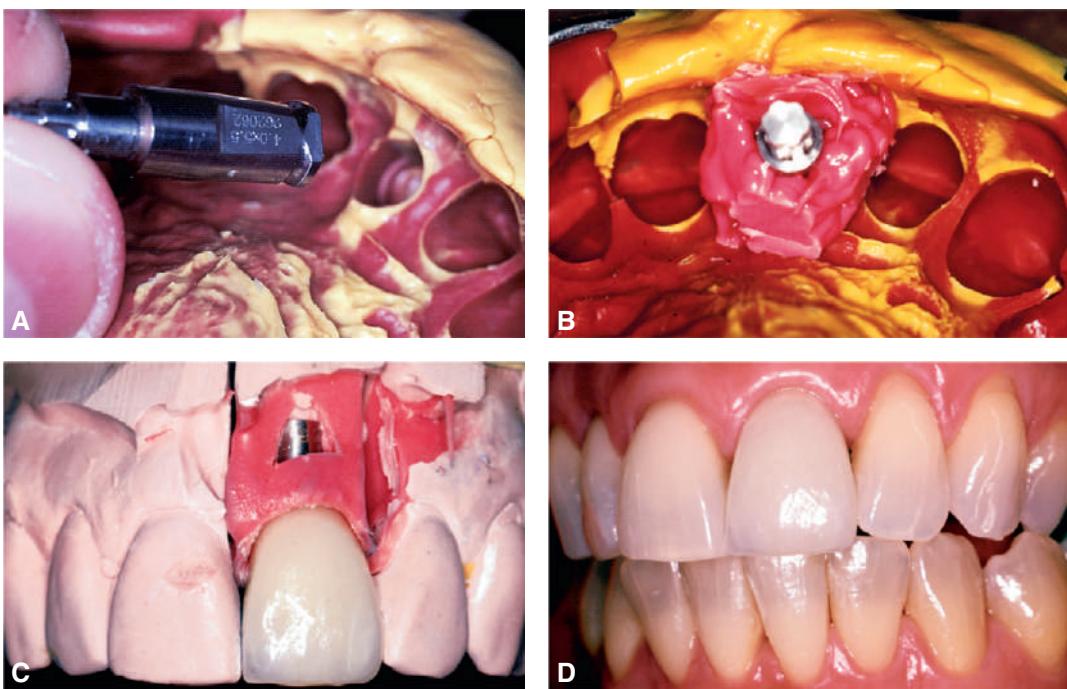


Fig. 13.39 (A and B) Polyether impression material injected around an implant analog before the impression material is poured. The gingival material should not cover any retention features of the analog. (C) The impression material reproduces the patient's soft tissue contours adjacent to the implant. The impression coping may be removed and other components inserted without loss of the associated anatomic landmarks. (D) Completed restoration. (Courtesy Dr. C. Pechous.)

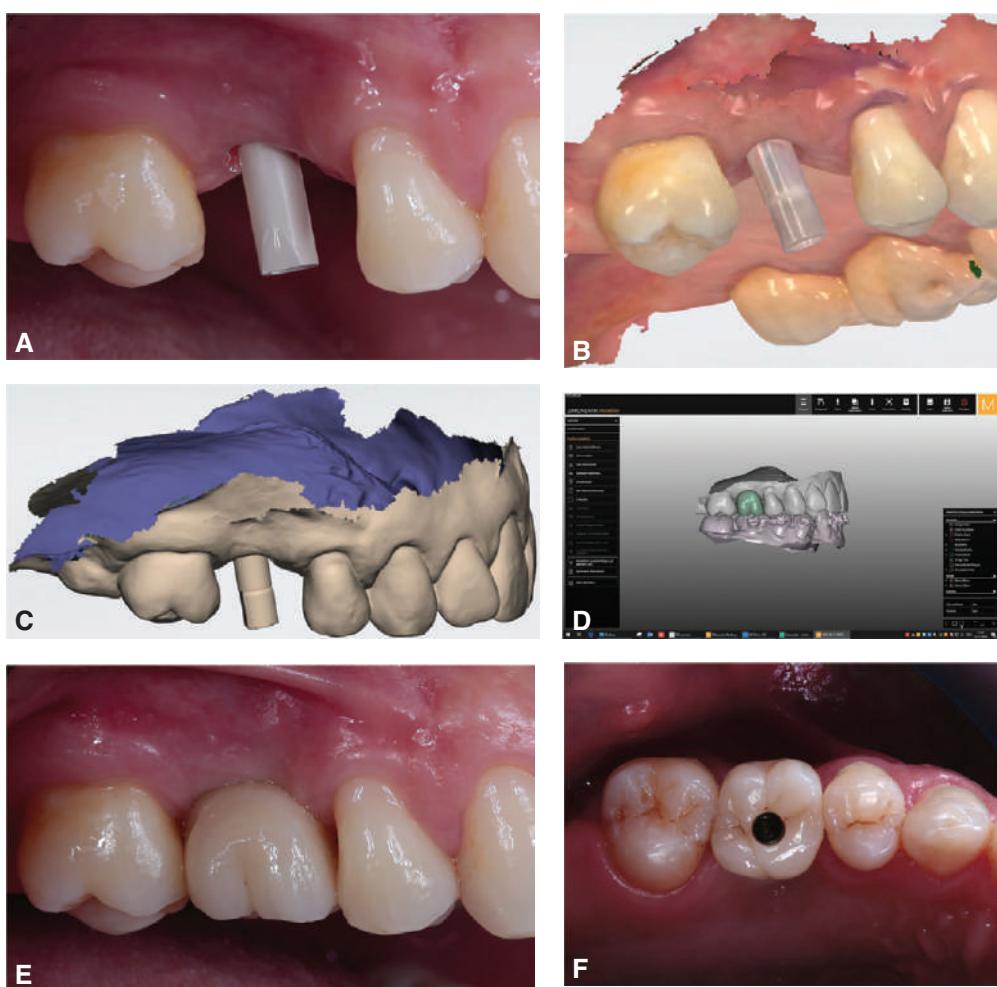


Fig. 13.40 (A) Intraoperative scan body. (B) Scanned image intraoperative scan body. (C) Standard tessellation language file image. (D) Virtual design in occlusion. (E) Buccal view of definitive crown. (F) Occlusal view of definitive crown. (Courtesy Dr. Manrique Fonseca.)

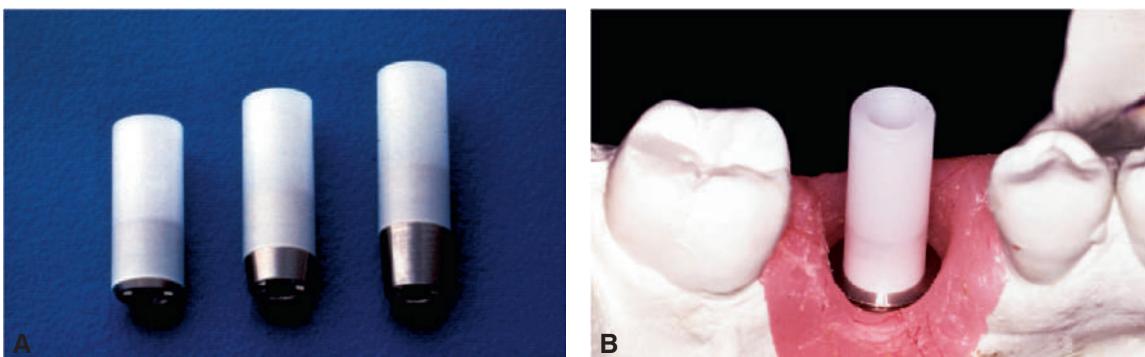


Fig. 13.41 (A) Waxing sleeves with gold alloy base and plastic extension. (B) On the laboratory cast, the technician can wax to the plastic extension. The wax and plastic are burned out, and the new alloy is cast onto the original alloy base.

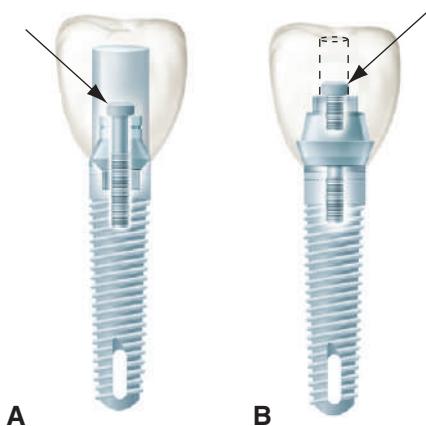


Fig. 13.42 Two types of prosthesis-retaining screws. (A) Nonsegmented crown retained to implant. (B) Crown retained on the abutment.

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 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. 13.45). 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. 13.27B).

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



Fig. 13.43 Prosthesis-retaining screws countersunk below the occlusal surface of the restoration.

- Distally missing teeth when cantilevers or partially 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 number 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. 13.46) and teeth in which endodontic treatment was unsuccessful (Fig. 13.47). Screw loosening has been associated most commonly with the terminally positioned single molar implant crown (Fig. 13.48).

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 Fig. 13.49. When the tissue has matured around the interim restoration, an



Fig. 13.44 (A) Two implants placed distal to the mandibular premolar. (B–D) The completed restoration is not connected to the crown on the natural tooth. (Courtesy Dr. R.B. Miller.)

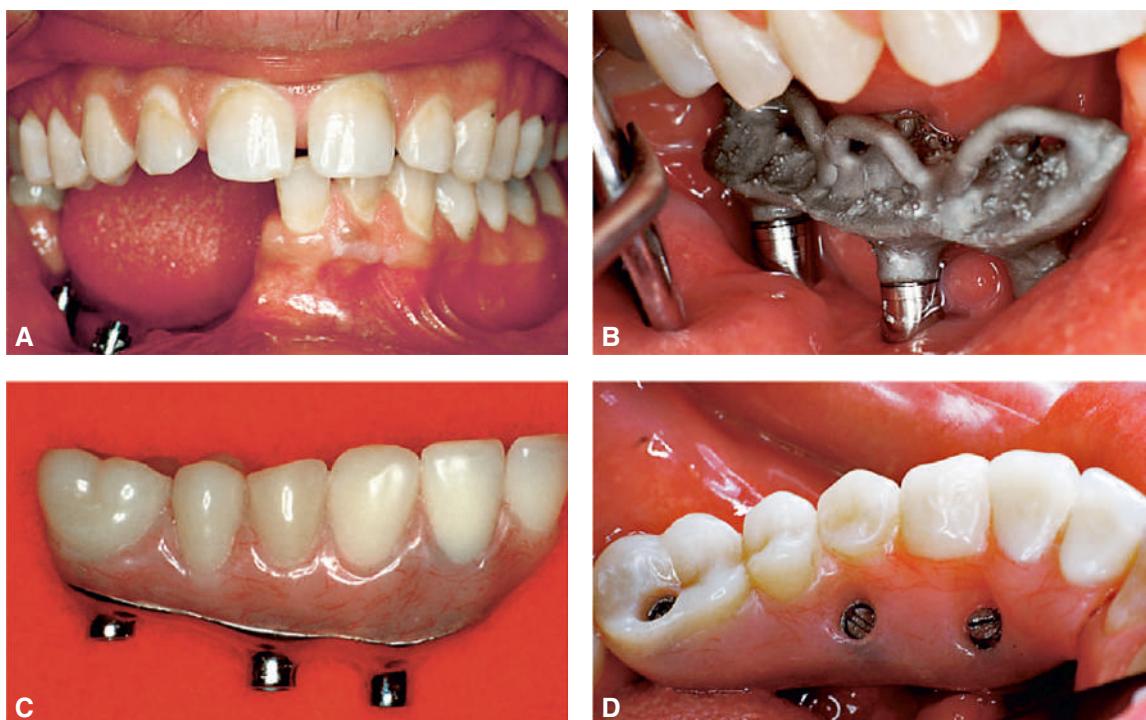


Fig. 13.45 (A) Large mandibular defect created by a shotgun wound. (B) Metal substructure of a metal-resin prosthesis evaluated on three implants in this defect. (C) Denture resin can effectively re-create the soft tissue color and contours in the completed restoration, sometimes less expensively than dental porcelain. (D) Metal-resin restoration over the defect.

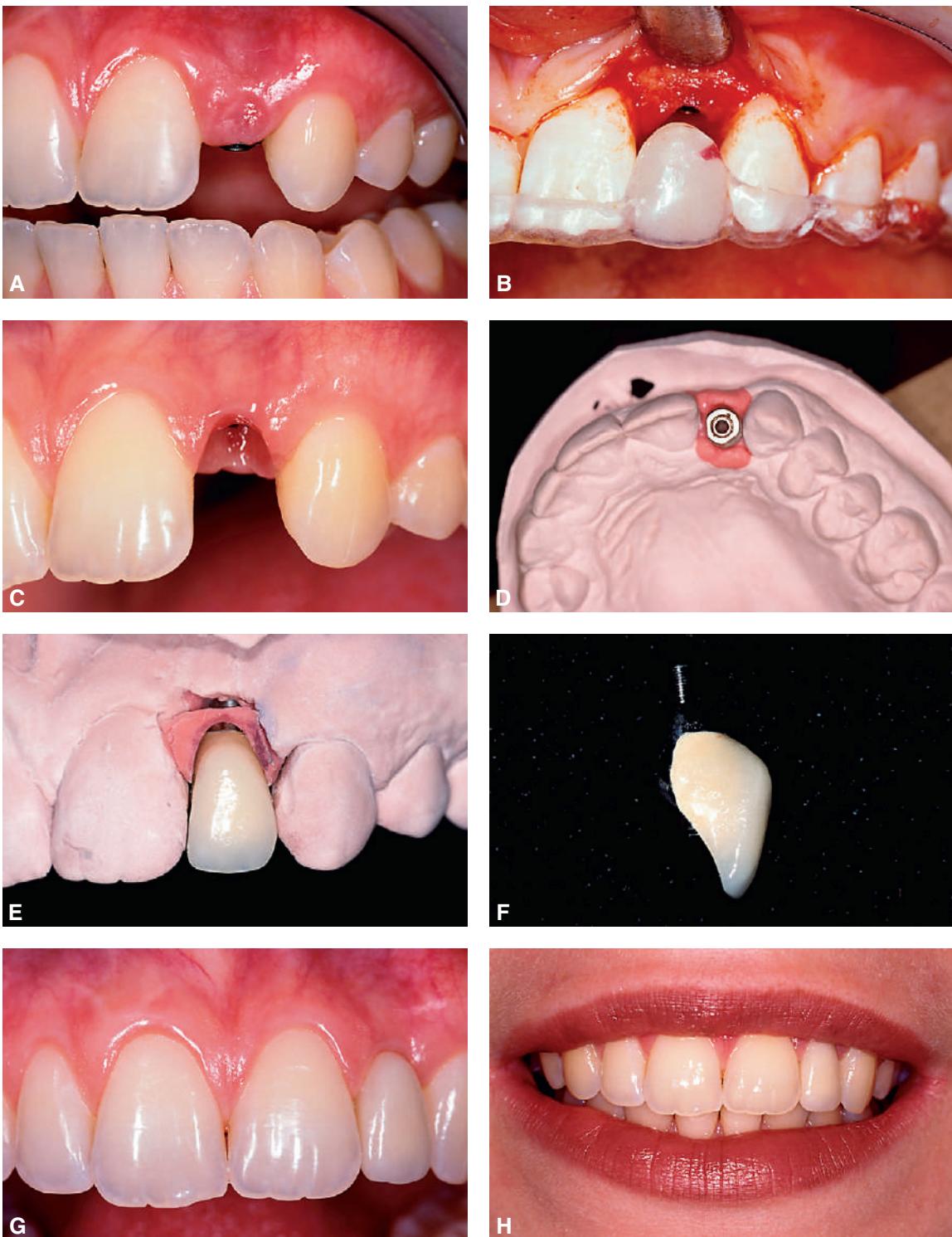


Fig. 13.46 (A) Congenital absence of maxillary lateral incisor. (B) Placement of dental implant through the use of a surgical template. (C) Final soft tissue contours. (D) Impression post projecting from the definitive cast. (E and F) Definitive restoration. (G and H) Single-tooth implant crown replacing the maxillary lateral incisor.

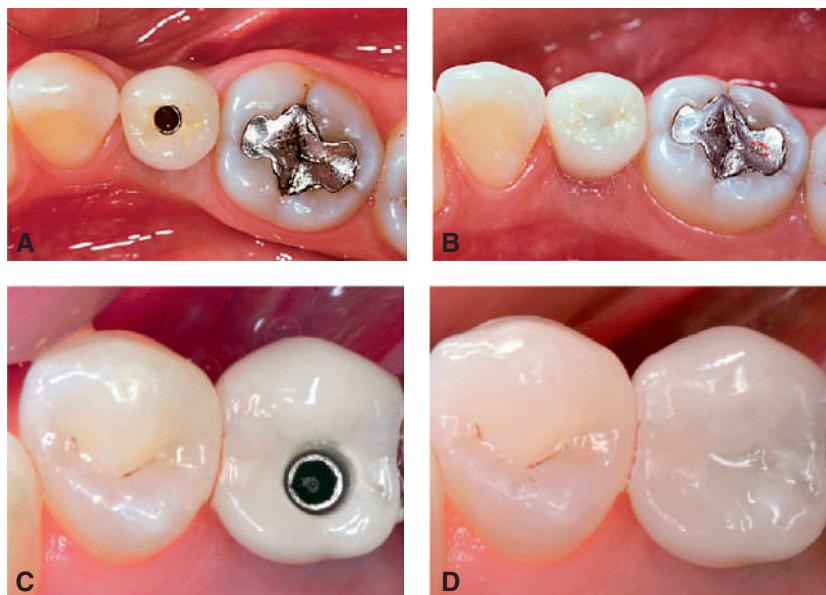


Fig. 13.47 (A) Occlusal view of a single-tooth implant-supported crown replacing a fractured mandibular premolar. (B) Implant crown with screw access restored. (C) Occlusal view of a screw-retained mandibular second premolar implant-supported crown. (D) Implant crown with screw access hole restored. (Courtesy Dr. Jairo Sainz.)



Fig. 13.48 Screw loosening is most commonly associated with single-tooth molar implant-supported crowns.

impression can be made to complete the definitive restoration (Fig. 13.50). 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. 13.51). 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 definitive soft tissue result.

Treatment Planning for Optimal Prosthetic Material-Soft Tissue Junction in High Smile Line Situations

In situations where soft tissues of patients are highly visible, treatment planning should be carried out carefully to optimally position the implant superstructure-natural soft tissue junction. Detailed and comprehensive preplanning is essential for a favorable outcome. Diagnostic appliances and surgical guides facilitate the process to achieve an optimal result. In some situations, bone removal and leveling may be necessary to position this junction optimally (Fig. 13.52).

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. 13.53–13.55).

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 to attach directly onto the implants or cemented onto titanium abutments or onto a titanium framework that attaches to the implants.

In recent years, high-performance polymers have been introduced as a framework material for implant-supported fixed prostheses.¹⁶ These frameworks are used with titanium abutments/CAD-CAM PMMA, or ceramic crowns can be used in combination with polymer frameworks (Fig. 13.56).

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 ceramic crowns on the framework (see Fig. 13.55).



Fig. 13.49 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 resin 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 rotary instrument can be used when sufficient attached tissue is present. (J) Soft tissue contouring improves esthetics, minimizes pocket depths, and allows for 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.



Fig. 13.50 (A) Soft tissue around a maxillary implant interim restoration after 6 weeks of healing. (B) New soft tissue contours, in comparison with the healing abutment previously in place. (C) The definitive impression is made, and a definitive cast is fabricated. The new soft tissue contours are reproduced. (D) Implant-supported 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 5-year follow-up photographs show that the patient has maintained healthy soft tissue contours. (Courtesy Dr. J.A. Holloway.)



Fig. 13.51 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 impression coping in relation to the adjacent teeth is registered with silicone before it is unscrewed from the mouth. (D) Implant analog attached to the impression coping. (E) Diagnostic stone cast prepared to position analog. (F) Template placed back on diagnostic cast. (G) Dental plaster flowed around the implant analog. The position of the implant analog is identical to the position of the implant in the mouth. (H–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.)



Fig. 13.52 (A) CAD-CAM PMMA surgical guide and diagnostic tooth arrangement. (B) Frontal view demonstrating high smile line. (C) Surgical guide in place to evaluate the smile line. (D) Bone leveling. (E) Intraoperative view of definitive fixed implant-supported prosthesis. (F) Frontal view. (From Yilmaz B, Diker E, Ovchinnik V, Abou-Ayash S. Management of a partially edentulous patient with idiopathic root resorption by using digital and conventional implant planning technologies. *J Prosthetic Dent.* 2022;127(1):15–21.)

Different framework designs have been proposed for complete fixed dental prostheses (Fig. 13.57).¹⁷ 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. 13.58).

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. Because the prosthesis is screw-retained, the dentist can remove it, allowing access to 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 the 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. 13.59).



Fig. 13.53 (A–D) A metal-ceramic implant-supported restoration may be indicated if adequate bone and soft tissue contours are available.

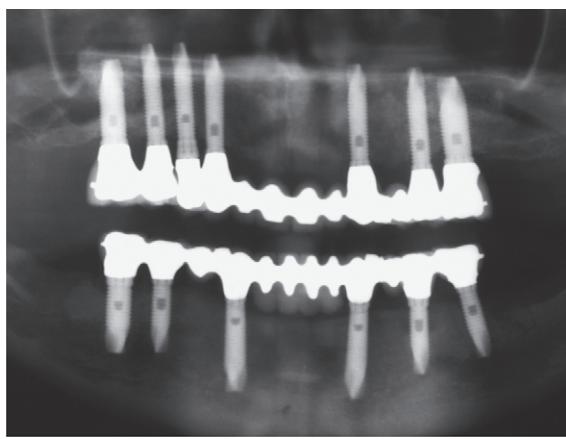


Fig. 13.54 Radiograph of the patient in Fig. 13.53, showing fixed restorations supported by seven implants in the maxilla and six in the mandible.

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.^{18–24}

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 do not allow for the placement

of implants axially.²⁵ 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 occlusal forces on the cantilever portion of the prosthesis (Fig. 13.60).^{26–29} 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 completely 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.^{30–33} Clinicians have reported positive clinical outcomes with the placement of implants at an angled trajectory.^{19,20,22,34} In these clinical protocols, interim

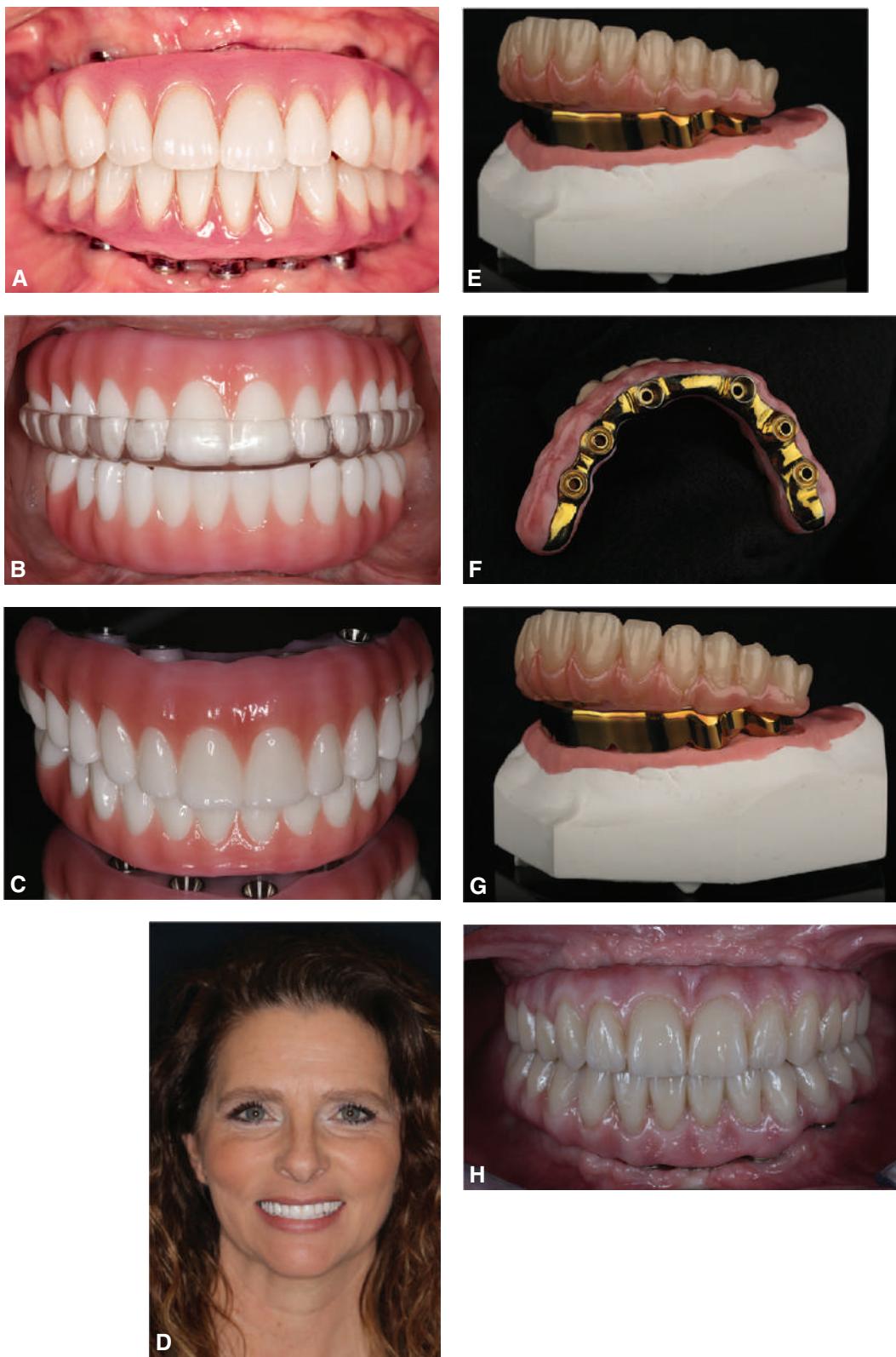


Fig. 13.55 (A and B) Metal-resin. (C) Zirconia-ceramic restorations. (D) Frontal view. (E–G) Zirconia superstructure with anodized titanium framework. (H) Intraoral view. (E–H, Courtesy of Dr. Manrique Fonseca.)

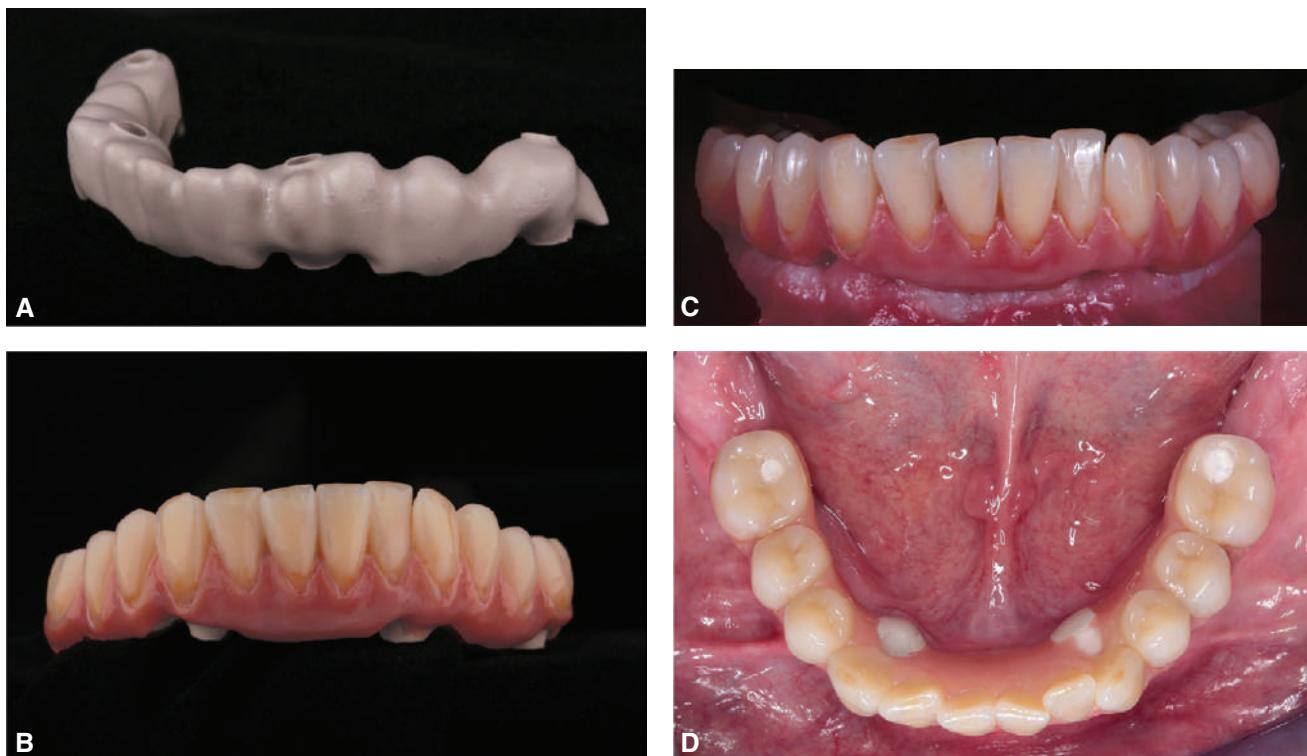


Fig. 13.56 (A) Polymer framework. (B and C) Acrylic resin applied. (D) Intraoperative view. (Courtesy Dr. Manrique Fonseca.)

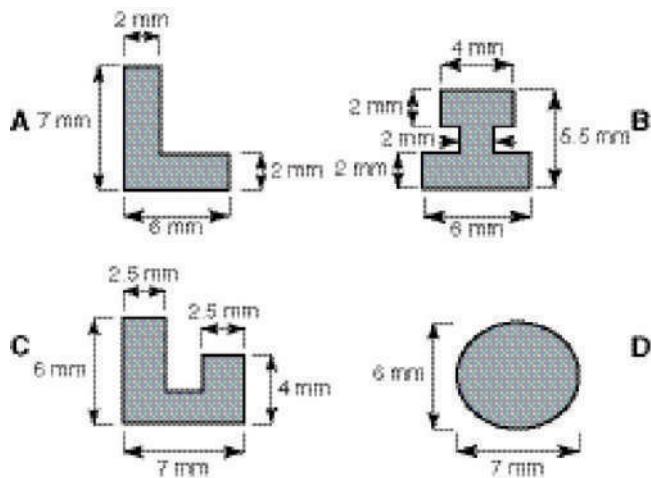


Fig. 13.57 Complete arch restoration framework designs: L-shaped (A), I-shaped (B), U-shaped (C), and elliptical sections (D). (Adapted from Stewart RB, Staab GH. Cross-sectional design and fatigue durability of cantilevered sections of fixed implant-supported prostheses. *J Prosthodont*. 1995;4[3]:188.)

restorations are most commonly used to load the implants immediately. These “conversion type” acrylic resin interim restorations necessitate definitive prosthetic rehabilitation and may be prone to fracture.³⁵ 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. 13.61).³⁶

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 definitive 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.³⁷

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. 13.62). 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 tissue evaluation, calculus débridement, and any other necessary modifications. In addition, future

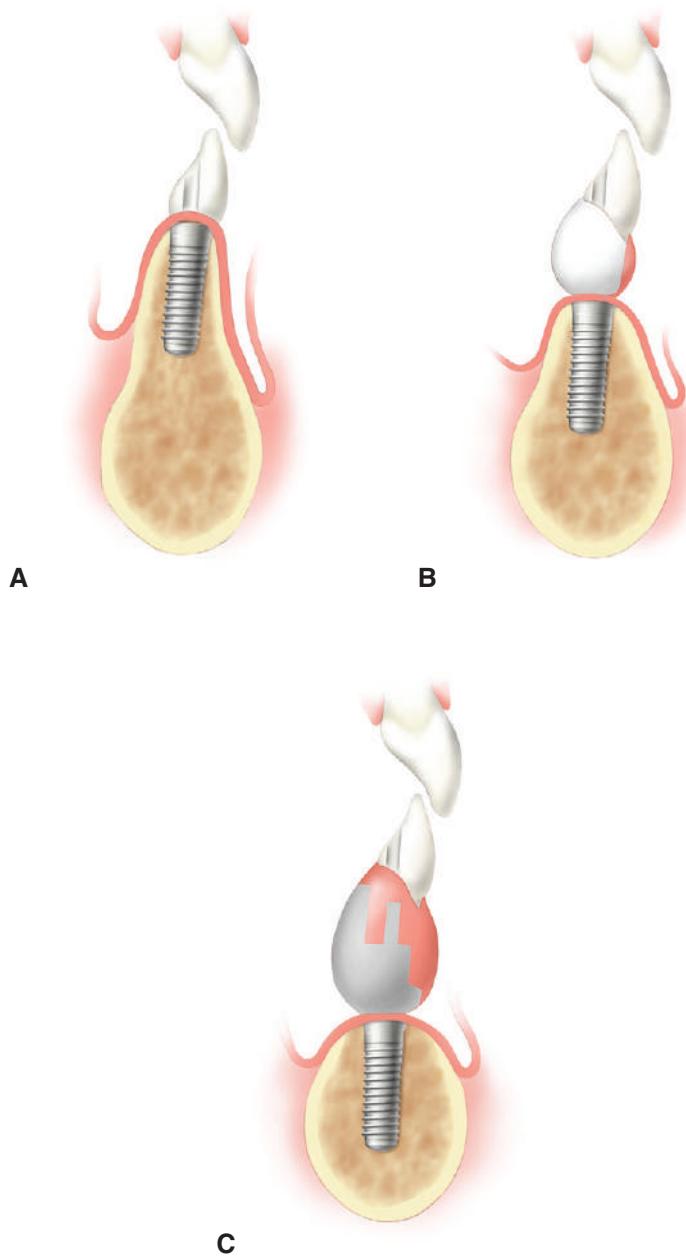


Fig. 13.58 The amount of bone resorption dictates the treatment options for an edentulous patient. (A) With minimal resorption, metal-ceramic restorations may be possible. (B) Moderate resorption can be restored with zirconia-ceramic restorations. (C) Moderate to severe resorption may necessitate pink resin-to-metal or pink ceramic-metal/zirconia restorations. (Adapted from drawing by Dr. Michael D. Scherer, DMD, MS.)

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 connections

have been reported.³⁸ 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. 13.63). 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,

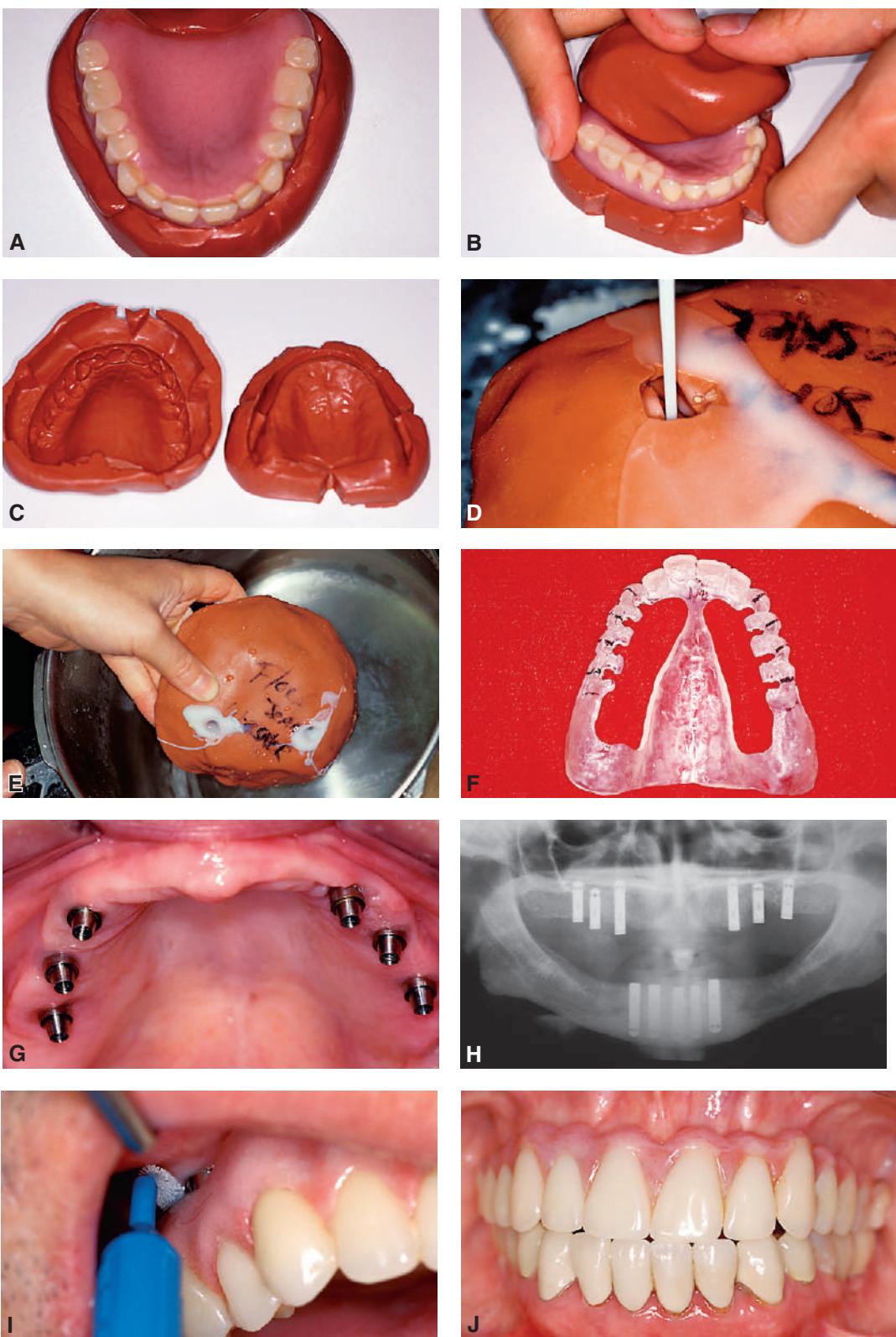


Fig. 13.59 Posterior implant placement for a maxillary complete arch prosthesis. A surgical template can be fabricated for an edentulous patient by duplicating the existing denture in clear resin. (A–C) Putty impression material is used to form a mold of the fitting and polished surfaces of the denture, 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 to 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.

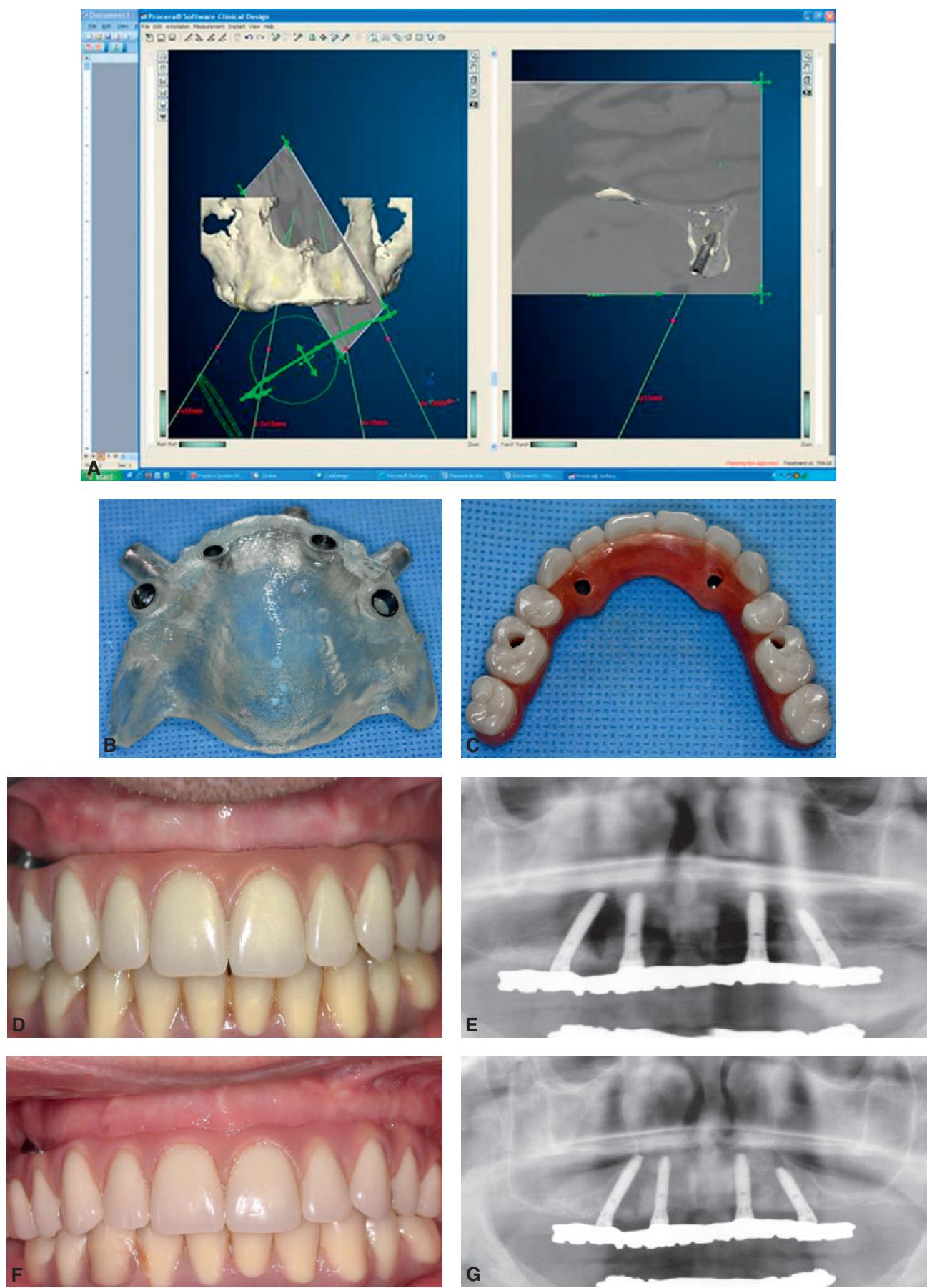


Fig. 13.60 (A–E) Protocol for an angled implant. Five-year follow-up intraoperative (F) and panoramic (G) views.

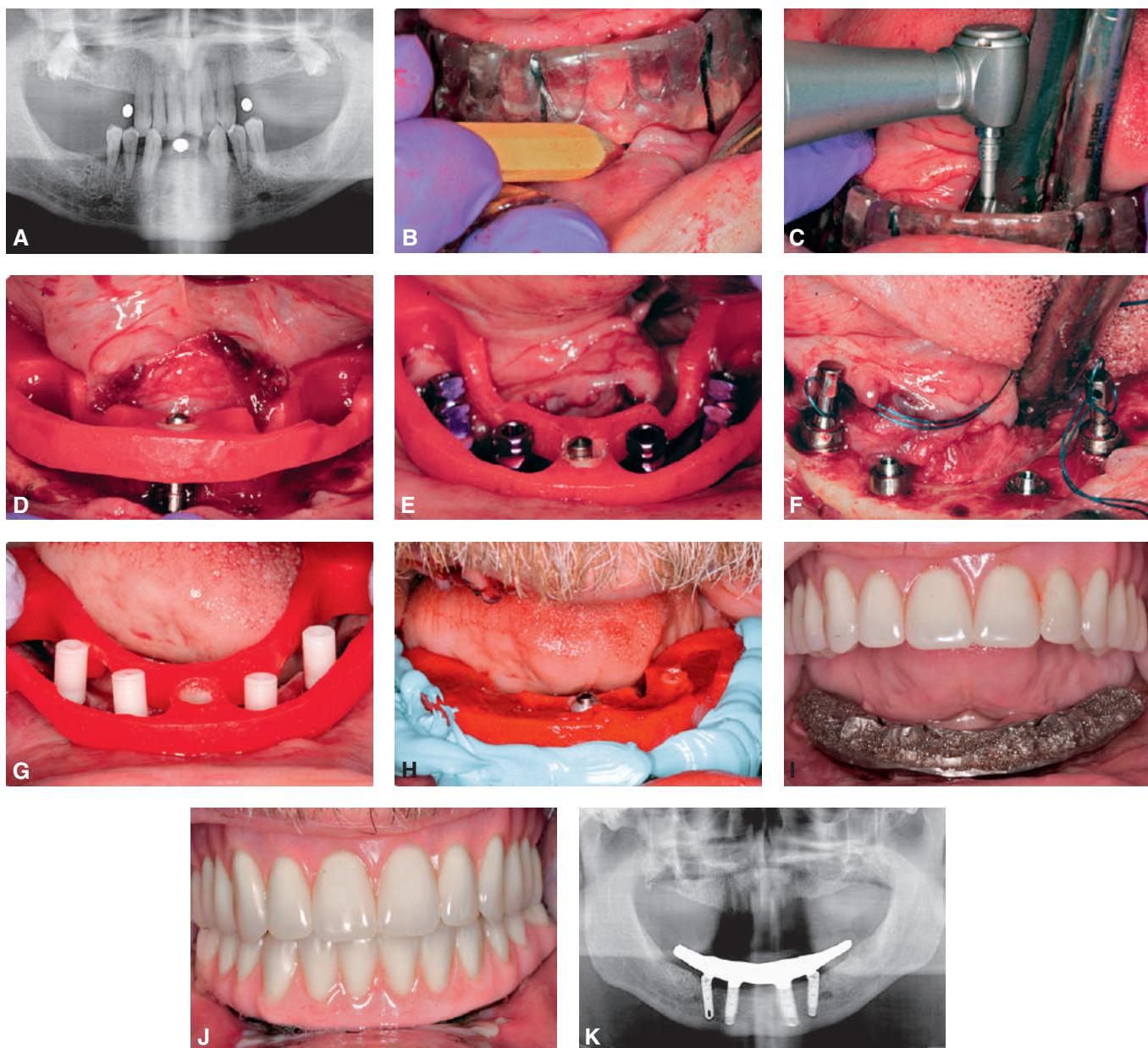


Fig. 13.61 (A) Preoperative panoramic radiograph. (B) Surgical guide in place to determine the amount of bone reduction. (C) Implant site preparation using the surgical guide. (D and E) Acrylic resin framework in place before implant placement to verify implant positions. (F) Abutments screwed onto implants. (G) Acrylic resin framework with waxing sleeves. (H) Acrylic resin framework-waxing sleeves-gingival clearance record complex. (I) Metal framework evaluation. (J) Intraoral view of maxillary immediate complete and mandibular metal-resin complete dental prosthesis. (K) Postoperative panoramic radiograph.

lateral forces (which tend to separate the joint) should be eliminated or reduced (Fig. 13.64; Box 13.4).

BIOMECHANICAL FACTORS AFFECTING LONG-TERM IMPLANT SUCCESS

Occlusion

Bone resorption around dental implants can be caused by premature loading or repeated overloading. Vertical or 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 natural dentition, bone remodeling typically occurs once the severe stress concentration is reduced or eliminated. In the osseous integrated implant system, however, after the 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.

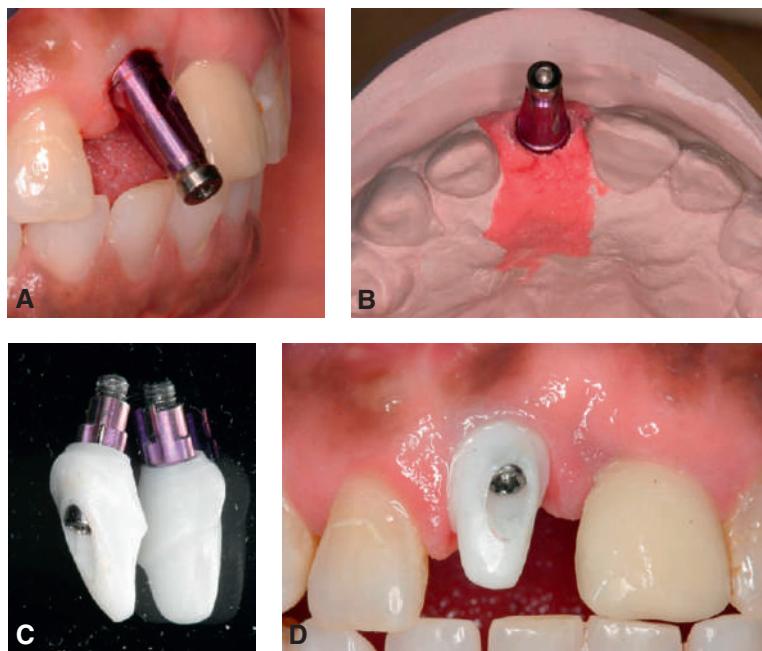


Fig. 13.62 (A) Implant in a facially inclined position to replace the maxillary right central incisor. (B) A laboratory cast demonstrates facial angulation of the implant. An angled abutment (C) improves the esthetic restoration (D). A cement-retained restoration would be necessary to avoid a hole through the facial surface.

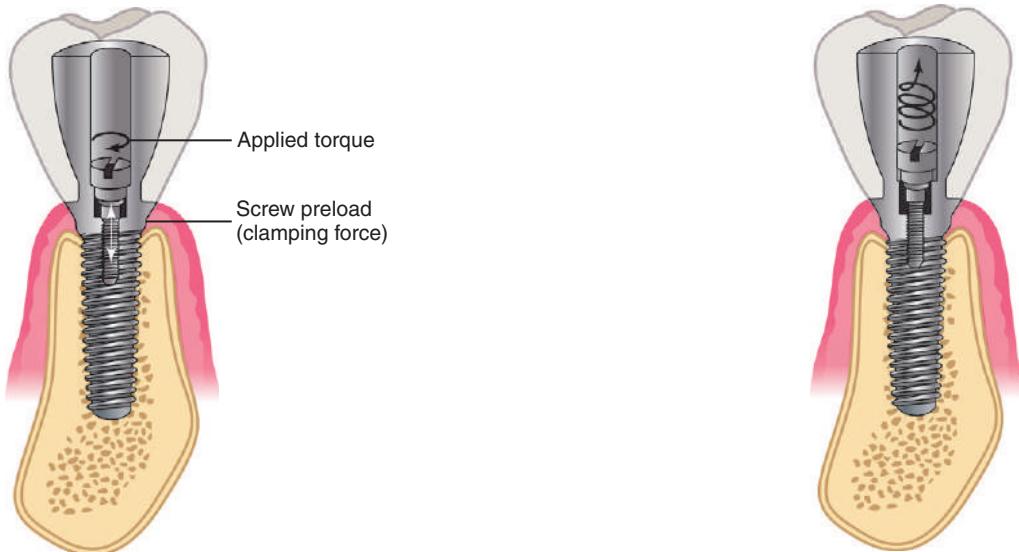


Fig. 13.63 Torque on the screw develops a preload (clamping force) between the implant and the crown.

Fig. 13.64 The screw will loosen only if the joint-separating force is greater than the clamping force.

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.³⁹ Flatter inclines can be developed on implant-supported cusps, which would create more

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

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.

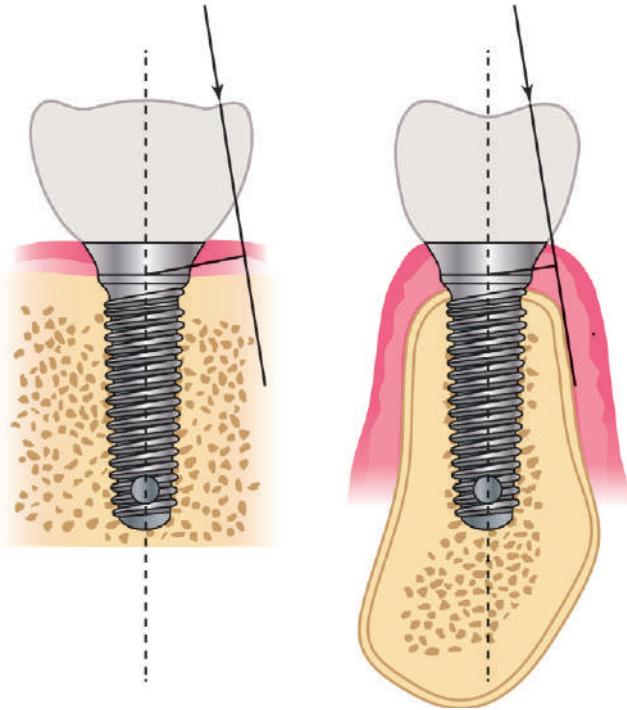


Fig. 13.65 Sharper cusp inclines and wider occlusal tables increase the resultant force on implant components.

vertical resultant forces and a shorter moment arm (Fig. 13.65). Whenever possible, a cusp-fossa relationship should be established in maximum intercuspsation 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 shown⁴⁰ 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.

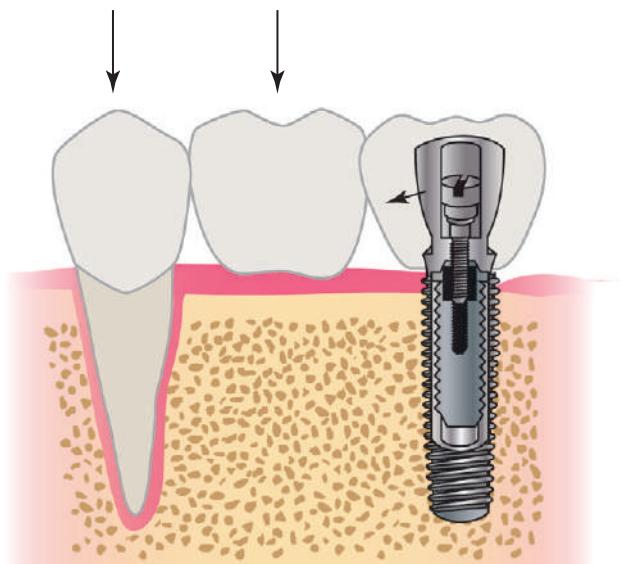


Fig. 13.66 When a single implant is attached to a natural tooth, occlusal forces on the natural tooth and pontic cause stress to be concentrated at the superior portion of the implant.

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 the bone of poorer quality. When implants longer than 13 mm can be placed in the 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 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.⁴¹

Connecting Implants to Natural Teeth

It has been suggested⁴² 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 the 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. 13.66). 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 for such reasons it is necessary to connect an implant to a natural tooth, multiple implants or natural tooth abutments should be used. A semi-precision attachment (keyway) in the prosthesis between the implant and the natural tooth may solve potential problems (Fig. 13.67).⁴² 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 semi-precision attachment may be that it allows a screw-retained implant-abutment crown to be removed for periodic evaluation.

When circumstances dictate the use of a natural tooth abutment, a telescopic coping should be considered. This is definitively 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. 13.68).

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 amount of space or any amount of movement with finger pressure should be discernible on any of the other implant abutments (Fig. 13.69). If a framework does not fit passively, it must be sectioned and soldered and reassessed for a 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. 13.70), some manufacturers can fabricate definitive ceramic or titanium abutments of any shape or angle with computer-aided design and computer-aided manufacture (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. 13.70).⁴³



Fig. 13.67 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.)

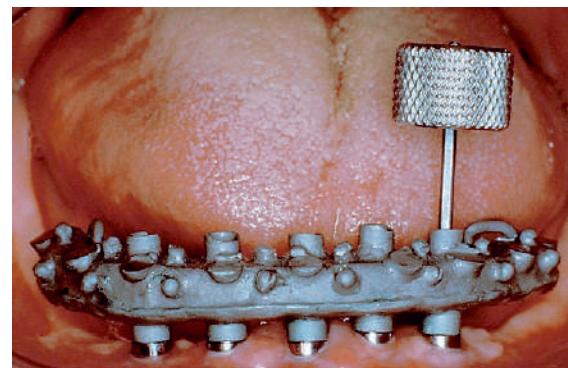


Fig. 13.69 Metal framework fit should be evaluated with only a single retaining screw tightened in place. Any detectable incomplete seating necessitates framework correction.



Fig. 13.68 (A) Maxillary abutments positioned to support a fixed prosthesis. (B) Metal evaluation of maxillary rehabilitation with implant-supported abutments and telescopic copings.



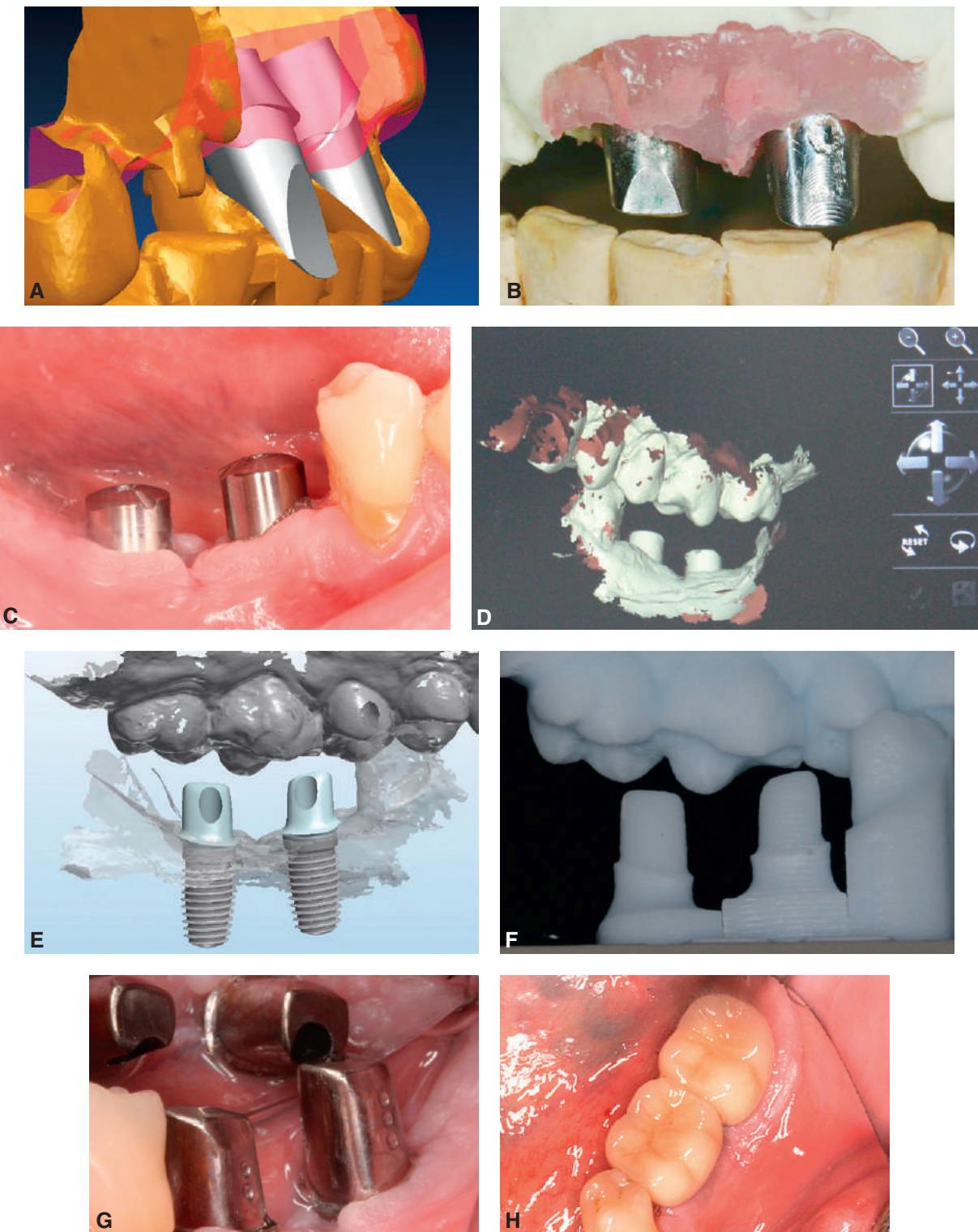


Fig. 13.70 (A) Virtual implant-supported abutments designed on the computer screen. (B) Titanium abutments fabricated through the use of computer-aided design and computer-aided manufacture (CAD-CAM) technology. (C) Intraoperative scannable abutments. (D) Intraoperative scan file. (E) Virtually designed abutments. (F) Stereolithographic models of abutments. (G) CAD-CAM-fabricated custom titanium abutments. (H) Metal-ceramic crowns.

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.

- 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 the prosthesis. Fracture of implant components is usually attributed to fatigue from biomechanical overload. Some instruments are available for the removal of broken prosthetic/abutment screw fragments (Fig. 13.72).⁴⁴

Failure of the implant prosthesis is usually traceable to sub-optimal laboratory procedures or prosthesis design (Figs. 13.73 and 13.74).

COMPLICATIONS

Bone Loss

The primary complication with dental implant therapy is bone loss around the implant (Fig. 13.71). 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

SUMMARY

Implant-supported prostheses, involving cylindrical osseous integrated fixtures placed in a two-stage surgical 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.

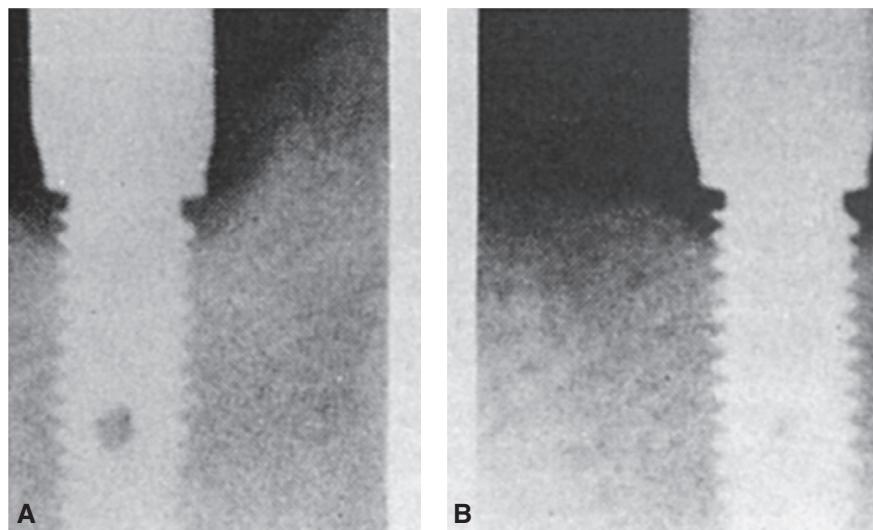


Fig. 13.71 To monitor implant bone loss, radiographs should be obtained once a year. (A) At the time of delivery. (B) At the 1-year follow-up visit.

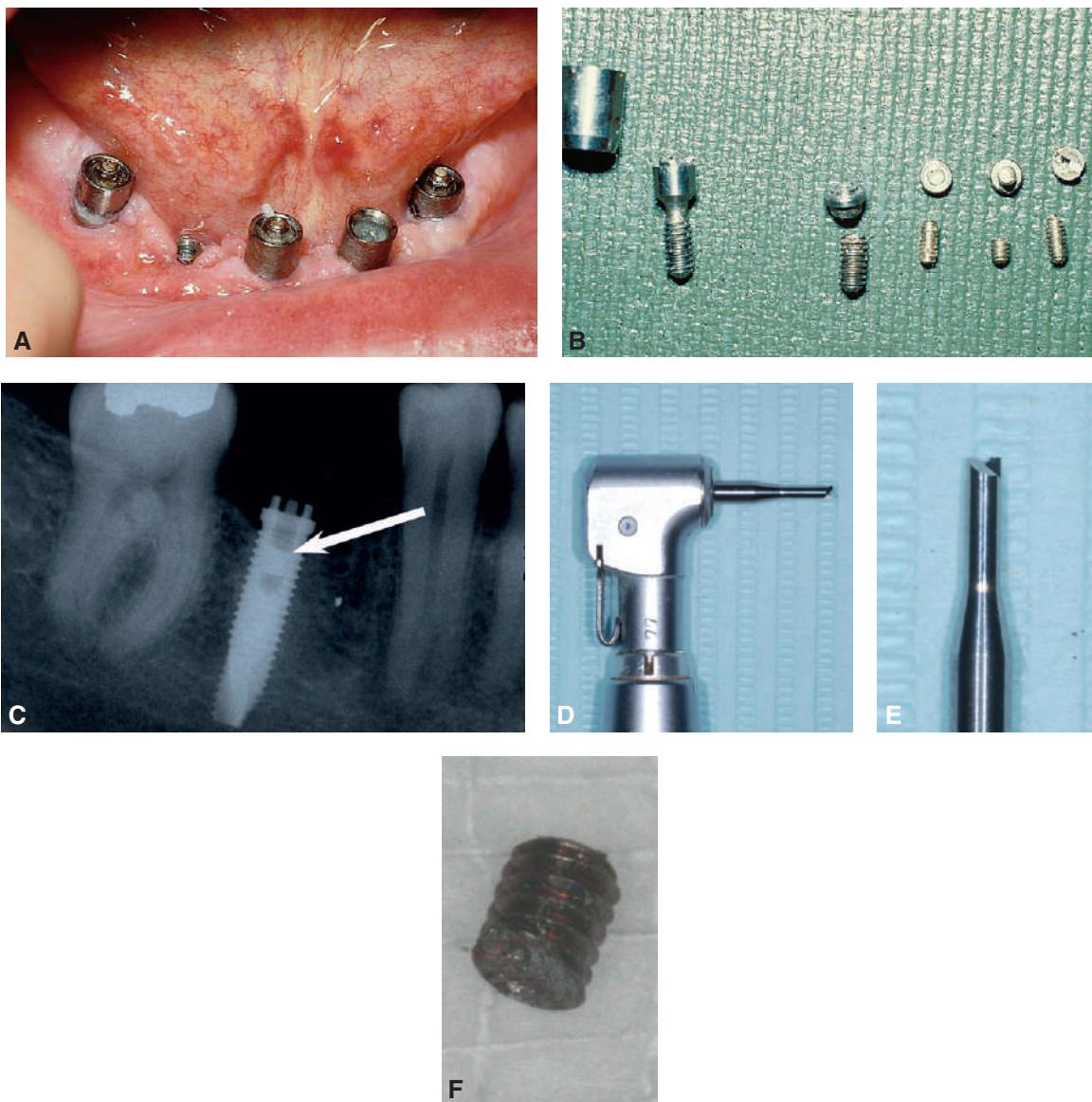


Fig. 13.72 (A–C) Fractured abutment and retaining screws on a metal-resin implant-supported prosthesis. (D–F) Screw removal tool used to remove screw fragments (arrow).



Fig. 13.73 Porcelain fracture on an implant prosthesis with inadequate metal support.



Fig. 13.74 Cantilever fracture on a metal-resin prosthesis. The prosthesis can be retrieved easily for a laser-welded repair.

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 the optimum placement of the implant or implants. The surgeon's main concern is that 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, 2 to 6 months are required for the bone to heal against the implant after two-stage surgery.^{45,46} 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.

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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Tissue Management, Scanning, 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 or other materials specifically developed for this purpose. 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 impression material has set as a “negative” replica, it retains sufficient elasticity to be removable from the mouth; after verification that all necessary information has been 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 definitive restoration (see Chapter 17).

Regardless of the system used, an acceptable impression must accurately capture all aspects of the prepared tooth: 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 scans must be free of artifacts, lest inaccuracies result.

The mouth is a challenging environment in which to make an accurate impression. For either approach to impression making, moisture control is one of the most important prerequisites for success. Except for the polyethers, all elastomeric impression materials are hydrophobic¹ (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. Any bleeding must also be controlled to obtain a successful impression. Similarly, because dentin and enamel do not reflect light in an identical manner, some optical systems require that the teeth be covered with a thin coating that reflects light more uniformly. These must be applied to dry tissues. However, with the advances in digital scanning technologies, more and more intraoral scanners now avoid the use of coatings while successfully capturing the hard and soft intraoral 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 enlargement of the gingival sulcus through mechanical, chemical, or surgical means, yet 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 present, 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, not well 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 disastrous results. Periodontal disease must be treated and resolved before fixed prosthodontic treatment is initiated.

On occasion, a defective restoration contributes to greater plaque accumulation² 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 dental 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, this has the disadvantage when part of the cotton is saturated, the entire roll must be replaced. The use of moisture-absorbing cards (see Fig. 14.2D) 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 Svedoject [E.C. Moore Company] or the Speejector [Pulpdent Corporation]) should be considered (see Fig. 14.2B 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. 14.2E). As an alternative to the rubber dam and cotton rolls a dental isolation device, such as Isolite (see Fig. 14.2F), may be used to achieve the desired oral control of moisture, humidity, and displacement.

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}

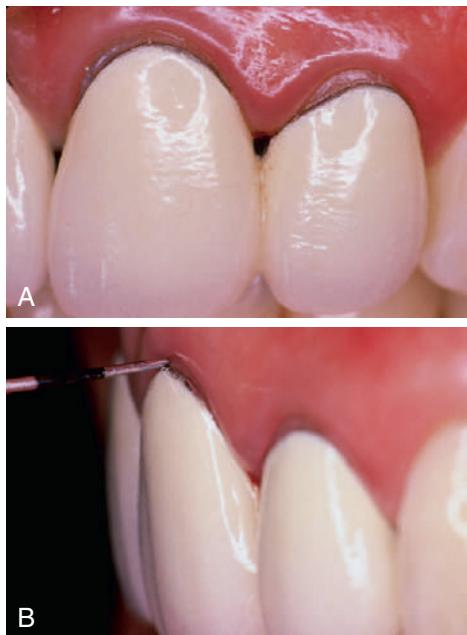


Fig. 14.1 Compromised embrasure form (A) and excessive contours (B) have contributed to the inflammatory response and recession of the gingival tissue.

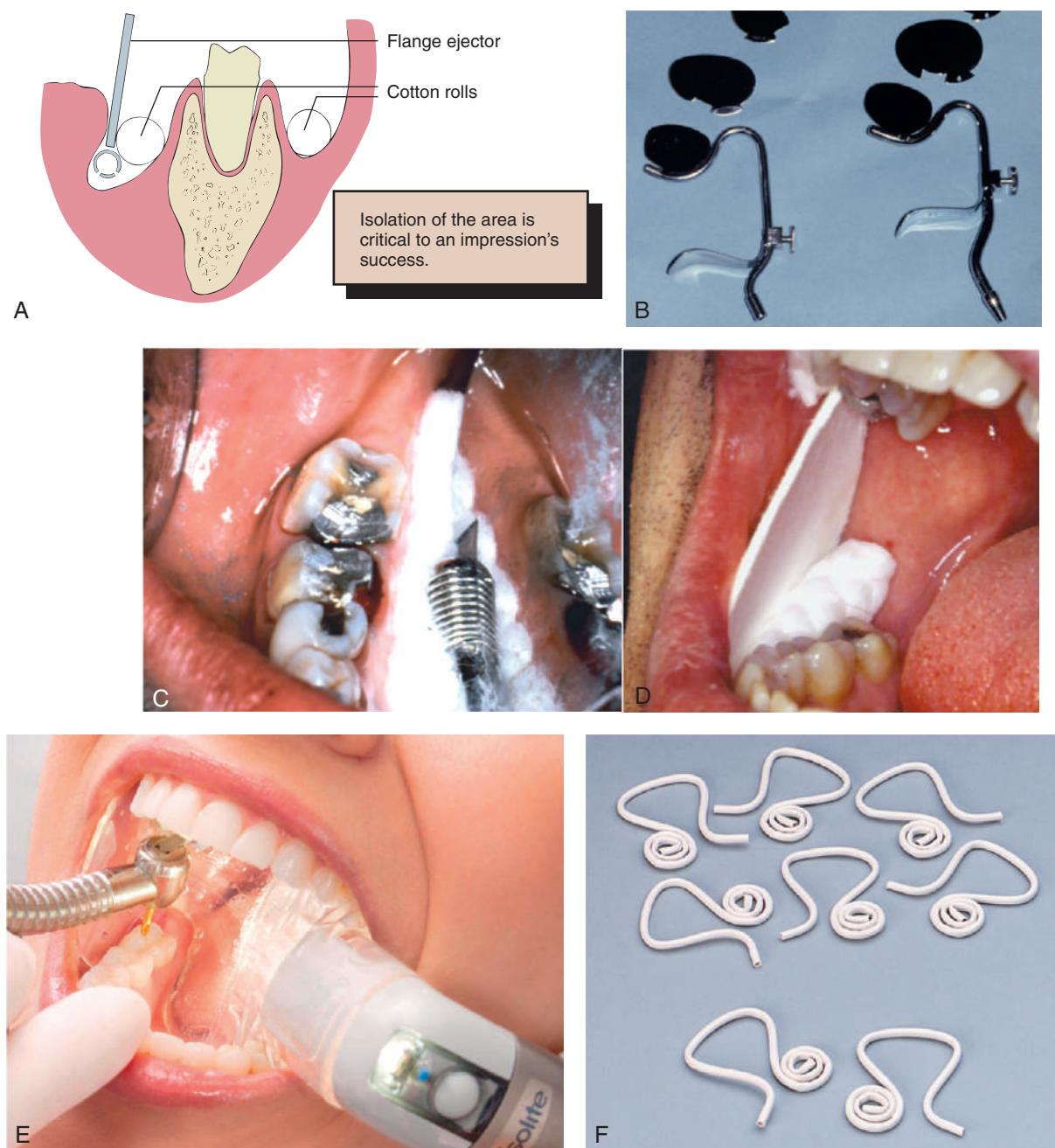


Fig. 14.2 Saliva control for impression making. (A) When correctly placed, maxillary cotton rolls block salivary flow from the parotid gland. The evacuator removes saliva from the floor of the mouth, keeping the prepared tooth dry while the flange displaces the tongue medially. (B) Svedoptyer (left) and Speejector (right) saliva evacuators. (C) Svedoptyer 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.)

TABLE 14.1 Medications With Antisialagogic Effect

Brand Name	Active Ingredient	Dosage
Pro-Banthine	Propantheline bromide	7.5–15 mg
Robinul (Robinul Forte)	Glycopyrrrolate	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.)

(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 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

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, Inc.]) is used. However, larger sizes of braided cord should be avoided because they can have a tendency to double up and thus 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 lateral tissue displacement.

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.



Fig. 14.3 Cord has been placed intrasulcularly as close to the level of the prepared margin as possible to displace tissue laterally.

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 ($\text{Fe}_2[\text{SO}_4]_3$) 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, perhaps of more importance, on the smear layer.^{12,13} Fig. 14.5 is a series of scanning electron micrographs of dentin after various durations of exposure to a commonly used $\text{Fe}_2(\text{SO}_4)_3$ 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 post-operative 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 $\text{Fe}_2(\text{SO}_4)_3$ or AlCl_3 .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 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



Fig. 14.4 Hemostatic agents.

TABLE 14.2 Acidity of Commonly Used Hemostatic Agents

Agent	Manufacturer	Active Ingredient	Vehicle	Mean pH
Astringedent	Ultradent	15.5% $\text{Fe}_2(\text{SO}_4)_3$	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% $\text{Fe}_2(\text{SO}_4)_3$	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; $\text{Fe}_2(\text{SO}_4)_3$, ferric sulfate; HCl, hydrochloride.

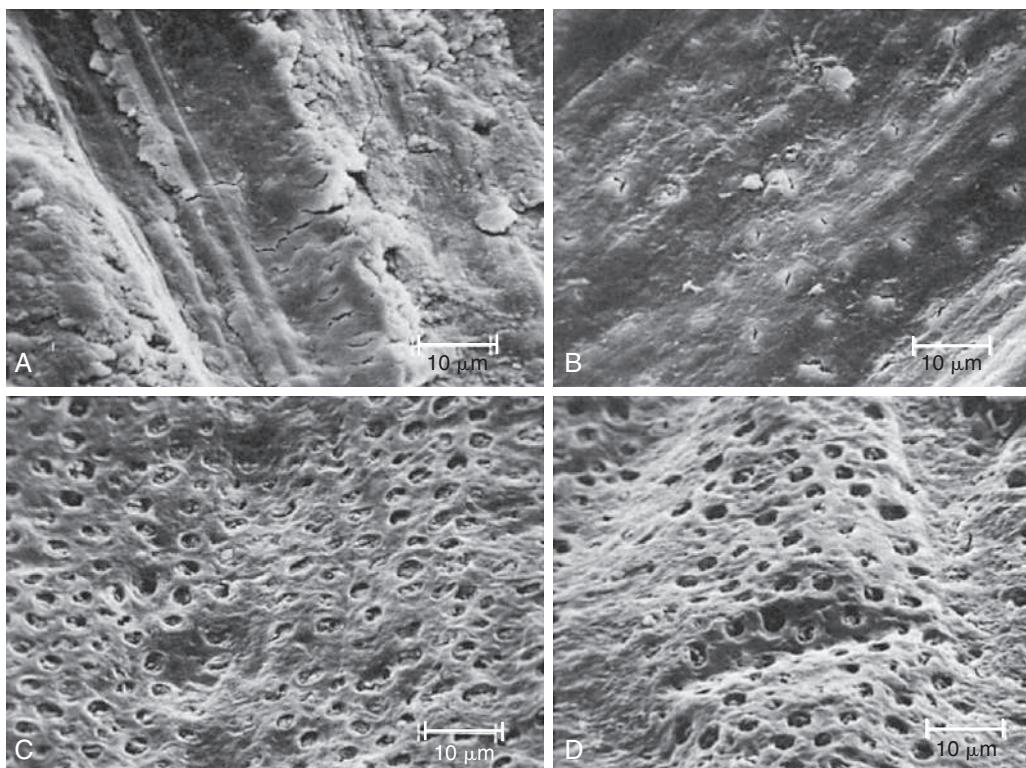


Fig. 14.5 Disturbance of the dentinal smear layer after contact with hemostatic agents. (A) Dentin surface prepared with a high-speed, fine-grit diamond. (B) After exposure to 15.5% ferric sulfate ($\text{Fe}_2(\text{SO}_4)_3$) solution for 30 seconds. The smear layer is largely removed, but many dentinal 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*. 1994;72:4.)

- air. Do not excessively desiccate the tooth because this may lead to postoperative sensitivity.
- Cut a length of cord sufficient to encircle the tooth (Fig. 14.7A and B).
 - 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.
- Twist nonbraided cords tightly for easier placement.
 - Loop the cord around the tooth, and gently push it into the sulcus with a suitable instrument (see Fig. 14.7C).

It is often easiest to start interproximally (see Fig. 14.7D), 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. 14.7E) 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).

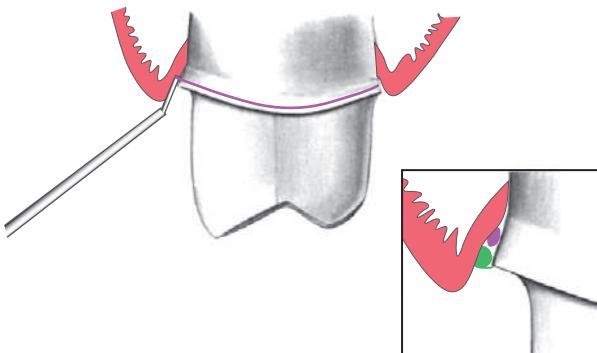


Fig. 14.6 Dual cord technique. The smaller displacement cord is left in place during impression making, whereas the larger cord at the level of the margin is removed immediately before the impression material is gathered by syringe.

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 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



Fig. 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.)



Fig. 14.7 (A) 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.)

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

Hemorrhage control may be facilitated by the use of $\text{Fe}_2(\text{SO}_4)_3$ solution applied directly to the bleeding site, although the dentist should be cautioned that the solution has been reported to have a cytotoxic effect.¹⁸

Step-by-step procedure

1. Fill the syringe with $\text{Fe}_2(\text{SO}_4)_3$ solution (Fig. 14.9A) and attach the infuser tip (see Fig. 14.9B). 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. 14.9C).
3. Irrigate the area with an air-water syringe (see Fig. 14.9D) and gently dry the tissues with air. Inspect to determine the degree to which bleeding has diminished (see Fig. 14.9E). 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

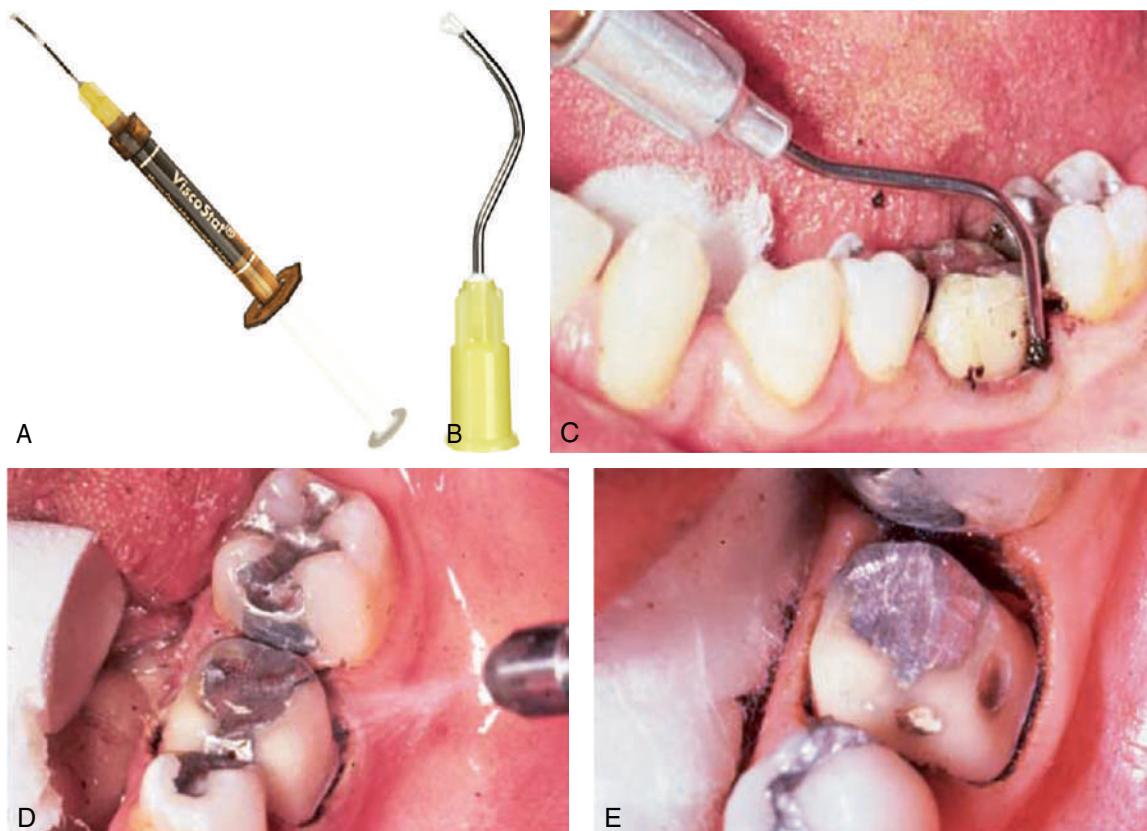


Fig. 14.9 Hemorrhage control with ferric sulfate ($\text{Fe}_2(\text{SO}_4)_3$) delivered with an infuser syringe. (A) and (B) $\text{Fe}_2(\text{SO}_4)_3$ coagulative hemostatic gel and tip of infuser syringe. (C) $\text{Fe}_2(\text{SO}_4)_3$ is released as the tip is moved back and forth in contact 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.)

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% $\text{Fe}_2(\text{SO}_4)_3$] 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 (Take 1, KaVo Kerr Corp.) (Fig. 14.10) as an alternative to cord.¹⁹ 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.²⁰ However, less tissue displacement is achieved than with cord, which may make subsequent laboratory steps such as die trimming more problematic.²¹ Improved displacement may be achieved if the paste is directed into the sulcus by applying pressure with a hollow cotton roll (ROEKO Comprecap, Coltène).

Other displacement pastes rely on volumetric expansion as initially described by Feinmann and Martignoni,²² 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 FoamCord, Coltène) is based on the identical principle, but instead of an interim restoration a hollow cotton roll (ROEKO Comprecap, Coltène) is used to apply pressure to the expanding foam (Fig. 14.11). Additional expanding foam can be inserted into the hollow of the cotton roll.

Occlusal Matrix Impression Technique

The volumetric expansion pastes are effective because resistance in an occlusal direction exerted by either an 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,²³ and subsequently with more contemporary materials by Livaditis,²⁴ 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,



Fig. 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–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–I, Courtesy Dr. Tony Soileau.)



Fig. 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 a 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). Expanding foam can also be injected into the hollow of the cotton roll. (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 or the scan made. (A, Courtesy Coltène, Cuyahoga Falls, Ohio.)

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 unit²⁵⁻²⁸ (Fig. 14.13A) may be used for minor tissue removal before impression making. In one technique,²⁹ the inner epithelial lining of the gingival sulcus is removed, which thus improves access for a subgingival crown margin (see Fig. 14.13B-F) and helps effectively control postsurgical hemorrhage³⁰ (provided that the tissues are not inflamed). Unfortunately, there is the potential for gingival tissue recession after treatment.³¹

An electrosurgery unit works by passage of a high-frequency current (1 to 4 million Hz [1 Hz = 1 cycle/s]) through the tissue from a large electrode to a small one. At the small electrode, the current 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.²⁶

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),³² even though newer devices are designed to deflect unwanted current flow³³ 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 should be used instead.)
- 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.
- 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.³⁴
- 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

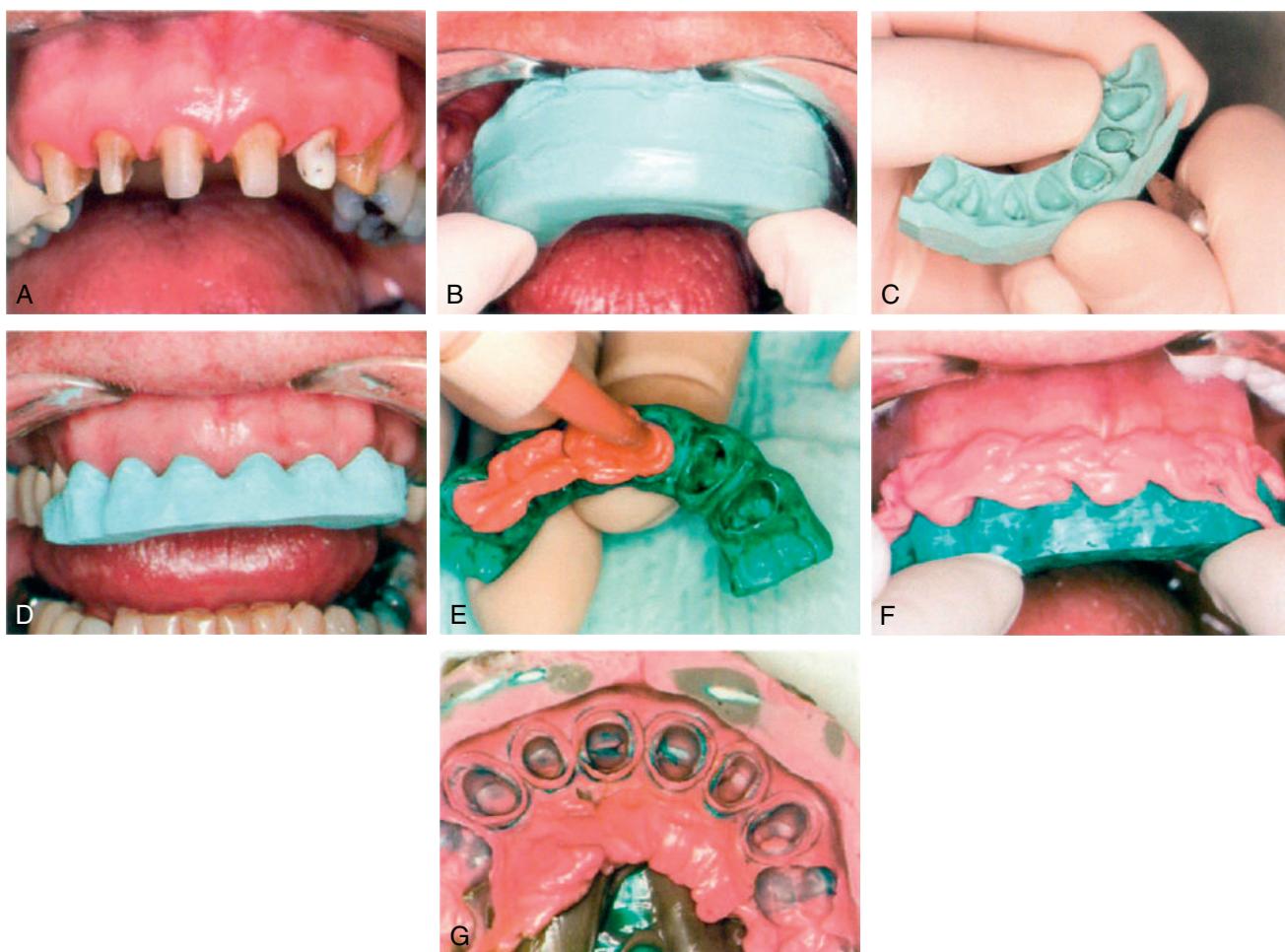


Fig. 14.12 Occlusal matrix impression system. (A) Maxillary anterior teeth are prepared for complete crowns. (B) Matrix is made in the carrier with elastomeric impression material putty before soft tissue is displaced. Registration of the gingival crest is the primary objective. (C) Facial and palatal 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*. 1998;79:208.)

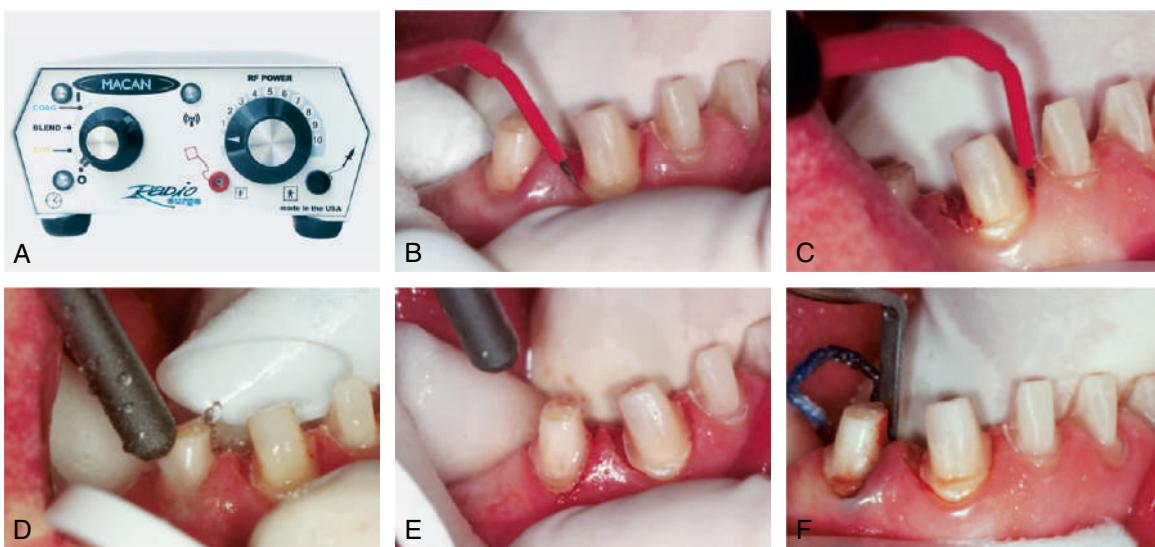


Fig. 14.13 (A) An electrosurgery unit. (B) The tip of the electrode is used to probe the area where the incisions will be made. (C) The tip of the electrode is passed through the hyperplastic tissue. The area is irrigated (D) and dried for inspection (E). (F) After tissue removal, cord placement precedes impression making. (A, Courtesy Macan Engineering Co., Chicago, Illinois.)



Fig. 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.)

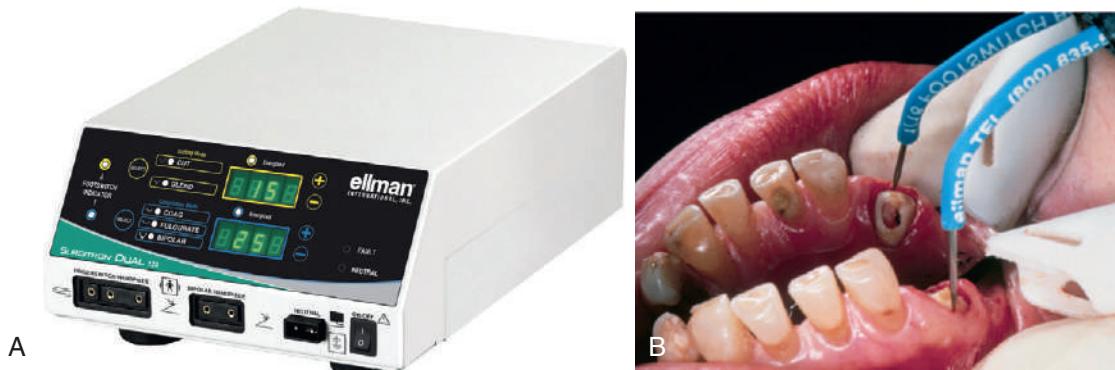


Fig. 14.15 (A) Radiosurgery unit. (B) The gingival sulcus enlarged before impression making. (Courtesy Ellman, A Cynosure Company, Hicksville, NY.)

impression making (Figs. 14.14 and 14.15).^{35,36} 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 claimed³⁷ 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.³⁸ Different waveforms 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 accuracy³⁹ and surface detail⁴⁰ 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 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



Fig. 14.16 Reversible hydrocolloid impression material. Tray (A) and wash material (B). (C) Syringe material. (Courtesy Dux Dental, Oxnard, California.)

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 h; 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

viscous syringe material. The required temperature changes are achieved by submersion in a special conditioning unit (see Figs. 14.36 and 14.37) and the use of 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.⁴¹ Therefore, an additional advantage of reversible hydrocolloid is that a custom impression tray is not required.

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.³²

Polysulfide contracts slightly during polymerization, but the effects can be minimized with a custom impression tray to reduce the bulk of the material.⁴² 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.⁴³

The high tear resistance^{44,45} 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,⁴⁶ 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.



Fig. 14.17 Polysulfide polymers. (Courtesy GC America Inc., Alsip, Illinois.)

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.⁴¹

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.⁴⁷ Care is also needed to avoid contaminating the putty surface with saliva, which prevents the wash impression from adhering properly.⁴⁸

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,



Fig. 14.18 Condensation silicone. (Courtesy Coltène, Cuyahoga Falls, Ohio.)

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 shrinkage⁴⁹ is unusually low in comparison with most room temperature–cured polymer systems. However, its thermal expansion⁵⁰ is greater than that of polysulfide.

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 hypersensitivity⁵¹ 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.⁵²

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



Fig. 14.19 Polyether impression material. (Courtesy 3M ESPE Dental, St. Paul, Minnesota.)

resins), it is similar in many ways to condensation silicone except that it has much greater dimensional stability⁵³ (equivalent to that of polyether polymer), and its working time is more affected by temperature.⁴⁰ 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.⁵⁴ One disadvantage of some of these materials is that setting can be inhibited by selected latex gloves⁵⁵ or by interim resin materials.⁵⁶ Dithiocarbamates, which are used in glove manufacturing as either vulcanizing agents or accelerators, have been implicated as causative agents.⁵⁷ Glove exposure to alcohol has been shown to exacerbate setting inhibition for selected combinations of impression material and latex gloves.⁵⁵ 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,⁵⁸ 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.⁵⁹

Like condensation silicone, addition silicones are hydrophobic. Some formulations contain surfactants, which give them hydrophilic properties,⁶⁰ imparting wettability similar to that of the polyethers.⁶¹ However, these products also expand like polyether when in contact with moisture.⁶² Addition silicone is generally used by combining a low-viscosity syringe material



Fig. 14.20 Addition silicone. (Courtesy GC America Inc, Alsip, Illinois.)

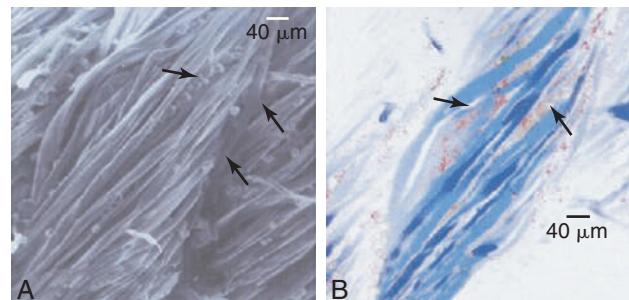


Fig. 14.21 (A) Scanning electron microscope finding of gingival displacement cord contaminated by latex glove contact. Arrows indicate particles on surfaces and within fibers of gingival displacement cord. (B) Electron probe microanalysis of gingival displacement cord contaminated by latex glove contact. 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.* 2005;93:433.)

with a higher-viscosity tray material, although monophase formulations are also available. It is easier to trap bubbles with the monophase formulation.⁶³

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.

Vinyl Polyether Silicone

Burak Yilmaz

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.⁶⁴



Fig. 14.22 Vinyl polyether silicone. (Courtesy GC America Inc, Alsip, Illinois.)

Vinyl polyether silicone has been reported to combine the ease of removal of addition silicone with the hydrophilicity (wetting properties) of polyether,⁶⁵ making it a promising material for challenging situations where moisture control is difficult, such as narrow, deep gingival crevices.⁶⁶ An in vitro study concluded that the dimensional stability and surface detail reproduction of vinyl polyether silicone is comparable to those of polyether and polyvinyl siloxane.⁶⁷ However, clinical studies are needed to investigate the accuracy of this new material.

SCANNABLE ELASTOMERIC IMPRESSION MATERIALS

As an alternative to conventional impression making and stone pouring, scannable elastomeric impressions can be scanned without pouring a stone cast. Their physical properties are different than those of conventional elastomers, particularly their surface brightness, which improves digitalization. Scannable elastomeric materials have been reported to enable obtaining digital casts of favorable accuracy without a stone cast being poured. They present a suitable alternative to achieve optimal accuracy to fabricate fixed dental prostheses.⁶⁸

IMPRESSION TRAYS

Impression material choice 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.

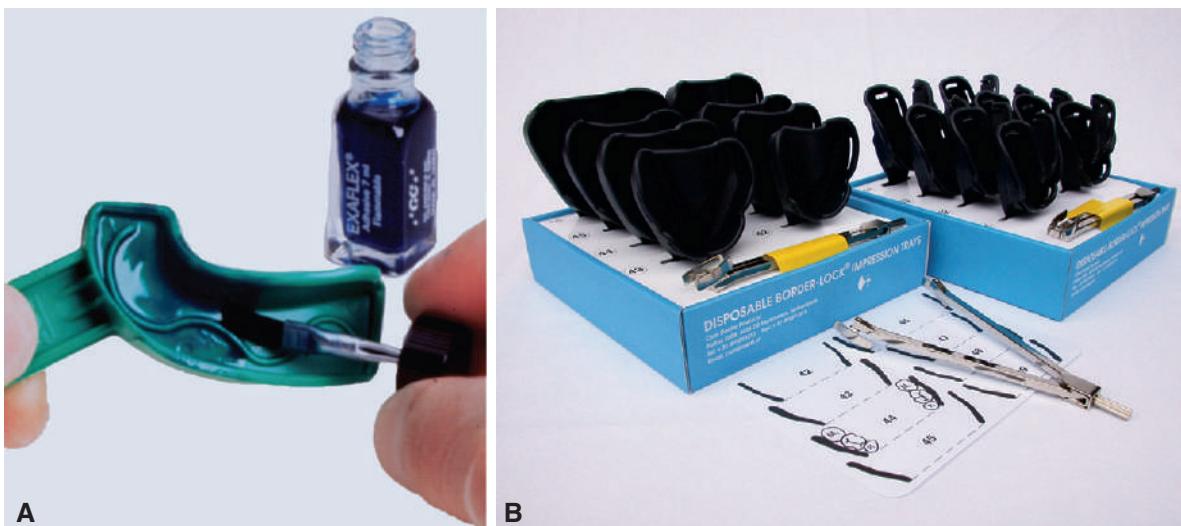


Fig. 14.23 (A) This prefabricated segmented tray relies on internal modification to ensure material thickness. (B) This system allows the dentist to match tray size to patient arch width. (B, Courtesy Clan Dental Products, Maarheeze, The Netherlands.)

Adhesives should be applied sufficiently in advance to allow thorough drying, although they may remain slightly tacky to touch. Because evaporation of their 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.⁶⁹

CUSTOM TRAY FABRICATION

A custom tray improves the accuracy⁷⁰ 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 comparable with that of impressions made with an autopolymerized resin.^{71,72} Light-polymerized materials are convenient because a storage period is not needed for the completion of polymerization (Fig. 14.26).⁷³ 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.⁷⁴

With any system, tray rigidity is important because even slight flexing of the tray causes distortion of the polymerized impression material. This is particularly frustrating because the errors are usually undetectable until the practitioner attempts to seat the restoration. For this reason, thin, disposable plastic trays are unacceptable.⁷⁵ Tray 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

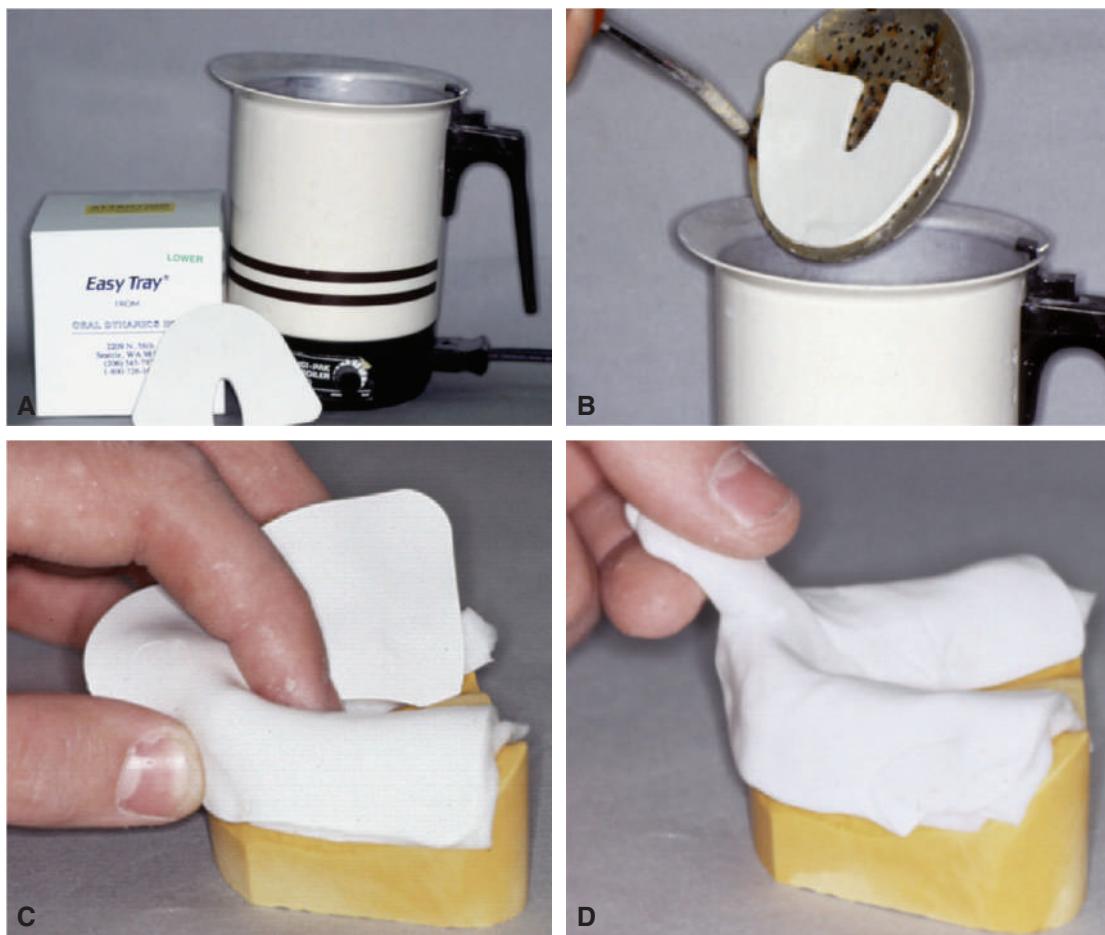


Fig. 14.24 Thermoplastic custom tray material. (A and B) The material is softened in hot water. (C and D) The material has been adapted to the spaced cast.

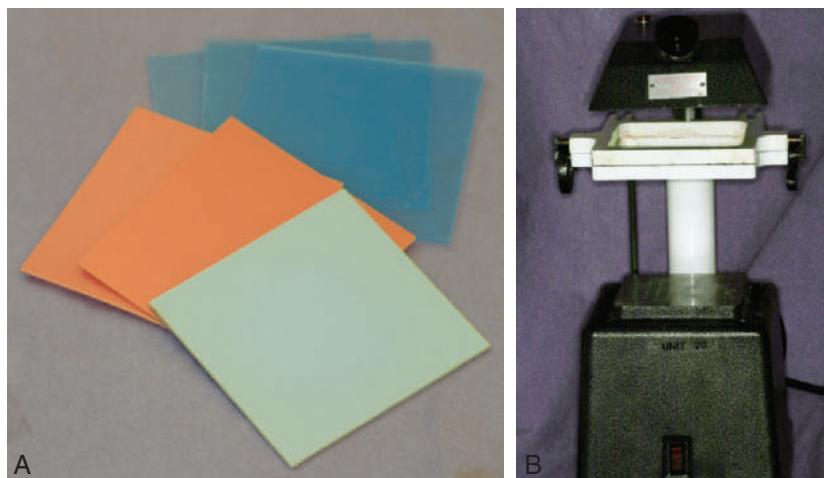


Fig. 14.25 Vacuum-formed custom tray material. The thermoplastic sheets (A) are much thicker and more rigid than those used for making interim restorations (see Chapter 15), but the same equipment is used (B).

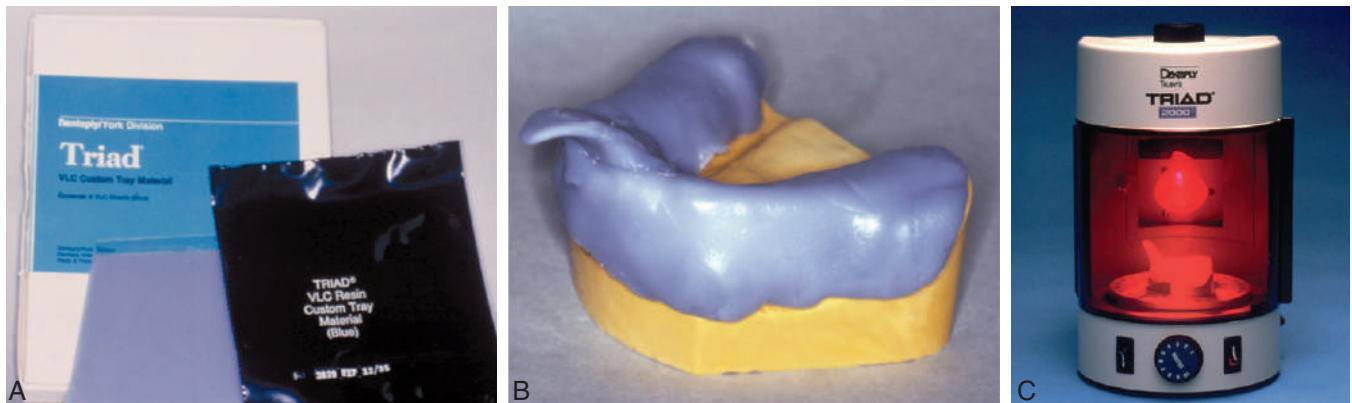


Fig. 14.26 Visible light-polymerized custom tray material. The material is removed from the packet (A) and adapted to the spaced cast (B). (C) The assembly is placed on the turntable of a special polymerization unit and exposed to intense light.

- 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 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.



Fig. 14.27 If necessary, a tray stop can be placed on the hard palate.

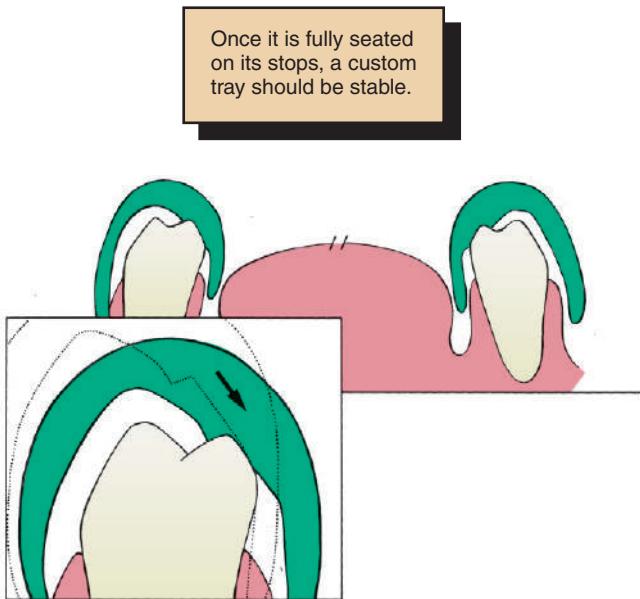


Fig. 14.28 Drawing of a cross section through a mandibular custom tray. Stops have been placed on the nonfunctional cusps so that distortion does not interfere with the intercuspal relationship. The 45-degree slope helps to center the tray during seating (arrow). Space for the impression material is present.

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.
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).



Fig. 14.29 Buccal ridges can be provided to facilitate removal of the impression. (Courtesy Dr. H. Lin.)

9. After the material has polymerized, remove it from the cast and trim it with an acrylic-trimming bur (see Fig. 14.30R) 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. 14.30A–H).

6. Remove photopolymerized tray material sheets from their lightproof packaging (see Fig. 14.30H) 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. 14.30I). Two sheets are needed to make each tray and should be cut as shown in Fig. 14.30J. Carefully adapt the large piece of material to the cast, being careful not to extend the material beyond the scribed borders (see Fig. 14.30K–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. 14.30N). 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. 14.30O). 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. 14.30P). Paint the tray with the air-barrier coating provided by the manufacturer (see Fig. 14.30Q).
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. 14.30R). Add additional resin as needed.



Fig. 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. (I) Some resin is applied into the areas for the stops and small edentulous spaces. (J) Sheets should be cut as shown.



Fig. 14.30 Cont'd 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.)

Evaluation

The completed custom tray needs to be rigid, with a consistent thickness of 2 to 3 mm. It should extend about 3 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,⁷⁶ 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. Impression trays can also be made from light-polymerizing materials (see Fig. 14.26).



Fig. 14.31 A custom tray should be smooth and well finished. This will enhance its acceptability to the patient.

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

- Evaluate the custom tray in the patient's mouth to verify its fit. Correct the tray as needed.
- Apply tray adhesive to extend a few millimeters onto the external surface of the tray (Fig. 14.32A). Allow

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.

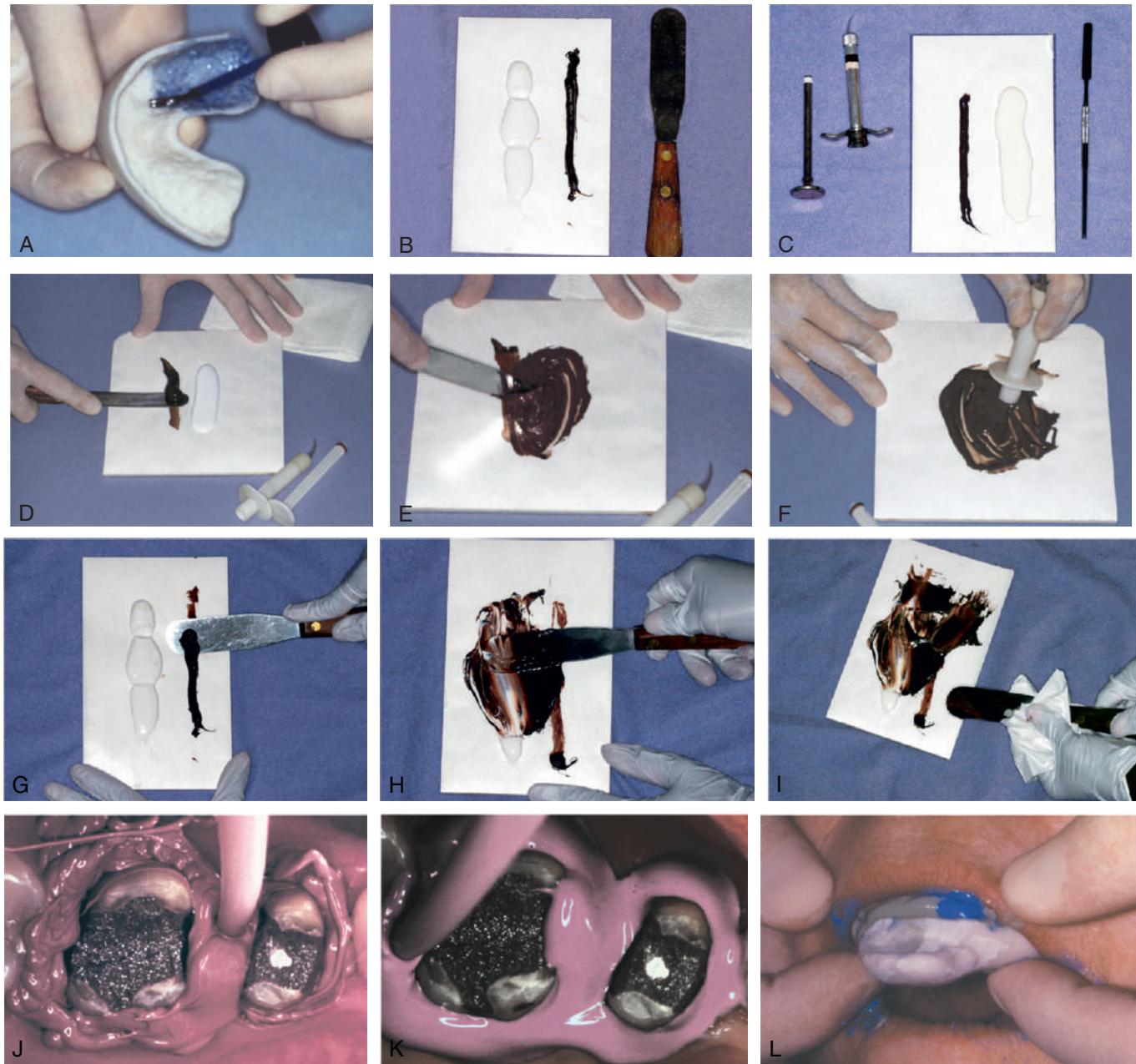


Fig. 14.32 Elastomeric impression making (polysulfide polymer). (A) Adhesive is applied to the tray. Sufficient time is allowed for drying. (B) Heavy-bodied tray material. (C) Light-bodied syringe material. (D) The brown catalyst is picked up first. (E) The brown catalyst is thoroughly mixed with the white base material. (F) Impression syringe is loaded. (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.

- 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. 14.32B and C).

When mixing polysulfide polymers, pick up the brown catalyst first (see Fig. 14.32D), 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. 14.32E). 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. 14.32F) 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. 14.32G–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 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. 14.32J 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. 14.32J and K).

11. Seat the tray (see Fig. 14.32L). 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.⁷⁷ 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.

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.⁷⁸ 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 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

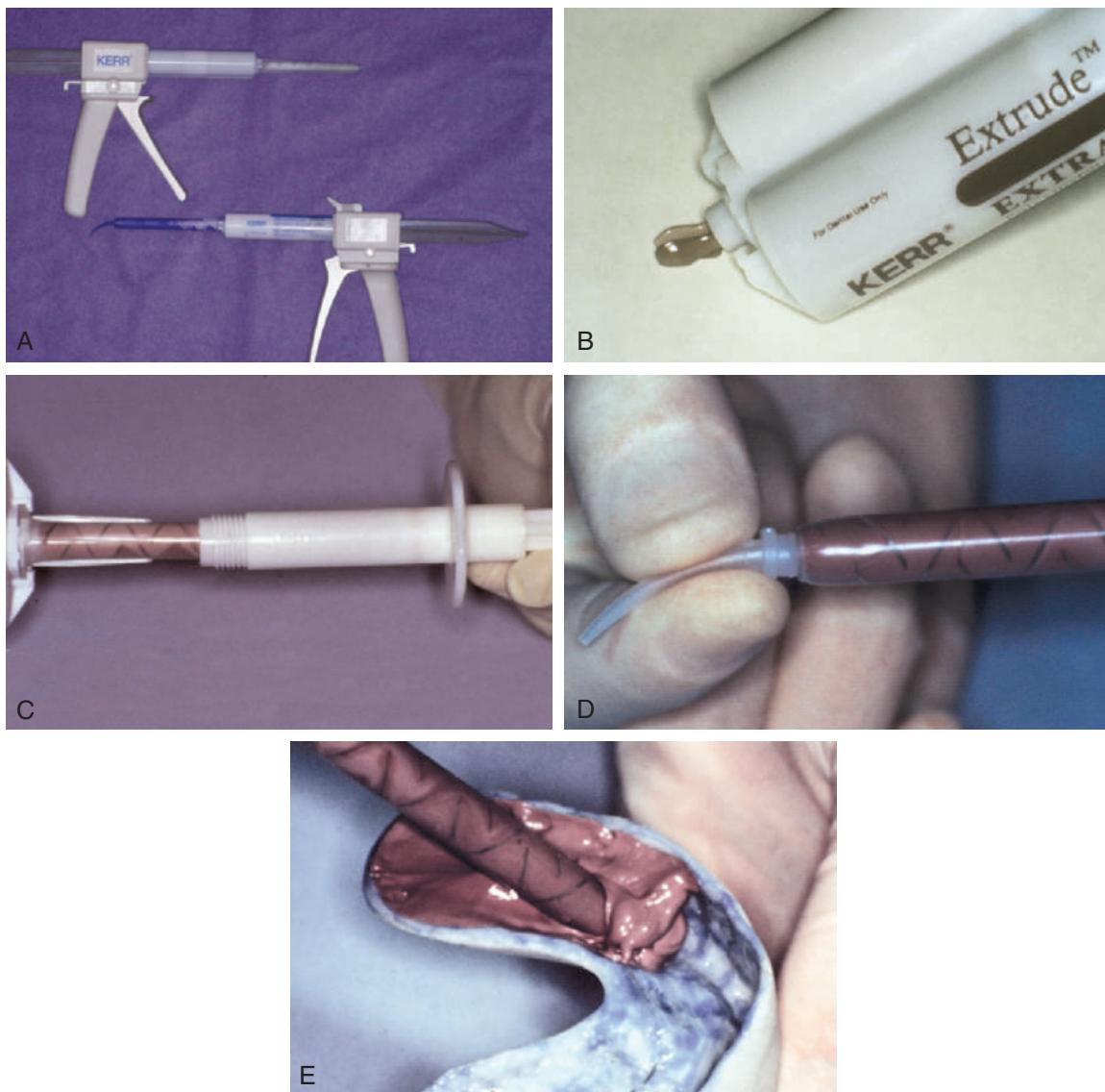


Fig. 14.33 (A) Automix addition silicone impression materials are available in various degrees of viscosity. (B) The barrels should be “bled” to ensure that any partially set material is removed and that the flow is even from each component. To prevent cross contamination of the catalyst and base, a 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).

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 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 ($\approx 65^{\circ}\text{C}$ [150°F]) for maintaining liquefied materials until they are needed
- A tempering bath ($\cong 40^{\circ}\text{C}$ [105°F]) for reducing the temperature of the heavy-bodied tray material enough to avoid tissue damage



Fig. 14.34 Machine mixing system. (A) Pentamix machine. (B) Polyether impression material. (C) Loading an impression tray. (Courtesy 3M ESPE Dental, St. Paul, Minnesota.)

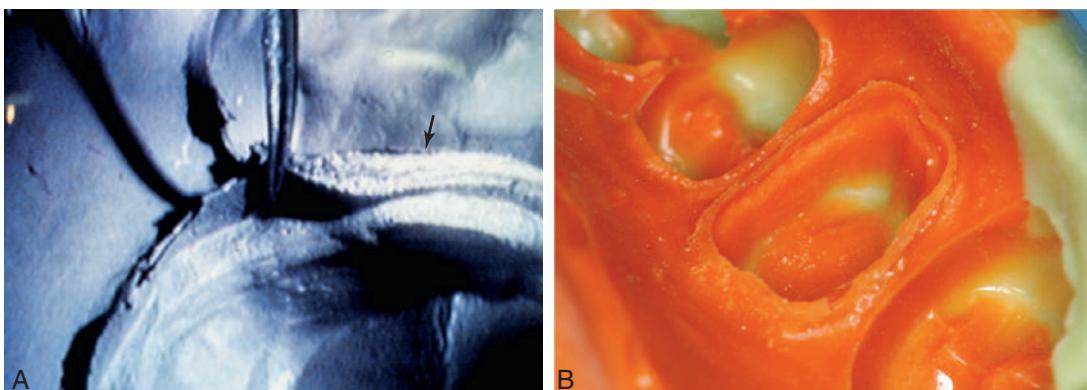


Fig. 14.35 Impression evaluation. (A) Low magnification of elastomeric impression. On the left, an adequate cuff is formed by material extending beyond the preparation margin. On the right side (arrow), the impression does not extend adequately. (B) This impression reproduces an adequate amount of the unprepared tooth structure cervical to the preparation margin.

Step-by-Step Procedure

- Select the correct size of water-cooled impression tray. For maximum accuracy, use the largest size that can be comfortably accommodated by the patient.
- Place prefabricated stops across the posterior of the tray to prevent overseating and to provide additional retention.
- For adequate access, displace the gingival tissues as previously described.
- Fill the impression tray with heavy-bodied material from the storage bath. Add wash material to the surface of the hydro-colloid tray material in the area of the preparation and one adjacent tooth (Fig. 14.37A and B). Submerge the tray in a tempering bath (see Fig. 14.37C).



Fig. 14.36 Hydrocolloid conditioning equipment consists of three thermostatically controlled water baths: boiling or liquefaction, storage, and tempering. (Courtesy Dux Dental, Oxnard, California.)

5. Carefully remove the cord from the sulcus, and flood the sulcus with warm water (see Fig. 14.37D).
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. 14.37E).
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).

Evaluation

A reversible hydrocolloid impression is evaluated in the same manner as polysulfide polymer (see Fig. 14.37F). 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 short-span fixed partial dentures made to conform to the existing occlusion.^{79,80} The impression is made in maximum intercuspal position 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.⁸¹ The impression includes the prepared tooth, the adjacent teeth, and the opposing teeth and records their maximum intercuspal relationship (hence the name "triple tray"). Because the impression is made at the occlusal vertical dimension, the technique facilitates making an accurate impression^{82,83} and occlusal record. However, the laboratory stages must be performed 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 intercuspal position without interference with the tray. If the preliminary impression (external mold) for the interim restoration (see Chapter 15) is made with a closed-mouth tray, this will serve as a useful rehearsal of the procedure for the patient (Fig. 14.38A).
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 intercuspal position 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. 14.38E). 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 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.

Evaluation

The completed impression (Fig. 14.39) is inspected carefully before the definitive cast is made. An elastomeric impression

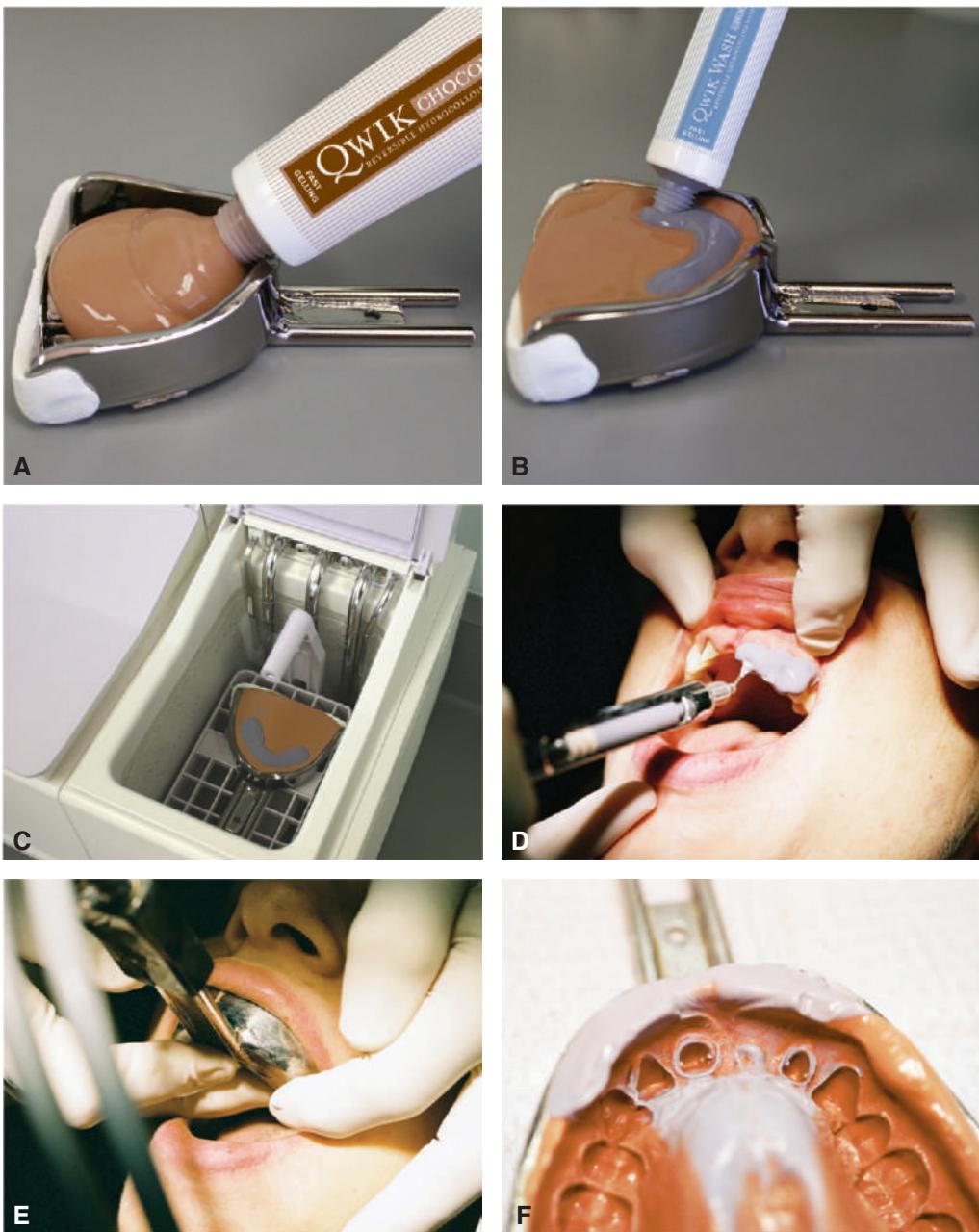


Fig. 14.37 Hydrocolloid impression technique. (A) The water-cooled impression tray is loaded with heavy-bodied material. (B) The wash hydrocolloid is squeezed onto the tray material in the area of the preparations. (C) The filled tray is placed in a tempering bath for the recommended 3 minutes. (D) The 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.)

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.

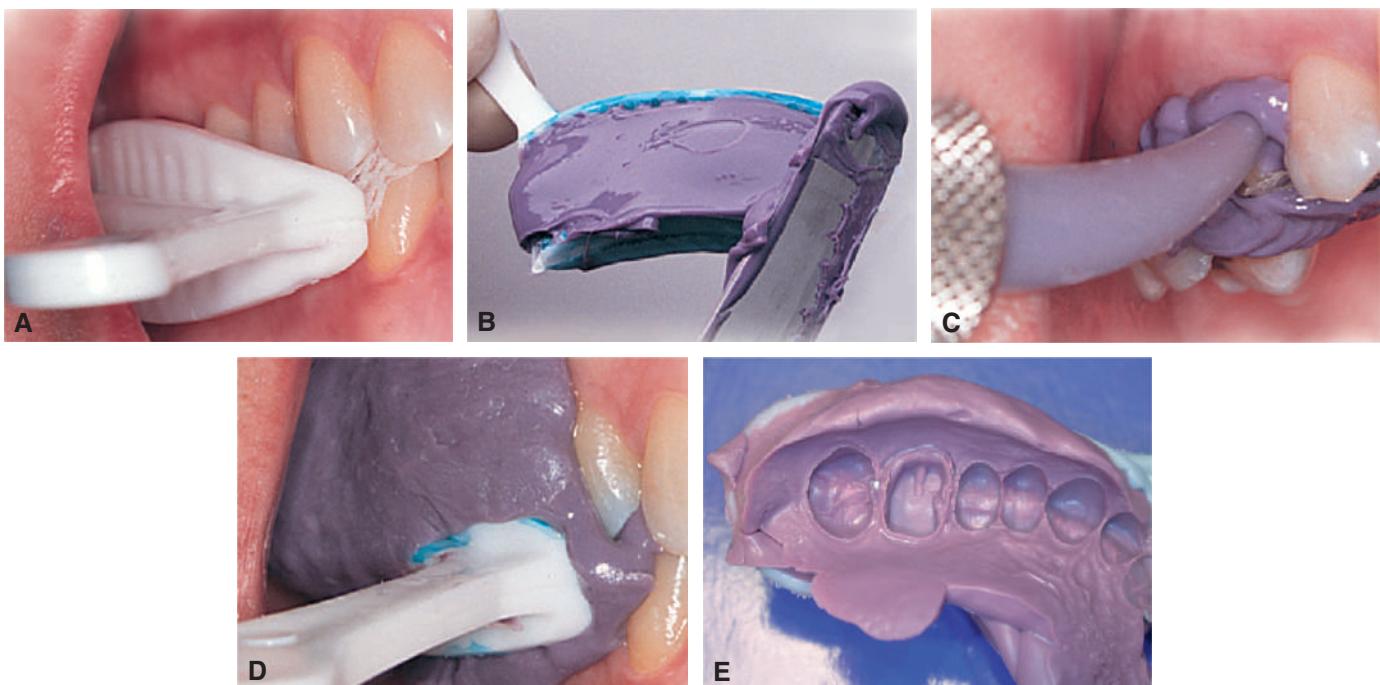


Fig. 14.38 Closed-mouth impression technique. (A) The tray is selected and evaluated. (B) The tray is loaded. (C) Impression material is delivered by syringe. (D) Patient closes into maximum intercuspation. (E) Completed impression. (A–D, Courtesy Premier Dental Products Co., Plymouth Meeting, Pennsylvania.)

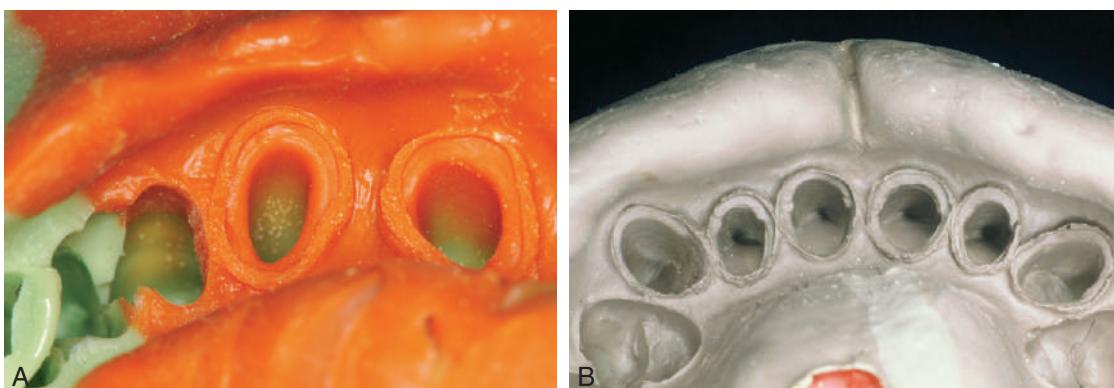


Fig. 14.39 The completed impression. (A and B) Careful technique ensures a complete cuff of impression material beyond the margin and greatly facilitates trimming of the die and contouring of the wax pattern.

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.

Disinfection

When removed from the patient's mouth, it must be assumed that all impressions have been in contact with body fluids. The materials should be disinfected according to the recommended procedures for the material being used. After removal,

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.^{84–87}

TABLE 14.4 Recommended Disinfection Method by Impression Material

Disinfection	Irreversible ^a Hydrocolloid	Reversible ^a Hydrocolloid	Polysulfide	Silicones	Polyether ^b
Glutaraldehyde 2% (10-min 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 data	Yes	Yes	No
Phenolic glutaraldehydes	Not recommended	Yes	Yes	Yes	No

^aImmersion 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.

^bImbibition 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*. 1992;20(10):31.

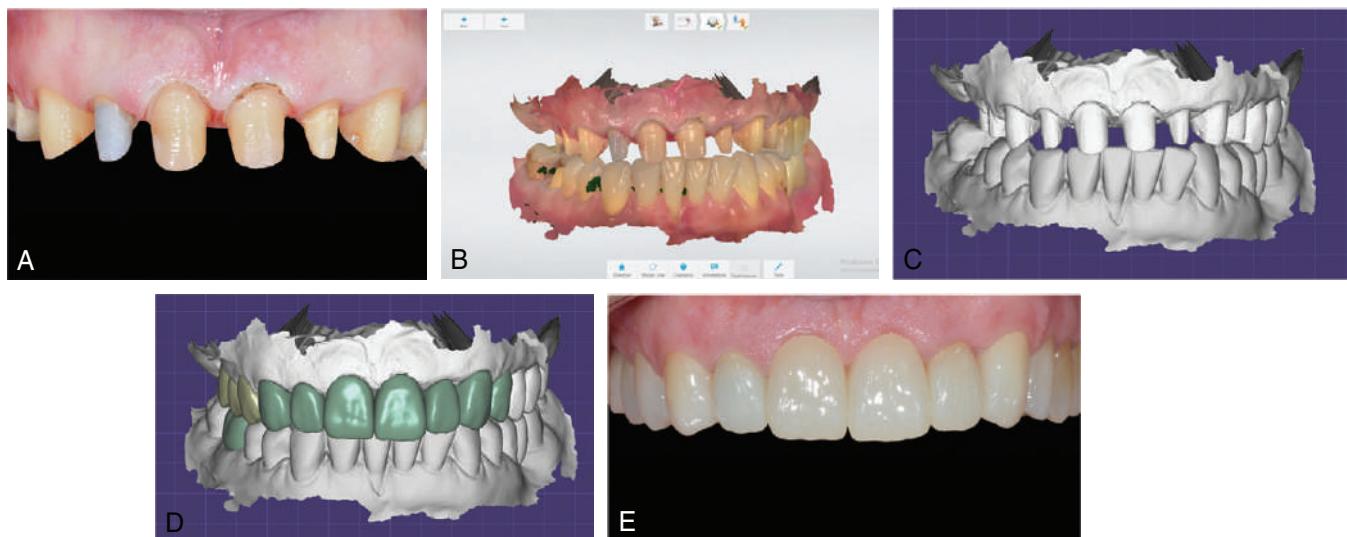


Fig. 14.40 (A) Frontal view of prepared teeth. (B) Intraoral scan images of both arches. (C) Scan images in design software. (D) Design files of crowns on software in occlusion. (E) Definitive crowns. (Courtesy of Dr. Oguz Ozan.)

DIGITAL SCANNING TECHNIQUES

Dental digital scanning systems were initially envisioned by Duret in the 1970s for digital scanning directly in the patient's mouth or on a cast.⁸⁸ 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.⁸⁹ Initial scanning relied on stripe scanning and 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 intraoperative adjustment. Scanning technologies evolved in the subsequent decades, and the dimensional accuracy of optical scanning of tooth preparations today is comparable to or even more accurate than conventional impression techniques.^{90,91}

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.

The market penetration of digital scanning technologies has advanced considerably in the last decade because of patient comfort, and because the captured data permit acceleration of certain steps in the laboratory fabrication process. Digital scans can be sent electronically to fabrication units in the dental office for chairside fabrication of restorations for same-day delivery, or alternatively, to off-site dental laboratories for fabrication of definitive fixed prostheses through digital or conventional means (see Chapter 25). In a systematic review and meta-analysis published in 2021, it was reported that the patients preferred digital scanning over conventional impressions and digital scans were less time-consuming than conventional impression techniques (Fig. 14.40).⁹² A clinical study concluded that both dental students and operators after some initial training in scanning preferred digital scans made for diagnostic purposes over making conventional impressions.⁹³

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.⁹⁴ 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. 14.41). 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 light-emitting diodes 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. 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.

Confocal Imaging

Confocal imaging makes use of an optical range finder similar to that found in a camera and relies on acquisition of focused and unfocused images from selected distances.⁹⁵ From the focal length of the lens, areas in sharp focus are detected by the system and the distance to the object is calculated. An object can then be reconstructed by subsequent images made at different focal points, aperture values, and from different angles.⁹⁶

Parallel Confocal Scanning

iTero Principle

In contrast with the other laser scanners, one system uses a multitude of 30,000 concurrent beams of red light. Its scanner head has optics that forces specific reflected light to pass through into a preprogrammed sensor. Light reflected from known distances

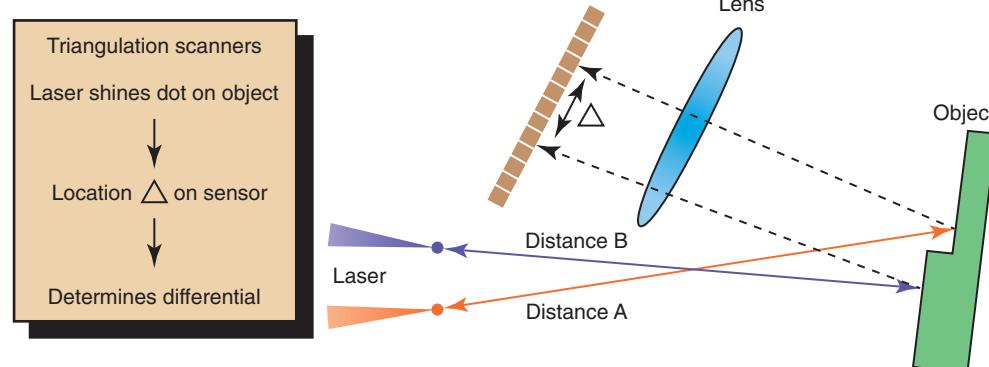


Fig. 14.41 How a triangulation scanner works.



Fig. 14.42 Optical impression being generated.

will pass through the filtering device and be used to compute the geometry of the substrate. The illustrated system captured over 7,000,000 points at over 235 focal depths 50 µm apart, 20 times per second. Its telecentric system is said not to require powdering.

■ ■ ■

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 be 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 (Fig. 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.

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.

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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Interim Fixed Restorations

Van Ramos, Jr., Contributing Author

Interim crowns or fixed partial dentures (FPDs) 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 days 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 the time and effort 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, treatment of periodontal disease, clinical crown lengthening, or assessment of functional occlusion). Whatever the intended length of treatment time, an interim restoration must maintain its own integrity and 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.¹

REQUIREMENTS

An optimum interim fixed restoration must satisfy many interrelated factors, which can be classified as biologic, mechanical, diagnostic, 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,

caries, 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.^{1,2} 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 result in caries or cause irreversible pulpitis, with the consequent need for root canal treatment.³

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 finish line is placed intrasulcularly.⁴ If the interim fixed restoration is inadequate and plaque control is impaired, gingival health deteriorates.^{5,6}

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, particularly for bonded restorations) very difficult; thus the smoothness of a restorative material has a direct impact on gingival health.⁶ 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 insertion appointment, when the definitive restoration makes premature contact. It is sometimes possible to correct this, 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 or unnecessarily adjust the opposing tooth. Horizontal movement results in excessive or deficient proximal contacts. The former necessitates tedious chairside adjustment; the latter involves a laboratory procedure to add metal or ceramic to the deficient site.

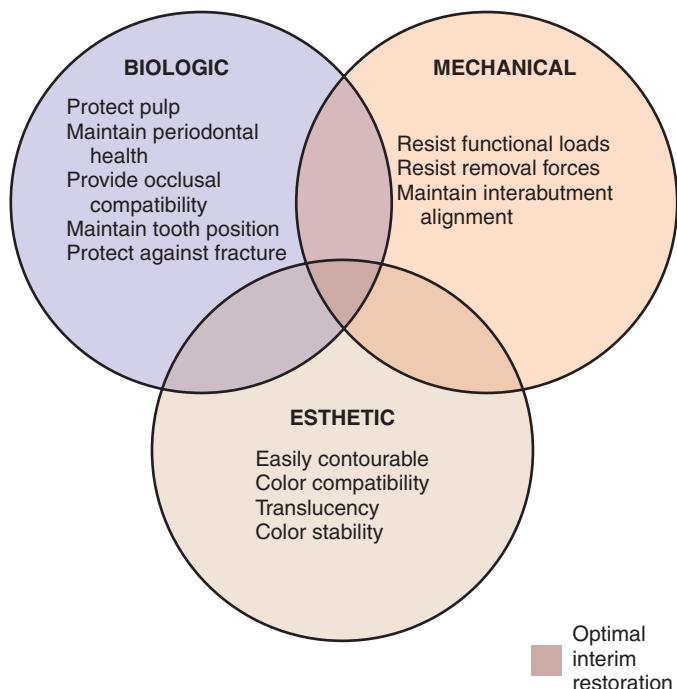


Fig. 15.1 Factors to be considered in making an interim restoration. The *central area* represents the optimum, in which biologic, mechanical, diagnostic, and esthetic requirements are adequately met.

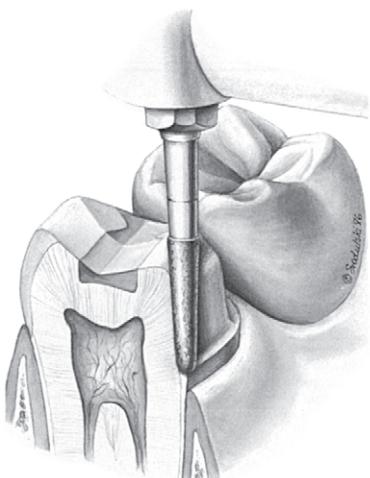


Fig. 15.2 Pulp trauma and exposure of the dentinal tubules from tooth preparation.

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

Rough margins around interim restorations will jeopardize subsequent procedures.

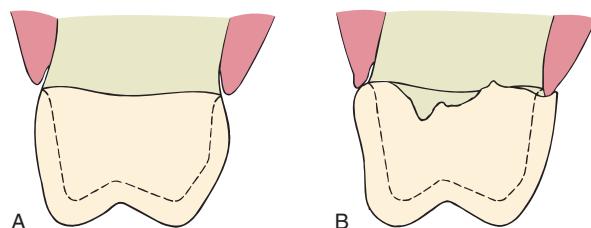


Fig. 15.3 An interim restoration should have good marginal fit, proper contour, and a smooth surface finish. (A) A properly contoured interim restoration. It is smoothly continuous with the external surface of the tooth. (B) Overcontouring. The transition from the restoration to the root surface is irregular, 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.

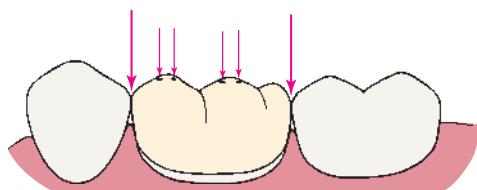


Fig. 15.4 Proper occlusal and proximal contacts promote patient comfort and maintain tooth position.

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.

Prevention of Enamel Fracture

The interim fixed restoration should protect teeth weakened by tooth preparation (Fig. 15.6). This is particularly true with partial coverage designs, in which the finish line 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 and costly remake.

Mechanical Requirements

Function

The greatest stresses in an interim fixed restoration occur during mastication. Unless the patient avoids contacting the

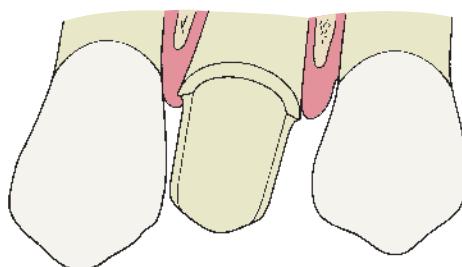


Fig. 15.5 A missing proximal contact allows tooth migration. The resulting root proximity may necessitate surgical or orthodontic correction to allow impression making.

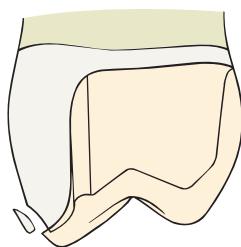


Fig. 15.6 The interim restoration must protect the tooth. Fracture of a tooth after the impression phase delays treatment and jeopardizes restorability.

restoration when eating, internal stresses are similar to those occurring in the definitive restoration. However, the strength of interim materials is inferior to definitive materials,⁷ 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), although with conservative, minimally invasive preparations, recommended for high-strength restorative materials where possible, and also with partial-coverage interim restorations and FPDs, more frequent breakage occurs. Minimal tooth reduction is biologically favorable for the tooth; however, interim materials still need adequate strength.

An FPD must function as a beam in which substantial occlusal forces are transmitted to the abutments. This creates high stresses in the connectors,⁸ 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) but not at the expense of cleansability. 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 connector height and depth. 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.

In some instances, fiber-reinforced, laboratory-processed resin, heat-processed polymethyl methacrylate (PMMA), milled or three-dimensional (3D)-printed^{9,10} PMMA, a reinforcing metal mesh,¹¹ or cast metal reinforced interim restorations can spare the practitioner and the patient inconvenience, lost time, and the expense of remaking an interim restoration (Box 15.1).



Fig. 15.7 This acrylic resin interim crown fractured. The interocclusal record between the preparation and its antagonist shows that the preparation was underreduced.

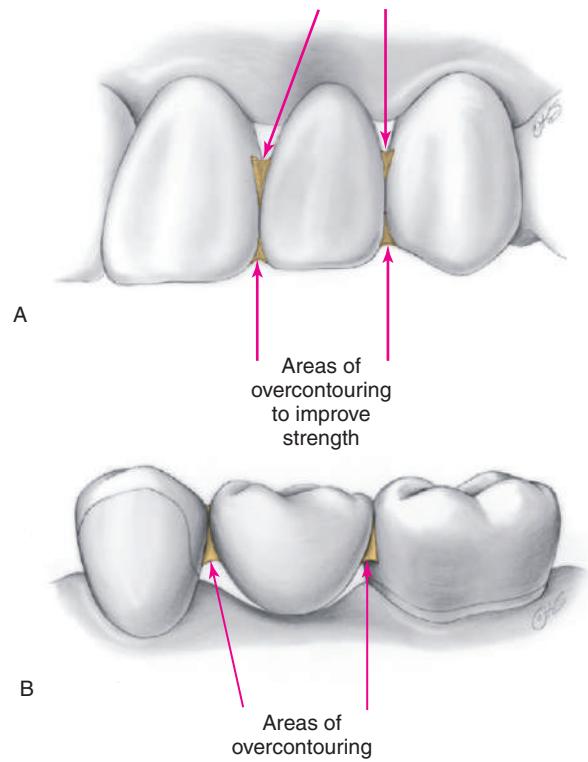


Fig. 15.8 The connectors of an interim fixed partial denture are often purposely overcontoured. (A) In the anterior region, the degree of overcontouring is substantially limited by esthetic requirements. (B) In the posterior region, esthetics is less restrictive, but overcontouring still must not jeopardize the maintenance of periodontal health.

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 office. Displacement is best prevented through proper tooth preparation and an

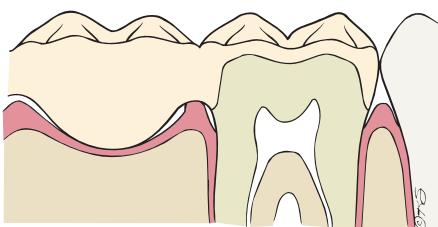


Fig. 15.9 In this mesiodistal section, an overcontoured connector impinges on the gingiva. Pressure ischemia and poor access for plaque removal promote gingivitis.

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BOX 15.1 Indications for Reinforced Interim Restorations

- A long-span posterior fixed partial denture
- Prolonged treatment time
- Patient's inability to avoid excessive forces on the prosthesis
- Above-average masticatory muscle strength
- History of frequent breakage

interim restoration with adequately adapted intaglio surface.¹² Excessive space between the restoration and the tooth places greater compressive, tensile, and shear forces on the luting agent, which has lower strength than regular cement and thus fractures under 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 at an optimal thickness, it does not break upon removal.

Diagnostic Requirements

Changes to functional and interarch relationships can be evaluated with interim restorations. These changes can be in the form of alterations to the occlusal plane, anterior guidance, discclusion pattern, treatment position, functional patterns, and occlusal vertical dimension. This is especially important for the wear patient or those with multiple restorative procedures that have severely altered tooth anatomy. Interim restorations are based on a diagnostic waxing after appropriate clinical records have been made. The patient is then allowed to "test drive" the new occlusion, and both the clinician and patient can decide when it is time to move toward definitive restorations. Interim crowns that continually break or decement will tell the clinician that (1) occlusion is not correct or, at least, not compatible with the patient's functional and parafunctional movements or (2) the resistance/retention form of the tooth preparations is inadequate.

Esthetic Requirements

The appearance of an interim fixed restoration is particularly important in the esthetic zone. 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,¹³ 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 esthetic zone 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. A correctly contoured 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 can also be done with a chair-side intraoral scanner. This process is most efficient when it begins with a manual or digital diagnostic waxing procedure. Involving the patient in decision making increases the patient's satisfaction.

Ideal Properties

The characteristics of an ideal interim material are many,¹ and some are listed 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



Fig. 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.

Currently Available Materials

As yet, an ideal interim material has not been developed, although preformed blocks or pucks for the digital techniques come close.¹⁴ However, this incurs additional costs and requires specific armamentarium. A major problem for the autopolymerizing materials still to be solved is dimensional change during solidification. These materials (Fig. 15.11) shrink and cause marginal discrepancy,^{15,16} especially when the direct technique is used (Fig. 15.12). In addition, the powder-liquid resins currently used are exothermic and not entirely biocompatible.¹⁷ The computer-aided design/computer-aided manufacturing (CAD-CAM) materials offer superior internal adaptation, marginal fit, and improved flexural strength.^{13,18} However, in-office mills often require an additional software program 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.

The currently available materials¹ can be divided into four resin groups for either conventional or digital techniques:

- PMMA
- Poly-R' methacrylate^a
- Bis-acryl (bisphenol A-glycidyl methacrylate [bis-GMA] resin)
- Light-polymerized resin

The properties of these resins are compared in Table 15.2. 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^{19,20} 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 autopolymerizing interim materials may interfere with the polymerizing of polyvinyl siloxane elastomeric impression materials.²¹ Although the tooth preparation can be cleaned with 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.

Materials and Forms

The most common materials currently in use for chairside and CAD-CAM fabrication of interim restorations are PMMA or poly-R' methacrylate resins, bis-acryl, or light polymerized resin. Currently, bis-acrylics are the most popular for chairside fabrication and prepolymerized PMMA is the most popular for CAD-CAM fabrication. No matter which materials are used, their physical properties allow them to be used for both lining procedures of preformed crowns and as the interim crown material itself. In addition, a wide array of procedures involving a variety of materials are available to make satisfactory interim restorations (Fig. 15.13). Techniques can be categorized as conventional, digital, or a combination of conventional and digital. The conventional technique requires that a template be formed into which a plastic or unset material is expressed, poured, or packed. Furthermore, the template is created by two correlated parts: one forming the external contour of the crown or FPD, the other forming the prepared tooth surfaces and (when present) the edentulous ridge contact area. The terms *external surface form* (ESF) and *preparation surface*

^a The R' represents an alkyl group larger than methyl (e.g., ethyl or isobutyl).



Fig. 15.11 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.)

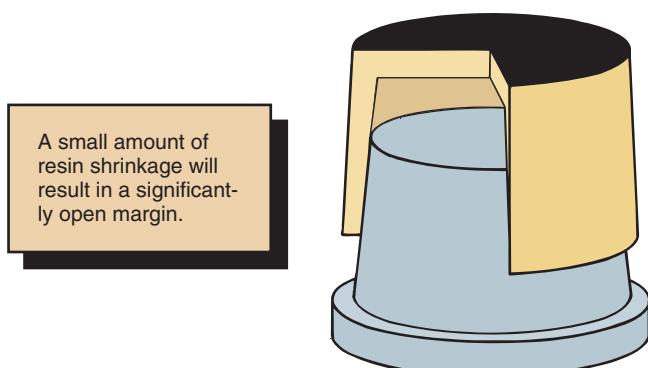


Fig. 15.12 With ideal axial wall convergence, a 2% reduction in crown diameter results in a comparatively high marginal discrepancy.

form (PSF) are suggested for these parts. These terms are used in the ensuing discussions.

External Surface Form

There are two general categories of ESFs: customized template and preformed.

Custom

A custom template ESF is a negative reproduction of either the patient's teeth before preparation or a diagnostic cast that has been modified with a manual or digital waxing. The most common materials for this application are irreversible hydrocolloid, addition silicone (heavy body or putty), and thermoplastic sheets. Impressions made in a quadrant tray with irreversible hydrocolloid or addition 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. In addition, this preoperative impression can be sent to the dental laboratory, providing an excellent guide for axial tooth contours. 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. 15.14). The moldable putty (silicone) materials are popular because they can be used without a tray and are easily trimmed to minimum size with a sharp knife or even digitally printed. In addition, their flexibility facilitates subsequent removal of the polymerized resin (Fig. 15.15).

TABLE 15.2 Ranked Characteristics of Representative Provisional Restoration Resins

Material	CHARACTERISTIC													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Jet (PMMA)	2 ^a	2 ^b	3	1 ^c	1 ^b	3 ^b	1 ^d	2	1	1	2 ^e	1	3	1
Duralay (PMMA)	1 ^b	—	3	—	—	—	1	2	1	1	—	1	3	1
Trim (PR'MA)	2 ^b	1 ^b	2	3 ^c	—	3 ^b	2 ^b	3	1	1	3 ^e	1	2	1
Snap (PR'MA)	2 ^b	2 ^b	2	—	—	2 ^b	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
Prottemp Garant (bis-GMA composition)	1 ^a	1	1	2	2	1	2 ^b	3	2	2	1 ^e	2	1	2
Tuff-Temp (dual-polymerized, urethane)	1	1	1	3 ^f	—	1	2	3	1	2	1	2	2	2
Unifast LC (light-polymerized, PR'MA)	2 ^a	2 ^b	3	—	—	2 ^b	2	1	3	1	—	2	3	2
Triad (light-polymerized, urethane DMA composition)	2 ^d	3 ^b	1	1	1 ^b	1 ^b	3 ^b	1	3	3	—	3	1	3
CAD-CAM Materials	1 ⁱ	1	1	1 ^j	2 ⁱ	1	1	1	1	1	1	3	1	3

^aSource of data: Tjan AHL, et al. Marginal fidelity of crowns fabricated from six proprietary provisional materials. *J Prosthet Dent.* 1997;77:482.

^bSource of data: Wang RL, et al. A comparison of resins for fabricating provisional fixed restorations. *Int J Prosthodont.* 1989;2:173.

^cSource of data: Gegauff AG, Pryor HG. Fracture toughness of provisional resins for fixed prosthodontics. *J Prosthet Dent.* 1987;58:23.

^dSource of data: Koumjian JH, Holmes JB. Marginal accuracy of provisional restorative materials. *J Prosthet Dent.* 1990;63:639.

^eSource of data: Gegauff AG, Rosenstiel SF. Effect of provisional luting agents on provisional resin additions. *Quintessence Int.* 1987;18:841.

^fSource of data: Kerby RE, et al. Mechanical properties of urethane and bis-acryl interim resin materials. *J Prosthet Dent.* 2013;110:21.

^gSource of data: Castelnuovo J, Tjan AH. Temperature rise in pulpal chamber during fabrication of provisional resinous crowns. *J Prosthet Dent.* 1997;78:441.

^hSource of data: Doray PG, et al. Accelerated aging affects color stability of provisional restorative materials. *J Prosthodont.* 1997;6:183.

ⁱSource of data: Peng C-C, et al. Assessment of the internal fit and marginal integrity of interim crowns made by different manufacturing methods. *J Prosthet Dent.* 2020;123:514-522.

^jSource of data: Yao J, Li 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.* 2014;112:649.

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.

A customized template ESF can also 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. 15.16). 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 on the prepared tooth or teeth, and fully seated as the patient lightly closes the jaws into maximum intercuspsation. Little additional effort is then required to adjust the occlusal contacts. However, the thinness of the material may also be a disadvantage in the direct technique. The material is a poor dissipater of the heat released during resin polymerization, and so if autopolymerizing PMMA resin is being used, care must be taken to remove it from the mouth before potential thermal injury can occur. This is generally

not a problem with a bis-acryl resin. A thermoplastic ESF has other uses in fixed prosthodontic treatment, in both the clinical and the laboratory phase; for example, if well made it can be helpful in evaluating the adequacy of tooth reduction (Fig. 15.17).^{22,23}

Transparent sheets are available in cellulose acetate or polypropylene of various sizes, shapes, and thicknesses; a 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



Fig. 15.13 Although there are many variations, molds used in making interim restorations consist of an external surface form (ESF) and a tissue surface form (PSF). Direct techniques entail use of the patient's mouth directly as the PSF. (A) Indirect technique: ESF is an alginate impression; PSF, a quick-set plaster cast. (B) Direct technique: ESF is a baseplate wax impression; PSF, the patient. (C) Direct technique: ESF is a vacuum-formed acetate sheet; PSF, the patient. (D) Direct technique: ESF is a polycarbonate preformed shell; PSF, the patient. (E) Indirect-direct technique: ESF is a custom preformed three-unit fixed partial denture shell (maxillary right central incisor to canine) made indirectly; PSF, the patient. (F) Indirect technique: ESF is a silicone putty impression; PSF, a quick-set plaster cast of the preparations.

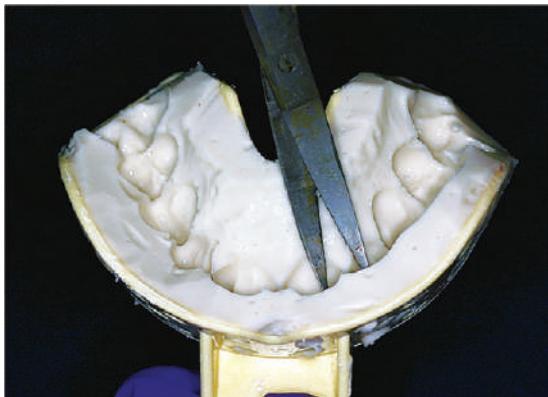


Fig. 15.14 Shortening proximal projections of the impression material facilitates complete reseating of the external surface form. Note that excess impression material palatally and facially has been trimmed away with a sharp knife for this reason. The anterior sextant tray shown was selected because it adequately captures the teeth adjacent to the proposed interim restoration.

because it is convenient and economical (see Fig. 15.13B), although it is usually not adapted easily with a high degree of precision; additional adjustment time is required.

Preformed

Various preformed crowns are available that use generic tooth forms, or they can be digitally designed and produced to be compatible with the existing occlusion. The preformed generic tooth forms must be modified for the opposing occlusion, which may induce minor occlusal changes. The generic preformed variety rarely satisfies 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. The digitally designed and produced "shell" type (CAD-CAM) are usually part of a well-thought-out treatment plan, and they too must be lined for a custom fit to the prepared tooth or teeth. Most crown forms need some modification (internal relief, venting, axial recontouring, occlusal adjustment) in addition to



Fig. 15.15 (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.



Fig. 15.16 (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. (E) Automated positive pressure thermal forming machine (Great Lakes Dental Technologies).

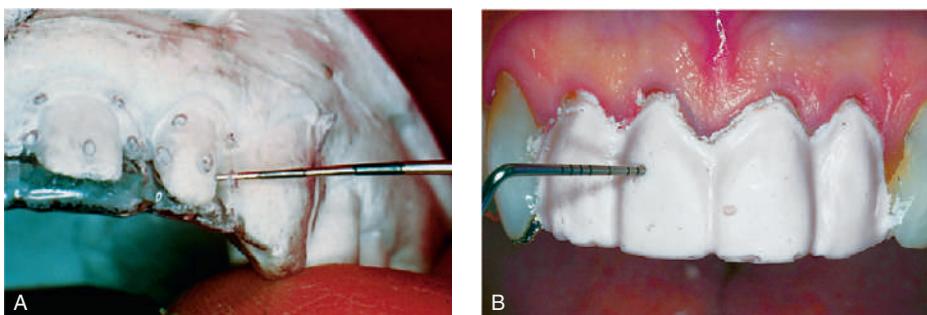


Fig. 15.17 (A) The thinness and transparency of these external surface forms (ESFs) allow their use directly as tooth-reduction guides both in and out of the mouth. (B) The dentist may assess tooth reduction by using the ESF to mold alginate over the prepared tooth. When the alginate is set, the ESF is removed, and a periodontal probe is pushed through the alginate for measurements at desired locations. (B, Courtesy Dr. T. Roongruangphol.)



Fig. 15.18 (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.

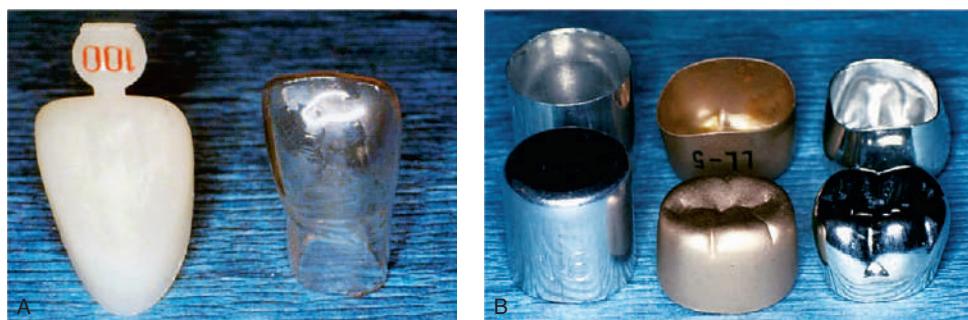


Fig. 15.19 (A) Preformed anterior crown forms: polycarbonate (left) and cellulose acetate (right). (B) Preformed posterior crown forms: aluminum shell (left), aluminum anatomic (center), and tin-silver anatomic (right).

the lining procedure (Fig. 15.18). When extensive modification is required, a customized or digitally designed ESF is superior because it is less time consuming. Generic preformed crowns are limited to use as single restorations because it is not feasible to use them as pontics for FPDs.

Materials from which generic preformed ESFs are made (Fig. 15.19) include polycarbonate, cellulose acetate, aluminum, tin-silver, and nickel-chromium. These are available in a variety of tooth types and sizes and can be purchased in a kit (Table 15.3).

Polycarbonate. Polycarbonate (Fig. 15.20) has the most natural appearance of all the generic preformed materials. When properly selected and modified, it rivals a well-executed porcelain restoration in appearance. Although it is available only in 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.

Cellulose acetate. Cellulose acetate is a thin (0.2- to 0.3-mm), transparent material available in all tooth types and a range

TABLE 15.3 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 ^a	X ^a	X	X	5	7.17	

^aPrimary teeth.



Fig. 15.20 Polycarbonate crowns. They are available in maxillary and mandibular incisor, canine, and premolar shapes.

of sizes (see Fig. 15.19A). 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 occlusal and proximal contacts.

Aluminum and tin-silver. Aluminum (Fig. 15.21) and tin-silver are suitable for posterior teeth. The most elaborate crown forms have anatomically shaped occlusal and axial surfaces.



Fig. 15.21 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.

The most basic and least expensive forms are merely cylindrical shells resembling a tin can (see Fig. 15.19B).

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 finish line 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 (see Fig. 15.19B). However, 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 finish lines are used. For other finish line designs, cervical enlargement should be performed indirectly on a swaging block, which should be supplied with the crown kit.

Stainless steel. Stainless steel shells (Fig. 15.22) 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.

CAD-CAM PMMA or composite resin. CAD-CAM crowns can also be preformed and then lined at chair side. Materials are available in either block or puck form, or in light polymerizing liquid form, depending on the type of milling machine or printer used in its fabrication. These crowns or FPDs can be milled in a shell form (preformed) that must be lined on the prepared. One of the interesting things about these materials is that restorations can be produced in either monochromatic blocks or pucks or produced in a multilayered form with different levels of chroma from gingival to incisal for a more lifelike-looking restoration (Fig. 15.23A and B). The improved physical properties of these materials allow for an extended time of use, which is particularly helpful when treating complex oral rehabilitation patients in which the clinician would like to “test drive” an occlusal scheme, alter the occlusal vertical dimension,

or develop proper crown form to facilitate orthodontic treatment. 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 blocks 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 interim restoration, so that delamination, separation, or leakage does not occur between the milled material and the relining material.

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, 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. In addition, if the polymerization process is not properly initiated or if it is prematurely terminated, the resultant restoration may



Fig. 15.22 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.

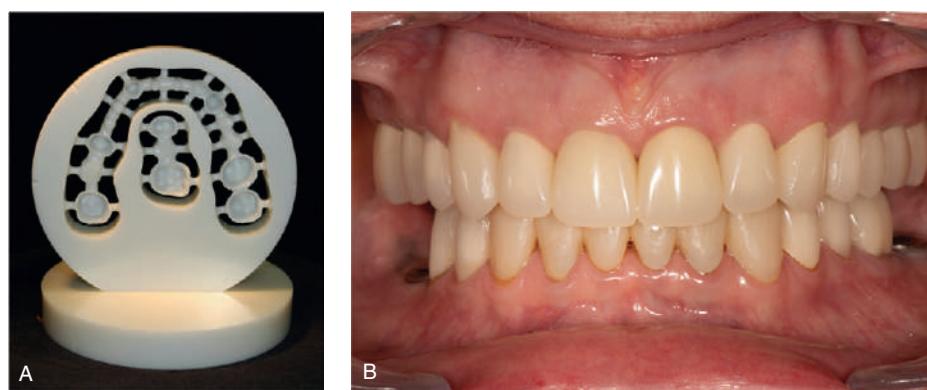


Fig. 15.23 (A) Computer-aided design/computer-aided manufacturing (CAD-CAM) interim restorations milled from resin disk. (B) Polymethyl methacrylate multilayered CAD-CAM interim crowns. (Courtesy of Dr. Pakwan Varapongsittikul.)

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 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.

Benzoyl peroxide decomposes to free radicals at approximately 50°C or greater 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. In addition, 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 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 15.2.

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.

TECHNIQUES AND PROCEDURES

Conventional techniques and procedures have been standardized for many years, and these have served the profession and patients well. However, digital technology is now such an integral part of modern dentistry that techniques and procedures

related to interim restorations have been adopted. Although CAD-CAM technology has obviated the need for interim restorations in many cases because definitive restorations can be immediately fabricated, not all clinical situations are amenable to treatment with same-day CAD-CAM 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 dentist and patient can now evaluate comfort, function, and appearance before the fabrication of the definitive restorations.

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.²⁴ 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.¹⁸ 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. 15.24).

Preparation Surface Form

There are two primary categories of PSFs: *indirect* (impression required for lab procedure) and *direct* (intraoral procedure). A third category, *indirect-direct*, is the sequential application of these. All procedures typically require either a lining procedure or remargination procedure because of the limitations of the materials involved. In addition, all three procedures can be accomplished with a conventional or digital workflow. One of the most important aspects of interim crown fabrication, regardless of technique, is access to the finish lines of the preparation(s). If these are not visible or accessible, the restorations will not provide the pulpal or periodontal protection required of an interim prosthesis. In most instances, displacement cord is necessary for proper exposure of the tooth preparation finish line.

Indirect Procedure

An impression is made of the prepared teeth and ridge tissue and is poured in quick-setting gypsum or polyvinyl siloxane.²⁵ The interim restorations are fabricated outside the mouth and can be fabricated from PMMA or poly-R' methacrylate, bis-acryl composite resin, or light polymerized composite resin. This technique (Table 15.4) has several advantages and disadvantages over the direct procedure and are material related. If using autopolymerizing PMMA or poly-R' methacrylate, contact of free monomer with the tooth preparation(s) or gingiva may cause damage¹⁵ and an allergic reaction or sensitization.^{26–28} One group of investigators²⁸ reported a 20% incidence of allergic sensitivity in patients previously exposed to a monomer patch test. Sensitization may be related to frequency of exposure; in allergic patients, exposure to even small amounts of monomer usually causes painful ulceration and stomatitis (Fig. 15.25). Material choice is also relevant in terms of heat production during polymerization. Bis-acryl resin produces much less heat than PMMA. In vitro studies^{29–31} have shown peak temperature increases of approximately 10°C in the pulp chambers of prepared teeth upon which direct PMMA interim restorations were made (Fig. 15.26). That amount of temperature elevation is capable of causing irreversible damage to the pulp.³² 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, peak temperatures were not reached until 7 to 9 minutes had elapsed (Fig. 15.27).³⁰ 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 Fig. 15.27, the temperature rise is negligible at 3 minutes,

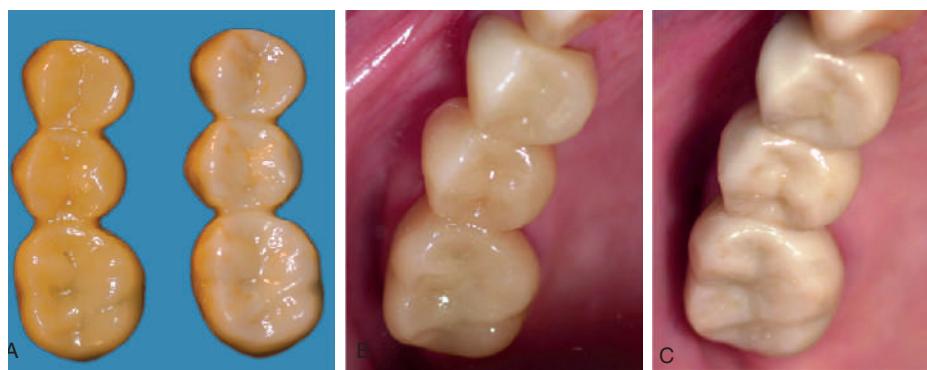


Fig. 15.24 (A) Maxillary three-unit fixed partial denture (FPD) milled from polymethyl methacrylate as an interim (*left*) and the definitive restoration fabricated from monolithic zirconia (*right*). (B) The interim restoration used during the healing of a dental implant in the opposing arch. (C) The definitive zirconia FPD.

which suggests that thermal injury is easily avoidable. 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.^{33,34} This is because (1) the stone 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 FPDs are likely to have unacceptable marginal discrepancies caused by shrinkage and distortion and must be remargined.³⁵

Direct Procedure

The patient's prepared teeth and gingival tissues (in the case of an FPD) directly provide the PSF, and so the intermediate steps

of the indirect technique are eliminated (see Table 15.4). The direct technique has significant advantages and disadvantages. Advantages include using fewer materials, which improves efficiency, and perhaps better fit depending on the accuracy of materials used in the indirect technique. Disadvantages are material dependent. When using autopolymerizing PMMA or poly-R' methacrylate, there is potential tissue trauma from the polymerizing resin and inherently poorer marginal fit. Bis-acryl resins shrink less and produce less heat but may not provide the flexural strength of a PMMA. However, most materials that undergo a polymerization process have some degree of shrinkage and normally require a reline to optimize marginal adaptation.

The digital workflow for the direct procedure incorporates a digital scan of the prepared teeth and an occlusal record.

TABLE 15.4 Summary of Techniques Used to Fabricate Interim Crowns

Technique	Preparation Surface Form	External Surface Form	Advantages	Disadvantages
Direct	Tooth preparation itself	Custom or preformed	<ul style="list-style-type: none"> 1. Quick 2. Easy 3. No laboratory work needed 	<ul style="list-style-type: none"> 1. Free monomer (PMMA) 2. Heat production (PMMA) 3. Margin inaccuracy
Indirect	Analog of tooth preparation	Custom or digital	<ul style="list-style-type: none"> 1. Easy on tissues 2. No polymerization shrinkage 3. Marginal accuracy 	<ul style="list-style-type: none"> 1. Time consuming 2. Increased costs
Indirect/direct combination	Diagnostic preparation	Custom or digital	<ul style="list-style-type: none"> 1. Easy on tissues 2. Efficient 	<ul style="list-style-type: none"> 1. Prior preparation is estimate; internal adjustment may be needed before relining
Digital	Scan of tooth preparation	Custom digital form	<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> 1. Digital impression and in-office mill needed 2. Some blanks are monochromatic 3. Increased costs

PMMA, Polymethyl methacrylate.



Fig. 15.25 Allergic reactions after brief exposure to polymethyl methacrylate (PMMA) monomer. (A) Labial ulcerations. (B) Gingival ulcerations. (C) Adverse tissue reaction to contact with PMMA interim pontics 6 days after placement.

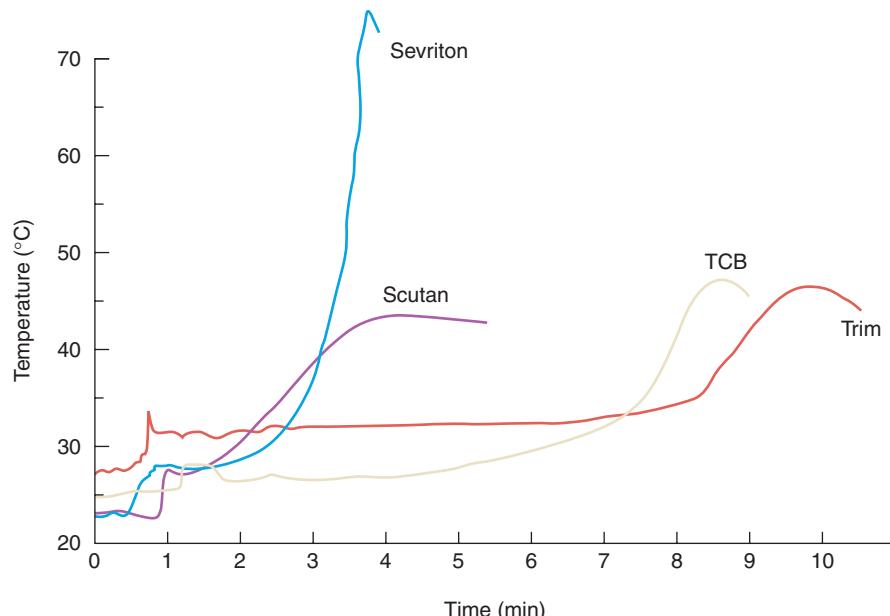


Fig. 15.26 Heat generated during resin polymerization. Under nonclinical experimental conditions, the temperature rises are severe. Sevrilon (a polymethyl methacrylate resin) produced significantly higher temperatures than did the others represented. This is useful information for selecting resins to be used intraorally, although under clinical conditions the differences may be insignificant. *TCB*, Temporary crown and bridge. (Redrawn from Braden M, Clarke RL, et al. A new temporary crown and bridge resin. *Br Dent J*. 1976;141:269.)

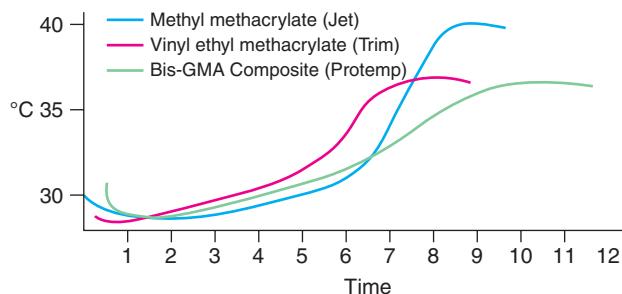


Fig. 15.27 These exotherms (time in minutes) are derived from a simulated clinical procedure for making a single crown with silicone putty as the external surface form (ESF). A thermocouple probe in the pulp chamber of an extracted tooth was used to measure temperature changes. Initial readings reflect 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, Grant BE, et al. Temperature rise in the pulp chamber during fabrication of provisional crowns. *J Prosthet Dent*. 1989;62:622.)

The software program is then used to propose the crown form and material, check the occlusion and interproximal contacts, and mill out the restoration.

Indirect-Direct Procedure

In this technique (see Table 15.4), the indirect component produces a “custom-made preformed ESF” from an analog or digital

waxing. The tooth or teeth can then be intentionally underprepared on a diagnostic cast (analog) or a digital file with a software program designed to produce “shell temporaries.” The thickness of the shell is controlled by how much is intentionally underprepared on the diagnostic cast or that parameter can be set in the software program. The analog or digital tooth preparation then becomes the temporary PSF. The direct component of the procedure is to line the shell intraorally after tooth preparation for a custom fit.

The indirect-direct approach certainly reduces chair time but increases laboratory time for someone in the office. Other advantages are material dependent. If PMMA or poly-R' methacrylate is used, the volume of resin is reduced, thereby minimizing heat production from the exothermic reaction. If an FPD is being fabricated, there will be no contact of monomer with the soft tissue in the pontic(s), thereby reducing the risk of allergic reaction. Disadvantages are increased lab costs and the potential that it may take some time to obtain adequate seating of the restoration before the lining procedure.

PROCEDURES

The basic clinical armamentarium (Fig. 15.28) and the basic laboratory armamentarium (Fig. 15.29) 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. It is also important to note that for the conventional techniques, only the two most common materials (autopolymerizing PMMA and bis-acryl) will be discussed. The digital workflow

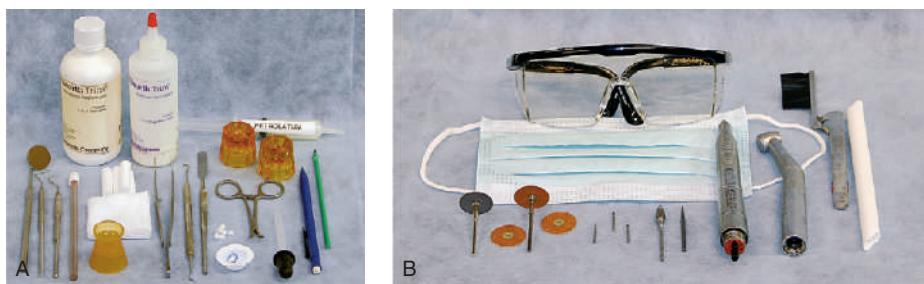


Fig. 15.28 (A and B) Basic clinical armamentarium for interim fixed prostheses.

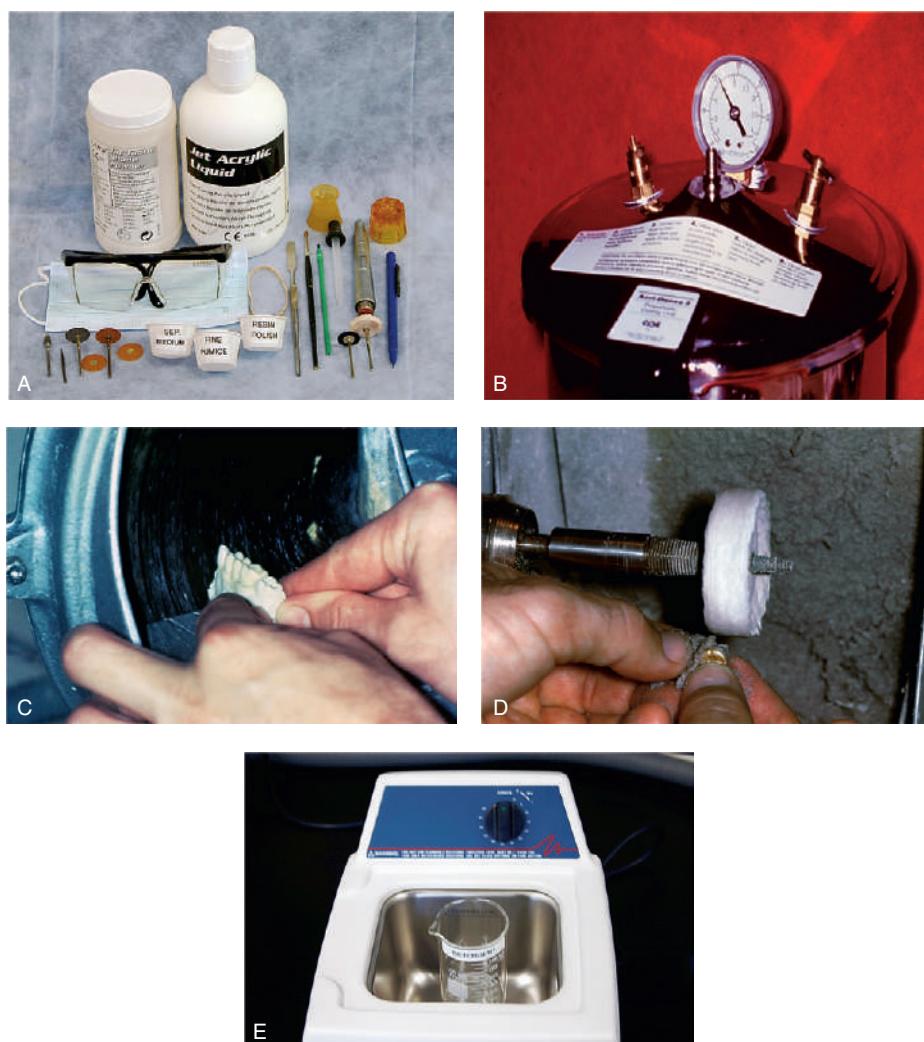


Fig. 15.29 Basic laboratory armamentarium for interim fixed prostheses. (A) Assorted small items appearing on the accompanying list (see text). (B) Pressure-polymerization vessel. (C) Cast trimmer. (D) Dental lathe and dust collector. (E) Ultrasonic cleaner and liquid detergent.

also incorporates prepolymerized materials, with PMMA being the most commonly used at this time.

Basic Clinical Armamentarium

- Gloves
- Face mask
- Protective eyewear
- Mouth mirror
- Explorer
- Periodontal probe
- Saliva evacuator
- Cotton rolls
- Gauze squares
- Gingival displacement cord

- Astringent solution
- Cotton-roll pliers
- Plastic filling instrument
- Cotton pellets
- Petrolatum or water-soluble lubricant
- Interim material
 - Flowable composite resin
 - Light polymerization unit
- Dropper
- Two dappen dishes
 - Automix delivery system and mixing tip
- Cement spatula
- Backhaus towel clamp forceps
- Straight slow-speed handpiece
- Carborundum disks with mandrels, latch type handpiece (PMMA)
- Fine garnet paper disks ($\frac{1}{8}$ -inch diameter) with mandrels, latch-type handpiece (PMMA)
 - Coated abrasive disks with mandrels (bis-acryl)
- 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
- Gypsum-resin separating medium
- Interim material
 - Flowable composite resin
 - Light polymerizing unit
- Dropper
 - Automix delivery system and mixing tip
- 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 ($\frac{1}{8}$ -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 or paste
- Ultrasonic cleaner with detergent solution

Interim Fixed Partial Dentures: Custom Indirect Method

The custom indirect procedure is probably the best overall technique for FPDs and should provide the most predictable results; however, directly fabricated 3-unit FPDs are acceptable.

Additions to Clinical Armamentarium

- Shade guide (should be custom made, material specific)
- Irreversible hydrocolloid impression material (regular or fast set)
- Rubber bowl
- Impression tray
- Mixing spatula

Step-by-Step Procedure

1. After shade selection and tooth preparation, obtain an impression tray for an irreversible hydrocolloid impression and apply the corresponding adhesive. A sextant impression is adequate only if it extends one tooth beyond the abutments, and so the ESF will correspond accurately to the cast (PSF).
2. Displace the gingiva with cord, if necessary, to expose the cavosurface finish lines (Fig. 15.30).
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 or polyvinyl siloxane die material
- 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—known as slurry water).³⁶ Alternative methods include adding salt, mixing with lukewarm water, or using a commercially available quick-setting plaster.

1. Pour the quick-setting stone, plaster, or polyvinyl siloxane die material 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.
3. Paint the cast uniformly with separating medium (Fig. 15.31). 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 finish lines of the preparations with a soft lead pencil to serve as a guide for trimming later. This should not be done where the



Fig. 15.30 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 preparation surface form.



Fig. 15.32 A polymer syringe with a widened orifice (2 mm in diameter) is useful for filling the external surface form. 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.

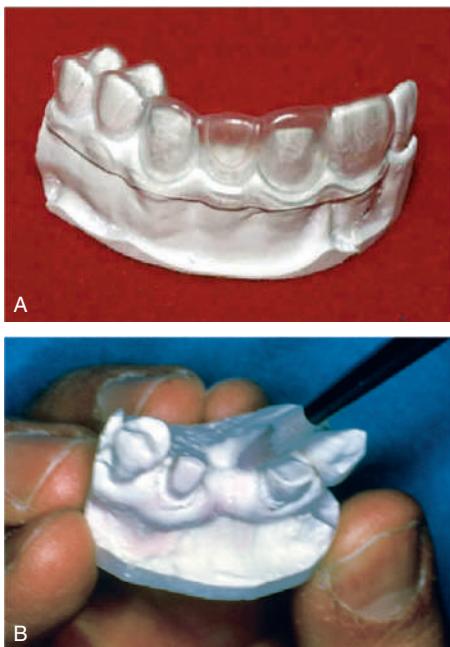


Fig. 15.31 (A) After trimming, the indirect preparation surface form (PSF) is fitted with the external surface form to verify accurate passive indexing. (B) With this accomplished, the forms are separated, and the PSF is completely coated with a resin-gypsum separating medium (brushed on).

finish lines are visible because the pencil marks are difficult to remove from the resin.

4. Make ready the material of choice. Mix autopolymerizing resin (e.g., methyl methacrylate), and load it into a polypropylene syringe. The orifice of the syringe tip should be approximately 2 to 3 mm in diameter. Attach a mixing tip to a bis-acryl cartridge, and load into its corresponding dispensing gun.
5. Fill the ESF methodically with the syringe or mixing tip, 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. 15.32).

6. Seat the PSF into the filled ESF (Fig. 15.33). They can be lightly held together by rubber bands. PMMA is placed in warm water (40°C [100°F]) in a pressure vessel, after which air is applied at approximately 0.15 MPa (20 pounds/square inch). Postpolymerizing heat treatment has been shown to improve physical properties,^{31,37} and pressure polymerization reduces resin porosity. Bis-acryl is allowed to bench set according to the manufacturer's instructions.
7. Remove the assembly after 5 minutes or according to the manufacturer's instructions.
8. Separate the ESF from the polymerized resin restoration, which usually remains in contact with the PSF (Fig. 15.34). The bulk of the stone can be removed on a cast trimmer and with a carborundum disk (Fig. 15.35). The restoration is easily removed from the polyvinyl siloxane die material, with no chance of damage to the resin. Usually, more effort is required to separate a stone or plaster PSF. If the finish lines were marked with lead, die-like remnants of the PSF should be retained for use as a guide to correct trimming.
9. Eliminate resin flash with an acrylic resin-trimming bur and a fine-grit garnet paper disk for PMMA or a high-speed tungsten carbide bur or diamond rotary instrument for bis-acryl, followed by coated abrasive disks.
10. Contour the pontic areas according to proper pontic design (Fig. 15.36) as described in Chapter 20. Often, a thin diamond disk is necessary to adequately contour the interproximal areas for form and hygiene access.
11. PMMA can be finished with wet pumice; however, bis-acryl is best finished with appropriate coated disks and polishers. The gingival surface of the pontic must be highly polished. 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.

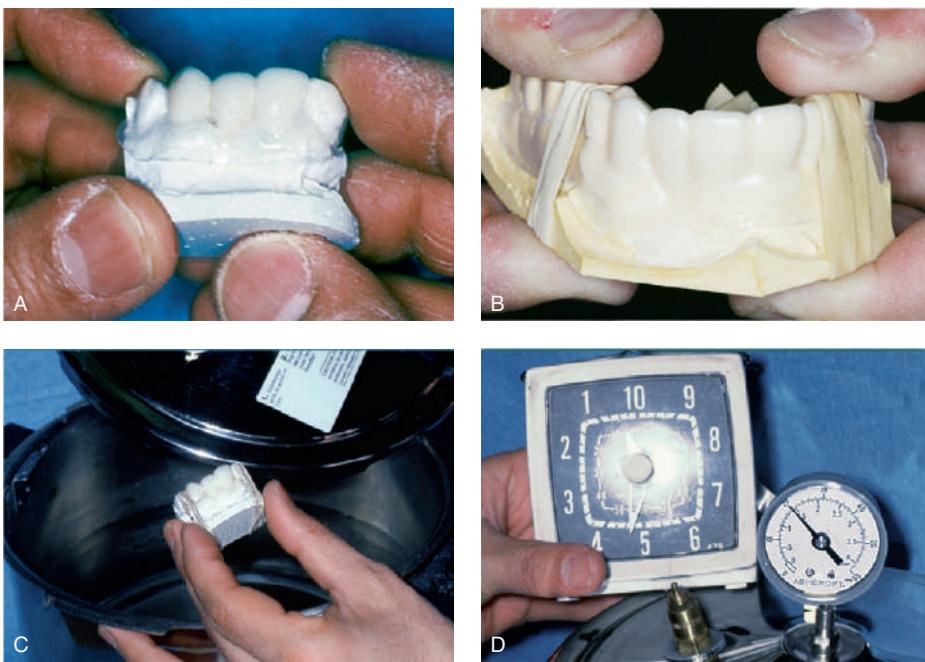


Fig. 15.33 (A) The resin-filled external surface form is seated on the preparation surface form. (B) Rubber bands are placed around the mold assembly and located over adjacent unprepared teeth. This avoids distorting the external surface form. (C) The assembly is placed into a pressure vessel filled with warm water. (D) The resin polymerizes for 5 minutes under 0.15 MPa (20 pounds/square inch) pressure.



Fig. 15.34 External surface form removed.

- Clean the restoration, using appropriate infection control procedures in preparation for clinical evaluation.

Interim Fixed Partial Dentures: Custom Direct Method

Step-by-Step Procedure

- After tooth preparation, displace the gingiva with cord, if necessary, to expose the cavosurface finish lines (see Fig. 15.30).
- Evaluate the ESF for complete seating on the nonprepared teeth.
- Make ready the material of choice. If using autopolymerizing PMMA or poly-R' methacrylate, mix the resin and load it

into a polypropylene syringe. The orifice of the syringe tip should be approximately 2 to 3 mm in diameter. If using bis-acryl, attach a mixing tip to the cartridge and load it into its corresponding dispensing gun.

- Fill the ESF methodically with the syringe or mixing tip, starting at one end of the restoration space and working to the other. To avoid trapping air, keep the syringe or mixing tip in constant contact with the resin. The mold should not be overfilled; the resin should just reach the level of the gingiva (see Fig. 15.32).
- Seat the ESF onto the prepared tooth or teeth, and hold to the correct position. The preparation can be lightly coated with water-soluble lubricant if desired, but normally the patient's saliva acts as enough of a lubricant to separate the ESF. Undercuts in adjacent teeth can be blocked out with an intraoral putty.
- When the rubbery stage of polymerization is reached (approximately 2 minutes in the mouth for PMMA resin), 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 FPD 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. Always follow manufacturer's instructions on when to remove from the tooth preparations. This is particularly true with a bis-acryl because formulations may have unique working and setting times.

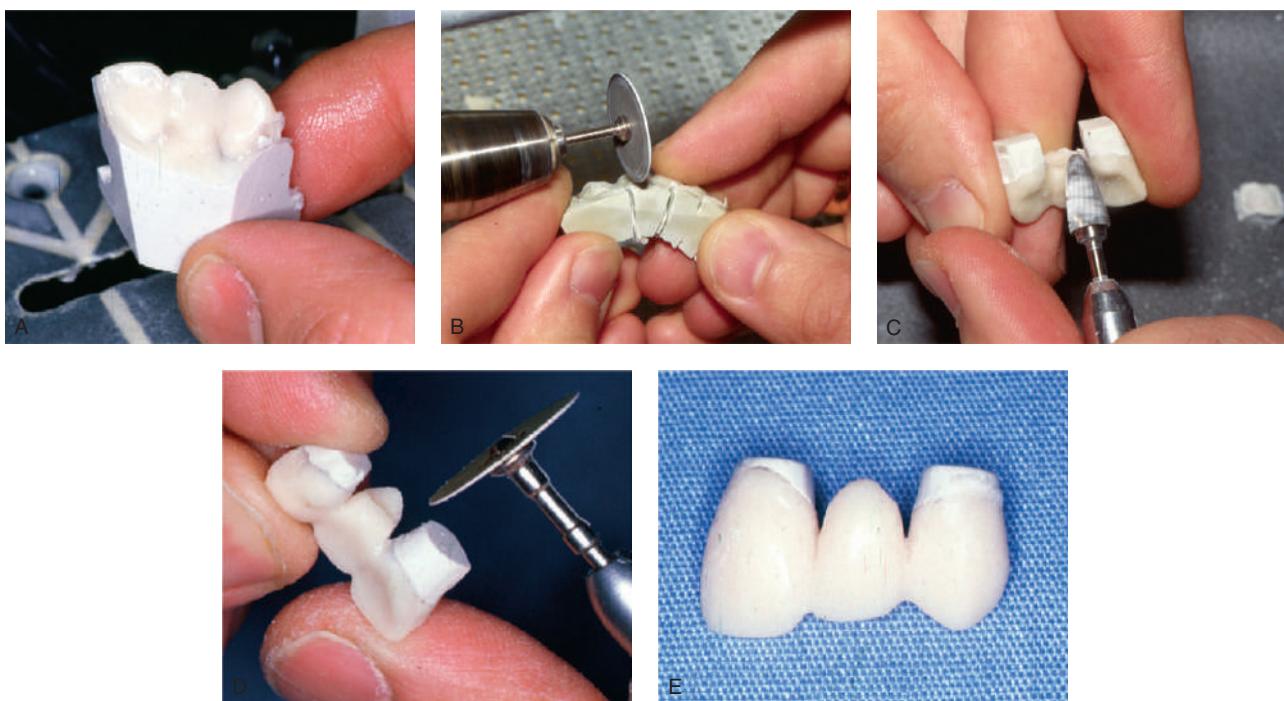


Fig. 15.35 The preparation surface form is reduced to attain the final shape of the restoration. (A) Bulk reduction on a cast trimmer. (B) Sectioning and removal of pontic-contact areas with a carborundum disk. (C) Linguogingival surface of the pontic shaped with a tapered bur. (D) An abrasive disk ($\frac{1}{8}$ -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.



Fig. 15.36 The restoration before clinical evaluation.

7. Place the interim restoration in warm water (37°C) to hasten polymerization for PMMA. This step is not necessary for bis-acryl.
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 for PMMA resin (Fig. 15.37). A high-speed tungsten carbide bur works well for bis-acryl resin. Use a fine-grit garnet paper disk or coated disks to complete axial shaping.

Evaluation

The interim FPD 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 be corrected by the addition of resin through the brush-bead technique for PMMA

or flowable composite resin for bis-acryl (Fig. 15.38A and B; see Fig. 15.72). When using flowable composite resin, the contaminated surfaces must be first cleaned with phosphoric acid for 15 seconds and thoroughly air-dried. Unfilled resin is then applied and light polymerized. The tooth preparation finish line is coated with a thin film of petrolatum or water-soluble lubricant. Flowable resin is applied to the finish line of the preparation, and the crown or FPD is seated on the tooth. A brush is then used to brush the flowable resin onto the external surface of the crown and then light (see Fig. 15.38C).

Unacceptable marginal fit can always be corrected (see "Interim Fixed Partial Dentures: Custom Indirect-Direct Method," Clinical steps 3 to 8 of "Step-by-Step Procedure"). If using PMMA resin, make sure 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. 15.39). Adequate intraoral evacuation and eye protection are essential.

After using appropriate infection control procedures, PMMA restorations must return to the laboratory for wet pumice finishing and dry polishing with resin-polishing compound. If access to the gingival surfaces of the pontics is restricted, a $\frac{3}{4}$ -inch-diameter felt wheel can be used for polishing. Bis-acryl interim restorations can be polished adequately at chair side using appropriate coated disks and polishing paste.

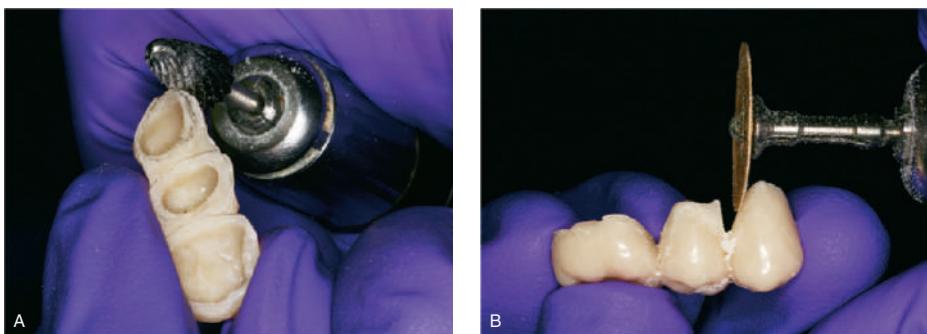


Fig. 15.37 Removal of excess after the lining resin hardens. (A) Gross resin excess is quickly removed. (Margins must be avoided.) (B) The final axial contours, connectors, and marginal fit are perfected with an abrasive disk rotating toward the margin to prevent debris from obscuring the margin. Note the orientation of the disk, parallel to the desired final contour.



Fig. 15.38 (A) Flowable resin is used to improve adaptation to a finish line. (B) Flowable resin fully covers the finish line. (C) After seating the interim crown, flowable resin is brushed on all surfaces of the restoration before light polymerization.



Fig. 15.39 Intraoral adjustment of occlusal contacts.

Interim Fixed Partial Denture: 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. 15.40):

- Diagnostic PSF (duplicate of conservatively prepared diagnostic cast)
- ESF (vacuum-formed polypropylene sheet)
- Original diagnostically prepared cast mounted on an articulator
 - Chairside intraoral scanner to produce a standard tessellation language (STL) file of the scanned arch or a



Fig. 15.40 Additions to the basic laboratory armamentarium for the indirect-direct procedure: the diagnostic preparation surface form and the polypropylene external surface form.

scanned diagnostic cast imported into a dental management software program

- Articulating ribbon

Step-by-Step Procedure

The standardized conventional method can be modified to a digital workflow. This will be described in conjunction with the conventional method. The basic idea is the same: produce a preformed ESF (shell crown or FPD) that can be lined intraorally.

1. Prepare the abutment teeth on articulator-mounted diagnostic casts (Fig. 15.41). 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. If this process is being done with a digital workflow, the software program can be instructed to “prepare the tooth or teeth” to a particular depth. A crown or FPD form is then produced by the software program (which can be modified if necessary) and the occlusion and interproximal contacts perfected. The information is relayed to a milling machine, and the crown(s) is/are milled from an appropriately selected interim material. Prepolymerized PMMA is an often-used material because of its superior physical properties. After appropriate disinfection, these crowns are then ready for intraoral lining to the prepared tooth or teeth.

2. For the conventional technique, make an irreversible hydrocolloid impression of the diagnostic preparations to duplicate them in stone (Fig. 15.42).
3. Apply separating material to the PSF.
4. Perform a diagnostic waxing procedure on the articulated casts. This step is often recommended in the treatment planning phase as well. A silicone ESF is made from the diagnostically waxed cast. However, 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. 15.43).

5. Check that the ESFs and PSFs fit together accurately (Fig. 15.44).
6. Using a syringe (PMMA) or the automix delivery system (bis-acryl), apply the resin into the ESF, and complete the interim restoration as described in the preceding section (see Figs. 15.32–15.36).
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. Remember that diagnostic casts made from alginate are subject to elastic deformation, so adjustment time is expected.
8. Finish and clean the preformed ESF for clinical evaluation, which follows tooth preparation (Fig. 15.45).

Addition to Clinical Armamentarium

- Custom preformed ESF



Fig. 15.41 Preparations involved in making the articulator-mounted diagnostic cast. (A) Conservative depth-orientation grooves. (B) Placement of supragingival cavosurface margins.



Fig. 15.42 The prepared cast is duplicated by means of an alginate impression. This creates the indirect tissue surface form. Quick-set plaster is used.

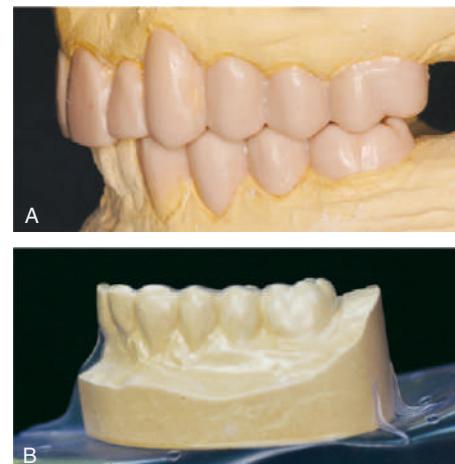


Fig. 15.43 Creating a custom external surface form (ESF) from a diagnostic waxing. (A) The diagnostically waxed articulated casts. Patterns should satisfy biologic, mechanical, and esthetic requirements. (B) If a thermoplastic ESF is desired, the completed waxing must be duplicated in stone.

Step-by-Step Procedure

1. Prepare the patient's teeth in the usual manner.
2. Try in the conventional or digitally fabricated preformed ESF (Fig. 15.46). 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-direkt 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. 15.47). Like materials produce the best results; however, when lining either a milled or heat-polymerized PMMA, the clinician can make the decision to

use either autopolymerizing PMMA or even a poly-R' methacrylate resin if there is potential for trauma to the tissue.

3. Apply a uniform coat of water-soluble separator on the prepared abutment teeth, gingival tissues, and outside of the ESF.



Fig. 15.45 The completed custom-preformed external surface form. This is the end product of the indirect component of the indirect-direkt technique.



Fig. 15.44 Proper relationship between the external surface form and the preparation surface form. If it is necessary to remove any cast artifacts to correct the relationship, this should be done before the separating medium is applied.



Fig. 15.46 The custom-preformed external surface form 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.



Fig. 15.47 Lining the custom-preformed external surface form. This is the direct component of the indirect-direkt technique. (A) Oral tissues are protected with petrolatum. (B) Vent holes help to 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.)

4. Make a vent hole with a round bur through the occlusal (or lingual) surface of each retainer. If the ESF is a bis-acryl resin, clean the intaglio surface by either airborne-particle abrasion or by applying phosphoric acid for 20 seconds and then rinsing and drying. Apply bonding agent, air thin, and use a polymerization light. If using MMA, wet a brush with liquid monomer and apply to the intaglio surface for 1 minute to prepare the surface to accept the additional material.
5. Fill the retainers with the interim material. If using MMA, seat the restoration after it loses its surface sheen. If using bis-acryl, seat immediately. 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 polymerizes.
6. When the rubbery stage of polymerization is reached (approximately 2 minutes in the mouth for MMA), 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 FPD 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. Always follow manufacturer's instructions on when to remove from the tooth preparations. This is particularly true with a bis-acryl because formulations may have unique parameters related to working and setting time.
7. Place the interim restoration in warm water (37°C) to hasten polymerization and improve the physical properties of PMMA. This step is not necessary for bis-acryl.
8. After 3 to 5 minutes, eliminate the excess resin. The bulk of it can be removed with an acrylic resin-trimming bur or

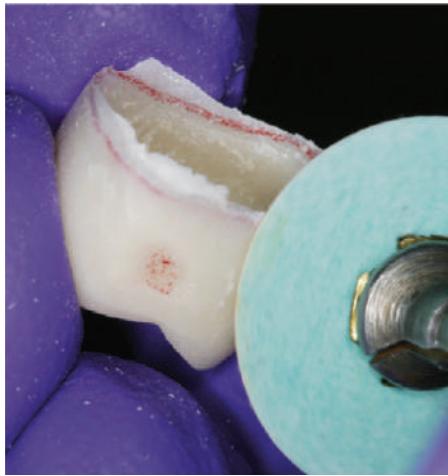


Fig. 15.48 Flash at the margin of a restoration whose axial surface was contoured with proper disk orientation. (Courtesy Dr. R.E. Kerby.)

carborundum disk for MMA (see Fig. 15.37). A high-speed tungsten carbide bur works well for bis-acryl. Use a fine-grit garnet paper disk or coated disks 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 finish line is fully covered. Often this flash can be easily peeled away from the margin with the fingers (Fig. 15.48).

The clinician then confirms the marginal fit and occlusion, refinishes and polishes where necessary, and cements the restoration (Fig. 15.49).

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 FPDs. Because pontics are not involved, creating an ESF is more straightforward. 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 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, particularly when a polyvinyl siloxane die material is used, because the interim restoration is easily removed.



Fig. 15.49 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.)

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)

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 or water-soluble lubricant 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. PMMA or bis-acryl resin can also be used.
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. 15.50).
7. Place the resin in a cup of warm water (37°C) for 5 minutes. This step is not necessary for bis-acryl resin.
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.



Fig. 15.50 A floss handle facilitates removal of an inlay resin interim restoration during late rubbery stage.

11. Clean and dry the cavity preparation, and place a thin coat of interim cement on the cavity walls. Immediately insert the interim restoration.
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.

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 or water-soluble lubricant to the prepared tooth surface.
3. Using a plastic instrument wetted with alcohol, form the pre-selected 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 PSF 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; a polyvinyl siloxane die material reduces the incidence of fracture of the interim restoration.
4. Photopolymerize the resin, and remove it from the tooth surface.
5. Thoroughly clean the petrolatum or water-soluble lubricant 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 distoincisor line angles and the third centered 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). However, such coincidences 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 measurement as a guide to trimming the shell so that it matches the approximate

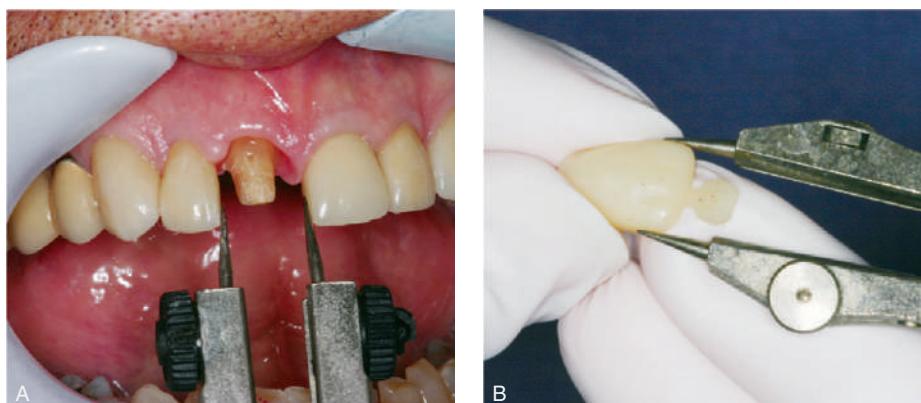


Fig. 15.51 Crown selection. (A) Measuring the mesiodistal width of the space with dividers. (B) Selecting the appropriate crown size for the measured space.

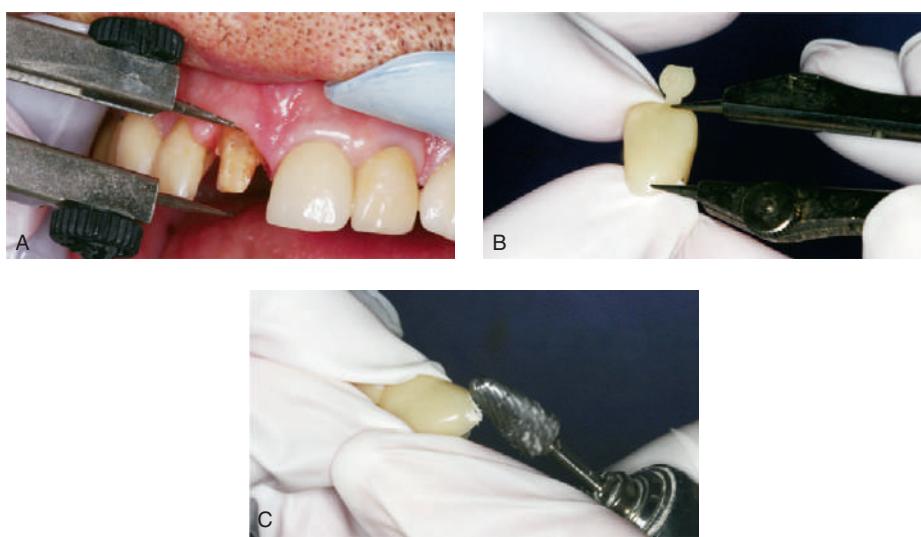


Fig. 15.52 Crown length adjustment. (A) Incisocervical height required for the completed restoration. (B) Measurement transferred to the crown. (C) Cervical portion of the crown adjusted to duplicate the curvature of the cavosurface margin.

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 or water-soluble lubricant 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 or PMMA 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.
7. When the rubbery stage of polymerization is reached (after approximately 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.
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).



Fig. 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.

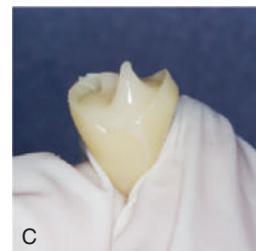
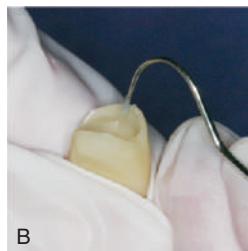


Fig. 15.54 Lining the adjusted shell. (A) Protection with petrolatum. The shell is filled with resin (B) and is seated (C) when the resin does not slump after a peak is formed with the tip of an explorer. (D) Excess resin is immediately removed after the crown has been positioned.

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 ($\frac{3}{8}$ -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 approximately 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.

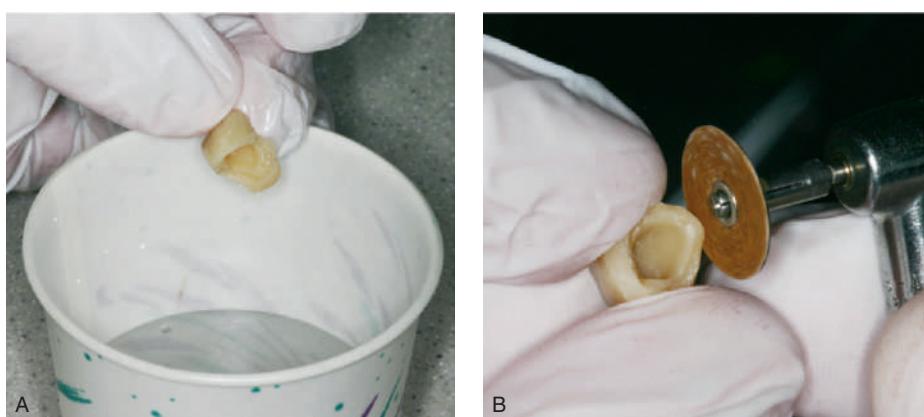


Fig. 15.55 (A) When the resin has reached the rubbery stage, the crown is removed and placed in warm water (40°C). Hot water must not be used because it increases resin shrinkage. However, warm water is not recommended for polymethyl methacrylate resin because excessive shrinkage makes the marginal fit unacceptable. (B) After approximately 5 minutes in warm water, the resin should be rigid enough for removal of the excess lining resin starting with a coarse garnet disk.

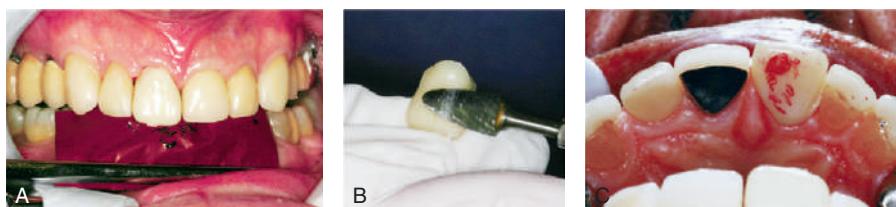


Fig. 15.56 (A) A considerable amount of lingual reduction may be needed. If only minor reduction is necessary, it can be accomplished intraorally. (B) To increase efficiency and ensure the patient's comfort, any bulk reduction should be accomplished extraorally. (C) Finalized lingual contour promotes 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.

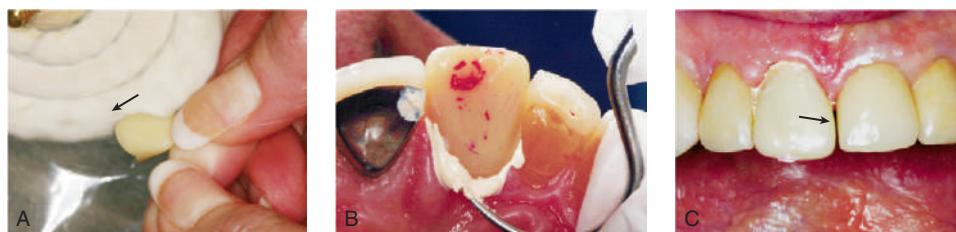


Fig. 15.57 (A) A rag wheel and pumice are used before polishing with compound. Note the parallel orientation of the wheel to the crown's axial surface at the point of contact (arrow). The crown should be positioned so that the wheel rotates from the surface toward the margin. (B) An explorer and dental 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.

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.
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 intercuspatation is reached (Fig. 15.61).



Fig. 15.58 Additions to the basic clinical armamentarium for aluminum crown forms.

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 supraocclusal 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.
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 approximately 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).

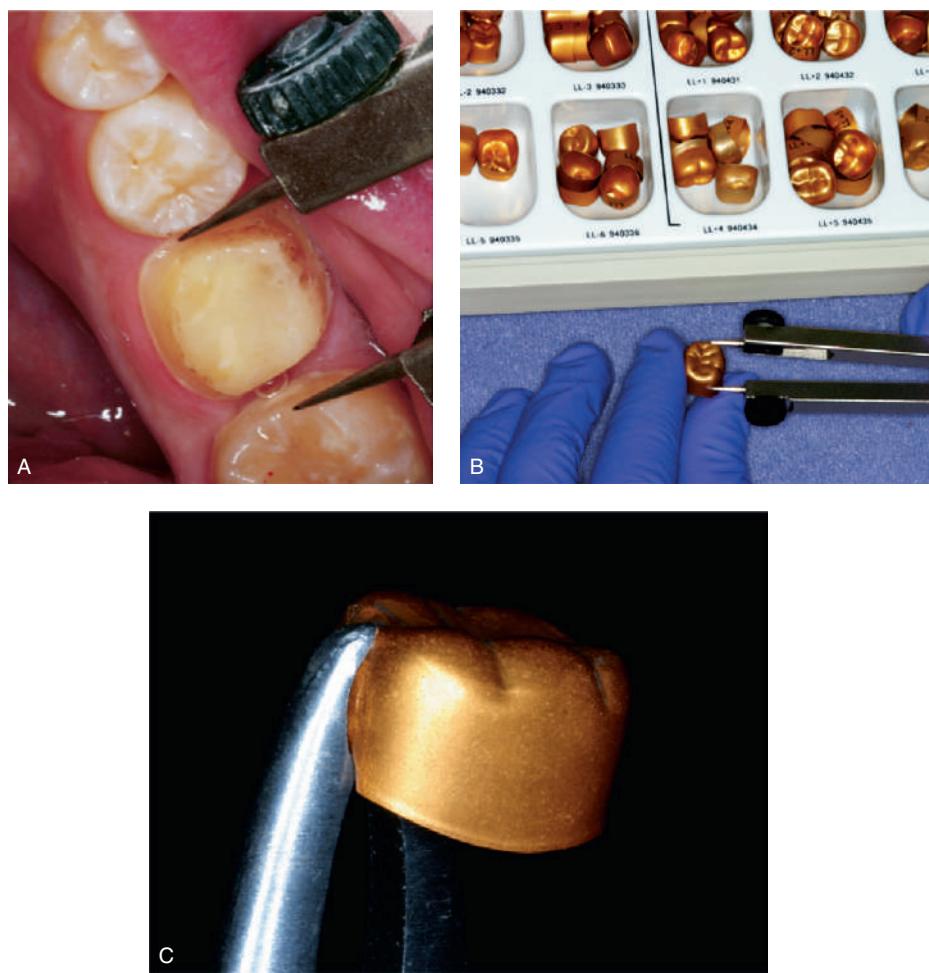


Fig. 15.59 Aluminum crown selection and modification. (A) Mesiodistal dimension of the space. (B) Appropriate crown size, nearest this measurement. (C) Contouring pliers modifying axial wall form.

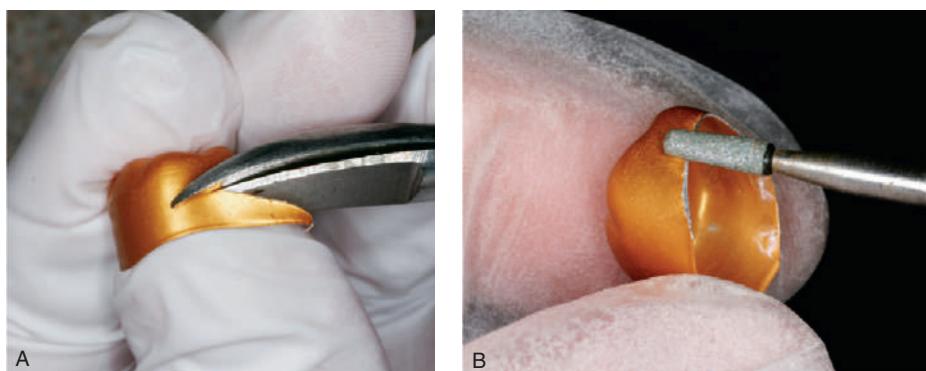


Fig. 15.60 (A) Cervical portion of the crown trimmed to proper length. (B) Smoothing the cut edge to prevent gingival injury.

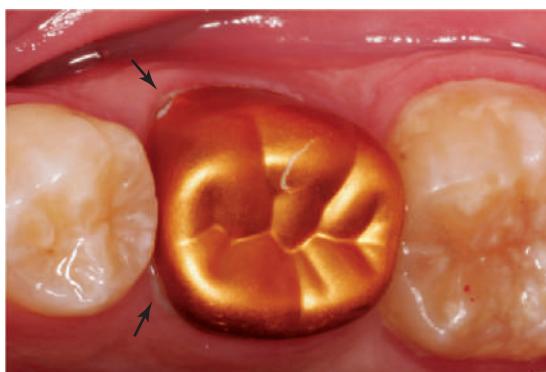


Fig. 15.61 The patient is instructed to occlude on the shell after the length has been adjusted. Note the occlusal indentation and gingival blanching (*arrows*). Where the shell causes blanching, additional shortening is needed.

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 12). An interim restoration is needed while the casting is being made. The goal is to incorporate a temporary post into the interim crown or retainer. The temporary post can come from a kit that matches the size of the post drill with a temporary aluminum post. These kits can also incorporate a post

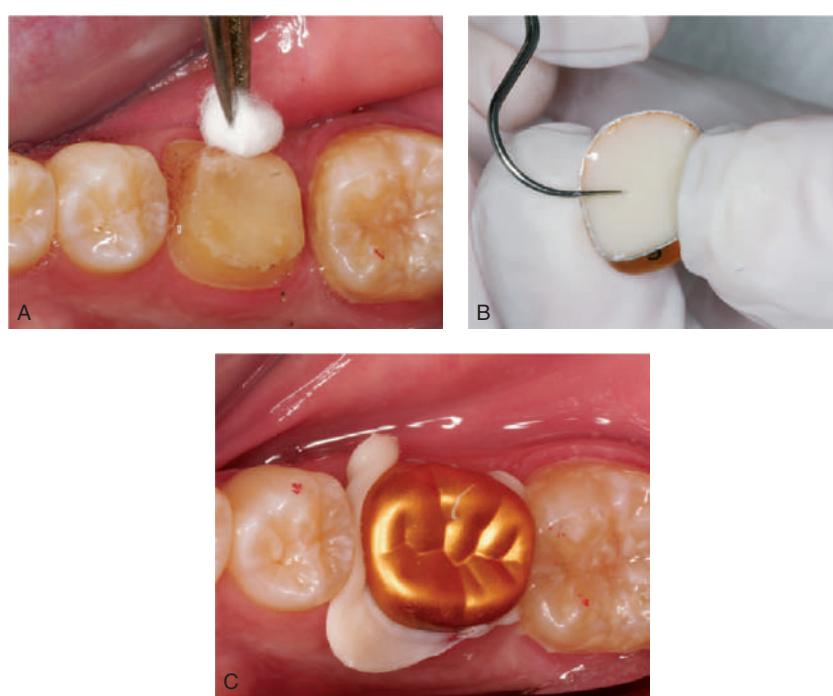


Fig. 15.62 (A) The prepared tooth is protected with petrolatum. (B) The adjusted shell is filled with lining resin and seated to just short of its final position after the resin has lost its sheen. (C) The final position is determined by the patient's closing into maximum intercuspsation. Excess resin is immediately removed.

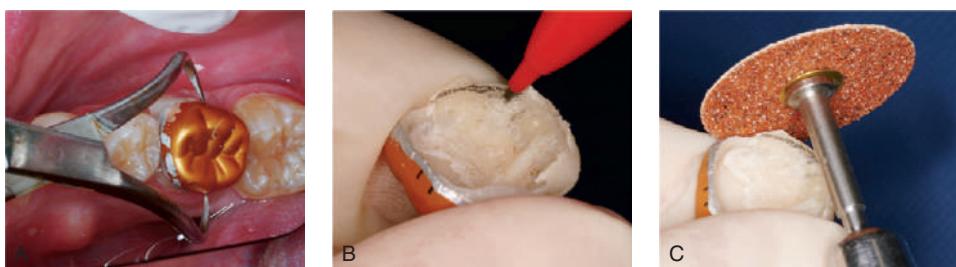


Fig. 15.63 (A) Backhaus forceps provides definite purchase of the shell for controlled removal. (B) After 5 minutes in warm water, the margin is marked with a pencil. (C) A coarse garnet disk is recommended for initial contouring of the axial surfaces. This usually necessitates partial removal of the 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.

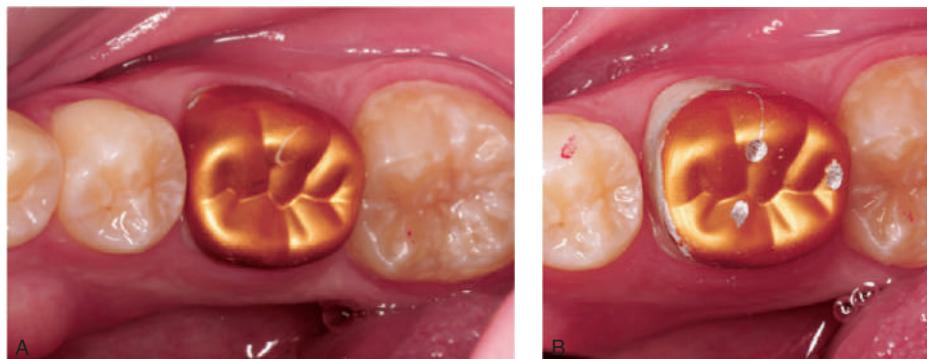


Fig. 15.64 (A) Proper contouring of the axial walls exposes lining resin in the cervical area. Note the indentations in the shell from the Backhaus forceps. (B) Final occlusal adjustment removes the anodized gold finish, but this is of no concern.

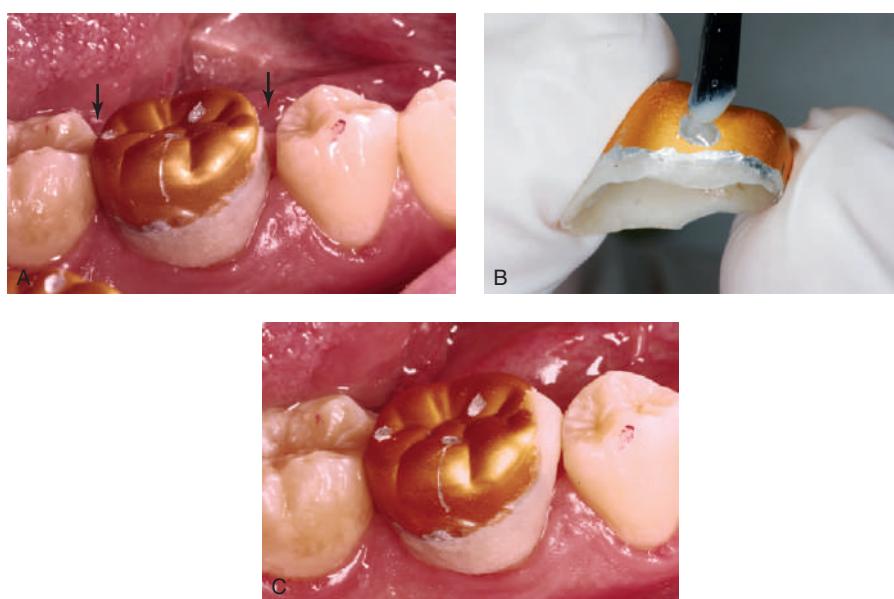


Fig. 15.65 Adding proximal contacts to aluminum crowns. (A) Contacts are absent in this lined crown (arrows). (B) The metal in the contact area is ground away to expose the underlying resin. The brush-bead technique is then used for correcting the deficiency. (C) Appearance of the crown after resin addition to the mesial surface. Further contouring with a disk is recommended to improve the gingival embrasure form.

pattern for chair-side fabrication of a pattern for a casting, and an impression post for a lab fabricated casting (Fig. 15.66).

Additions to Clinical Armamentarium

- Wire
- Wire-cutting pliers
- Cylindrical green stone, straight handpiece
- Wire-bending pliers
- Paper points
- All in one cast/prefabricated post system

Step-by-Step Procedure

1. After the post space has been modified according to acceptable guidelines (reference) using a drill appropriately sized



Fig. 15.66 Interim post kit with corresponding drills, interim posts, impression posts, and direct pattern posts.

for the root. Choose the matched temporary post, and place it into the root. Any undercuts within the coronal portion of the canal space should be blocked out with a restorative material such as light polymerized composite resin. Alternatively, 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. Modify the length of the temporary post at its apical end so that only 2 to 3 mm of the retentive portion extends out of the canal orifice. Have the patient close into maximum intercuspalation to make sure there is 1 to 2 mm of clearance between the retentive portion of the temporary post and the opposing occlusion. If using a wire, 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.
3. Lubricate the tooth and surrounding soft tissues with water-soluble lubricant. Paper points or microbrushes are convenient for lubricating the post space. Block out undercuts from the proximal surfaces of adjacent teeth with dental putty or caulk material.
4. If using a bis-acryl resin, express some of the material around the retentive component of the interim post. If using a PMMA or poly-R' resin, prepare two dappen dishes, placing powder in one and liquid in the other. Wet a sable brush with monomer, and then dip the brush into the powder. Let the wet brush bead up some of the powder, and then apply this to the retentive portion of the interim post.
5. Fill the ESF with interim resin material. If using PMMA, look for the point when the resin loses its surface gloss and seat the ESF over it (Fig. 15.67). If using bis-acrylic resin, the action is the same but the ESF should be placed immediately

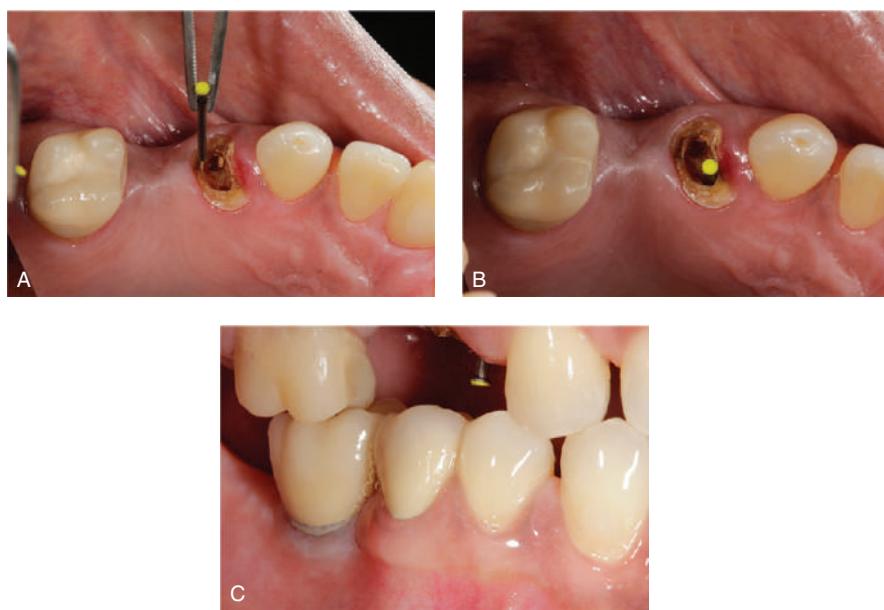


Fig. 15.67 (A) Correct post size is selected according to the canal diameter. (B) Post is seated, and its extension outside the canal is noted before placement of external surface form. A gauze throat pack is recommended to protect the patient from aspirating or swallowing the post. The patient should not be placed in the supine position. (C) Nail head of post should extend 2 to 3 mm outside the canal space.

after the ESF is filled. 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) or according to the manufacturer's instruction when using bis-acryl. 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 or post 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. This step is not necessary with bis-acryl resin. The post or wire must not be disturbed while the resin is soft. If the interim restoration 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 (as described earlier for PMMA or bis-acryl resin), clean, and cement the restoration (*Fig. 15.68*).

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
- 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



Fig. 15.68 Interim post and crown as one unit after pick up.

Available Materials

Of the currently available materials (*Fig. 15.69*), zinc oxide-eugenol (ZOE) cements have enjoyed success for many years because of its strength and obtundent effect on the pulp, in addition to its acceptable sealing properties.³⁸ Unfortunately, however, free eugenol acts as a plasticizer of methacrylate resins. It has been shown to reduce surface hardness³⁹ and presumably strength. New resin applied over polymerized resin previously in contact with free eugenol results in softening⁴⁰ 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 composite resins 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. Because many definitive crowns and FPDs are now cemented with resin cements that are also affected by eugenol, noneugenol cements have become more popular, although some of these formulations have a yellow color that can adversely affect the esthetics of the interim restoration.⁴¹ Zinc phosphate, zinc polycarboxylate, and glass ionomer cements are not recommended because their comparatively high strength makes removal of the interim restoration 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.

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 or zinc polycarboxylate.⁴² Conversely, sometimes minimum strength is desired, as with temporary placement of the definitive restoration.



Fig. 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.)

(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.

Armamentarium

The following equipment is needed (Fig. 15.70):

- Interim luting agent
- Mixing pad
- Cement spatula
- Plastic filling instrument
- Petrolatum



Fig. 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.

- 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. 15.71A).
2. Mix the two pastes together rapidly, and apply a small quantity just occlusal to the cavosurface margin (see Fig. 15.71B). A marginal bead of cement forms the required seal against oral fluids. 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. 15.71C).
4. Carefully remove excess with an explorer and dental floss (see Fig. 15.71D–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 evaluated and irrigated with the air-water syringe.

Removal, Recementation, and Repair

Armamentarium

- Backhaus towel clamp forceps or hemostatic forceps
- Spoon excavator
- Ultrasonic cleaner with cement-remover solution

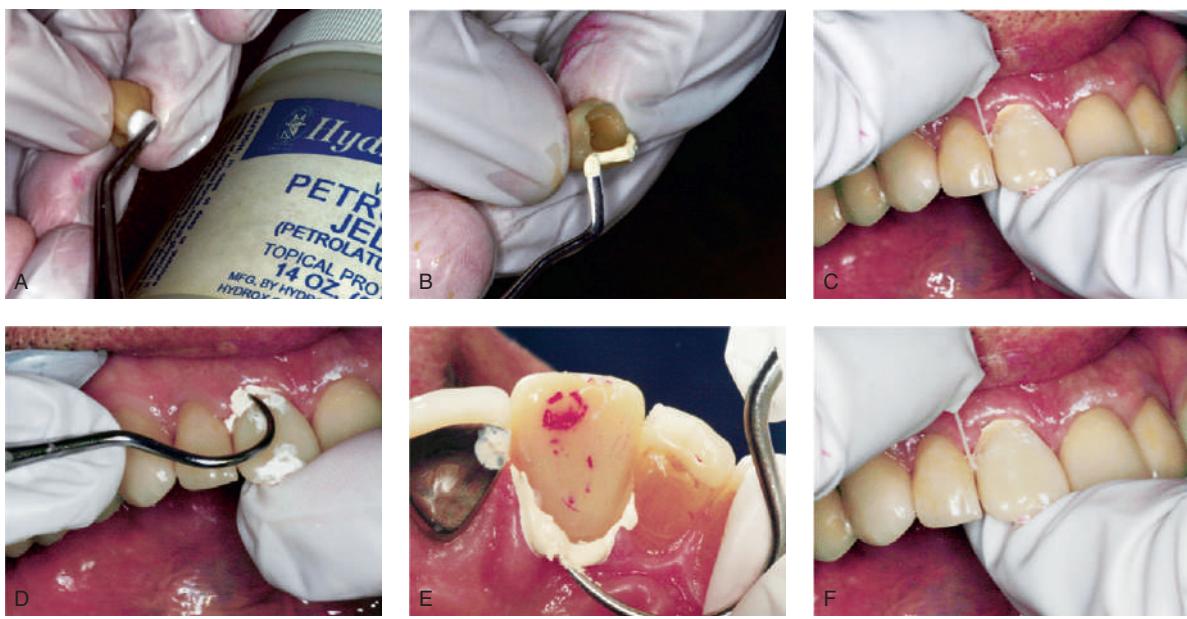


Fig. 15.71 Luting procedure. (A) The external surface is lightly coated with petrolatum to aid removal of the set luting agent. (B) Careful placement of the luting agent seals the margins and reduces the clean-up effort. (C) The restoration is seated with firm finger pressure, or (for posterior restorations) the patient may occlude 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 to remove excess cement), followed by copious irrigation with the air-water syringe.

The interim restoration is removed when the patient returns for placement of the definitive restoration, for continued tooth preparation, or for impression making. 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 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 FPD is being removed. If one abutment retainer suddenly breaks loose, the other can be subjected to severe flexure stresses when the FPD acts as a lever arm. This is especially true if a bis-acryl resin was used. 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 FPD.

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 or chair-side airborne-particle abrasion unit.
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



Fig. 15.72 Backhaus towel clamp forceps provides positive purchase on interim restorations. For maximum control, occlusal finger pressure is applied directly to the tines.

surface is relieved slightly and painted with liquid 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. In addition, achieving translucency in an interim crown can be a significant challenge for patients with unabraded teeth.

Color

Although 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 quickly; overmanipulation



Fig. 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.



Fig. 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.

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



Fig. 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 partial denture abutments and are splinted together to help resist dislodgment.

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 PSF 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 PSF. 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 PSF 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 PSF 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.

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.

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.^{43–45} 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).

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 (GC America Inc.), which is 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



Fig. 15.76 (A) Ceramic crown restoring the right maxillary central incisors. (B and C) Maxillary anterior teeth restored with facial veneers and a ceramic fixed partial denture. (B and C, Courtesy Dr. D.H. Ward.)

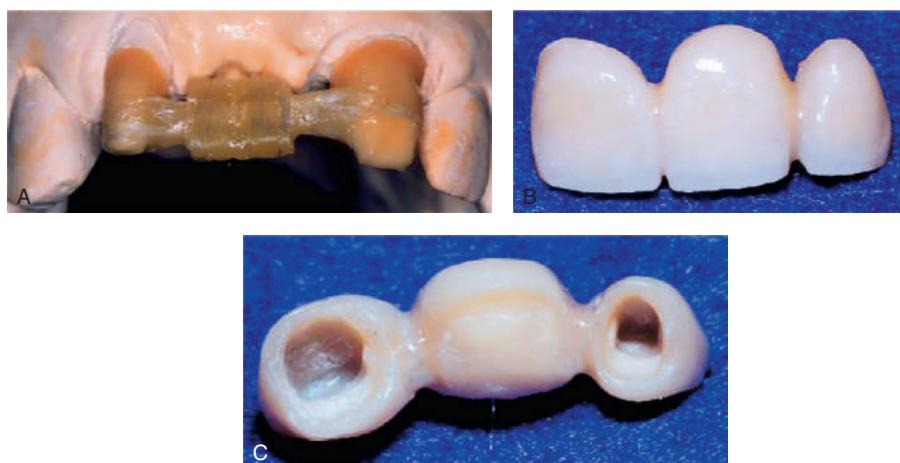


Fig. 15.77 (A) Fiber-reinforced composite (FRC) substructure for a three-unit polymer fixed partial denture (FPD). (B) Particulate composite resin veneers completed over FRC substructure. (C) Internal surface of FRC-reinforced polymer FPD.

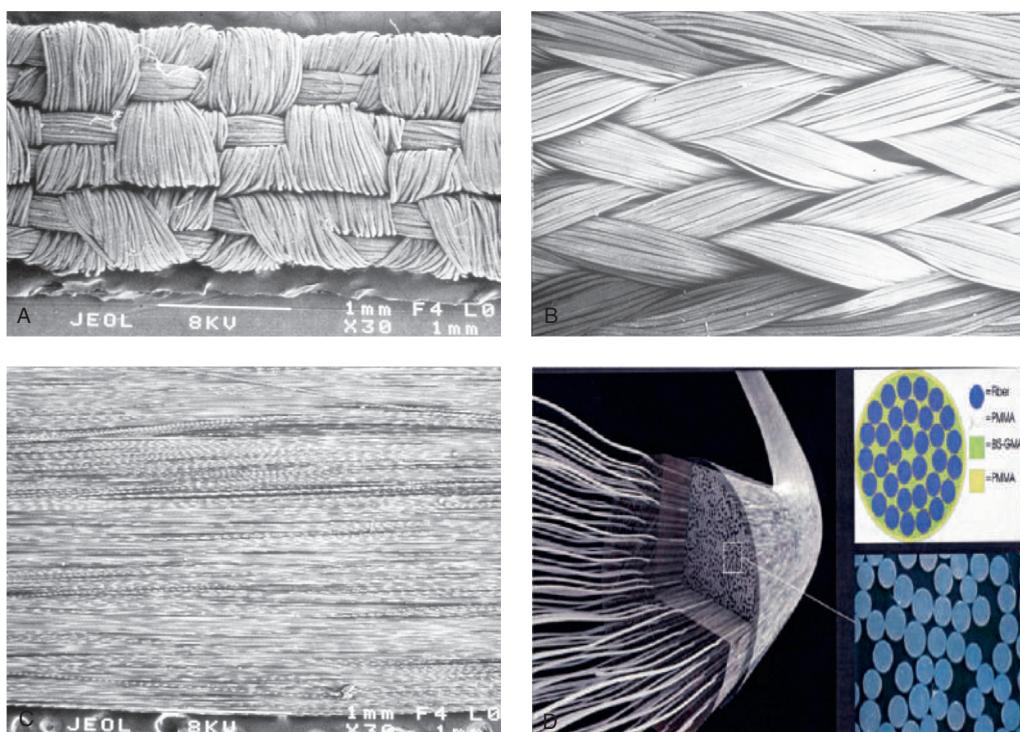


Fig. 15.78 Scanning electron micrographs of fiber-reinforced composite (FRC) materials. (A) Woven polyethylene FRC (Construct, Kerr Corporation). (B) Braided polyethylene FRC (Ribbond, Ribbond, Inc.). (C) Unidirectional long glass fiber FRC (FibreKor, Pentron Clinical Technologies, LLC). (D) Unidirectional long glass fibers with a polymethyl methacrylate outer membrane (everStick, GC America Inc.).

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.⁴⁶ 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.^{44,46-49} 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 Fig. 15.79.

• • •

TABLE 15.5 Flexure Properties of Commercial Fiber-Reinforced Composite Materials^a

Material	Fiber Type	Fiber Architecture	FLEXURAL STRENGTH (MPa)		FLEXURAL MOD(ULUS (GPa)	
			<i>m</i>	<i>sd</i>	<i>m</i>	<i>sd</i>
FibreKor 2K	Glass	Unidirectional	541	32	25.0	2.0
FibreKor 16K	Glass	Unidirectional	639–919 ^b	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

m, Mean; *sd*, standard deviation.

^aData generated in the authors' laboratory.

^bManufacturer's data.



Fig. 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.

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.

STUDY QUESTIONS

- What are the ideal properties of an interim restorative material? What are the ideal properties of the optimum interim luting agent?
- List at least five requirements for the success of an interim restoration.
- Explain why these factors are crucial for clinical success. What would occur if they were not appropriately performed or obtained?
- 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.
- What are the currently available materials for fabrication of interim restorations? What are their respective material properties, advantages, and disadvantages?
- Explain the basic chemical events involved in resin polymerization.
- What factors should be considered in the decision of whether to use a direct, indirect, or indirect-direct fabrication technique for interim fixed partial denture?

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Communicating With the Dental Laboratory

Harald Heindl and Daniela Heindl, Contributing Authors

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 the challenges faced by the dental laboratory technician is at a serious disadvantage when prescribing and delegating laboratory procedures. Crucial to the development of sound clinical judgment is a thorough understanding of technical procedures and their rationale, which are described in this and the other chapters of this section.

QUALITY AND QUALIFICATION

The advent of digitization and automation has brought numerous changes and challenges to the industry. The best-prepared individuals know how to combine traditional craftwork with modern technology. In an effort to standardize and increase quality per the American Dental Association (ADA) policy on dental laboratory registration and disclosure, Washington state's HB 1177 took effect beginning 2020. It is among a few states that have adopted the ADA policy and it can reasonably be expected that other states will follow.¹ There are currently eight states requiring in-state dental laboratories and four states that require out-of-state dental laboratories to register. Eleven states require a disclosure of point of origin; ten, the disclosure of materials used; and five states require at least one certified dental technician (CDT) in a dental laboratory. For extra certification a laboratory can obtain the titles CDL laboratory or DAMAS laboratory. To become a CDT one must pass a written comprehensive examination, a written specialty examination, and a hands-on practical examination in the same specialty. The six specialties available are complete dentures, partial dentures, crown and bridge (fixed prosthodontics), ceramics, orthodontics, and implants. The prestigious certification as a prosthodontist will have exposed the dentist to all technological procedures and techniques used in the dental laboratory, allowing excellent communication and planning throughout all phases of treatment leading to predictable results and success (Fig. 16.1A–F).

MUTUAL RESPONSIBILITIES

Good communication—the key to the overall success of the dental team^{2–4}—requires a close working relationship between the dentist and dental laboratory technician. Anticipating satisfactory results is unrealistic if the dentist does not have a reasonable amount of experience with, and a thorough understanding of, the applicable 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 pertinent technical and material science limitations. Only then can the dentist select the best compromise between (1) technical limitations, (2) biologic considerations, and (3) esthetic needs. Similarly, if the dental laboratory technician does not appreciate and respect the clinical demands or the treatment rationale of the dentist, the results will likely be unsatisfactory. 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 dental laboratory 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 serious problems in dentist-technician communication. In other studies and opinions concerning dentist-technician interaction, whether written by dentists or dental laboratory technicians, the authors emphasize that better patient care is achievable only by better communication.⁸

The ADA has 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



Fig. 16.1 (A) Initial situation of a patient with severe erosion and attrition. (Courtesy Dr. Stephen Phelan.) (B) Additive diagnostic waxing showing proposed changes in tooth form, proportions, and length. (C) Occlusal view of diagnostic waxing. (D) Interim restoration based on the diagnostic waxing. (Courtesy Dr. Stephen Phelan.) (E) Definitive porcelain laminate veneer restorations before delivery. (F) Seated porcelain laminate veneer restorations. (Courtesy Dr. Stephen Phelan.)

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 that is to be performed, describe the materials that 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 to 4.
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 Dental 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 occlusal registration furnished by the dentist.
3. The laboratory/technician should match the shade that was described in the original written instructions.
4. The laboratory/technician should notify the dentist within 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 (PPE) 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 that 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 undermine achieving optimal results.

Infection Control

The U.S. Department of Health and Human Services¹⁰ and the ADA¹¹ have 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 In light of recent events, it cannot be stressed enough that ample stock of disinfectants and PPE is necessary for both the dental office and the dental laboratory.

Tooth Preparation

An organized approach to tooth preparation is discussed in Chapters 7 to 11, which provides the criteria for minimally necessary clearances for the various types of restorations.

Inadequate tooth reduction is a common error. Obviously, on long clinical crowns of vital teeth (e.g., after 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. Inexperienced technicians tend to resolve the problem by over-contouring, but this often 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. Timely communication regarding any deviation from “ideal” criteria is essential and will prevent misunderstanding or unrealistic expectations.

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. However, in practice, few dentists do this. If the teeth are properly prepared and the impression is accurate, the margins should be obvious, which makes this 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.

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 destined to fail from the start. 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.”

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 work authorization form should include the following:

- General description of the restoration to be made
- Material specification
- Desired occlusal scheme
- Connector design for fixed dental prostheses
- Pontic design, including the material specification for tissue contact
- Substructure design
- Information regarding the shade selection for esthetic restorations, stump shade if applicable to the desired restorative material as well as gingiva shades if gingiva needs to be mimicked
- Implant brand, style, and size of platform
- 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 dentist’s prescription of a specific material. Written instructions should be explicit.

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 pose a

challenge for the technician to comply with a specific request, and discussing its importance and possible alternatives that may be acceptable instead will help achieve the desired result without compromise.

Diagnostic Waxing

In the Glossary of Prosthodontic Terms diagnostic waxing is defined as “a waxing of intended restorative contours on dental casts for the purpose of evaluation and planning restorations; a wax replica of a proposed treatment plan.” Diagnostic waxing is a fundamental step in successful restorative dental treatment. It represents a physical 3-dimensional blueprint proposing a functional and esthetic outcome of the restorative treatment ([Fig. 16.2A–D](#)). A duplicate cast, matrices, stents, and reduction guides made from the waxing are necessary tools for a number of surgical and restorative procedures. Also, a trial restoration generated from it can give the patient a realistic impression of how the future restoration will look (see [Chapter 2](#)). A vacuum-formed shell derived from the duplicate cast of the diagnostic waxing is used to create the interim restorations (see [Fig. 16.1D](#)). The use of silicone matrices and guides generated from the diagnostic waxing during tooth preparation is extremely helpful to ensure that adequate tooth structure has been removed to make enough room for the anticipated restorative materials.

It cannot be overemphasized that the diagnostic waxing must accurately represent the desired result of the treatment¹³ and should be done with the greatest diligence.

Therefore, it is of utmost importance to record all the information needed to create the desired outcome. This includes a complete digital photograph series ([Fig. 16.3](#)), facebow mounted casts, and instructions about the desired changes and patient expectations. Detailed instructions are a helpful guide to any dental professional assigned with this task. Esthetic parameters, like incisal edge position, tooth length, proportions, and morphology, should be addressed. The type of definitive restoration has to be considered also, e.g., for future porcelain veneer restorations the waxing should be done additively¹⁴ on the pre-operative cast to avoid excessive enamel reduction in the preparation. Information about functional parameters like the occlusal scheme and function, increase or decrease of the vertical dimension of occlusion, and increased loading as in the presence of parafunctional activities like bruxism, or any particular high-stress areas are required. If all such factors are carefully identified and taken into consideration, the restorative result will be esthetically pleasing with an excellent prognosis.

Mounting, Cross Mounting, and Verification of Occlusal Records

The precise mounting of the definitive cast with its opposing cast is of utmost importance. Incorrect mountings can result in a remake of the prosthetic device or hours of adjustment and a subsequent compromised result. Typically, mounting casts is delegated to the dental laboratory technician and should be done with the greatest carefulness and accuracy.

1. First, clean all casts free of any occlusal defects and imperfections. Remove voids and bubbles carefully using a scalpel.

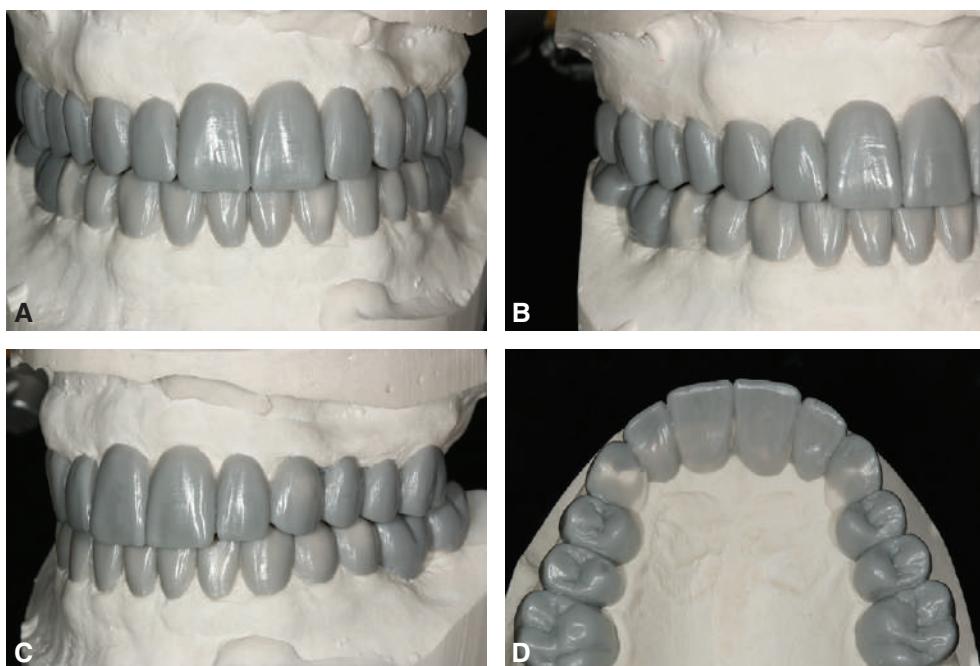


Fig. 16.2 Diagnostic waxing. Gray wax used for better visualization of tooth form and contours. (A) Frontal view. (B) Right lateral view. (C) Left lateral view. (D) Occlusal view.



Fig. 16.3 Digital photograph series. Views provide information about a relaxed smile, repose, amount of tooth showing, excursive positions, and closeups for information about form, as well as complete arch images to show general alignment of the dentition. (Courtesy Dr. Stephen Phelan.)

2. The maxillary cast of the interim restorations is then mounted on a semi-adjustable articulator using a facebow transfer. Using a designated system like the Kois facebow (Kois Dentofacial Analyzer) (see Chapter 2) takes guesswork on the occlusal plane out of the equation and is highly recommended.
3. Subsequently the mandibular cast of the interim restorations is mounted against the maxillary cast using an occlusal record (Fig. 16.4A).
4. Finally, the definitive cast is mounted against the opposing arch. The CR registration record must be prepared for this mounting procedure. Excessive material is trimmed with a scalpel and widows are cut to ensure visual confirmation of proper seating of records on the casts (see Fig. 16.4B through G). Casts made from polyvinyl siloxane or polyether impressions are more accurate than those made from alginate impressions. Once the cast with the preparations and the opposing cast are



Fig. 16.4 (A) Cross-mounted casts of maxillary interim restorations opposing mandibular arch. (B) Trimmed occlusal record 1. (C) Trimmed occlusal record 2. (D) Precise fitting record left side. (E) Precise fitting record right side. (F) Precise fitting occlusal record on cast made from addition silicone impression. (G) Poor adaptation of same occlusal record on cast made from alginate impression. (H) Maxillary cast of prepared teeth versus mandibular cast prepared for mounting procedure. (I) Assembly for verification of occlusal records using Mandibular Position Indicator. (J) Imprint made using occlusal record 1. (K) SAM Mandibular Position Indicator. (L) Imprint in red from record 1. (M) Imprint in blue from record 2 exactly matching the location of record 1.

seated in the record both can be stabilized in a number of ways. A popular method is to attach them together with a glue gun and old long shank burs and then mount on the articulator using a mounting plaster with low setting expansion (see Fig. 16.4H).

A critical step in completing the restorations with the highest precision is a verification of the occlusal records. For the popular SAM 3 articulator, the Mandibular Position Indicator (MPI) (see Fig. 16.4J), which is a modified maxillary member of the SAM 3 articulator, can be used for verification of the occlusal records. Another use of this instrument is to visually show discrepancies between centric relation and maximal intercuspal position. The MPI has sliding cubes that contact the mesial poles of the condylar elements. A self-adhesive graph paper is placed on the cubes and the maxillary cast is transferred from the articulator to the MPI. The first set of CR records is used to position the maxillary to the mandibular cast. The cubes of the MPI are moved toward the articulator condyles back and forth and by placing articulation paper in between an imprint is created on the graph paper (see Fig. 16.4K–M).

This procedure is performed for the right and left side. The same technique is repeated by using the second set of CR records. The second imprints are created with an articulation paper in a different color (see Fig. 16.4N). The imprints on both sides should mark the same spot, indicating that the occlusal records are identical and repeatable, and the mounting is correct.

If this is not the case it is important to correctly identify the cause which may be multi-factorial. It could be an incorrect mounting, distorted casts, one or two inaccurate occlusal records, or a combination of two or all of these factors.

Cast of Interim Prosthesis and Its Use

An important piece of information for the dental laboratory technician is the shape of the interim restoration being worn by the patient, especially for fixed prostheses that are to be fabricated in the esthetic zone. The interim prosthesis is often a modified and fine-tuned version of the earlier diagnostic waxing and represents the dentist- and patient-approved physical blueprint for the definitive restoration. Any changes or adaptation thereof in an effort to perfect the details have to be relayed to the dental laboratory technician. A photograph of the interim FDP in situ with any additional corrective drawing and/or notes on it is a great way to point these out. Alternatively, an analog or virtual cast of the interim prosthesis will provide tremendous help to the ceramist to mimic its appearance in the definitive restorations.

The cast of the interim prosthesis can be cross-mounted with the definitive cast and its opposing arch and can then be used for the fabrication of a custom incisal guide table (see Chapter 2). The custom incisal guide table in Fig. 16.5A was fabricated from light polymerizing resin. Its use allows the transfer of the established envelope of function from the interim to the definitive restorations, taking into consideration any wear patterns that may have developed during function.¹⁴ Wear patterns in an interim restoration can provide important clues to assist in achieving optimal anterior guidance.

Various silicone indexes generated from the interim cast are essential to copy tooth length, shape, midline, and arrangement for the definitive restorations. An occlusopalatal index is mainly used to copy all these parameters (see Fig. 16.5B and C).

A buccolingual matrix will give a good visualization of how much room is available on the labial or buccal aspect (see Fig. 16.5D). These two types of matrices are excellent tools to control the space for the two critical working steps of framework fabrication and the subsequent layering of porcelain. This application ensures a properly designed framework and a more uniform thickness of the porcelain, well supported by the substructure (see Fig. 16.5E and F).

Shade Selection

The dental team must meet the high expectations and demands of today's esthetic focused patients. A thorough understanding of the principles of color science (see Chapter 23) is essential for the dentist and the dental laboratory technician to replicate the appearance of natural teeth. Color and translucency are two of the primary factors to be considered in achieving good color matches. A key element, however, is the experience of respectively the clinician and ceramist with a specific shade guide and porcelain system. The tooth color can be recorded and transmitted using digital photography, electronic shade scanning devices, and traditional shade mapping sheets.^{15,16}

Fundamentals for recording tooth shade are:

1. The teeth need to be clean. An extra tooth cleaning appointment before definitive shade selection is often advisable.
2. Neutral colored surroundings and background is preferred (see Chapter 23).
3. Examine the patient under different light sources (natural and artificial). Natural daylight at midday is preferred, but not direct sunlight. Artificial light must be color-corrected light of between 5000 K (D50) and 7500 K (D75).¹⁷ Ideally, both the dentist and dental ceramist should be using the same artificial light source. Results may be improved with the use of a special handheld shade selection device such as the Rite-Lite 2 (AdDent) or the Smile Lite (Smile Line USA).¹⁸
4. Avoid dehydration of teeth. Shade selection needs to take place at the beginning of the dental appointment and not after tooth preparation and impression making. Dried enamel appears opaque and whitish and a flawed color match will be the consequence. Some teeth dehydrate within seconds. In this case the patient needs to keep the teeth wet by using her/his tongue.
5. Use a standard shade guide like Vita Classic, Vita 3D Master, or Ivoclar Chromascop for basic orientation of hue, chroma, and value (Fig. 16.6A).
6. Use individual shade tabs from the porcelain system being utilized (Fig. 16.6B and C). Most porcelain manufacturers offer dentin and enamel shade tabs made from their porcelain materials.
7. If necessary, make custom shade samples (Fig. 16.6D).
8. Position the sample next to the natural tooth.
9. Give your eyes a break after 8 seconds because of eye fatigue.
10. Make photographs of shade tabs held next to the teeth from different angles.
11. High-resolution digital photographs are of utmost importance to help the ceramist mimic shade distribution.
12. Determine areas of translucency and/or opacity. Highly translucent teeth have a tendency to be lower in value because they absorb more light in comparison to more



Fig. 16.5 (A) Custom incisal guide table. (B) Fabrication of occlusal index. (C) Occlusal index. (D) Cast of the interim restorations used for generating buccal index. (E) Buccal index showing room for veneering porcelain. (F) Incisal index showing proper designed zirconia frameworks with ideal support for layering porcelain.

- opaque teeth which have more light reflection, exhibiting a higher value or brightness.
13. Use black and white photography for assessment of the value (Fig. 16.6E). A comparison photograph of the teeth with a standard shade guide tab can be helpful.
 14. Standard shade tabs can be customized by using light-polymerized, resin-based staining kits. 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 can be used by the ceramist as a reference.
 15. Electronic scanning devices like spectrophotometers and colorimeters are additional tools for the shade selection process. Several of these systems provide a detailed color analysis in printed or electronic format which is very useful for the shade communication between the members of the restorative team (Fig. 16.6F).
 16. Cross-polarizing filters will eliminate unwanted reflections on the tooth surface, thus allowing a deeper look into the intrinsic layers of the tooth.
 17. Record all special characterizations as:
 - Areas of high chroma intensity
 - Translucent zones
 - Cracks and craze-lines
 - Hypercalcifications (Fig. 16.6G)
 - Dentin lobes and dentin rays (Fig. 16.6H)
 - Incisal halos (Fig. 16.6H)
 - Secondary dentin
 18. A diagram of the desired appearance of the definitive restoration incorporating all these special characteristics should be developed from these observations. The diagram should be large enough to designate dentin shades, incisal/enamel shades, and any applicable individual characterization. The diagram can be hand-written or painted. Since there is often a lot of information put in such a diagram it is helpful to make one separate diagram for the dentin layers and another one for the enamel layers (Fig. 16.6I and J).
 19. Determine the degree of luster or shininess of the tooth surface (high, medium, low). In order to communicate

- the degree of luster using dental images, saliva should be removed before photographs are taken (Fig. 16.6K and L).
20. Study and analyze the tooth surface and morphology of adjacent teeth. The best strategy is to use a plaster cast made from either a polyvinyl siloxane or polyether impression (printed casts or casts made from alginate impressions are less suitable). The light source is then directed at a very flat angle parallel to the facial surface of the tooth (Fig. 16.6M). The appreciation of the texture can be enhanced with a thin application of silver powder (Fig. 16.6N).
21. Photographs with shade tabs of the prepared teeth are essential to help make the correct choices when creating highly esthetic ceramic restorations (Fig. 16.6O).

For some patients it may not be possible to achieve a match with standard shade guides. For these patients, a trial porcelain firing is a good approach, before completing the restoration (Fig. 16.6P). In even more complex situations, where no standard dentin or enamel shade tabs are matching, custom-made dentin and/or enamel shade tabs are the first approach to achieve a good color match (Fig. 16.6Q). Such customized dentin and enamel shade samples can be fabricated in a fairly

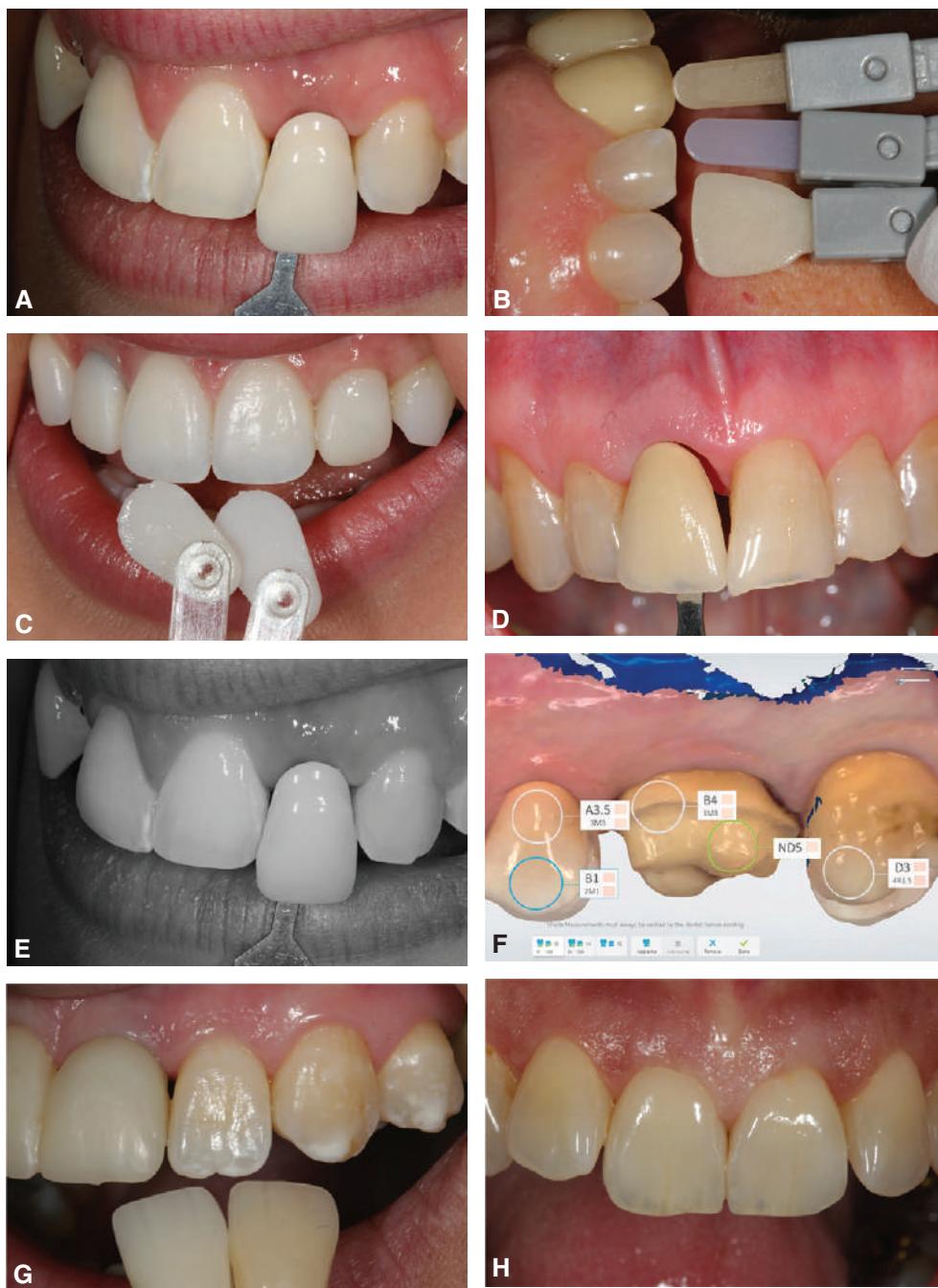


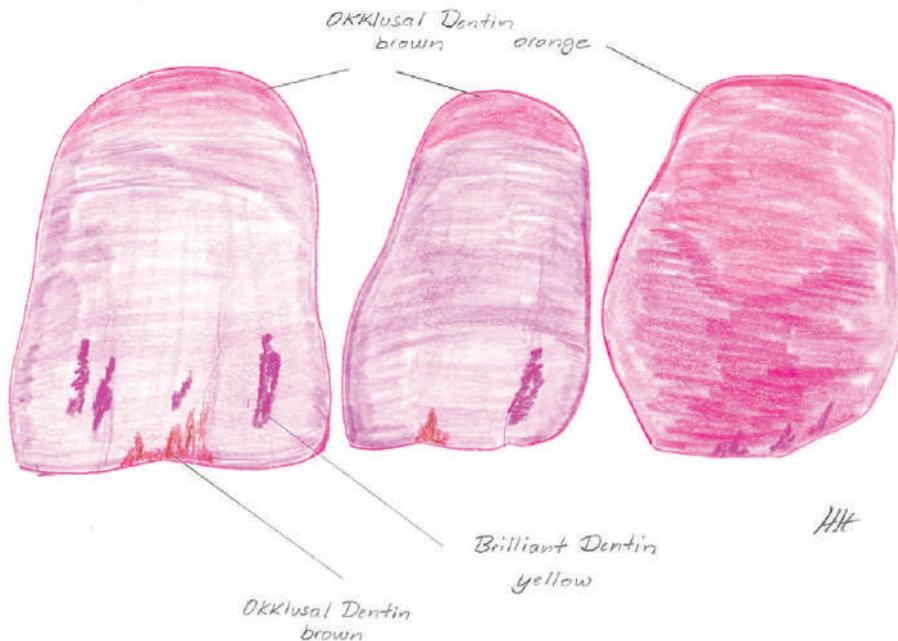
Fig. 16.6 (A) Selection of basic shade using Vita classic shade guide. (B) Use of enamel shade tabs from manufacturer. (C) Use of dentin shade tabs from manufacturer. (D) Laboratory-made custom shade sample. (E) Black and white photo for better assessment of value. (F) Electronic shade scan. (Courtesy Dr. Robert Walter.) (G) Hypercalcification. (H) Dentin rays, mamelons, incisal halo, crack lines, etc.

Dentin built-up (John)

Dentin A 3.5

A 3.5

B 3/4



Enamels, Transpas and Effect powders (John)

EI + Dentin A2/A3

Transpa
brown greyCervical Incisal
orangeSpecial Incisal
grey

TS 2

Brown
grey

NT

Khaki

TS 2

NT

Khaki

NT

Transpa
orange grey

HE

J

Fig. 16.6 Cont'd (I) Shade map dentin shades. (J) Shade map enamel layers.

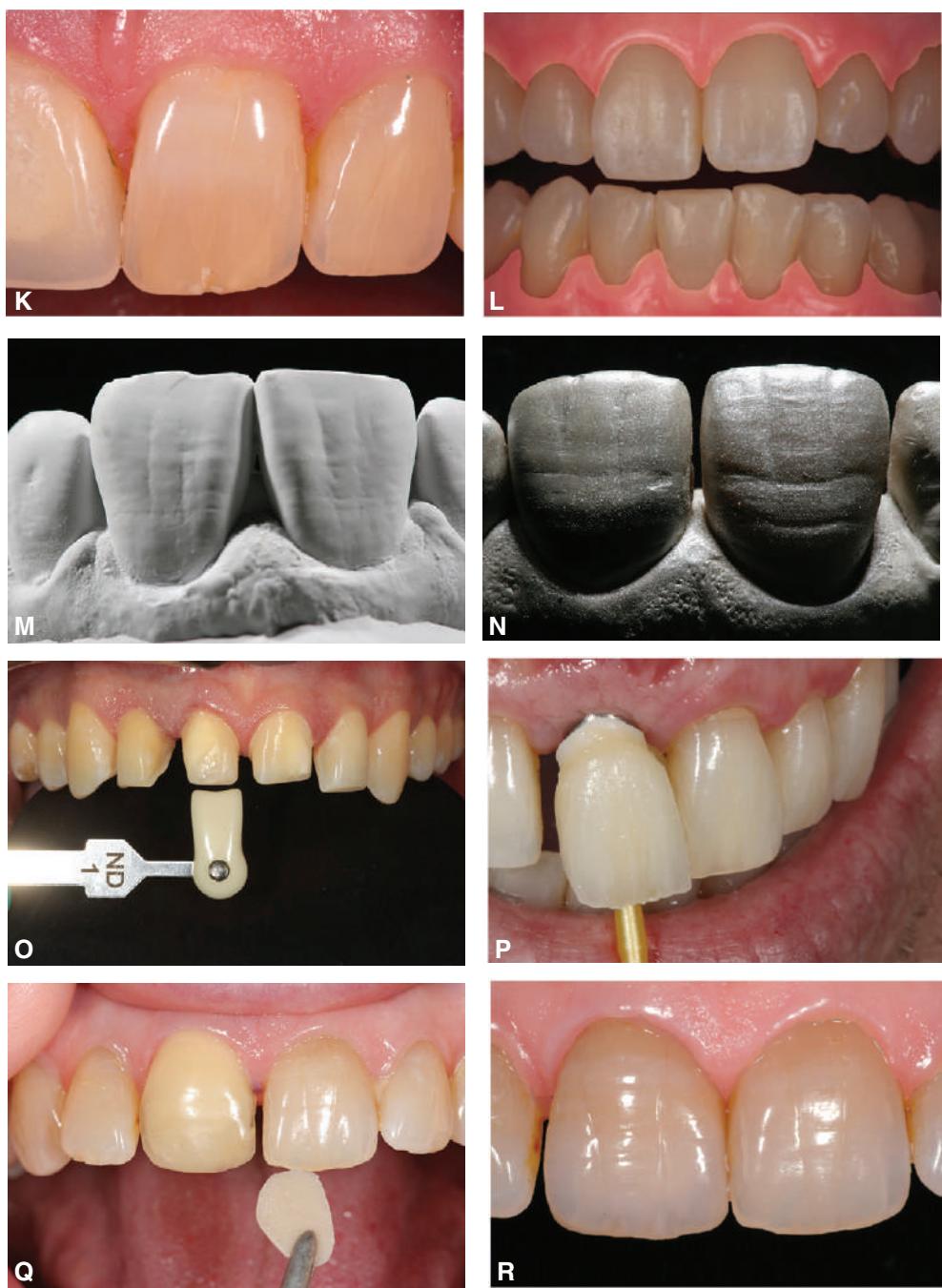


Fig. 16.6 Cont'd (K) Smooth shiny surface luster. (L) Matte surface luster. (Courtesy Dr. Robert Walter.) (M) Tooth surface made visible. (N) Surface texture comparison between restoration and natural tooth using silver powder. (O) Shade photo of preps. (P) Trial in bisque bake stage. (Q) Custom shade sample for communication of dentin shade. (R) Ceramic crown on maxillary right central incisor. (Courtesy Dr. Ariel Raigrodski.)

short time even when the patient is present for the appointment. Subsequently, the restoration can be evaluated in a bisque stage before final characterization, and glazing.

However, creating restorations that are undistinguishable from the natural dentition requires more than great color matching.¹⁹ Other key elements including tooth form, surface texture, and surface luster are crucial in mimicking nature. Only if all these variables are carefully considered and addressed in the definitive restoration to a high degree of skill will a truly pleasing outcome be achieved (Fig. 16.6R).

APPROPRIATE CHECKS

When treating patients with fixed dental prostheses, the dentist must decide whether the restorations should be completed through porcelain application in the laboratory, or if a preliminary appointment for substructure evaluation is needed. Routine evaluations of the substructure are recommended for all long span fixed partial dentures, particularly if the treatment involves implants. Similarly, it may be advantageous to plan an evaluation appointment for final contouring, texturing,

and characterization of any restoration in the bisque bake stage, before glazing. It takes extra time and effort to perform these clinical procedures (see Chapter 29), but patients and technicians alike will recognize and appreciate the dedication to quality every step of the way.

The use of checklists by both clinician and technician can be helpful.²⁰ Before a patient leaves the dental office, the dentist must 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 are present; that the impression material is still firmly attached to the tray after removal from the mouth; and that no contact has occurred between any tooth surfaces and the tray, which can lead to inaccuracies in that area or even push the contacting tooth out of its natural position during impression taking (especially important when restoring a single central incisor). For casts, the dentist must confirm they are not distorted; have no large bubbles, voids, or damage; and are of good quality in general.

SUMMARY

The keys to superior fixed prosthodontics are communication and dedication. By employing analytic tools like a diagnostic waxing and a detailed shade communication protocol, the planning and fabrication of high-quality dental prostheses have become reliable and predictable, surpassing the patient's esthetic and functional expectations.

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?
5. List and discuss at least 15 of the presented fundamentals to record tooth shade.

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Definitive Casts and Dies

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Abdulaziz Alzaid, Contributing Authors*

Because direct fabrication of definitive restorations for extra-coronal restorations is inconvenient and time consuming, practically all wax patterns are made in the dental laboratory. The indirect technique requires an accurate reproduction of the prepared tooth, the surrounding soft tissues, and the adjacent and opposing teeth. A conventional solid cast-and-die system captures all the information necessary for the dental laboratory technician to fabricate the prescribed restoration. Most commonly, solid definitive casts are fabricated from dental stone (see [Chapter 2](#)), although some other materials may be used as well. For an increasing number of dental procedures, virtual casts can be created from digital data captured with a scanner.

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 (3D) formats that enable the dental laboratory technician to use virtual tools for certain phases of the restoration fabrication process. Virtual systems continue to improve and have gained widespread acceptance in the dental laboratory industry; even at their current level of development, they provide significantly improved efficiency.

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 dental 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. The second section of this chapter 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, preferably 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.

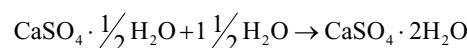
MATERIALS SCIENCE

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:



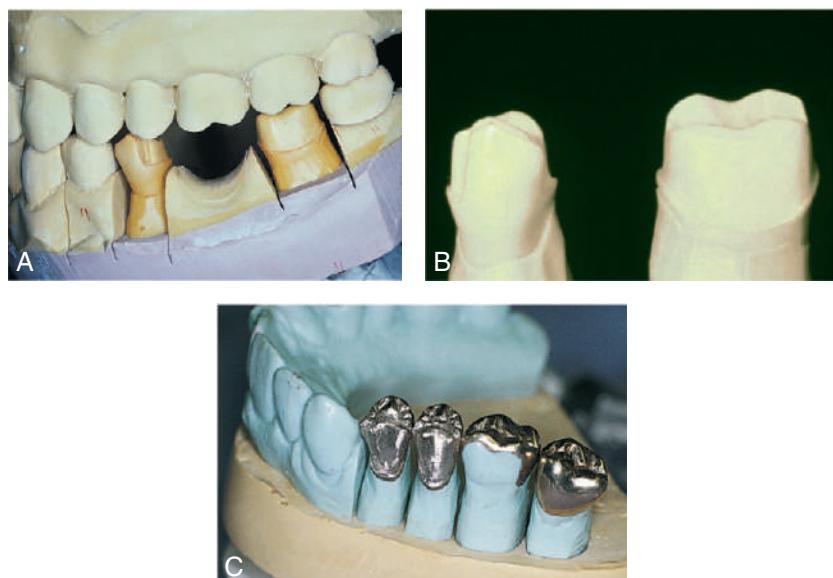


Fig. 17.1 Removable die system. (A) Definitive cast. The dies of the prepared teeth are retained by the dowel pins in the pink base pour. (B) The individual stone dies removed from the cast. (C) Epoxy dies with metal castings. (B, Courtesy Dr. J.H. Bailey.)

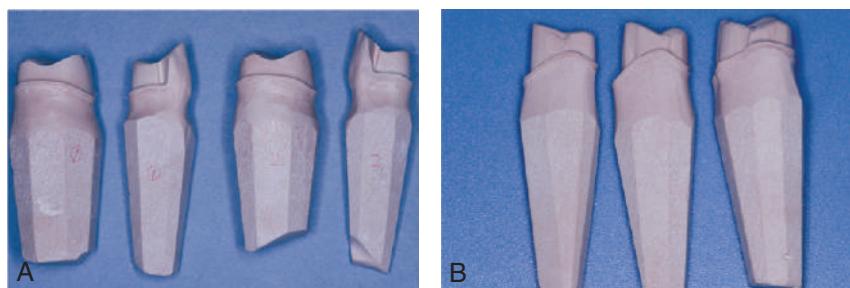


Fig. 17.2 Examples of individual dies. (A and B) These are sectioned from a solid pour.

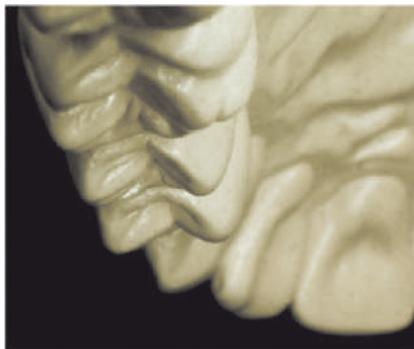


Fig. 17.3 Defect-free occlusal surfaces are essential for precise articulation.

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 among the various types of dental gypsum are attributable to calcination. The physical 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

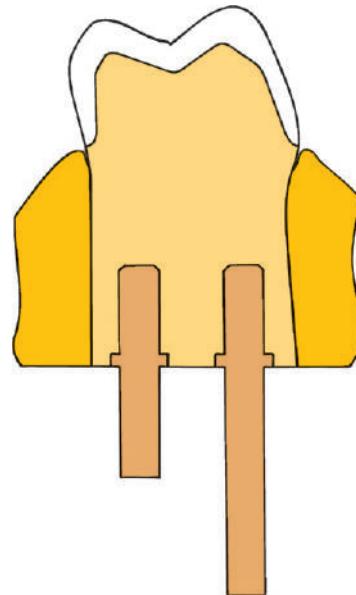


Fig. 17.4 To facilitate trimming, the impression should extend beyond the preparation margin. A properly trimmed die must have the same cervical contour as the tooth (light yellow). The gold areas on the side indicate the parts of the die to be removed during trimming.

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 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 approach⁵ 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 formulations¹¹ 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 better¹⁴; 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.

Digital

The digital workflow has revolutionized laboratory procedures that have withstood the test of time. Restorative dentistry has depended on and been proud of the accuracy and reproducibility of its impression materials and dental stones. Although a digital die may not be as accurate when multiple abutments are involved, they do provide excellent accuracy when restoring a single tooth.^{15a} Furthermore, they address many weaknesses inherent with the traditional stone die. Digital dies do not abrade or get damaged during restoration fabrication. Routine calibration of equipment resolves issues of expansion or contraction inherent with traditional materials. A digital file can be used multiple times without the need for duplication and can be instantly shared between dentist and dental laboratory technician without wasted shipping time. The laboratory procedures may be less technique sensitive and easier to learn as compared with the traditional stone technique (Fig. 17.5).

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 study²⁰ revealed that the best detail reproduction was obtained when Impregum F die material (3 M ESPE Dental) was combined with Extrude Light impression material (Kerr Corp).

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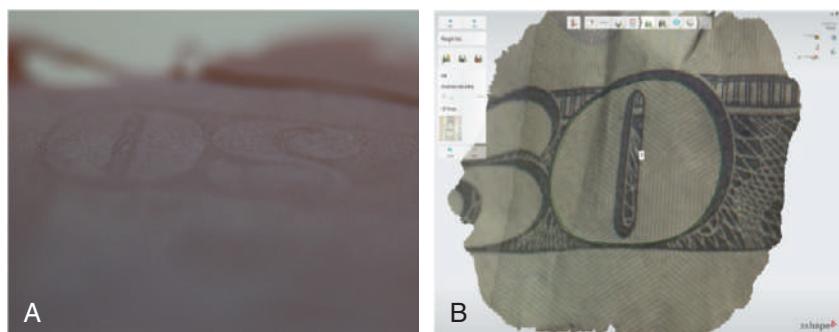


Fig. 17.5 Impression and scan of a \$20 bill. (A) Polyvinyl siloxane impression captures a high level of surface detail. (B) Optical scan was also able to detect the changes in elevation of the ink on the bill. However, the digital workflow was able to provide more detail and identify the edge of the zero in the 20, not possible with a stone die from the polyvinyl siloxane impression.

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.
- 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.

Available Methods for Traditional Stone Casts

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. 17.6). 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 Pindex system (Coltène; Fig. 17.7), multiple or interlocking dowels are used to ensure such rotational resistance.

The cast is made in two pours of type IV or V stone of contrasting colors: the first reproduces 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 of the two pours. 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. 17.8).

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

The Pindex system is designed to facilitate this latter technique. All removable die systems depend on careful execution so 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 brass dowel pins produced the least occlusogingival reseating discrepancy.²²

Solid Cast With Individual Die

The solid cast-individual die system, fabricated from a *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. 17.9). 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 the margins can be readapted immediately before the pattern is invested.

An advantage of the conventional solid cast-individual die system is that this 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 can facilitate development of axial contours of the restorations. Training support personnel is easier for this system than for removable die systems. Additionally, the conventional solid cast can be scanned and an appropriate file format created for a digital workflow.

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
Digital Workflow	Intuitive to learn Does not abrade or become damaged	High initial cost, software updates, and maintenance fees	Single or multiple unsplinted restorations	Routine calibration needed
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.



Fig. 17.6 Dowel pins.



Fig. 17.7 Removable dies made with the Pindex dowel system (see Fig. 17.22). (Courtesy Coltène, Altstatten, Switzerland.)

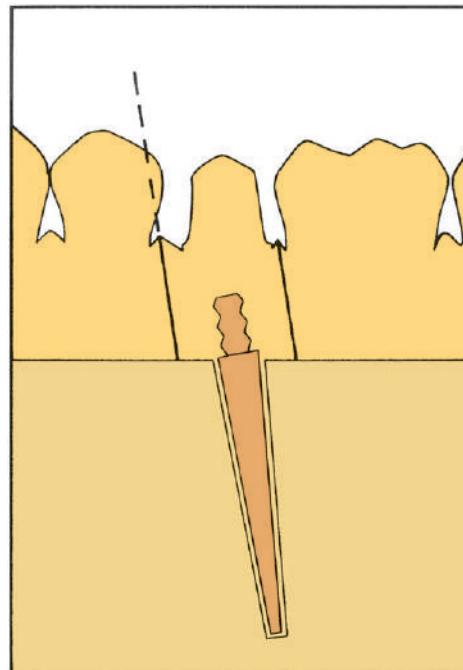


Fig. 17.8 Incorrect alignment of the dowel pin prevents removal of the die. The proximal surface of the adjacent tooth blocks die removal (dashed line).

Disadvantages of the conventional 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, once the restoration has been fabricated 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).

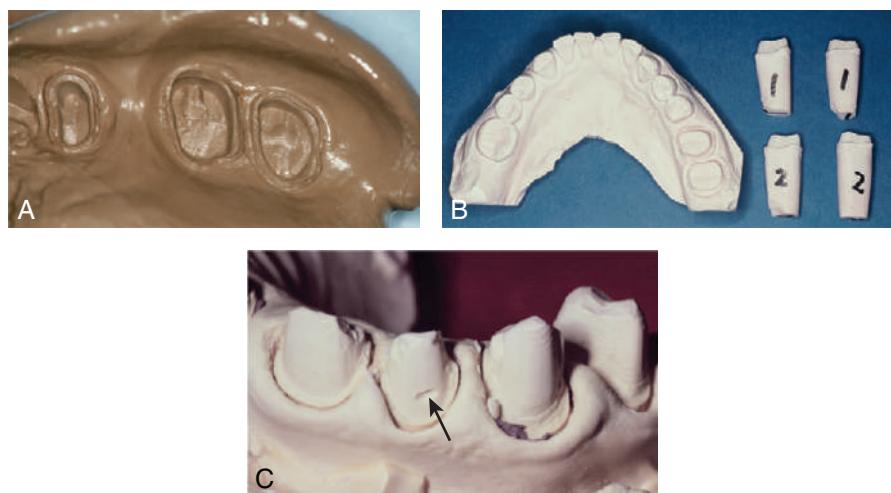


Fig. 17.9 (A) An accurate impression is essential for successful fixed prostheses. (B) The first and second pours have been sectioned into individual dies. The third pour will be the definitive cast. (C) Small defects (arrow) can sometimes be overcome, but any voids make the laboratory phase much more difficult.

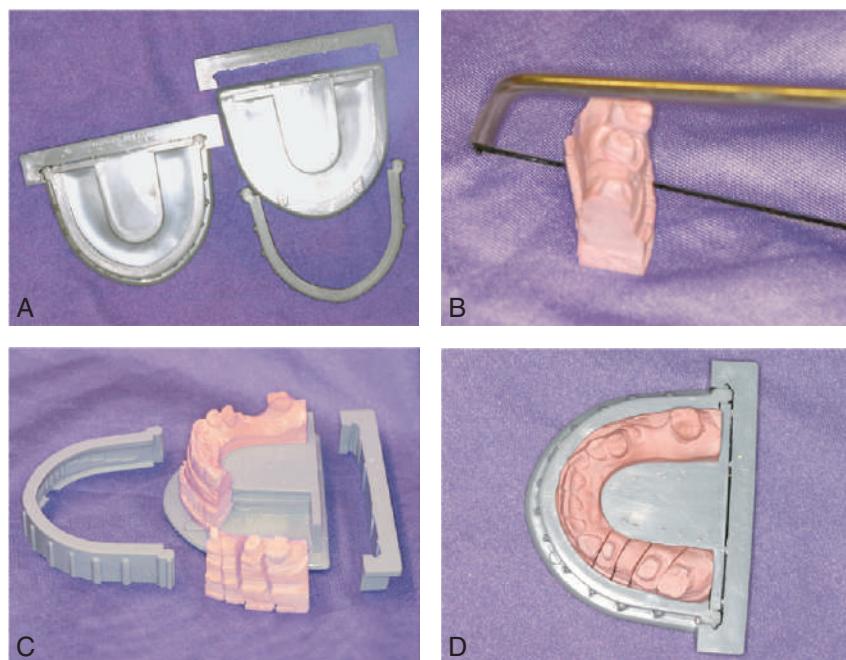


Fig. 17.10 The Di-Lok system. (A) The system involves the use of specially segmented trays. With a single-pour technique, the impression is formed in the usual way, and the Di-Lok tray is filled. Then the tray is inserted into the impression while the stone is still wet. After the die stone has fully 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.)

Alternative Die Systems

In the Di-Lok (DentiFax/Di-Equi) system (Fig. 17.10), a specially articulated tray is used for 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, Fig. 17.11) and the Zeiser model system (Zeiser Dentalgeräte GmbH) (Fig. 17.12), a precision drill is used, and special baseplates are aligned and drilled to provide die removal.



Fig. 17.11 Dental Ventures of America (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 replaced over poured impression. (H) Set cast is removed from the baseplate with gentle tapping. (I) The cast is trimmed. (J) The cast is sectioned. (K and L) Definitive casts trimmed with the DVA Model System. (A–K, Courtesy Dental Ventures of America, Inc., Corona, California. L, Courtesy Dr. A.G. Wee.)

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 laboratory 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 conventional solid cast technique simplifies cast-and-die fabrication and is a common computer-aided design/computer-aided manufacture (CAD/CAM) workflow for when a traditional impression is used. There is no need for special equipment for die pins, and the soft tissues immediately adjacent to the preparations are not removed. However, if a CAD/CAM workflow is not used, the waxing and porcelain stages are more difficult. The use of a conventional solid definitive cast precludes errors caused by incomplete seating of a removable die. In practice, this means that the components of a fixed partial denture (FPD) can be indexed from the cast for assembly; on the other hand, it also means that if an FPD is not fabricated accurately, the stone abutment teeth can be easily broken off, which makes subsequent steps more difficult.



Fig. 17.12 (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.)

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 before the pattern is invested. As the pattern is transferred back and forth from the solid cast to the separate individual die, the risk of pattern breakage is increased in comparison with removable die systems. After casting, some difficulty may be encountered in seating metal castings on the solid cast, and it may have to be relieved slightly to enable complete seating.

In contrast to the solid cast, 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 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 conventional solid cast (multiple-pour) technique and the Pindex system.

Armamentarium

The following equipment is needed (Fig. 17.13):

- Impression
- Small camelhair brush
- Type IV or V dental stone
- Water



Fig. 17.13 Armamentarium for pouring dies depending on system used.

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 partial denture 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)	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
Dental Ventures of America 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	

- Surfactant
- Dowel pins
- Retention devices
- Orientation aids
- Vacuum mixer and bowl
- Mixing spatula
- Vibrator
- Petrolatum
- Pencil
- Die saw

After the impression has been removed from the patient's mouth, it is washed under running tap water, air dried, 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 Fig. 17.14. 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. 17.15A 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. 17.15A).
3. Close the mixing bowl, and select the applicable mixing program (see Fig. 17.15B).

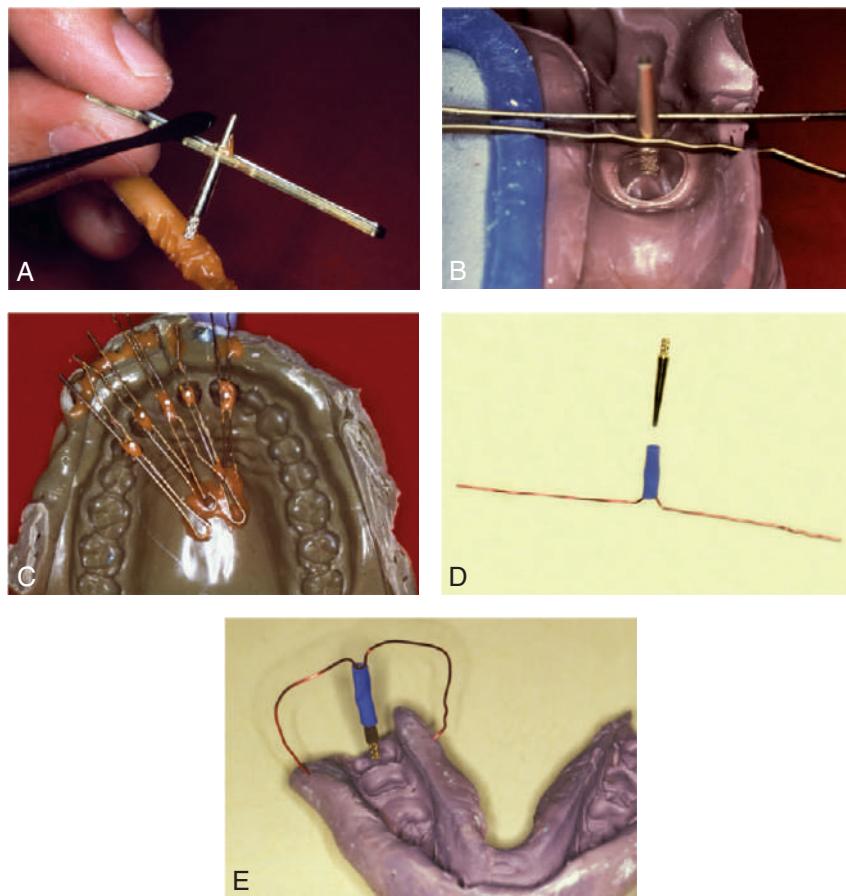


Fig. 17.14 Positioning dowel pins before cast pouring can be accomplished with bobby pins and sticky wax (A–C) or with prefabricated wire-tube aid (D and E).

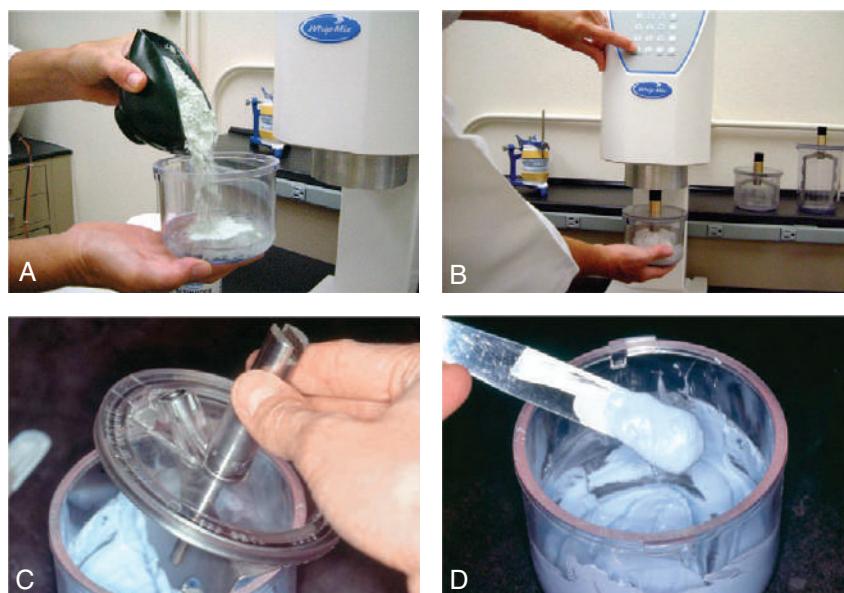


Fig. 17.15 Vacuum method of mixing type IV stone. (A) The mixing bowl is rinsed, and excess water is shaken out. Measured distilled water is poured into the bowl, and weighed powder is added, or premeasured envelopes are used. The powder-to-liquid ratio should be in accordance with the manufacturer's 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.)

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. 17.15C).
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. 17.16). Therefore, small quantities of stone should be added incrementally in one area, which allows the stone to seek its own path (Fig. 17.17). 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 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}.

Bubbles form where two masses of material meet.

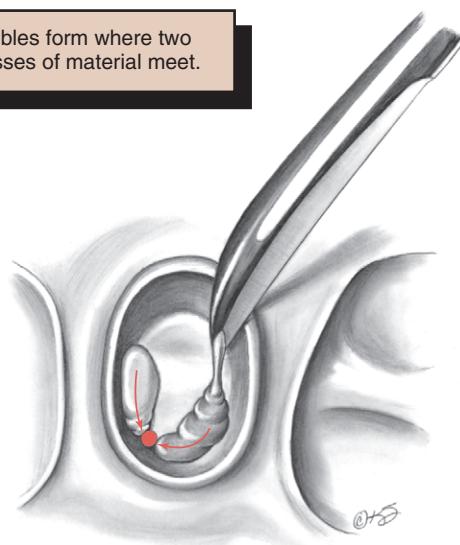


Fig. 17.16 Incorrect technique for pouring an impression. An air bubble (red circle) is trapped if two masses of stone (arrows) are allowed to meet.

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. 17.18 and 17.19).

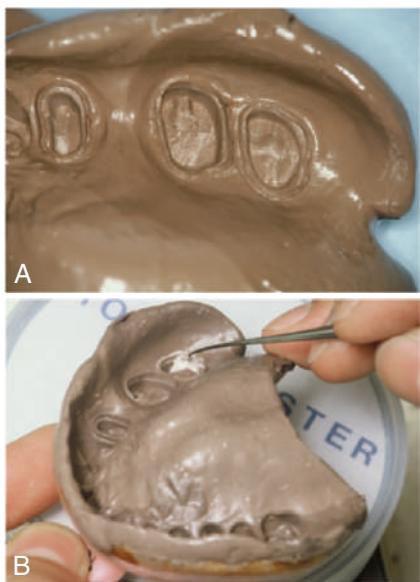


Fig. 17.17 Pouring an impression. (A and B) To avoid trapping air, start with a very small amount of stone.

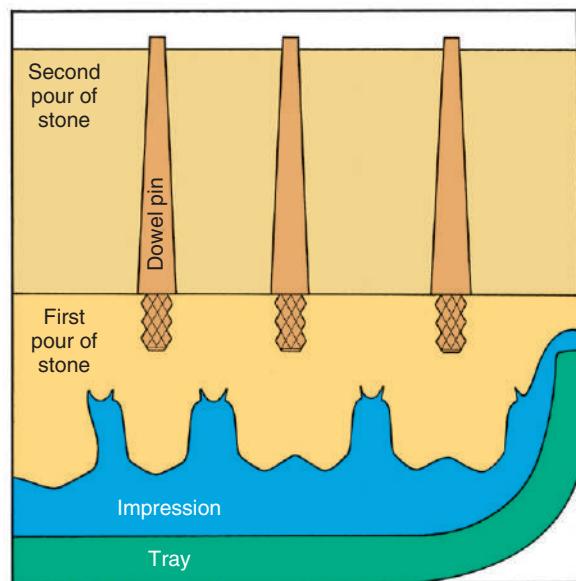


Fig. 17.18 Dowel pins must be carefully positioned so that the first pour of stone completely covers the knurled head of each pin; otherwise, the parts do not separate cleanly. However, the stone should not extend onto the shaft and reduce stability.

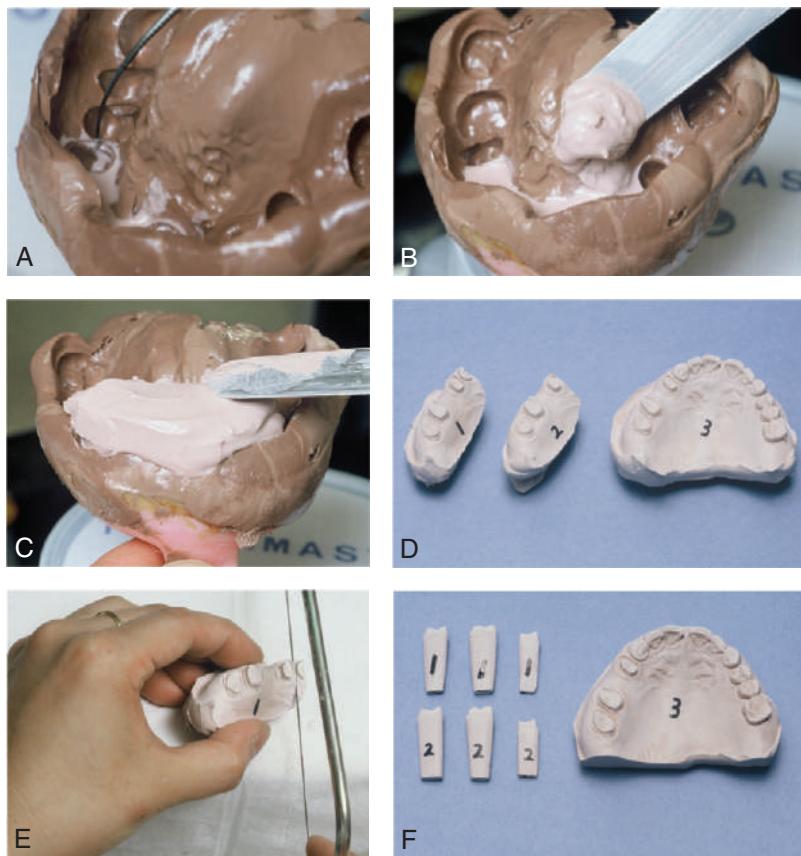


Fig. 17.19 Pouring an impression for individual dies and solid cast (multiple-pour system). (A) The critical margin area must be covered. (B) Stone is added in the preparation area only. (C) Bulk for the die handles must be sufficient. (D) The first and second pours (individual dies) and the third pour (definitive cast). (E) Sectioning the individual dies. (F) The trimmed dies and definitive cast before articulation.

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. 17.19C). The occlusal surfaces of teeth immediately adjacent to the preparation will be filled with stone, but this is of no concern (see Fig. 17.19). When the first pour has set, the cast is separated and repoured. The first pour is then sectioned into individual dies.

8. Place retentive devices³¹ in areas where there are no dowels so that the two layers of stone do not separate in the wrong place (Fig. 17.20). 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

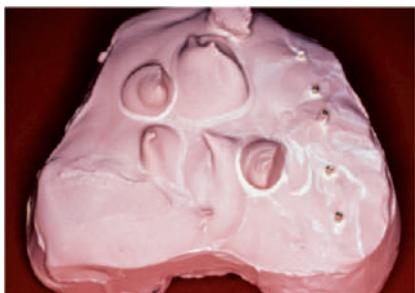


Fig. 17.20 Blobs of stone serve as retention devices in parts of the cast where separation is not desired.

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. 17.21 and 17.22). 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. 17.23). 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. 17.24.)

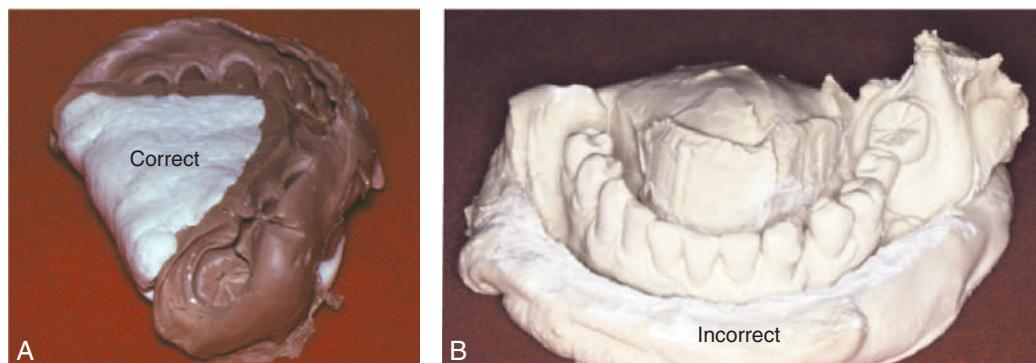


Fig. 17.21 (A) A molding material is used to block out the lingual aspect before a mandibular impression is poured. (B) Otherwise, excess stone will have to be ground away to obtain access to the lingual surfaces, which is a tedious process.

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 using specific recommended protocol, 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. 17.22).

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. 17.22M). When the operator saws from the base, it is important to protect the fragile dies with a soft cloth.

*Coltène.

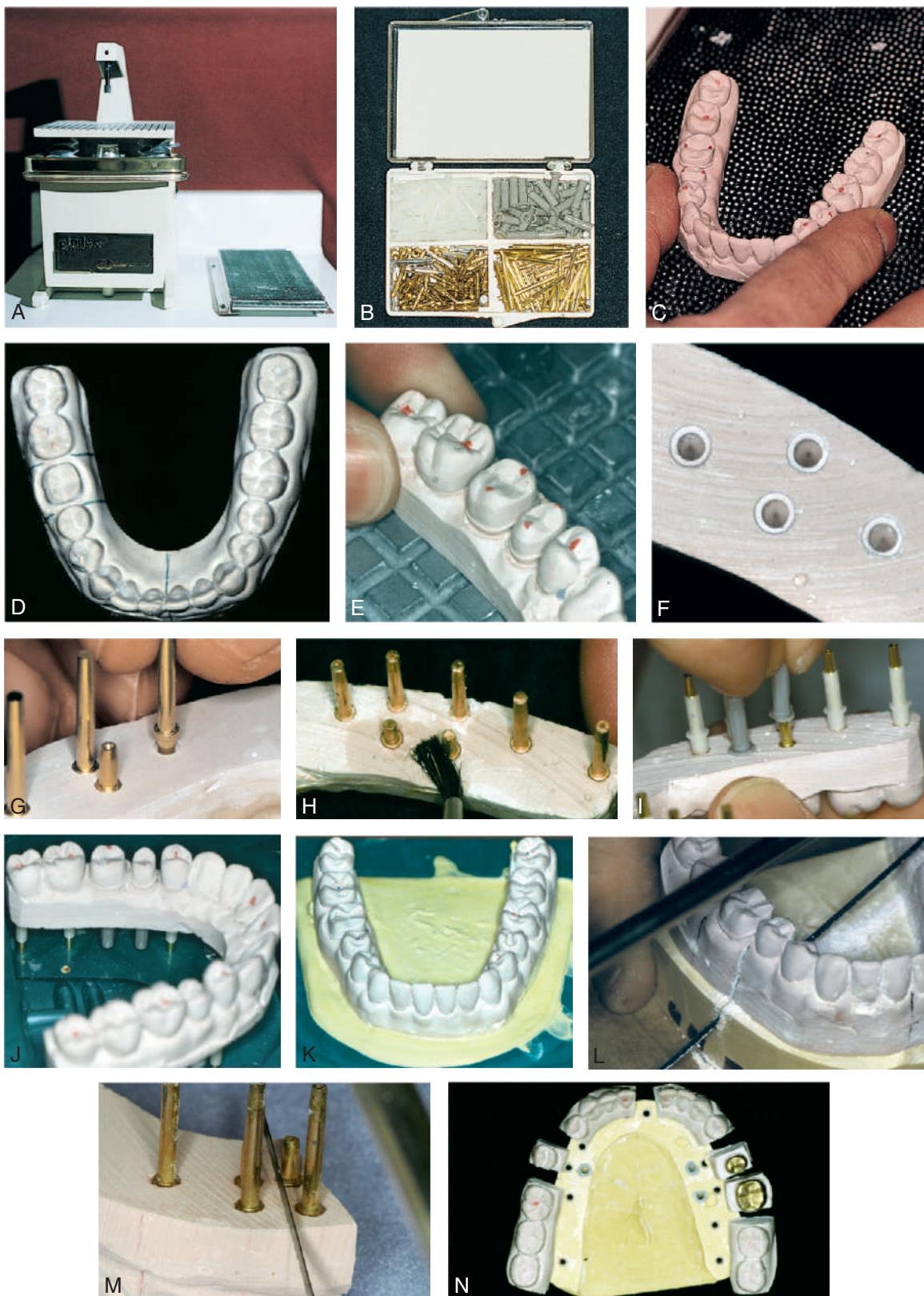


Fig. 17.22 The Pindex system consists of a special drill press (A) and brass dowels and plastic sleeves (B). (C) The impression is poured in stone, separated when set, and trimmed to a horseshoe shape. The base must be absolutely flat (a trimmer is provided). (D) The location of each dowel is marked 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–M, Courtesy Dr. J.O. Bailey. N, Courtesy Coltène, Cuyahoga Falls, Ohio.)

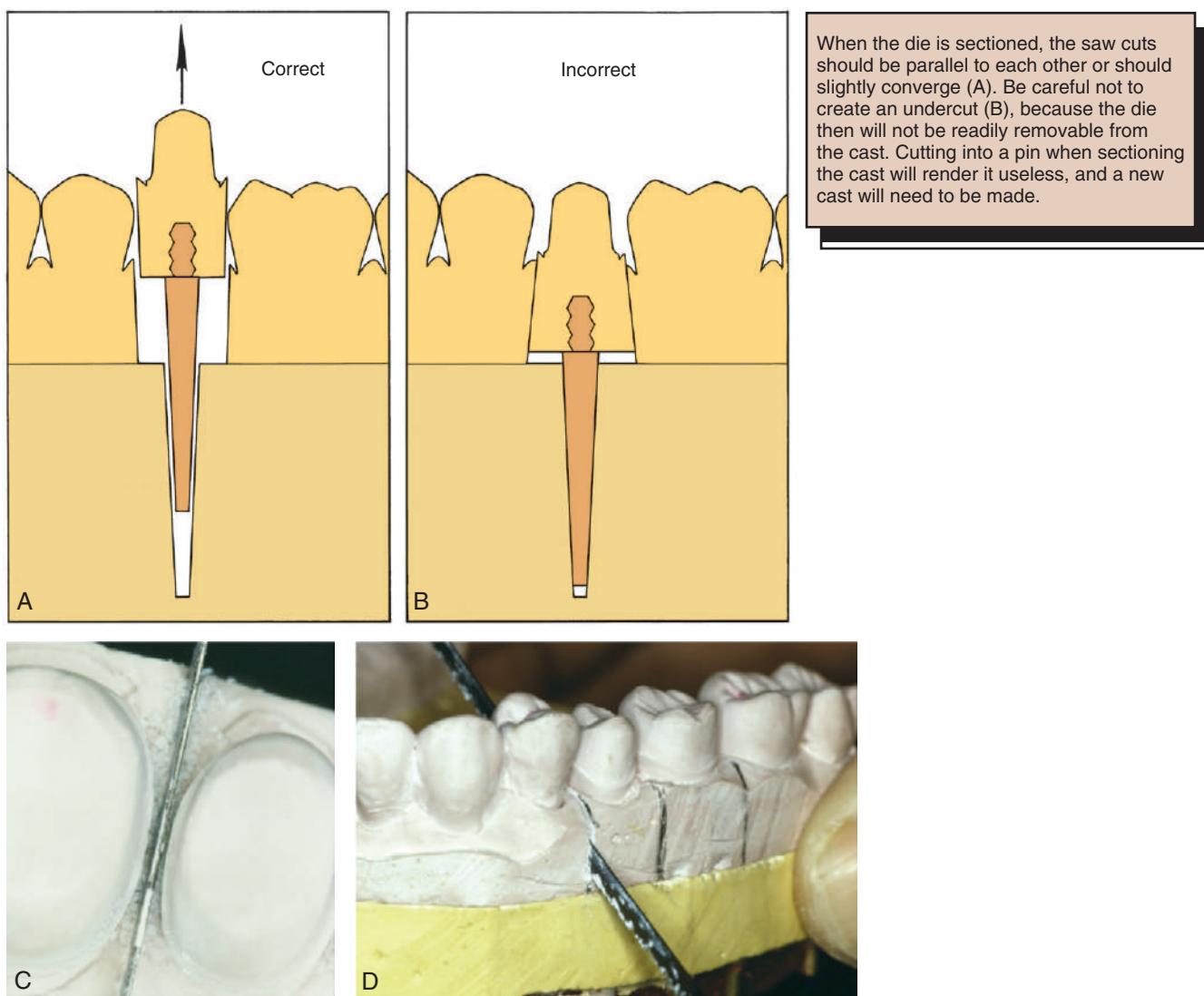


Fig. 17.23 Sectioning removable dies. (A) The saw cuts should converge slightly toward the dowel; otherwise, the die will be locked in by undercuts (B). (C) The intended saw cuts are marked in pencil, and the saw blade is carefully positioned. It must not touch the prepared tooth. (D) The first pour is sawed completely through. Finishing the cut short of the second pour will prevent a clean separation.

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 Chapter 18). 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. 17.25).

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 inferior part of the base where the dowels penetrate. This expedites removal of the individual segments (Fig. 17.26).

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

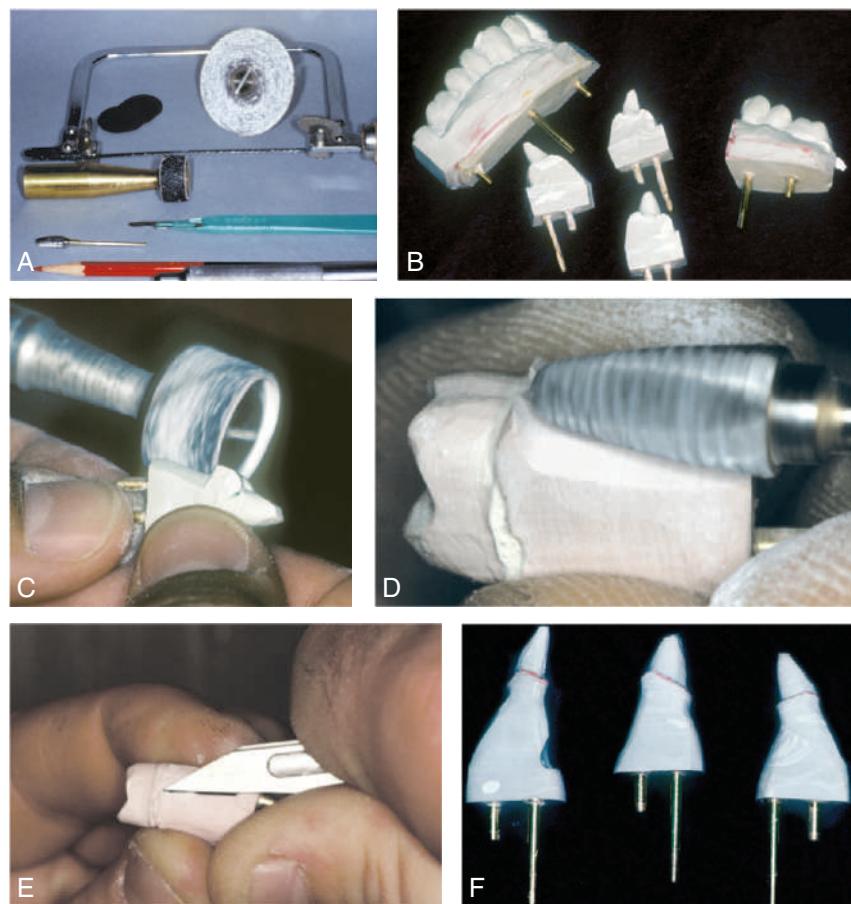


Fig. 17.24 Trimming dies. (A) Armamentarium: saw, gypsum trimming disk, separating disks, Arbor band, scalpel, acrylic-trimming bur, colored pencil. (B) Sectioned dies. In this instance, the Pindex system has been used. (C) Bulk trimming is accomplished with an Arbor band on a lathe equipped with efficient 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.)

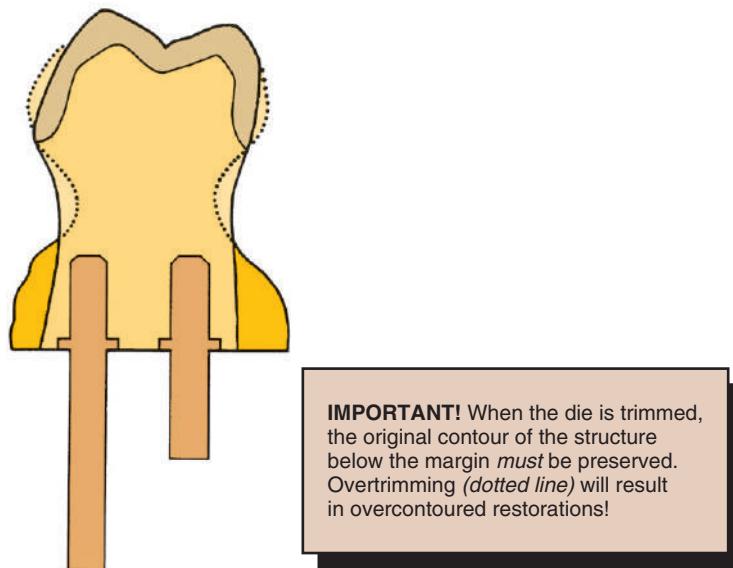


Fig. 17.25 Excessive trimming causes the resulting crown to be bulky because the trimmed die acts as a guide to gingival contour when the restoration is being waxed.